APPENDIX 1-1 EXCERPT FROM ROUND 1 CEAA PACKAGE 2

This appendix was included in the April 8, 2020 filing. It has not been provided as part of this submission because of its large size. Please refer to the April 8, 2020 fling to view this appendix.

APPENDIX 1-2 EXCERPT FROM ROUND 1 CEAA PACKAGE 3

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APPENDIX 1-3 EXCERPTS FROM IAAC CONFORMITY PACKAGES 2 AND 3

This appendix was included in the April 8, 2020 filing. It has not been provided as part of this submission because of its large size. Please refer to the April 8, 2020 fling to view this appendix.

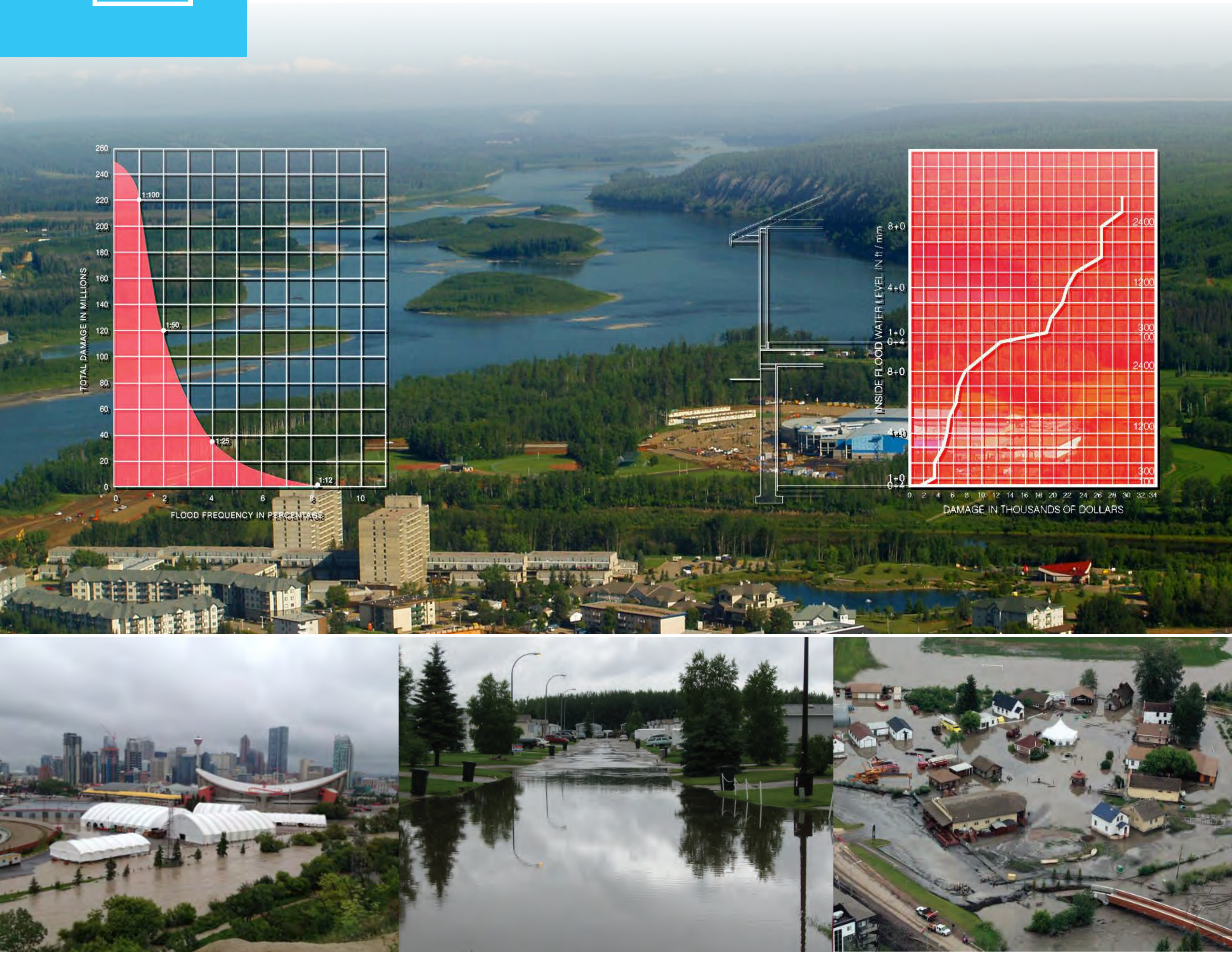
APPENDIX 3-1 PROVINCIAL FLOOD DAMAGE ASSESSMENT STUDY (2015), ENVIRONMENT AND SUSTAINABLE RESOURCE DEVELOPMENT. PREPARED BY IBI GROUP.

Appendix 3-1 Provincial Flood Damage Assessment Study (2015), Environment and Sustainable Resource Development. Prepared by IBI Group.
June 2020

IBI

Golder Associates

Alberta Government



REPORT

Provincial Flood Damage Assessment Study

Prepared for Government of Alberta

ESRD - Resilience and Mitigation

by IBI Group

February 2015

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February 6, 2015

Ms. Heather Ziober
Project Manager, Strategic Integration and Projects
Government of Alberta
Environmental and Sustainable Resource Development
205 J.G. O'Donoghue Building
7000 - 113 Street
Edmonton, AB T6H 5T6

Dear Ms. Ziober:

PROVINCIAL FLOOD DAMAGE ASSESSMENT STUDY

Enclosed please find the draft final report for the aforementioned assignment. The report describes in detail the updating of content and structural damage curves, the development of the Rapid Flood Damage Assessment Model for application within Alberta, along with Provincial adjustment indices for application to other municipalities and future flood events. The report is prefaced with a review of best practices within Canada, the United States, Europe and Australia. The report is supported by several appendices describing the various depth-damage curves and assumptions employed in their construction. As discussed, the updated curves and Rapid Flood Damage Assessment Model provide the Province with a state-of-the-art set of tools with which to assess flood damages.

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

Yours truly,

IBI GROUP

Stephen Shawcross
Director

Augusto Ribeiro, P.Eng.

SS/mp

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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Provincial Flood Damage Assessment Study

Prepared for Government of Alberta
ESRD - Resilience and Mitigation
by IBI Group and Golder Associates Ltd.
February 2015

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Executive Summary

Executive Summary

Introduction

In July of 2014 IBI Group along with Golder Associates Ltd. were retained by the Alberta Government, ESRD Operations, Resilience and Mitigation Branch to undertake the Provincial Flood Damage Assessment Study.

The purpose of the study is threefold:

1. to update/develop flood damage curves in select communities at risk of flooding to 2014 economic values and establish adjustment indices for their use in different flood prone communities across Alberta;
2. to develop a computerized model for estimating flood damages; and
3. to undertake flood damage estimates for select communities throughout Alberta.

Review of Best Practices

A comprehensive review of both historic and recent approaches to flood damage assessment was undertaken, highlighting key assumptions, differences in methodology, weaknesses, general applicability and any noteworthy aspects that should be considered for incorporation into the proposed approach and project deliverables. The analysis considered Canadian, U.S., European and Australian experience.

It is instructive to note that the more recent studies of flood damage curves show a marked increase in damages at lower levels of flooding for both structures and contents, reflecting higher contents values per structure overall, lower levels of content repair and salvageability (planned obsolescence/throw away society) and current renovation practices which favour wholesale rather than incremental repair and rehabilitation to flood impacted structures.

From a Canadian, and specifically Alberta perspective, review of the literature and past studies reveals that the approach to developing stage-damage curves previously developed in Alberta on the Fort McMurray and Elbow River Studies is still relevant and further, that in the Canadian context no new methodologies have been developed nationally, or provincially since the definitive studies were undertaken. The methodologies as described were based on a first principles approach employing Alberta-specific building practices and contents data.

The primary improvement in flood damage estimation modelling involves the integration and use of GIS and related computerized data (property assessments) as exemplified in the HAZUS-MH and HEC-FDA, along with the British MCM flood damage estimation models. The obvious drawbacks in employing these models verbatim is the complexity of the data input process, particularly for the HAZUS-MH program, the proprietary nature of the programs, U.S. regional-based stage-damage curves, and the specific applications for which the programs were developed.

The intent of the current study is to develop a user-friendly model incorporating the GIS functions with enough flexibility to accommodate varying levels of data sophistication and alternate approaches to damage estimation.

Update of Content and Structural Stage-Damage Curves

For the purposes of this study, direct flood damages were estimated separately for residential and non-residential structures, and also for losses to structures versus contents. Previous damage estimation experience indicates that potential losses vary significantly by the type of use, reflecting differences in construction materials, techniques and quality, and also in the amount and nature of contents located within those structures. The analysis rendered updated depth-damage curves for various categories of residential and non-residential structures and their contents based on extensive first and second order research including representative sampling of residences and non-residential structures within selected functional groups. The results compare favourably with those of other similar analyses, and in particular recent U.S. experience. The values reflect current residential content and non-residential inventory, display and storage practices, and consequently could be applied with minimal modification to other similar areas within the Province. The updated curves also reflect the current practice of discarding the great majority of content items that have had even the slightest exposure to floodwaters.

Provincial Adjustment Indexes: Applying 2014 Calgary Stage-Damage Curves to Other Municipalities and Future Events

Indexes were developed for the 60 identified flood study municipalities for updating the damage curves based on future price changes and to reflect regional differences in construction and contents values.

Development of Rapid Flood Damage Assessment Model

A Rapid Flood Damage Assessment Model was developed for use in the current and future flood damage assessment studies. The model is a state-of-the-art computerized relational database for mass assessment of flood damages. It incorporates GIS digital mapping and Digital Elevation Models (DEM), allows for the integration of municipal assessment data where applicable, incorporates the HEC-RAS hydraulic model for estimating flood elevations and allows for the application of various damage curves including the updated Alberta-based depth-damage curves. The RFDAM system has been developed using Free and Open-Source Software (FOSS) such that the program can be used by all without having to pay for a commercial license for in-house use. RFDAM has improved significantly on other flood damage estimation models and provides a user-friendly, made in Alberta approach to flood damage assessment.

Pilot Study and Field Verification

The City of Calgary was selected as the centre from which to conduct the pilot study for a variety of reasons as follows:

- Recent flood damage experience (2013) of City agencies and private organizations, particularly with respect to cost of damages.
- Large inventory of potential residential and commercial structural types and categories.
- Familiarity of study team with the flood hazard area along with past flood damage work within the City including 1986 for the Elbow River, 1987 for the Bow River in Inglewood, and 1992 for the entire city.
- Recent update of hydraulic modelling in 2012 and analysis of 2013 flood flows.
- Availability of accurate flood clean-up and rehabilitation costs by various types of residential and commercial structures.
- Anticipated detailed tax assessment records.
- Requirement for early delivery of benefit/cost analysis of major mitigatory alternatives.

Field verification employing Google Earth and Streetview/Apple Maps ground level photography was employed to visually inspect and qualify all flood damaged non-residential and multi-residential structures, and a large, representative sample of single-family residential structures. For the non-residential component, business category was verified, and where required, modified to reflect specific retail categories. In addition, presence or absence of parkades was noted along with structural type. Elevation of main floor to grade was also adjusted where required.

For multi-family residential, the number of storeys was verified along with presence or absence of parkades and below-grade units. With respect to the latter, elevations were established for units below-grade along with the elevation of main floor units.

For the single-family component, classification (AA, A, B, C, D) was verified along with elevation of main floor with respect to grade.

In summary, there was a very low level of error in the inventory data, or differences between actual and default values. This aspect of the approach strongly supports the use of online ground level photography in the Rapid Flood Damage Assessment modelling.

Identification of High Priority Municipalities

As part of a Province-wide flood damage reduction initiative, 58 flood prone study municipalities were identified. On the basis of level of risk of flood damage, four high priority municipalities were identified as follows: Calgary, High River, Fort McMurray and Drumheller. These municipalities are the focus of the initial tranche of flood damage assessments undertaken as part of the Provincial Flood Damage Assessment Study.

1 Introduction

1 Introduction

1.1 Background

Flood damage estimates are required for evaluating the cost effectiveness of projects designed to alleviate flood impacts. In the past, flood damages have been examined by virtue of three basic techniques: (1) the first entails an examination of the floodplain immediately after the water recedes. If such estimates were available for every flood over a period of many years, a damage-frequency curve could be created; (2) an alternative method is to determine the damage caused by three or four recent floods whose hydrologic frequency can be determined and a smooth damage frequency curve plotted through these points; however, for most floodplains, changes in land use with calendar time prevent direct usage of a damage-frequency relationship from historical damages; (3) the third method entails hydrologically determining various flood elevations for specific flood frequencies and deducing synthetically the damages that would occur given these flood events. This analysis provides a synthetic damage-frequency curve from which one can estimate average annual damages for a given study area.

The third method is the one most frequently employed primarily due to a number of limitations inherent in the first two techniques. To reiterate, land use changes over time prevent the direct usage of damage-frequency relationships based on historical damages; this is particularly problematic for jurisdictions experiencing rapid growth. In addition, flood damage payments do not necessarily reflect real damages; however, they can serve as a useful check. Moreover, there are generally insufficient events to extrapolate from, and large voids in the data render the techniques susceptible to error.

In light of the above, the third methodology is considered the best approach for obtaining accurate and representative estimates of damages based on current economic factors.

In 1981 IBI Group, along with Ecos Engineering, were retained by Alberta Environment and the City of Fort McMurray to undertake a comprehensive study of flood damages for the City of Fort McMurray. A subsidiary objective of the study was to develop depth-damage curves that could be applied on future flood damage studies undertaken throughout Alberta. Content damage and structural damage curves were developed for all residential housing types as well as commercial structures including retail, office and industrial uses. The curves and associated flood damage database management system were subsequently employed on a large number of flood damage reduction studies throughout Alberta including the Drumheller Valley, the Athabasca Basin, Pembina Basin, City of Medicine Hat, City of Calgary, Town of High River and Hamlet of Bragg Creek. Values were updated with indexing to account for inflation and real economic growth and regional and provincial economic differences to render reliable flood damage estimates and construct damage-frequency relationships with which to undertake benefit/cost analysis.

It is now some 34 years since the original research was undertaken and the curves were developed. In the interim, the type and value of household contents have changed dramatically, along with the use and level of improvements in typical basements. Given these substantial changes, it is prudent to update the accepted flood damage estimation techniques to accurately reflect potential damages and hence provide a more reliable base for benefit/cost analyses and the ultimate selection of potential flood mitigation alternatives.

Accordingly, in July of 2014 IBI Group along with Golder Associates Ltd. were retained by the Alberta Government, ESRD Operations, Resilience and Mitigation Branch to undertake the Provincial Flood Damage Assessment Study.

1.2 Purpose

The purpose of the study is threefold:

1. to update/develop flood damage curves in select communities at risk of flooding to 2014 economic values and establish adjustment indices for their use in different flood prone communities across Alberta;
2. to develop a computerized model for estimating flood damages; and
3. to undertake flood damage estimates for select communities throughout Alberta.

1.3 Scope/Deliverables

The scope of the study, including deliverables, is outlined as follows:

1. Update residential, commercial and industrial synthetic depth-damage curves to 2014 economic values and establish adjustment indices for use in different flood prone communities across Alberta. Including all structures located in the floodplain (privately, government, and municipal owned).
2. Develop a “Rapid Flood Damage Assessment Model” to incorporate GIS input/data (LiDAR, building footprint/area, floodplain).
3. Coordinate, facilitate and arrange for information and data gathering from participating municipalities and communities.
4. Update content damage curves to reflect ownership contents and their distribution within the basement and main floor levels.
5. Update structural damage curves to reflect current usage and levels of improvement to basements and main floor levels.
6. Apply the Rapid Flood Damage Assessment model to estimate flood damages using GIS data. The GIS data to be obtained from the affected municipalities. The input data would include LiDAR DEM, lot parcel, building area, and floodlines for the different return floods on record.
7. Provide an implementation schedule consisting of planned tasks and activities, start and end dates, and the resources required to complete the tasks. Provide an updated schedule monthly.
8. Arrange, coordinate and chair monthly project meetings. Minute the meetings and distribute accordingly.
9. Provide presentations to the client and other government ministries, as required.

2 Review of Best Practices

2 Review of Best Practices

2.1 Introduction

As part of the Athabasca Basin Feasibility Study undertaken by IBI/Golder in January of 2014, a general review of flood damage assessment methodologies and programs was undertaken to determine if any improvements or changes in best practices had occurred over the last 30 years since benchmark work was undertaken by IBI/Ecos in Fort McMurray in 1982. The general literature review showed that the approach previously developed was still relevant, and further, that in the Canadian context no new methodologies had been developed nationally, or provincially since the definitive studies were undertaken. The following section is devoted to a more comprehensive review of both historic and recent approaches, highlighting key assumptions, differences, weaknesses, general applicability and any noteworthy aspects that should be considered for incorporation into the proposed approach and project deliverables.

2.2 An Overview of Flood Damage Calculation Procedures

The estimation of flood damages in water resources management studies is a four-part procedure. **Exhibit 2.1** illustrates the flow chart of activities which are usually included in this type of study. The general flow of information implied within Exhibit 2.1 is described below.

Damages incurred are proportional to depth of flooding which is, in turn, dependent upon the hydraulic characteristics of the watercourse and floodplain and the magnitude of the flood flow. Therefore, definition of flood damages for a particular flood first involves the prediction of flows for return periods (probabilities) of interest. The channel and floodplain characteristics are then considered in order to transform the design flows into depth or stage. Damage versus depth characteristics for various categories of land use (residential, commercial, industrial, public and agricultural) and broader categories such as indirect and direct are then determined for the study area. These relationships are combined with the flood stage predictions in an integrating, or accumulating procedure, to sum categories of damage for various return periods of floods. A common technique for expressing the damage estimate involves integrating beneath the damage versus probability curve to achieve an estimate of the expected value of annual damages. This estimate changes with alternative flood damage mitigative measures. Reductions of estimated annual damages can then be compared to the annualized project costs.[1]

2.3 Depth-Damage Curves

A depth-damage function is a mathematical relationship between the depth of water above or below the first floor of a building and the amount of damage that can be attributed to that water.[2] The focus of previous studies undertaken in Canada (e.g., Acres Limited, 1968; Book and Princic, 1975; MacLaren, James F. Limited, 1975; Frigon, 1978; Totten Sims Hubicki, 1980; IBI Group, 1982; Marshall Macklin Monaghan, 1982; Ecos, 1983; Paragon Engineering, 1985; WER/IBI/Ecos,1986) has been on damage as a function of depth of inundation. Although other factors, including time of flooding, velocity of floodwaters, duration of flooding, sediment load and warning time, may all be relevant to the damages that would be incurred in the event of a flood, these other factors are difficult to incorporate, and when considered relevant, have been included by add-on or percentage factors.[3] Curves designed in these studies can be subdivided into two general classes: “synthetic” curves and “incident of damage” curves. Both types of

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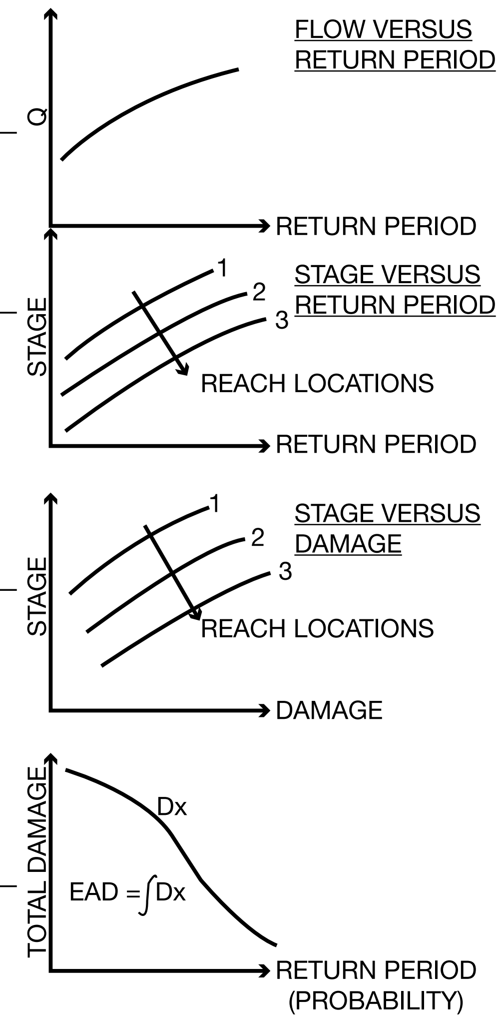
[1] Paragon Engineering Limited, *Flood Damages: A Review of Estimation Techniques*, Ontario Ministry of Natural Resources, March 1984.
[2] U.S. Army Corps of Engineers, *Catalog of Residential Depth-Damage Functions*, IWR Report 92-R-3, May 1992.
[3] McBean, Fortin, Gorrie, *A Critical Analysis of Residential Flood Damage Estimation Curves*, Canadian Journal of Civil Engineering, 1986.

General Flood Damage Calculation Methodology

INPUT	TASK
	IDENTIFICATION OF DAMAGE CENTRE
- DRAINAGE AREA - STEAMFLOW RECORDS - PAST STEAMFLOW ANALYSES	HYDROLOGIC ANALYSIS - SINGLE STATION FREQUENCY ANALYSIS - REGIONAL FREQUENCY ANALYSIS - TESTS FOR SUITABILITY OF LOW RECORD
- CHANNEL AND FLOODPLAIN GEOMETRY - ROUGHNESS COEFFICIENTS - BRIDGE AND CULVERT DETAILS	HYDRAULIC ANALYSIS - BACKWATER PROFILES THROUGH DAMAGE CENTRE FOR ALL RETURN PERIOD FLOODS - SELECT DAMAGE REACHES - ESTIMATE STAGE (DEPTH) FOR EACH REACH RETURN PERIOD
- TOPOGRAPHIC SURVEY OF STRUCTURES - SYNTHETIC/HISTORICAL STAGE DAMAGE CURVES - COMMERCIAL/INDUSTRIAL INVENTORIES - AGRICULTURAL	STAGE DAMAGE CALCULATIONS - SELECT TYPE OF DAMAGE CURVE FOR VARYING LAND USE - MODIFY OR ADD TO CURVES DEPENDING ON PROJECT SPECIFICS - ACCUMULATE DAMAGE ESTIMATES FOR STAGE INCREMENTS
	TOTAL DAMAGE CALCULATIONS - DETERMINE DAMAGE VERSUS RETURN PERIOD (PROBABILITY) AND ACCUMULATE OVER ALL REACHES - INTEGRATE UNDER DAMAGE VERSUS PROBABILITY CURVE TO ESTIMATE EXPECTED ANNUAL DAMAGE (EAD)

OUTPUT



Source: Paragon Engineering "Flood Damages: A Review of Estimation Techniques" - Ministry of Natural Resources (March 1984) these curves involve structural and contents damages to residential and commercial/industrial/ institutional buildings. Structural damages refer to damages to the building and to building components that are not taken when an individual is moving, such as the furnace, hot water heater, wall-to-wall carpeting, etc. Conversely, contents damages are damages to moveable contents of a structure.[4]

Several approaches have been employed relative to developing synthetic depth-damage curves. The two most commonly utilized in the aforementioned studies are referred to as the Acres Method[5] and the FIA Method[6]. The primary differences in the methodologies are outlined as follows:

Acres Method	FIA Method
1. Canadian experience.	1. U.S. regionalized experience (no Canadian verification).
2. Units by construction type relative to architectural/economic categories.	2. Units by construction type.
3. Contents damage evaluated through survey.	3. Contents damage expressed as a percent age of appraised value of structure .
4. Structural damage evaluated through detailed estimation of categories.	4. Structural damage expressed as a percentage of appraised value of structure.
5. Requires classification by category.	5. Requires individual appraisal of each unit.
6. Contents damage relates to general income grouping through unit categorization.	6. Contents damage is not related to income.
7. Considers basement damage.	7. Does not adequately consider basement damage.
8. Detailed evaluation for non-residential damage curves.	8. Non-residential damage curves inadequately represented.

In the United States the first flood damage evaluations were developed at the beginning of the '50s by Gilbert White (father of floodplain management), and were followed by the development of guidelines and several sets of damage functions by the Federal Emergency Management Agency (FEMA) and the U.S. Army Corps of Engineers. The U.S. Army Corps of Engineers continues to develop and update regional depth-damage curves for use in the different states.

There is a wide discrepancy in the damage curves used by the Corps and by FEMA. The Corps developed residential depth-damage tables in the 1990s and further expanded and updated the tables in 2003. In partnership with replacement cost specialists Marshall and Swift/Boeckh, the Corps has developed the Corps of Engineers Floodplain Inventory Tool (CEFIT), which complements the Hydrologic Engineering Center's Flood Damage Analysis (HECF-FDA) package. In contrast, FEMA's depth-damage curves were taken from old National Flood Insurance Administration (FIA) databases of questionable accuracy and reliability. These damage curves have not been updated since the 1980s[7].

4 Ibid.
5 Acres Limited, *Guidelines for Analysis, Volume II Flood Damages*, Government of Canada and Ontario Joint Task Force on Water Conservation Projects in Southern Ontario, Niagara Falls, 1968.
6 Federal Insurance Administration, U.S. Department of Housing and Urban Development, *Flood Hazard Factors, Depth-Damage Curves, Elevation-Frequency Curves, Standard Rate Tables*, 1970.
7 Association of State Floodplain Managers, *Use of Benefit/Cost Analysis for FEMA Programs*, ASFPM, 2007.

2.3.1 Fort McMurray Stage-Damage Curves

One of the underlying objectives expressed by Alberta Environment and the City of Fort McMurray in conducting the flood damage estimate study was the achievement of a high level of confidence in the damage estimates. To this end, a work program was developed for the sampling of residential structures that would facilitate statistical accuracy. The work program entailed obtaining detailed contents estimates for a stratified random sample of a statistically significant number of residential units in the various categories upon which stage-damage curves were based. In addition, a level loop survey was undertaken to determine the elevations of all units within the floodplain to within 0.1 metre accuracy.

The study approach employed is briefly summarized as follows:

1. Inventory of all residential and commercial structures within the flood study area.
2. Level loop survey of all units to within 0.1 metres accuracy.
3. Creation of damage curves for residential and commercial structures by means of detailed contents and structure survey.
4. Generation of statistically significant damage curves for residential structures to attempt to obtain 90 percent accuracy in the total damage estimates for residential units.
5. Assessment of flood damages to residential and commercial structures for a range of flood frequencies as well as damages to infrastructures, utilities and indirect damages.
6. Assessment of average annual damages for the study area.
7. Assessment of future damage potential within the study area.

2.3.1.1 Definition of Structural Categories

Accurate assessment of residential flood damages requires the formulation of models capable of describing major variations in house types found throughout the study area. Subsequently; synthetic unit stage-damage function curves are developed for categories of typical or representative unit types.

The residential classification scheme employed in the Acres study categorized residential structures as either wood or brick with a further definition of three sub-categories for each of these. This system of classification conformed to a scheme devised by the Ontario Department of Municipal Affairs. A handbook was published by the Department which contained detailed descriptions and cross-sections of the types of homes found within each of the sub-categories, thus facilitating efficient and consistent field classification within the pilot study and subsequent studies employing the Acres methodology.

The general elements of this scheme are set out in **Exhibit 2.2**.

Exhibit 2.2: Acres Residential Classification Scheme

Class	Department Of Municipal Affairs Designation	General Criteria
1. Wooden (or stucco)		
AW	D-7 to D-10	Solid, architect-designed wooden structure. May be ultra-modern or older two-storey. High-class, solid construction and materials.
BW	D-4 to D-6	Double wall frame home. Typical of middle-class housing developments. Most wooden homes fall into this class.
CW	D-1 to D-3	Rough frame structure, thin walls. May have stucco or imitation brick coating.
2. Brick (or stone)		
AB	C-8 to C-10	Mansion-like or ultra-modern appearance. Very high quality in construction and materials.
BB	C-6 to C-7	Typical mass-produced ranch-style or two-storey home.
CB	C-4 to C-5	Cheap brick or concrete block bungalow.

On the basis of the inventory undertaken for Fort McMurray, the Acres classification scheme was modified to reflect the particular nuances of the study area and furthermore, expanded to include several structural types not addressed within the Acres scheme. These consisted of mobile homes, walk-up apartments, (wooden frame), and apartment towers. As no brick residential structures were encountered, the brick sub-category was deleted from the classification scheme. Three sub-categories were devised for each of the main categories, reflecting primarily the quality and, to a lesser extent, size (m^2) of the units (there is generally a strong correlation between the latter two factors).

For computing flood damages, a further subdivision was undertaken within the categories indicating unit type as either bungalow (one storey), one and a half storey (split level) or two storey. This further definition of residential dwellings was a refinement not evidenced in previous studies of flood damages (Acres, Fraser River Basin, FIA) and resulted in much more representative synthetic stage-damage functions.

The residential classification scheme devised for the Fort McMurray study is detailed in **Exhibit 2.3**. Representative examples of each structural type are illustrated in the accompanying photographs (see **Exhibit 2.4**).

Exhibit 2.3: Fort McMurray Residential Classification Scheme

Class	General Description
AW-1* AW-2 AW-3	Typical custom constructed housing built, for the most part, during the 1970's architecturally designed with control of materials selection and consideration of increased insulation values, vapour seals, passive and active solar heating systems. Interior materials, finishes and general décor reflect an above average upgrading to· the personal requirements of the owner. These houses represent the high end in terms of real estate values.
BW-1 BW-2 BW-3	Typical subdivision construction of the 1960's, constructed by the developer or builders from a selection of stock design plans in accordance with design guidelines for exterior materials control. Exterior materials are typically aluminum and wood siding, stucco and brick veneer. The size of the unit, style and lot size set the average real estate value. These houses have average insulation values and represent middle real estate values.
CW-1 CW-2 CW-3	Typically constructed during the 1940's to 60's, units are of average design, less than average m^2 (<300), have a low level of insulation value, no vapour barrier or vapour seal and generally have exterior finishes of wood siding and stucco. Generally, these units are located in the core area have a high land to building value ratio and represent the lower end real estate values. Many units will have upgraded interior finishes.
D-1 D-2 D-3 D-4	Mobile Home, Double Wide - Good Quality Mobile Home, Double Wide - Poor Quality Mobile Home, Single Wide - Good Quality Mobile Home, Single Wide - Poor Quality
MA	Apartment Towers
MW	Walk-Up Apartments ,Row Townhouses

* 1, 2, 3 denotes above average, average and below average quality within the A, B and C categories. This differentiation was later dropped for sampling purposes.

2.3.1.2 Content Damage Curves

From the outset of the study, it was considered paramount to the exercise to generate content damage curves specifically for Fort McMurray. To this end, a work program was established which entailed obtaining detailed contents estimates for a stratified random sample of a statistically significant number of residential units in the various categories upon which the stage-damage curves could be based. The survey developed for the program was directed toward obtaining up-to-date total depreciated contents per residential category.

From past experience, which again was verified in this investigation, the collection of baseline data on a unit by unit basis constitutes a complex and time consuming exercise and in order to optimize collection of key, relevant data, the survey tool was refined to reflect this concern with a consideration of the following assumptions:

Residential Classification

- Automobiles were not accounted for. Normally these would be driven out of the hazard area particularly under Fort McMurray flood conditions. Although it is anticipated that a percentage would be subjected to flood damage, no statistical information is available that would allow for a quantification of this potential damage. For the 1977 flood, there were no major indications of high damage to abandoned automobiles. For cars not suffering impact damage, restoration costs are minimal.
- Furnaces and water heaters are addressed under structural damage.
- Clothing and items under $100 were not considered (for further discussion, see the following section)
- Watches, jewellery and small valuables would normally accompany the residents in their flight from the hazard area.
- The computation of flood damages assumed no human adjustment factors relative to past flood experience. This assumption is a function of the limited tenure of a substantial portion of residents within the Town. In past studies, human response is not necessarily consistent with tenure, is sporadically applied, and methods tend to vary considerably along with the success of these methods. For these reasons, human adjustment factors are not considered within the Fort McMurray Study. While they could constitute a significant factor in established areas with a long history of flooding, they do not constitute a factor in estimating residential losses within the Fort McMurray Study.

2.3.1.2.1 Questionnaire Design and Calculations

The basic design of the residential questionnaire was derived from a review of past studies. It was refined and updated to reflect changes in household contents as a result of changes in consumer purchasing patterns over the previous 14 years. Questionnaires were operationalized for easy computerization and a content damage program was developed[8]. The primary focus of the questionnaire was on direct damages to contents. Structural data was also collected in order to assist with structural damage estimates and clean-up cost estimates.

The list of contents utilized in previous studies was updated and extended through a pre-test inventory of several Calgary residences, and a final list of 82 common content items was developed. An open-ended section allowed the coding of any number of additional or uncommon items. Critical levels – top and bottom – were measured for all contents in every tenth unit. This was undertaken to verify the critical levels that were pre-coded for selected items.

In order to permit the calculation of damages to contents at various flood levels, interviewers noted the location of the item in the structure, i.e., basement, first level, second level, third level or garage. The interviewers also noted the number of a given item, its cost, critical level, top height and age. The use of this methodology made it possible to compute synthetic damage curves with greater accuracy and efficiency in the office, when the field work was completed.

Three cost ranges were determined for each of the 82 content items in the survey based on an extensive review of retail sales catalogues and price advertisements. For any given item, the low cost estimate was typical of a poorer quality item, the middle estimate was typical of average quality, and the high estimate was typical of above average quality. In the field, interviewers assessed the quality and size of items in order to select the appropriate cost category.

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[8] Additional categories were added to floor and wall materials (concrete and earth) and coded in the field. These were subsequently included in the various analyses.

Interviewers recorded critical levels for each item in the field. For any item, the critical level is defined as the distance from the floor to that part of the item at which significant flood damage would result. A review of architectural standards indicated that many common household items have relatively fixed critical levels. Accordingly, the critical levels were precoded for many items of the survey; however, interviewers were instructed to recode any deviations of these precoded levels and to record the critical levels of any non-precoded items in the field.

The extent of direct flood damage to various objects as well as restoration costs for flood damaged items were determined through consultation with experienced service and repair establishments. Restoration costs varied widely, with some items requiring minimal expenditure to restore to new condition, while other items required extensive repairs or were destroyed at the critical level. In general, restoration costs were found to be significantly higher as a percentage of an item's new cost than was the case in previous studies. For this reason, the least cost option was generally to replace an item at its depreciated value rather than to attempt to restore it. Typical exceptions to this rule were large, high quality, expensive, or new items.

Depreciation of a new item cost was calculated on a straight line basis. Life expectancies for the various cost classes of each item were compared with those of other studies and updated from discussions with furniture and appliance dealers. At the same time, minimum depreciated values were obtained for most items. The depreciated value of a given item was computed by subtracting from its new cost, the new cost multiplied by the age of the item, divided by its life expectancy, i.e.:

$$\text{Straight Line Depreciated Value} = \text{New Cost} - \frac{\text{(New Cost x Age of Item)}}{\text{Life Expectancy of Item}}$$

To assess the amount of potential flood damage to an item, the straight line depreciated value, the minimum depreciated value, and the cost of restoration were compared. The final depreciated value of the item was set to the greater of the minimum depreciated value or the straight line depreciated value. This value was then compared to the restoration cost, and the lesser of the two values was selected as the estimate of the maximum potential damage to the item. The estimate of damage was then multiplied by the quantity of the item to give the total estimate for the item.

After the computation of the estimate of maximum potential damage for refrigerators and freezer, a constant was added to represent the value of the loss of the food contents. Thus, for each operating refrigerator in a dwelling unit, a value of $100 was added to the estimate, and for each operating freezer a value of $200 was added. Bookcases and record stands, which are generally less valuable than their contents, were assigned a new cost which reflected the value of their storage capacity. For this reason, it was not necessary to add a constant value to represent the potential damage to their contents.

Although interviewers noted furnaces, water heaters, and water softeners as content items, these items were not included in the content damage calculations. Potential damage to these items was included in the ·structural damage estimates.

Many items were, of necessity, excluded from the inventory. Since the pre-test indicated that respondent fatigue was likely to become a serious problem (interviews of over an hour's duration were not uncommon), items with an estimated new cost of less than $100 were specifically excluded from the inventory. While such items are likely to be numerous in a given dwelling unit, their total value is likely to be relatively insignificant because smaller and less expensive items tend to depreciate relatively quickly. Costs of tabulating for each dwelling all items under $100 was another factor contributing to the deletion of these items.

Clean-up costs for various floor and wall type finishes were obtained from experienced cleaning and janitorial services. Floor clean-up costs varied widely, depending on the floor finish. For all floor types, the cost estimates assume an initial wet vacuuming to pick up excess water and silt deposits. Concrete, tile, linoleum and wood floors would then be cleaned with a disinfectant and deodorant solution and then, with the exception of concrete, waxed. After the initial vacuuming, wall-to-wall carpet must be removed and cleaned. Since underpadding generally cannot be successfully cleaned, it must be removed and replaced, after which the carpet must be reinstalled. It should be noted that the clean-up costs assume no structural damage to the sub-floor or joists. This is addressed under structural damages. Drapery cleaning costs assumed a double fullness of material with a 10.16 cm pleat and an average 142.24 cm length. Draped window areas were computed to be equal to 15% of the total floor area on levels 1 to 3, i.e., garages and basement areas were excluded.

In light of the results of previous studies relative to obtaining historical flood damage data and the fact that a significant portion of the Fort McMurray population was and still is transient, due primarily to the nature of the industrial base, questions pertaining to past damages were not included in the residential questionnaire.

2.3.1.3 Structural Damage Estimates

The structural characteristics of residential units in each class were determined through field inspection by qualified architectural personnel and consultation with the local building industry. For each unit type, average m^2, perimeters, lengths of interior walls and types of finishes were calculated. This information was collected during the residential survey and included in the computer program.

Estimates of unit prices for replacing and/or repairing flood damaged materials were obtained from local suppliers and contractors. All structural damage curves reflect the costs of repair or restoration estimated on the basis of present day Fort McMurray material and labour costs.

Based on the house characteristics and unit prices, damage for each 300 mm (one foot) of flooding was estimated for each unit type and for generic types (bungalow, two-storey, split level) within certain categories.

Structural damages were based on the characteristics of a typical ice jam flood assuming a 6 - 8 day recession period. It assumed virtually no damage to walls due to hydrostatic pressure as water would backup through floor drains and leak in around window sashes and laundry vents, etc. Ice damage, if applicable was accounted for as an increased factor in indirect damages.

In the Acres study an arbitrary figure of 5% was used to depreciate replacement costs to restoration values. This was effected to avoid the over-estimation of damages often brought about by the fact that one cannot give a building a five-year old coat of paint. Conversely, in the Fraser River Study, no depreciation rates were applied to standard unit costs of replacing and/or repairing high, medium, and low quality flood damaged materials. Their rationale was that only in the case of paint damage could a depreciation rate have been justified and the inclusion of such a rate would have had an insignificant effect on the total structural damage estimate.

For the Fort McMurray study it was assumed that the major structural components of a typical house, if maintained, have a life expectancy that virtually defies application of arbitrary depreciation rates. In general, deterioration is related primarily to finishes, wall and floor coverings, etc., and these in the average home are generally well kept up. Consequently, no depreciation rates were applied to replacement and/or restoration values used to construct the structural stage-damage curves.

2.3.2 Commercial/Industrial Flood Damage

2.3.2.1 Introduction

Flood damages for commercial establishments include damages to inventory, equipment and buildings as well as clean-up costs. As with the residential component, damages are calculated separately for contents and structures. This group, due to the range and diversity of activities covered does not demonstrate the same uniformity as the residential grouping. Consequently, categorization is a much more complicated procedure and necessitates the grouping of similar functions.

Three fundamental procedures were carried out in the formulation of synthetic unit-damage curves for this category:

1. Review of previous studies to establish classification system;
2. Development of field program and survey tools; and
3. Inventory of establishments within each class.

The following sections describe the development of synthetic unit stage-damage functions for the various classes of commercial establishments within the Fort McMurray study area. These functions in combination with the commercial inventory, level loop data and flood elevation-frequency information rendered total commercial flood damages for the Lower Townsite and Waterways.

2.3.2.2 Inventory of Commercial/Industrial Structures

The inventory was carried out in a similar manner to the residential structure inventory, i.e., all commercial/industrial structures within the designated flood study area were recorded, photographed and an inventory sheet completed. The description for the industrial and commercial structures included floor areas, which were estimated during the fieldwork. In most cases, the floor area estimates were updated by data provided by the City. In addition to these floor area data, the City also provided an up-to-date listing of property ownership for the entire Lower Townsite, as well as an updated list of existing business types for the industrial and commercial areas. This data served as a check on the completeness of the inventory.

In total, some 303 commercial/industrial establishments were inventoried, constituting some 230,000 m^2 (2.5 million ft^2). Photographs of representative commercial/industrial/institutional establishments are contained in **Exhibit 2.5**.

2.3.2.3 Development of the Questionnaire and Damage Categories

The primary objective of the survey of commercial/industrial activities was to gather sufficient information on potential damage to allow the construction of average unit - damage curves for various categories of commercial/industrial enterprises. The initial step in this analysis involved the grouping of the 303 establishments inventoried into 19 functionally similar categories. This was based in part on previous studies including Acres 1968, Fraser River Study 1975, and FlA. While some of these categories are relatively homogeneous, several are catch-alls for a variety of non-related activities.

The questionnaire employed in the survey was modelled after previous examples although somewhat condensed due to the total number of establishments to be inventoried and the significantly increased number of categories. Essentially the survey was directed towards obtaining information relative to damages to inventory, equipment, raw materials, and structures, as well as clean-up costs.

Representative Commercial Industrial Establishments

Industrial

Office

Office

Commercial-Retail

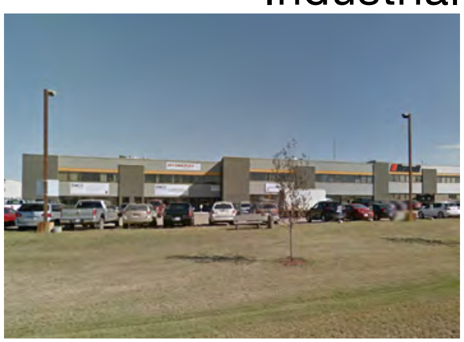
Industrial

Institutional

Institutional

Commercial-Retail

Industrial



Warehouse

Warehouse

Commercial-Retail

A stratified representative sample of commercial and institutional establishments was made, whereas all warehouse/industrial establishments were surveyed, as this group displays such a diversity of activities that generalized stage-damage curves based on a limited sample are not feasible[9]. To quote from Acres, “there is a wide variety of industry types, and no generalizations can be made of content and structural characteristics within these types since this is determined by the unique production requirements of each plant. Therefore, a functional or structural classification, such as those used for residential and commercial establishments, would not be meaningful for industrial stage-damage analysis”[10].

The general approach employed during the survey was to query proprietors or store managers regarding: the value of their inventories, the percentage damageable at each unit depth of flooding, possibilities of salvage, values of equipment and furniture and structural characteristics of the building including heating and air conditioning systems, electrical panels, etc. If this type of cooperation was not received, field personnel obtained a rough estimate of the total inventory by sampling it on the premises. Essentially, shelves, racks, counters and display cabinets were measured and the value of goods found in selected sample areas within each type of display or storage unit was recorded. For example, an inventory of all the goods found on a shelf within a number of 300 mm (one foot lengths) was taken at regular intervals. The average value per 300 mm of sample shelving was then applied to the entire length of .shelving to obtain the total value of goods in the unit. This method provided a very approximate determination of the firm’s total inventory damage for every 300 mm of flooding.

2.3.2.4 Content Damage Curves

In terms of content damages to commercial establishments, the primary difference between this category and the residential category is that the contents relate primarily to inventory as opposed to furniture and common household articles. The other major difference is that total content damage is based on the non-salvageable portion of the inventory versus the depreciated value of household contents. Similar to the assessment of residential content damages, no adjustment was made as a result of possible flood response due to past flood experience.

2.3.2.5 Structural Damage Curves

For structural damages to commercial and industrial structures, Acres dropped the detailed functional classification and instead developed two overall curves for (a) brick, concrete block and stone structures, and (b) wooden structures. In comparing these curves, there exists little if any difference in damage/m^2 of flooding, with wood suffering marginally higher damage/m^2 of floor area by 10 or 20 cents/m^2.

During the inventory phase of the study, main structural types of commercial and industrial establishments were identified as brick, concrete block, steel and wood; however, structural damages as a result of flooding are not specifically related to exterior material type. The principal damage suffered is that to interior components of these buildings including insulation, partition walls, flooring, ceilings, doors, heating, mechanical and electrical systems, etc. Accordingly, a four-fold structural classification was developed for the Fort McMurray Study to be applied to the 19 functional categories. The four categories included office/retail, industrial/warehouse, hotels/motels, and institutional.

The office/retail category generally exhibited a higher level of finishing, carpeting, wallboard, higher level of ceiling finishes, more doors and partitions, etc. The industrial warehouse category demonstrated similar interior space and was characterized by small offices with virtually no

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9 Kates, R.W., *Industrial Flood Losses: Damage Estimation in the Leigh Valley, University of Chicago, RES, Paper No. 98*, University of Chicago Press.
10 Acres Limited, Op Cit.

partitions and a very low ratio of finished to unfinished interior space. With respect to hotels, this was an extremely difficult category to assess given that the hotels inventoried were quite different with respect to the internal characteristics and arrangement of function rooms including banquet halls, restaurants, lounges, etc. There was a relatively low level of information and therefore a large number of assumptions relative to developing a curve for this particular establishment.

Similarly, there was a very limited sample for the institutional establishments with only one elementary school, a library and government office inventoried. Institutional establishments cover the spectrum from schools to libraries to churches to firehalls, etc. Some of these buildings are expensive to construct and very limited information was available on costs and potential damage to various systems and individual components. While some time was spent calculating costs/m^2 of constructing schools within Fort McMurray, considerably more effort was required to develop a representative curve for institutional establishments using several examples to derive a unit curve for structural damages.

In light of the somewhat tenuous results that could be expected based on the construction of a curve from the limited information within this category, it was decided to employ the institutional curve developed in the Fraser River Study. Substantially more time was allocated in this study for the derivation of an institutional damage function.

Estimates of unit prices for replacing and/or repairing flood damage materials were obtained from local suppliers and contractors. All structural damage curves reflect the costs of repair or restoration estimated on the basis of present day Fort McMurray material and labour costs.

Again, structural damages were based on the characteristics of a typical ice jam flood, assuming a six to eight day recession period. It assumed virtually no damage to walls due to hydrostatic pressure as water would leak in around window sashes, doors, and other openings. Further, it assumed no damage to structures as a result of blocks of ice contacting exterior walls.

In summary, to compute the structural damage estimates, the 19 commercial and industrial and institutional categories were aggregated into four basic structural categories: office/retail; industrial/warehouse; hotels/ motels; and institutional. Average floor areas and linear wall measurements were computed within each aggregated structural category. These averages, in combination with the field gathered construction data, were used to create a hypothetical composite structure which was representative of all of the structures in that category. The structural stage-damage curves were computed using this hypothetical model. Given the diversity of building types and sizes, the composite structure generally did not bear a resemblance to any one building in the sample. However, the unit area average structural damages constitute an accurate representation of the aggregated sample.

2.3.3 City of Calgary Stage-Damage Curves 1986

IBI/Ecos along with WER were retained by the City of Calgary and Alberta Environment in 1986 to conduct the Elbow River Floodplain Management Study. For damage estimation purposes, additional research was undertaken on institutional damages and damages to Stampede Park. The Fort McMurray stage-damage curves were indexed as well to reflect 1986 Calgary values.

2.3.3.1 Institutional Damages

Since the Elbow River Study Area contained major hospitals, schools and other institutional facilities, and given the specialized nature of these facilities and the potential high economic and social impacts associated with flood events, it was decided to undertake a detailed survey for schools and hospitals within the Flood Hazard Area. Four institutional facilities were selected for this analysis as follows:

- The Mission Professional Centre;
- The Cliff Bungalow Elementary School;
- The Colonel Belcher Hospital; and
- The Holy Cross Hospital.

For these facilities contents and structural damages were estimated and stage-damage curves developed.

2.3.3.2 Conclusions

As evidenced by the results it was noted that there was a significant variation within the institutional category directly related to the functional diversity within the category itself. Unlike grocery, hardware, pharmacy, clothing and furniture establishments , which tend to demonstrate a homogeneity of product type and display methods, the institutional category tends to be a catch-all for a variety of unrelated services . In this latter aspect it is much more akin to the industrial/warehouse category which is also typified by a wide variety of functions with content and structural characteristics determined by the unique production requirements of each plant.

Generalizations are hard to make in functional or structural classifications such as those used for residential and commercial establishments and therefore are not as meaningful.

2.3.3.3 Damages to Stampede Park

The purpose of this component was to assess the potential economic loss which would be caused by a 1:100 year flood at Stampede Park. The flood risk period was identified as occurring between May 15 and September 15. As utilization of the park varies widely through the May to September flood hazard interval, three independent flood loss cases were examined:

- The first, or base case identified the potential economic loss suffered through flood damage to permanent structures and facilities, and through the impairment of ongoing operations and activities.
- The second case specified those additional potential economic losses to facilities, operations and activities which would be associated with a flood during the 11 day period of the annual Calgary Exhibition and Stampede.
- Finally, the third case examined potential economic losses associated with the range of other events typical of the use of Stampede Park on an “average” spring or summer day. Thus, the three cases singly or in combination represented the range of economic losses which could be associated with a 1:100 flood of Stampede Park.

2.3.3.3.1 Content Damage Curves

Potential content damages were assessed by combination of a visual inspection of various premises, and discussions with senior management and day-to-day facilities’ users.

2.3.3.3.2 Structural Damage Curves

In conjunction with the content damage assessment section, all available plans, elevations and cross sections of permanent structures and facilities were acquired. Qualified architectural personnel reviewed the various facility plans, and then verified the structural characteristics of the facilities through field inspections. The 44 buildings on site were categorized into five primary construction types based on construction classification, cost and use.

Damage estimates were based on the then current City of Calgary costs for materials, labour and service. Structural damage and restoration cost estimates were also based on the characteristics of a 1:100 year flood event, assuming a one and a half day recession period. The estimates also assumed virtually no damage to walls or slabs through hydrostatic pressure, as exterior forces would be balanced by water backup through drains and leakage through vents, etc.

2.3.3.3.3 Stampede Depth-Damage Curves

Flood damage estimates were calculated by interviewing Stampede officials, and exhibitors, operators and owners of the numerous concessions and displays which constitute the exhibition. For selected high value or unique operations, every available operator was interviewed, while a sample of operators of specific types of facilities were interviewed. For example, 16 of 179 food concessionaires were interviewed with respect to flood damages.

Approximately 85 personal and telephone interviews were conducted to assemble the data required to estimate the flood damages associated with the Stampede. A standard interview format was established to direct the data collection efforts.

Essentially, concessionaires were asked questions concerning: a) the structure that the concession was operated from (e.g., its dimensions, age, the construction materials used, its value); and b) the contents of the structure (e.g., equipment, furnishings, merchandise, total value and salvageability of these). In addition, the concessionaires were asked to estimate the extent of the damages that would occur to the structure and contents at incremental flood levels.

The various uses were classified by functional type and location as either inside or outside a permanent structure. Each standard curve was broadly applicable to a functional use, e.g., food services or shows. In total, six functional categories were identified; however, certain of these uses did not occur in both locations, hence 10 standard depth-damage curves were generated (4 common by function to both locations = 8 standard curves; and 1 specialized function to each location = 2 standard curves). Damage curves were also generated for specialized uses, such as mobile television studios, the Indian Village, etc.

2.3.4 Industrial and Commercial Depth-Damage Curve Assessment[11]

A recent article summarizes the development of depth-damage curves for industrial and commercial economic sectors based on observed damages in Taiwan following the flood event of the 2001 Nari typhoon.

Flood damages reported by business entities to the National Tax Administration were analyzed to determine the type of business entity, its geolocation, and flood depth during the typhoon. The business entities suffering direct flood damage were classified using the Standard Industrial Classification scheme (SIC) into four principal categories: manufacturing; wholesale trade; retail trade; and service. Agriculture and mining industrial class entities were excluded from the analysis. The rationale for the four-fold classification is that the industries aggregated within each class tend to have similar processes and means of storing input and output goods, and also to yield sufficient numbers of entities in each class to support development of stage-damage curves.

The reporting entities within each of the four analyzed industry classes were further subdivided by size of business into large and small entity sub-groups. The classification scheme therefore resulted in a division of the reporting business entities into eight groups.

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[11] Ming-Daw Su et al, *Industrial and Commercial Depth-Damage Curve Assessment*, WSEAS Transactions on Environment and Development, Issue 2, Volume 5, February 2009.

Stage-damage curves were constructed for each of the eight groups by plotting the total reported damage from each entity against the known flood depth at that location. The resulting curves are published in the document. In general, the curves tend to indicate damage commencing at relatively low flood depths (typically less than 0.3 metres) with damages increasing rapidly in a somewhat linear fashion to flood depths in the vicinity of 1.2 - 1.5 metres, and then levelling off.

The simple classification of commercial entities in the four class scheme may have some applicability in Alberta. However, simple disaggregation of entities into small versus large scales reduces the usefulness of the stage-damage curves; although the large entity curves generally display similar slopes, the actual monetary value of damages is typically an order of magnitude greater from the small to large scale entities.

The above finding points to the advisability of accounting for direct damages on a dollar per unit of floor area basis, rather than on a per-entity basis.

2.3.5 Red River Basin Stage-Damage Curve Update[12]

This study commissioned in 2000 included a review of existing stage-damage curves along with a review of damage information for the Red River flood of 1997. The Terms of Reference were to consider structural, infrastructure, and agricultural damage estimates only. Other direct and indirect damages were not to be included.

The updated depth-damage relationships were developed using data from actual damages paid as a result of the 1997 flood. Geographical information system technology was used to fulfill the objective of presenting the estimated spatially-distributed damages.

2.3.5.1 Depth-Damage Relationships

1997 damage data was used to develop the depth-damage relationships wherever possible. As well, previous studies utilizing depth-damage relationships were reviewed to provide background data for the updated relationships. The majority of the existing curves utilized in previous studies were not developed specifically for Manitoba or the Red River Valley. They were adopted from studies in southwestern Ontario, Alberta and the United States. The only depth-damage relationship developed specifically for Manitoba was for the 1958 Royal Commission on Flood Cost/Benefit (Templeton Curve). This study considered that past work, and analyzed new damage data to create more representative curves. Other data sources were considered, including studies performed by Manitoba Natural Resources and the U.S. Army Corps of Engineers.

2.3.5.2 Depth-Damage Curve Development Methodology

Damage claim data was provided by the Manitoba Emergency Management Organization (MEMO). A total of 186 out of 5,000 claims were provided for the development of the updated depth-damage relationships. The methodology for preparation of the depth-damage curves for structure flood damages considered the following:

- The structures were separated into specific categories with similar characteristics. Typical structure categories included single storey residential, multi-storey residential, mobile home and commercial/industrial/public buildings.
- Residences were generally considered to have basements. Commercial, industrial and institutional buildings were considered to not have basements.

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[12] KGS Group, *Red River Basin Stage-Damage Curves Update and Preparation of Flood Damage Maps*, International Joint Commission, January 2000.

- The assessed market value of each structure was determined from the tax assessment database or from MEMO records.
- MEMO flood claims were used to determine the value of the contents losses as a percent of the building value.
- The curves developed included three components of loss as defined by MEMO: foundation, structure components and moveables. Moveables were considered to include building contents; individual pre-emptive flood fighting costs; crop inventory losses; yard restoration and other losses.

Damages were referenced to depth of flooding above the first floor level (the reference level). The relationships developed provide an estimate of damages as a percent of the market value of the structure for all depths of flooding above or below the reference level. The market value was assumed to be equal to the assessed value of the structure as determined by the Manitoba Rural Development Tax Assessment Branch. This general relationship then allows the application of the damage function to any structure in the building category as long as the market or assessed value of the structure is known.

The Manitoba Rural Development tax assessment database was utilized to define all possible building types. Approximately 375 unique class descriptors exist in this database defining the general classes and sub-classes of buildings. These descriptors were used to group the buildings into more general categories for application of the depth-damage relationships. The groups derived from the database are considered to be consistent with previously-developed relationships utilized in previous studies by the Province. Thirteen categories were considered applicable for the analysis as they are consistent with previous work. They include:

1. Single Storey Residences
2. Multiple Storey Residences
3. Bi-level Residences
4. Mobile Home Residences
5. Attached Buildings - Residential
6. Attached Buildings (Multi Storey) - Residential (Second Storey Additions & Balconies)
7. Detached Buildings - Residential
8. Agricultural Buildings- Barns (Hog, Poultry, Dairy & Horse)
9. Agricultural Buildings- Out Buildings Granaries, Tanks, Shops, Shelters, Quonsets
10. Commercial Buildings - Apartments
11. Commercial Buildings - General
12. Commercial Buildings - Agricultural & Service
13. Government Buildings

It became apparent that the 1997 Flood damage data would not support the construction of updated depth-damage relationships for all of the above categories. The capability to input the various relationships was, however, incorporated into the model should future relationships be developed.

Attempts were made to acquire as much damage claim data for each structural category, but two significant problems with the MEMO data became apparent as the data was being transferred.

- MEMO's records did not distinguish between the desired types of structures effectively within the claim file. The claim data was compared to the tax roll to ensure that the damage data was assigned to the proper residential category.
- No claims were forwarded from MEMO for bi-level residences. Since the data did not vary significantly between single and multi-storey residences, damages for bi-level residences were estimated using the single storey residence depth-damage relationship.

Very few commercial/industrial claims were processed, and the information forwarded to KGS Group for the study was considered not to be representative of typical commercial buildings. Since no new depth-damage curves in this category could be developed using MEMO data, the single storey residential curve was used as a basis to estimate damages. This approach was considered reasonable for the following reasons:

- Previous studies indicate that "few differences between structural damages to residential and commercial buildings and only slight differences were evident for damages to commercial buildings of wood exterior and brick, stone or concrete block exteriors".
- In rural areas, construction of commercial and light industrial buildings is considered to be similar in nature to housing and agricultural buildings (i.e., wood frame construction).
- Previous studies indicate that commercial/industrial buildings should be assessed on a case-by-case basis. This approach was considered to be beyond the scope of this project, but could be considered in future refinements of the model for estimating damages.
- Although MEMO does not necessarily accept claims from all types of businesses and industry, once accepted, the claim is handled similarly to all other types of claims. Therefore, it is anticipated that claims paid would also be similar.
- Precedent has been set for the application of the residential curve to commercial buildings by the Ad Hoc Task Force on Manitoba Flood Mitigation Projects.

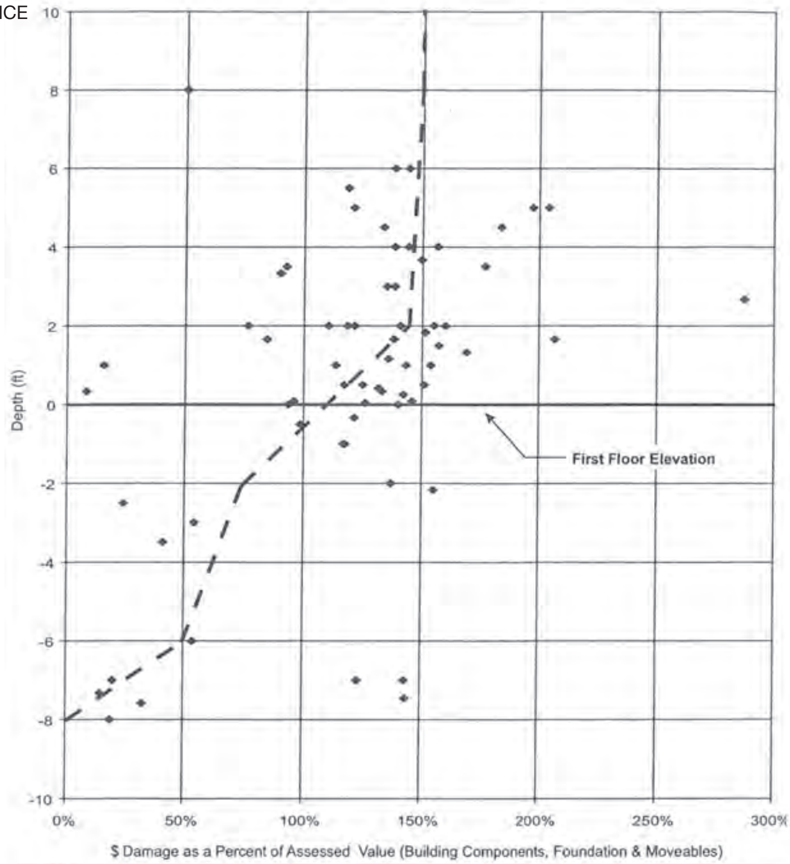
2.3.5.3 Depth-Damage Relationships

Exhibit 2.6A/B/C shows the damage data from the 1997 flood, and the curves used for this study. As can be seen, significant scatter exists in the data, making the development of the relationships difficult. To be consistent with previous studies, the general shape of the curve was assumed to be similar to other depth-damage relationships. Damage data points, which deviate significantly from the chosen relationship line, are considered to be outliers.

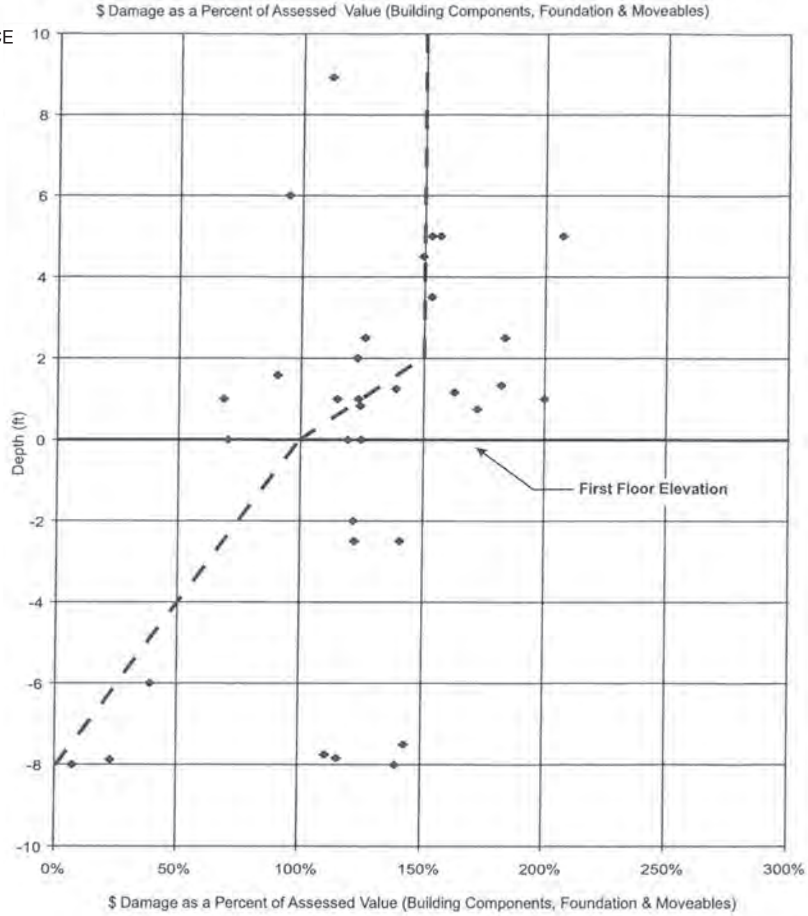
In general, the depth-damage relationships developed show that the damages exceed the market (assessed value) of the home as the flood depth increases beyond the first floor. This trend is consistent with previous studies, but the slope of the MEMO data relationship is greater than previous curves. As an example, the single storey residence curve developed for this study is shown (see **Exhibit 2.7)** in comparison to the "Templeton Curve" developed for the Royal Commission on Flood Cost-Benefit. The new relationship has significantly higher percentages of damages up to 6 feet above the first floor. The largest variation occurs at the first floor level where the new curve predicts damages at approximately 110 percent of market value as opposed to approximately 30 percent for the "Templeton Curve". There are likely a number of reasons for the differences including the increase in developed basements in homes, and a changing political view of compensation for flooding upstream of Winnipeg.

Depth-Damage Curves

SINGLE STOREY RESIDENCE



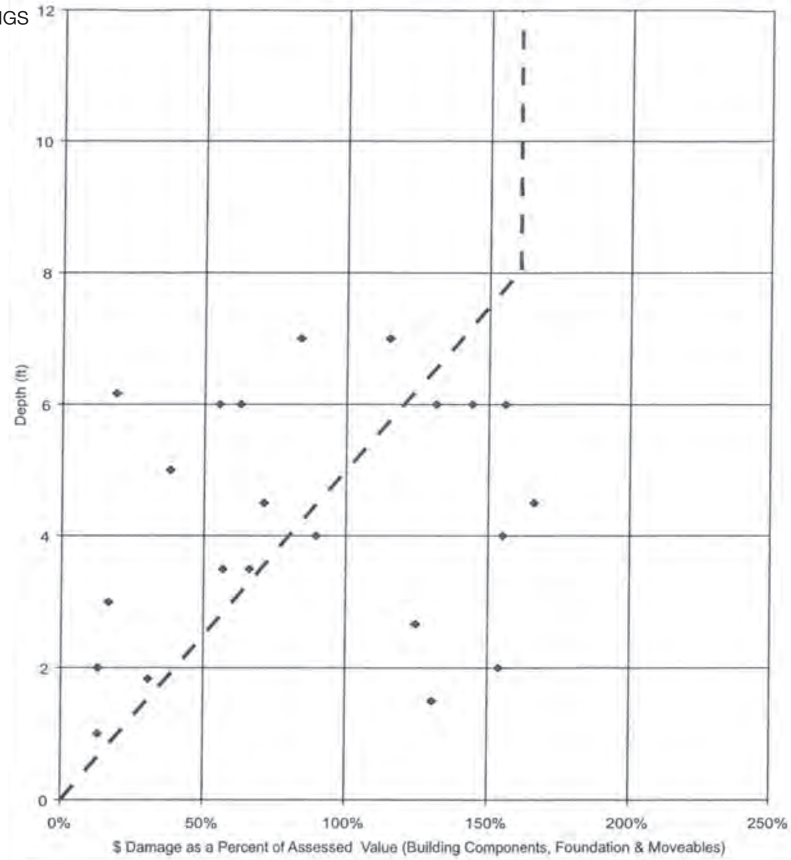
MULTIPLE STOREY RESIDENCE



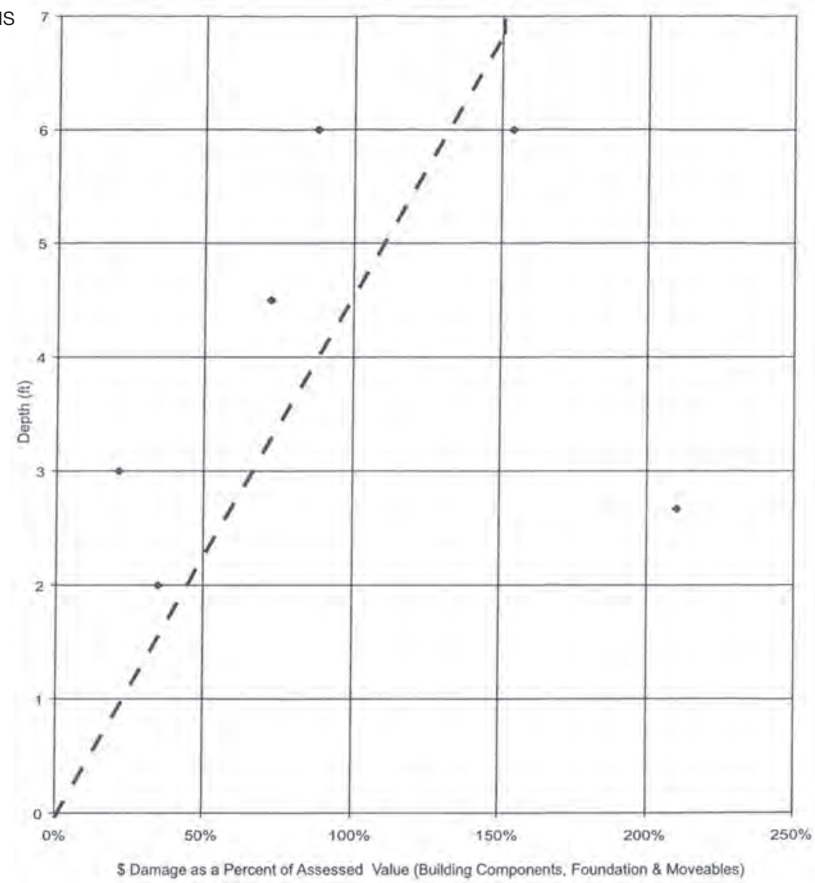
KGS Group, *Red River Basin Stage-Damage Curves Update and Preparation of Flood Damage Maps*, International Joint Commission, January 2000.

Depth-Damage Curves

DETACHED RESIDENTIAL BUILDINGS



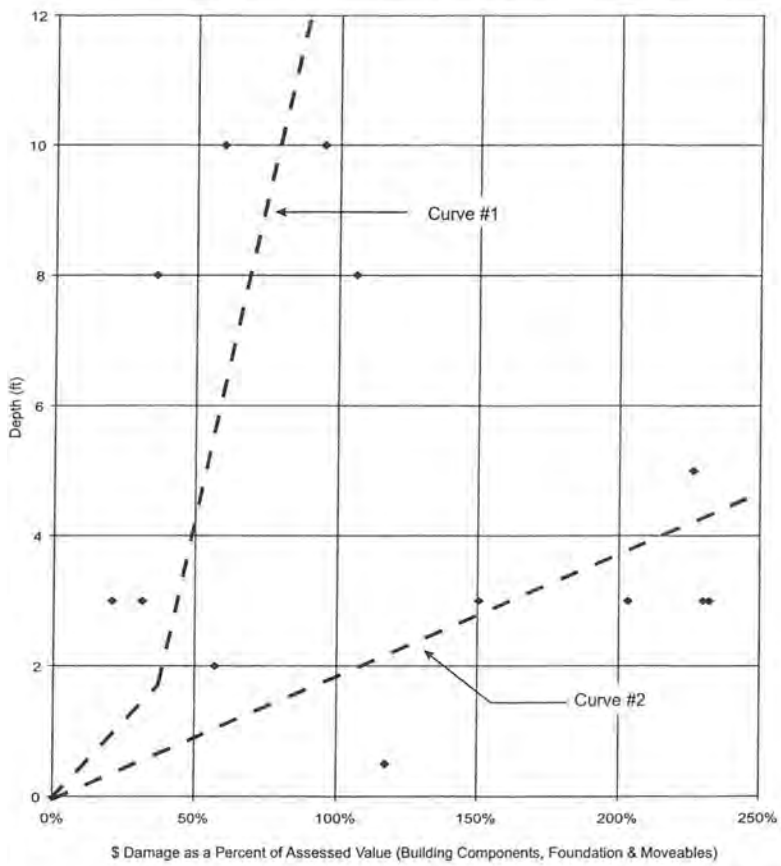
AGRICULTURAL BUILDINGS - BARNS



KGS Group, *Red River Basin Stage-Damage Curves Update and Preparation of Flood Damage Maps*, International Joint Commission, January 2000.

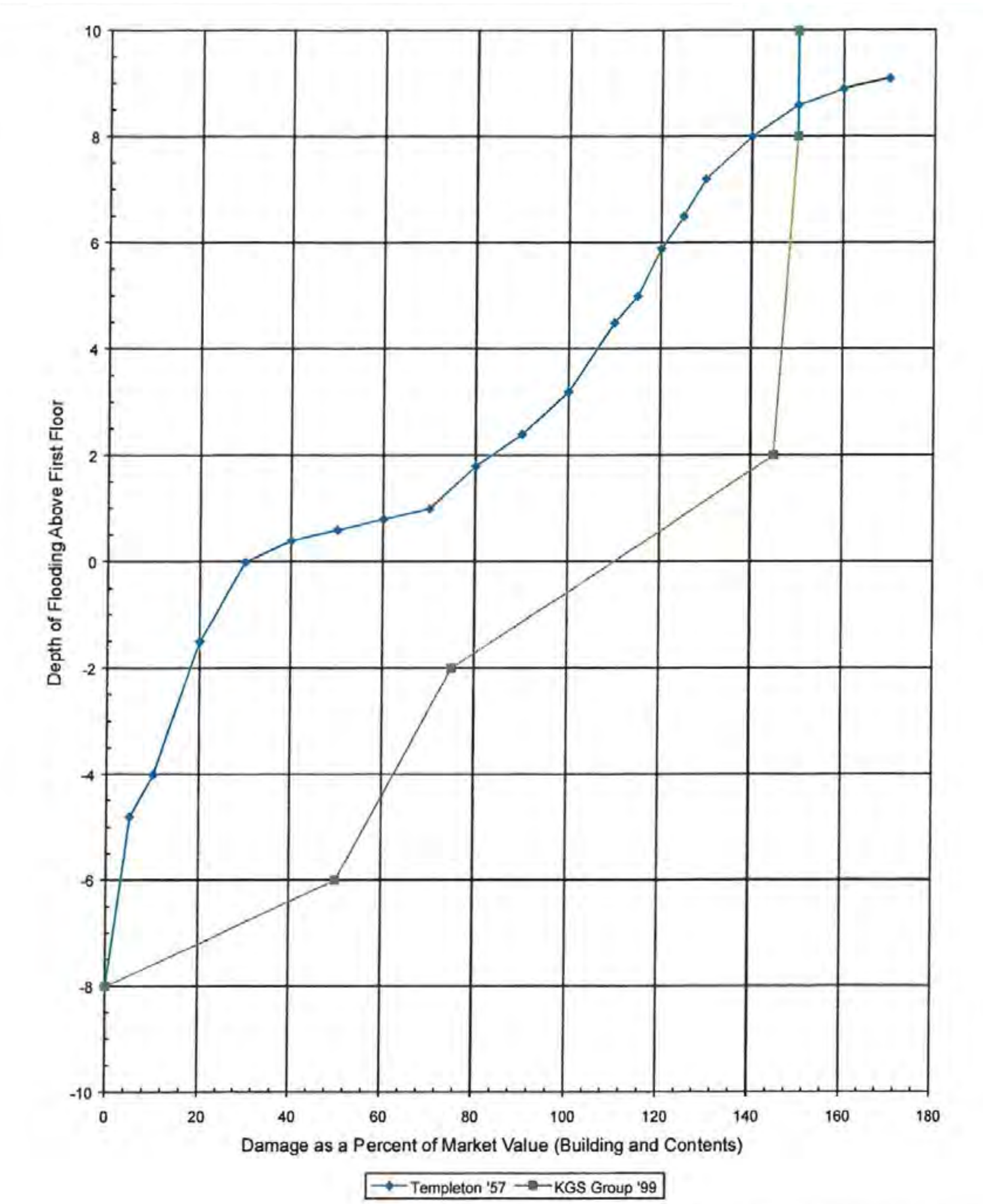
Depth-Damage Curves

AGRICULTURAL BUILDINGS - OUTBUILDINGS



KGS Group, *Red River Basin Stage-Damage Curves Update and Preparation of Flood Damage Maps*, International Joint Commission, January 2000.

Comparison of Depth-Damage Relationships



KGS Group, *Red River Basin Stage-Damage Curves Update and Preparation of Flood Damage Maps*, International Joint Commission, January 2000.

As can be seen in the curves, the relationships were developed as “piece-wise” linear relationships. These relationships were digitized for use in the computer data model and related the depth of flooding to the assessed value of the structure. As described above, no curves could be developed from the data for commercial, industrial or institutional buildings. The damages for these building were calculated based upon the single storey residence curve shown on Exhibit 2.6A.

2.3.5.4 Conclusions

1. The overall approach to calculate damages due to flooding in the Red River Valley shows that the geographical information system (GIS) technology is an effective tool for calculating and showing the spatial and temporal impacts of flooding in the Red River Valley.
2. The depth-damage relationships developed using new flood damage data are consistent with actual damages paid as a result of the 1997 flood. The shape of the updated curves is consistent with existing curves, but produces higher damage estimates than previously developed relationships. The estimates produced by the developed relationships are also higher than those commonly used elsewhere in North America.
3. Depth-damage relationships based upon 1997 flood damage data were developed for residential and agricultural type buildings.
4. Depth-damage relationships could not be developed for commercial, industrial or institutional buildings due to a lack of claims processed by the Manitoba Emergency Management Organization (MEMO). Residential curves were considered to be representative, and were used to estimate updated depth-damage curves for these structures.
5. Infrastructure damages were included in the model and calibrated to reported 1997 flood damage levels. Relationships were developed, which can be used to extrapolate the damage estimate to other floods of differing magnitudes.
6. The calculation of structural damages using the GIS and the data model is considered representative because it accounts for permanent flood protection structures in the Red River Valley, which are permitted by the Water Resources
7. Branch. This includes the community ring dykes.

2.3.6 Australian Experience[*]

2.3.6.1 Report for Bundaberg Council – Floodplain Action Plan[13]

In Queensland, the most relevant publication on flood damage assessment is in the *Guidance on the Assessment of Tangible Flood Damages* (Queensland Department of Natural Resources and Mines, 2002), based on research done by the Australian National University in the ANUFLOOD project (Smith & Greenway, 1988). Nationally, the most up-to-date stage-discharge damage assessment methodology is the DECCW (Department of Environment, Climate Change and Water) methodology outlined in the *Floodplain Risk Management Guideline: Residential Flood Damages* (DECCW, 2007). These two methodologies have been combined to provide flood damages estimates for selected land use types, resulting in the adopted methodology shown below.

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[*] Values are expressed in Australian dollars.
[13] GHD, *Report for Bundaberg Council – Floodplain Action Plan*, 41/26909.

Methodology for Assessment of Potential Tangible Damages

TANGIBLE	DIRECT	Urban	Internal	Commercial	DNRM Stage-Damage Curves
				Residential	DECCW Stage-Damage Curves
			External	Commercial	Negligible
				Residential	DECCW Stage-Damage Curves
			Structural		$20,000 per property based on high depth/velocity criteria
		Infrastructure			15% of Total Direct Damages (DECCW)
		Rural			15% reduction in sugar cane yield where flood depth is greater than 1.2 (BSES 2008)
	INDIRECT	Commercial			55% of Direct Damages (DNRM)
		Residential			DECCW Stage-Damage Curves

Both the DNRM and DECCW methodologies utilize stage-damage curves to estimate the internal damage experienced due to above-floor flooding at a given property. To calculate the damage of a given flood event, the peak flood level at the building is used to calculate an above-floor flood water depth, which is plotted on the stage-damage curve to derive the corresponding damage cost.

There have been a number of studies examining the complex question of what appropriate stage-damage curves are for different building types, land uses and geographical locations. Stage-damage curves were used to calculate the direct and indirect damage to residential, commercial and industrial properties. Rural and agricultural damages, as well as building structural damages, were calculated by different means as described in the following sections. A description of the varying curves and application methodologies for buildings within each land use type is provided in the following sections.

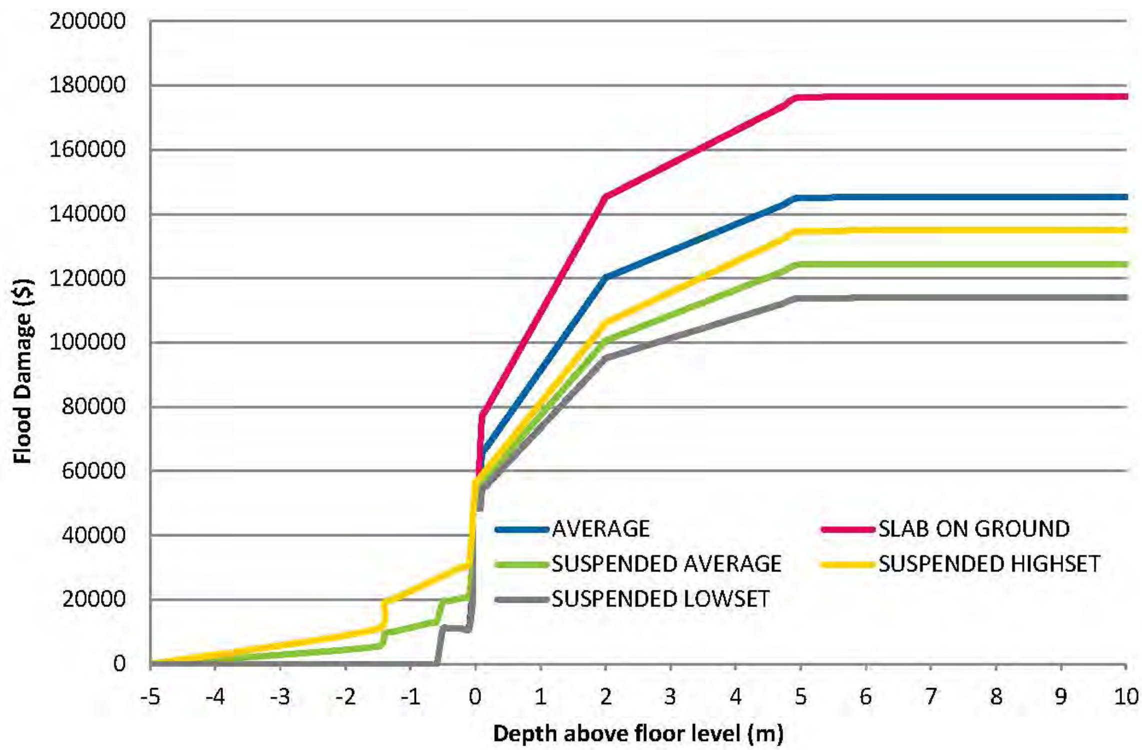
2.3.6.1.1 Residential

The DECCW methodology as described in the *Floodplain Risk Management Guideline: Residential Flood Damages* (DECCW, 2007) was adopted for the assessment of residential flood damages. This was thought to be more appropriate for the assessment of residential damages than the Queensland DNRM methodology as the stage-discharge curves are more tailored to locality and construction type information. They were also preferred as they have some provision for indirect costs, which the ANUFLOOD curves lack.

The DECCW method utilizes separate stage-discharge curves for different residential building types. In the case of the Bundaberg region, residential properties could be categorized as slab on ground, low-set stumps or high-set stumps. Categories for 'unknown' and unknown set stumps' were assigned to those buildings where limited information was possible.

The DECCW residential curves are based on various input data including bench height, CPI, regional cost factor, flood awareness, flood warning time, typical cost of contents, typical building footprint and insurance. For high-set houses there is some accommodation for damages associated with flooding beneath the floor level, as often this space is used for storage. The DECCW method accounts for a combination of direct and indirect damages including allowances for clean-up costs and alternative accommodation.

DECCW Residential Damage Curves



2.3.6.1.2 Commercial and Industrial

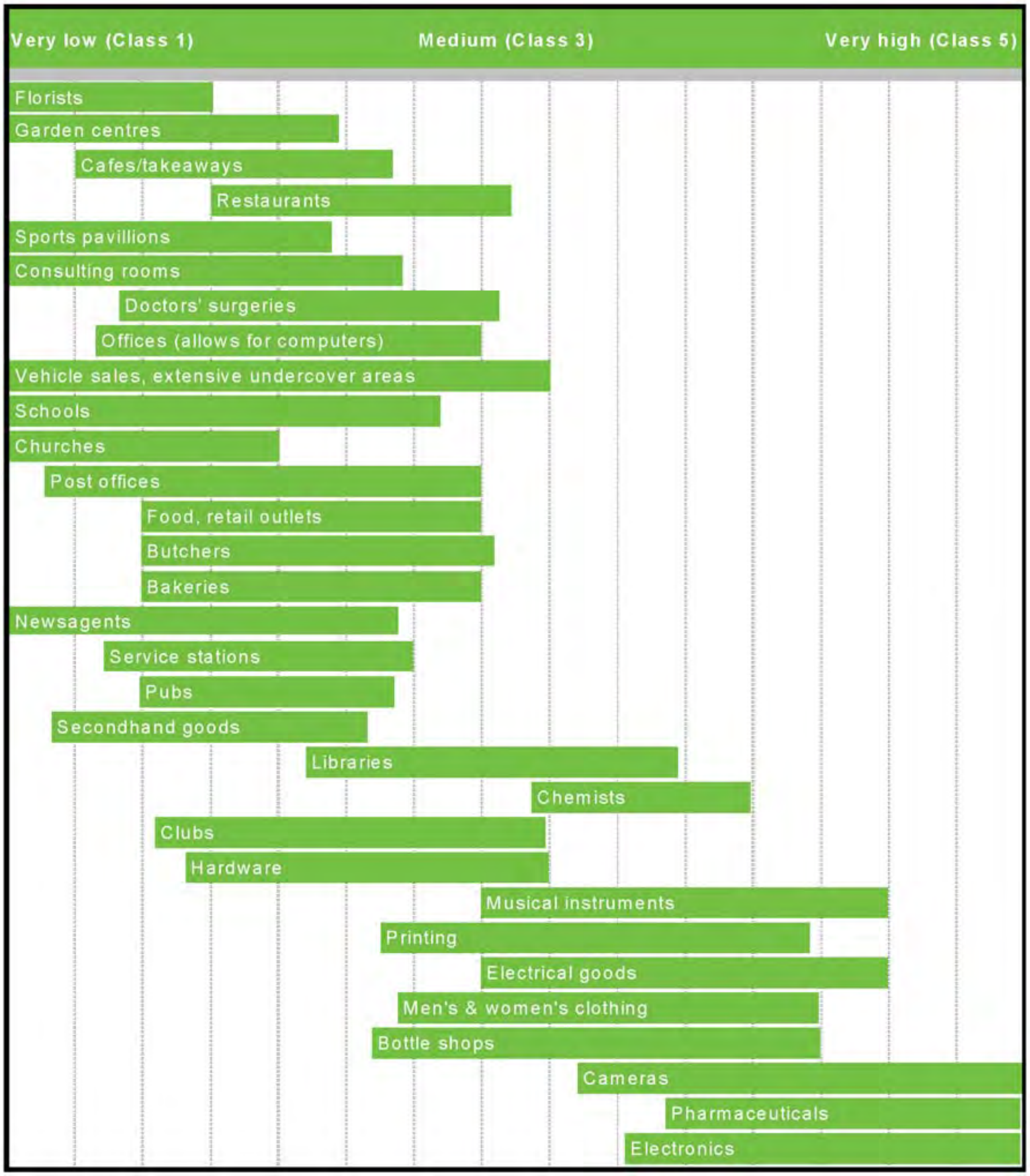
The Queensland DNRM methodology (DNRM, 2002), which is based on the stage-discharge curves developed by ANUFLOOD (Smith & Greenway, 1988) was adopted for the assessment of damages to commercial properties. This methodology utilizes various stage-damage curves based on both building size and contents value categories. Contents value was determined based on the guidance provided for commercial contents value classes 1-5. While there are multiple stage-damage curves available, BRC land use data was used to select the following categories to represent the typical commercial properties of the Bundaberg region:

- Small < 186 m^2/ Class 1
- Small < 186 m^2/ Class 3
- Medium, 186 to 650 m^2/ Class 1
- Medium, 186 to 650 m^2/ Class 3
- Large > 650 m^2/ Class 1
- Large > 650 m^2/ Class 3

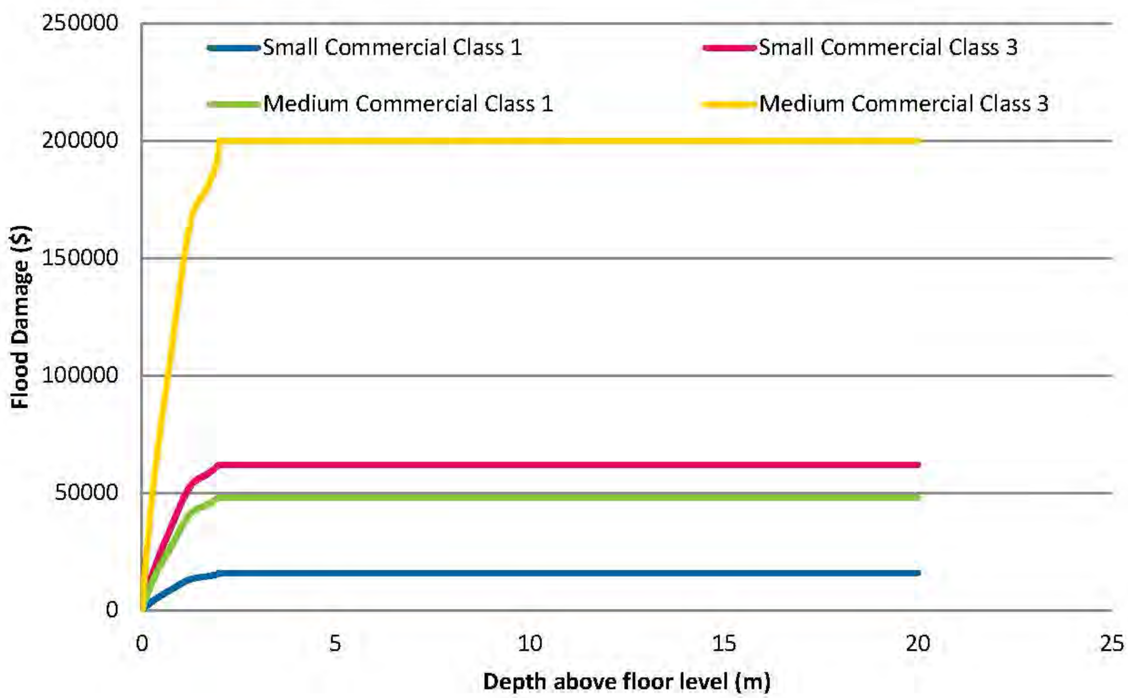
These stage-damage curves were updated to present day using CPI. It should be noted that curves for the small and medium sized buildings provide damages per property, while the large building curves provide damage estimates per unit of floor area (in this case m^2). These were used to estimate direct damages.

To account for indirect damages, the DNRM methodology suggests an estimate of 55% of direct damages. This is relatively high, as indirect damages to commercial properties can be substantial due to loss of business, disruption to public infrastructure and higher clean-up costs.

Commercial Contents Value Classes

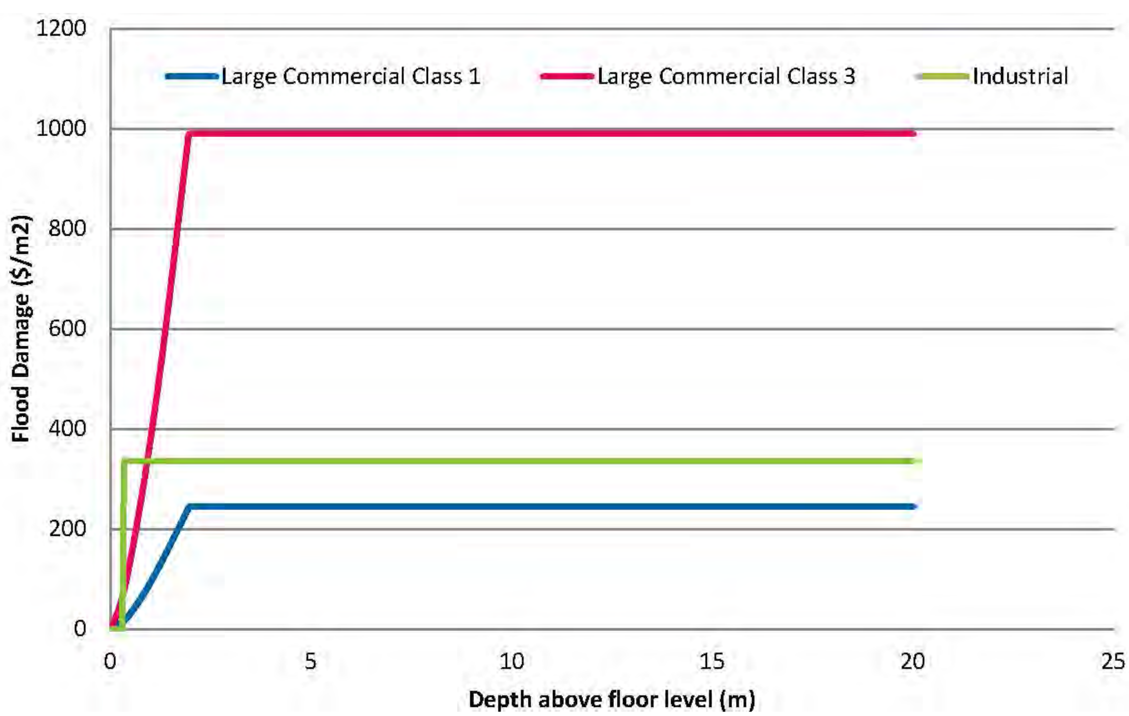


Stage-Damage Curve for Small and Medium Size Commercial Properties



Industrial damages were estimated using the suggested damages for the Rapid Appraisal Method (RAM) for Floodplain Management. This accords $302/m^2 where depth is greater than 0.3 metres.

Stage-Damage Curve for Large Commercial and Industrial Properties



2.3.6.1.3 Structural Damage

Structural damage is separate from the internal damages as estimated by the stage-discharge curves. The structural damage is a separate assessment of potential water damage to the fabric of the building and its overall stability. This may include water damage to wiring, gates, fences, and structural failure. Significant structural damage typically is likely to occur when the velocity-depth product is greater than 1 m^2/s (DIPNR, 2005; DNRM, 2002). High velocities (2 m/s) or high depths (2 m) can also cause significant structural damage due to the scouring of foundations, water pressure, flotation and debris loading. Structural damages were assessed based on these three parameters, with a value of $20,000 assigned per property where significant structural damage is estimated to occur.

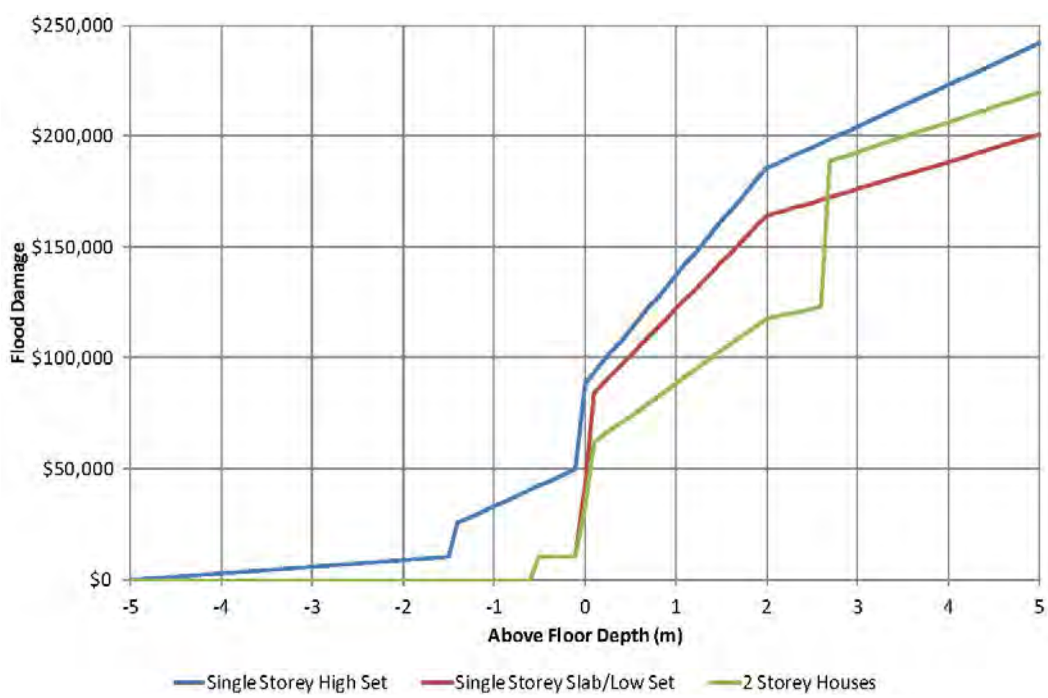
2.3.6.2 Ballina Floodplain Risk Management Study[14]

2.3.6.2.1 Residential Damages

For residential properties, the DECCW3 methodology outlined in *Floodplain Risk Management Guideline: Residential Flood Damages* (DECCW, 2007b) was adopted. This approach is based on stage-damage curves developed by Risk Frontiers for three different typical types of residential dwellings in the floodplain; low set, high set and double storey. The curves are based on a number of input parameters including typical house size, bench and storey heights, CPI, regional and scale cost factors, and awareness and warning times. The three resultant residential stage-damage curves for low set, high set and double storey dwellings in the Ballina Shire are shown below.

It was noted that the DECCW methodology does not explicitly account for multi-unit dwellings. In lieu of any data specific to multiple unit damages, it was agreed to directly factor estimated damages by the number of units per storey.

Ballina Shire Residential Stage-Damage Curves



[14] *Ballina Floodplain Risk Management Study*, January 2012.

2.3.6.2.2 Commercial Damages

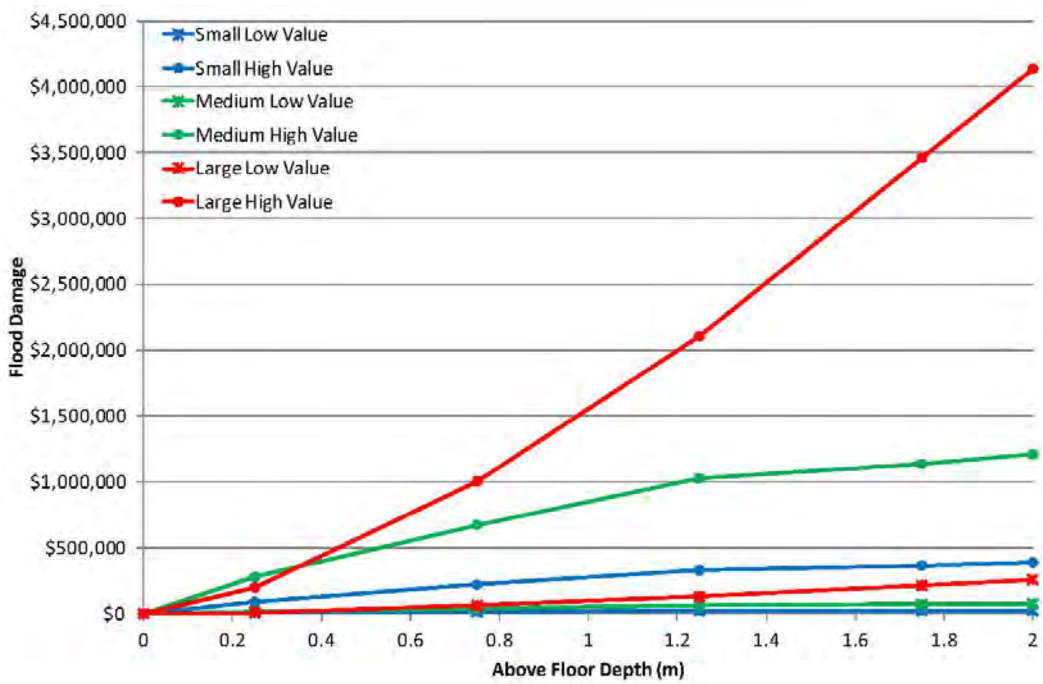
The Office of Environment and Water does not presently have specific NSW guidance on commercial flood damages. The Queensland NRM4 methodology was therefore adopted, as outlined in *Guidance on the Assessment of Tangible Flood Damages* (2002) and based on stage-damage curves developed for ANUFLOOD5. This is consistent with approaches adopted for a number of other northern NSW assessments.

The NRM methodology comprises 15 different stage-damage curves based on a combination of building size and contents value categories:

- 3 building size categories based on floor area:
  - Small < 186 m^2;
  - Medium 186 to 650 m^2; and
  - Large > 650 m^2.
- 5 contents value categories based on the nature of the business, from class 1 (low) to class 5 (high).

The curves for small and medium buildings provide typical damage estimates per property, however the curves for large buildings provide damage estimates per unit floor area (i.e., per m^2).

Ballina Shire Commercial Stage-Damage Curves



Note: Large commercial property flood damages are based on the property area. An area of 650m² has been used in the figure above.

2.3.7 Summary and Conclusions

It is instructive to note that the more recent studies of flood damage curves show a marked increase in damages at lower levels of flooding for both structures and contents, reflecting higher contents values per structure overall, lower levels of content repair and salvageability (planned obsolescence/throw away society) and current renovation practices which favour wholesale rather than incremental repair and rehabilitation to flood impacted structures.

From a Canadian, and specifically Alberta perspective, review of the literature and past studies reveals that the approach to developing stage-damage curves previously developed in Alberta on the Fort McMurray and Elbow River Studies is still relevant and further, that in the Canadian context no new methodologies have been developed nationally, or provincially since the definitive studies were undertaken. The methodologies as described were based on a first principles approach employing Alberta-specific building practices and contents data. It is anticipated that the updated curves will reflect current usage and levels of improvements to basements and main floor levels of residential and commercial structures and take into consideration current rehabilitation practices/approaches, which have changed somewhat over the intervening years.

2.4 Flood Damage Estimation Modelling

2.4.1 Flood Damage Database Management System (FDDBMS)

As part of the work undertaken by IBI/Ecos for Alberta Environment during the early 1980s, a computerized database inventory of residential and commercial units within the flood risk areas was developed using a CPM micro computer and BASIC program. The system and process developed was ahead of its time. It was the first computerized flood damage assessment system that computed flood damages to each building in the floodplain. This system was subsequently ported to the IBM-PC and MS-DOS using the PC File application.

FDDBMS was developed for use in Alberta and was subsequently used for flood damage assessment in the Province of Saskatchewan under a flood damage reduction program undertaken by Saskatchewan Environment. It was then modified for use in the province of Manitoba under a project entitled “Development of Depth-Damage Curves for Residential and Farm Structures in Southern Manitoba”, under the Canada-Manitoba Flood Damage Reduction Program for Canada's Inland Waters Directorate.

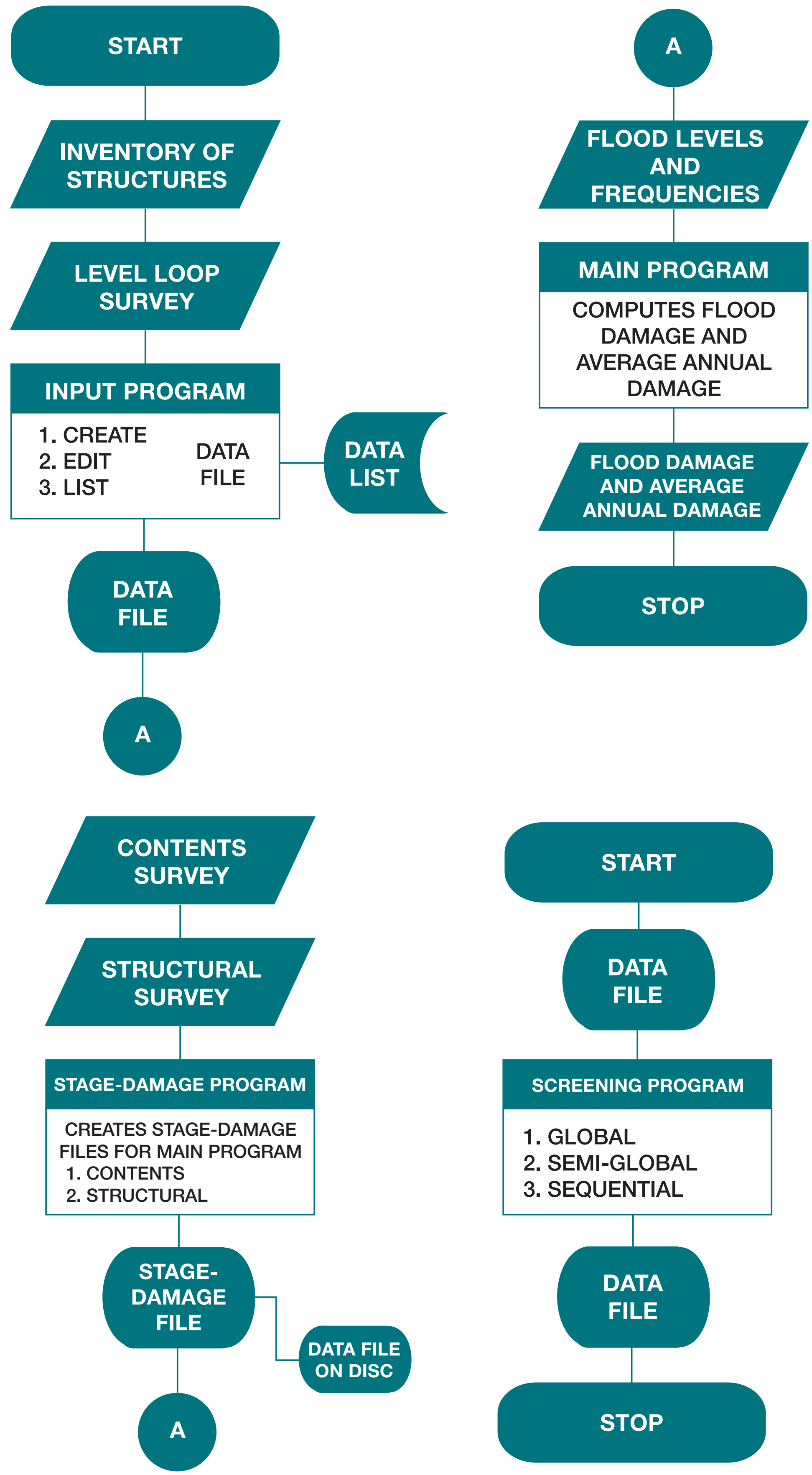
Comparative Flood Damage Estimation Program (CFDEP) was a modified version of FDDBMS designed to use the data base derived from the Flood Damage Survey Forms from seven communities in the Red River Valley and other adjacent watersheds in Manitoba. This data was collected by the Manitoba Flood Disaster Assistance Board which was formed by the Manitoba Government to administer the relief assistance, provided by the Federal and Provincial Governments.

A flow chart of FDDBMS is shown on **Exhibit 2.8**. It comprises a number of modules. The main module sequentially processes all the structures in the floodplain and adjacent-to areas (for basement flooding). The structural database is created using hardcopy planimetric maps and a level loop windshield survey to obtain structure type classification, grade and main floor elevation. Each structure is assigned a unique tag number plotted on the hardcopy map. The structural inventory module is a separate input module.

Another is the stage-damage module which is used to input multiple content and structural damage curves which are applied to the building inventory in the flood affected areas. Each damage curve is assigned a classification that is related to the units in the building inventory. The main difference between FDDBMS and CFDEP was that the latter was designed to apply multiple damage curves to the same building structures for comparative analysis of curves.

The main module applies the flood levels for different reaches (zones) from the different return floods computed from the U.S. Army Corps of Engineers HEC-2 application to the building database. It computes the flood damages using the assigned depth-damage curves and

FDDBMS Application Flow Diagram



combines a set of flood frequencies to compute average annual damages (AAD) for an area to be used in benefit/cost analysis.

In addition to residential and commercial building structures in the floodplain the module also computes basement flooding in adjacent-to areas.

2.4.2 FLDDAM Program

FLDDAM was a program written for the Ontario Ministry of Natural Resources (MNR) in conjunction with their Flood Damage Estimation Guide in 1989. While the program is still available, the depth-damage curves have not been updated since 1985 and the program itself quite outmoded.

2.4.3 DAMS/DAMP

DAMS/DAMP was a combination package for both archiving stream gauge data from remote sites and assessing potential flood damages produced under the supervision of Conservation Halton in the 1990s. It is a very basic program and has limited applicability on this assignment.

2.4.4 URB1, ECON2

URB1, ECON2 are flood damage estimation models produced by the U.S. Department of Agriculture (USDA) for estimating both urban and agricultural flood damage respectively. Like the MNR's FLDDAM model these programs are DOS-based with data entry requiring a separate program. The program is not particularly user-friendly nor in a Windows format.

2.4.5 FloodEcon

FloodEcon is referenced by the USDA as a newer update, combining URB1 and ECON2. However, the USDA has since converted to the USACE HEC-FDA damage assessment program rather than focusing efforts to update their own models.

2.4.6 HAZUS-MH

HAZUS-MH is a multi-hazard estimation model produced by the U.S. Federal Emergency Management Agency (FEMA) for estimating potential losses from earthquake, wind and flood disasters. It is GIS-based, but has been created largely for the U.S. insurance industry and has limited applicability in a Canadian context.[15]

General

The flood model includes a library of more than 900 damage curves for use in estimating damage to various types of buildings and infrastructure. Based on estimated property damage, the model estimates shelter needs and direct and indirect economic losses arising from floods. It also contains sub-routines for analyzing the effects of flood warning and certain structural mitigation alternatives.

Inventory and Valuation

A unique aspect of the flood model has to do with depreciation as opposed to cost of repair as the general measure of economic loss. This is due to the influence of the National Flood Insurance Program which pays claims on the basis of depreciated value. To develop this capability, data from a widely used source of building costs (Means 2000) is employed in the form of three tabular depreciation models for residential structures, based on actual structure age and general condition (Good, Average, and Poor). For commercial/industrial and

[15] C. Scawthorn et al, *Natural Hazards Review*, Volume 7, No. 2, May 1, 2006.

institutional structures depreciation is determined from observed age and building framing material (frame, masonry on wood, and masonry on steel).

Direct Damage

The HAZUS flood model uses estimates of flood depth along with depth-damage functions to compute the possible damage to buildings and infrastructure that may result from flooding. The outputs of the damage module are area weighted estimates of damage as a percent of replacement cost, at the Census Block or for a given building. These are used as inputs to the induced physical damage and direct economic and social loss modules.

Depth-Damage Functions

The HAZUS flood model uses the Federal Insurance Administration's (FIA) "credibility weighted" depth-damage curves and selected curves developed by various districts of the U.S. Army Corps of Engineers (USACE) for estimating damages to the general building stock.

Damage to General Building Stock

The algorithm for estimating direct physical damage to the general building stock is quite simple, and is computed for each occupancy class in a given Census Block, with default damage functions along with the estimated water depths to determine the associated percent damage. The estimated percent damage is then multiplied by the total replacement value or the depreciated replacement value of the occupancy class in question to produce estimates of total damage or total depreciated damage.

Damage to Essential Facilities

Depth-damage curves are used in a similar fashion for essential facilities through the use of editable default damage functions. These facilities are defined as those that provide service to the community and those that should be functional following a flood, such as hospitals, fire stations and schools.

Damage to Lifeline Systems

Damage to transportation and utility lifeline systems is estimated based on the vulnerabilities of the various components to inundation, scour/erosion, and debris impact/hydraulic loading. These components include bridges; water and wastewater system components and electrical power, communications, natural gas and petroleum lifeline systems. Impacts to system functionality, relative cost of component and overall time to recover from damage are also taken into consideration. Routines also take into consideration damage to vehicles and damage and loss to crops.

Consideration of Warning in Depth-Damage Relationship

Flood forecasting is a regular occurrence and the capability of estimating possible reduction of flood damage by taking actions after warning is provided in the flood model by consideration of warning time and altering depth-damage functions. The effectiveness of flood warning and reducing damage is estimated by modification of Day Curves, developed by Harold Day in a series of publications in the late 1960s and damage reduction related to forecast lead time which is defined as the time required for warning dissemination and effective public response. It is instructive to note that flood damage reductions resulting from the implementation of contingency measures were estimated in several studies undertaken by IBI/Ecos (1979 Flood in the Red River Valley, Drumheller Flood Control Study, 1984; and the Elbow River Flood Study in Calgary, 1986).[16]

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[16] Stephen W. Shawcross, *Flood Damage Reductions Resulting from the Implementation of Contingency Measures*, Proceedings of the 11th Annual Conference of the Association of State Floodplain Managers, Seattle, Washington, June 8-13, 1987.

Direct Economic Losses

Within the flood model methodology, direct economic losses include building repair and replacement costs (structural and non-structural damage), buildings' contents losses, building inventory losses, relocation expenses, capital-related income losses (previously loss of proprietor's income), wage losses, and rental income losses. The first three categories are building-related losses termed capital stock losses, while the last four are time-dependent income losses, requiring an estimation of building restoration or outage time.

Indirect Economic Losses

The model includes modules for estimating indirect losses resulting from flooding. The model employs two levels of analysis: Level 1 is a rapid high level analysis requiring minimal user input, while Level 2 requires model users to provide more detailed economic data on the affected area. The Level 1 analysis employs synthetic indirect economic loss tables reflecting the general economic structure (in a ten industry typology) of the affected area. In a Level 2 analysis, more detailed county level economic structure data are employed. The model is tightly geared to economic data formats employed in the United States, and has limited applicability in Canada at Level 2.

Some interesting enhancements in the indirect loss model include more detailed analysis of agricultural and tourism industry indirect losses, and the impact of flood damage to structures on the local tax base, and ultimately local government property tax revenue and government spending.

The model identifies the issue of substitution of economic inputs and outputs from areas outside of a typically small flood-affected zone. Model documentation cautions users that evaluation of indirect economic losses for small study areas could very well be "meaningless" due to substitution.

2.4.7 HEC-FDA

HEC-FDA is the flood damage estimation model produced by the U.S. Army Corps of Engineers (USACE). It is a risk-based analysis tool intended for use in the feasibility analysis phase of different flood mitigation measures, including a without project scenario. HEC-FDA has a function to import HEC-RAS and HEC-2 files (provided those packages are configured to produce output in the FDA format), and runs in a Windows environment. HEC-FDA is a free piece of software, and includes extensive documentation.

It is one of HEC's "next generation" (NexGen) of hydrologic engineering and water resources planning software. The NexGen project encompasses: rainfall-runoff analysis (HEC-HMS), river hydraulics (HEC-RAS), reservoir system analysis (HEC-ResSim), flood damage analysis (HEC-FDA), and real-time river forecasting for reservoir operations. The NexGen software has a Windows-style user interface and operates on Windows XP and Windows NT.

The HEC-FDA program replaces HEC's previous PC version flood damage analysis package (April 1994). The new HEC-FDA program contains enhanced versions of all their features plus a risk-based analysis procedure for formulating and evaluating flood damage reduction measures.

In terms of analyzing the economics of flood risk management projects, the program: (1) stores hydrologic and economic data necessary for an analysis; (2) provides tools to visualize data and results; (3) computes expected annual damage and equivalent annual damages; (4) computes annual exceedence probability and conditional non-exceedence probability as required for levy certification; and (5) implements the risk analysis procedures described.

User Interface

The HEC-FDA program provides a Graphical User Interface (GUI) that is designed to make the program easy and efficient to use. The interface provides the following functions:

- file management
- data entry, importing, and editing
- data selection and assignments
- hydrologic and economic analyses
- tabulation and graphical displays of results
- reporting facilities

Database

HEC-FDA uses a relational database to store data and output for reports and the database is the central part of HEC-FDA. The xBase format was chosen for the program because it is: 1) an adopted industry standard; 2) compatible with the file structure found in commercial software; and, 3) functional in the multiple platform environments. The database operations require use of internal identifiers to relate the program's data sets. This presents special design considerations to avoid potential database corruption from affects of multiple users.

Analysis Steps

These steps are used in formulating and evaluating plans with HEC-FDA:

- Define a study for both with- and without-project conditions, this is a team effort.
- Enter study configuration data, this is a team effort.
- Enter hydrology and hydraulics data. Performed by the hydrologic and hydraulics team members, normally concurrent with the economic analyses.
- Enter economics data and/or compute aggregated stage-damage functions. Performed by the economics team members, normally concurrent with the hydrology and hydraulics analyses.
- Perform the expected annual damage/equivalent annual damage calculations, normally performed and reviewed by the study team.

Risk Analysis

Risk analysis explicitly incorporates a description of uncertainty in discharge-frequency, stage-discharge, and stage-damage relationships in the economic and performance analyses of alternative plans. The process uses Monte Carlo simulation, a statistical sampling-analysis method, to compute the expected value of damage and damage reduced, while explicitly accounting for the impact of uncertainty. Risk analysis thus provides an opportunity to make more informed decisions.

In addition to providing more information for the assessment of flood risk management projects, risk analysis also produces an important collateral benefit: it focuses attention on the important issue of uncertainty inherent in hydrologic and economic computations. Because uncertainty in these computations propagates from uncertainty in the underlying data, methods, and assumptions, attention is eventually refocused on these sources. This attention should eventually lead to improvements in data collection and analysis methods, as more accurate (i.e., less uncertain) data sets, methods, and assumptions are developed to reduce the uncertainty contributed from that particular source.

2.4.8 European Experience

There are a wide variety of flood damage models in use throughout Europe, differing substantially in their approaches and economic estimates. In 2012, B. Jongman et al[17] undertook a qualitative and quantitative assessment of seven flood damage models, using two case studies of past flood events in Germany and the United Kingdom. The qualitative analysis illustrated that modelling approaches varied strongly and that current methodologies for estimating infrastructural damage are not as well developed as methodologies for the estimation of damage to buildings. The quantitative results illustrated that the model outcomes are very sensitive to uncertainty in both vulnerability (i.e., depth-damage functions) and exposure (asset values) whereby the first has a larger affect than the latter. The paper stated that care needed to be taken when using aggregated land use data for flood risk assessment and that it was essential to adjust asset values to the regional economic situation and property characteristics. The paper concluded with a call for the development of a flexible but consistent European framework that applies best practices from existing models while providing room for including necessary regional adjustments.

Models Evaluated

The seven flood damage models developed for simulating direct flood damage included FLEMO (Germany), Damage Scanner (Netherlands), Rhine Atlas (Rhine Basin), the Flemish Model (Belgium), Multi-Coloured Manual (United Kingdom), HAZUS-MH (United States) and the JRC Model (European Commission/HKV).

Five out of seven of the damage models used in the study (FLEMO, Damage Scanner, Rhine Atlas, Flemish Model, JRC Model) are developed for aggregated land use data such as CORINE,[18] which take into account that each of the land use classes containing built-up area also include a fair share of less damage-prone land cover apart from buildings. In contrast, HAZUS-MH and the Multi-Coloured Manual are specifically designed for individual objects and thus cannot be applied directly to CORINE land use data.

The Corine land cover employed in flood damage estimation covers some 44 classes of land use and is presented as a cartographic product at a scale of 1:100,000.

Exhibit 2.9 demonstrates the qualitative properties of the damage models.

Object Versus Area-Based Models

An important division that can be recognized is between the object-based HAZUS-MH and MCM models on the one hand, which use a large number of object types and corresponding flood damage characteristics, and the more aggregated surface area-based models on the other hand. The object-based models have the advantage that they can control for varying building density in areas that have the same Corine land use class. At the same time, area-based models are used more easily for rapid calculation over larger areas and can be applied to scenario analysis.

Input Data

A further difference relates to the data upon which the models are based. FLEMO has a strong empirical foundation, with reported damage data used both in the development and validation of the model. HAZUS-MH and the Rhine Atlas are, to a limited extent, based on empirical data. The other models are almost purely synthetic, with maximum damage values and depth-damage

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[17] B. Jongman et al, *Comparative Flood Damage Model Assessment: Towards a European Approach*, Natural Hazards and Earth System Sciences, December 2012.

[18] Coordination of Information on the Environment (CORINE) is a European program initiated in 1985 by the European Commission, aimed at gathering information relating to the environment on certain priority topics for the European Union (air, water, soil, land cover, coastal erosion, biotypes, etc.).

Qualitative Properties of Damage Models

Damage model	Scale of application	Regional differentiation	Units of analysis	Hydrological characteristics	Data method	Number of unit classes	Cost base	Empirical validation	Function	Reference
FLEMO	Local Regional National	Local asset values	Surface area	Depth Contamination	Empirical	5–10	Replacement values	Yes	Relative	Thieken et al. (2008) Kreibich et al. (2010)
Damage Scanner	Regional National	No	Surface area	Depth	Synthetic	5–10	Replacement values	No	Relative	Klijn et al. (2007)
Flemish Model	Regional National	No	Surface area	Depth	Synthetic	5–10	Replacement values	No	Relative	Vanneuville et al. (2006)
HAZUS-MH	Local Regional	Local asset values	Individual objects Surface area	Depth Duration Velocity Debris Rate of rise Timing	Empirical-synthetic	>20	Replacement values Depreciated values (user's choice)	Yes	Relative	FEMA (2009)
MCM	Local Regional	No	Individual objects	Depth	Synthetic	>20	Depreciated values	Limited	Absolute	Penning-Rowsell et al. (2010)
Rhine Atlas	Local Regional	No	Surface area	Depth	Empirical-synthetic	10–20	Depreciated values	No	Relative	ICPR (1998)
JRC Model	Regional National European	GDP-normalisation	Surface area	Depth	Empirical Synthetic (Statistical)	5–10	Replacement values Depreciated values (averaged values)	No	Relative	Huizinga (2007)

Source: B. Jongman et al: "Comparative Flood Damage Model Assessment" - Natural Hazards and Earth System Sciences (2012) curves developed using “what if” analysis of the effect of simulated flood characteristics on different land use classes. Models based on empirical data could be more accurate when applied to a similar case study, but, as with synthetic models, the question remains whether data from a flood event in a certain location can be applied to another region or county.

Damage Estimates

Exhibit 2.10 illustrates the results of modelled damages versus reported damages for the Eilenburg and Carlisle floods.

Relative Distribution

Exhibit 2.11 shows the magnitude of the modelled damage as well as the relative distribution over the residential, commercial/industrial and infrastructure classes. Note that FLEMO, HAZUS and MCM do not have depth-damage curves for infrastructure and thus do not include an estimate for this class. This finding matches the general consensus that estimation of direct residential and commercial building damage is the best developed part of flood damage models and is surrounded by less uncertainty than the estimation of infrastructure losses.

Object Versus Area-Based

The results of the analysis show that care needs to be taken with aggregated land use data such as CORINE, which do not always accurately display local heterogeneity in object density and typology. Whether an object-based or area-based approach is more suited depends both on the scale of the study area and the quality of the land use data. Smaller-scale studies in which the damage estimates of individual properties strongly affect the outcome would benefit from an object-based approach. On much larger-scale analyses, the local inaccuracies can be expected to average out to a certain extent.

2.4.9 Summary and Conclusions

The primary improvement in flood damage estimation modelling involves the integration and use of GIS and related computerized data (property assessments) as exemplified in the HAZUS-MH and HEC-FDA, along with the British MCM flood damage estimation models. The obvious drawbacks in employing the models verbatim is the complexity of the data input process, particularly for the HAZUS-MH program, the proprietary nature of the programs, U.S. regional-based stage-damage curves, and the specific applications for which the programs were developed.

The intent in this exercise is to develop a user-friendly model incorporating the GIS functions with enough flexibility to accommodate varying levels of data sophistication and alternate approaches to damage estimation.

2.5 Indirect Damages

2.5.1 Preamble

Indirect damages include such things as costs of evacuation, employment losses, administrative costs, net loss of normal profit and earnings to capital, management and labour, general inconvenience, etc., and are generally calculated as a percentage of direct damages. Values can range from 10% to 45% for specific land use categories but are commonly calculated as being 20% of direct damages. Kates (1965) analyzed a number of studies by the Corps of Engineers to find values of 15% for residential damage, 37% for commercial, 45% for industrial, 10% for utilities, 34% for public property, 10% for agriculture, 25% for highway, and 23% for railroads.

Results of Model Runs Versus Reported Damages for Eilenburg and Carlisle

Eilenburg

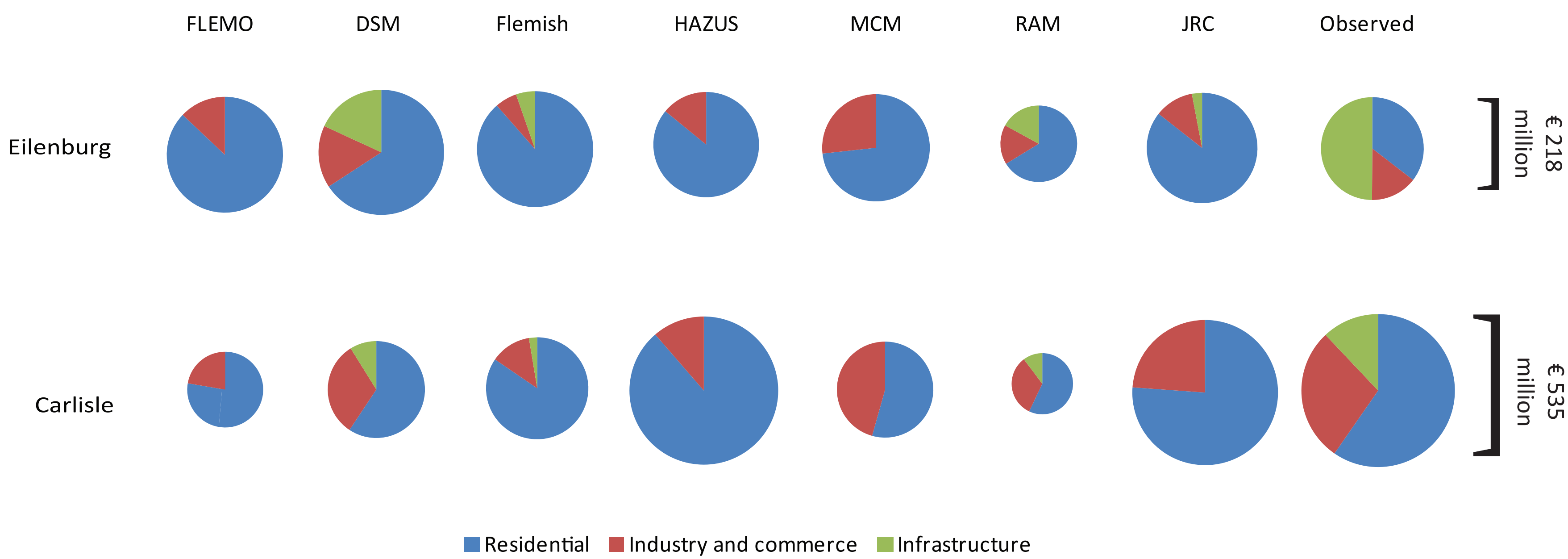
Inundation				Modelled damages (€millions)							Reported (€millions)
CLC Code	CLC Label	Inundated area (m^2)	Average depth (m)	FLEMO	DSM	Flemish	HAZUS	MCM	RAM	JRC	
111	Continuous urban fabric	0	0	0	0	0	0	0	0	0	77
112	Discontinuous urban fabric	2 211 425	1.71	130	252	494	128	174	67	165	
121	Industrial or commercial units	529 725	1.91	19	61	34	21	64	17	22	32
122	Road and rail networks and associated land	667 000	2.17	0	69	30	0	0	17	6	109
Total		3 408 150	1.83	150	383	558	149	238	102	193	218

Carlisle

Inundation				Modelled damages (€millions)							Reported (€millions)
CLC Code	CLC Label	Inundated area (m^2)	Average depth (m)	FLEMO	DSM	Flemish	HAZUS	MCM	RAM	JRC	
111	Continuous urban fabric	27 675	1.6	2	8	7	19	5	1	14	321
112	Discontinuous urban fabric	572 275	1.52	38	65	121	172	73	18	214	
121	Industrial or commercial units	322 950	1.79	12	39	19	25	66	11	71	151
122	Road and rail networks and associated land	154 925	1.09	0	11	4	0	0	3	0	64
Total		1 077 825	1.54	52	123	152	216	144	34	299	535

Source: B. Jongman et al: “Comparative Flood Damage Model Assessment” - Natural Hazards and Earth System Sciences (2012)

Magnitude of Estimated Damages by Type Versus Observed



Source: B. Jongman et al: "Comparative Flood Damage Model Assessment" - Natural Hazards and Earth System Sciences (2012)

Indirect damages are best evaluated by developing a checklist of potential effects and methodically assessing each one. The checklist would logically include the amount of use and the duration of interruption of transportation and communication facilities, the number of workers and farmers depending on closed plants and the amount of business lost through a flood emergency. The magnitude of each effect may be estimated by interviewing those affected during recent floods and unit economic values may be assigned by market analysis. Finally, the results may be summed to render a total value for indirect damages.

The complexity of the above evaluation process has led agencies to estimate indirect damages from direct damages based on percentages as discussed previously. The Canada-Saskatchewan Flood Damage Reduction Program uniformly applied an indirect damage calculation of 20% of all categories (combined) of direct damages. This figure is in keeping with guidelines developed by the U.S. Soil Conservation Services who in the past suggested the following ranges for indirect damages:

- Agricultural 5% to 10%
- Residential 10% to 15%
- Commercial/Industrial 15% to 20%
- Highways, Bridges, Railroads 15% to 25%
- Utilities 15% to 20%

2.5.2 Literature Review[19]

2.5.2.1 Kates, 1965[20]

The percentages adopted by Kates were based on several studies undertaken by the U.S. Army Corps of Engineers which depicted indirect flood losses as consisting primarily of business losses and cost of emergency measures (see **Exhibit 2.12**). The business and financial losses detailed by the Corps included the various economic losses other than physical damages such as net loss of normal profits and earnings to capital, management, and labour in the zone of flood influence. The Corps stressed that such losses bore no consistent relation to physical damages and further were to be derived from specific independent data for the interests and properties involved. The estimates excluded all losses that could be compensated for by increased economic activity in the area affected at a later date (postponed sales, etc.) or in an unaffected area at anytime (alternative sales by competitors, etc.), and also losses to activities remote from the flooded area where adjustments could be made during or after flood periods to avoid or compensate for the loss.

Kates suggested that estimation of these damages in a consistent manner posed serious difficulties and further that they are subject to greater variance than estimates of physical damage. Further he recommended case studies of actual interruptions of production with emphasis on obtaining reliable figures on the capacity of firms to recoup production losses and the real costs of transfer where such takes place.

[19] Reproduced in part from the *Elbow River Floodplain Management Study: Technical Appendix - Volume 1;* produced in August 1986 by WER, IBI/Ecos for Alberta Environment and the City of Calgary Engineering Department.

[20] Kates, R.W., *Industrial Flood Losses: Damage Estimation in the Lehigh Valley*, University of Chicago, Res. Paper No. 98, University of Chicago Press.

Comparison of Values Computed for Four Districts | From the Flood Damages of August 18-20, 1955

Business Loss and Cost of Emergency Measures as a Percentage of Physical Damage (A)

Class	New York (B)	Baltimore (C)	Washington (D)	Philadelphia (E)				
					1958 Supplemental Survey			
				Original Survey 1955	Port Jervis	Del. Reach C-2	Schuylkill Reach 5	Adopted
Residential	20	11	30	13				15
Commercial	33	43	23	48	35	35	40	37
Industrial	25	123	116	119	34	48	47	45
Utility	4	37	51	9				10
Public	50	227	21	44				34
Agricultural	10		15	5				10
Highway		60	60	8				25
Railroad	50	21	2	23				23

(A) Includes Red Cross expenditures in Philadelphia and Baltimore Districts. Adopted percentages are also considered to include these expenditures.

(B) New York District: With the exception of agricultural and public classes, the percentages are based on reported damages for 80 percent of the damage in the District. Agricultural and public values are based on sample determinations.

(C) Baltimore District: Residential percentage is based on a table previously developed. The highway value is estimated. Other values are based primarily on reported roads.

(D) Washington District: Residential, commercial, industrial, and railroad percentages are based primarily on reported damages. Other values estimated.

(E) Philadelphia District: All percentages are based on reported damages.

Source: U.S. Congress, House Doc. 522, 87th Congress, 2nd Session, Appendix D,

*Kates 1965

2.5.2.2 Acres, 1968[21]

In order to simplify their calculations, Acres divided indirect damages into two major types, those affecting establishments (homes and businesses) and those affecting the entire community. Indirect damages to establishments were characterized as arising from the interruption of normal daily activities and included loss of sales and production to businesses, the disruption of residential living conditions, the costs of flood fighting and long-term floodproofing. Indirect damages also involved the extra work required to prepare for a flood, the costs of flood fighting, and long-term floodproofing.

With respect to businesses, preparatory work costs included the expenses involved in removing stock and production equipment from the vulnerable areas, hiring flood fighting equipment and extra staff and paying extra wages to existing staff. Indirect damages to residential units included costs incurred due to evacuation, employment losses due to flood fighting, the costs of long-term floodproofing and decreases in capital value of the property.

Acres described indirect damages to the area of the community not directly affected by the flood, as generally in the nature of inconvenience and involving the disruption of public utilities and delays in transportation, resulting in disruption of normal daily activity elsewhere. In addition, these include the substantial but hidden administrative costs relative to the amount of time spent by municipal councils, engineering departments, and police and fire departments on emergency measures during and after heavy floods.

Information necessary to estimate possible indirect damages in the study area (Galt, Ontario) was obtained from four main sources:

1. Interviews with businessmen, plant managers, and residents who had past experience with flooding.
2. Organizations such as Canada Manpower and Dun & Bradstreet relative to wage and sales figures for individual establishments and for the entire area.
3. Interviews with utilities and public agencies that would be affected.
4. Reports on other flood damage studies.

In analyzing the aforementioned data, Acres found that some information for estimating indirect damages to individual commercial and residential establishments was available; however, no data could be obtained for estimating costs of inconveniences to the community as a whole. Therefore, no estimates of total indirect damages could be made. Given the substantial gaps in the background information, the Acres study attempted to test the applicability of several previously established estimating techniques in the study area, focusing on the two major indirect losses typical to Galt commercial and residential establishments – loss of business and evacuation costs. Indirect costs arising from direct damages to residential areas were estimated according to the techniques used by the Royal Commission on Flood Costs – Benefit in Manitoba. These damages consisted of the costs involved in obtaining alternative accommodation, extra food, and wages lost by the household.

With respect to indirect residential damages, Acres found that the range of 10% to 15% used by the United States Soil Conservation Service was sufficiently accurate for estimating the minimum amount of indirect damages at Galt.

Concerning commercial indirect damages, expressed as a percentage of estimated direct damages to the various establishments, the indirect damage figure ranged from 8% to 23% depending on the depth of flooding. Acres state that the examples analyzed were based on

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[21] Acres Limited, *Guidelines for Analysis, Volume II Flood Damages*, Governments of Canada and Ontario Joint Task Force on Water Conservation Projects in Southern Ontario, Niagara Falls, August 1968.

many assumptions which would be subject to debate. Notwithstanding, they suggested the estimate made by the U.S. Soil Conservation Service of 15% to 20% would be a reasonable assessment.

In light of the findings on indirect damages at Galt, Acres concluded the following:

1. Because of the many unpredictable variables involved and the uniqueness of each case, no rule can be said to apply in all cases.
2. Although indirect damages are not exclusively a function of physical damages, they should be estimated in those terms due to the lack of data and synthetic estimating techniques available.
3. The figures used by the U.S. Soil Conservation Service appeared to be the most applicable to the type of flood which occurs in Southern Ontario. However, these percentage figures should be applied with caution and adopted as a minimum at best.

2.5.2.3 Environment Canada, 1975[22]

In the study of flood damages in the Fraser River Basin, indirect damages were categorized under two main headings: income losses, and miscellaneous flood damages. The latter included both direct and indirect damages as follows: extra costs of food, costs of evacuating people, the value of the loss of use of flood plain dwellings, damages to roads, railways, schools, apartments, utilities, barns and outdoor buildings.

Income losses were classified as primary or secondary, the former referring to losses incurred by floodplain activities forced to shut down because of a flood and the latter including losses borne by non-floodplain firms forced to reduce production when flooding destroyed their markets or sources of raw materials.

The following constitute some of the major assumptions made relative to estimating income losses:

1. Since the referent group in this study was British Columbia, only the income portion of production losses that could neither be deferred nor transferred to parties within the Province was considered an admissible income loss.
2. The only costs of production delays and transfers representing a real loss to the economy as a whole are frictional costs (frictional costs result because transfers in space involve extra transport costs and transfers in time (deferrals) , increased production costs).
3. The trade sector would not realize true income losses. The disruption of normal sales of wholesale, retail and service trade establishments located on the floodplain would not constitute a net loss to the Province because such sales can be either deferred of transferred to non-floodplain firms.

The following overview was presented in the study as it related to primary income losses: “The level of accuracy of estimates of permanent production losses is unknown. According to most company officials, such losses would depend on too many uncontrollable and extra-provincial factors (including national economic conditions) to be reliably predictable. Any companies whose markets are local and specialized, expected to be able to defer all production losses not transferred to other British Columbia firms. Others, whose local sales can usually be replaced by imports (example meat packers), believe that any disruption would result in a complete loss

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[22] Book, A.N. and Princic, R., *Estimating Flood Damages in the Fraser River Basin*, Environment Canada, Inland Waters Directorate, Pacific and Yukon Region, Vancouver, 1975.

to the Province. Still others, whose products compete in world markets, thought that unfilled out-of-province orders would be transferred to foreign competitors and lost to British Columbia."

The study rendered primary income losses for specific industrial groups as follows:

1. Sawmills, shake and shingle mills – an average of 55% of their lost production would be permanently forfeited to out-of-province firms.
2. Paper box and bag industry – returns from the industrial survey indicated that British Columbia would suffer permanent income losses if paper box and bag industries were forced to halt production.
3. Plywood manufacturers plywood manufacturers potentially affected by flooding claim that most production losses could be either deferred or transferred to B.C. firms, however, they suggested that there would be a loss of foreign markets accounting for approximately 0% to 10% of the value of production lost during the flood.
4. Meat and fish processing plants – all production and income (value added) losses inflicted by a flood on British Columbia meat processors would be permanent as imported meat would immediately fill any market voids created by delays in shipments induced by production setbacks.
5. Other industries – no typical income losses could be readily ascribed to other classes of floodplain industries. Consequently, industrial managers and the field team for the study had to estimate losses by examining each establishment individually.

An attempt was undertaken to determine secondary income losses or the income lost by non-floodplain establishments as a result of the failure of floodplain industries to make purchases from them. Calculations included those losses resulting from the severance of transportation arteries, both road and rail.

Exhibit 2.13 illustrates the method used in calculating primary and secondary income losses.

The study concluded the following about primary and secondary income losses: "The host of assumptions and unstable conditions, upon which these estimates rest, indicate the unpredictable nature of these losses and the potential error inherent in the estimates. Although the results are reliable for calculations of this kind, no claim can be made for their absolute accuracy."

It was also discovered that secondary income losses represented a very small part of the total potential flood damages.

As previously indicated, miscellaneous flood damages contained both direct and indirect damages and therefore are not directly applicable to the Elbow River Flood Study. These damages constituted only 10% of total potential flood losses and therefore very little time was spent estimating them. The procedures used to assess miscellaneous damages in the study were crude, however, it was concluded that further refinement would not provide more credible results or make the analysis of total damages in the Fraser Basin more meaningful.

Example of Method Used in Calculating Primary and Secondary Income Losses and Transfer Costs

A "Typical Industry"

A Value of Flood Disrupted Production ($'000)	B Production that can be Deferred or Transferred ($'000)	C Transfer Cost ($'000)	D Value of Production Permanently Lost to Out-of-Prov. Firms ($'000)	E Primary Income Loss: Income Permanently Lost to Out-Of-Prov. Firms ($'000)	F Value of Production Reductions of Input Industries From: Out-of-Province B.C. ($'000)	G Value of Production Reductions of Input Industries From: Out-of-Province B.C. ($'000)	H Secondary Income Loss: Income Lost by B.C.'s Input Firms ($'000)
		240.0 x .02-4.8		50.0	1) Forestry 0.0	60.0	60x.5=30.0
					2) Other Textiles 10.0	4.0	4x.3=1.2
					3) Misc. Machinery 0.0	30.0	30x.4
					4) Metal Stamping 0.0	20.0	20x.4-8.0
			200		5) Industrial Chem. 10.0	6.0	6 x .4 = 2.4
					6) Other 10.0	0	0
Total		4.8		50.0			53.6

TOTAL INCOME LOSS TO B.C. | "C" (Transfer Cost) + "H" (Secondary Income Loss)

*Fraser River Basin Study, 1975

(A) Value of flood-disrupted production =

Value of annual production x $\frac{\text{No. of Days Shut Down}}{\text{Total Number of Production Days per Annum}}$

(B) Value of Production transferred or deferred = (A) x portion deferred or transferred to provincial firms

(C) Transfer cost - (B) x .02

(D) Value of permanently lost production = A-B

(E) Income permanently lost to out-of-province firms (primary income loss = Dx $\frac{\text{Annual Income}}{\text{Annual Production}}$

(F) Value of reduction of production and out-of-province firms was obtained directly from reporting industries

(G) Value of reduction of production of provincial firms was obtained directly from reporting industries

(H) Income lost by B.C.'s input firms (secondary income loss) = G x income/ production ratio of input firms

2.5.2.4 Canada-Saskatchewan Flood Damage Reduction Program[23]

Two studies undertaken under the auspices of the Canada Saskatchewan Flood Damage Reduction Program in Eastend and Swift Current estimated indirect damages as 20% of all categories (combined) of direct damages. This figure is in keeping with guidelines developed by the U.S. Soil Conservation Services and appears to have been adopted by the Program.

2.5.2.5 U.S. Soil Conservation Services[24]

The United States Department of Agriculture, Soil Conservation Services, suggests the following ranges for indirect damages:

- agricultural 5% to 10%
- residential 10% to 15%
- commercial and industrial 15% to 20%
- highways, bridges and railroads 15% to 25%
- utilities 15% to 20%

2.5.2.6 Metro Toronto and Region Conservation Authority[25]

The MTRCA, in line with earlier American practices, estimated total indirect damages as 75% of direct damages in the Humber River Area for a flood of Hurricane Hazel's magnitude. Although this may appear high by the present standards employed, the actual study in which this percentage was applied took place only five years after the devastating flood associated with Hurricane Hazel and this could have been a factor in employing the high ratio of indirect to direct damages.

2.5.2.7 Fort McMurray Flood Damage Estimates Study, 1979[26]

Indirect damages in this particular study were calculated as percentages of direct damages as follows:

- residential 15% of direct damages
- commercial 35% of direct damages
- industrial 45% of direct damages
- institutional 34% of direct damages

The values were taken from “urban drainage and flood control projects – economic, legal and financial aspects” in Colorado State University.

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23 Canada-Saskatchewan Flood Damage Reduction Program, Saskatchewan Environment, Regina, 1981/83.
24 U.S. Soil Conservation Services.
25 Metro Toronto and Region Conservation Authority.
26 Nichols and Associates Ltd., *Economic Analysis of Fort McMurray Flood Abatement Measures*, Fort McMurray Technical Committee on Flood Abatement, Fort McMurray, 1979.

2.5.2.8 Fort McMurray Flood Damage Estimation Study, 1982[27]

For the Fort McMurray Flood Damage Estimation Study undertaken in 1982 indirect damages were calculated at percentages of direct damages as follows:

- residential 20% of direct damages
- commercial 41% of direct damages
- infrastructure 25% of direct damages
- utilities 20% of direct damages
- highways 25% of direct damages

2.5.2.9 Drumheller Flood Control Study, 1984[28]

For the Drumheller Flood Control Study undertaken in 1984, indirect damages were calculated as percentages of direct damages as follows:

- residential 15% of direct damages
- commercial/industrial 25% of' direct damages
- utilities 15% of direct damages
- highways 10% of direct damages

2.5.2.10 City of Medicine Hat Flood Damage Mitigation Study[29]

For this study undertaken in 1998, indirect damages were calculated as percentages of direct damages as follows:

- residential 20% of direct damages
- commercial/industrial 35% of' direct damages
- infrastructure 24% of direct damages

2.5.2.11 High River Economic Analysis of Flood Control Measures[30]

For the High River Study undertaken in 1997, indirect damages were calculated as percentages of direct damages as follows:

- residential 20% of direct damages
- commercial/industrial 30% of' direct damages
- infrastructure 15% of direct damages

[27] IBI Group and Ecos Engineering Services Ltd., *Phase II-B, Flood Damage Estimates, Fort McMurray Flood Damage Reduction Program, Technical Report*, Alberta Environment and the City of Fort McMurray, Fort McMurray, 1982.
[28] IBI Group and Ecos Engineering Services, *Drumheller Flood Control Study*, Alberta Environment and the City of Drumheller, 1984.
[29] Agra Earth and Environmental and IBI Group, *City of Medicine Hat Flood Damage Mitigation Study*, City of Medicine Hat, Medicine Hat, Alberta, 1998.
[30] IBI Group, *Economic Analysis of Flood Control Measures*, Alberta Environment and City of High River, High River, Alberta, 1997.

2.5.2.12 California Department of Water Resources, 2012[31]

In the Flood Damage Analysis for the Central Valley, the California Department of Water Resources calculated commercial indirect losses based on estimated gross business output or sales for each commercial structure type. Output per employee and average square feet per employee were used to determine an output per square foot by industry.

The period of business interruption was based on a depth of flooding versus business interruption damage function developed by the U.S. Federal Emergency Management Agency (FEMA). This depth-damage function is shown below:

Depth of Flooding Relative to Main Floor Elevation (ft)	Business Interruption (Days)
-2	0
-1	0
0	0
1	45
2	90
3	135
4	180
5	225
6	270
7	315
8	360
9	405
10+	450

For each flood frequency, the number of business interruption days was multiplied by the estimated daily production value for each commercial structure. The total lost output was then reduced by a capacity utilization factor.

Measuring business loss as gross output or sales may overstate the damages because the interruption will also reduce costs, not just sales. A more accurate measure would be net income. Furthermore this estimation does not consider factors such as businesses making up for interruption after the flood or ability to relocate and continue operations during the flood.

No expression of business loss (commercial indirect damages) as a percentage of commercial direct damages is available because residential and commercial direct damages are summed together.

Emergency indirect damages, such as evacuation or loss of public services were described but not calculated in this damage analysis.

[31] Department of Water Resources, State of California, *2012 Central Valley Flood Protection Plan, Flood Damage Analysis*, 2012.

2.5.3 Summary

The approach proposed to be employed on the Provincial Flood Damage Assessment Study of individual municipalities should involve a review of the current situation within the flood study area, i.e., major transportation routes affected by flooding, percentage of industries and businesses affected by flooding, number of residences affected by flooding, and average duration of flooding event etc. and the application of the appropriate percentage to reflect the relative severity (high, medium or low) of the flood event.

3

Update of Content and Structural Stage-Damage Curves

3 Update of Content and Structural Stage-Damage Curves

3.1 Introduction

For the purposes of this study, direct flood damages are estimated separately for residential and non-residential structures, and also for losses to structures versus contents. Previous damage estimation experience has indicated that potential losses vary significantly by the type of use, reflecting differences in construction materials, techniques, and quality, and also in the quantity and nature of contents located within those structures. These previously-observed findings were replicated in this study.

This section sets out the approach to estimation of structural and content flood losses for residential and non-residential uses, and includes the stage-damage curves resulting from the analysis of the structural and content data.

3.2 Residential Curves

3.2.1 Definition of Structural Categories

Accurate assessment of residential flood damages requires the formulation of a classification scheme capable of encompassing significant variations in housing types found throughout the study area. Subsequently, synthetic unit stage-damage function curves are developed for each category of typical or representative residential unit type.

The residential classification scheme previously employed by the consultant team in various Canadian studies has been refined for this analysis. Residential structures are classified according to their construction techniques, size and quality, and their number of storeys. As property tax assessment data and GIS building footprint data are now readily available, that information is used to classify residential structures as single unit or low density unit types; medium density; and high density.

The low density unit types include detached and semi-detached units; townhouse units with individual entries to grade; and mobile homes. These low density types may be single storey or two or more storeys in height, and typically have full basements and attached or detached vehicle parking structures. For single detached structures, 1 storey and 2+ storey structures are further differentiated, while split level and bi-level structures are treated as single storey structures with full or partial basement development.

The medium density units are dwellings located in low-rise apartment buildings of 4 or fewer storeys, typically of wood frame construction. These units may or may not include an underground parking structure.

The high density units are dwellings located in apartment towers of 5+ storeys, typically of concrete and light steel framing construction. These structures typically have underground vehicle parking.

The residential classification scheme is summarized in **Exhibit 3.1**; photographs of typical residential structures of each type are depicted in **Exhibit 3.2A/B/C/D**.

3.2.2 Data Collection

Residential contents and structure data were collected from a representative sample of dwelling units located in the Calgary and Edmonton areas. Dwelling units sampled were located outside of flood-affected areas because at the time of data collection many dwelling units in the affected

Residential Classification Scheme

Class	Floor Area	General Description
AA-1 AA-2	372+ m^2 (4,000+ ft^2) Typical 456 m^2 (4,903 ft^2)	Typically custom construction built during the 2000s, with superior architectural design and premium quality construction materials, finish materials and workmanship. These units typically include numerous large windows, extensive basement finishing, superior millwork, and built-in high-quality appliances. These very large dwelling units are few in number, and account for the highest reaches of the real estate price distribution, with an average value of $3,400,000.
A-1 A-2	223 – 371 m^2 (2,400 – 3,999 ft^2) Typical 266 m^2 (2,858 ft^2)	The A Class structures are relatively large, high-end homes typically featuring moderately high-quality construction materials and finishes. These units have good quality millwork and large window area ratios, and typically have most of the basement areas finished, and have attached garages. While much more numerous than the AA Class, the A units represent a relatively small share of the total population of single dwelling units, reflective of their upper-middle price positioning, with an average value of $1,400,000.
B-1 B-2	112 – 223 m^2 (1,200 – 2,399 ft^2) Typical 163 m^2 (1,754 ft^2)	B Class units are generally the most numerous type of single dwelling units in Alberta municipalities. These average quality units were generally built from stock plans as tract or speculative housing for mid-market consumers, from the 1950s onward. These houses are typified by conventional design, and medium quality materials, finishes and workmanship, with some basement finishing and detached garages. They have an average value of $680,000.
C-1 C-2	<112 m^2 (<1,200 ft^2) Typical 88 m^2 (947 ft^2)	The C Class units tend to be older housing stock in inner-city locations, or tract starter housing in newer suburban locations. These houses are of average to below average quality in terms of design and construction materials, finishes and workmanship. Generally, units of this class located in the municipal core area have a high land to building value ratio as these structures are approaching functional and physical obsolescence. While C Class units represent the lower range of real estate values, many of these units have been upgraded by owners and feature average or better quality finishes in the renovated areas. They have an average value of $450,000.
D	Typical 128 m^2 (1,377 ft^2)	D Class units are mobile homes, located on temporary foundations, and without basements. These units tend to reflect the lower range of real estate values.
MA	Typical 93 m^2 (1,002 ft^2)	MA units are apartment units located in high-rise (5+ storey) structures. The high-rise apartment towers are typically of concrete and light steel frame construction, and have one or more levels of underground parking.
MW	Typical 65 m^2 (704 ft^2)	MW units are apartments located in low-rise (less than 5 storey) apartment structures. These structures are typically of wood construction and often have single level concrete parking structures underground.

Residential Classification - Typical Examples

AA

AA

A

A

Residential Classification - Typical Examples

B

B

C

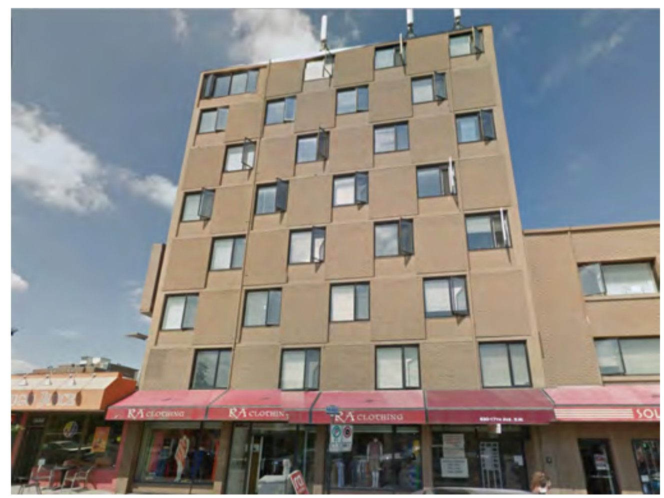
C

Residential Classification - Typical Examples

D

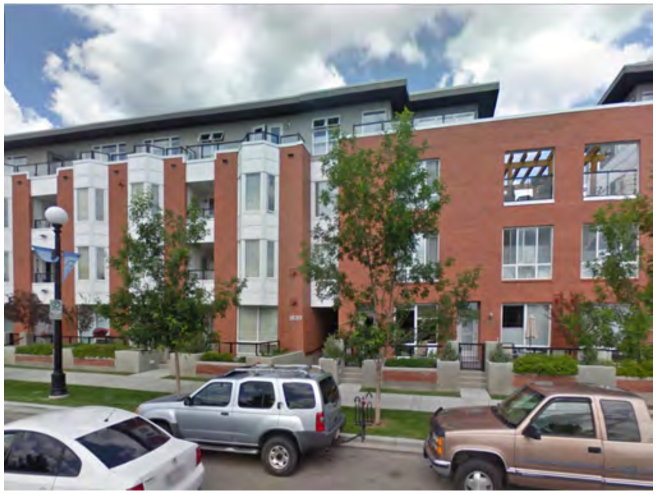
D

MA



MA

Residential Classification - Typical Examples



MW

MW

areas had not been restored, refurnished, or had been remediated with materials or designs that were not typical of pre-flood conditions. For these reasons, the sampled dwelling units are considered proxies for the pre-flood condition of units located in potential flood-affected areas across Alberta.

Considerable effort was expended to identify units that are “typical” of their residential classification in terms of size, assessed value, and apparent quality. Occupants of these units were recruited for participation in the survey with a letter from the consulting team explaining the nature and purpose of the data collection effort. Very low refusal rates (less than 10%) were experienced, as interviewers followed up on the recruitment letter with personal visits and telephone calls to establish appointments for the data collection.

A small team of well-trained interviewers – all members of the IBI Group planning practice – completed 83 dwelling unit surveys. Interviewers used computer-aided data capture (**Exhibit 3.3A/B/C** depicts the data capture forms) to acquire and record structure and contents data. Interviewers were also equipped with laser distance measuring devices to measure and record structure and contents dimensions.

Interviewers recorded information on:

- single unit building floor area or multi unit apartment floor area;
- exterior finish materials and proportions;
- elevation from grade to top of first floor at entry;
- individual room names, dimensions and location (storey) within the dwelling unit;
- individual room, floor and wall finishes and areas;
- dimensions of closets and storage shelving or storage units; and
- the number, location, dimensions, and quality/value of all significant value (>$100) content items located on the basement level, main floor level, in the garage, and outside at grade.

The contents inventory was aided by reference to a look-up table containing lists of approximately 80 furnishing and other content items commonly found in Alberta residences. Interviewers also manually entered information on unusual or rare items not found in the common inventory look-up table.

Interviewers assessed each item of contents to determine the depth of flooding at which significant damage would commence (the “critical level”), and the level at which the item would be completely inundated. Through visual assessment, reference to the look-up tables, and discussion with the unit occupant, interviewers evaluated the quality and price range for each item of contents. Finally, in any unusual circumstances interviewers recorded comments on the items in question for later evaluation in the office.

The resulting structural and content inventory data were uploaded for office analysis using relational database and spreadsheet software.

3.2.3 Content Damage Curves

The review of best practices undertaken at the commencement of this study confirmed the advisability of developing content damage curves specifically for application in Alberta. In addition, given the broad ranges observed in study area residential unit floor areas and value/quality it was determined that contents damages curves should be developed separately for each storey (basement and main level) and each residential structural category, calculated on a $/m^2 basis. These damage per unit of floor area estimates could then be employed in the damage estimation model for any classified residential structure in the Province.

Project 36910

Survey ID# ____________________

CONFIDENTIAL FLOOD DAMAGE ESTIMATE STUDY

1. **Interview Date:** ____________________

2. **Interviewer:** ____________________

HOME INFORMATION

3. **Address:** ____

   Unit # Bldg # Street Name & Type Quadrant City

4. **Residential Classification:** *(circle selection)*

   AA B C D MA MW

5. **Structural Type:** *(circle selection)*

   Single Storey Two Storey Split Level

6. **Basement:** *(circle selection)*

   No Basement Crawlspace Partial Basement Full Basement

7. **Exterior Finish:** *(enter finish & enter percentage on building)*

   Finish options: Brick/Stone Vinyl siding Stucco Wood Other

	Finish	% of Finish on Exterior
Finish 1		
Finish 2		
Finish 3		

8. **Building Footprint:** *(enter measured values in **meters** to single decimal value)*

Length (m)								.	
Width (m)								.	
Total Area (Sq m)								.	

9. **Building Elevation:** *(enter measured value of Exterior grade to first floor in **meters** to single decimal value)*

Height (m)				.	

Page ________ of ________

IBI

Project 36910

Survey ID# ___________________________

HOUSEHOLD ROOM INFORMATION

ADD Room & Contents tables as required for each Survey

10. **Location:**

For each Room complete the following details in the table below:

Room Name: *(enter description)*

Level: *(in house)* **Level 0, Level 1, Level 2, Garage, Exterior**

Room Length & Width: *(enter values in* ***meters*** *to single decimal value)*

Floor surface: **Concrete, Ceramic Tile, Vinyl/Laminate, Wood, Carpet**

Wall surface: **Finished** or **Unfinished**

Closet Lengths: *(enter summed values in* ***meters*** *to single decimal value)*

RM #	Room Name	LEVEL	Length (m)	Width (m)	Floor Surface (options)	Wall Surface (options)	Closet Lengths (Total m)
			.	.			.
			.	.			.
			.	.			.
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Page ________ **of** _________

Project 36910

Survey ID# ____________________________

11. Inventory of Contents for Rooms:

See Excel spreadsheet for items: ..\10.3 ExcelFiles\Contents values.xlsx

#	Item Name or Description	LEVEL	ROOM	NUMBER	COST RANGE (Low/Med/High)	Critical Height (cm)	Top Height (cm)
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Page ________ **of** _________

Past content inventory experience was augmented with pilot inventories conducted on several residences to identify the types of content items most commonly found in Alberta dwelling units. An extensive price survey was then conducted, which identified over 4,000 individual unit prices for these common household items. The price data was analyzed to determine price ranges for individual items; for any given item, the low cost estimate is typical of a poorer quality item, the middle estimate was typical of average quality, and the high estimate was typical of above average quality. The pricing analysis attempted to identify prices for the typical range of consumer goods. In some cases interviewers identified content items of unusual quality or value which was not captured in the standard price ranges; in these cases interviewers entered multiple quantities of the item to approximate its estimated actual value.

The list of merchants surveyed to acquire price data, and the individual item list and corresponding price categories are located in **Appendix A**.

Interviewers recorded “critical levels” for each content item in the field. For any item, the critical level is defined as the distance from the floor to that part of the item at which significant flood damage would result. Interviewers also recorded the “top level” of each item to permit calculation of the complete inundation levels.

In some cases such as storage shelving, bookcases, clothing closets, media storage units, and refrigerators and freezers, typical content values were estimated from pre-test detailed inventories, and contents value allowances were added to these items. In addition, interviewers measured the storage capacity of furnishings and closets on a linear basis during the inventory of household contents, and content and furnishing values were estimated accordingly for those items. Damages were calculated for items with significant vertical dimensions (e.g., clothing closets, wine bottle storage) with damage commencing at the critical level, and increasing in proportion to flood depths.

The probable extent of direct flood damage to the common content items identified in the inventories as well as the potential for salvageability and restoration of flood damaged items were determined through consultation with insurance industry contacts, cleaning and restoration contractors, and disaster recovery contractors, all of whom had experience in the 2013 Alberta floods.

The consensus view of the contractors consulted is that many non-permeable materials commonly found in household contents could be salvaged, cleaned and restored if their exposure to floodwater was limited to a number of hours. However, it is also the consensus view of these respondents that this type of immediate recovery response is only possible if few residential units are affected; there is insufficient capacity in the recovery and remediation industry to accommodate larger scale and longer duration flood events. In addition, the disaster recovery respondents noted that the combination of high ambient temperatures and prolonged high humidity levels following the flooding of a residential unit virtually ensure that organic materials in the household – even those not exposed to direct flooding – were likely to become contaminated with mold within 72 hours of the onset of flooding.

Given the industry’s limited capacity to respond with pumping, sediment removal, and mechanical drying efforts, this finding again pointed to the improbability of salvageability for a large proportion of typical household contents. Finally and perhaps most importantly, the restoration specialists noted that even in cases where item recovery, transport, gross and fine cleaning, sanitization, drying, restoration, storage, and eventual return is possible, the cost of such recovery effort generally greatly exceeds the value of most common items of household content.

For the reasons set out above, all of the content items identified in the residential inventories would be destroyed once the depth of flooding exceeded the item’s critical level. It is acknowledged that this assumption of zero salvageability may overstate damages for some content items. However, no attempt is made to calculate additional damages in residential units occurring to items which are not wetted by floodwater but which are damaged by exposure to humidity and possible finish deterioration or mold growth.

The values assigned to residential contents are estimates of their current replacement cost. In light of previous experience, no attempt is made to depreciate the value of these items. Rather, the current replacement cost estimates are intended to capture the totality of economic damage occurring through flooding, assuming that all of the contents damaged will be replaced with similar quantities and sizes of new items of like quality.

Interviewers noted the presence and location of significant fixtures and mechanical items such as furnaces, air conditioners, water heaters and softeners, etc. These items were not included in content damage calculations, but are included in structural damage estimates.

Many small items were, of necessity, excluded from the inventory. Since the pre-test indicated that respondent fatigue was likely to become a serious problem (interviews of up to two hour's duration were not uncommon), individual items with an estimated new cost of less than $100 were generally excluded from the inventory. While such low value items are likely to be numerous in a given dwelling unit, their total value is considered relatively insignificant.

In addition, to preserve respondents' privacy and minimize refusals during the recruitment process, interviews were conducted on a "no touch" basis with closed storage items such as cabinets, closets, and dressers not opened by interviewers. Respondents were queried on the potential presence of high value items in closed storage areas, and interviewers concluded each room's inventory by asking if any other significant items should be included at that location.

Content stage-damage curves were calculated for each storey and each class of residential dwelling unit. The calculated flood damages occurring at each depth of flooding above floor level were averaged on a per square metre of floor area basis. The residential content damage curves are located in **Appendix B**. The residential content damage values per square metre of floor area are located in **Appendix C**.

As noted in the preceding section on the definition of structural categories, some very large and high value single-family homes were observed in the flood affected area in Calgary (accounting for less than 1% of the total inventory). The A Class contents damage curves are not expected to adequately estimate the quantity of damages that would occur in these luxury homes. Since it was not possible to obtain a reliably large sample of contents inventories in this class, the AA Class contents were estimated from the A Class content damage curves with a 44% premium reflecting the observed difference in the assessed values per square metre of floor area of the AA structures over the A Class structures.

3.2.4 Structural Damage Curves

The structural characteristics of residential units in each class were determined through field inspection by qualified architectural personnel and consultation with the local building industry. During the inventory of residential structures, interviewers collected information on building floor areas, exterior finishes, building and room perimeters, and types of finishes.

Typical unit floor areas of the basement (if present) and the first floor were determined for each class of residential unit from municipal assessment data. These average floor areas and the data collected through field inspection and the contents and structure surveys were combined to produce specifications for typical units in each residential classification.

Estimates of unit prices for cleaning, replacing and/or repairing flood damaged materials were obtained from local suppliers and contractors. All structural damage curves reflect the costs of cleaning, repair, and restoration estimated on the basis of 2014 Calgary material and labour costs. The structural damage estimates include the cost of removing residual standing water and sediment, removal and disposal of damaged items, structural drying and sanitization, and inspection and testing for dryness and residual contamination.

The insurance and remediation contractor specialists consulted indicated that the common practice in residential flood remediation is to remove and replace all non-structural materials that have been contacted by floodwater. In addition, due to wicking of moisture upwards through semi-permeable building materials, very high ambient humidity levels inside structures, and the probability of mold growth on common residential finish materials, it is now a recommended and generally observed practice to remove virtually all finish materials on a floor level that experiences any significant duration and depth of flooding with Category 3 water[32].

The major structural components of a typical dwelling unit, if properly maintained, have a life expectancy that virtually defies application of arbitrary depreciation rates. In general, deterioration is related primarily to wear of finishes, wall and floor coverings, etc., and these materials in the typical home are generally well-maintained. Consequently, no depreciation estimates have been applied to replacement and/or restoration values used to construct the structural stage-damage curves.

Based on the dwelling unit characteristics and unit prices, damage for each 300 mm (1 foot) of flooding was estimated for each class of residential unit, floor level, and structural type (1 storey and bi-level versus 2+ storey). (Attached and detached garage damages are included for A, B, and C class structures; MA and MW parkade damages are calculated separately on a structure-specific basis – see Section 3.5.1 Multi-Level Below-Grade Parkades) The resulting structural stage-damage curves are located in **Appendix D**. That appendix also includes the typical unit specifications and unit cost estimates employed to calculate the damage curves. The structural damage curve data are expressed in $/m^2 of floor area. The residential structural damage values are located in **Appendix E**.

3.2.5 External Damages

In more recent studies, external damages to residential properties are being considered and included in flood damage estimates. The New South Wales Department of Environment, Climate Change and Water includes external damages in their stage-damage curves to items such as mowers, gardens, tools and shed contents. Based on a recent study in Ballina, this was estimated at approximately $9,200 per inundated residential property.

The U.S. Army Corps of Engineers, in some of their more recent studies, have defined external damages as the cost of flooding to gardens and other outdoor structures and employed a value of $5,000 per residential building.

In the Australian examples vehicles are typically not included in damage assessments, despite being classed as a valid external damage, as these are often moved to higher ground during a flood, and to ensure vehicle damage does not drive justification for mitigation works. The HEC-FDA program contains curves for vehicle damage if appropriate.

In both the U.S. and Australian examples external damages to commercial and industrial property are assumed to be negligible, with the majority of property damage typically expected to be attributable to the contents of the building.

For the purposes of the Provincial Flood Damage Assessment Study, garden tools, garden furniture and garage (both attached and detached) contents were inventoried as part of the residential contents survey and have been accounted for within the new stage-damage curves. In terms of general landscaping and yard clean-up, a nominal value of $2,500 was applied to the

32 Defined by the IICRC (Institute for Inspection, Cleaning and Restoration Certification) as water which is highly contaminated and could cause death or serious illness if consumed by humans. Examples: sewage, rising floodwater from rivers and streams, ground surface water flowing horizontally into homes.

C class structures; this was increased to $5,000 for Bs, $7,500 for As, and $15,000 for AAs. For MA and MW class structures, particularly in inner City locations, landscaping requirements are quite varied and sometimes take the form of rooftop gardens and terraces. For these classes, a value of $15,000 per building was employed.

3.3 Commercial/Industrial Curves

3.3.1 Introduction

Flood damages to non-residential buildings including commercial/industrial and institutional establishments, include damages to inventory, equipment and buildings as well as clean-up costs. As with the residential structures, damages are calculated separately for contents and structures. This group, due to the range and diversity of activities covered does not demonstrate the same uniformity as the residential grouping. Consequently, categorization is a much more complicated procedure and necessitates the grouping of similar functions.

Updating of synthetic depth-damage curves involved the following activities:

- Dialogue with the insurance industry relative to value of contents, salvageability and other aspects of damage to various types of businesses.
- Dialogue with retailers relative to value of inventories, salvageability, value of equipment and fixtures, etc.
- A thorough review of U.S.-based case studies undertaken by the U.S. Army Corps of Engineers including detailed analysis of inventory values by business type.
- Review of depth-damage curves developed for various types of businesses in Australia.
- Updating of existing commercial stage-damage curves by specific category of goods using CPI data.
- Representative sampling where most significant changes were believed to have occurred, i.e., grocery, general office, financial services, electronics, medical, schools, hardware/carpet, hotels, restaurants, personal services.

3.3.2 Data Collection

The commercial inventory data collection process was similar to that employed for collection of residential data. Owners or managers of facilities typical of the commercial classification were identified and requested to participate in the contents inventory with a formal letter of introduction Interviewers followed up the recruitment letters to establish appointments for data collection. No potential respondents declined to participate.

Interviewers visited the selected establishments to measure floor areas and finishes; noted the types, number, value, and vertical arrangement of equipment, fixtures and significant furnishings; and obtained information on the value of commercial inventory. Content depth-damage relationships were established in consultation with the facility managers, as were potential levels of inventory salvageability.

The potential levels of content salvage by commercial class are detailed in **Exhibit 3.4**. In general, reported levels of salvageability are lower than previously-observed, reflecting the same restoration difficulties, health and safety liability concerns, and cost issues described in the residential contents section.

The fixtures and furnishings damages reflect replacement costs, while commercial content inventories reflect replacement (wholesale) values. The non-residential content damage curves

Alberta Commercial/Industrial Sample Summary

	Classification	Average m^2	Average m^2 Sampled	Sample Size	Percent Salvageability
A1	General Office	1,107	495	6	10
B1	Medical	386	498	3	5
C1	Shoes	138	178	3	5
C2	Clothing	427	132	3	5
C3	Stereos/TV/Electronics	385	386	4	5
C4	Paper Products	225	363	3	5
C5	Hardware/Carpet	594	570	3	10
C6	Misc. Retail	463	140	5	8
D1	Furniture/Appliances	336	362	3	5
E1	Groceries	1,023	1,233	4	5
F1	Drugs	926	1,089	2	5
G1	Auto	385	781	3	30
H1	Hotels	661	447	3	5
I1	Restaurants	438	330	3	5
J1	Personal Service	163	86	3	10
K1	Financial	421	344	3	10
L1	Warehouse/Industrial	637	512	28	30
M1	Theatres	901	952	1	5
N1	Other/Institutional	1,366	891	5	10
O1	Hospital	7,613	7,613	2	5
				90	

are located in **Appendix F**. The non-residential content damage values are detailed in **Appendix G**.

3.3.3 Content Damage Curves

In terms of content damages to commercial establishments, the primary difference between this category and the residential category is that the contents relate primarily to inventory as opposed to furniture and common household articles. The other major difference is that the total content damage is based on the non-salvageable portion of the inventory versus the replacement value of household contents. Similar to the assessment of residential content damages, no adjustment is made as a result of possible flood response due to past flood experience.

The following sub-sections describe each commercial/industrial class, salvageability values and other information which assisted in the formulation of content damage curves. Commercial content damage curves are contained in Appendix F.

3.3.3.1 General Office – A-1

This grouping includes municipal and provincial offices, real estate, consulting businesses and other professional offices such as surveyors and engineers.

There is diversity of contents as well as the manner in which they are arranged/stored within the actual office space. Widespread throughout this classification is an overall lack of substantial inventory, consequently the majority of flood damage is sustained by office furnishings/fixtures and files/hard storage in addition to computers, photocopiers, printers, etc. Salvage value was established at 10%.

3.3.3.2 Medical – B-1

The medical category pertains to doctors' and dentists' offices, as well as medical and veterinary clinics. Basically 50% of damages occurring in this category are related to fixtures, i.e., office furnishings, as well as the medical equipment that may be present in the office. Generally inventory in this category consists of drugs kept within the dispensary. Flood damage to these articles results in 100% loss due to the possibility of contamination. This fact also holds true for the majority of other pharmaceutical products. Highest dollar damage results from damage sustained by the scientific equipment. Salvageable articles in these particular facilities are predominantly related to fixtures. A salvage value of 5% was established for the medical category.

3.3.3.3 General Merchandise

3.3.3.3.1 Shoes – C-1

These businesses are typically found in shopping malls and to a lesser extent streetfront situations. A wide variety of accessory items are also sold in conjunction with the shoes; however, these items usually constitute a small part of the total inventory and hence potential damage for these components is minimal. This particular category has one characteristic not prevalent in the other categories, that being that the majority of inventory is in storage and very little of the stock is in the actual selling/display area. With regard to the storage of the inventory, the majority of stock is stored approximately 0.46 m to 0.61 m off the ground to a height of approximately 1.52 m to facilitate access to merchandise. Flood damage to the shoe boxes, though not necessarily to the shoes themselves, results in a near total loss of inventory or at least a drastic cost reduction in a flood sale situation. The salvage value was estimated at 5%.

3.3.3.3.2 Clothing – C-2

Considerable variation is encountered in the method of display/storage for this category, contributing to a diversity of results in the contents tables. Contamination renders the stock unsaleable and a salvageability value of 5% was established for clothing stores.

3.3.3.3.3 Stereo/TV/Electronics – C-3

Businesses included in this category are audio and video equipment sales, computer and peripherals, small appliances, cameras, musical instruments, and office equipment. Smaller outlets for these types of goods are being replaced by the larger box store outlets carrying a wide variety of electronics products. Because of the high value of most of the goods, damage costs are high and salvageability low. A 5% salvage value was attached to this particular category.

3.3.3.3.4 Paper Products – C-4

Stationery, office supplies and book stores are included under the category of paper products. The common element shared by these businesses is the almost total destruction of inventory as a result of flood damage. Calculation of the depth damage table is relatively straight forward due to the fact that the majority of this stock is regularly spaced on a common shelving system throughout the store. A salvage value of 5% is employed for this category.

3.3.3.3.5 Hardware/Carpet – C-5

Hardware stores, as well as paint and carpet stores are included under hardware/carpet, due to an overlapping of this product type. Display of goods in most of these outlets is directly on the floor with minimal use of shelving which would result in a considerable portion of the inventory being destroyed at very low flood levels. While most of the tool items, pipes, metal goods, etc in the hardware stores could be recovered with very little water damage, damage to packaging results in a much lower salvageability value for these items.

With respect to paint products, due to their storage in tin cans, rapid rusting of the containers, particularly along the seams contaminates the paint in a relatively short period of time. Also, water results in the destruction of the exterior labels and renders the product virtually unsaleable, as a result of the time involved to remove the lids, identify the paint and re-label the cans. Salvage value has been established at 10% for this category.

3.3.3.3.6 Miscellaneous Retail – C-6

This category includes retail/commercial businesses not included under the specific designations above. As expected, this category displays a great diversity of product types as well as the methods and type of display/storage. Salvageability is pegged at 8% for this category.

3.3.3.3.7 Generalized Retail – C-7

This curve was created for instances where tax assessment and related municipal data or lack of ground level photography does not allow for identification of the specific retail use. This generalized retail curve aggregates the other retail categories including C-1, C-2, C-3, C-4, C-5, C-6, D-1 and E-1 to render an overall retail category average.

3.3.3.4 Furniture/Appliances – D-1

This classification is relatively straightforward with consistency in both product types and methods of display and storage. In the past, salvageability was much higher due to the ability to repair flood damaged items. Modern practices have reduced previous high salvageability levels of 50% to 5%.

3.3.3.5 Groceries – E-1

Grocery stores demonstrate uniformity of product and display methods. Due to contamination of food stuffs, damage results in destruction of virtually 100% of the inventory. However, larger outlets such as Safeway, Co-op, etc. have diversified and offer a number of non-food items. Consequently, salvageability is slightly higher in the larger outlets, but overall still relatively low at 5%.

3.3.3.6 Drugs – F-1

Businesses in this classification generally carry a wide range of sundry items in addition to the pharmaceutical products sold. Sundry products have some recovery value; however, any medical or pharmaceutical products suffering water damage have virtually no salvageability due to the possibility of contamination. A salvageability value of 5% is used in this category.

3.3.3.7 Auto – G-1

Included under this category are any businesses related to the sale and maintenance of automobiles, i.e., new and used car sales, parts suppliers, auto body and repair shops, muffler and transmission repair, and car washes. In the event of a flood, permanent water damage to vehicles and the majority of materials used in the repair and maintenance of the same is relatively low. A salvage value of approximately 30% has been established for use in this particular category.

3.3.3.8 Hotels – H-1

This particular category includes both hotel and motel facilities. Inventory includes furniture and appliances, bedding and linen goods, food stuffs, liquor inventory, etc. A salvage value of 5% is employed for this category.

3.3.3.9 Restaurants – I-1

All food serving establishments are classified under restaurants including both “sit down” and “fast food” type outlets. Flooding results in damages to food inventory, utensils, cooking equipment and fixtures. A salvage value of 5% is employed in this category.

3.3.3.10 Personal Service – J-1

Businesses in this category include travel services, dry cleaning, hairstylist/beauty salons and general services. There is a wide variety of materials/inventory found in this classification as well as the methods and types of storage. However, inventory is quite limited and stored in relatively small areas and is generally subject to 100% damage within a very small depth range. A general lack of inventory is common in all business types within this category. The majority of damage would be sustained by the machinery and equipment used. Salvage value for personal services has been estimated at approximately 10%.

3.3.3.11 Financial – K-1

The financial category includes banks and trust companies and is similar to the general office category. The greatest loss to the establishments within this class occurs when water reaches files and more expensive computer, photocopying and printing equipment. Establishments in this classification are very similar with respect to contents, inventory and fixtures, and exhibit similar depth-damage characteristics. Furnishings and other pertinent articles can usually be salvaged and a salvage value of 10% is employed for this category.

3.3.3.12 Warehouse/Industrial – L-1

The types of businesses in this category are extremely diverse ranging from storage and retailing of consumer goods to relatively heavy manufacturing plants.

Larger, established businesses tend to have contingency plans for the removal of stock, vehicles, equipment, etc. A salvage value of approximately 30% is employed for the warehouse/industrial category.

3.3.3.13 Theatres – M-1

The greatest loss in terms of dollar value is sustained by the projection equipment; however, this equipment is generally kept at a fairly high level. The lower levels of theatres contain seating, screen and equipment and shelving pertaining to the confection area. Again, reflecting more current practices, the majority of seating would be non-salvageable and an overall salvage value of 5% is employed in this category.

3.3.3.14 Institutional/Other – N-1

This category contains education, cultural and recreational facilities including libraries, YMCAs, post offices, schools, churches and recreation centres. There is a considerable diversity of contents and in general the salvage materials are consistent with general office, with the exception of educational institutes and libraries where a substantial portion of the inventory relates to books. A salvage value of 10% has been established for this category.

3.3.4 Structural Damage Curves

Structural damage curves for non-residential buildings were developed from first principles based on a four-fold classification of building types as previously developed for flood damage assessment in Alberta. The four categories include office/retail, industrial/warehouse, hotel/motel and institutional. For the purposes of this study a fifth category was added for high-rise residential and office towers along with multi-level parkades which are discussed in Section 3.5.1.

Updated curves were constructed employing actual building plans to determine areas and levels of finishes. Estimates of unit prices for replacing and/or repairing flood damaged materials were obtained from local suppliers and contractors. All structural damage curves reflect the costs of repair or restoration estimated on the basis of present-day City of Calgary material and labour costs. One difference noted by contractors with respect to restoration of non-residential versus residential structures was the practice of “stepped” rehabilitation versus wholesale residential renovation at low levels of flooding. This is due to a number of factors including: 1) the use of more durable materials that have a higher level of salvageability; 2) cleaning and structural drying is easier to implement; 3) as commercial buildings are a for-profit venture, owners attempt to minimize repair costs and downtime; and 4) finally, insurers exercise a higher degree of caution in residential remediation due to potential liability relative to health and occupancy issues.

The office/retail category generally exhibits a higher level of finishing, carpeting, wallboard, higher level of ceiling finishes, more doors and partitions, etc.

The industrial/warehouse category typically contains a small portion of office and then is generally characterized by a lack of partitions and a very low ratio of finished to unfinished interior space.

The hotel/motel category typically has a combination of suites and function rooms including banquet halls, restaurants and lounges on the lower levels with a medium to high level grade of interior finish.

The institutional category covers a variety of buildings including schools, libraries and other purpose-built public facilities with durable interior and exterior finishes and generally more expensive construction.

Structural damages have been based on inundation with a two to three day recession period. It assumes virtually no damage to walls due to hydrostatic pressure as water is anticipated to leak in around window sashes, doors and other openings. Further, the curves assume no damage to structures as a result of blocks of ice (associated with ice jam flooding) contacting exterior walls.

Structural damage curves and a detailed description of restoration activities and assumptions employed in constructing these curves is contained in **Appendices H** and **I**.

3.3.4.1 Multi-Level Below-Grade Parkades

Stand-alone multi-level below-grade parkades, along with those associated with mid and high-rise office and residential buildings, constitute a new damage category not previously encountered in the literature. For the purposes of developing representative damage functions, two publicly-run facilities and a single private structure that suffered damages during the 2013 Calgary flood were analyzed including the Civic parkade in the Central Business District, the McDougall parkade in the west end of the downtown core and the parkade associated with the office/retail project at 400 Kensington House in Hillhurst. Damages varied considerably from a high of $11.7 million suffered by the Civic Plaza to $153,000 for the Kensington House parkade. Damages and flood conditions associated with each are briefly described as follows:

Civic Plaza Parkade

This is a 241.55 m^2 (260,000 ft^2) parkade with 588 stalls on 7 levels. Damages were caused by overland flooding in addition to sewer backup. The damages resulted in a complete write-off of all electrical and mechanical systems, including elevators. All architectural elements, doors, frames and masonry block, along with all the related systems were replaced for a total cost of $11.7 million which equates to approximately $484/m^2 ($45/ft^2).

McDougall Parkade

The McDougall parkade constitutes some 22,297 m^2 (240,000 ft^2) and accommodates 655 parking stalls on 5 levels. Damages at this facility were caused by wall seepage and sewer backup, with approximately 0.6 m (2 ft) of water reported on the bottom of Level P5. Damages totalling $1 million ($226 m^2/$21/ft^2) were related to replacement of elevators, clean-up, repair to the fire alarm system and rehabilitation of the wall system. It is instructive to note that flood mitigation measures have been put in place at both Municipal facilities to prevent or minimize future damages.

Kensington House

The parkade at Kensington House constitutes some 3716 m^2 (40,000 ft^2) on three levels and accommodates approximately 102 parking stalls. Damage was confined to the lower level of the parkade or approximately 1272 m^2 (13,697 ft^2) and was caused by sewer backup. Damages were limited to electrical components including conduits and fixtures, along with flood fighting (sump operations) and clean-up. There were no other structural, mechanical or elevator issues and flooding was confined to the lower level of the parkade to a depth of approximately 0.3 m (1 ft). The claim for damages was $153,000 or approximately $120/m^2 ($11/ft^2).

For the purposes of damage estimation for these types of facilities it is suggested that the higher bound is a very exceptional circumstance and is unlikely to represent typical damages to these types of structures. The mid range condition of $226/m^2 ($21/ft^2) is considered to be much more representative of damages that would be experienced within multi-level below-grade parkades.

Accordingly, for those facilities within the flood risk area that are subject to surface water flooding, a value of $215/m^2 ($20/ft^2) is proposed to be employed.

3.4 Summary

The preceding analysis has rendered updated depth-damage curves for various categories of residential and non-residential structures and their contents based on extensive first and second order research including representative sampling of residences and non-residential structures within selected functional groups. The results compare favourably with those of other similar analyses, and in particular recent U.S. experience. The values reflect current residential content and non-residential inventory, display and storage practices, and consequently could be applied with minimal modification to other similar areas within the Province. The updated curves also reflect the current practice of discarding the great majority of content items that have had even the slightest exposure to floodwaters.

4 Provincial Adjustment Indexes: Applying 2014 Calgary Stage-Damage Curves to Other Municipalities and Future Events

4 Provincial Adjustment Indexes: Applying 2014 Calgary Stage-Damage Curves to Other Municipalities and Future Events

4.1 Updating to Current Year Dollars

The stage-damage curves presented in this report express damage estimates in 2014 dollars. As a result of inflation – the general upward trend in prices – these estimates may not be directly applicable to future flood events. However, since changes in a variety of prices are regularly tracked by Statistics Canada, it is possible to develop an appropriate index to update base-year estimates to accommodate relevant price changes over time.

Damage estimates from a previous base year can be updated to a new base year. To do so, one simply multiplies the damage values by the ratio of the current index value over the index value from the previous base year, as follows:

Current Damages = Base Year Damages x (Current Index / Base Year Index).

4.1.1 Available Measures of Price and Spending Change

4.1.1.1 Consumer Price Index

A widely used measure of inflation is the consumer price index (CPI) for all items published by Statistics Canada. The CPI is a measure of the rate of price change for goods and services purchased by consumers. It is obtained by comparing, through time, the cost of a fixed basket of commodities purchased by Canadian consumers in a particular year. Since the basket contains commodities of unchanging or equivalent quantity and quality, the index reflects only pure price movements[33]

The goods and services are classified in hierarchical groups with common end-use or are substitutes for each other. For example, "refrigerators and freezers" is a group in the basic class "household equipment", which in turn, comes under the larger group "household operations, furnishings, and equipment".

The "All-Items" CPI aggregated index includes the following major groups:

1. Food;
2. Shelter;
3. Household operations, furnishings, and equipment;
4. Clothing and footwear;
5. Transportation;
6. Health and personal care;
7. Recreation, education, and reading; and
8. Alcoholic beverages and tobacco products.

Each item comprising the CP basket of goods and services is weighted according to regional household spending survey data. For example, in the latest published weighting for Alberta,

[33] 1996 Statistics Canada, Your Guide to the Consumer Price Index – Catalogue No. 62-557-XPB

gasoline had a weight of 3.81 while coffee and tea had a weight of 0.24.[34] This reflects the fact that households spend on average more money on gasoline than coffee and tea and a 5% increase in the price of gasoline would have a greater impact on the average consumer. Both the relative price of an item (i.e., inflation) and the spending patterns of consumers (i.e., weighting) change over time. An individual, non-weighted index value is also available for each product group.

Note: Published indices relate to a time base year where the index is given a value of 100.0. For example, the current CPI time base year is 2002 and the January 2014 all items CPI was 123.1. This means that consumer prices were 23.1% higher in January 2014 than in 2002. When comparing index levels, the base periods must be the same.

4.1.1.2 Construction Price Indices

Statistics Canada conducts regular construction price surveys for residential, apartment, and non-residential buildings. The residential survey occurs monthly while apartment and non-residential surveys are quarterly. These surveys measure changes over time in the contractor's selling price of new construction with constant specifications.

Excluding the price of land, the construction price indexes provide a method of comparing construction costs that include materials, labour, equipment, and contractors' current overhead and profit, and market conditions.

In the new housing price survey, reported prices are adjusted for changes in quality of structure. This is done to attempt to measure changes in price over time of identical houses in consecutive periods. This is important for flood damage estimates as it is assumed the repairs will be to restore the house to its prior condition, regardless of quality changes in new home construction.

4.1.1.3 Survey of Household Spending

The Survey of Household Spending (SHS) is not a direct measure of changing prices. It is, however, an important input to calculate the weighting of the CPI and provides detailed information on the spending habits of Canadian households.

Unlike the CPI, the spending amounts contained in the SHS account for changes in both quality and quantity, or mix of purchases made by a household over time. In other words, the SHS identifies the total value spent on a product type instead of the individual price of a constant product.

4.1.2 Updating Residential Content Damages

The published all items CPI is commonly used to update content damage estimates from a previous year. As noted above, this is a composite index reflecting price movements of a full collection of products and services purchased by consumers. However, damage from flooding affects only a particular group of items from the CPI basket. The relative cost of these items and respective rates of change over time may be different from the all items CPI changes. Using the all items CPI could therefore introduce error in the analysis of flood damages. However, since all sub-categories are individually indexed, it is possible to select items directly related to flood damage.

An index that directly relates to the base year stage-damage curve can be constructed using the contents survey results the curve is based on. This content flood damage index includes the groups of items identified, weighted according to their value in relation to the total value of

[34] Weighting Diagram of the Consumer Price Index - 2011 Basket at January 2013 Prices, Canada, Provinces, Whitehorse and Yellowknife http://www23.statcan.gc.ca/imdb-bmdi/document/2301_D47_T9_V2-eng.htm

contents from the survey. The list of CPI categories, total sample replacement cost, and relative weight is illustrated in **Exhibit 4.1**.

Exhibit 4.1: Weighting of Flood-Affected Contents

Category	Value	Weight
Household Furnishings & Equipment	$3,435,000	59%
Clothing and Footwear	$1,202,723	21%
Recreation	$1,181,000	20%

With the weighting and component price indexes identified, a contents flood damage index can be constructed based on the formula:

Contents Flood Damage Index = Σ ((component index i) x (weight i))

An example of this formula using CPI data for a 20 year period between 1994 and 2013 is shown in **Exhibit 4.2** below.

Exhibit 4.2: Sample Indexing of Content Value with CPI

CPI Category	Weight	1994		2013	
		Index	Weighted Index	Index	Weighted Index
Household Furnishings & Equipment	59%	94.4	55.73	93.2	55.02
Clothing and footwear	21%	98.3	20.32	93.7	19.37
Recreation	20%	89.7	18.20	99.1	20.11
Summed Flood Index			**94.25**		**94.50**

Source: CANSIM Table 326-0020 CPI, 2011 basket, (2002=100), Geography: Alberta

Accordingly, the index for 1994 is 94.25, and for 2013 is 94.5. This would mean that the value of contents is essentially unchanged over this 20-year period.

This finding clearly illustrates another challenge of using the CPI to index household content value over time. The CPI is an instrument to measure pure price changes of standardized goods. It intentionally does not account for changes in quality or technology. Computers and other electronics illustrate this effect: the index price of a computer with an unchanging processing capability will drop substantially over a relatively short time. However, because the technology continues to improve, the average new purchase price may be unchanged or even increase.

Additionally, the individual CPI indices cannot account for changes in consumer behaviour due to changing prices or incomes. For example, if clothing prices drop or income increases, a household may buy more clothing thus having a clothing inventory of a value that did not decrease.

A better measure of the change in household content value over time is the Statistics Canada Survey of Household Spending (SHS). Average household expenditures are measured annually in categories similar to the CPI and are available at the provincial level. If average household spending on televisions, for example, remains the same over a period of ten years, it is assumed that there will be the same dollar value of television equipment in the household, even if the CPI of an unchanging television set fell substantially.

The results of the SHS can be used to index the residential content value between two years in the same way as the CPI by using the weighted value of spending in the flood-affected categories, as illustrated in **Exhibit 4.3.**

Exhibit 4.3: Sample Indexing of Content Value with SHS

Category	Weight	1997		2012	
		Amount	Weighted Amount	Amount	Weighted Amount
Household Furnishings & Equipment	59%	$1,561	$922	$2,874	$1,697
Clothing and Accessories	21%	$2,396	$495	$4,591	$949
Recreation	20%	$3,496	$709	$5,226	$1,060
Weighted Total			**$2,126**		**$3,706**

Source: CANSIM Tables 203-0001 & 203-0021, SHS, Geography: Alberta

Continuing with this example, a 1997 content damage amount can be updated to 2012 with the following Formula:

2012 Damages = 1997 Damages x (2012 Weighted SHS / 1997 Weighted SHS)

Accordingly 2012 content values can be estimated to be 174% of the 1997 content values.[35] Future residential content indexes can be created in the same manner using the SHS component spending amounts available at that time.

A sample comparison of the all item CPI, a weighted flood categories CPI, and a weighted flood categories SHS index using available data between 1994 and 2013 is illustrated in **Exhibit 4.4**, indexed to 100.0 in 2002.

4.1.3 Updating Non-Residential Content Damages

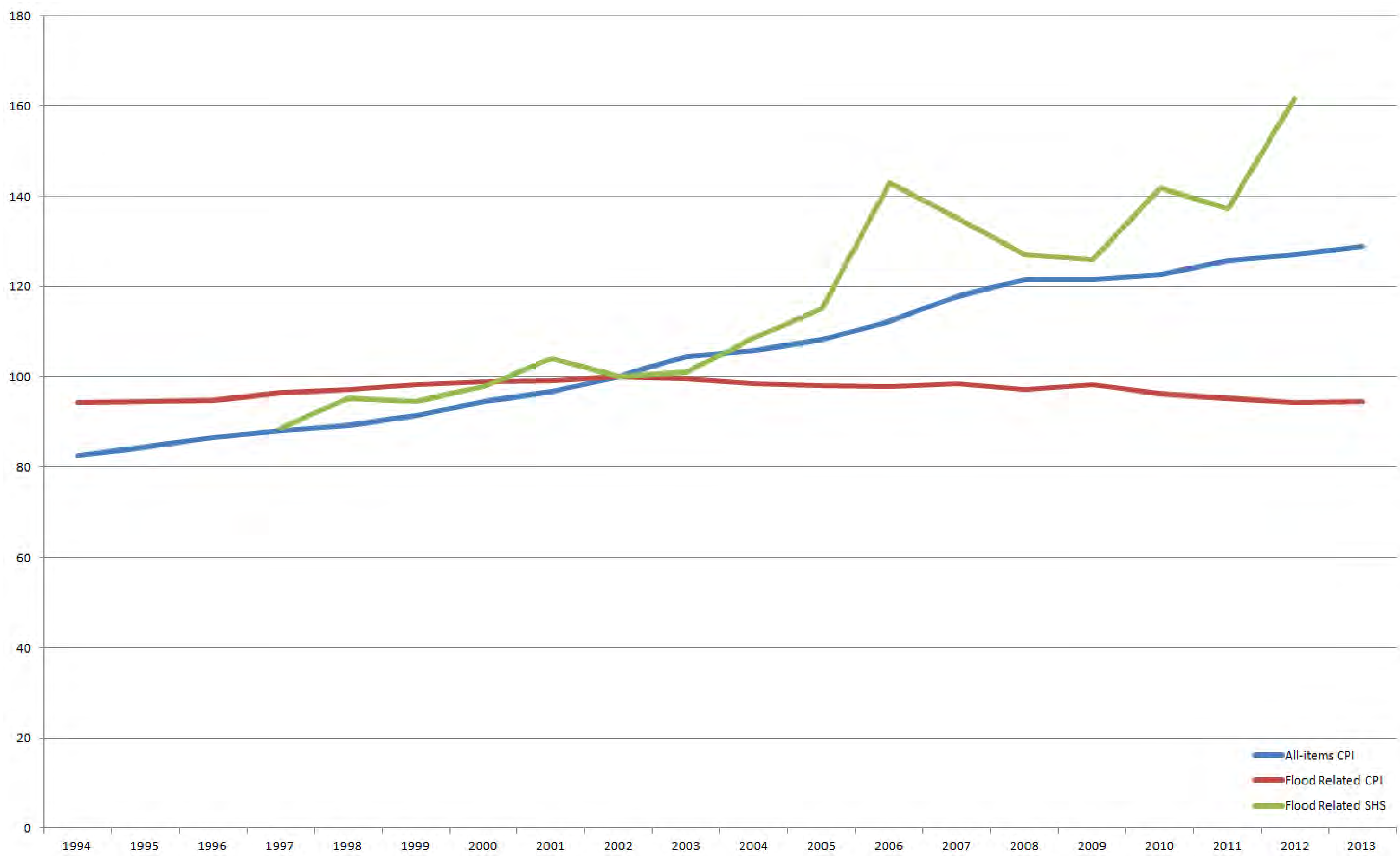
As with the residential buildings, the content of a commercial, industrial, or institutional building susceptible to flood damage is not reflected by the CPI basket in either composition or weighting. The problem with accounting for quality changes with category-specific index values is also present. An electronic equipment price index, for example, would indicate that the inventory value of an electronics store is dropping over time.

The assumed relationship between household spending and content value, however, does not apply to commercial contents. If consumers are purchasing more of a product, there will likely be more stores rather than an increase in inventory value. If consumers are purchasing higher quality products, the inventory will likely be comprised of the higher quality products. Additionally, commercial structures contain varying combinations of inventory and other furnishings and equipment and there is no spending survey for non-residential categories.

Without conducting new content surveys for each commercial structure category, a general index that avoids product-specific omission of quality changes is required. As part of the CPI, Statistics Canada provides the special aggregate "Goods" to exclude services, shelter, and

[35] This sample comparison uses data from two survey series. Due to changes in methodology, series 203-0001 (1997-2009) was terminated and replaced with series 203-0021 in 2010.

Comparison of Flood-Related Price Index and Flood-Related Household Spending to All Items Consumer Price Index (2002 = 100)



energy that would not be affected by flooding. As the components of this aggregate are weighted by province according to the SHS, it can be assumed to represent the general composition of commercial contents, including non-durables that are insignificant in value at any one time in a household but may represent a significant value of commercial inventory.

Therefore, the formula for updating commercial content damages for future dates is as follows:

Future Damages = 2014 Damages X (Future CPI Goods Aggregate / 2014 CPI Goods Aggregate)

4.1.4 Updating Structural Damages

Structural flood damage is the estimated cost for repair and/or replacement of building components damaged by flooding. The price of construction/restoration is dependent on the building type. The main categories of building type are as follows:

- House (single dwellings, semi-detached, and row-houses)
- Apartment (vertical attached dwellings)
- Non-Residential (commercial, industrial, and institutional)

Statistics Canada regularly publishes construction price indices for the above categories of buildings, as well as infrastructure construction. Restoration of a flood-damaged building is not equivalent to new building construction. For example, structural items such as wall studs, foundation concrete, and electrical wires may not be replaced after a flood. However, the construction price indices are the most relevant measure of changes in real market price for construction work. These indices cover all representative construction materials, general and trade contractors' labour, equipment, overhead, and profit while excluding the cost of land, design, and development and real estate fees.

The 2014 base year structural damage estimates can be updated using the most recently published construction price index for the corresponding building type.

4.1.5 Updating Damages Summary

A summary table of recommended methods for updating the damage estimation curves developed in this report for application to other years is provided in **Exhibit 4.5**.

4.2 Regional Adjustments

The stage-damage curves presented in this report express damage estimates in 2014 dollars in the Calgary area market. In addition to changes in price over time, there are substantial regional price differences across Alberta markets. Demographic, economic, and geographic factors all influence the price of goods and services at the regional level. Unlike the CPI data from Statistics Canada, regional price data is not regularly published.

4.2.1 Measuring Spatial Price Differences

The CPI measures changes in price of an equal basket of goods in the same place at different times. Measuring the price of that equal basket in different places at the same time allows for regional price comparisons. A spatial price survey can be used to create an index to compare the costs of goods between communities.

4.2.2 Adjusting Content Damages

The replacement price of flood-damaged contents may vary between communities. In 2010, Alberta Finance and Enterprise, Budget and Fiscal Planning conducted a Spatial Price Survey

Summary of Methods to Update Damages to Other Years

Damage Type	Index Used	Index Components & Weighting		New Damages Formula
Contents - Residential	Survey of Household Spending	Household Furnishings & Equipment	59%	$2014\ \text{Damages} \times \frac{\Sigma\,((\text{current component expense}) \times (\text{weight}))}{\Sigma\,(2014\ \text{component expense}) \times (\text{weight})}$
		Clothing & Accessories	21%	
		Recreation	20%	
Contents - Non-Residential	Consumer Price Index	Goods special aggregate		$2014\ \text{Damages} \times \frac{\text{current goods index}}{2014\ \text{goods index}}$
Structure - Residential - House	New Housing Price Index	N/A		$2014\ \text{Damages} \times \frac{\text{current new housing index}}{2014\ \text{new housing index}}$
Residential - Apartment	Apartment Building Construction Price Policy	N/A		$2014\ \text{Damages} \times \frac{\text{current apartment index}}{2014\ \text{apartment index}}$
Structure - Non-Residential	Non-Residential Building Construction Price Index	N/A		$2014\ \text{Damages} \times \frac{\text{current non-residential index}}{2014\ \text{non-residential index}}$

on behalf of Alberta Education. The report presents survey findings for 34 selected Alberta communities with Edmonton designated as the reference base.

The goods and services used for the study were similar to the survey items used by Statistics Canada to construct the CPI. The weighting of each item is also derived from the CPI, using SHS. Therefore, it also includes items that would not be representative of flood-damaged building contents and the relative weight of items is not applicable. Therefore a new flood damages variation of the index must be constructed.

Exhibit 4.6 illustrates the categories and relative weighting that were included in the 2010 Alberta Spatial Price Survey.

Exhibit 4.6: 2010 Alberta Spatial Price Survey Categories and Weights

Category	Weight
Dairy	1.45
Fats & Oils	0.12
Cereals & Breads	1.73
Processed Fruits & Vegetables	0.67
Fresh Fruits & Vegetables	1.35
Meat, Fish, Poultry	2.35
Frozen & Packaged Foods	2.59
Restaurant Meals	4.29
Personal Care Products	2.48
Household Supplies	2.14
Household Services	6.61
Household Equipment	3.87
Recreation & Leisure	8.36
Transportation	17.74
Clothing	3.78
Shelter	17.72
Utilities	5.51

As with the adjustments between years using the CPI and SHS, the individual weighted category indexes for Household Equipment (59%), Clothing (21%), and Recreation (20%) can be used to construct a new index for residential contents between communities. Non-residential content damages will be best represented by an aggregate of all goods, excluding household services, transportation, shelter, and utilities.

The 34 surveyed communities are listed in **Exhibit 4.7** with their corresponding re-weighted flood-affected contents index for residential and commercial structures. With this new index, the estimated value of household contents in a different community is determined as follows:

(Value Community B) = (Value Community A) x ((Index Community B) / (Index Community A))

Exhibit 4.7: Spatial Flood-Affected Contents Indexes

Community	Residential Contents	Non-Residential Contents
Edmonton	100.0	100.0
Athabasca	101.5	102.0
Barrhead	99.8	101.6
Brooks	94.2	100.1
Calgary	98.2	100.3
Camrose	98.8	98.5
Canmore	105.9	109.2
Cold Lake	96.5	98.5
Drayton Valley	99.5	98.5
Drumheller	97.1	100.5
Fort McMurray	101.9	103.4
Grande Cache	101.8	102.2
Grande Prairie	97.4	101.7
Hanna	101.5	103.3
High Level	96.5	103.3
High Prairie	97.4	101.7
High River	100.2	98.5
Hinton	100.9	102.6
Jasper	104.6	105.2
Lethbridge	99.8	97.9
Lloydminster	98.1	99.6
Medicine Hat	93.5	96.7
Olds	98.4	99.1
Peace River	99.2	101.3
Pincher Creek	99.6	99.5
Ponoka	98.8	99.1
Red Deer	99.5	100.5
Rocky Mountain House	96.4	101.3
Slave Lake	99.7	99.9
St. Paul	100.7	102.4
Stettler	95.9	96.4
Taber	97.8	100.4
Vegreville	93.8	95.0
Wainwright	97.2	98.4
Whitecourt	99.8	97.4

4.2.3 Adjusting Structural Damages

The 2010 Alberta Spatial Price Survey does not contain prices related to construction for application to structural damages. Alberta Infrastructure has developed location factors that are applied to construction costs for facilities across the province. Tendering prototypical buildings in various locations at the same time has allowed refinement of locational factors that are used to determine contract pricing and for facility development budgeting.

Although these location factors are used for all structure types, including housing projects, they are primarily derived from institutional building construction, such as hospitals and schools that comprise the majority of government spending. No separate factors are available for housing, apartments, and commercial buildings. Unlike the construction of a new hospital, which may require special trades not available in smaller communities, flood restoration work is more likely to be completed by local trades and thus labour cost differences may be exaggerated.

Nonetheless, as these factors are derived from the experience of Alberta Infrastructure in building across Alberta, they are the best available representation of construction cost differences in the province.

Exhibit 4.8 illustrates the location factors on a map of Alberta. Edmonton is the base at 1.0 and the 100 km concentric rings around Calgary and Edmonton assist in extrapolating values for municipalities not indicated.

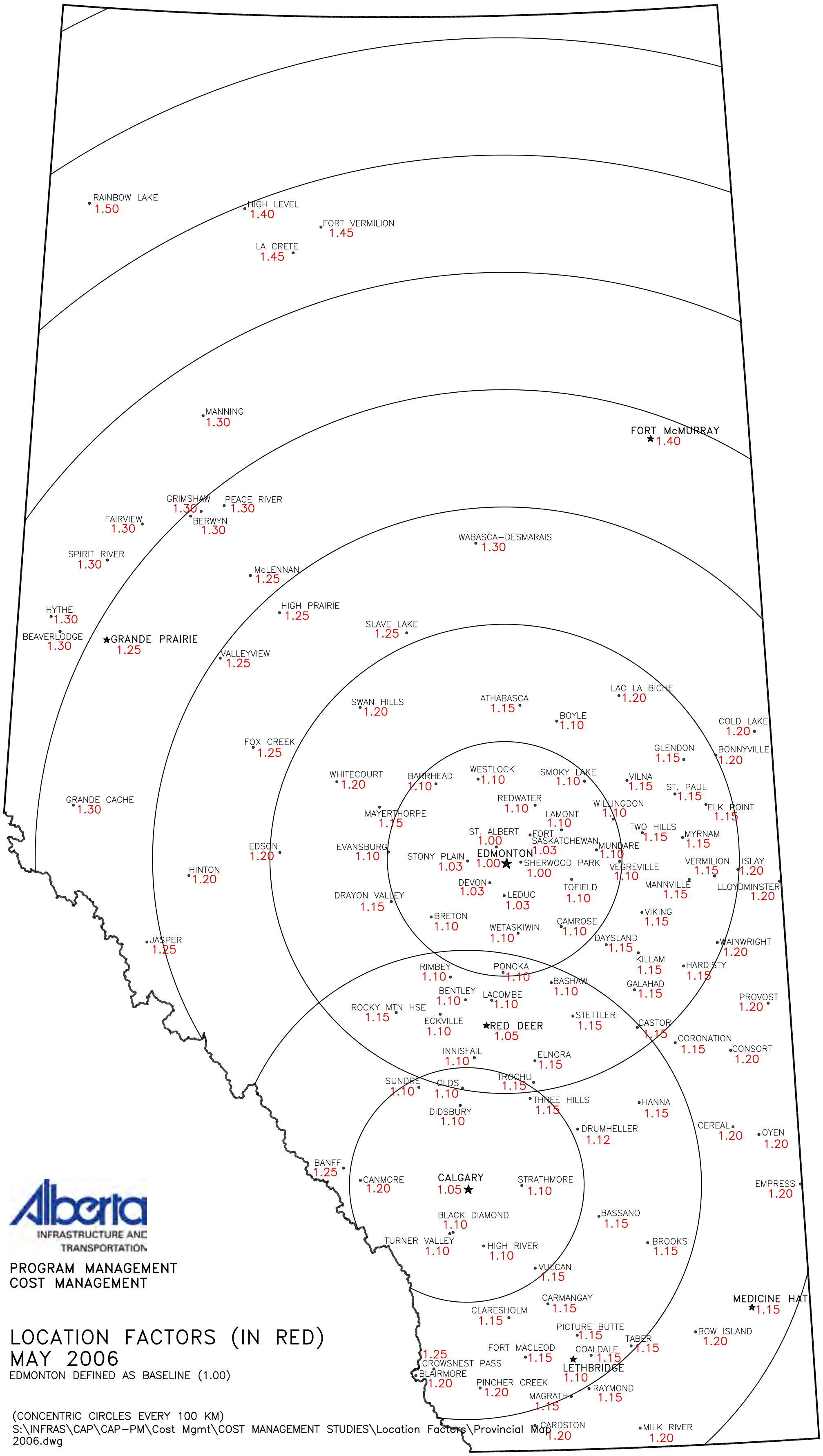
The following formula is used to adjust prices to other Alberta communities:

Value in Community B = (Value in Community A) x (Index Community B / Index Community A)

4.2.4 Adjustment Indexes for Study Communities/Locations

Exhibit 4.9A/B indicates the adjustment indexes to be applied to structure and contents stage-damage curves in the study locations. Calgary is the base municipality with an index value of 1.00. Damage values for other study locations are obtained by multiplying the Calgary damage value by the listed index value for the desired location and damage type.

Locational Factors for Alberta



Adjustment Indexes for Study Locations

Location	Structural Damage Index	Content Damage Index	
		Residential	Non-Residential
Airdrie	1.00	1.00	1.00
Athabasca	1.10	1.02	1.00
Banff	1.19	1.08	1.09
Barrhead	1.05	1.02	0.97
MD of Bighorm	1.19	1.08	1.09
Black Diamond	1.05	1.02	0.98
Bragg Creek	1.05	1.02	0.98
Calgary	1.00	1.00	1.00
Camrose	1.05	1.01	0.98
Canmore	1.19	1.08	1.09
Carbon	1.10	0.99	1.00
Cardston	1.14	1.00	1.00
Cochrane	1.05	1.02	0.98
Cougar Creek	1.19	1.08	1.09
Crowsnest	1.19	1.02	1.01
Devon	0.98	1.01	0.98
Didsbury	1.05	1.00	0.99
Drumheller	1.07	0.99	1.00
Eckville	1.05	1.01	1.00
Edmonton	0.95	1.02	1.00
Fort Macleod	1.10	1.02	0.98
Fort McMurray	1.33	1.04	1.03
Fort Saskatchewan	0.98	1.01	0.98
Fort Vermilion	1.38	1.04	1.03
Grande Prairie	1.19	0.99	1.01
High River	1.05	1.02	0.98
Hinton	1.14	1.03	1.02
Irvine	1.10	0.95	0.96
Lacombe	1.05	1.01	1.00
Lamont	1.05	1.02	1.00

Adjustment Indexes for Study Locations

Location	Structural Damage Index	Content Damage Index	
		Residential	Non-Residential
Lethbridge	1.05	1.02	0.98
Manning	1.24	0.99	1.01
Markerville	1.06	1.01	1.00
McDougal Flats	1.05	0.98	1.01
Medicine Hat	1.10	0.95	0.96
Millet	1.05	1.01	0.99
Nisku	0.98	1.02	1.00
Okotoks	1.03	1.00	1.00
Penhold	1.03	1.01	1.00
Pincher Creek	1.14	1.00	1.00
Pine Creek	1.00	1.00	1.00
Ponoka	1.05	1.01	1.00
Priddis	1.05	1.00	1.00
Pride Valley	1.14	1.02	0.97
Red Deer	1.00	1.01	1.00
Rochester	1.05	1.02	0.97
MD of Rockyview	1.01	1.00	1.00
Rycroft	1.24	0.99	1.01
Sangudo	1.10	1.02	0.97
Slave Lake	1.19	1.02	1.00
St. Albert	0.95	1.02	1.00
Stettler	1.10	0.98	0.96
Sundre	1.05	0.98	1.01
Thorsby	1.00	1.01	0.98
Turner Valley	1.05	1.02	0.98
Two Hills	1.10	1.00	0.99
Vegreville	1.05	1.00	0.99
Walsh	1.10	0.95	0.96
Watino	1.24	0.99	1.01
Whitecourt	1.14	1.02	0.97

5

Development of Rapid Flood Damage Assessment Model

5 Development of Rapid Flood Damage Assessment Model

5.1 Preamble

As part of the work undertaken by IBI/Ecos for Alberta Environment during the early 1980s, a computerized database inventory of residential and commercial units within the flood risk areas was developed using a CPM micro computer and BASIC program. The system and process developed was ahead of its time. It was the first computerized flood damage assessment system that computed flood damages for each building in the floodplain. This system was subsequently ported to the IBM-PC and MS-DOS using the PC File application.

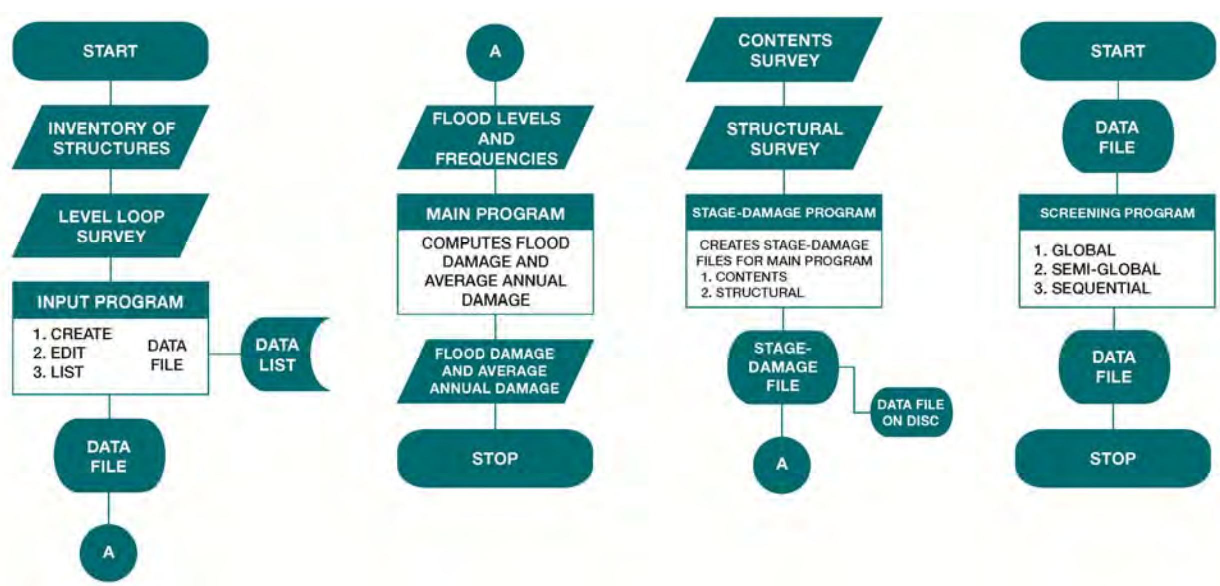
5.2 Flood Damage Database Management System

FDDBMS was developed for use in Alberta and was subsequently used for flood damage assessment in the Province of Saskatchewan under a flood damage reduction program undertaken by Saskatchewan Environment. It was then modified for use in the province of Manitoba under a project entitled "Development of Depth-Damage Curves for Residential and Farm Structures in Southern Manitoba", under the Canada-Manitoba Flood Damage Reduction Program for Canada's Inland Waters Directorate.

Comparative Flood Damage Estimation Program (CFDEP) was a modified version of FDDBMS designed to use the data base derived from the Flood Damage Survey Forms from seven communities in the Red River Valley and other adjacent watersheds in Manitoba. This data was collected by the Manitoba Flood Disaster Assistance Board which was formed by the Manitoba Government to administer the relief assistance, provided by the Federal and Provincial Governments.

A flow chart of FDDBMS is shown on **Exhibit 5.1**. It comprises a number of modules. The main module sequentially processes all the structures in the floodplain and adjacent-to areas (for basement flooding). The structural database was created using hardcopy planimetric maps and a level loop windshield survey to obtain structure type classification, grade and main floor elevation. Each structure is assigned a unique ID tag number plotted on the hardcopy map. The structural inventory module is a separate input module.

Exhibit 5.1: FDDBMS Application Flow Diagram



The stage-damage module is used to input multiple content and structural damage curves, which are applied to the building inventory in the flood affected areas. Each damage curve is assigned a classification that is related to the units in the building inventory. The main difference between FDDBMS and CFDEP was that the latter was designed to apply multiple damage curves to the same building structures for comparative analysis of curves.

The main module applies the flood levels for different reaches (zones) from the different return floods computed from the U.S. Army Corps of Engineers HEC-2 application to the building database. It computes the flood damages using the assigned depth-damage curves and combines a set of flood frequencies to compute average annual damages (AAD) for an area to be used in benefit/cost analysis.

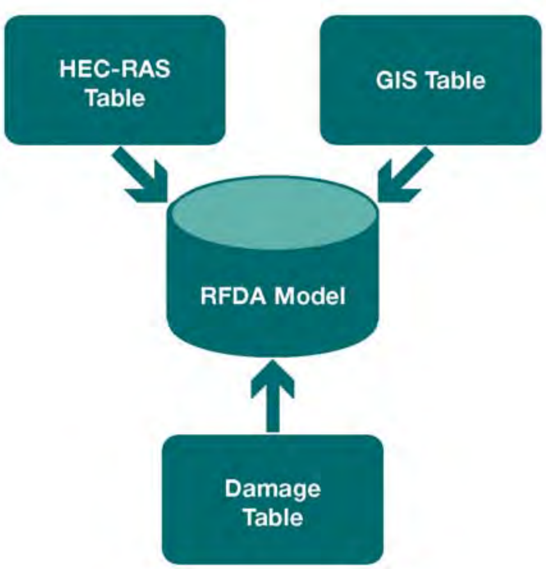
In addition to residential and commercial building structures in the floodplain the module contains a routine that can also compute basement flooding in adjacent-to areas.

5.3 Rapid Flood Damage Assessment Model (RFDAM)

Even though FDDBMS was ahead of its time in the use of a computerized relational data base for mass assessment of flood damages, it was felt it could be improved with the use of GIS, digital mapping and digital elevation models (DEM). Since its development in the late eighties computerized GIS has evolved to the point where all local governments are using it in some form. In addition, the creation of a contiguous digital cadastral parcel mapping fabric by GoA has led many local governments to adopt it for use with their in-house GIS. All municipalities have access to digital parcel maps from agencies like SPIN 2 and AltaLIS, etc.

The RFDAM model works with three input tables: (1) the GIS inventory table of residential, and commercial/retail buildings in the study area; (2) the specific depth-damage curves for contents and structures indexed to that community; and (3) the hydraulic flood-frequency-elevation table derived from the HEC-RAS model (see **Exhibit 5.2**).

Exhibit 5.2: RFDAM Input Tables

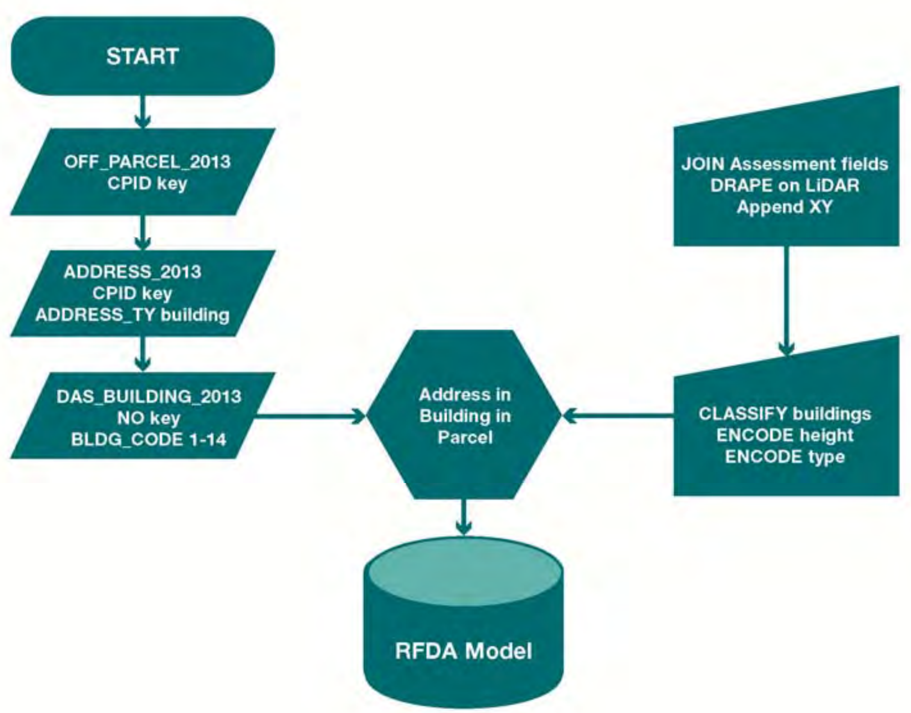


Municipalities in flood risk areas have access to high resolution satellite imagery, or orthophotos, which can clearly show the location of all buildings in their community. In addition they can overlay the images with property parcel boundaries. Many local governments have replaced contour mapping with LiDAR DEMs, which provide dense 3D points scanned by airborne radar with higher accuracies than traditional photogrammetry. This means that buildings in the floodplain and adjacent-to areas can be geocoded to a coordinate system.

The GIS building inventory table was designed to provide maximum flexibility in data collection input to the model. In the case where assessment data is available, main floor and basement areas can be extracted for use in the model. In cases where that is not available, the areas can be estimated via remote sensing.

Similarly, the elevation grade for the property can be extracted by draping on the 3D surface from LiDAR or other DEMs. Naturally the denser the ground points are, the more accurate the elevation will be. In the worst case elevations can be extracted from contour maps. The process is illustrated in **Exhibit 5.3**.

Exhibit 5.3: Calgary GIS and Assessment Data Preparation Process



It is therefore possible to integrate the hardcopy mapping components of FDDBMS with a completely digital approach using GIS and DEMs. The process for estimating flood damages using the model is shown in **Exhibit 5.4** and is described on a step-by-step basis as follows:

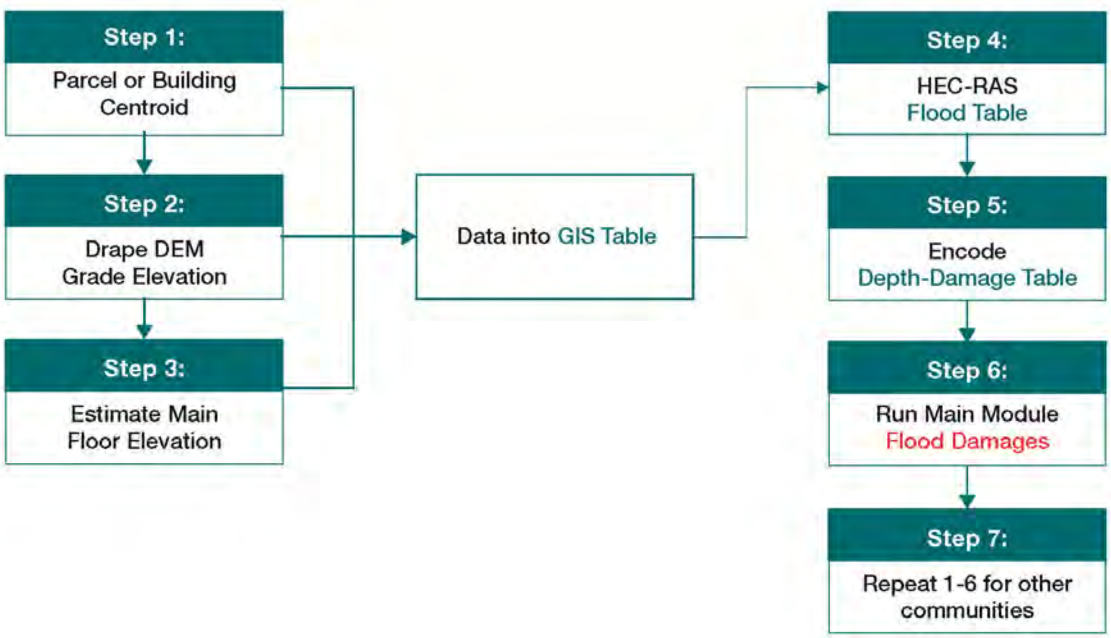
1. Load parcel base map coverage in GIS to generate centroid for draping. If the main floor area is available from assessment then this value should be used. This is available in larger communities but may not be readily available in smaller ones. In addition the building outline may be available. If not the building area could be digitized and automatically computed using GIS if necessary.

   Note: FDDBMS used damage curves that were averaged to residential building types and class because it was not possible to easily obtain individual building areas at that time. Now assessment or GIS areas for buildings can be employed.

2. Drape centroids on LiDAR DEM bare earth (BE) coverage to obtain grade elevation. BE coverage is created by applying sophisticated algorithms to compute the ground elevations without structures or vegetation.

3. Grade to main floor height may be estimated from a windshield level loop survey or Google Earth type street level photography. If that is not possible then an average grade height from past observations can be used in the model. The information from steps 1 to 3 are added to the 'GIS Inventory Table'.
4. Use the HEC-RAS model sections to define floodplain zones in the community, include the adjacent to areas using a buffer zone on the left and right of the cross-sections. Input table of flood elevations for the different return flood levels that will be used for flood damage calculations. This can be referred to as the 'Flood Table' (see **Exhibit 5.5**).
5. Code updated depth-damage curves for structure and contents for residential and commercial buildings into a 'Depth-Damage Table'. Damage curves developed specifically for Alberta were employed in the 1980s These have been updated to 2014 values for use within the entire Province through place-to-place indexing. These are the most current and accurate synthetic flood damage curves for depicting damages in Alberta.
6. Once the three key tables are generated the RFDAM model can be run to calculate the flood damages to residential and commercial structures within the floodplain and adjacent to areas for various return floods. From these, the average annual damages (AAD) can be estimated.
7. Steps 1 to 6 are repeated for each flood risk community. The RFDAM system has been developed using Free and Open-Source Software (FOSS). Quantum GIS (QGIS) has been selected as the GIS application of choice. RFDAM has improved significantly on the previous FDDBMS and provides a user-friendly, made in Alberta approach to flood damage assessment.

Exhibit 5.4: RFDAM Damage Estimate Steps

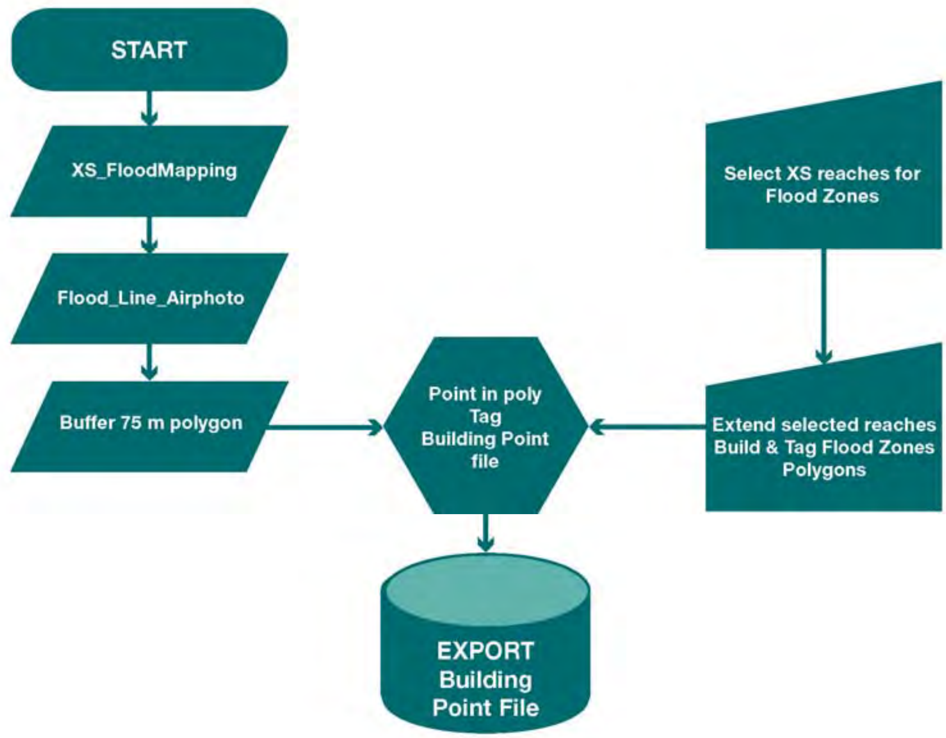


The conceptual design and detailed architecture has followed the basic structure of FDDBMS. However, refinements have been applied to take advantage of the new technology, including digital mapping and GIS. A detailed step-by-step tutorial will be available along with a user's manual that will allow users to apply the model for their municipality using the QGIS system.

The tutorial will include naming conventions and procedures that users are recommended to follow. However, the system is flexible enough to allow for user customization as well.

One of the advantages of FOSS, is that the software, like QGIS, can be used by all without having to pay for a commercial license for in-house use.

Exhibit 5.5: Flood Cross-Sections and Hydraulic Data Preparation Process



5.4 Quantum GIS (QGIS)

Similar to other software GIS systems QGIS allows users to create maps with many layers using different map projections. Maps can be assembled in different formats and for different uses. QGIS allows maps to be composed of raster or vector layers. Typical for this kind of software, the vector data is stored as either point, line, or polygon-feature. Different kinds of raster images are supported and the software can perform georeferencing of images.

Gary Sherman began development of Quantum GIS in early 2002, and it became an incubator project of the Open Source Geospatial Foundation in 2007. Version 1.0 was released in January 2009. The latest version is 2.2 released in 2014.

6 Pilot Study and Field Verification

6 Pilot Study and Field Verification

6.1 Selection of Calgary

The City of Calgary was selected as the centre from which to conduct the pilot study for a variety of reasons as follows:

- Recent flood damage experience (2013) of City agencies and private organizations, particularly with respect to cost of damages.
- Large inventory of potential residential and commercial structural types and categories.
- Familiarity of study team with the flood hazard area along with past flood damage work within the City including 1986 for the Elbow River, 1987 for the Bow River in Inglewood, and 1992 for the entire city.
- Recent update of hydraulic modelling in 2012 and analysis of 2013 flood flows.
- Availability of accurate flood clean-up and rehabilitation costs by various types of residential and commercial structures.
- Anticipated detailed tax assessment records.
- Requirement for early delivery of benefit/cost analysis of major mitigatory alternatives.

6.2 Field Surveys

Early on in the process ESRD was very sensitive to the plight of those residents and business owners who were still recovering from the ravages of the 2013 flood. Consequently, ESRD decided not to impose upon them further with a request for damage surveys while the losses and disruption were still fresh. Accordingly, it was decided to employ an approach that substituted proxies for the identified residential and commercial structural types within the flood hazard area.

6.3 City of Calgary Assessment Records

Data was requested and received from the City of Calgary Mass Appraisal, Planning and Reporting Assessment, and Infrastructure and Information Services over a period of approximately six weeks. Encrypted data came in the form of electronic shape files specific to the area of concern (the 1:100 year floodplain plus 500 m buffer area) and included all residential and commercial assessment records. The initial tranche of data included 31,079 non-residential records and 65,456 residential records. Each record contained some 150 data fields describing various attributes. Through the course of the process this was reduced to 45 attributes for residential units and 43 attributes for non-residential units.

The area of interest was subsequently reduced to the 1:100 year floodplain plus a 75 m buffer resulting in data for 5,620 single-family residential dwellings; 728 semi-detached, triplex and townhouse-style dwelling units; 275 multi-family apartment buildings; and 564 non-residential (commercial/industrial/institutional) buildings.

6.4 Issues With Respect to the Use of Assessment Data

There were many issues related to the use of the assessment data, the least of which relates to its ultimate utility in the Rapid Flood Damage Assessment Model. The key issues are summarized as follows:

- This was a very unwieldy dataset including several databases and some 14.5 million pieces of information.
- It was not of the content or quality that was expected.
- Data cleaning and clarification were very time consuming.
- Addressing irregularities greatly complicated the data inputting process (i.e., single address for multiple buildings).
- There were far too many codes and categories.
- Too many unpopulated fields.
- There was also a decided lack of clarity in the records and the glossary.
- Perhaps the most major issue related to the fact that assessed value within the record includes land and improvements and therefore one cannot apply standard Content to Structural Value Ratios (CSVR) as it will either overstate or understate the content value.
- Of the ±7,000 ground-appointed structures only 3,750 (54%) have a below-grade living space indicated. This is believed to be far too low and speculated that under-reporting relates to the fact that property owners are incentivized to conceal finished basement space, while the City has no real mechanism to report or record after the building inspection and occupancy permit have been granted.
- As well, for multi-tenant buildings there is no way of disaggregating assessed value by specific unit or use such that one could apply an appropriate Contents to Structure Value Ratio (CSVR).
- Business type descriptors for retail are not subdivided into specific types, i.e., shoes, clothing, electronics, paper products, groceries, etc. and therefore do not allow for the fine-grained contents assessment by specific business type.

6.5 Data Employed

The following tax assessment and GIS information was employed in the Rapid Flood Damage Assessment Model.

6.5.1 Single-Family Residential

Assessment

- CPID – Calgary Parcel Identification number.
- Complete street address.
- Number of storeys.
- Building type.
- Assessed value.
- Living space above.
- Living space below.
- Living space total.

GIS

- Geographic coordinates – X, Y.
- Building area.*

  * Information was collected, but assessed area versus GIS area was used in the model for the City of Calgary pilot study.

6.5.2 Multi-Family Residential

Assessment

- CPID – Calgary Parcel Identification number.
- Complete street address.
- Number of storeys.
- Building type.
- Assessed value.
- Living space above.
- Living space below.
- Living space total.

GIS

- Geographic coordinates – X, Y.
- Building area.
- For multi-family residential, GIS building area was employed versus assessment data, as assessment data was for the entire building as opposed to living space on the ground floor.

6.5.3 Non-Residential

Assessment

- CPID – Calgary Parcel Identification number.
- Predominant use.
- Sub-property code (business type).

GIS

- Geographic coordinates – X, Y.
- Building area.

6.6 Recommendations for Future Assessment Coding for RFDAM Purposes

Going forward it is strongly recommended that on subsequent tax assessments, municipalities include the following fields in the individual records:

Residential Units

1. Structural type:
   - number of storeys
2. Elevation of main floor from ground elevation.
3. For multi-storey buildings:
   - total number of storeys
   - total number of units
   - area of main floor
   - number of units on main floor
   - presence or absence of parkade
   - presence or absence of living space below-grade, including number of units and total square footage

Commercial/Institutional Structures

1. Business type by appropriate flood damage curve category.
2. Gross leasable area by business type on main floor.
3. Total square footage of main floor of building.
4. Presence or absence of parkade.

6.7 Field Verification

Field verification employing Google Earth and Streetview/Apple Maps ground level photography was employed to visually inspect and qualify flood damaged non-residential and multi-residential structures, and a large, representative sample of single-family residential structures. For the non-residential component, business category was verified, and where required, modified to reflect specific retail categories. In addition, presence or absence of parkades was noted along with structural type. Elevation of main floor to grade was also adjusted where required.

For multi-family residential, the number of storeys was verified along with presence or absence of parkades and below-grade units. With respect to the latter, elevations were established for units below-grade along with the elevation of main floor units.

For the single-family component, classification (AA, A, B, C, D) was verified along with elevation of main floor with respect to grade.

In summary, there was a very low level of error in the inventory data, or differences between actual and default values. This aspect of the approach strongly supports the use of online ground level photography in the Rapid Flood Damage Assessment modelling.

7 Identification of High Priority Municipalities

7 Identification of High Priority Municipalities

As part of a Province-wide flood damage reduction initiative, 60 flood prone study communities/locations were identified as follows.

- Airdrie
- Athabasca
- Banff
- Barrhead
- MD of Bighorn
- Black Diamond
- Bragg Creek
- Calgary
- Camrose
- Canmore
- Carbon
- Cardston
- Cochrane
- Cougar Creek
- Crowsnest Pass
- Devon
- Didsbury
- Drumheller
- Eckville
- Edmonton
- Fort Macleod
- Fort McMurray
- Fort Saskatchewan
- Fort Vermilion
- Grande Prairie
- High River
- Hinton
- Irvine
- Lacombe
- Lamont
- Lethbridge
- Manning
- Markerville
- McDougal Flats
- Medicine Hat
- Millet
- Nisku
- Okotoks
- Penhold
- Pincher Creek
- Pine Creek
- Ponoka
- Priddis
- Pride Valley
- Red Deer
- Rochester
- MD of Rocky View
- Rycroft
- Sangudo
- Slave Lake
- St. Albert
- Stettler
- Sundre
- Thorsby
- Turner Valley
- Two Hills
- Vegreville
- Walsh
- Watino
- Whitecourt

On the basis of level of risk of flood damage, four high priority municipalities were identified as follows: Calgary, High River, Fort McMurray and Drumheller. These municipalities are the focus of the initial tranche of flood damage assessments.

8 Appendices

Appendix A – Content Items and Prices

Content Items and Prices - Price Suppliers (4,000 individual item prices)

Amber's Furniture
Ashley Furniture Homestore
Atlas Appliance Expert
babies'R'us
Bass Pro Shops
Bed Bath Home
BestBuy
Birchwood Furniture
Galleries
Bombay Company
Bondars Furniture
Canada Mountain Bike Shop
Canadian Tire
Consumer Reports
Costco
Crate & Barrel
Cricklewood Interiors
Crossroads Furniture Gallery
Dell
Eisenberg's Fine Furniture
Fitness Depot
Furniture Depot
Future Shop
Giant Bicycles
Hockey Plus
Home Outfitters
Honda Power Equipment
Hudson's Bay
IKEA
JYSK
Lamps.com
Lane Home Furnishings
LaZboy Home Furnishings
Leon's Furniture
London Drugs
Lowe's
Major Appliances Inc.
McArthur Fine Furniture
Mountain Eqiupment Co-op
Office Depot
Pooltables.ca
PotteryBarn
Restoration Hardware
Sears
SleepCountry
SportChek
Staples
Structube Furniture
Target
The Brick
The Home Depot
The Source
Urban Barn
Visions Electronics
Walmart
Wickerland

Content Items and Prices - Inventory Items

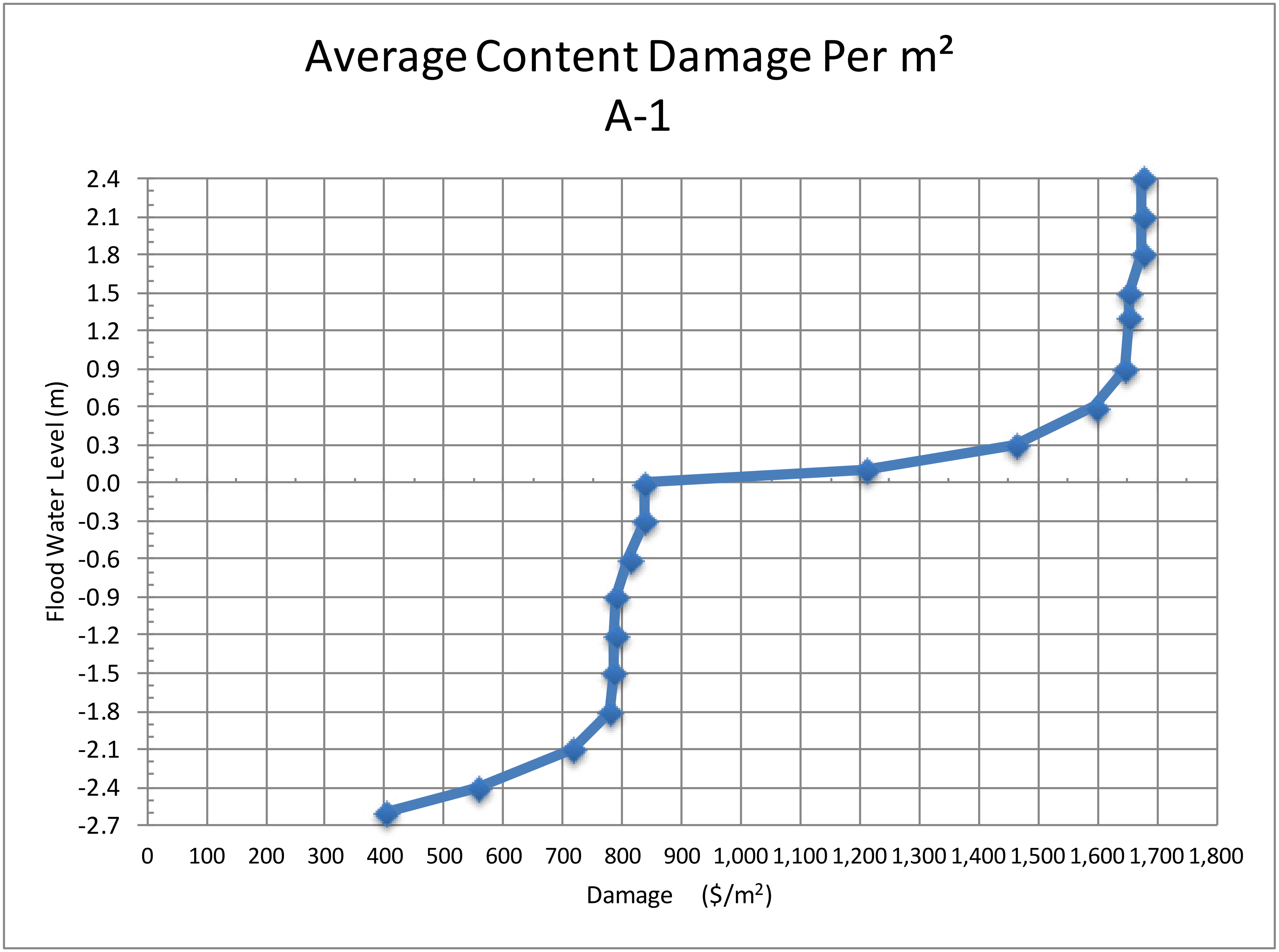
	LOW Mean 1	MEDIUM Mean 2	HIGH Mean 3	Mean All
Art / mirror on wall	$100	$250	$750	$367
BBQ	$210	$433	$1,119	$567
Bed head/foot board	$451	$917	$2,751	$1,318
Bed mattress	$651	$1,196	$2,265	$1,342
Bicycle	$223	$450	$2,962	$1,131
Bookcase linear meters	$702	$1,493	$2,511	$421
Camera / video	$133	$257	$933	$420
Camping gear set	$459	$693	$1,007	$712
Chest of drawers	$879	$1,632	$3,225	$2,008
Clothing closet linear meter	$1,402	$2,625	$5,240	$3,089
Clothing steamer	$153	$153	$153	$153
Coffee machine	$88	$144	$1,041	$395
Computer desktop	$574	$851	$1,330	$906
Computer laptop	$365	$612	$1,198	$709
Computer tablet	$204	$391	$724	$431
Cooktop / wall oven	$3,060	$3,780	$5,992	$4,213
Dining chair / table set	$558	$1,257	$3,085	$1,582
Dishwasher	$496	$734	$1,626	$925
Footstool / ottoman	$82	$151	$597	$263
Freezer	$993	$1,311	$1,908	$1,388
Furniture wall unit linear meters	$1,402	$2,625	$5,240	$3,089
Garden lawn mower / snow blower	$301	$494	$1,296	$673
Garden other power hand equipment	$89	$145	$320	$180
Iron & board	$106	$106	$106	$106
Kitchen equipment	$84	$216	$442	$250
Kitchen waste disposal	$193	$193	$193	$193
Lamp floor / table	$53	$146	$348	$177
Luggage set 3pc	$119	$255	$470	$276
Microwave	$105	$168	$372	$209
Musical instrument piano / organ	$2,000	$5,000	$10,000	$5,667
Musical instrument portable	$1,000	$3,000	$5,000	$3,000
Night stand	$156	$398	$966	$491
Occasional chair	$221	$451	$1,120	$578
Office chair	$119	$220	$555	$288

Content Items and Prices - Inventory Items

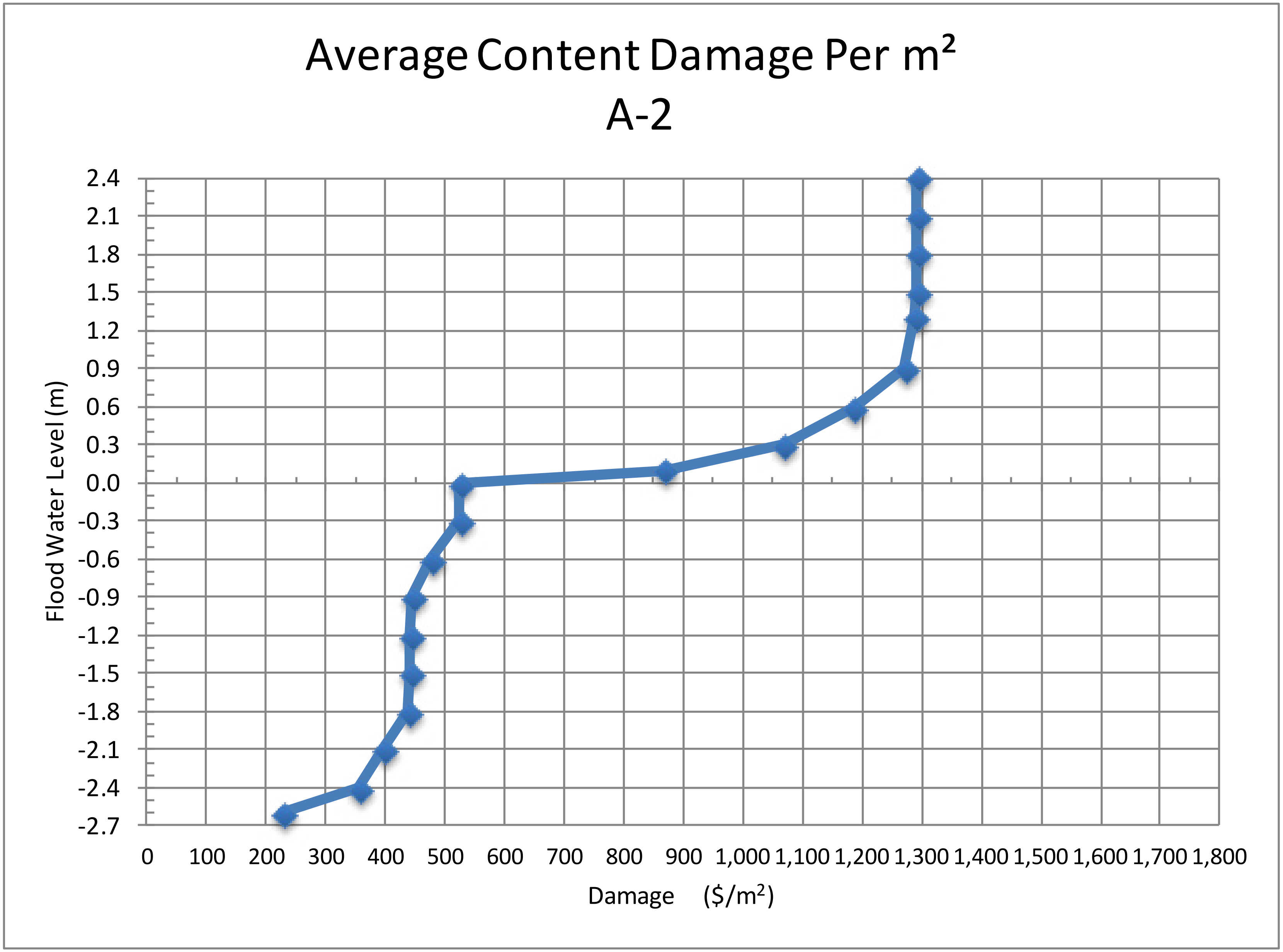
	LOW	MEDIUM	HIGH	
	Mean 1	Mean 2	Mean 3	Mean All
Office desk	$217	$702	$1,482	$781
Office paper shredder	$76	$158	$350	$189
Office printer	$79	$142	$344	$182
Outdoor patio set	$557	$1,608	$3,458	$1,827
Pool / games table	$304	$935	$2,895	$1,321
Refrigerator	$1,436	$2,311	$3,176	$2,290
Rug area <5m2	$226	$562	$951	$579
Rug area 10+m2	$1,089	$2,140	$5,755	$2,961
Rug area 5-10m2	$349	$739	$1,711	$925
Sewing / serger machine	$168	$347	$946	$487
Sideboard	$912	$1,729	$3,444	$1,982
Sofa/love seat per position	$271	$455	$899	$530
Sound system equipment	$244	$417	$941	$519
Sound system headphones	$62	$180	$335	$188
Sound system speakers	$142	$293	$834	$407
Sports gear set	$767	$767	$767	$767
Storage shelving linear meters	$272	$272	$272	$272
Stove	$870	$1,400	$2,232	$1,480
Table accent / end	$139	$295	$954	$443
Table coffee	$182	$359	$858	$452
Telephone set	$83	$83	$83	$83
Television DVR / streaming hub	$213	$213	$213	$213
Television set	$323	$797	$2,359	$1,114
Treadmill / elliptical	$546	$1,532	$2,873	$1,619
TV / media bench / cabinet	$226	$763	$2,437	$1,093
Vacuum portable	$162	$335	$563	$348
Warming drawer	$1,308	$1,308	$1,308	$1,308
Washer / dryer set	$1,199	$1,738	$2,572	$1,816
Weight machine	$641	$1,452	$3,720	$1,873
Window covering to floor				
Window covering to sill				
Wine rack number bottles	$10	$19	$38	$22
Workshop bench / table	$265	$265	$265	$265
Workshop power tools / equipment	$94	$150	$305	$179
	$472	$867	$1,760	

Appendix B – Residential Content Damage Curves

Residential Content Damage Curves



Residential Content Damage Curves



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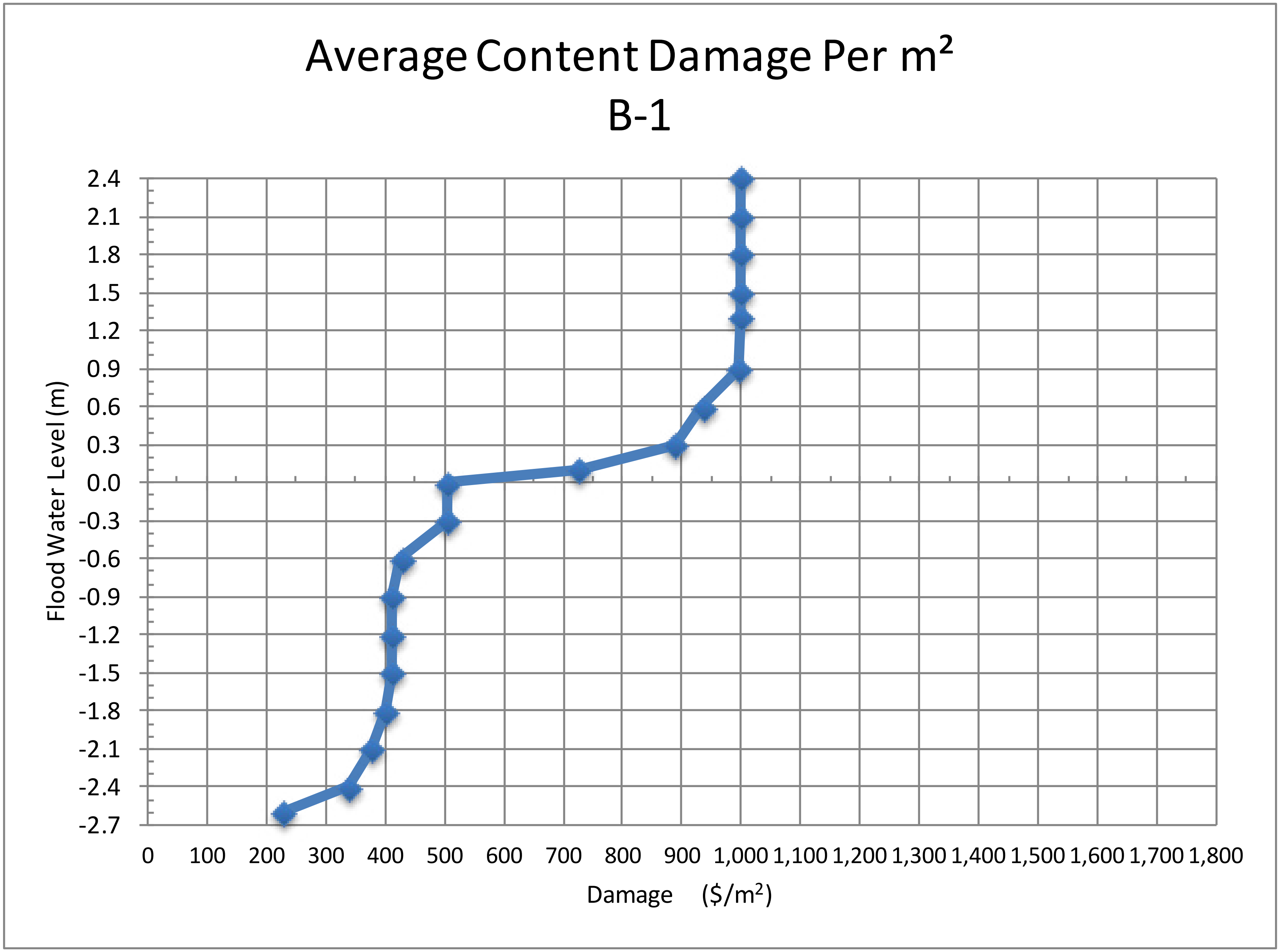

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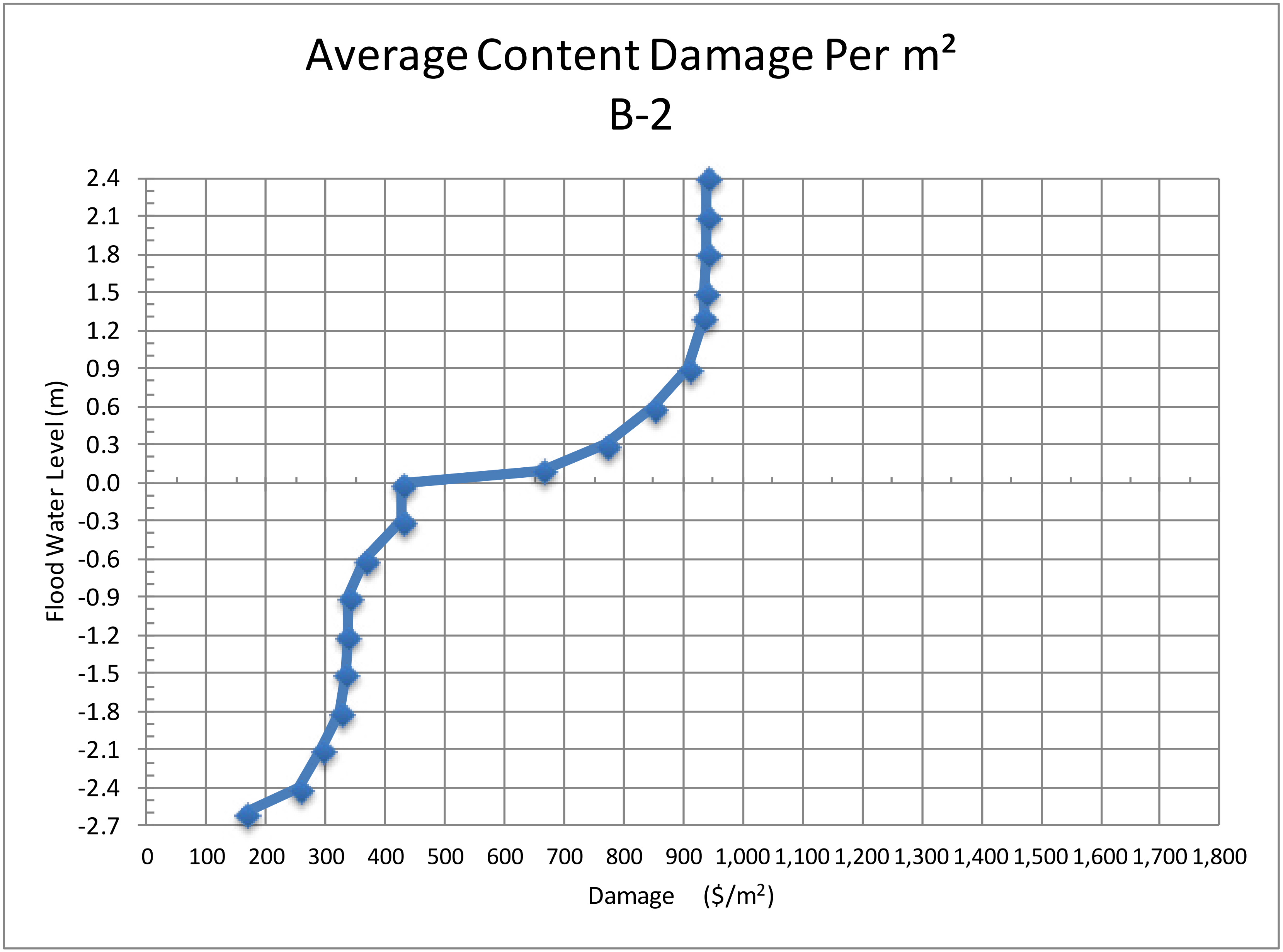

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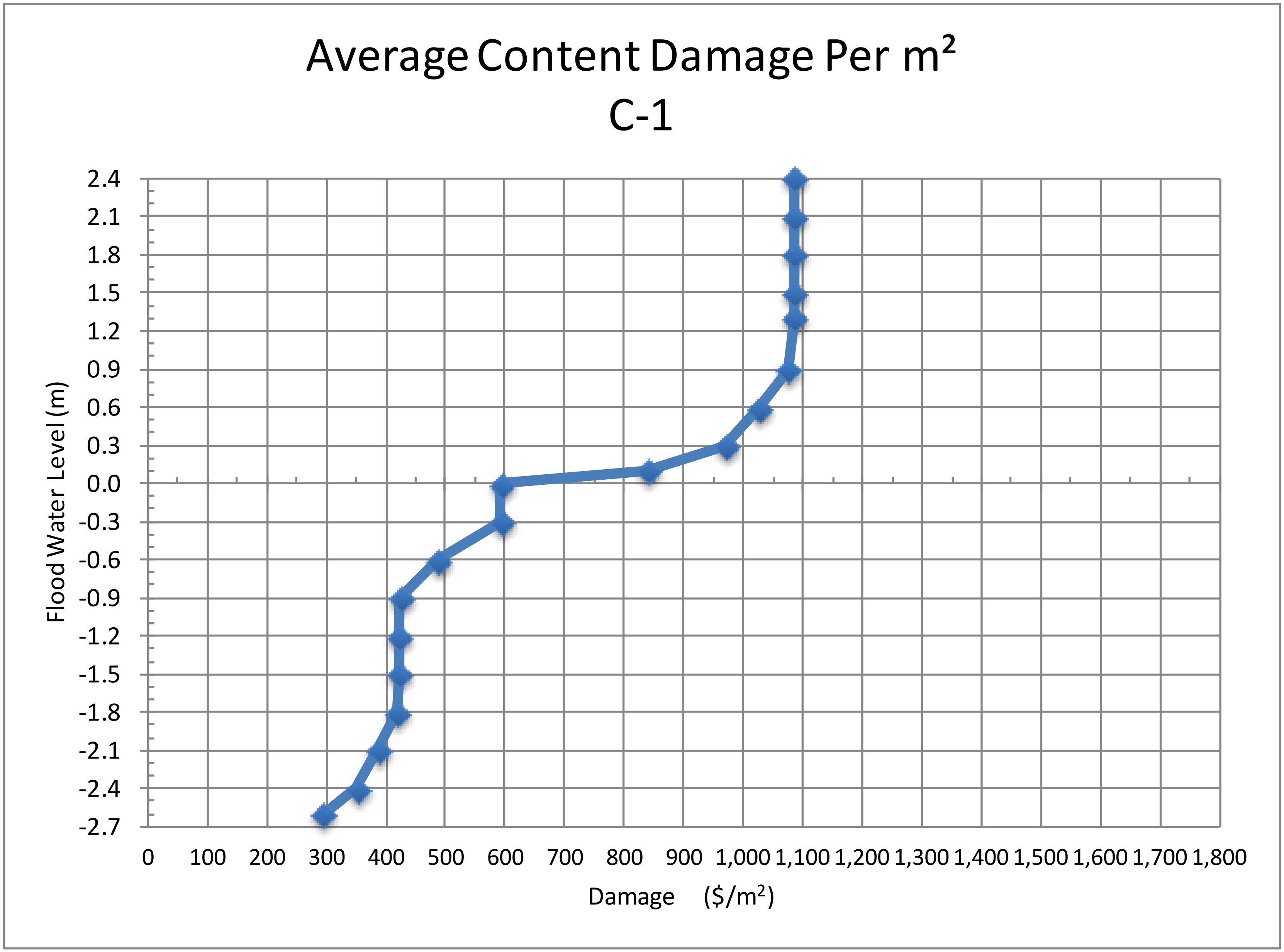

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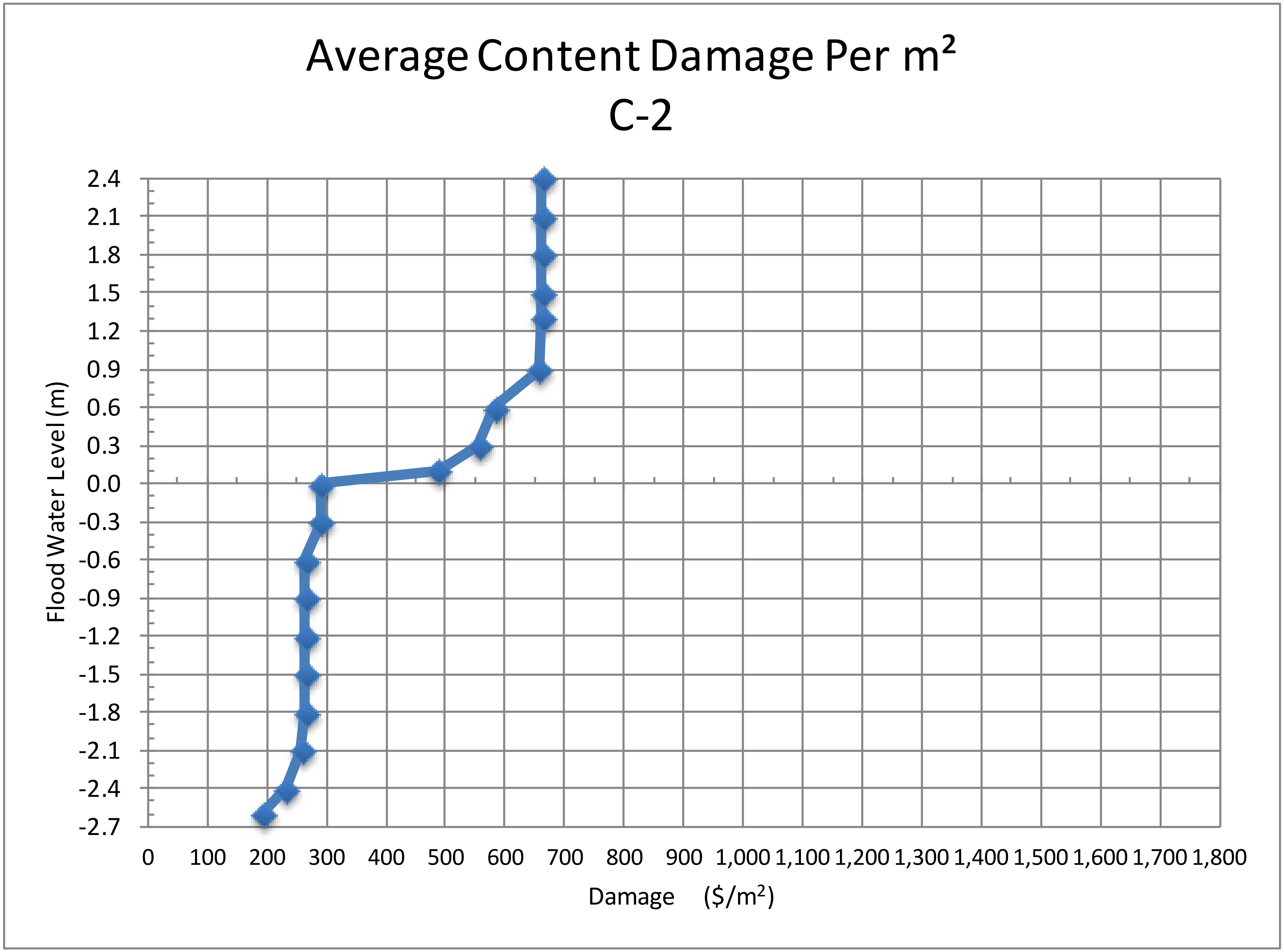
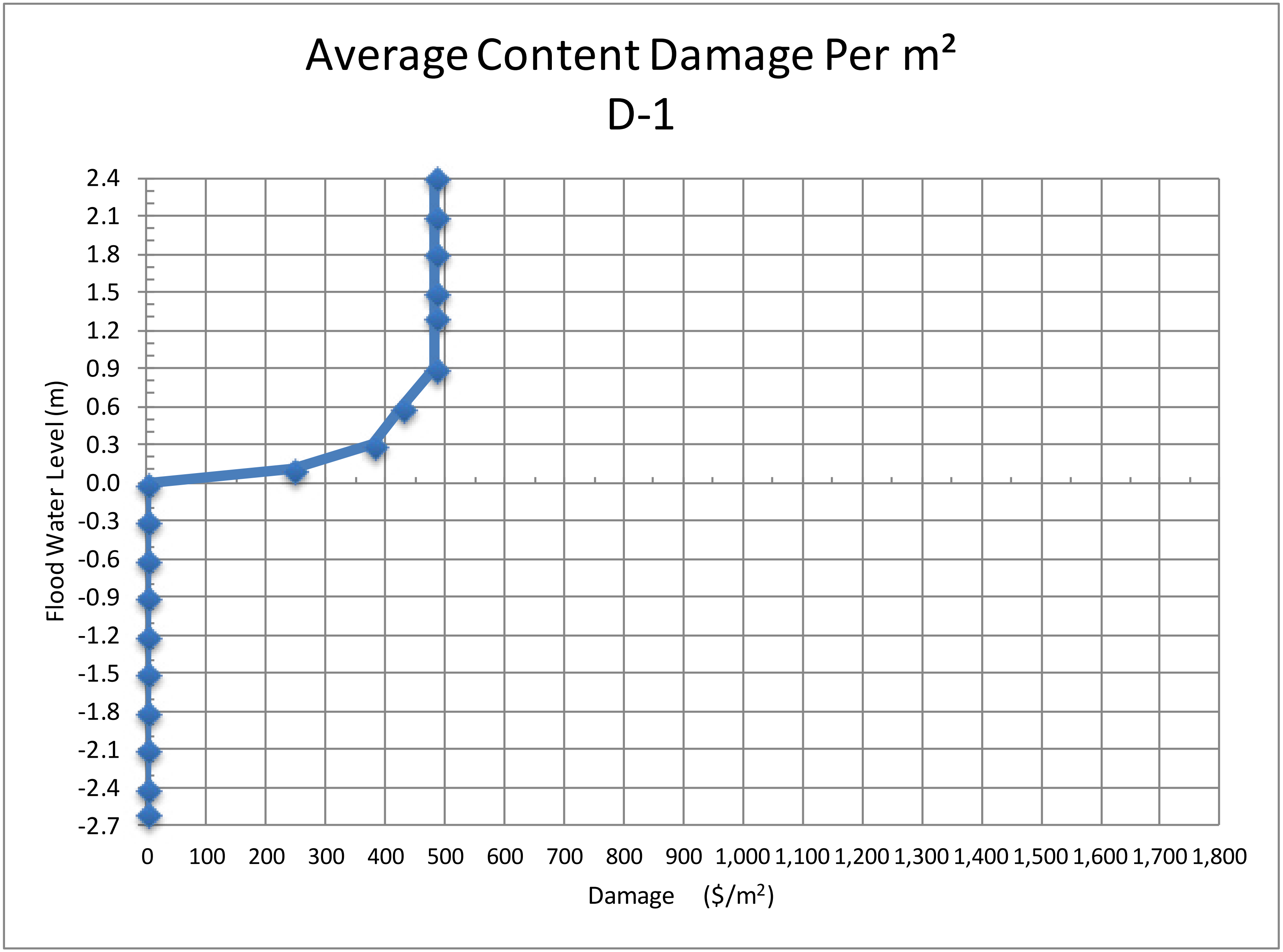


Residential Content Damage Curves



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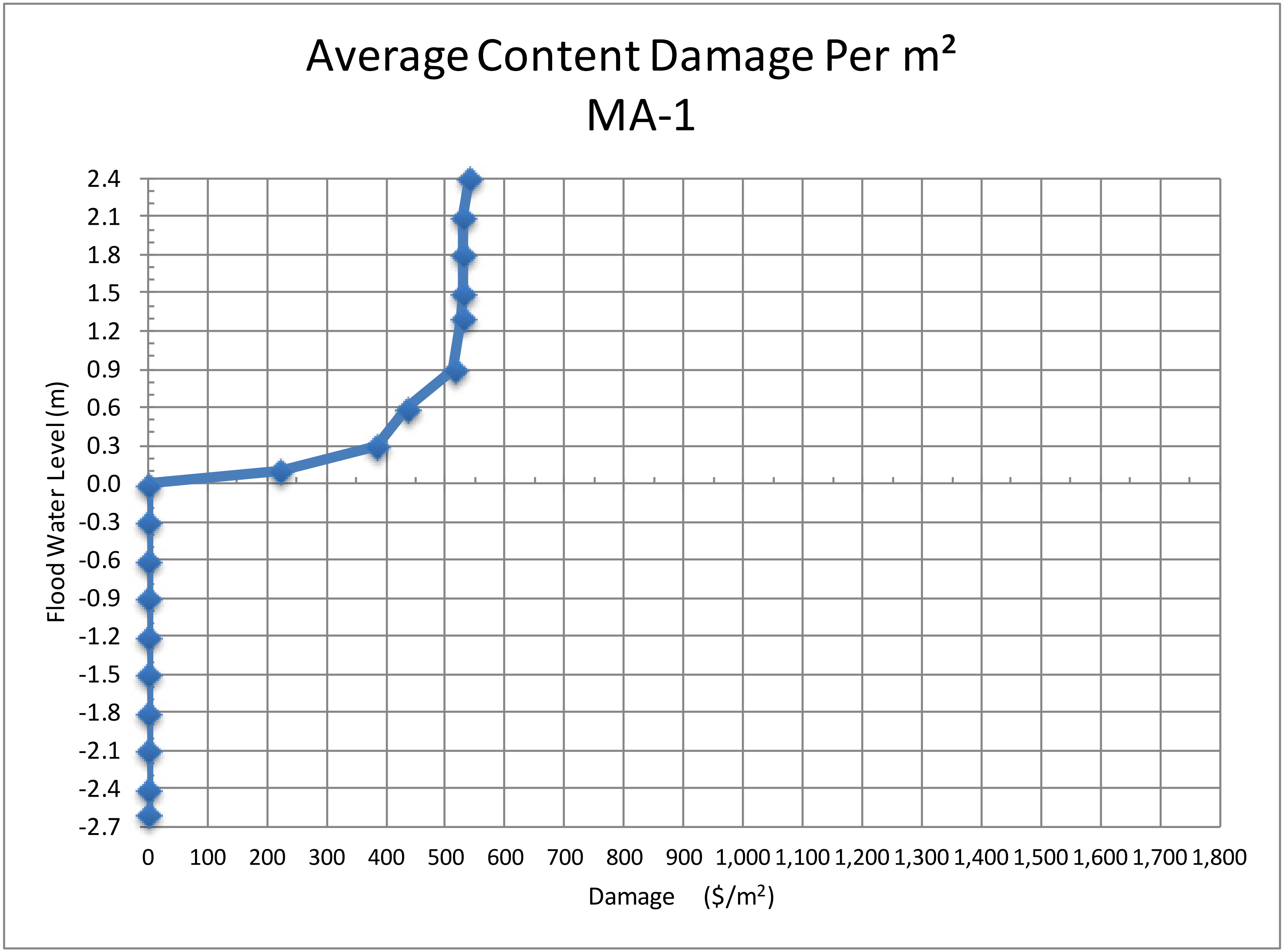
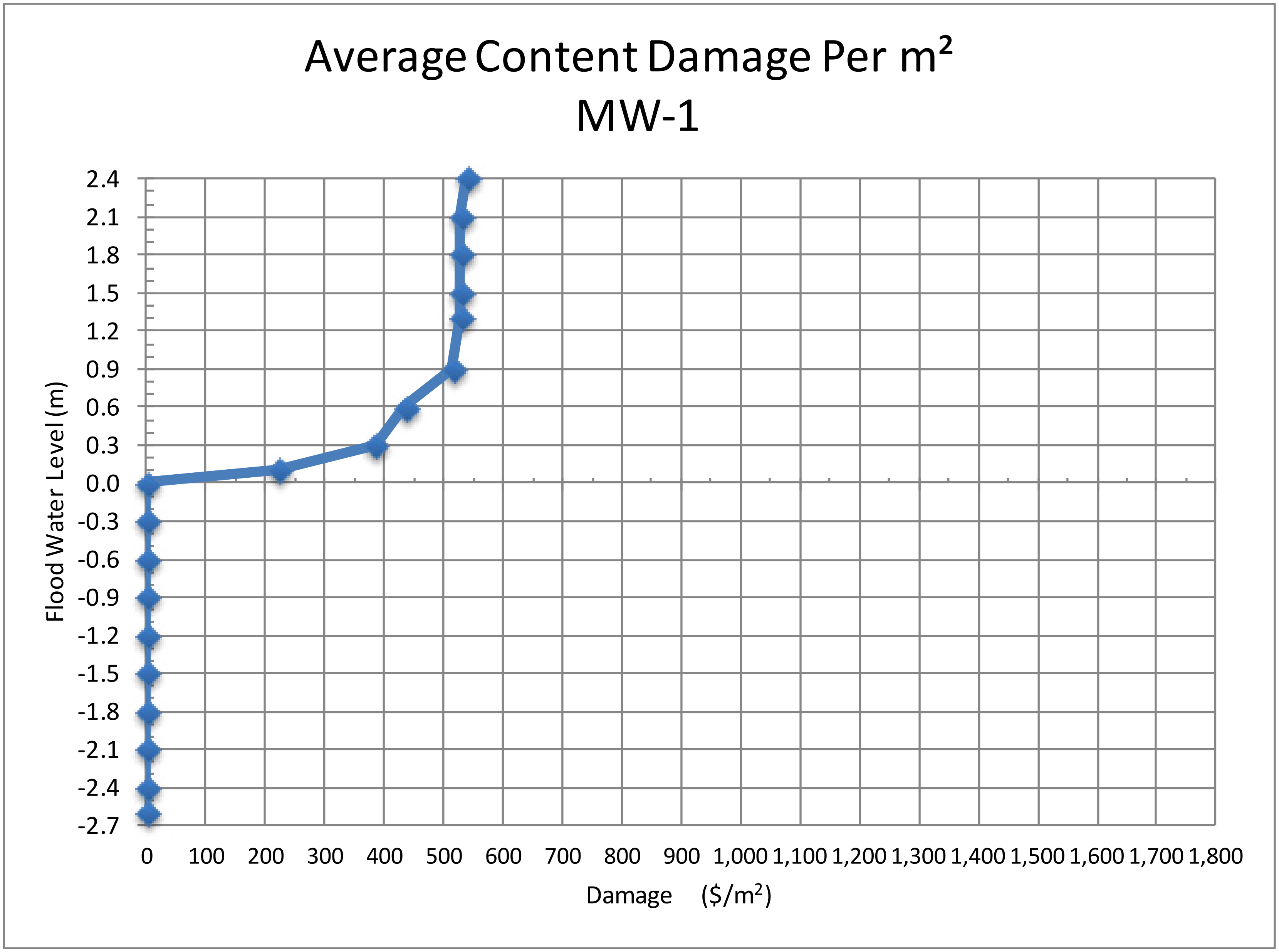


Residential Content Damage Curves



Appendix C – Residential Content Damage Values

Residential Content Damage Values

Residential contents damages by interior elevation and classification, Calgary, $/m2 floor area, 2014$

Interior elevation		Residential classification								
		A1	A2	B1	B2	C1	C2	D1	MA1	MW1
Top of Level 0 (basement) floor	-2.7	$0	$0	$0	$0	$0	$0	$0	$0	$0
	-2.6	$400	$226	$226	$163	$294	$191	$0	$0	$0
	-2.4	$554	$354	$339	$255	$350	$232	$0	$0	$0
	-2.1	$715	$395	$375	$294	$385	$257	$0	$0	$0
	-1.8	$778	$437	$401	$324	$418	$264	$0	$0	$0
	-1.5	$784	$440	$410	$332	$422	$264	$0	$0	$0
	-1.2	$786	$442	$411	$336	$422	$264	$0	$0	$0
	-0.9	$788	$444	$412	$336	$423	$264	$0	$0	$0
	-0.6	$810	$475	$426	$364	$487	$264	$0	$0	$0
Level 0 (basement) ceiling	-0.3	$836	$523	$504	$427	$592	$290	$0	$0	$0
Top of Level 1 (main) floor	0.0	$836	$523	$504	$427	$592	$290	$0	$0	$0
	0.1	$1,209	$866	$725	$662	$839	$487	$243	$221	$260
	0.3	$1,460	$1,068	$888	$769	$970	$554	$379	$384	$394
	0.6	$1,594	$1,186	$934	$848	$1,026	$582	$426	$435	$494
	0.9	$1,645	$1,271	$996	$908	$1,074	$657	$481	$514	$565
	1.3	$1,652	$1,289	$998	$934	$1,084	$662	$483	$527	$571
	1.5	$1,652	$1,290	$998	$935	$1,084	$662	$483	$528	$571
	1.8	$1,675	$1,290	$999	$938	$1,085	$662	$483	$528	$571
	2.1	$1,675	$1,290	$999	$938	$1,085	$662	$483	$528	$571
Level 1 (main) ceiling	2.4	$1,675	$1,290	$999	$939	$1,085	$662	$483	$538	$571

Damages include contents in attached/detached garages and outside storage; exclude contents in underground parking structures

Appendix D – Residential Structural Damage Curves

Summary of Specifications for Typical Unit Type A1 (Bungalow)

Area	$258m^2$	
Structure	Poured concrete foundation wall, wood frame floor (Conventional or Engineered System), wall and roof assembly.	
Ext. Cladding	Walls:	Siding (prefinished),Stucco, Brick, Stone.
	Windows:	Metal clad wood.
Interior Finishes		
Basement	Floor:	Ceramic tile, carpet, prefinished hardwood.
	Walls:	Wood or steel stud, drywall painted.
	Insulation:	Walls (R20), 6mil poly V.B.
	Ceiling:	T-bar, drywall stippled or textured.
	Doors:	Wood, solid core.
	Stairs:	Solid stringers, closed riser & plywood tread.
	Bathroom:	3 piece with tile finishes.
Ground Floor	Floor:	Ceramic tile, carpet, prefinished hardwood.
	Walls:	Drywall painted, wall vinyl.
	Ceiling:	Drywall stippled or textured, vaulted.
	Doors:	Wood, solid core.
	Insulation:	Walls (R20), Ceiling (R40), 6mil poly V.B.
	Cabinets:	Custom with island & granite / stone counters & backsplash.
	Bathroom:	3 & 4 piece with tile finishes.
Garage	Double attached wood frame walls and roof assembly on concrete slab on grade.	
	Ext. Walls:	Siding (prefinished), Stucco, Brick, Stone.
	Insulation:	Walls (R20), Ceiling (R40), 6mil poly V.B.
	Int. Walls:	Drywall painted.
	Ceiling:	Drywall painted.
	Windows:	Metal clad wood.
	Doors:	Prefinished Metal.

Note: Where two or more materials are shown, unit costs have been averaged.

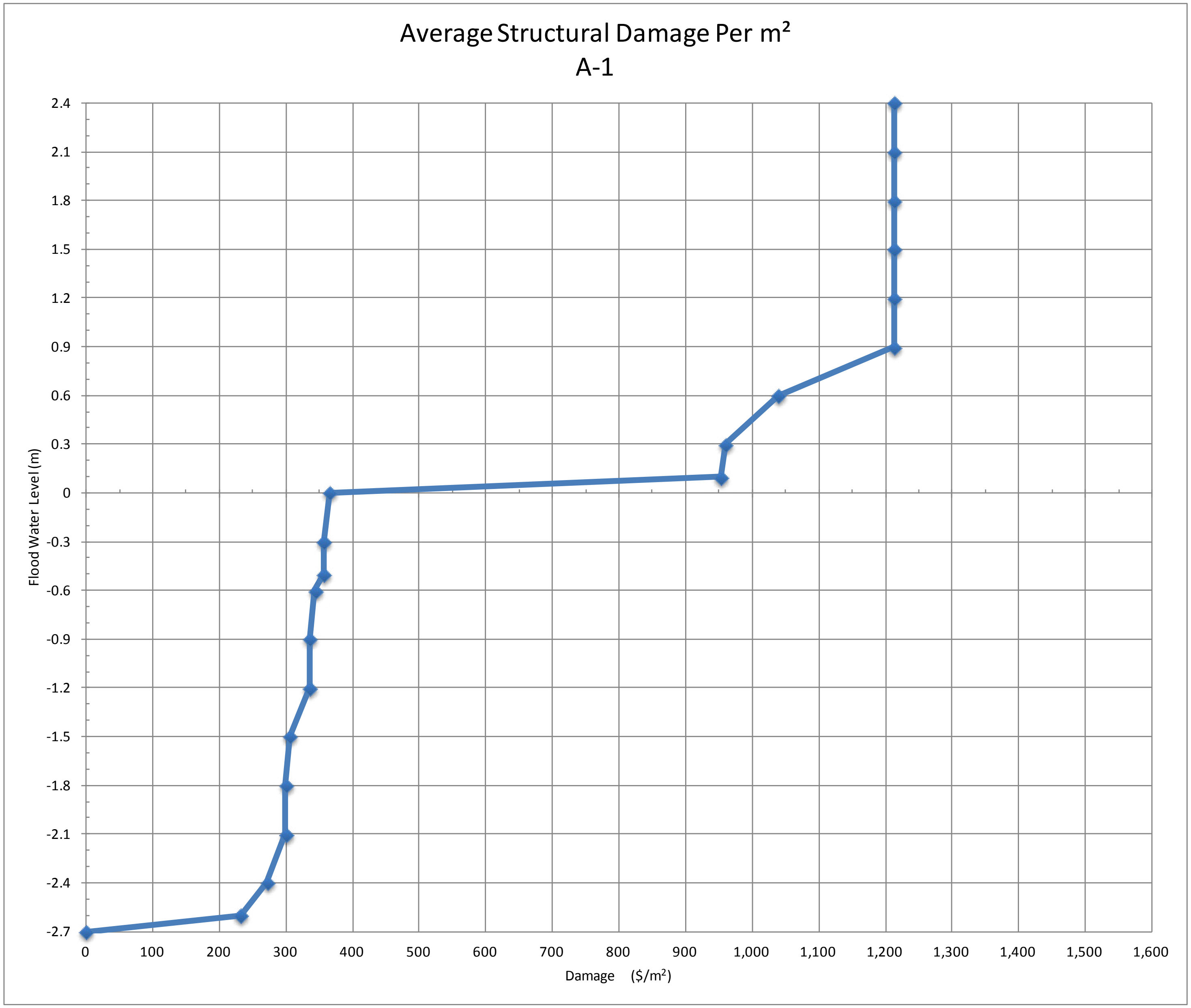
Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
Basement Level							
0 – 0.1	• Remove existing flooring. Clean and prepare slab. Install new flooring.	94	m²	$60	$5,640		
	• Remove existing carpet. Clean slab & install new carpeting.	164	m²	$110	$18,040		
	• Remove and replace baseboards.	192	linear m	$7	$1,344		
	• Visual inspection of sumps and weeping tile. Snake & clean. (10%).	1		$800	$800		
	• Remove and replace all drywall to walls & ceilings.	641	m²	$30	$19,230		
	• Remove and replace all poly vapour barrier.	154	m²	$1	$154		
	• Remove and replace all insulation.	154	m²	$3	$385		
	• Remove and replace all doors & hardware.	17	door	$400	$6,800		
	• Remove and replace all wood casings and door jambs.	17	opening	$125	$2,125		
	• Remove and replace hot water heater.	1	unit	$1,200	$1,200		
	• Remove, clean and re-install bathroom toilet, sink and tub.	1	bathroom	$500	$500		
	• Remove and replace bathroom cabinets.	1	cabinet	$750	$750		
	• Clean & service furnace.	2	hour	$125	$250		
	• Clean and sanitize all structural components after demolition is completed.	1	hour	$125	$125		
	• Implement structural drying.	8	hour	$75	$600		
						$57,943	$57,943
0.3	• Remove and replace furnace.	1	unit	$10,000	$10,000		
						$10,000	$67,943
0.6	• Remove and replace stairs.	1	staircase	$2,000	$2,000		
	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	basement	$5,000	$5,000		
						$7,000	$74,943

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.9	• N/A						
						$0	$74,943
1.2	• Remove and replace electrical service panel.	1	unit	$1,500	$1,500		
						$1,500	$76,443
1.5	• Remove and replace windows.	15	window	$500	$7,500		
						$7,500	$83,943
1.8	• N/A						
2.1	• Remove and replace all mechanical ductwork.	1	basement	$2,000	$2,000		
						$2,000	$85,943
2.4	• Inspect beams and floor joists.	2	hour	$125	$250		
						$250	**$86,193**
Main Floor							
0 – 0.1	• Remove existing flooring. Clean and sand subfloor sheathing. Install new flooring.	258	m²	$90	$23,220		
	• Remove existing carpet. Clean and sand subfloor sheathing. Install new carpeting.	258	m²	$125	$32,250		
	• Remove and replace baseboards.	273	linear m	$8	$2,184		
	• Remove and replace all drywall to walls & ceilings.	913	m²	$30	$27,390		
	• Remove and replace all poly vapour barrier.	154	m²	$1	$154		
	• Remove and replace all insulation.	154	m²	$3	$385		
	• Remove and replace all doors & hardware.	19	door	$700	$13,300		
	• Remove and replace all wood casings and door jambs.	19	opening	$125	$2,375		

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
	• Remove and replace all kitchen cabinets and counter tops.	1	kitchen	$40,000	$40,000		
	• Remove, clean and re-install bathroom toilet, sink and tub.	2.5	bathroom	$500	$1,250		
	• Remove and replace bathroom cabinets.	2.5	cabinet	$1,250	$3,125		
	• Clean and sanitize all structural components after demolition is completed.	4	hour	$125	$500		
	• Clean and sanitize all exterior building finishes.	4	hour	$125	$500		
	• Implement structural drying.	8	hour	$75	$600		
						$147,233	$147,233
0.3	• N/A						
						$0	$147,233
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	main floor	$20,000	$20,000		
						$20,000	$167,233
0.9	• Remove and replace all windows.	29	window	$1,500	$43,500		
						$43,500	**$210,733**
Garage							
0 – 0.1	• Clean and sanitize concrete floor.	1	hour	$125	$125		
	• Remove and replace all poly vapour barrier.	441	m²	$1	$441		
	• Remove and replace all insulation.	441	m²	$3	$1,103		
	• Remove and replace all man doors & hardware.	1	door	$750	$750		
	• Clean and sanitize all structural components after demolition is completed.	2	hour	$125	$250		
	• Clean and sanitize all exterior building finishes and overhead door.	2	hour	$125	$250		
	• Implement structural drying.	4	hour	$75	$300		
						$3,219	$3,219

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.3	• N/A						
						$0	$3,219
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	garage	$2,000	$2,000		
						$2,000	$5,219
0.9	• Remove and replace all windows.	2	window	$750	$1,500		
						$1,500	**$6,719**
					Grand Total	**$303,645**	**$303,645**

Residential Structural Damage Curves



Summary of Specifications for Typical Unit Type A2 (Two Storey)

Area	$265m^2$	
Structure	Poured concrete foundation wall, wood frame floor (Conventional or Engineered System), wall and roof assembly.	
Ext. Cladding	Walls:	Siding (prefinished),Stucco, Brick, Stone.
	Windows:	Metal clad wood.
Interior Finishes		
Basement	Floor:	Ceramic tile, carpet, prefinished hardwood.
	Walls:	Wood or steel stud, drywall painted.
	Insulation:	Walls (R20), 6mil poly V.B.
	Ceiling:	T-bar, drywall stippled or textured.
	Doors:	Wood, solid core.
	Stairs:	Solid stringers, closed riser & plywood tread.
	Bathroom:	3 piece with tile finishes.
Ground Floor	Floor:	Ceramic tile, carpet, prefinished hardwood.
	Walls:	Drywall painted, wall vinyl.
	Ceiling:	Drywall stippled or textured, vaulted.
	Doors:	Wood, solid core.
	Insulation:	Walls (R20), Ceiling (R40), 6mil poly V.B.
	Cabinets:	Custom with island & granite / stone counters & backsplash.
	Bathroom:	3 & 4 piece with tile finishes.
Garage	Double attached wood frame walls and roof assembly on concrete slab on grade.	
	Ext. Walls:	Siding (prefinished), Stucco, Brick, Stone.
	Insulation:	Walls (R20), Ceiling (R40), 6mil poly V.B.
	Int. Walls:	Drywall painted.
	Ceiling:	Drywall painted.
	Windows:	Metal clad wood.
	Doors:	Prefinished Metal.

Note: Where two or more materials are shown, unit costs have been averaged.

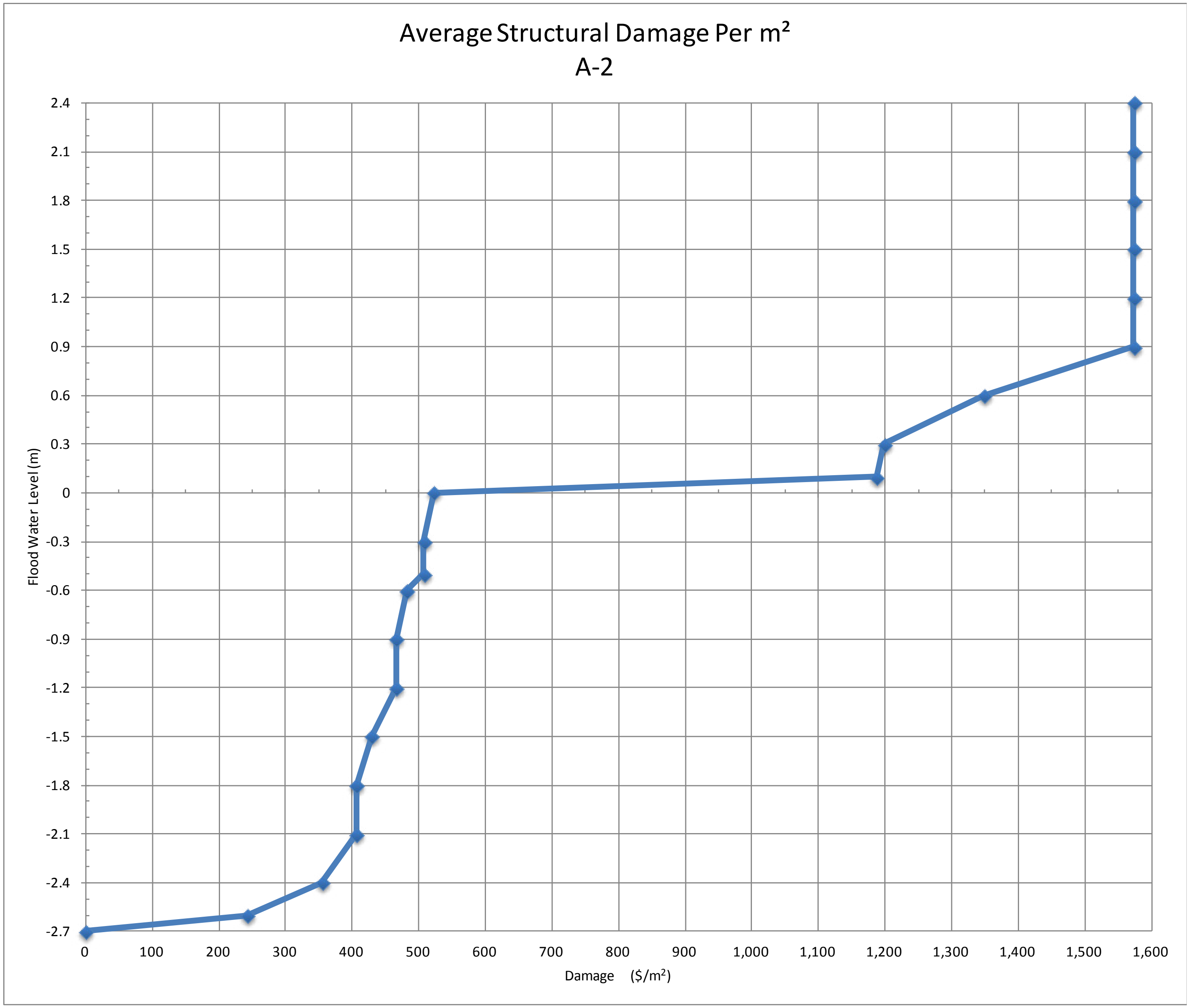
Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
Basement Level							
0 – 0.1	• Remove existing flooring. Clean and prepare slab. Install new flooring.	54	m²	$60	$3,240		
	• Remove existing carpet. Clean slab & install new carpeting.	79	m²	$110	$8,690		
	• Remove and replace baseboards.	105	linear m	$7	$735		
	• Visual inspection of sumps and weeping tile. Snake & clean. (10%).	1		$600	$600		
	• Remove and replace all drywall to walls & ceilings.	333	m²	$30	$9,990		
	• Remove and replace all poly vapour barrier.	111	m²	$1	$111		
	• Remove and replace all insulation.	111	m²	$3	$278		
	• Remove and replace all doors & hardware.	9	door	$400	$3,600		
	• Remove and replace all wood casings and door jambs.	9	opening	$125	$1,125		
	• Remove and replace hot water heater.	1	unit	$1,200	$1,200		
	• Remove, clean and re-install bathroom toilet, sink and tub.	1	bathroom	$500	$500		
	• Remove and replace bathroom cabinets.	1	cabinet	$750	$750		
	• Clean & service furnace.	2	hour	$125	$250		
	• Clean and sanitize all structural components after demolition is completed.	4	hour	$125	$500		
	• Implement structural drying.	8	hour	$75	$600		
						$32,169	$32,169
0.3	• Remove and replace furnace.	2	unit	$7,500	$15,000		
						$15,000	$47,169
0.6	• Remove and replace stairs.	1	staircase	$2,000	$2,000		
	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	basement	$5,000	$5,000		
						$7,000	$54,169

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.9	• N/A						
						$0	$54,169
1.2	• Remove and replace electrical service panel.	2	unit	$1,500	$3,000		
						$3,000	$57,169
1.5	• Remove and replace windows.	10	window	$500	$5,000		
						$5,000	$62,169
1.8	• N/A						
						$0	$62,169
2.1	• Remove and replace all mechanical ductwork.	1	basement	$2,000	$2,000		
						$2,000	$64,169
2.4	• Inspect beams and floor joists.	2	hour	$125	$250		
						$250	**$64,419**
Main Floor							
0 – 0.1	• Remove existing flooring. Clean and sand subfloor sheathing. Install new flooring.	0	m²	$90	$0		
	• Remove existing carpet. Clean and sand subfloor sheathing. Install new carpeting.	133	m²	$125	$16,625		
	• Remove and replace baseboards.	147	linear m	$8	$1,176		
	• Remove and replace all drywall to walls & ceilings.	484	m²	$30	$14,520		
	• Remove and replace all poly vapour barrier.	111	m²	$1	$111		
	• Remove and replace all insulation.	111	m²	$3	$278		
	• Remove and replace all doors & hardware.	12	door	$700	$8,400		
	• Remove and replace all wood casings and door jambs.	12	opening	$125	$1,500		

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
	• Remove and replace all kitchen cabinets and counter tops.	1	kitchen	$40,000	$40,000		
	• Remove, clean and re-install bathroom toilet, sink and tub.	2.5	bathroom	$500	$1,250		
	• Remove and replace bathroom cabinets.	2.5	cabinet	$1,250	$3,125		
	• Clean and sanitize all structural components after demolition is completed.	4	hour	$125	$500		
	• Clean and sanitize all exterior building finishes.	4	hour	$125	$500		
	• Implement structural drying.	8	hour	$75	$600		
						$88,585	$88,585
0.3	• N/A						
						$0	$88,585
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	main floor	$20,000	$20,000		
						$20,000	$108,585
0.9	• Remove and replace all windows.	20	window	$1,500	$30,000		
						$30,000	**$138,585**
Garage							
0 – 0.1	• Clean and sanitize concrete floor.	1	hour	$125	$125		
	• Remove and replace all poly vapour barrier.	441	m²	$1	$441		
	• Remove and replace all insulation.	441	m²	$3	$1,103		
	• Remove and replace all man doors & hardware.	1	door	$750	$750		
	• Clean and sanitize all structural components after demolition is completed.	2	hour	$125	$250		
	• Clean and sanitize all exterior building finishes and overhead door.	2	hour	$125	$250		
	• Implement structural drying.	4	hour	$75	$300		
						$3,219	$3,219

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.3	• N/A						
						$0	$3,219
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	garage	$2,000	$2,000		
						$2,000	$5,219
0.9	• Remove and replace all windows.	2	window	$750	$1,500		
						$1,500	**$6,719**
					Grand Total	**$209,722**	**$209,722**

Residential Structural Damage Curves



Summary of Specifications for Typical Unit Type B1 (Bungalow)

Area	$151m^2$	
Structure	Poured concrete foundation wall, wood frame floor (conventional or Engineered system), wall and roof assembly.	
Ext. Cladding	Walls:	Wood siding (prefinished or painted), Vinyl, Stucco, Brick, Stone.
	Windows:	Aluminum, wood, PVC.
Interior Finishes		
Basement	Floor:	Linoleum, ceramic tile, laminate, carpet or unfinished concrete floor.
	Walls:	Wood stud, drywall painted or unfinished.
	Insulation:	Walls (R12), 6mil poly V.B.
	Ceiling:	T-bar, drywall painted or stippled or unfinished.
	Doors:	Wood, solid or hollow core.
	Stairs:	Solid stringers, closed riser & plywood tread.
Ground Floor	Floor:	Linoleum, ceramic tile, laminate, carpet, prefinished hardwood.
	Walls:	Drywall painted.
	Ceiling:	Drywall stippled.
	Insulation:	Walls (R12), Ceiling (R20), 6mil poly V.B.
	Cabinets:	Plywood body, solid wood doors and drawers, P-Lam counter.
	Bathroom:	Tile to ceiling above tub or fibreglass tub enclosure.
Garage	Double detached wood frame walls and roof assembly on concrete slab on grade.	
	Walls:	Wood siding (prefinished or painted), Vinyl, Stucco, Brick, Stone.
	Insulation:	Walls (R12), Ceiling (R20), 6mil poly V.B. or unfinished.
	Windows:	Aluminum, wood, PVC.
	Doors:	Prefinished Metal or painted wood.

Note: Where two or more materials are shown, unit costs have been averaged.

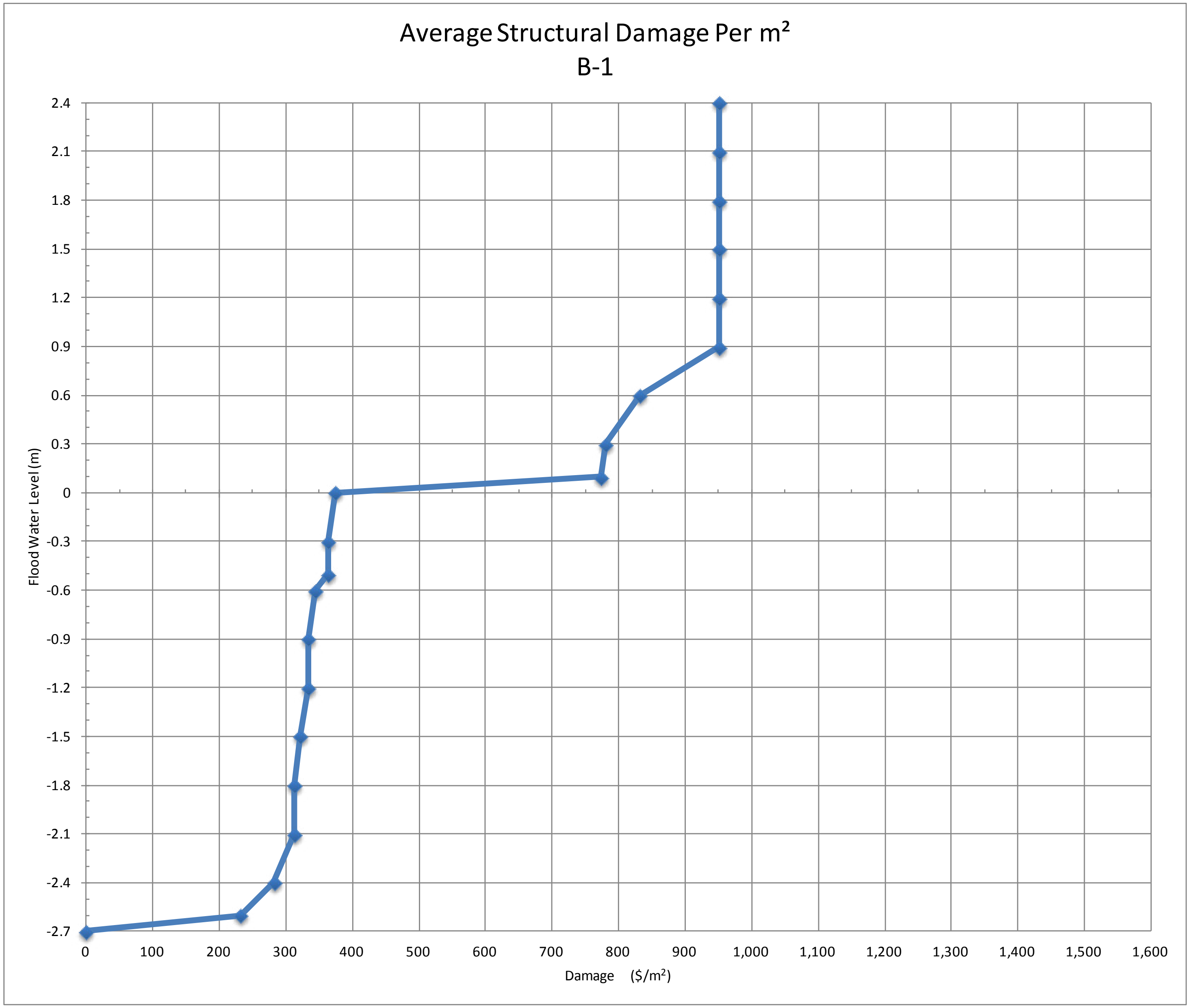
Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
Basement Level							
0 – 0.1	• Remove existing flooring. Clean and prepare slab. Install new flooring.	46	m²	$50	$2,300		
	• Remove existing carpet. Clean slab & install new carpeting.	105	m²	$100	$10,500		
	• Remove and replace baseboards.	125	linear m	$5	$625		
	• Visual inspection of sumps and weeping tile. Snake & clean. (10%).	1		$600	$600		
	• Remove and replace all drywall to walls & ceilings.	439	m²	$30	$13,170		
	• Remove and replace all poly vapour barrier.	118	m²	$1	$118		
	• Remove and replace all insulation.	118	m²	$3	$295		
	• Remove and replace all doors & hardware.	9	door	$300	$2,700		
	• Remove and replace all wood casings and door jambs.	9	opening	$100	$900		
	• Remove and replace hot water heater.	1	unit	$1,200	$1,200		
	• Remove, clean and re-install bathroom toilet, sink and tub.	1	bathroom	$500	$500		
	• Remove and replace bathroom cabinets.	1	cabinet	$500	$500		
	• Clean & service furnace.	2	hour	$125	$250		
	• Clean and sanitize all structural components after demolition is completed.	4	hour	$125	$500		
	• Implement structural drying.	6	hour	$75	$450		
						$34,608	$34,608
0.3	• Remove and replace furnace.	1	unit	$7,500	$7,500		
						$7,500	$42,108
0.6	• Remove and replace stairs.	1	staircase	$1,500	$1,500		
	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	basement	$3,000	$3,000		
						$4,500	$46,608

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.9	• N/A						
						$0	$46,608
1.2	• Remove and replace electrical service panel.	1	unit	$1,500	$1,500		
						$1,500	$48,108
1.5	• Remove and replace windows.	6	window	$300	$1,800		
						$1,800	$49,908
1.8	• N/A						
						$0	$49,908
2.1	• Remove and replace all mechanical ductwork.	1	basement	$1,500	$1,500		
						$1,500	$51,408
2.4	• Inspect beams and floor joists.	2	hour	$125	$250		
						$250	**$51,658**
Main Floor							
0 – 0.1	• Remove existing flooring. Clean and sand subfloor sheathing. Install new flooring.	8	m²	$75	$600		
	• Remove existing carpet. Clean and sand subfloor sheathing. Install new carpeting.	143	m²	$100	$14,300		
	• Remove and replace baseboards.	155	linear m	$5	$775		
	• Remove and replace all drywall to walls & ceilings.	524	m²	$30	$15,720		
	• Remove and replace all poly vapour barrier.	118	m²	$1	$118		
	• Remove and replace all insulation.	118	m²	$3	$295		
	• Remove and replace all doors & hardware.	13	door	$500	$6,500		
	• Remove and replace all wood casings and door jambs.	13	opening	$100	$1,300		

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
	• Remove and replace all kitchen cabinets and counter tops.	1	kitchen	$15,000	$15,000		
	• Remove, clean and re-install bathroom toilet, sink and tub.	2.5	bathroom	$500	$1,250		
	• Remove and replace bathroom cabinets.	2.5	cabinet	$1,000	$2,500		
	• Clean and sanitize all structural components after demolition is completed.	4	hour	$125	$500		
	• Clean and sanitize all exterior building finishes.	4	hour	$125	$500		
	• Implement structural drying.	6	hour	$75	$450		
						$59,808	$59,808
0.3	• N/A						
						$0	$59,808
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	main floor	$7,500	$7,500		
						$7,500	$67,308
0.9	• Remove and replace all windows.	18	window	$1,000	$18,000		
						$18,000	**$85,308**
Garage							
0 – 0.1	• Clean and sanitize concrete floor.	1	hour	$125	$125		
	• Remove and replace all poly vapour barrier.	349	m²	$1	$349		
	• Remove and replace all insulation.	349	m²	$3	$873		
	• Remove and replace all man doors & hardware.	1	door	$500	$500		
	• Clean and sanitize all structural components after demolition is completed.	2	hour	$125	$250		
	• Clean and sanitize all exterior building finishes and overhead door.	2	hour	$125	$250		
	• Implement structural drying.	4	hour	$75	$300		
						$2,647	$2,647

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.3	• N/A						
						$0	$2,647
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	garage	$1,500	$1,500		
						$1,500	$4,147
0.9	• Remove and replace all windows.	2	window	$500	$1,000		
						$1,000	**$5,147**
					Grand Total	**$142,113**	**$142,113**

Residential Structural Damage Curves



Summary of Specifications for Typical Unit Type B2 (Two Storey)

Area 166m^2

Structure Poured concrete foundation wall, wood frame floor (conventional or Engineered system), wall and roof assembly.

Ext. Cladding

Walls: Wood siding (prefinished or painted), Vinyl, Stucco, Brick, Stone.

Windows: Aluminum, wood, PVC.

Interior Finishes

Basement

Floor: Linoleum, ceramic tile, laminate, carpet or unfinished concrete floor.

Walls: Wood stud, drywall painted or unfinished.

Insulation: Walls (R12), 6mil poly V.B.

Ceiling: T-bar, drywall painted or stippled or unfinished.

Doors: Wood, solid or hollow core.

Stairs: Solid stringers, closed riser & plywood tread.

Ground Floor

Floor: Linoleum, ceramic tile, laminate, carpet, prefinished hardwood.

Walls: Drywall painted.

Ceiling: Drywall stippled.

Insulation: Walls (R12), Ceiling (R20), 6mil poly V.B.

Cabinets: Plywood body, solid wood doors and drawers, P-Lam counter.

Bathroom: Tile to ceiling above tub or fibreglass tub enclosure.

Garage Double detached wood frame walls and roof assembly on concrete slab on grade.

Walls: Wood siding (prefinished or painted), Vinyl, Stucco, Brick, Stone.

Insulation: Walls (R12), Ceiling (R20), 6mil poly V.B. or unfinished.

Windows: Aluminum, wood, PVC.

Doors: Prefinished Metal or painted wood.

Note: Where two or more materials are shown, unit costs have been averaged.

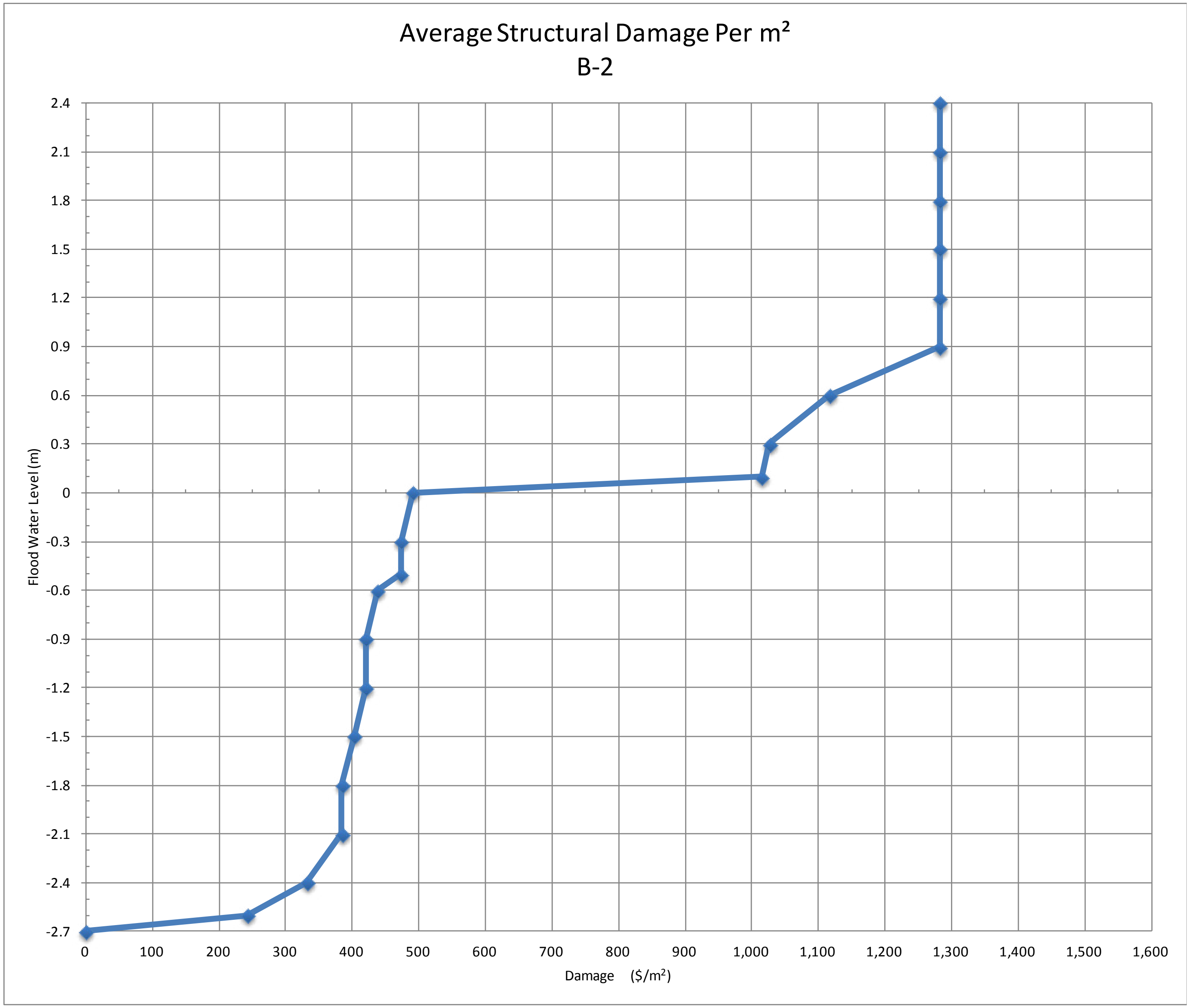
Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
Basement Level							
0 – 0.1	• Remove existing flooring. Clean and prepare slab. Install new flooring.	30	m²	$50	$1,500		
	• Remove existing carpet. Clean slab & install new carpeting.	53	m²	$100	$5,300		
	• Remove and replace baseboards.	66	linear m	$5	$330		
	• Visual inspection of sumps and weeping tile. Snake & clean. (10%).	1		$500	$500		
	• Remove and replace all drywall to walls & ceilings.	219	m²	$30	$6,570		
	• Remove and replace all poly vapour barrier.	87	m²	$1	$87		
	• Remove and replace all insulation.	87	m²	$3	$218		
	• Remove and replace all doors & hardware.	6	door	$300	$1,800		
	• Remove and replace all wood casings and door jambs.	6	opening	$100	$600		
	• Remove and replace hot water heater.	1	unit	$1,200	$1,200		
	• Remove, clean and re-install bathroom toilet, sink and tub.	1	bathroom	$500	$500		
	• Remove and replace bathroom cabinets.	1	cabinet	$500	$500		
	• Clean & service furnace.	2	hour	$125	$250		
	• Clean and sanitize all structural components after demolition is completed.	4	hour	$125	$500		
	• Implement structural drying.	6	hour	$75	$450		
						$20,305	$20,305
0.3	• Remove and replace furnace.	1	unit	$7,500	$7,500		
						$7,500	$27,805
0.6	• Remove and replace stairs.	1	staircase	$1,500	$1,500		
	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	basement	$3,000	$3,000		
						$4,500	$32,305

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.9	• N/A						
						$0	$32,305
1.2	• Remove and replace electrical service panel.	1	unit	$1,500	$1,500		
						$1,500	$33,805
1.5	• Remove and replace windows.	5	window	$300	$1,500		
						$1,500	$35,305
1.8	• N/A						
						$0	$35,305
2.1	• Remove and replace all mechanical ductwork.	1	basement	$1,500	$1,500		
						$1,500	$36,805
2.4	• Inspect beams and floor joists.	2	hour	$125	$250		
						$250	**$37,055**
Main Floor							
0 – 0.1	• Remove existing flooring. Clean and sand subfloor sheathing. Install new flooring.	9	m²	$75	$675		
	• Remove existing carpet. Clean and sand subfloor sheathing. Install new carpeting.	74	m²	$100	$7,400		
	• Remove and replace baseboards.	106	linear m	$5	$530		
	• Remove and replace all drywall to walls & ceilings.	336	m²	$30	$10,080		
	• Remove and replace all poly vapour barrier.	87	m²	$1	$87		
	• Remove and replace all insulation.	87	m²	$3	$218		
	• Remove and replace all doors & hardware.	8	door	$500	$4,000		
	• Remove and replace all wood casings and door jambs.	8	opening	$100	$800		

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
	• Remove and replace all kitchen cabinets and counter tops.	1	kitchen	$15,000	$15,000		
	• Remove, clean and re-install bathroom toilet, sink and tub.	2.5	bathroom	$500	$1,250		
	• Remove and replace bathroom cabinets.	2.5	cabinet	$1,000	$2,500		
	• Clean and sanitize all structural components after demolition is completed.	4	hour	$125	$500		
	• Clean and sanitize all exterior building finishes.	4	hour	$125	$500		
	• Implement structural drying.	6	hour	$75	$450		
						$43,990	$43,990
0.3	• N/A						
						$0	$43,990
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	main floor	$7,500	$7,500		
						$7,500	$51,490
0.9	• Remove and replace all windows.	14	window	$1,000	$14,000		
						$14,000	**$65,490**
Garage							
0 – 0.1	• Clean and sanitize concrete floor.	1	hour	$125	$125		
	• Remove and replace all poly vapour barrier.	349	m²	$1	$349		
	• Remove and replace all insulation.	349	m²	$3	$873		
	• Remove and replace all man doors & hardware.	1	door	$500	$500		
	• Clean and sanitize all structural components after demolition is completed.	2	hour	$125	$250		
	• Clean and sanitize all exterior building finishes and overhead door.	2	hour	$125	$250		
	• Implement structural drying.	4	hour	$75	$300		
						$2,647	$2,647

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.3	• N/A						
						$0	$2,647
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	garage	$1,500	$1,500		
						$1,500	$4,147
0.9	• Remove and replace all windows.	2	window	$500	$1,000		
						$1,000	**$5,147**
					Grand Total	**$107,691**	**$107,691**

Residential Structural Damage Curves



Summary of Specifications for Typical Unit Type C1 (Bungalow)

Area	$84m^2$	
Structure	Poured concrete foundation wall, wood frame floor wall and roof assembly.	
Ext. Cladding	Walls:	Wood siding painted, Vinyl, Stucco.
	Windows:	Wood.
Interior Finishes		
Basement	Floor:	Linoleum, carpet or unfinished.
	Walls:	Wood stud, drywall painted.
	Ceiling:	T-bar, drywall painted or unfinished.
	Doors:	Wood, hollow core.
	Stairs:	Solid stringers, closed riser & plywood tread.
Ground Floor	Floor:	Linoleum, laminate, carpet, hardwood.
	Walls:	Drywall painted.
	Ceiling:	Drywall stippled.
	Insulation:	Walls (R12), Ceiling (R20), 6mil poly V.B.
	Cabinets:	Plywood body, solid wood doors and drawers, P-Lam counters.
	Bathroom:	Tile to 1.2m above tub.
Garage	Single detached wood frame walls and roof assembly on concrete slab on grade.	
	Walls:	Wood siding painted, Vinyl, Stucco.
	Insulation:	Walls (R12), Ceiling (R20), 6mil poly V.B. or unfinished.
	Windows:	Wood.
	Doors:	Painted wood.

Note: Where two or more materials are shown, unit costs have been averaged.

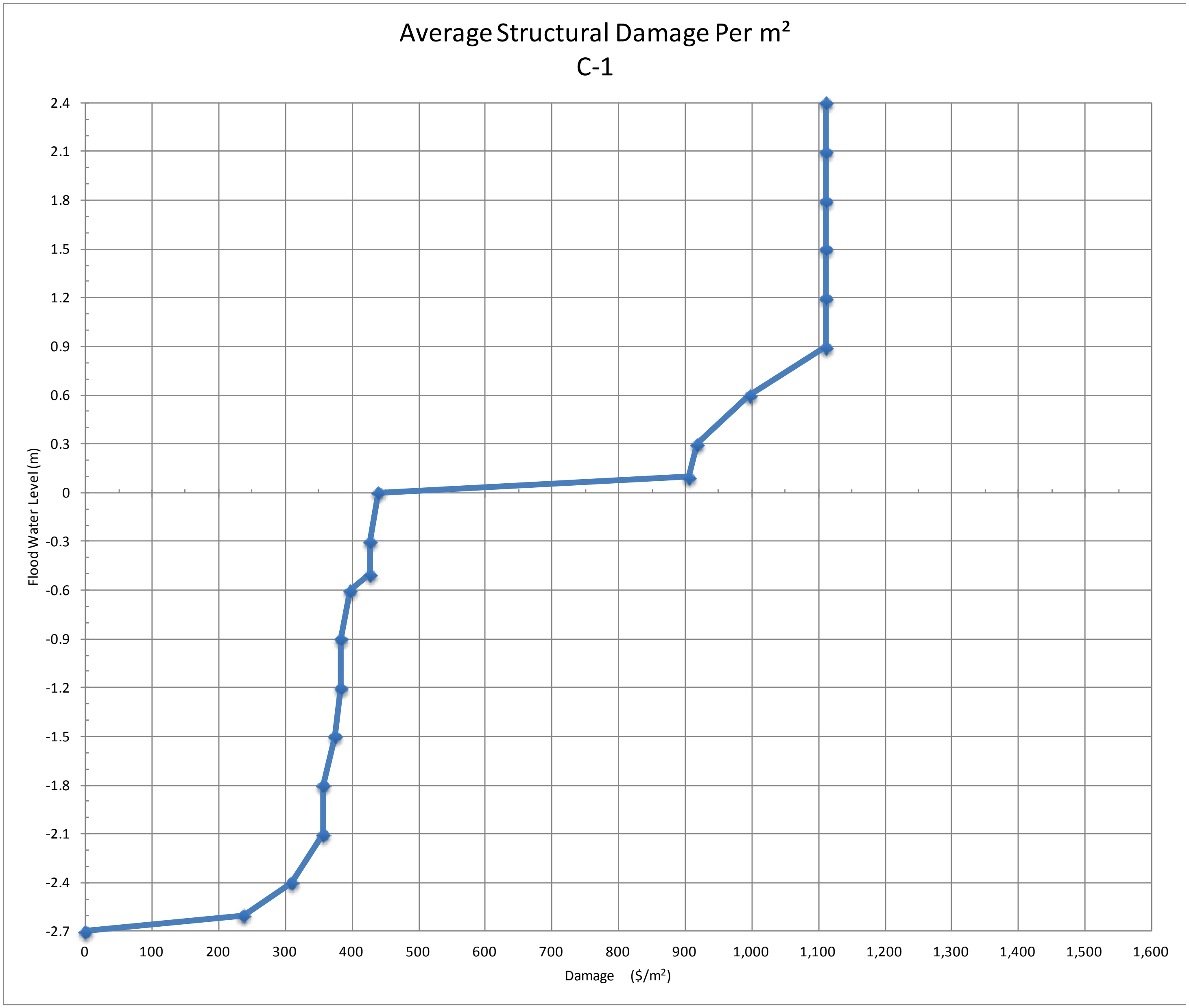
Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
Basement Level							
0 – 0.1	• Remove existing flooring. Clean and prepare slab. Install new flooring.	37	m²	$45	$1,665		
	• Remove existing carpet. Clean slab & install new carpeting.	47	m²	$90	$4,230		
	• Remove and replace baseboards.	71	linear m	$4	$284		
	• Visual inspection of sumps and weeping tile. Snake & clean. (10%).	1		$500	$500		
	• Remove and replace all drywall to walls & ceilings.	232	m²	$30	$6,960		
	• Remove and replace all poly vapour barrier.	88	m²	$1	$88		
	• Remove and replace all insulation.	88	m²	$3	$220		
	• Remove and replace all doors & hardware.	8	door	$250	$2,000		
	• Remove and replace all wood casings and door jambs.	8	opening	$90	$720		
	• Remove and replace hot water heater.	1	unit	$1,200	$1,200		
	• Remove, clean and re-install bathroom toilet, sink and tub.	1	bathroom	$500	$500		
	• Remove and replace bathroom cabinets.	1	cabinet	$350	$350		
	• Clean & service furnace.	2	hour	$125	$250		
	• Clean and sanitize all structural components after demolition is completed.	4	hour	$125	$500		
	• Implement structural drying.	4	hour	$75	$300		
						$19,767	$19,767
0.3	• Remove and replace furnace.	1	unit	$6,000	$6,000		
						$6,000	$25,767
0.6	• Remove and replace stairs.	1	staircase	$1,500	$1,500		
	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	basement	$2,500	$2,500		
						$4,000	$29,767

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.9	• N/A						
						$0	$29,767
1.2	• Remove and replace electrical service panel.	1	unit	$1,500	$1,500		
						$1,500	$31,267
1.5	• Remove and replace windows.	3	window	$250	$750		
						$750	$32,017
1.8	• N/A						
						$0	$32,017
2.1	• Remove and replace all mechanical ductwork.	1	basement	$1,200	$1,200		
						$1,200	$33,217
2.4	• Inspect beams and floor joists.	2	hour	$125	$250		
						$250	**$33,467**
Main Floor							
0 – 0.1	• Remove existing flooring. Clean and sand subfloor sheathing. Install new flooring.	21	m²	$65	$1,365		
	• Remove existing carpet. Clean and sand subfloor sheathing. Install new carpeting.	62	m²	$90	$5,580		
	• Remove and replace baseboards.	102	linear m	$4	$408		
	• Remove and replace all drywall to walls & ceilings.	327	m²	$30	$9,810		
	• Remove and replace all poly vapour barrier.	88	m²	$1	$88		
	• Remove and replace all insulation.	88	m²	$3	$220		
	• Remove and replace all doors & hardware.	9	door	$350	$3,150		
	• Remove and replace all wood casings and door jambs.	9	opening	$90	$810		

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
	• Remove and replace all kitchen cabinets and counter tops.	1	kitchen	$15,000	$15,000		
	• Remove, clean and re-install bathroom toilet, sink and tub.	1	bathroom	$500	$500		
	• Remove and replace bathroom cabinets.	1	cabinet	$750	$750		
	• Clean and sanitize all structural components after demolition is completed.	4	hour	$125	$500		
	• Clean and sanitize all exterior building finishes.	4	hour	$125	$500		
	• Implement structural drying.	4	hour	$75	$300		
						$38,981	$38,981
0.3	• N/A						
						$0	$38,981
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	main floor	$6,500	$6,500		
						$6,500	$45,481
0.9	• Remove and replace all windows.	12	window	$800	$9,600		
						$9,600	**$55,081**
Garage							$88,548
0 – 0.1	• Clean and sanitize concrete floor.	1	hour	$125	$125		
	• Remove and replace all poly vapour barrier.	220	m²	$1	$220		
	• Remove and replace all insulation.	220	m²	$3	$550		
	• Remove and replace all man doors & hardware.	1	door	$500	$500		
	• Clean and sanitize all structural components after demolition is completed.	2	hour	$125	$250		
	• Clean and sanitize all exterior building finishes and overhead door.	2	hour	$125	$250		
	• Implement structural drying.	4	hour	$75	$300		
						$2,195	$2,195
0.3	• N/A					**$0**	$2,195

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	garage	$1,000	$1,000		
						$1,000	$3,195
0.9	• Remove and replace all windows.	2	window	$500	$1,000		
						$1,000	$4,195
					Grand Total	**$92,743**	**$92,743**

Residential Structural Damage Curves



Summary of Specifications for Typical Unit Type C2 (Two Storey)

Area	$99m^2$	
Structure	Poured concrete foundation wall, wood frame floor wall and roof assembly.	
Ext. Cladding	Walls:	Wood siding painted, Vinyl, Stucco.
	Windows:	Wood.
Interior Finishes		
Basement	Floor:	Linoleum, carpet or unfinished.
	Walls:	Wood stud, drywall painted.
	Ceiling:	T-bar, drywall painted or unfinished.
	Doors:	Wood, hollow core.
	Stairs:	Solid stringers, closed riser & plywood tread.
Ground Floor	Floor:	Linoleum, laminate, carpet, hardwood.
	Walls:	Drywall painted.
	Ceiling:	Drywall stippled.
	Insulation:	Walls (R12), Ceiling (R20), 6mil poly V.B.
	Cabinets:	Plywood body, solid wood doors and drawers, P-Lam counters.
	Bathroom:	Tile to 1.2m above tub.
Garage	Single detached wood frame walls and roof assembly on concrete slab on grade.	
	Walls:	Wood siding painted, Vinyl, Stucco.
	Insulation:	Walls (R12), Ceiling (R20), 6mil poly V.B. or unfinished.
	Windows:	Wood.
	Doors:	Painted wood.

Note: Where two or more materials are shown, unit costs have been averaged.

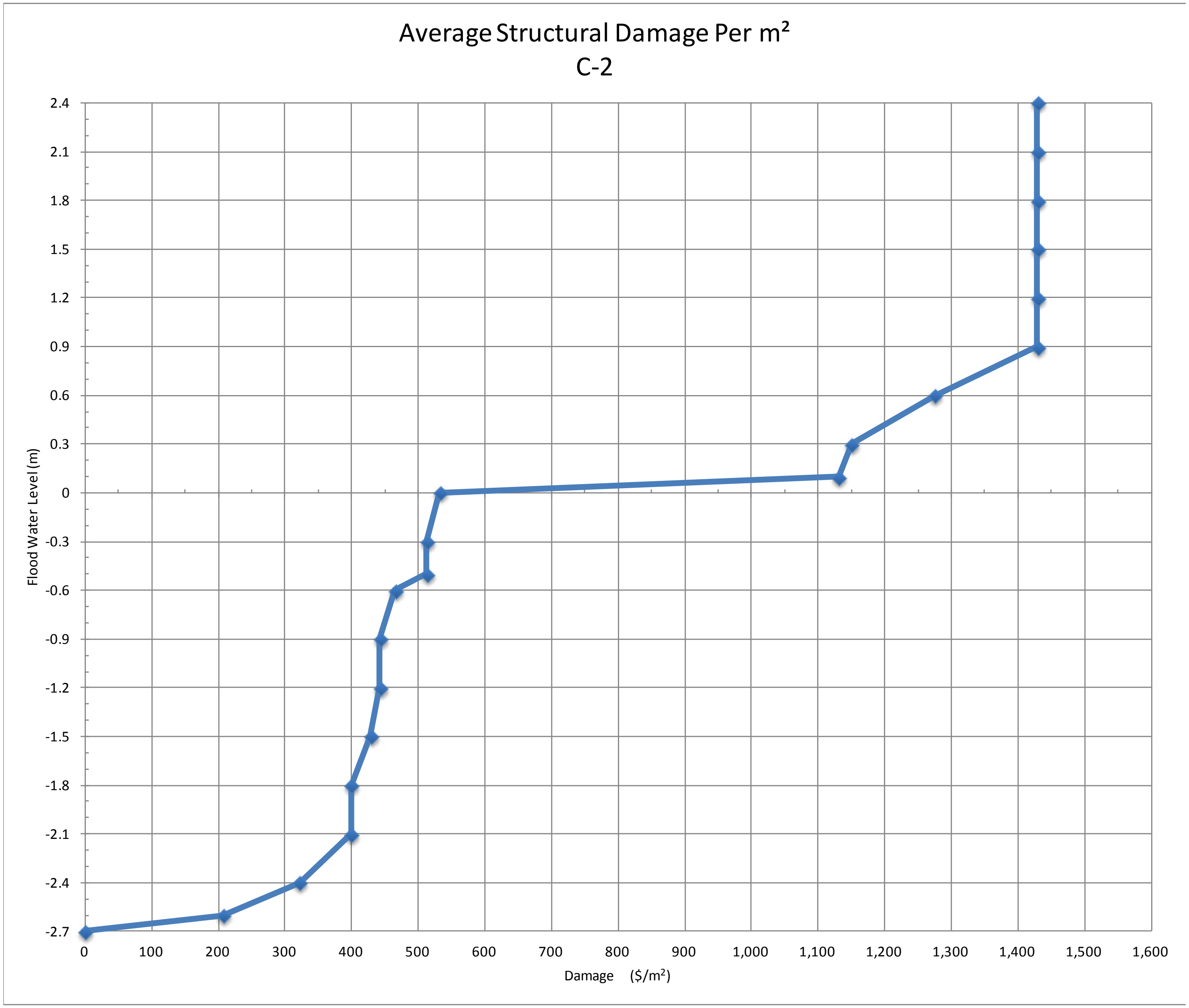
Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
Basement Level							
0 – 0.1	• Remove existing flooring. Clean and prepare slab. Install new flooring.	25	m²	$45	$1,125		
	• Remove existing carpet. Clean slab & install new carpeting.	24	m²	$90	$2,160		
	• Remove and replace baseboards.	26	linear m	$4	$104		
	• Visual inspection of sumps and weeping tile. Snake & clean. (10%).	1		$400	$400		
	• Remove and replace all drywall to walls & ceilings.	87	m²	$30	$2,610		
	• Remove and replace all poly vapour barrier.	67	m²	$1	$67		
	• Remove and replace all insulation.	67	m²	$3	$168		
	• Remove and replace all doors & hardware.	3	door	$250	$750		
	• Remove and replace all wood casings and door jambs.	3	opening	$90	$270		
	• Remove and replace hot water heater.	1	unit	$1,200	$1,200		
	• Remove, clean and re-install bathroom toilet, sink and tub.	1	bathroom	$500	$500		
	• Remove and replace bathroom cabinets.	1	cabinet	$350	$350		
	• Clean & service furnace.	2	hour	$125	$250		
	• Clean and sanitize all structural components after demolition is completed.	4	hour	$125	$500		
	• Implement structural drying.	4	hour	$75	$300		
						$10,754	$10,754
0.3	• Remove and replace furnace.	1	unit	$6,000	$6,000		
						$6,000	$16,754
0.6	• Remove and replace stairs.	1	staircase	$1,500	$1,500		
	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	basement	$2,500	$2,500		
						$4,000	$20,754

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.9	• N/A						
						$0	$20,754
1.2	• Remove and replace electrical service panel.	1	unit	$1,500	$1,500		
						$1,500	$22,254
1.5	• Remove and replace windows.	3	window	$250	$750		
						$750	$23,004
1.8	• N/A					**$0**	$23,004
2.1	• Remove and replace all mechanical ductwork.	1	basement	$1,200	$1,200		
						$1,200	$24,204
2.4	• Inspect beams and floor joists.	2	hour	$125	$250		
						$250	**$24,454**
Main Floor							
0 – 0.1	• Remove existing flooring. Clean and sand subfloor sheathing. Install new flooring.	12	m²	$65	$780		
	• Remove existing carpet. Clean and sand subfloor sheathing. Install new carpeting.	37	m²	$90	$3,330		
	• Remove and replace baseboards.	68	linear m	$4	$272		
	• Remove and replace all drywall to walls & ceilings.	212	m²	$30	$6,360		
	• Remove and replace all poly vapour barrier.	67	m²	$1	$67		
	• Remove and replace all insulation.	67	m²	$3	$168		
	• Remove and replace all doors & hardware.	6	door	$350	$2,100		
	• Remove and replace all wood casings and door jambs.	6	opening	$90	$540		

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
	• Remove and replace all kitchen cabinets and counter tops.	1	kitchen	$15,000	$15,000		
	• Remove, clean and re-install bathroom toilet, sink and tub.	1	bathroom	$500	$500		
	• Remove and replace bathroom cabinets.	1	cabinet	$750	$750		
	• Clean and sanitize all structural components after demolition is completed.	4	hour	$125	$500		
	• Clean and sanitize all exterior building finishes.	4	hour	$125	$500		
	• Implement structural drying.	4	hour	$75	$300		
						$31,167	$31,167
0.3	• N/A						
						$0	$31,167
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	main floor	$6,500	$6,500		
						$6,500	$37,667
0.9	• Remove and replace all windows.	10	window	$800	$8,000		
						$8,000	**$45,667**
Garage							$70,120
0 – 0.1	• Clean and sanitize concrete floor.	1	hour	$125	$125		
	• Remove and replace all poly vapour barrier.	220	m²	$1	$220		
	• Remove and replace all insulation.	220	m²	$3	$550		
	• Remove and replace all man doors & hardware.	1	door	$500	$500		
	• Clean and sanitize all structural components after demolition is completed.	2	hour	$125	$250		
	• Clean and sanitize all exterior building finishes and overhead door.	2	hour	$125	$250		
	• Implement structural drying.	4	hour	$75	$300		
						$2,195	$2,195

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.3	• N/A						
						$0	$2,195
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	garage	$1,000	$1,000		
						$1,000	$3,195
0.9	• Remove and replace all windows.	2	window	$500	$1,000		
						$1,000	$4,195
					Grand Total	**$74,315**	**$74,315**

Residential Structural Damage Curves



Summary of Specifications for Typical Unit Type D (Mobile Home)

Area	128m^2	
Foundation	Wood cribbing on grade w/ metal or wood skirting.	
Structure	Wood frame walls and roof assembly.	
Ext. Cladding	Walls:	Aluminum or vinyl siding, plywood trim.
	Windows:	Aluminum sliders in wood frame.
Interior Finishes		
	Floor:	Linoleum, carpet.
	Walls:	Drywall painted.
	Ceiling:	Drywall stippled.
	Insulation:	Walls (R12), Ceiling (R20), Floor (R20), 2mil poly V.B.
	Cabinets:	Plywood body, solid wood doors and drawers, P-Lam counters.
	Bathroom:	PVC in tub alcove.

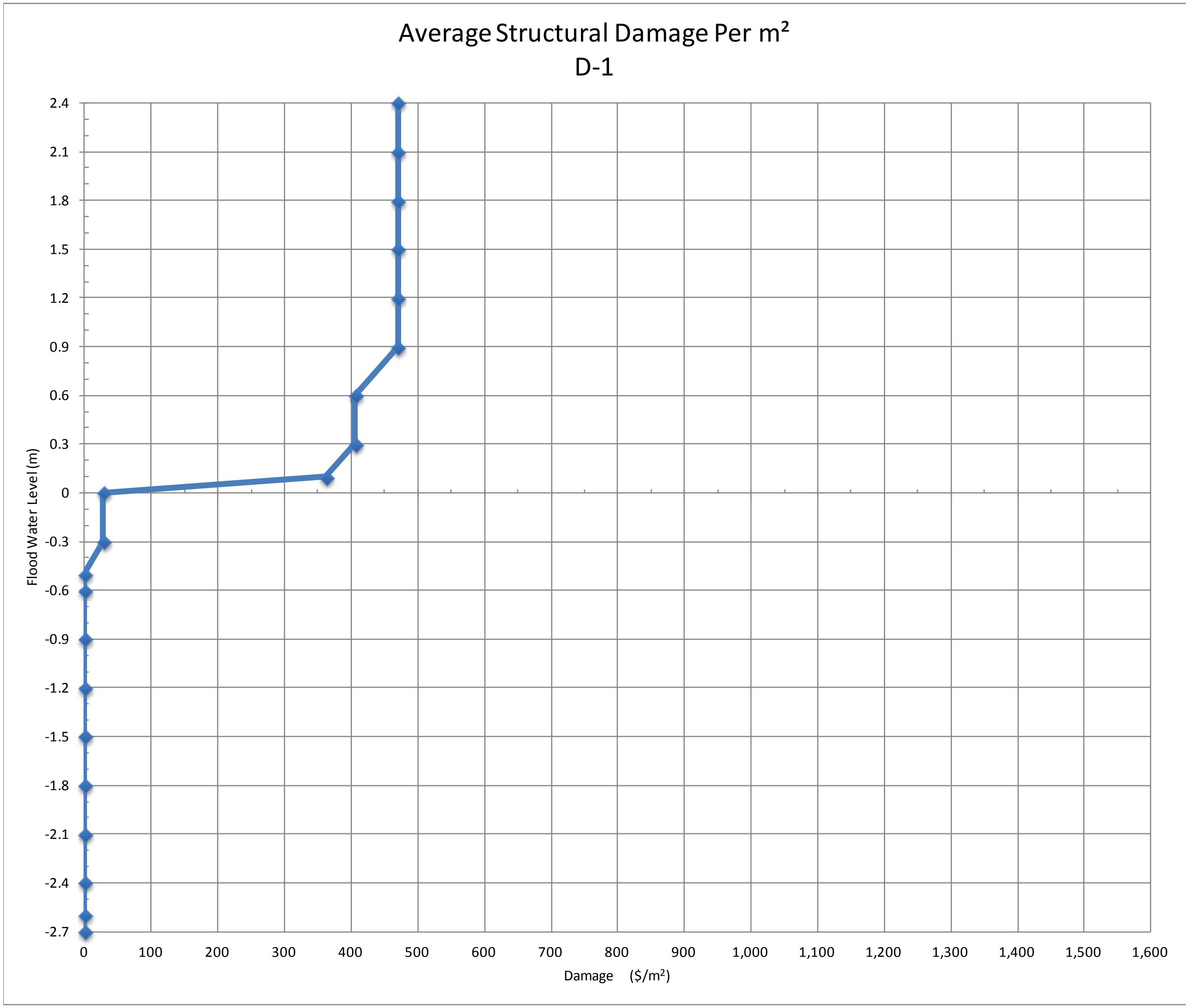
Note: Where two or more materials are shown, unit costs have been averaged.

Flood Damage Study **Building Type D**

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
Crawl Space							
0 – 0.1	• Remove and replace existing perimeter skirting with new skirting.	52	m²	$15	$780		
	• Remove and replace under floor poly vapour barrier.	128	m²	$1	$128		
	• Remove and replace under floor insulation.	128	m²	$3	$320		
	• Remove and replace under floor ductwork.	1		$1,200	$1,200		
	• Clean and sanitize all under floor components after demolition is completed.	4	hour	$125	$500		
	• Implement structural drying.	4	hour	$75	$300		
	• Inspect all structure and floor joists.	2	hour	$125	$250		
						$3,478	**$3,478**
Main Floor							
0 – 0.1	• Remove existing flooring. Clean and sand subfloor sheathing. Install new flooring.	78	m²	$60	$4,680		
	• Remove existing carpet. Clean and sand subfloor sheathing. Install new carpeting.	51	m²	$80	$4,080		
	• Remove and replace baseboards.	161	linear m	$3	$483		
	• Remove and replace all drywall to walls & ceilings.	516	m²	$30	$15,480		
	• Remove and replace all poly vapour barrier.	109	m²	$1	$109		
	• Remove and replace all insulation.	109	m²	$3	$273		
	• Remove and replace all doors & hardware.	11	door	$300	$3,300		
	• Remove and replace all wood casings and door jambs.	11	opening	$80	$880		
	• Remove and replace all kitchen cabinets and counter tops.	1	kitchen	$10,000	$10,000		
	• Remove, clean and re-install bathroom toilet, sink and tub.	2	bathroom	$500	$1,000		
	• Remove and replace bathroom cabinets.	2	cabinet	$650	$1,300		
	• Clean and sanitize all structural components after demolition is completed.	4	hour	$125	$500		

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
	• Clean and sanitize all exterior building finishes. • Implement structural drying.	4 4	hour hour	$125 $75	$500 $300		
						$42,885	$42,885
0.3	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	main floor	$5,500	$5,500		
						$5,500	$48,385
0.6	• N/A						
						$0	$48,385
0.9	• Remove and replace all windows.	11	window	$750	$8,250		
						$8,250	**$56,635**
					Grand Total	**$60,113**	**$60,113**

Residential Structural Damage Curves



Summary of Specifications for Typical Unit Type MA (Apartment Tower)

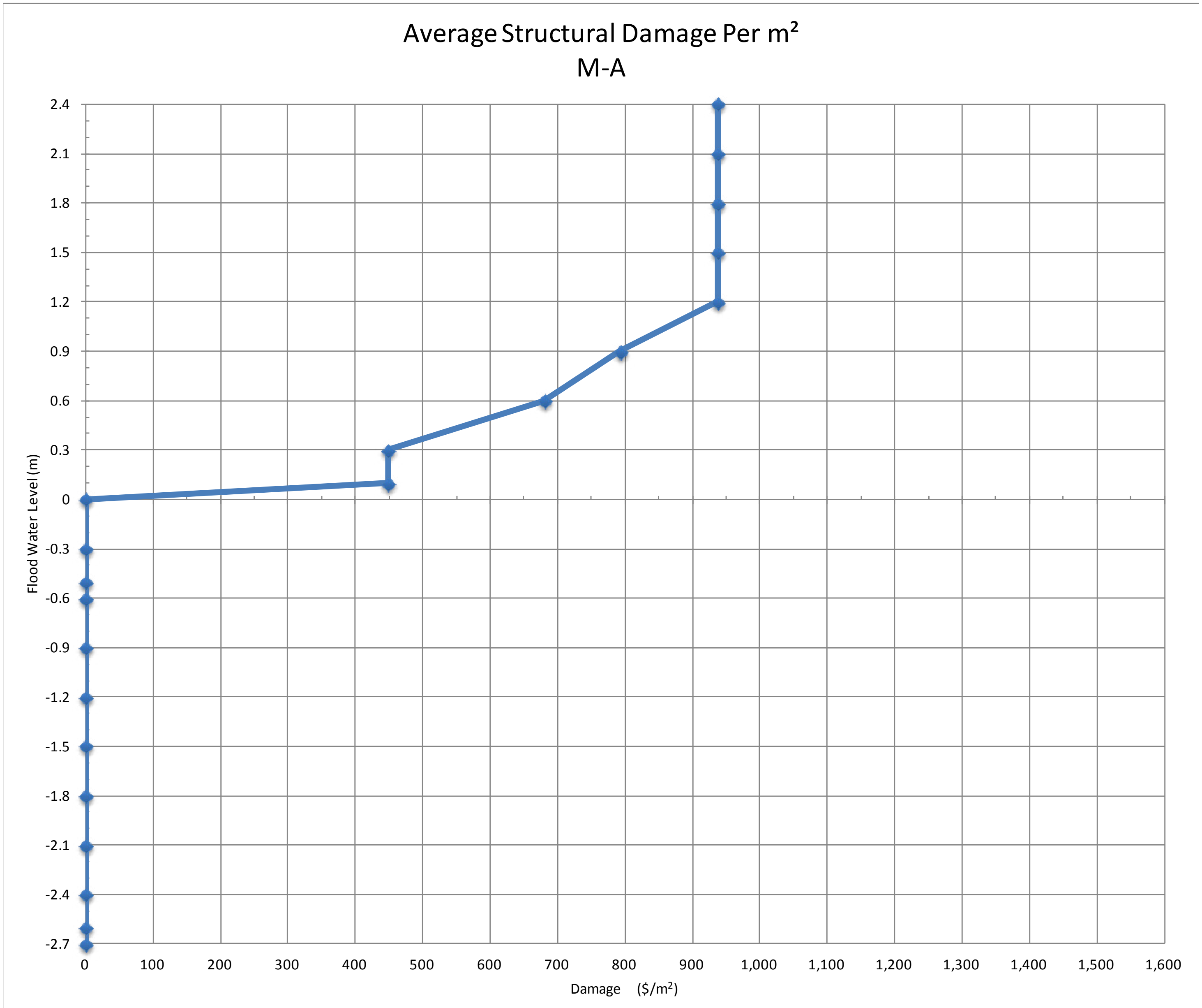
Structure	Poured concrete, foundation, parkade, columns and horizontal floor slabs including stairs.	
Ext. Cladding	Walls:	Steel studs, drywall sheathing and brick veneer.
	Windows:	Aluminum sliders in wood frame.
Interior Finishes		
Parkade:	Floor:	Concrete painted or unfinished.
	Walls:	Poured concrete or masonry – painted or unfinished.
	Doors:	Hollow metal & pressed steel frames.
	Ceiling:	Concrete painted.
Ground Floor:	Floor:	Linoleum, carpet, laminate.
	Walls:	Drywall painted.
	Doors:	Solid / hollow core wood.
	Ceiling:	Drywall stippled.
	Insulation:	Walls (R20), Ceiling (R40), 6mil poly V.B.
	Cabinets:	Plywood body, solid wood doors and drawers, P-Lam counters.
	Bathroom:	Tile to ceiling above tub.

Note: -Where two or more materials are shown, unit costs have been averaged.
-Damage costs compiled reflect damages for one unit plus a percentage of related common areas. To find total building damage costs, multiply unit cost time's number of units.

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
Parkade							
	• Restoration based on floor area.		m²				
Main Level							
0 – 0.1	• Remove existing flooring. Clean and prepare slab. Install new flooring.	14	m²	$65	$910		
	• Remove existing carpet. Clean and prepare slab. Install new carpeting.	77	m²	$90	$6,930		
	• Remove and replace baseboards.	109	linear m	$4	$436		
	• Remove and replace all drywall to walls & ceilings.	352	m²	$30	$10,560		
	• Remove and replace all poly vapour barrier.	46	m²	$1	$46		
	• Remove and replace all insulation.	46	m²	$3	$115		
	• Remove and replace all doors & hardware.	8	door	$350	$2,800		
	• Remove and replace all wood casings and door jambs.	8	opening	$90	$720		
	• Remove and replace all kitchen cabinets and counter tops.	1	kitchen	$15,000	$15,000		
	• Remove, clean and re-install bathroom toilet, sink and tub.	2	bathroom	$500	$1,000		
	• Remove and replace bathroom cabinets.	2	cabinet	$750	$1,500		
	• Check and clean heating units.	3	hour	$50	$150		
	• Clean and sanitize all structural components after demolition is completed.	4	hour	$125	$500		
	• Clean and sanitize all exterior building finishes.	4	hour	$125	$500		
	• Implement structural drying.	8	hour	$75	$600		
						$41,767	$41,767
0.3	• N/A						
						$0	$41,767

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	main floor	$6,500	$6,500		
	• Replace elevator doors	2	each	$7,500	$15,000		
						$21,500	$63,267
0.9	• Remove and replace all windows.	5	window	$800	$4,000		
	Replace security DVR	1	each	$6,500	$6,500		
						$10,500	$73,767
1.2	Replace fire panel	1	each	$7,500	$7,500		
	Replace intercom	1	each	$7,500	$6,000		
						$13,500	$87,267
Corridors, Amenity Areas, Lobby, Office, Stairs & Service Rooms:							
	• Average level of finish. Add 30% to level of damage in typical unit. As denoted by *.						
					Grand Total	**$87,267**	**$87,267**

Residential Structural Damage Curves



Summary of Specifications for Typical Unit Type MW (Walk-Up Apartments)

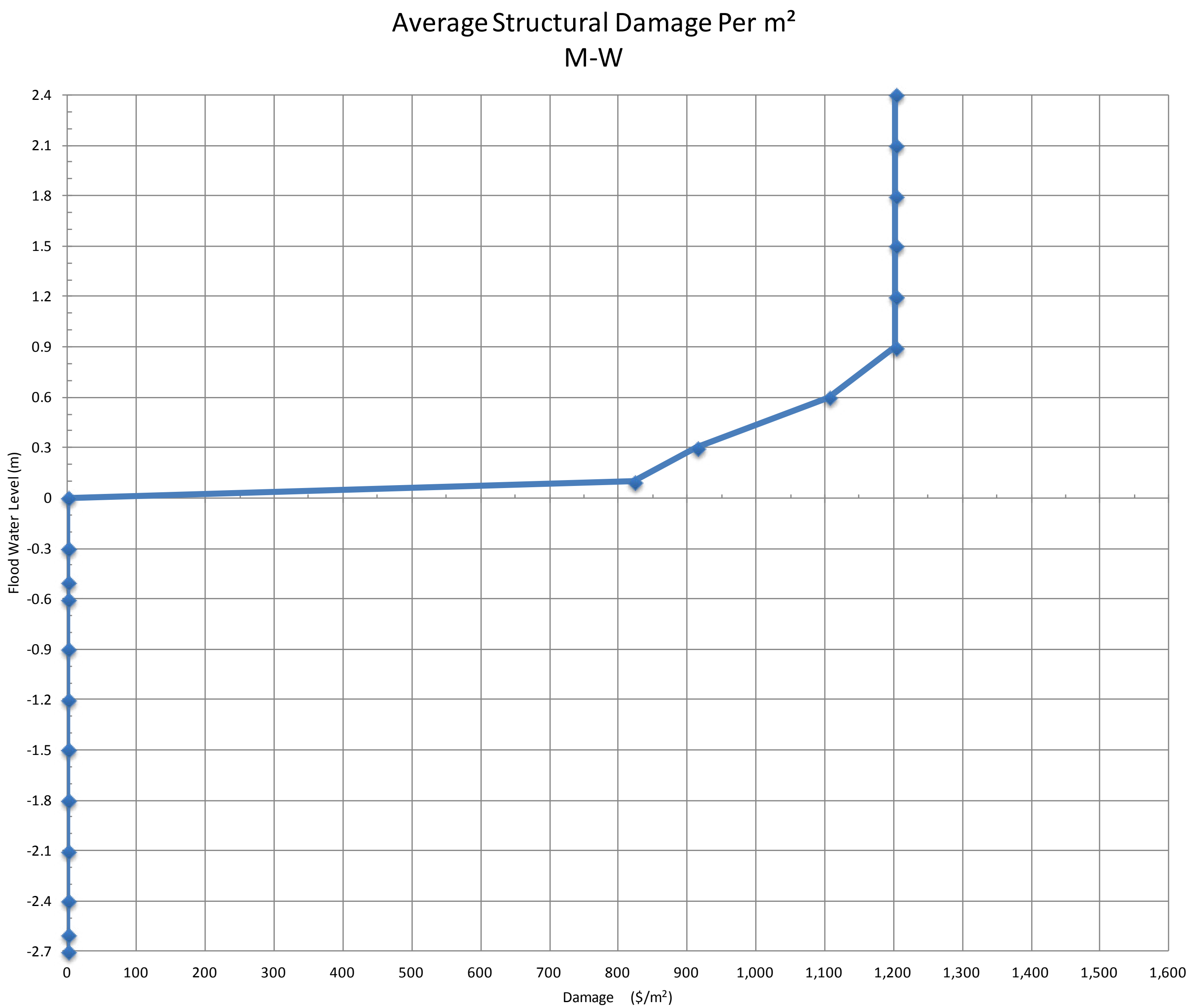
Structure	Poured concrete foundation wall, parkade, concrete slab on grade, wood frame walls, floor and roof assembly.	
Ext. Cladding	Walls:	Wood siding, painted / aluminum siding, prefinished / brick veneer.
	Windows:	Aluminum sliders in wood frame.
Interior Finishes		
Parkade:	Floor:	Concrete painted or unfinished.
	Walls:	Poured concrete or masonry – painted or unfinished.
	Doors:	Hollow metal & pressed steel frames.
	Ceiling:	Concrete painted.
Ground Floor:	Floor:	Linoleum, carpet, laminate.
	Walls:	Drywall painted.
	Doors:	Solid / hollow core wood.
	Ceiling:	Drywall stippled.
	Insulation:	Walls (R20), Ceiling (R40), 6mil poly V.B.
	Cabinets:	Plywood body, solid wood doors and drawers, P-Lam counters.
	Bathroom:	Tile to ceiling above tub.

Note: -Where two or more materials are shown, unit costs have been averaged.
-Damage costs compiled reflect damages for one unit plus a percentage of related common areas. To find total building damage costs, multiply unit cost time's number of units.

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
Parkade							
	• Restoration based on floor area.		m²				
Main Level							
0 – 0.1	• Remove existing flooring. Clean and prepare slab. Install new flooring.	32	m²	$65	$2,080		
	• Remove existing carpet. Clean and prepare slab. Install new carpeting.	100	m²	$90	$9,000		
	• Remove and replace baseboards.	190	linear m	$4	$760		
	• Remove and replace all drywall to walls & ceilings.	587	m²	$30	$17,610		
	• Remove and replace all poly vapour barrier.	55	m²	$1	$55		
	• Remove and replace all insulation.	55	m²	$3	$138		
	• Remove and replace all doors & hardware.	11	door	$350	$3,850		
	• Remove and replace all wood casings and door jambs.	11	opening	$90	$990		
	• Remove and replace all kitchen cabinets and counter tops.	1	kitchen	$15,000	$15,000		
	• Remove, clean and re-install bathroom toilet, sink and tub.	2	bathroom	$500	$1,000		
	• Remove and replace bathroom cabinets.	2	cabinet	$750	$1,500		
	• Check and clean heating units.	3	hour	$50	$150		
	• Clean and sanitize all structural components after demolition is completed.	4	hour	$125	$500		
	• Clean and sanitize all exterior building finishes.	4	hour	$125	$500		
	• Implement structural drying.	8	hour	$75	$600		
						$53,733	$53,733
0.3	• Mechanical	0.5	each	$12,000	$6,000		
						$6,000	$59,733

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panel.	1	main floor	$6,500	$6,500		
	• Mechanical	0.5	each	$12,000	$6,000		
						$12,500	$72,233
0.9	• Remove and replace all windows.	8	window	$800	$6,400		
						$6,400	$78,633
Corridors, Amenity Areas, Lobby, Office, Stairs & Service Rooms:							
	• Average level of finish. Add 30% to level of damage in typical unit. As denoted by *.						
					Grand Total	**$78,633**	

Residential Structural Damage Curves



Appendix E – Residential Structural Damage Values

Residential Structural Damage Values

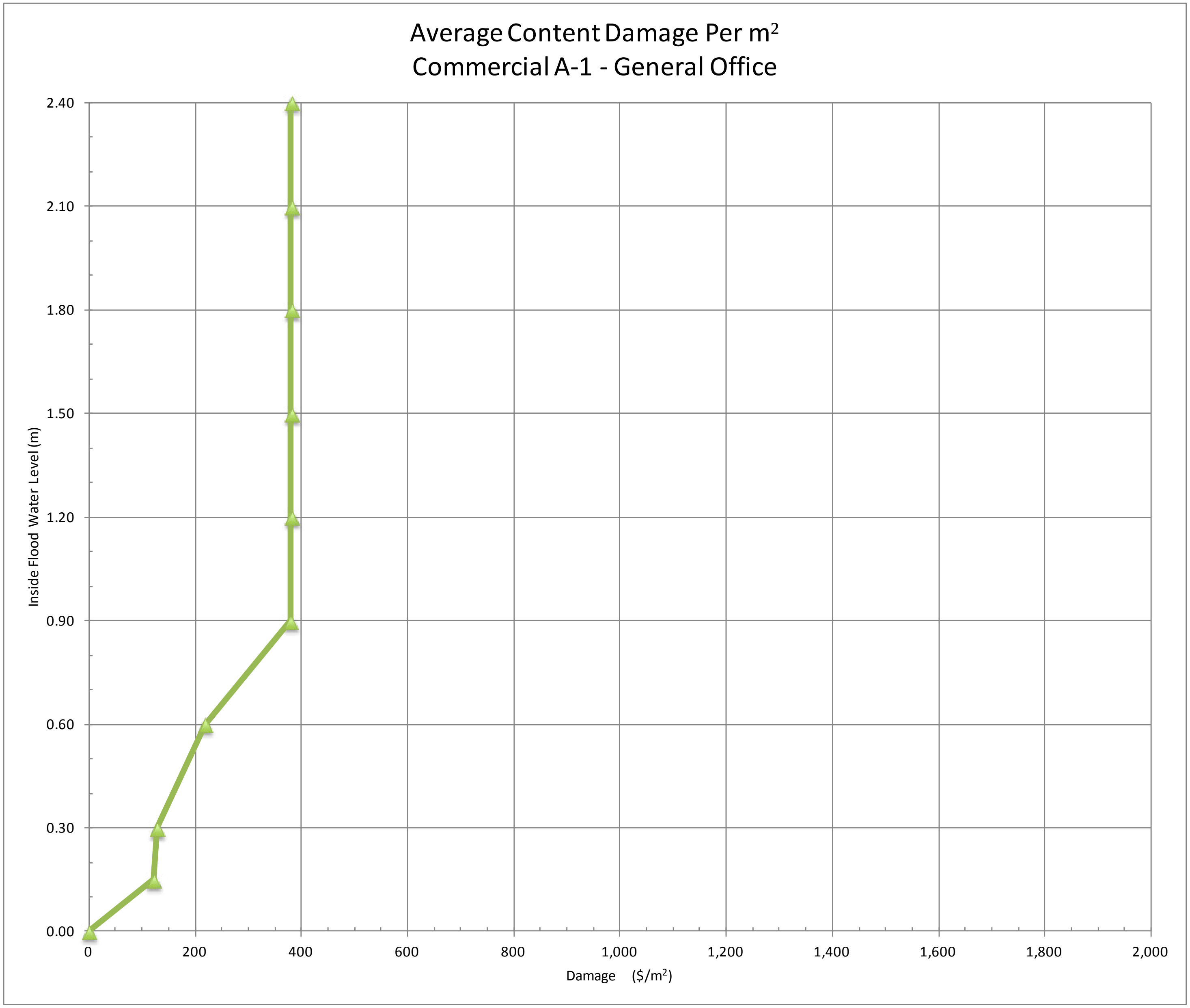
Residential structures damages by interior elevation and classification, Calgary, $/m2 floor area, 2014$

Interior elevation		Residential classification								
		A1	A2	B1	B2	C1	C2	D1	MA1	MW1
Top of Level 0 (basement) floor	-2.7	$0	$0	$0	$0	$0	$0	$0	$0	$0
	-2.6	$231	$241	$232	$242	$237	$207	$0	$0	$0
	-2.4	$271	$354	$282	$331	$309	$322	$0	$0	$0
	-2.1	$299	$406	$312	$385	$356	$399	$0	$0	$0
	-1.8	$299	$406	$312	$385	$356	$399	$0	$0	$0
	-1.5	$305	$429	$322	$402	$374	$428	$0	$0	$0
	-1.2	$335	$466	$334	$420	$383	$442	$0	$0	$0
	-0.9	$335	$466	$334	$420	$383	$442	$0	$0	$0
	-0.6	$356	$506	$362	$470	$424	$508	$0	$0	$0
Level 0 (basement) ceiling	-0.3	$357	$507	$363	$473	$427	$512	$27	$0	$0
Top of Level 1 (main) floor	0.0	$365	$522	$374	$490	$439	$532	$27	$0	$0
	0.1	$588	$665	$428	$1,014	$906	$1,131	$362	$449	$822
	0.3	$594	$676	$435	$1,026	$918	$1,150	$405	$449	$914
	0.6	$674	$826	$485	$1,115	$996	$1,275	$405	$680	$1,105
	0.9	$848	$1,051	$605	$1,282	$1,111	$1,429	$470	$792	$1,203
	1.3	$848	$1,051	$605	$1,282	$1,111	$1,429	$470	$937	$1,203
	1.5	$848	$1,051	$605	$1,282	$1,111	$1,429	$470	$937	$1,203
	1.8	$848	$1,051	$605	$1,282	$1,111	$1,429	$470	$937	$1,203
	2.1	$848	$1,051	$605	$1,282	$1,111	$1,429	$470	$937	$1,203
Level 1 (main) ceiling	2.4	$848	$1,051	$605	$1,282	$1,111	$1,429	$470	$937	$1,203

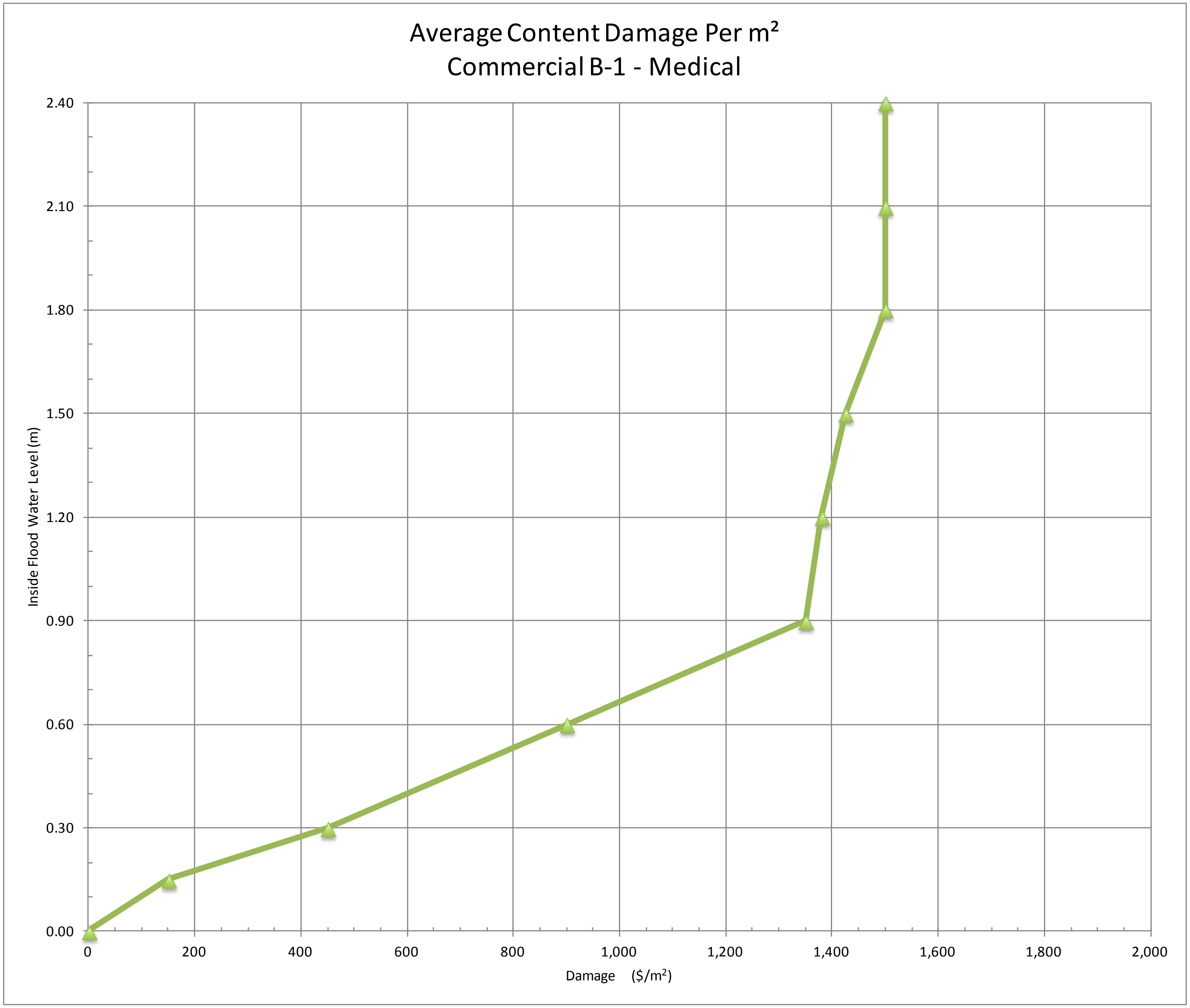
Damages include attached/detached garages; exclude underground parking structures and landscape remediation

Appendix F – Non-Residential Content Damage Curves

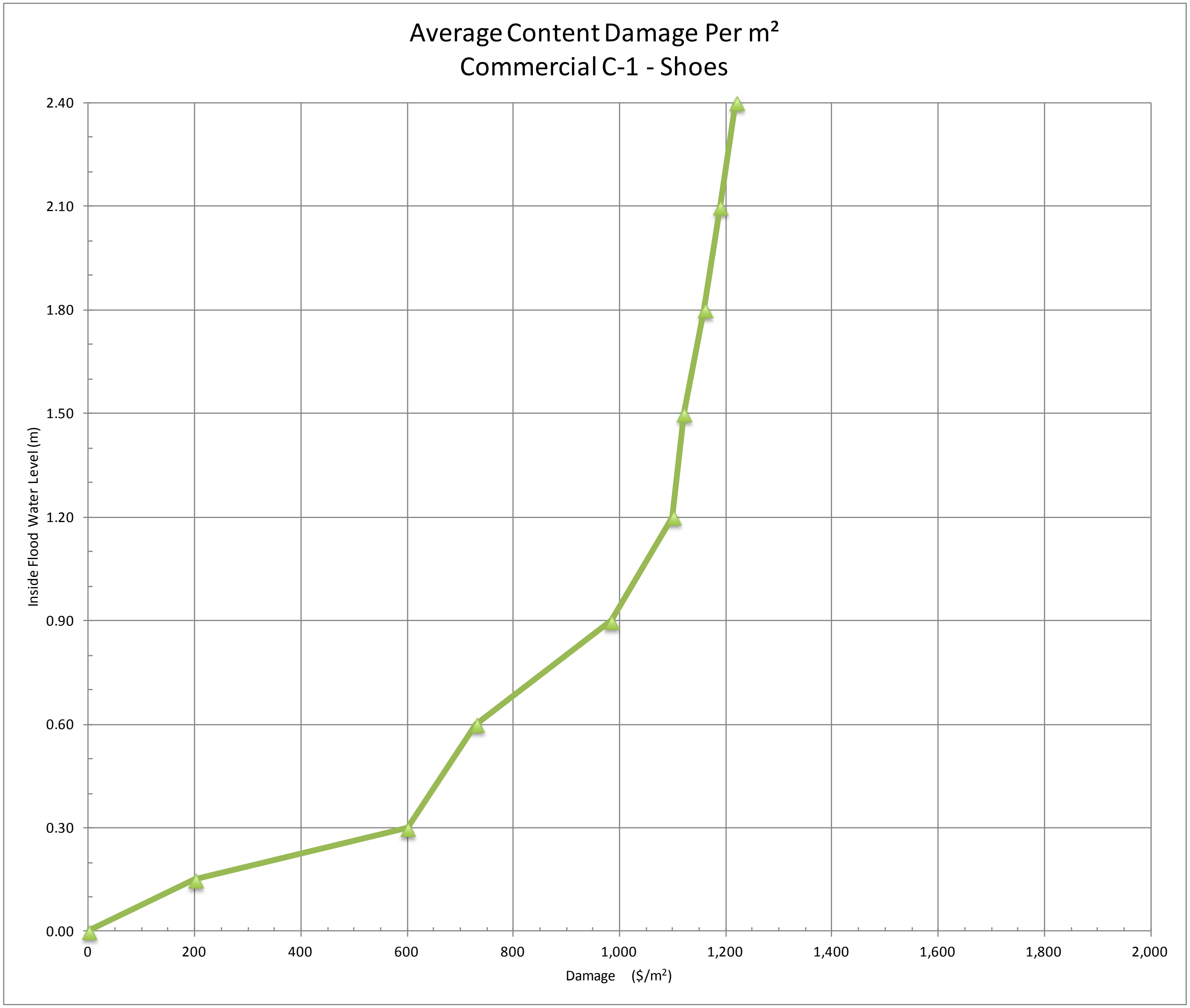
Non-Residential Content Damage Curves



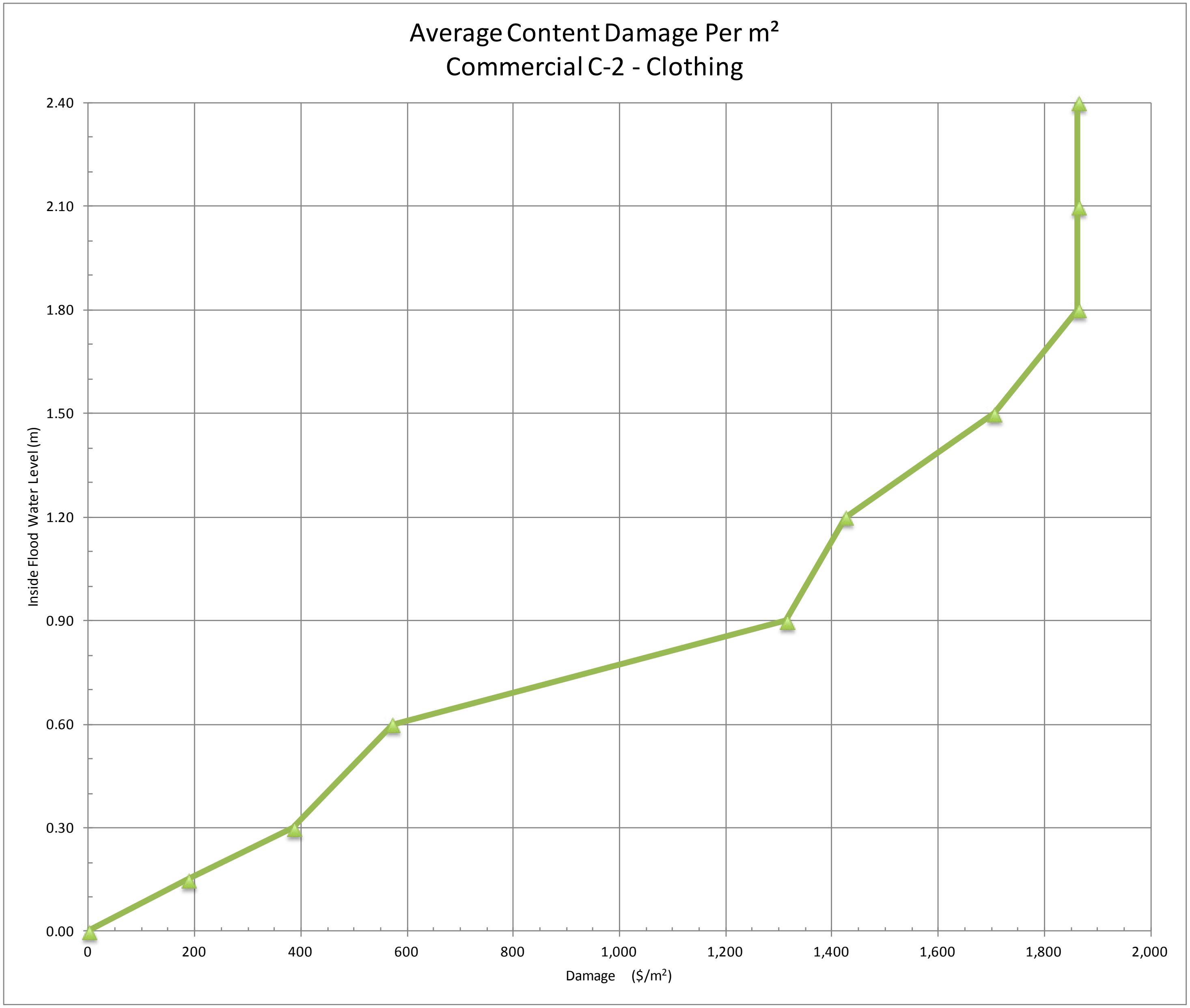
Non-Residential Content Damage Curves



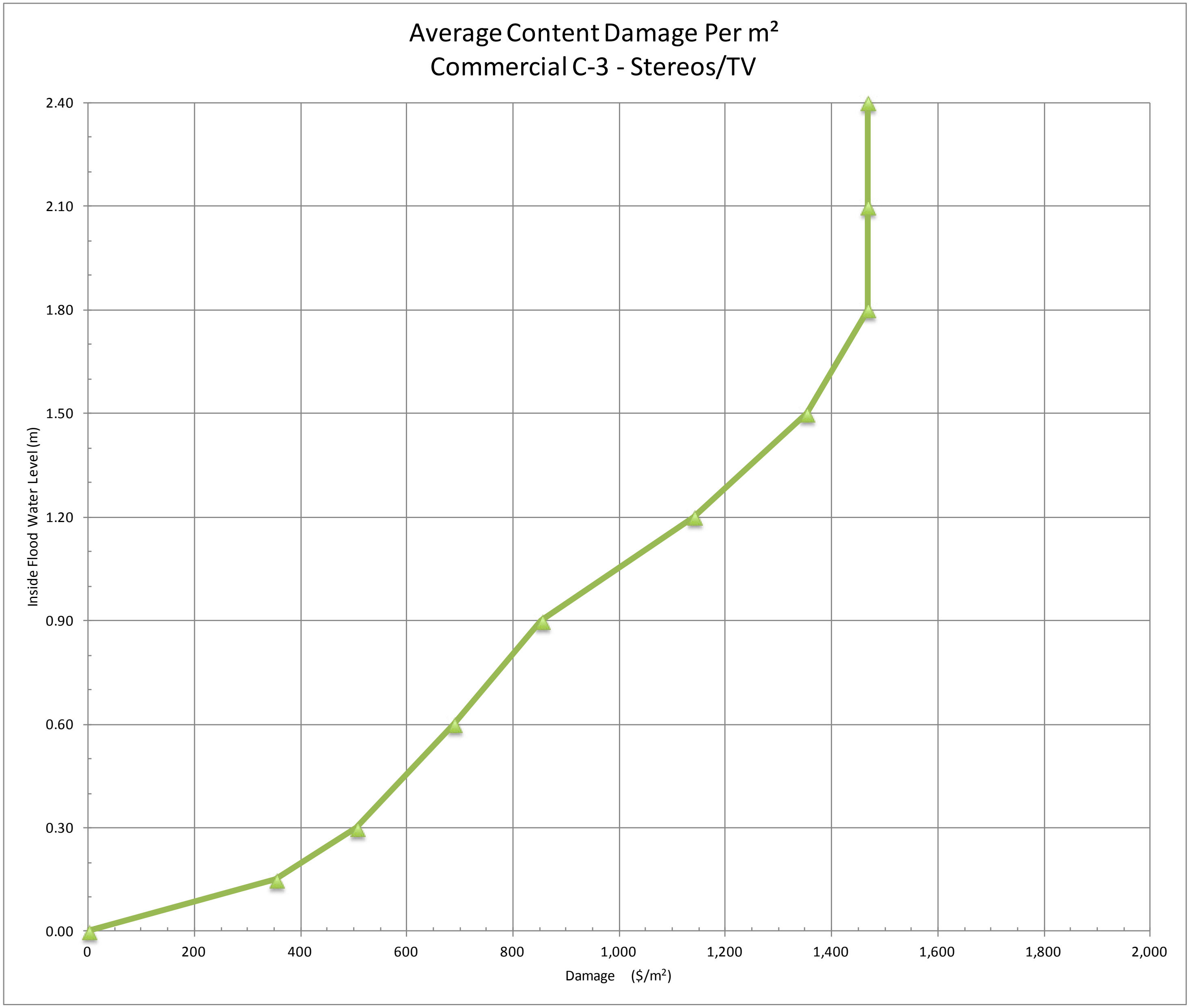
Non-Residential Content Damage Curves



Non-Residential Content Damage Curves



Non-Residential Content Damage Curves



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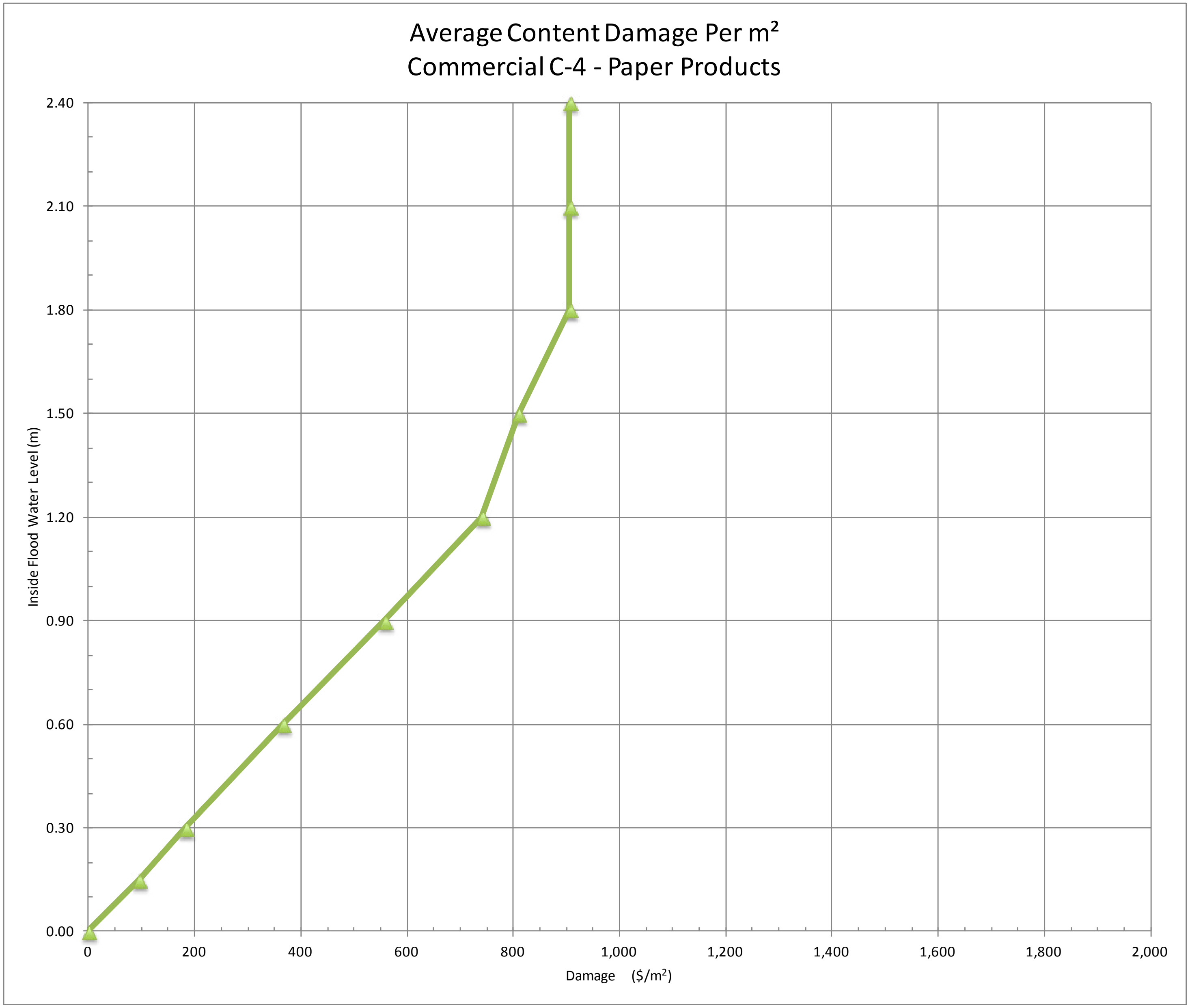

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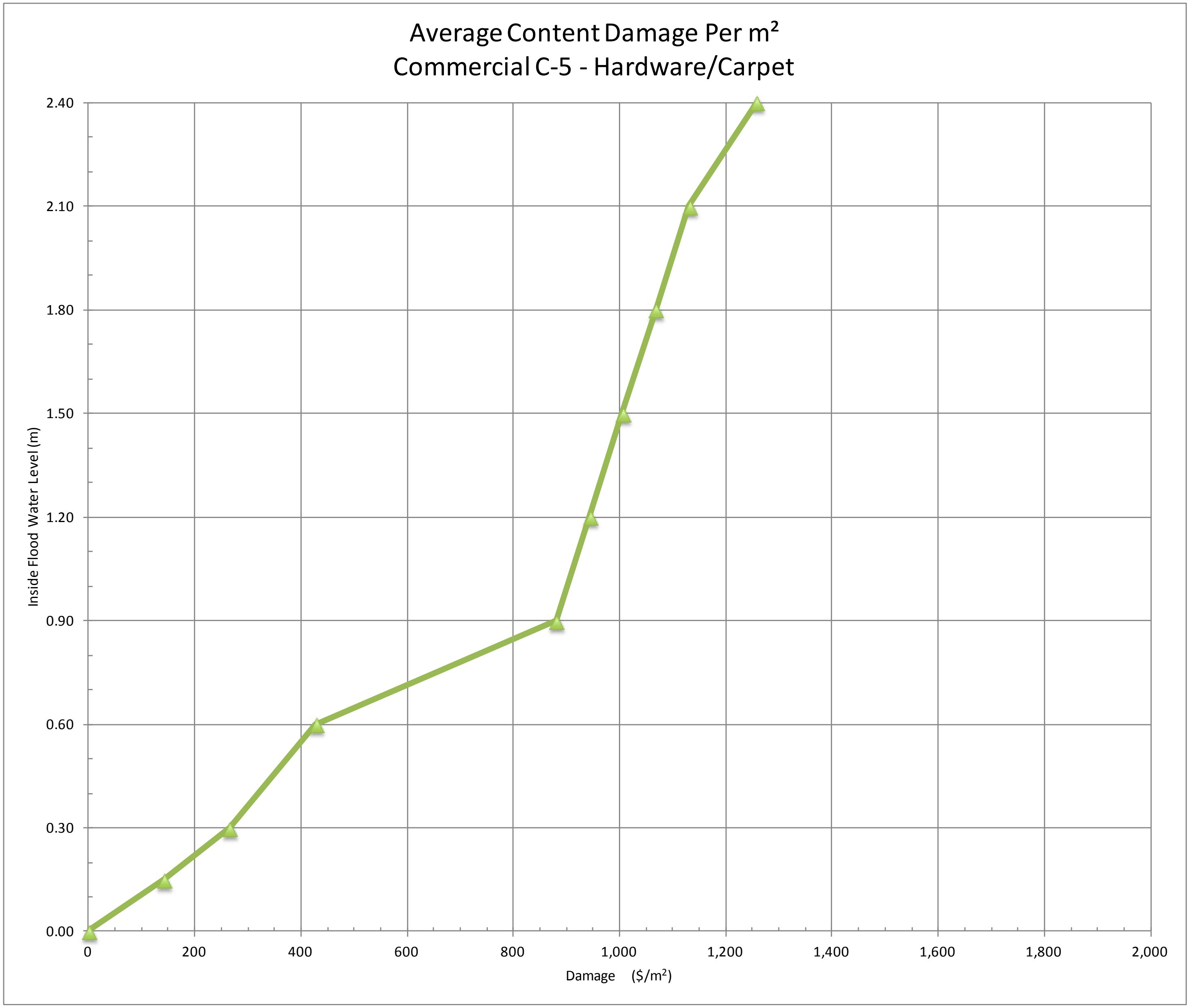

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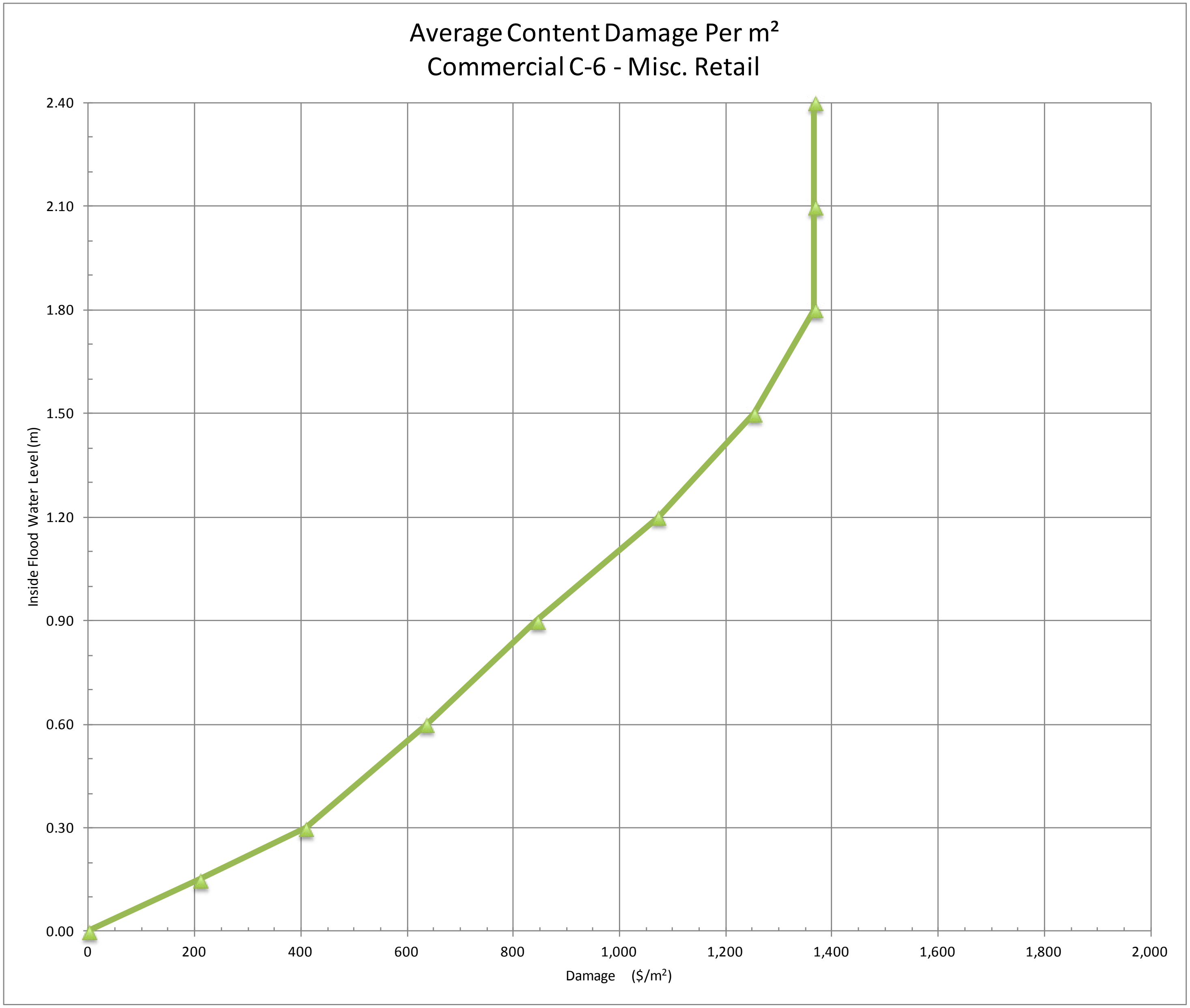

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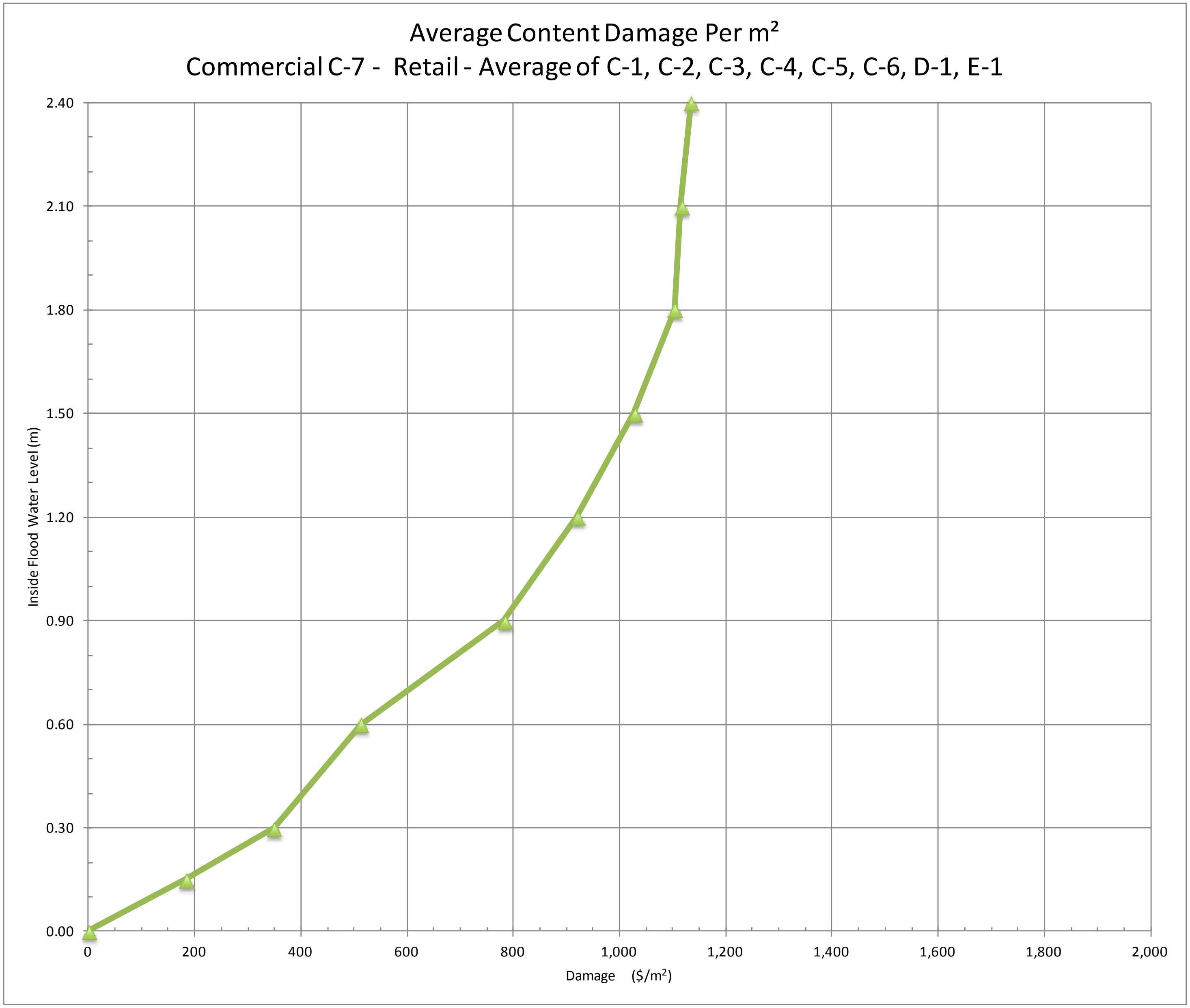

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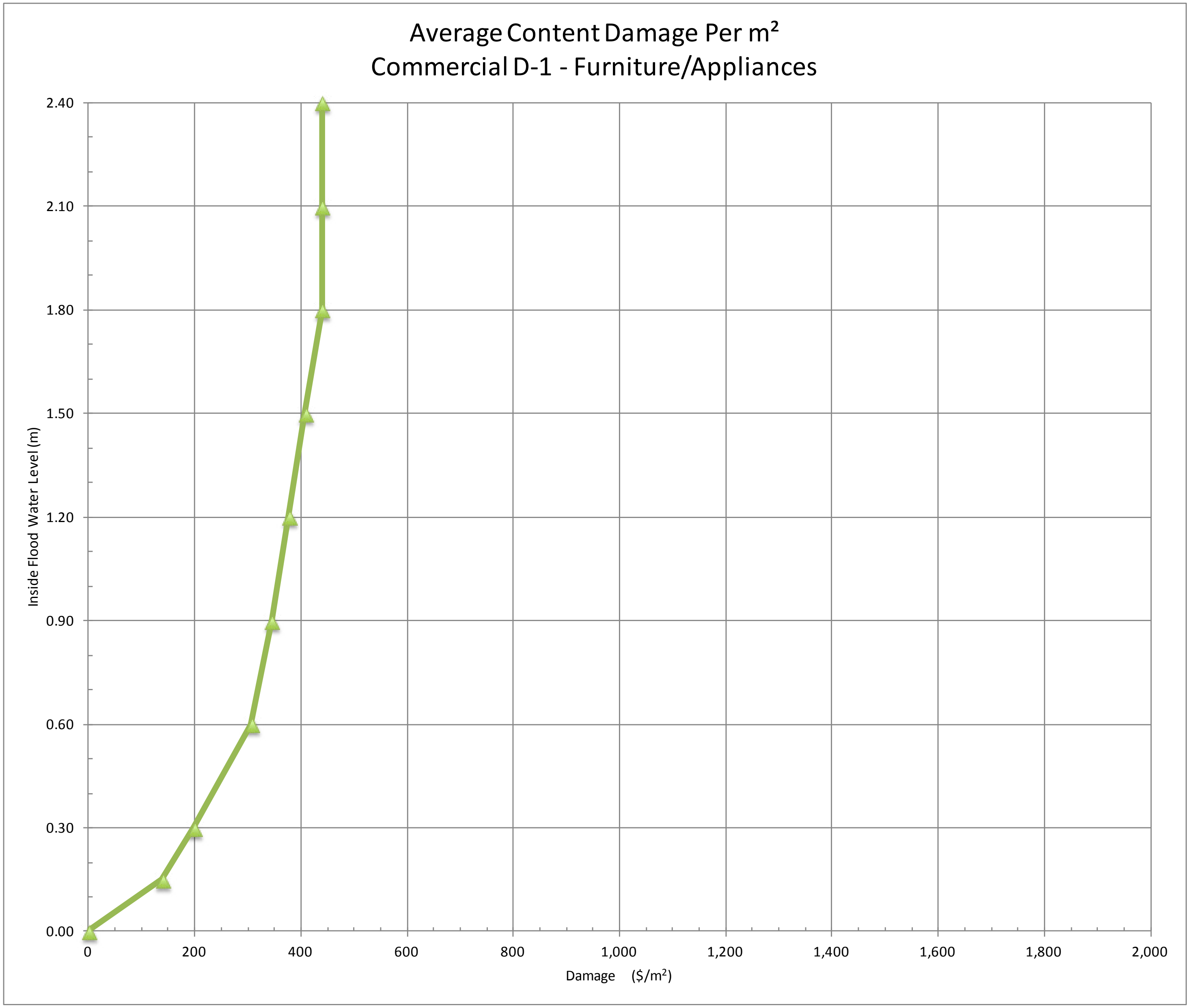
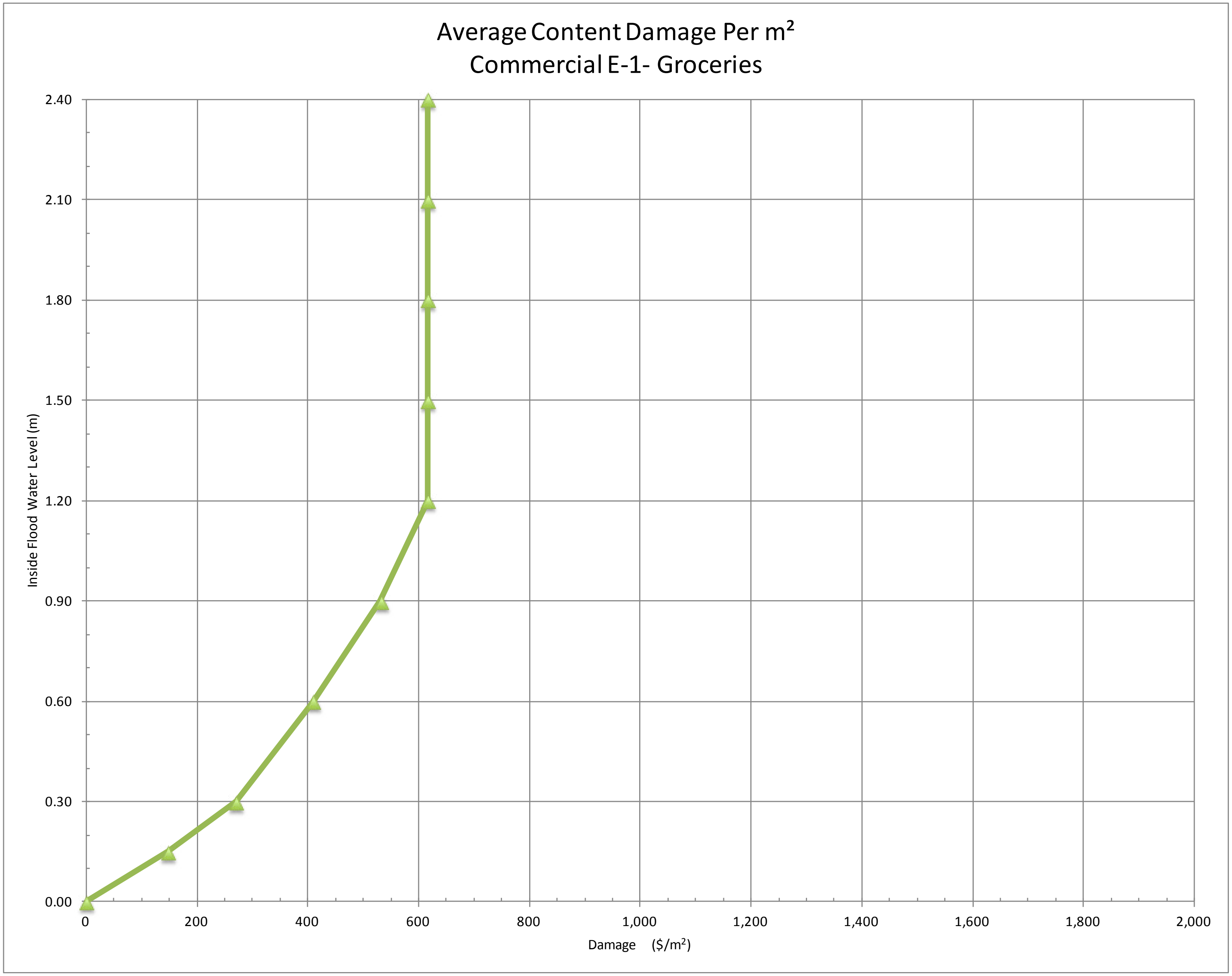
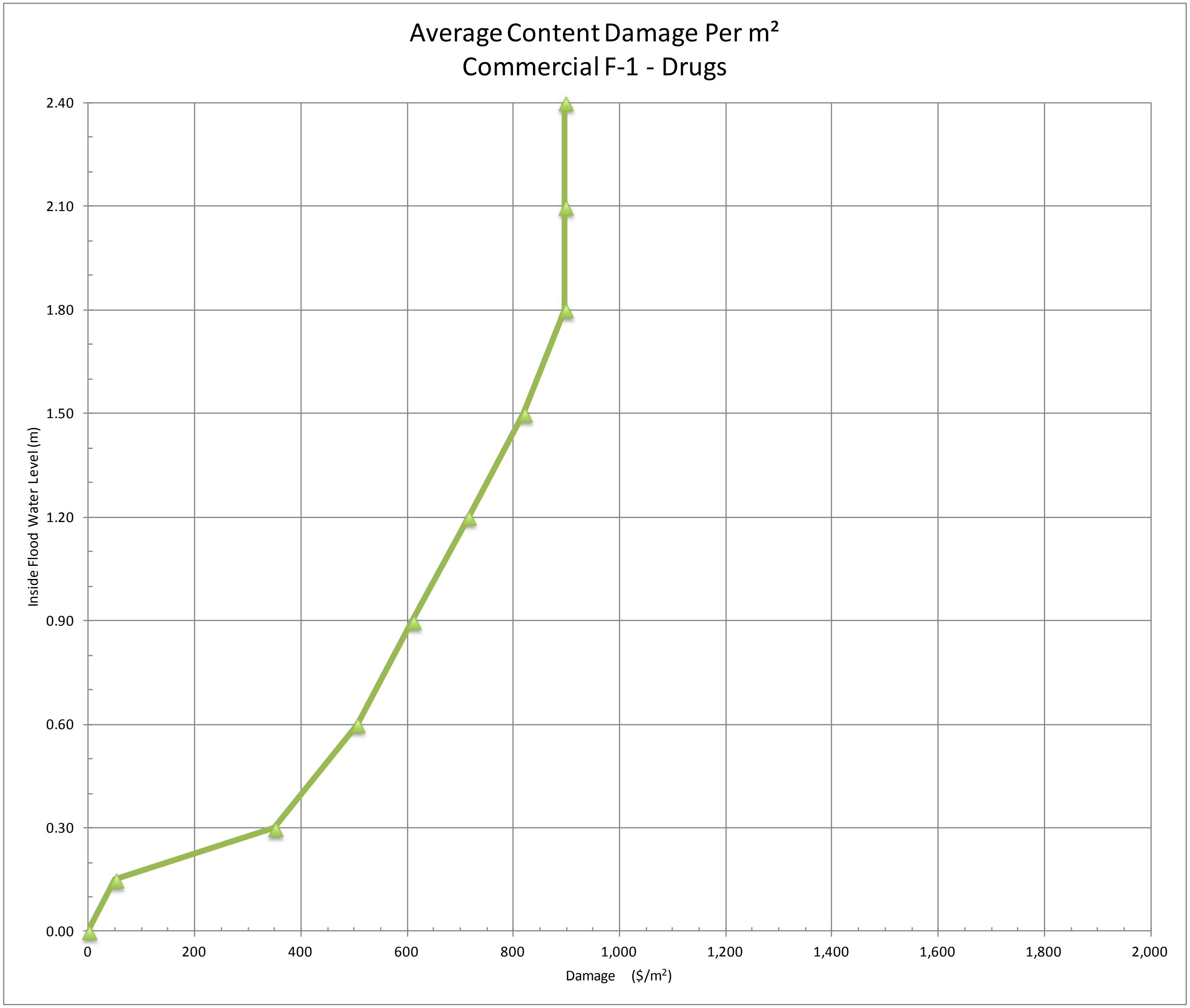


Non-Residential Content Damage Curves



Non-Residential Content Damage Curves



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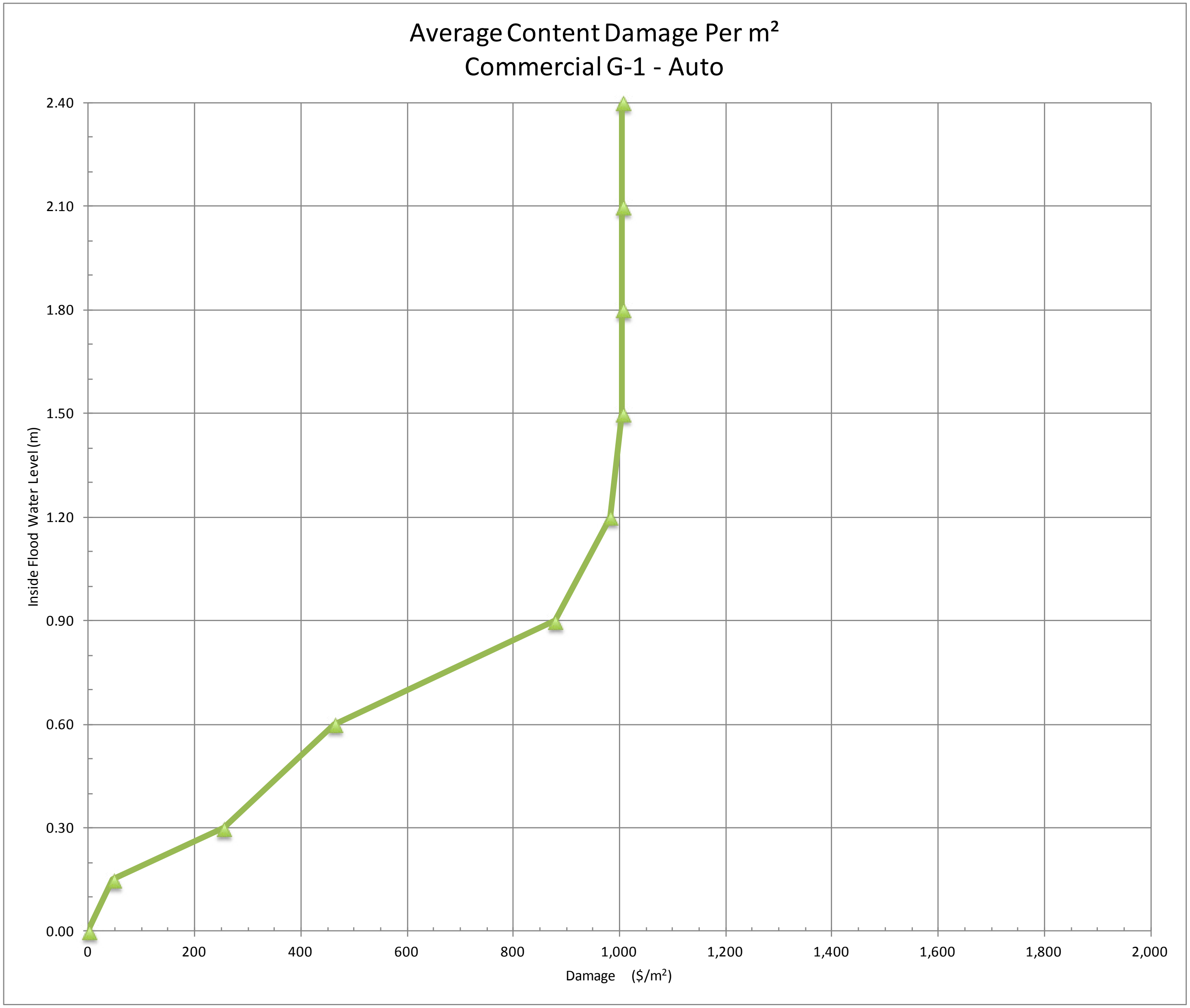
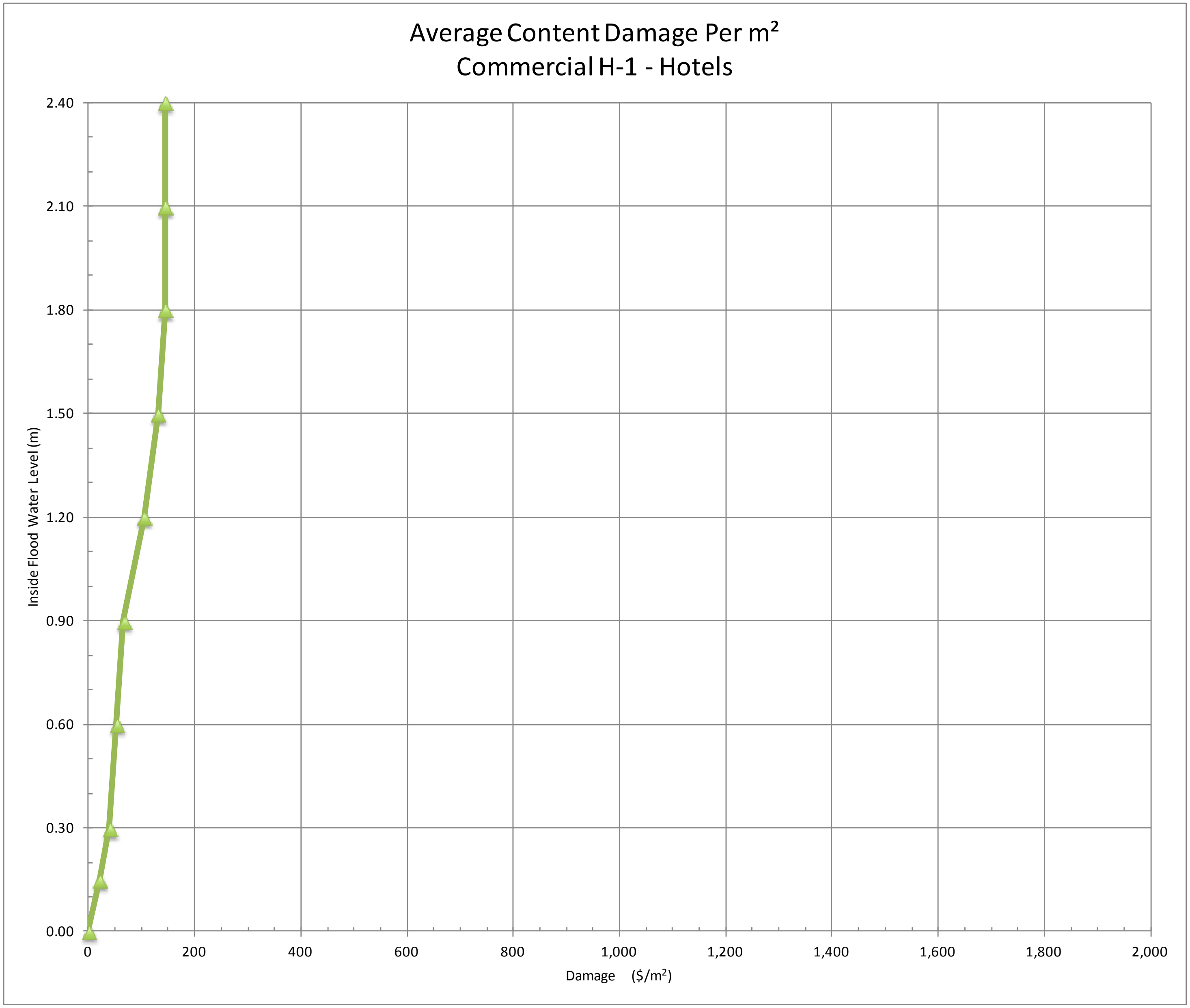
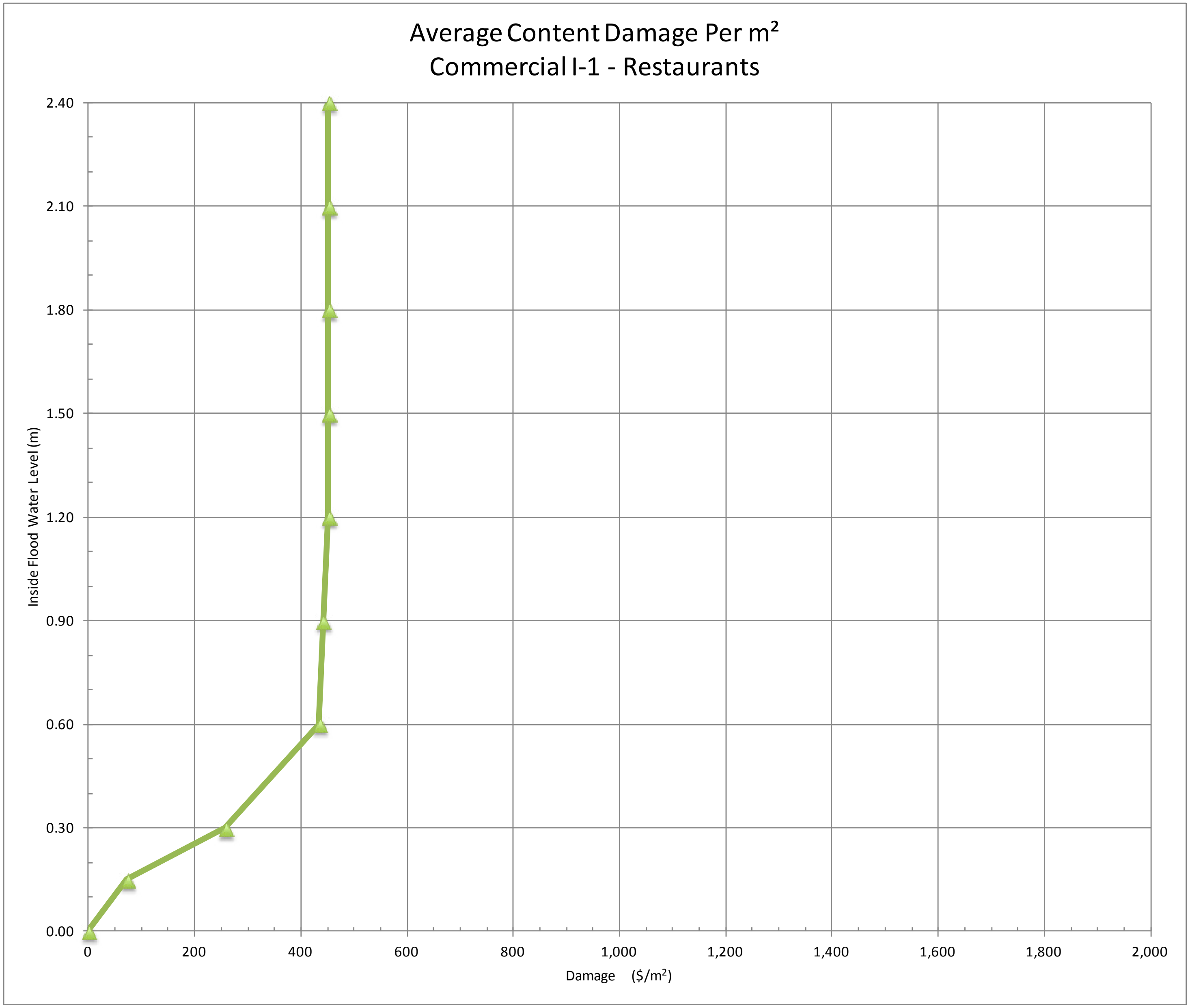


Non-Residential Content Damage Curves



Non-Residential Content Damage Curves



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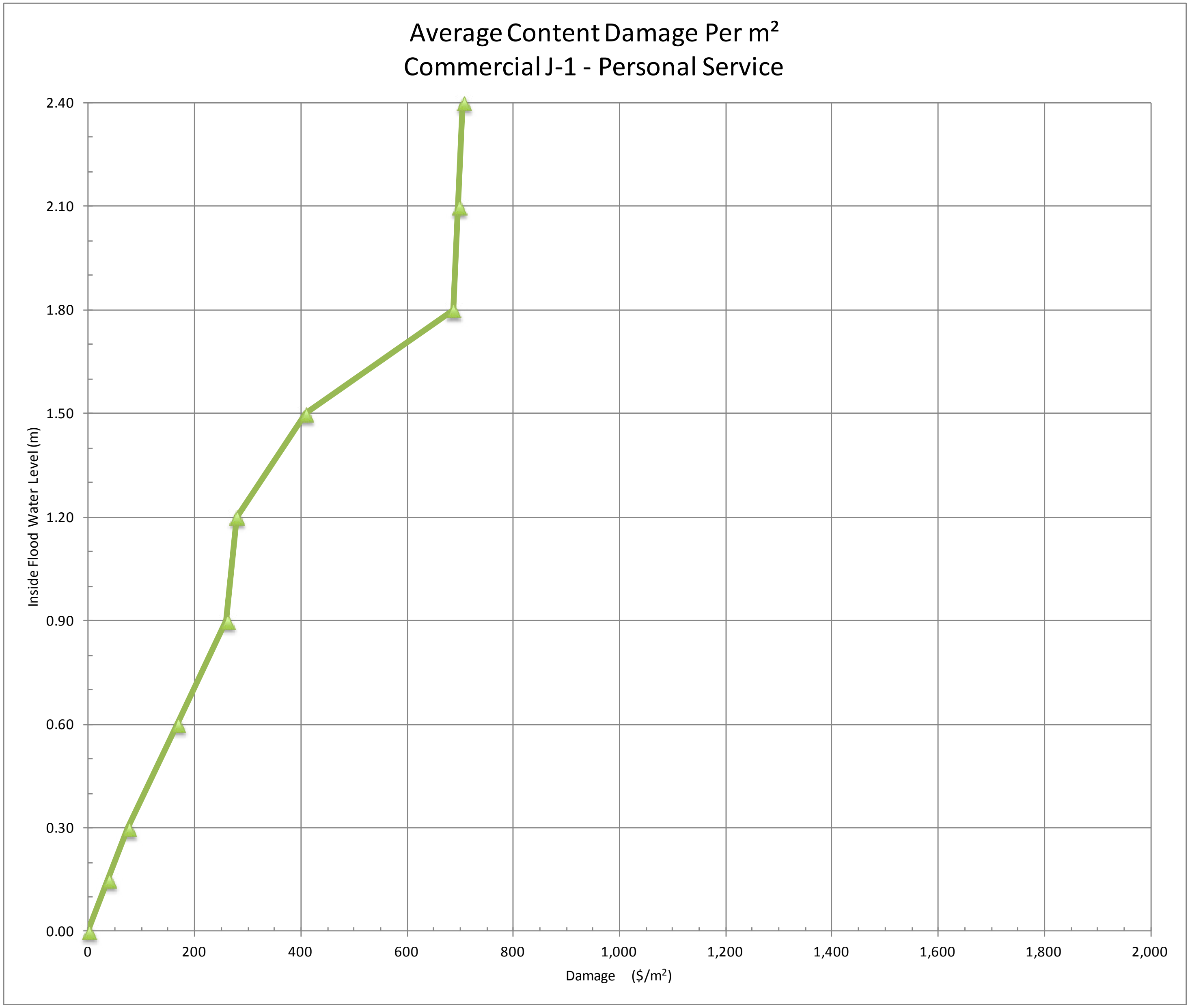
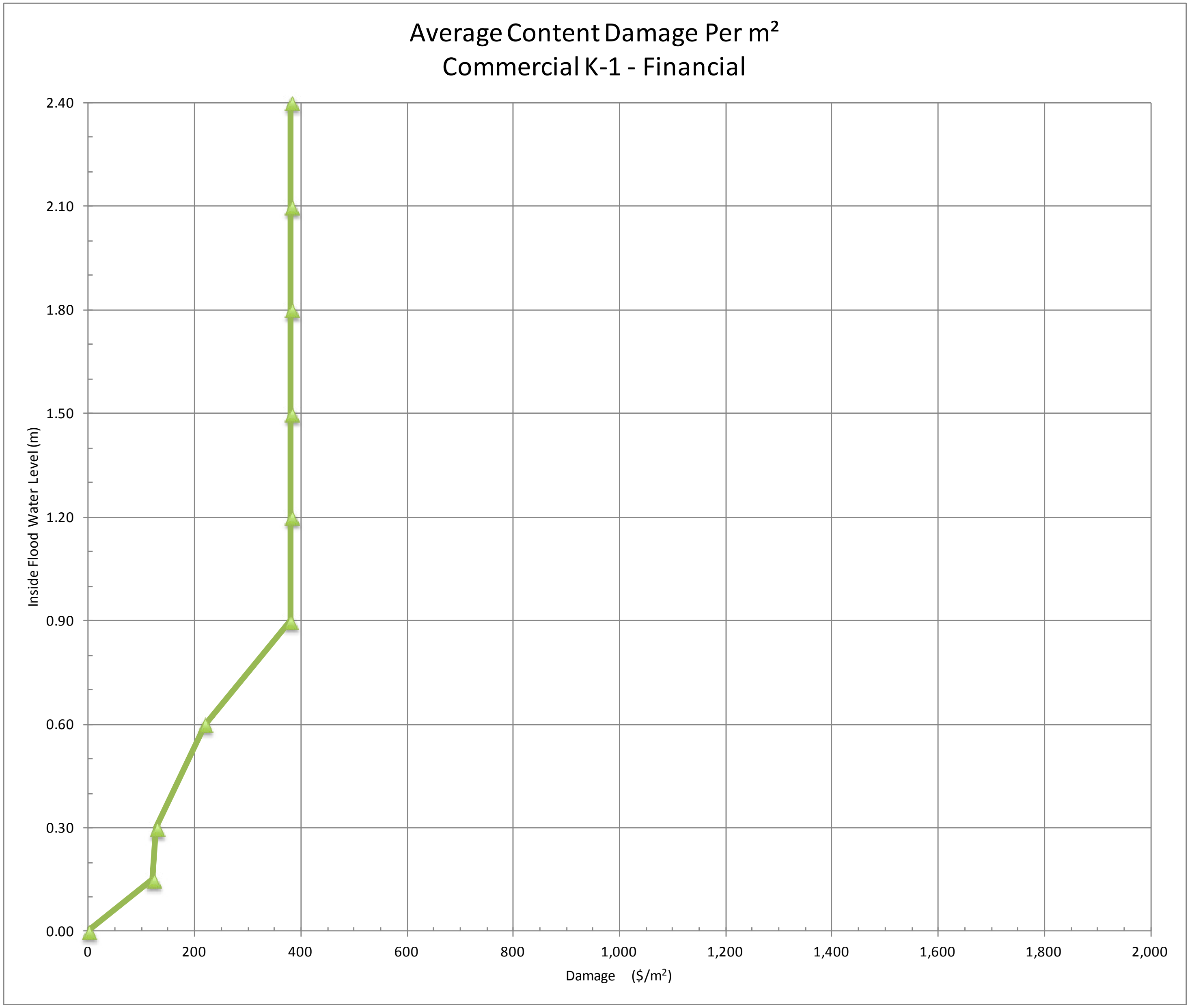
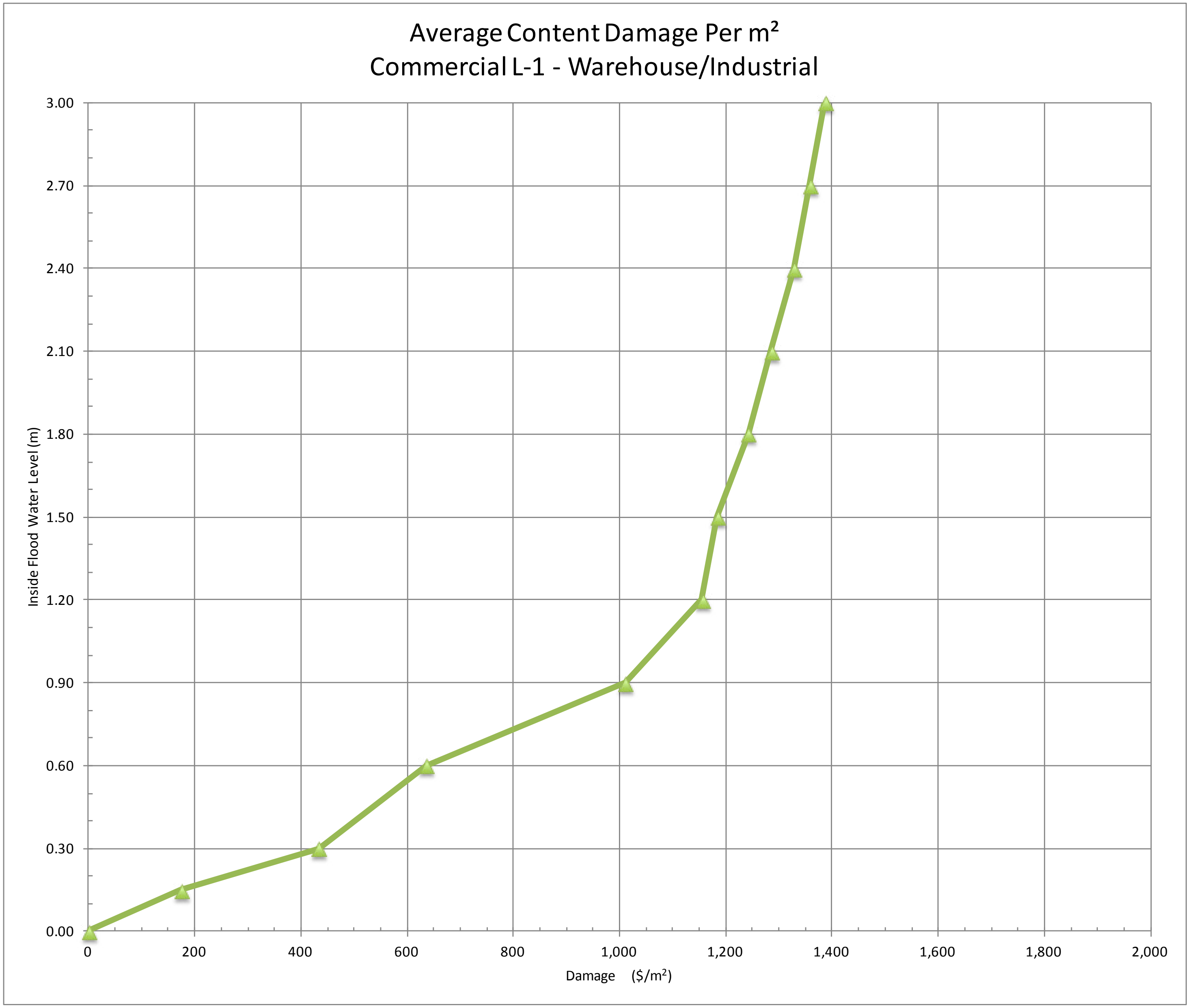


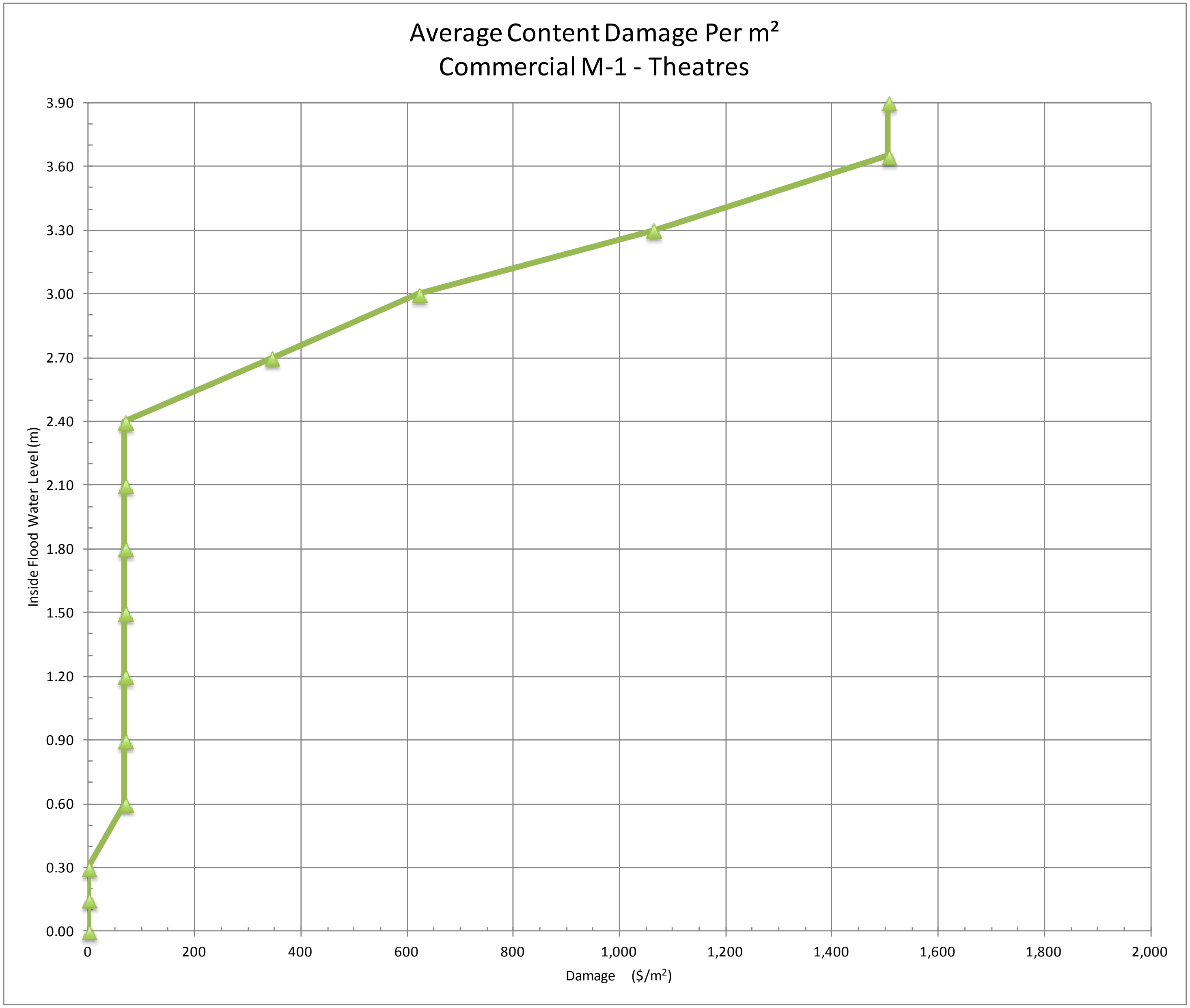
Non-Residential Content Damage Curves



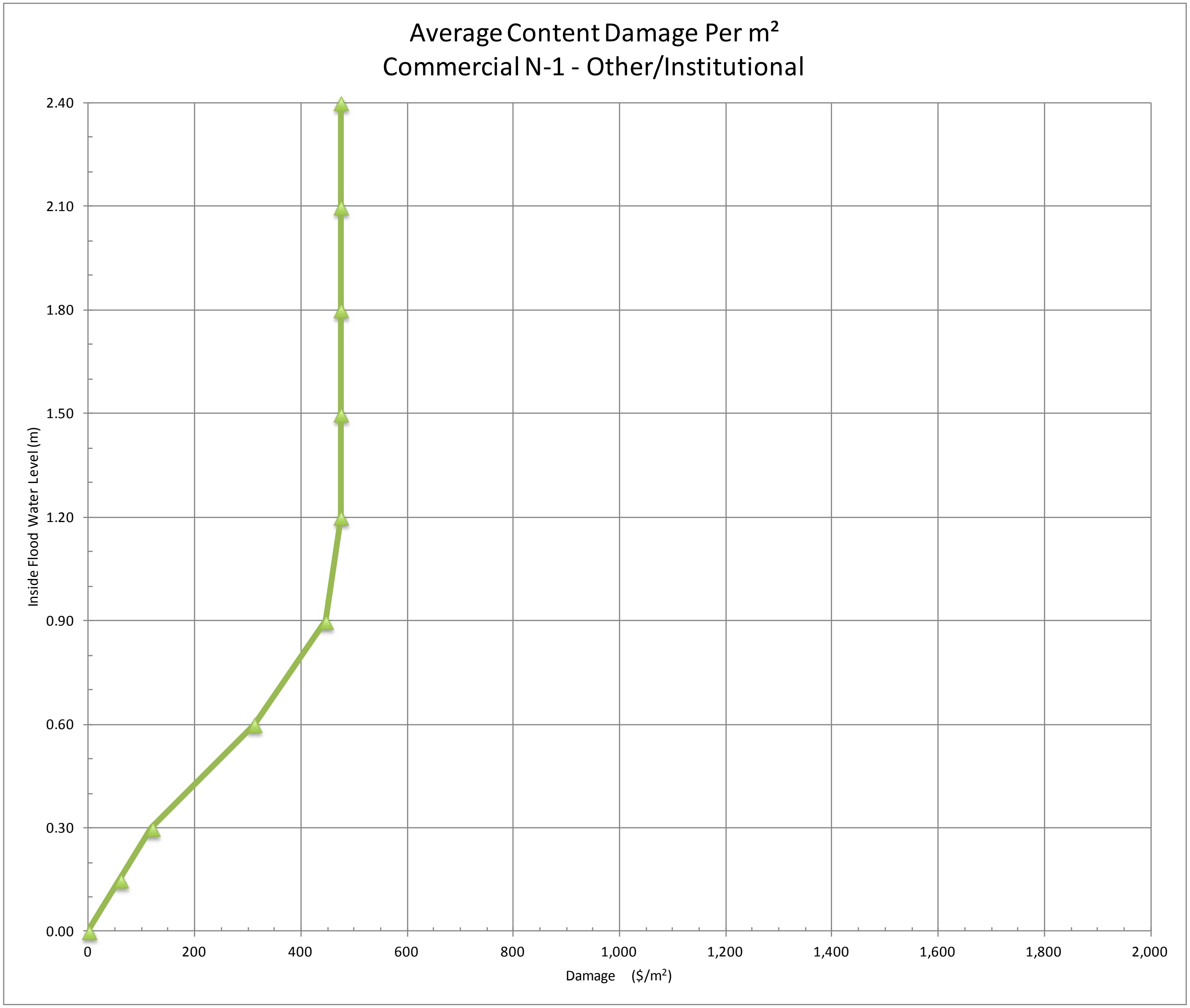
Non-Residential Content Damage Curves



Non-Residential Content Damage Curves



Non-Residential Content Damage Curves



Appendix G – Non-Residential Content Damage Values

Non-Residential Content Damage Values

Non-residential contents damages by interior elevation and classification, Calgary, $/m2 floor area, 2014$

Interior elevation		Non-residential classification																				
		A1	B1	C1	C2	C3	C4	C5	C6	C7 Av.	D1	E1	F1	G1	H1	I1	J1	K1	L1	M1	N1	N2
Top of Level 1 (main) floor	0.0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	0.2	$121	$150	$200	$187	$352	$96	$142	$209	$182	$138	$148	$50	$46	$20	$72	$37	$121	$173	$0	$59	$72
	0.3	$127	$450	$600	$385	$504	$183	$265	$408	$349	$198	$270	$350	$254	$39	$257	$74	$127	$433	$0	$119	$92
	0.6	$219	$900	$729	$572	$689	$366	$427	$636	$512	$306	$410	$505	$462	$52	$434	$167	$219	$635	$68	$312	$182
	0.9	$380	$1,350	$984	$1,314	$852	$557	$880	$844	$782	$345	$531	$610	$878	$65	$442	$260	$380	$1,011	$68	$446	$311
	1.2	$380	$1,380	$1,100	$1,425	$1,139	$740	$943	$1,072	$919	$376	$616	$715	$982	$104	$452	$278	$380	$1,155	$68	$475	$341
	1.5	$380	$1,425	$1,121	$1,705	$1,352	$810	$1,005	$1,252	$1,026	$408	$616	$820	$1,005	$131	$452	$408	$380	$1,184	$68	$475	$363
	1.8	$380	$1,500	$1,159	$1,862	$1,467	$906	$1,068	$1,366	$1,103	$439	$616	$897	$1,005	$144	$452	$687	$380	$1,242	$68	$475	$363
	2.1	$380	$1,500	$1,189	$1,862	$1,467	$906	$1,130	$1,366	$1,115	$439	$616	$897	$1,005	$144	$452	$696	$380	$1,285	$68	$475	$363
	2.4	$380	$1,500	$1,219	$1,862	$1,467	$906	$1,257	$1,366	$1,134	$439	$616	$897	$1,005	$144	$452	$705	$380	$1,328	$68	$475	$363
	2.7	$380	$1,500	$1,219	$1,862	$1,467	$906	$1,257	$1,366	$1,134	$439	$616	$897	$1,005	$144	$452	$705	$380	$1,357	$344	$475	$363
	3.0	$380	$1,500	$1,219	$1,862	$1,467	$906	$1,257	$1,366	$1,134	$439	$616	$897	$1,005	$144	$452	$705	$380	$1,386	$621	$475	$363
	3.3	$380	$1,500	$1,219	$1,862	$1,467	$906	$1,257	$1,366	$1,134	$439	$616	$897	$1,005	$144	$452	$705	$380	$1,386	$1,063	$475	$363
	3.7	$380	$1,500	$1,219	$1,862	$1,467	$906	$1,257	$1,366	$1,134	$439	$616	$897	$1,005	$144	$452	$705	$380	$1,386	$1,505	$475	$363
Level 1 (main) ceiling	3.9	$380	$1,500	$1,219	$1,862	$1,467	$906	$1,257	$1,366	$1,134	$439	$616	$897	$1,005	$144	$452	$705	$380	$1,386	$1,505	$475	$363

Appendix H – Non-Residential Structural Damage Curves

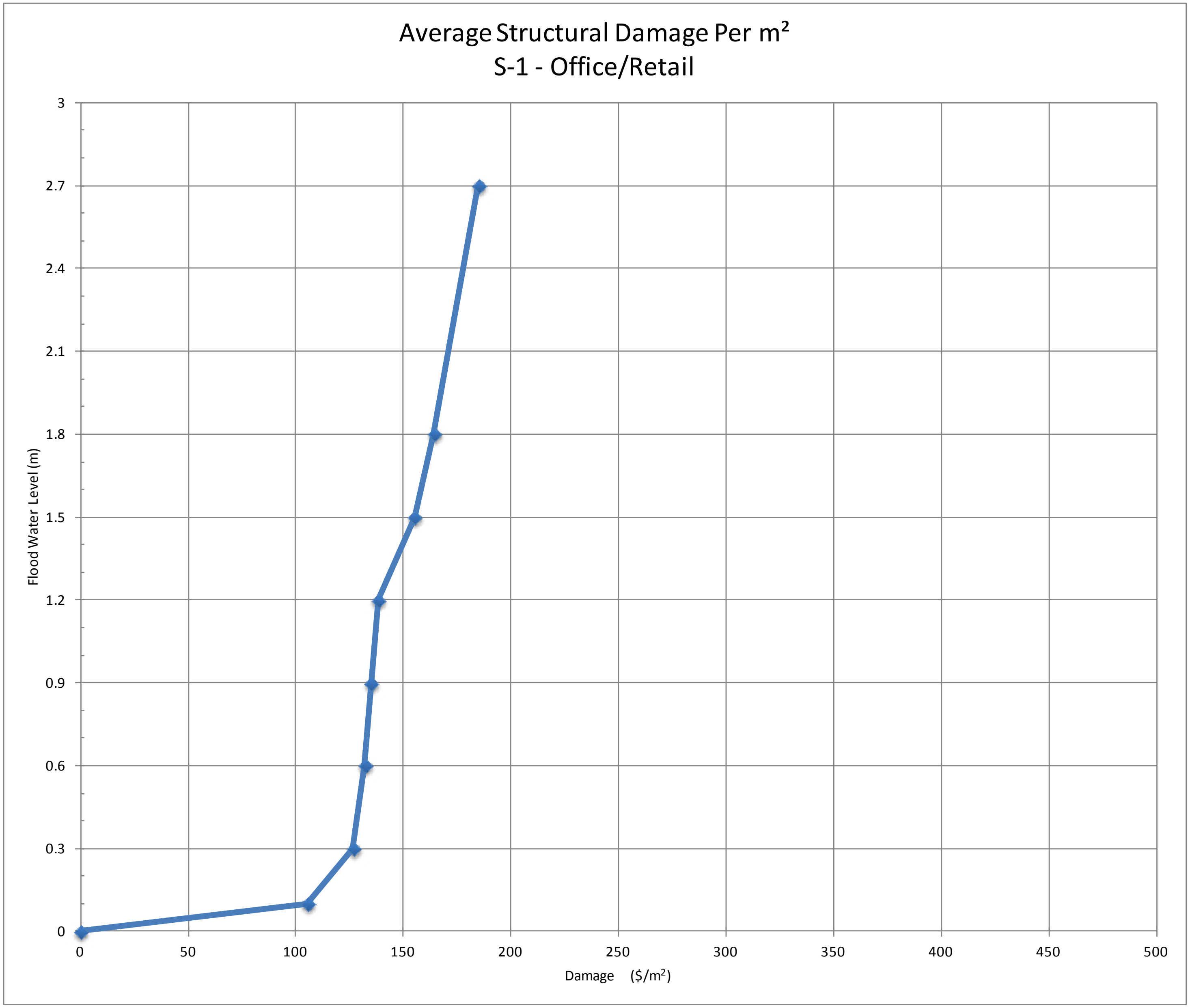
Summary of Specifications for Typical Building – Commercial (Office / Retail)

Structure	Poured concrete foundation wall, concrete slab on grade, load bearing masonry wall or light steel frame with steel joist and metal decking, convention or SBS roof.	
Ext. Cladding	Walls:	-Exposed masonry – unfinished. -Exposed masonry – painted. -Prefinished metal siding. -Stucco on masonry or steel stud. -Stone or brick veneer on masonry or steel stud. -Wood panels on masonry or steel stud.
	Windows:	-Prefinished metal with fixed glazing.
	Roof:	-Conventional 4-ply built-up or SBS on insulation and metal decking.
Interior Finishes		
Ground Floor:	Floor:	-Concrete slab – painted or unpainted. -Linoleum or VCT on concrete slab. -Ceramic tile on concrete slab. -Carpet on concrete slab. -Wood laminate on concrete slab.
	Walls:	-Drywall on steel stud - painted.
	Doors:	-Solid / hollow core wood.
	Ceiling:	-Suspended drywall or acoustic tile.
	Washrooms:	-Cabinets, plywood body, solid wood doors and drawers, P-Lam counters.
Mechanical	-Packaged heating and cooling units on roof. Zoned per level.	
Note:	-Where two or more materials are shown, unit costs have been averaged.	

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
Ground Floor							
0 – 0.1	• Remove existing flooring. Clean and prepare slab. Install new flooring.	108	m²	$65	$7,020		
	• Remove existing carpet. Clean slab & install new carpeting.	195	m²	$90	$17,550		
	• Remove and replace baseboards.	97	linear m	$6	$582		
	• Check and clean heating units.	8	hours	$75	$600		
	• Clean and sanitize all structural components after demolition is completed.	16	hour	$125	$2,000		
	• Clean and sanitize all exterior building finishes.	16	hour	$125	$2,000		
	• Implement structural drying.	24	hour	$75	$1,800		
						$31,552	$31,552
0.3	• Remove and replace drywall 150mm above soak line.	43	m²	$30	$1,290		
	• Remove and replace insulation 150mm above soak line.	18	m²	$3	$45		
	• Remove and replace all doors & hardware.	6	door	$350	$2,100		
	• Remove and replace all wood casings and door jambs.	6	opening	$90	$540		
	• Remove, clean and re-install washroom toilet and sink.	1	washroom	$500	$500		
	• Remove and replace washroom cabinets.	1	cabinet	$750	$750		
	• Remove and replace hot water heater.	1	unit	$1,200	$1,200		
						$6,425	$37,977
0.6	• Remove and replace drywall 150mm above soak line.	29	m²	$30	$870		
	• Remove and replace insulation 150mm above soak line.	12	m²	$3	$30		
	• Remove and replace electrical outlets and check wiring.	10	hour	$75	$750		
						$1,650	$39,627

Datum	Description of Restoration	Cost to Repair					Cumulative Total
		No. of Units	Unit	$/Unit	Cost	Total	
0.9	• Remove and replace drywall 150mm above soak line.	29	m²	$30	$870		
	• Remove and replace insulation 150mm above soak line.	12	m²	$3	$30		
						$900	$40,527
1.2	• Remove and replace drywall 150mm above soak line.	29	m²	$30	$870		
	• Remove and replace insulation 150mm above soak line.	12	m²	$3	$30		
						$900	$41,427
1.5	• Remove and replace drywall 150mm above soak line.	29	m²	$30	$870		
	• Remove and replace insulation 150mm above soak line.	12	m²	$3	$30		
	• Remove and replace electrical switches and wiring back to the service panel.	16	hour	$75	$1,200		
	• Remove and replace electrical service panel.	2	panel	$1,500	$3,000		
						$5,100	$46,527
1.8 – 2.4	• Remove and replace drywall to full height.	86	m²	$30	$2,580		
	• Remove and replace insulation to full height.	36	m²	$3	$90		
						$2,670	$49,197
2.7 (Ceiling)	• Remove and replace ceiling system.	115	m²	$30	$3,450		
	• Remove and replace electrical light fixtures.	10	fixture	$200	$2,000		
	• Caulk at exterior windows.	4	window	$200	$800		
						$6,250	$55,447
					Grand Total	**$55,447**	**$55,447**

Non-Residential Structural Damage Curves



Summary of Specifications for Typical Building – Commercial (Industrial / Warehouse)

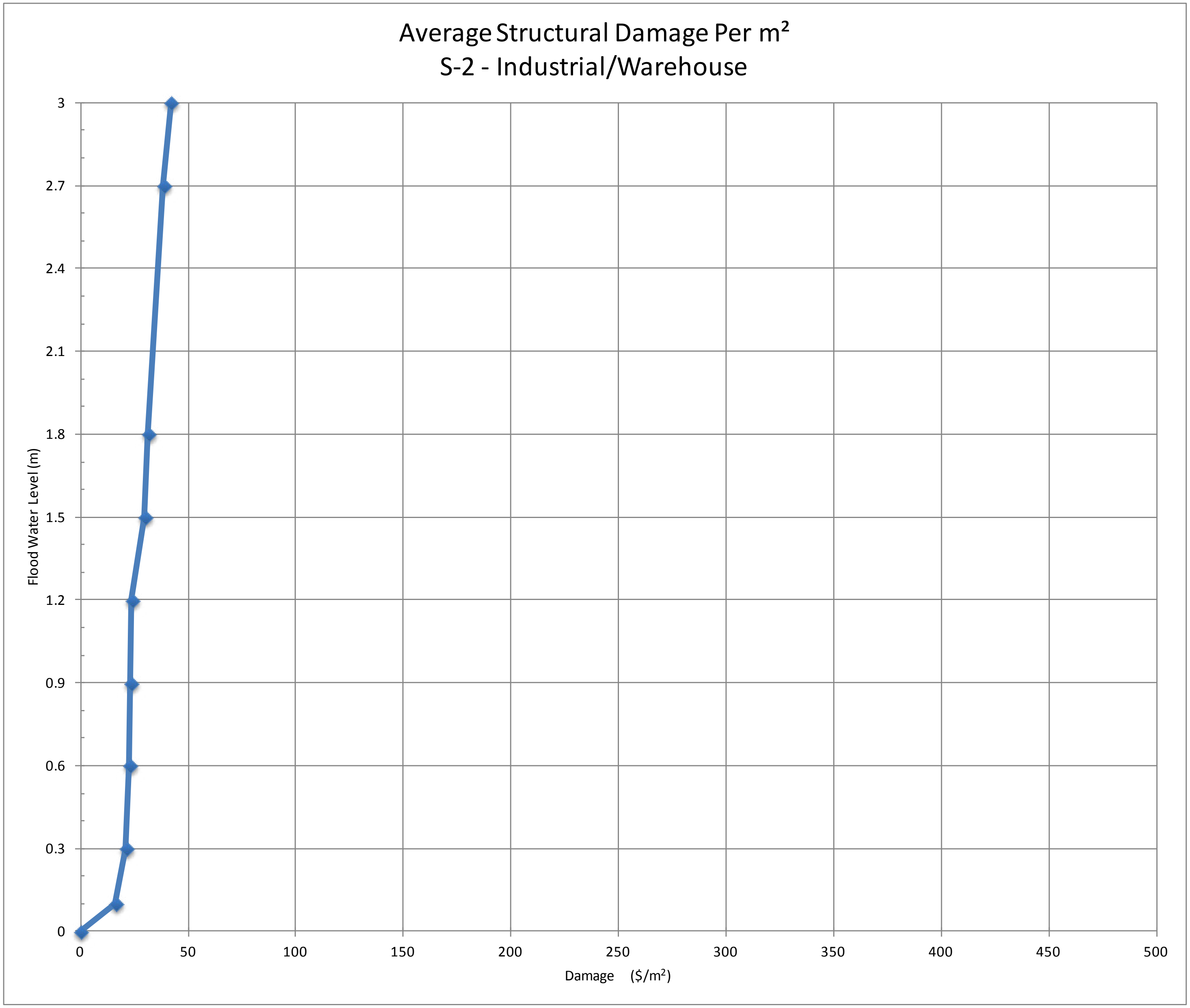
Structure	Poured concrete foundation wall, concrete slab on grade, load bearing masonry wall or Systems steel frame with steel joist and metal decking or metal prefinished systems roof.	
Ext. Cladding	Walls:	-Exposed masonry – unfinished. -Exposed masonry – painted. -Prefinished metal siding.
	Windows:	-Prefinished metal with fixed glazing.
	Roof:	-Conventional 4-ply built-up membrane on insulation and metal decking. - Insulated sloping metal systems roof.
Interior Finishes		
Ground Floor:	Floor:	-Concrete slab – painted or unpainted. -Linoleum or VCT on concrete slab. -Ceramic tile on concrete slab. -Carpet on concrete slab.
	Walls:	-Drywall on steel stud - painted.
	Doors:	-Solid / hollow core wood.
	Ceiling:	-Suspended drywall or acoustic tile.
	Washrooms:	-Cabinets, plywood body, solid wood doors and drawers, P-Lam counters.
Mechanical	-Packaged heating and cooling units on roof. Zoned per level.	
Note:	-Where two or more materials are shown, unit costs have been averaged.	

Datum	Description of Restoration	Cost to Repair				Cumulative Total
		No. of Units	Unit	$/Unit	Cost	
Ground Floor						
0 – 0.1	• Remove existing flooring. Clean and prepare slab. Install new flooring.	87	m²	$65	$5,655	
	• Remove existing carpet. Clean slab & install new carpeting.	8	m²	$90	$720	
	• Remove and replace baseboards.	49	linear m	$6	$294	
	• Check and clean heating units.	4	hours	$75	$300	
	• Clean and sanitize all structural components after demolition is completed.	16	hour	$125	$2,000	
	• Clean and sanitize all exterior building finishes.	16	hour	$125	$2,000	
	• Implement structural drying.	24	hour	$75	$1,800	
						$12,769
0.3	• Remove and replace drywall 150mm above soak line.	22	m²	$30	$660	
	• Remove and replace insulation 150mm above soak line.	23	m²	$3	$58	
	• Remove and replace all doors & hardware.	2	door	$350	$700	
	• Remove and replace all wood casings and door jambs.	2	opening	$90	$180	
	• Remove, clean and re-install washroom toilet and sink.	1	washroom	$500	$500	
	• Remove and replace washroom cabinets.	1	cabinet	$750	$750	
	• Remove and replace hot water heater.	1	unit	$1,200	$1,200	
						$4,048
0.6	• Remove and replace drywall 150mm above soak line.	15	m²	$30	$450	

Datum	Description of Restoration	Cost to Repair				Cumulative Total
		No. of Units	Unit	$/Unit	Cost	
	• Remove and replace insulation 150mm above soak line.	16	m²	$3	$40	
	• Remove and replace electrical outlets and check wiring.	10	hour	$75	$750	
						$1,240
0.9	• Remove and replace drywall 150mm above soak line.	15	m²	$30	$450	
	• Remove and replace insulation 150mm above soak line.	16	m²	$3	$40	
						$490
1.2	• Remove and replace drywall 150mm above soak line.	15	m²	$30	$450	
	• Remove and replace insulation 150mm above soak line.	16	m²	$3	$40	
						$490
1.5	• Remove and replace drywall 150mm above soak line.	15	m²	$30	$450	
	• Remove and replace insulation 150mm above soak line.	16	m²	$3	$40	
	• Remove and replace electrical switches and wiring back to the service panel.	16	hour	$75	$1,200	
	• Remove and replace electrical service panel.	2	panel	$1,500	$3,000	
						$4,690
1.8 – 2.4	• Remove and replace drywall to full height.	43	m²	$30	$1,290	
	• Remove and replace insulation to full height.	46	m²	$3	$115	
						$1,405

Datum	Description of Restoration	Cost to Repair				Cumulative Total
		No. of Units	Unit	$/Unit	Cost	
2.7 (Ceiling)	• Remove and replace ceiling system. • Caulk at exterior windows.	158 4	m² window	$30 $200	$4,740 $800	
						$5,540
3.0 – 4.2	• Service and repair HVAC systems. • Remove and replace electrical light fixtures.	12 10	hour fixture	$75 $200	$900 $2,000	
						$2,900
					Grand Total	**$33,572**

Non-Residential Structural Damage Curves



Summary of Specifications for Typical Building – Commercial (Hotel / Motel)

Structure	Poured concrete foundation wall, concrete slab on grade, load bearing masonry wall or steel frame with steel joist and concrete slab.	
Ext. Cladding	Walls:	-Steel studs, gypsum sheathing and brick veneer.
	Windows:	-Prefinished metal or aluminum sliders in wood frames.
	Roof:	-Conventional 4-ply built-up or SBS on insulation and metal decking.
Interior Finishes		
Ground Floor:	Floor:	-Linoleum -VCT tile -Laminate -Carpet
	Walls:	-Drywall painted.
	Ceiling:	-Drywall stippled.
	Insulation:	-Walls (R12) -Ceiling (R20) -6mil poly V.B.
	Cabinets:	-Plywood body, solid wood doors and drawers, P-Lam counters.
	Bathroom:	-Tile to ceiling above tub or fibreglass tub enclosure.

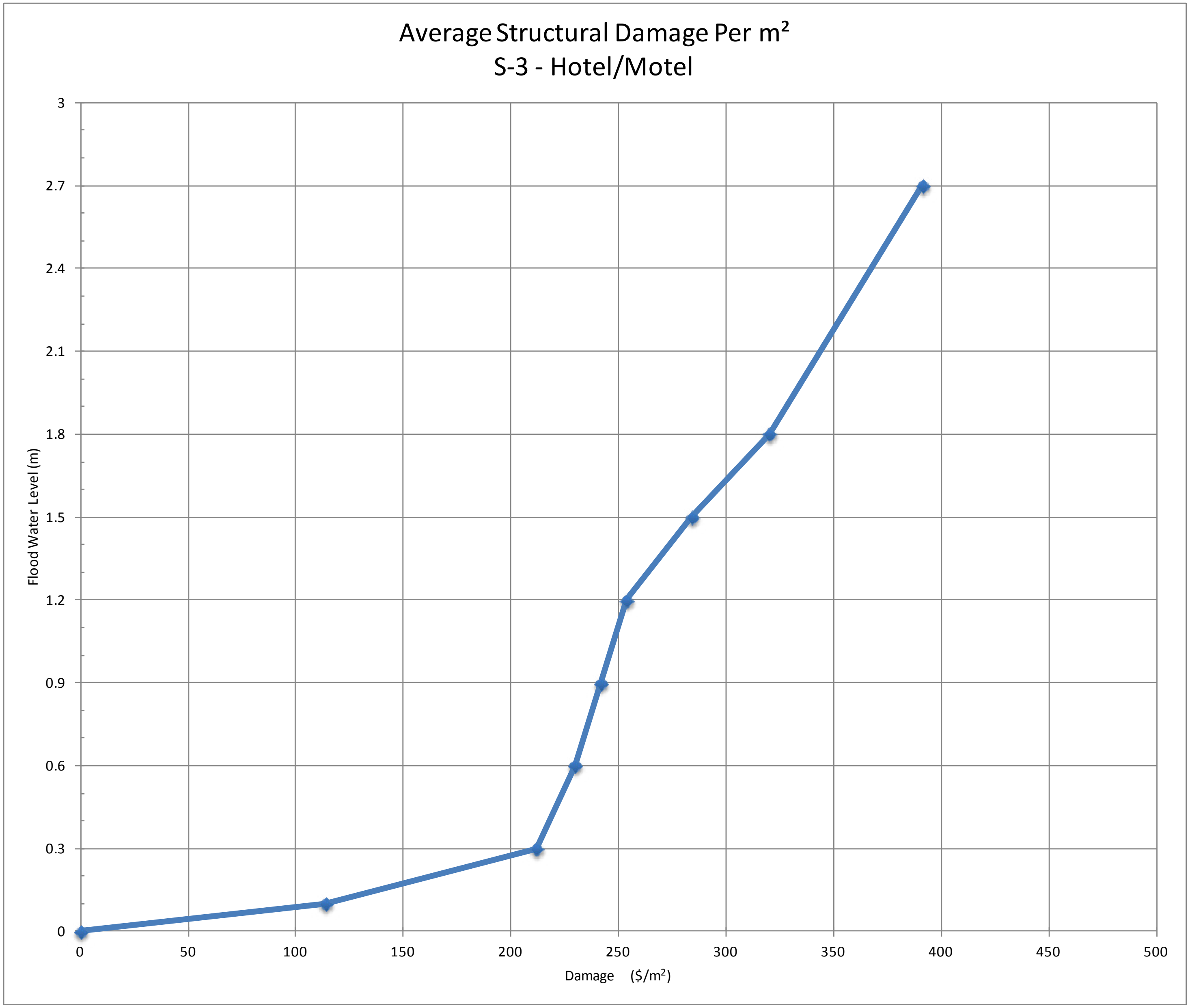
Note: -Where two or more materials are shown, unit costs have been averaged.

Datum	Description of Restoration	Cost to Repair				Cumulative Total
		No. of Units	Unit	$/Unit	Cost	
Ground Floor						
0 – 0.1	• Remove existing flooring. Clean and prepare slab. Install new flooring.	125	m²	$65	$8,125	
	• Remove existing carpet. Clean slab & install new carpeting.	125	m²	$90	$11,250	
	• Remove and replace baseboards.	330	linear m	$6	$1,980	
	• Check and clean heating units.	16	hours	$75	$1,200	
	• Clean and sanitize all structural components after demolition is completed.	16	hour	$125	$2,000	
	• Clean and sanitize all exterior building finishes.	16	hour	$125	$2,000	
	• Implement structural drying.	24	hour	$75	$1,800	
						$28,355
0.3	• Remove and replace drywall 150mm above soak line.	148	m²	$30	$4,440	
	• Remove and replace insulation 150mm above soak line.	40	m²	$3	$100	
	• Remove and replace all doors & hardware.	20	door	$350	$7,000	
	• Remove and replace all wood casings and door jambs.	20	opening	$90	$1,800	
	• Remove, clean and re-install washroom toilet and sink.	8	washroom	$500	$4,000	
	• Remove and replace washroom cabinets.	8	cabinet	$750	$6,000	
	• Remove and replace hot water heater.	1	unit	$1,200	$1,200	
						$24,540
0.6	• Remove and replace drywall 150mm above soak line.	98	m²	$30	$2,940	

Datum	Description of Restoration	Cost to Repair				Cumulative Total
		No. of Units	Unit	$/Unit	Cost	
	• Remove and replace insulation 150mm above soak line.	26	m²	$3	$65	
	• Remove and replace electrical outlets and check wiring.	20	hour	$75	$1,500	
						$4,505
0.9	• Remove and replace drywall 150mm above soak line.	98	m²	$30	$2,940	
	• Remove and replace insulation 150mm above soak line.	26	m²	$3	$65	
						$3,005
1.2	• Remove and replace drywall 150mm above soak line.	98	m²	$30	$2,940	
	• Remove and replace insulation 150mm above soak line.	26	m²	$3	$65	
						$3,005
1.5	• Remove and replace drywall 150mm above soak line.	98	m²	$30	$2,940	
	• Remove and replace insulation 150mm above soak line.	26	m²	$3	$65	
	• Remove and replace electrical switches and wiring back to the service panel.	20	hour	$75	$1,500	
	• Remove and replace electrical service panel.	2	panel	$1,500	$3,000	
						$7,505
1.8 – 2.4	• Remove and replace drywall to full height.	295	m²	$30	$8,850	
	• Remove and replace insulation to full height.	79	m²	$3	$198	
						$9,048

Datum	Description of Restoration	Cost to Repair				Cumulative Total
		No. of Units	Unit	$/Unit	Cost	
2.7 (Ceiling)	• Remove and replace ceiling system. • Remove and replace electrical light fixtures. • Caulk at exterior windows.	405 20 8	m² fixture window	$30 $200 $200	$12,150 $4,000 $1,600	**$17,750**
					Grand Total	**$97,713**

Non-Residential Structural Damage Curves



Summary of Specifications for Typical Building – Commercial (High-Rise Residential/Office)

Structure	Poured concrete, foundation, parkade, columns and horizontal floor slabs including stairs.	
Ext. Cladding	Walls:	-Stone masonry cladding on concrete. -Stone masonry cladding on concrete block. -Stone masonry cladding on metal studs. -Aluminum composite panels on concrete. -Aluminum composite panels on metal studs. -Composite wood panels on metal studs.
	Windows:	-Window wall system with glass or metal panel spandrels.
Interior Finishes		
Parkade:	Floor:	-Concrete painted or unfinished.
	Walls:	-Poured concrete or masonry – painted or unfinished.
	Doors:	-Hollow metal & pressed steel frames.
	Ceiling:	-Concrete painted.
Ground Floor:	Floor:	-Stone tile. -Carpet.
	Base:	-Rubber. -MDF wood. -Stone tile.
	Walls:	-Stone tile. -Stone veneer. -Wood veneer. -Drywall painted. -P-Lam panel.
	Doors:	-Steel with pressed steel frame. -Hollow metal with pressed steel frame. -Hollow core wood with wood frame. -Solid core wood pressed steel frame. -Aluminum with aluminum frame. -Glass with aluminum frame.
	Ceiling:	-Drywall stippled. -Drywall painted. -Concrete painted. -Concrete stippled. -Exposed structure. -T-bar system – acoustic. -T-bar system – wood.

Insulation:	-Acoustic fire batt insulation (int.). -Rigid board insulation (ext.). -Breathable vapour barrier membrane.
Cabinets:	Plywood body, solid wood doors and drawers, P-Lam counters.
Bathroom:	Tile to ceiling above tub.

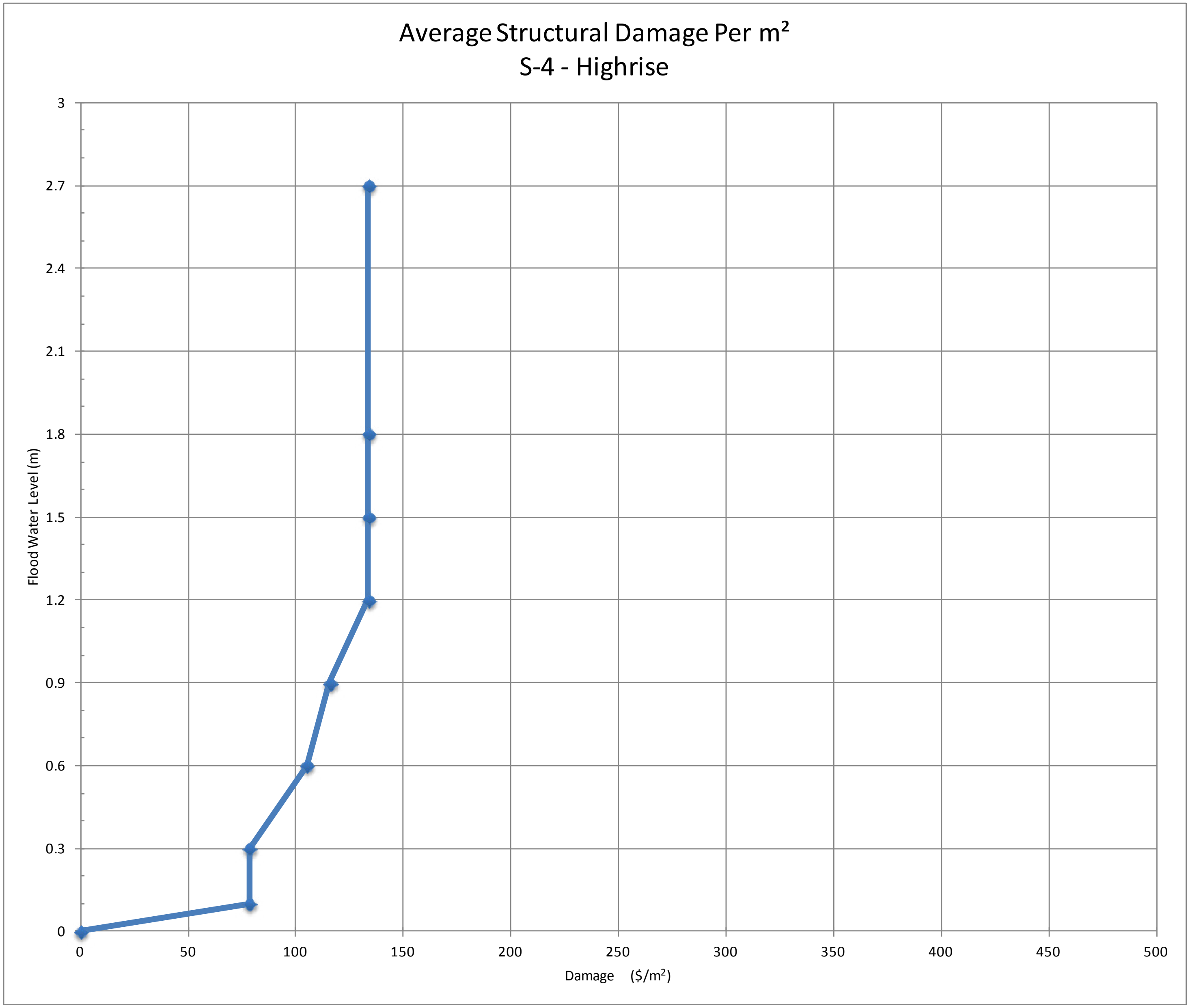
Note: -Where two or more materials are shown, unit costs have been averaged.

Datum	Description of Restoration	Cost to Repair				Cumulative Total
		No. of Units	Unit	$/Unit	Cost	
Parkade (Per Level)						
	• Remove and replace or rebuild Mechanical System equipment. • Clean and sanitize all structural components after demolition is completed. • Clean all sumps, floor drains and backflow preventers. • Implement structural drying. • Paint all components required after cleaning and drying is completed. • Remove and replace all doors & hardware.					
Note	Parkade restoration is calculated at $215/m2 ($20/ft2) based on floor area per level.	750	m²	$215	$161,250	
Main Level						
0 – 0.1	• Remove existing flooring. Clean and prepare slab. Install new flooring.	50	m²	$65	$3,250	
	• Remove existing carpet. Clean and prepare slab. Install new carpeting.	50	m²	$90	$4,500	
	• Remove and replace baseboards.	150	linear m	$6	$900	
	• Remove and replace all drywall to walls & ceilings.	450	m²	$30	$13,500	
	• Remove and replace all poly vapour barrier.	350	m²	$1	$350	
	• Remove and replace all insulation.	350	m²	$3	$875	
	• Remove and replace all doors & hardware.	8	door	$800	$6,400	
	• Remove and replace all wood casings and door jambs.	8	opening	$100	$800	
	• Remove and replace all kitchen cabinets and counter tops.	1	kitchen	$20,000	$20,000	
	• Remove, clean and re-install bathroom toilet, sink and tub.	2	bathroom	$500	$1,000	

Datum	Description of Restoration	Cost to Repair				Cumulative Total
		No. of Units	Unit	$/Unit	Cost	
	• Remove and replace bathroom cabinets.	2	cabinet	$750	$1,500	
	• Clean and sanitize all structural components after demolition is completed.	16	hour	$125	$2,000	
	• Clean and sanitize all exterior building finishes.	16	hour	$125	$2,000	
	• Implement structural drying.	24	hour	$75	$1,800	
						$58,875
0.3	• N/A					
						$0
0.6	• Remove and replace electrical outlets, switches, light fixtures and wiring back to the service panels.	1	main floor	$5,000	$5,000	
	• Replace elevator doors	2	each	$7,500	$15,000	
						$20,000
0.9	• Inspect and re-seal window wall system.	8	hour	$50	$400	
	• Replace Secutity DVR	1	each	$6,500	$6,500	
	• Check & clean heating units.	8	hour	$50	$400	
	• Check, clean and service Electrical service.	8	hour	$75	$600	
						$7,900
1.2	• Replace fire alarm control panel	1	each	$7,500	$7,500	
	• Replace intercom access panel	1	each	$6,000	$6,000	
						$13,500

Datum	Description of Restoration	Cost to Repair				Cumulative Total
		No. of Units	Unit	$/Unit	Cost	
Corridors, Amenity Areas, Lobby, Office, Stairs & Service Rooms:	• Average level of finish. Add 30% to level of damage in typical unit. As denoted by *.					
					Grand Total	**$100,275**

Non-Residential Structural Damage Curves



Summary of Specifications for Typical Building – Commercial (Institutional)

Structure	Poured concrete, foundation, crawl space, columns and structural floor slabs including steel beams and joists with load bearing masonry walls.	
Ext. Cladding	Walls:	-Metal cladding on concrete block. -Split faced block on concrete block. -Manufactured stone on concrete block. -Metal cladding on steel studs. -Split faced block on steel studs. -Composite aluminum panels on steel studs.
	Windows:	-Aluminum framed sealed double glazed window unit.
Interior Finishes		
Crawl Space:	Floor:	-50mm sand bed on 6 mil poly vapour barrier.
	Walls:	-Poured concrete – unfinished.
	Doors:	-Steel access hatches with steel frames.
	Ceiling:	-Exposed structure.
Main Floor:	Floor:	-Ceramic tile. -Carpet. -Linoleum. -Hardwood. -Concrete – finished & unfinished.
	Base:	-Rubber. -Wood. -Ceramic tile. -Carpet.
	Walls:	-Ceramic tile. -Stone veneer. -Wood veneer. -Drywall painted. -P-Lam panel.
	Doors:	-Steel with pressed steel frame. -Hollow metal with pressed steel frame. -Solid core wood pressed steel frame. -Aluminum with aluminum frame.
	Ceiling:	-Drywall painted. -Concrete painted. -Exposed structure. -T-bar system – acoustic.

Insulation:	-Batt insulation.
Millwork:	Plywood body, solid wood doors and drawers, P-Lam counters.
Washrooms:	Full height tile to all walls.

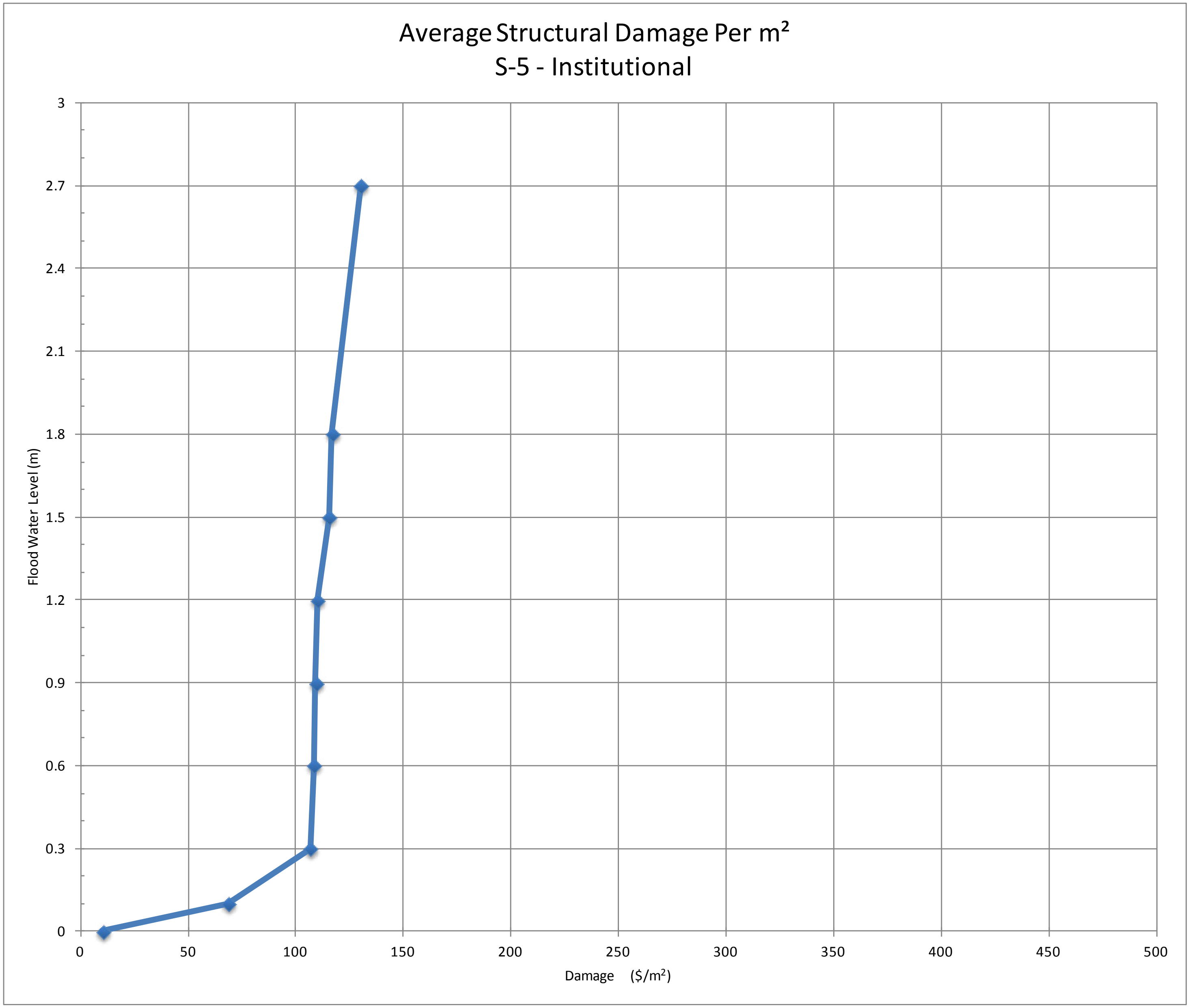
Note: -Where two or more materials are shown, unit costs have been averaged.

Datum	Description of Restoration	Cost to Repair				Cumulative Total
		No. of Units	Unit	$/Unit	Cost	
Crawl Space						
0 – 0.1	• Clean and sanitize all Mechanical piping and ductwork. • Clean and sanitize all structural components. • Clean all sumps, floor drains and backflow preventers. • Implement structural drying.	3983	m²	$10	$39,830	
						$39,830
Main Floor						
0 – 0.1	• Remove existing flooring. Clean and prepare slab. Install new flooring.	1465	m²	$65	$95,225	
	• Remove existing carpet. Clean and prepare slab. Install new carpeting.	568	m²	$90	$51,120	
	• Remove existing wood flooring. Clean and prepare slab. Install new wood flooring.	486	m²	$140	$68,040	
	• Remove and replace all baseboard materials.	1000	linear m	$6	$6,000	
	• Clean and sanitize all structural components after demolition is completed.	36	hour	$125	$4,500	
	• Clean and sanitize all exterior building finishes.	36	hour	$125	$4,500	
	• Implement structural drying.	40	hour	$75	$3,000	
						$232,385
0.3	• Remove and replace drywall 150mm above soak line.	107	m²	$30	$3,210	
	• Remove and replace Interior insulation 150mm above soak line.	107	m²	$3	$268	

Datum	Description of Restoration	Cost to Repair				Cumulative Total
		No. of Units	Unit	$/Unit	Cost	
	• Remove and replace all wood door slabs & hardware.	60	door	$500	$30,000	
	• Remove, clean and re-install washroom fixtures.	14	washroom	$1,500	$21,000	
	• Remove and replace washroom Millwork.	14	cabinet	$750	$10,500	
	• Remove and replace all Millwork.	2500	m²	$35	$87,500	
						$152,478
0.6	• Remove and replace drywall 150mm above soak line.	107	m²	$30	$3,210	
	• Remove and replace insulation 150mm above soak line.	107	m²	$3	$268	
	• Remove and replace electrical outlets and check wiring.	40	hour	$75	$3,000	
						$6,478
0.9	• Remove and replace drywall 150mm above soak line.	107	m²	$30	$3,210	
	• Remove and replace insulation 150mm above soak line.	107	m²	$3	$268	
						$3,478
1.2	• Remove and replace drywall 150mm above soak line.	107	m²	$30	$3,210	
	• Remove and replace insulation 150mm above soak line.	107	m²	$3	$268	
						$3,478
1.5	• Remove and replace drywall 150mm above soak line.	107	m²	$30	$3,210	
	• Remove and replace insulation 150mm above soak line.	107	m²	$3	$268	
	• Remove and replace electrical outlets switches.	80	hour	$75	$6,000	

Datum	Description of Restoration	Cost to Repair				Cumulative Total
		No. of Units	Unit	$/Unit	Cost	
	• Remove and replace electrical service panels.	8	panel	$1,500	$12,000	
						$21,478
1.8 – 2.4	• Remove and replace drywall to full height.	150	m²	$30	$4,500	
	• Remove and replace insulation to full height.	150	m²	$3	$375	
						$4,875
2.7 & Above	• Remove and replace ceiling system.	375	m²	$30	$11,250	
	• Remove and replace electrical light fixtures.	150	fixture	$200	$30,000	
	• Caulk at exterior windows.	50	window	$250	$12,500	
						$53,750
					Grand Total	**$518,228**

Non-Residential Structural Damage Curves



Appendix I – Non-Residential Structural Damage Values

Non-Residential Structural Damage Values

Non-residential structures damages by interior elevation and classification, Calgary, $/m2 floor area, 2014$

Interior elevation		Non-residential structural classification: S1 - Office/Retail	S2 - Industrial/ Warehouse	S3 - Hotel/Motel	S4 - Highrise	S5 - Institutional
Top of Level 1 (main) floor	0.0	$0	$0	$0	$0	$10
	0.1	$105	$16	$113	$79	$68
	0.3	$127	$21	$212	$79	$107
	0.6	$132	$23	$230	$105	$108
	0.9	$135	$23	$242	$116	$109
	1.2	$138	$24	$254	$134	$110
	1.5	$155	$30	$284	$134	$115
	1.8	$164	$31	$320	$134	$117
	2.7	$185	$38	$391	$134	$130
Level 1 (main) ceiling	3.0	$185	$42	$391	$134	$130

Damages exclude underground parking structures and landscape remediation

Appendix J – Selected References

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APPENDIX 3-2 PROVINCIAL FLOOD DAMAGE ASSESSMENT STUDY CITY OF CALGARY: ASSESSMENT OF DAMAGES (2015), ENVIRONMENT AND SUSTAINABLE RESOURCE DEVELOPMENT. PREPARED BY IBI GROUP.

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT
RESPONSE TO NRCB AND AEP SUPPLEMENTAL INFORMATION REQUEST 2,
DATED NOVEMBER 18, 2019

Appendix 3-2 Provincial Flood Damage Assessment Study City of Calgary: Assessment of Damages (2015), Environment and Sustainable Resource Development. Prepared by IBI Group.
June 2020

REPORT

Provincial Flood Damage Assessment Study City of Calgary: Assessment of Flood Damages

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

IBI GROUP
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February 6, 2015

Ms. Heather Ziober
Project Manager, Strategic Integration and Projects
Government of Alberta
Environmental and Sustainable Resource Development
205 J.G. O'Donoghue Building
7000 - 113 Street
Edmonton, AB T6H 5T6

Dear Ms. Ziober:

PROVINCIAL FLOOD DAMAGE ASSESSMENT STUDY
CITY OF CALGARY: ASSESSMENT OF FLOOD DAMAGES

Enclosed please find the draft final report for the aforementioned assignment. The report describes in detail flood damages for the City of Calgary under a range of return frequencies from 1:2 year to 1:1000 year. Damages were calculated employing updated curves and the Rapid Flood Damage Assessment Model developed specifically to assess damages within the Province of Alberta.

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

Yours truly,

IBI GROUP

Stephen Shawcross
Director

Augusto Ribeiro, P.Eng.

SS/mp

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

J:\36910_PrvnFldDmgSt\10.0 Reports\10.5 Text\Part 2 - Calgary\PTL-Ziober-GovofAB-PFDAS-Calgary_2015-02-06.docx\2015-02-06\MP

Provincial Flood Damage Assessment Study
City of Calgary: Assessment of Flood Damages

Prepared for Government of Alberta
ESRD - Resilience and Mitigation
by IBI Group and Golder Associates Ltd.
February 2015

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Executive Summary

Executive Summary

Introduction

Background

Flood damage estimates are required for evaluating the cost effectiveness of projects designed to alleviate flood impacts. Accordingly, in July of 2014 IBI Group along with Golder Associates Ltd. were retained by the Alberta Government, ESRD Operations, Resilience and Mitigation Branch to undertake the Provincial Flood Damage Assessment Study.

The purpose of the study was threefold:

1. to update/develop flood damage curves in select communities at risk of flooding to 2014 economic values and establish adjustment indices for their use in different flood prone communities across Alberta;
2. to develop a computerized model for estimating flood damages; and
3. to undertake flood damage estimates for select communities throughout Alberta.

The first two components of the Provincial Flood Damage Assessment Study have been completed and are available under separate cover. The City of Calgary was identified as a high priority centre and selected as the pilot municipality for the updating of flood damage curves and development of a Rapid Flood Damage Assessment Model. It is the subject of this study.

Purpose

The primary purpose of the study is to estimate flood damages for a range of flood events such that average annual damages can be computed and employed in a subsequent benefit/cost analysis of potential flood mitigation alternatives.

Scope

The study applies the Rapid Flood Damage Assessment Model to estimate damages using a variety of primary and secondary data sources including tax assessment records and GIS data.

Methodology

To allow for a consistent approach to the evaluation of flood mitigation alternatives, the Province has adopted a standard methodology for flood damage assessment. It employs updated depth-damage curves for various categories of residential and non-residential structures and their contents based on extensive first and second order research including representative sampling of residences and non-residential structures within selected functional groups. The values reflect current residential content and non-residential inventory, display and storage practices. It also employs a Rapid Flood Damage Assessment Model, a computerized relational database for mass assessment of flood damages developed specifically for Alberta using local assessment and GIS data.

City of Calgary

Background

The City of Calgary is the largest city in Alberta and the third largest municipality and fifth largest Census Metropolitan Area (CMA) in Canada. It is situated at the confluence of the Bow River and the Elbow River in the southern part of the Province, in an area of foothills and prairie, approximately 80 km (50 miles) east of the front ranges of the Canadian Rockies.

History of Flooding

Major floods have occurred on the Bow River in 1902, 1915, 1929, 1932 and 2013. Major floods have occurred on the Elbow River in 1915, 1923, 1929, 1932, 2005 and 2013. These are traditionally summer floods caused by a combination of snowmelt and saturated ground conditions, in combination with heavy storms.

There is a continuous record from 1911 of Bow River flows at Calgary; the three largest known floods all occurred before 1911 – in 1879, 1897 and 1902. Reasonably reliable estimates are available for the floods of 1897 and 1902. The fourth-highest known flood at Calgary occurred in 1932. Due to the fortunate coincidence that the just-constructed Glenmore Reservoir, its reservoir still dry, stood in the path of that flood, the damage and disruption caused was much less than might have been expected.

Floodplain Mapping

Nine flood elevations were employed to compute flood damages, including the 1:2, 1:5, 1:10, 1:15, 1:20, 1:50, 1:100, 1:200, 1:500, and 1:1000 year flood events. Flood elevation data was based on the hydraulic output of the HEC-RAS Model provided by the City of Calgary and based on the Bow and Elbow River updated hydraulic model project by Golder Associates dated April 2012.

Inventory of Buildings

Within the identified flood hazard area, which includes the 1:100 year design flood plus a 75 m buffer, the number of buildings totals approximately 7,200 (excluding outbuildings such as garages and storage sheds) and is comprised of 5,620 single-family residential dwellings; 728 semi-detached, triplex and townhouse-style dwelling units; 275 multi-family apartment buildings; and 564 non-residential (commercial/industrial/institutional) buildings.

Damage Estimates

Total damages for the Bow and Elbow Rivers with the sewer backup condition are detailed in Exhibit 3.13 and summarized as follows.

Residential Damages

Direct residential damages equate to $687 million under 1:100 year flood conditions and constitute some 59% of total direct damages.

Commercial Damages

Commercial direct damages equate to $111 million for the 1:100 year flood event or just under 10% of total direct damages.

Infrastructure Damages

Infrastructure damages for the 1:100 year flood are estimated at $299 million or 26% of total direct damages.

Damages to Stampede Park

Direct damages to Stampede Park, including the Saddledome, for the 1:100 year flood equate to $69 million or 6% of total direct damages.

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

Indirect Damages

Indirect damages by themselves constitute some $649 million or 56% under 1:100 year flood conditions. (Indirect damages equate to a higher proportion of direct damages for the lower frequency floods; the unweighted average indirect share is 73% across the range of events.) This is an exceptionally high proportion, driven by commercial indirect damages and Stampede indirect damages in particular.

Total Damages

Total damages including direct and indirect damages for the 1:100 year flood are estimated at $1.815 billion for the Bow and Elbow Rivers combined, with sewer backup damages included.

Average Annual Damages

Average annual damages for the Bow and Elbow combined are $84,431,000 and for the Elbow by itself, $30,111,000.

Alternative Damage Scenario

The previous damage assessment is reflective of worst case conditions, in particular as it relates to commercial indirect damages, Stampede indirect damages and infrastructure damage, especially at the higher flood frequencies. An alternative damage scenario has been developed which reduces damage in these categories.

Exhibit 3.19 describes the reduced total damage estimates. As evidenced, total damages for the Bow and Elbow Rivers for the 1:100 year event have been reduced from $1.815 billion to $1.237 billion with a concomitant reduction in average annual damage from $84,431,000 to $56,342,000. For the Elbow the average annual damage has been reduced from $30,111,000 to $21,729,000.

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

1 Introduction

1 Introduction

1.1 Background

Flood damage estimates are required for evaluating the cost effectiveness of projects designed to alleviate flood impacts. Accordingly, in July of 2014 IBI Group along with Golder Associates Ltd. were retained by the Alberta Government, ESRD Operations, Resilience and Mitigation Branch to undertake the Provincial Flood Damage Assessment Study.

The purpose of the study was threefold:

1. to update/develop flood damage curves in select communities at risk of flooding to 2014 economic values and establish adjustment indices for their use in different flood prone communities across Alberta;
2. to develop a computerized model for estimating flood damages; and
3. to undertake flood damage estimates for select communities throughout Alberta.

The first two components of the Provincial Flood Damage Assessment Study have been completed and are available under separate cover. The City of Calgary was identified as a high priority centre and selected as the pilot municipality for the updating of flood damage curves and development of a Rapid Flood Damage Assessment Model. It is the subject of this study.

1.2 Purpose

The primary purpose of the study is to estimate flood damages for a range of flood events such that average annual damages can be computed and employed in a subsequent benefit/cost analysis of potential flood mitigation alternatives.

1.3 Scope

The study applies the Rapid Flood Damage Assessment Model to estimate damages using a variety of primary and secondary data sources including tax assessment records and GIS data.

2 Methodology

2 Methodology

To allow for a consistent approach to the evaluation of flood mitigation alternatives, the Province has adopted a standard methodology for flood damage assessment. It is briefly summarized hereinafter.

For a more detailed description of best practices, principles and guidelines refer to the Alberta Government Bulletin contained in **Appendix A**.

2.1 Preamble

In a flood event, direct damages can occur both to buildings and infrastructure because of the inundation (hydrostatic effects) and action of the moving water (hydrodynamic effects).

Direct flood damages to residential dwellings includes both content and structural damages as well as the clean-up costs. Flood damages for commercial properties includes damage to inventory, equipment, and buildings in addition to clean-up costs. As with the residential component, these damages are generally calculated separately for contents and structures.

The commercial structures, due to the nature, range, and diversity of business activities, do not demonstrate the same uniformity in terms of damage per unit as residential structures. Consequently, categorization is a much more complicated procedure, and the grouping of similar functions for the purposes of estimating flood damages is done in order to maintain study costs within economic reason.

In a first principles approach, damages for residential and commercial/industrial units are estimated employing the updated synthetic depth-damage curves developed for general usage in Alberta. On an ongoing basis, curves are indexed to current values employing Consumer Price, Household Expenditure, and Construction Cost Indices ratios that allow for the conversion of the original base year values to present day values.

Flood events also cause indirect damages. These damages generally include such things as costs of evacuation, alternative accommodation during the flood event, loss of wages and business income due to disruption of business establishments and transportation routes, administrative costs, flood fighting costs, general inconvenience, and general clean-up.

Finally, and most importantly, flooding may represent a threat to human life and well-being, not only for those residing directly within the floodplain but also for those individuals who may work within the area as well as those volunteers and professionals who are involved in flood fighting activities (see **Exhibit 2.1**).

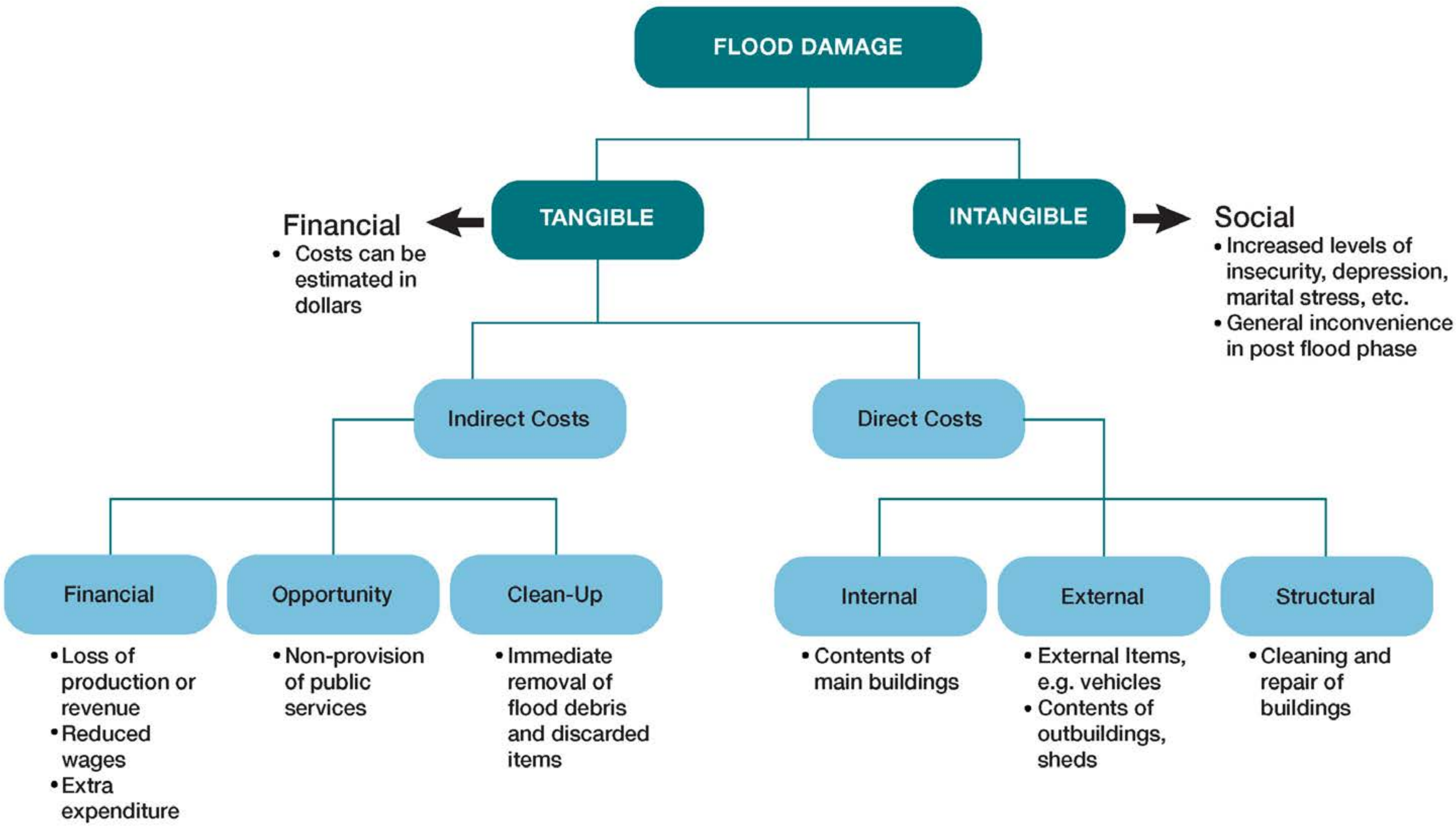
2.2 Flood Elevations

Flood elevations are generally obtained by one of the following methods:

- Direct measurements taken during an actual flood event.
- High watermark surveys taken after the flood peak has passed.
- Recorded levels at Water Survey of Canada Hydrometric stations.
- Computed by numerical computer models that have been developed to simulate flows in river and stream channels and across floodplain (overbank) areas.

Unless otherwise specified, the primary source of flood elevation data is the ESRD River Forecast Centre (RFC).

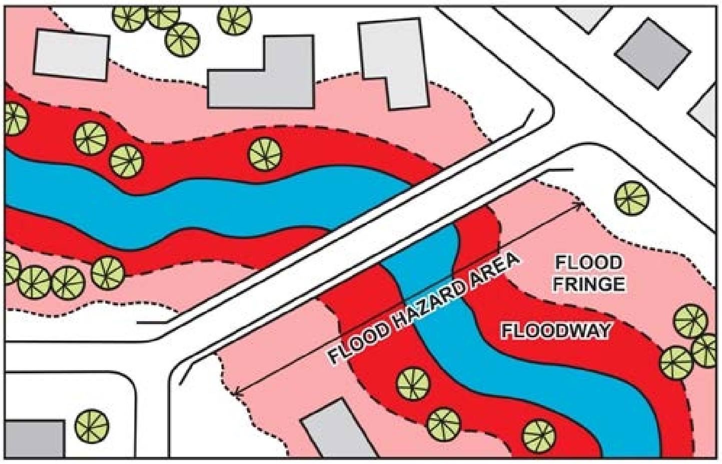
Types of Flood Damage



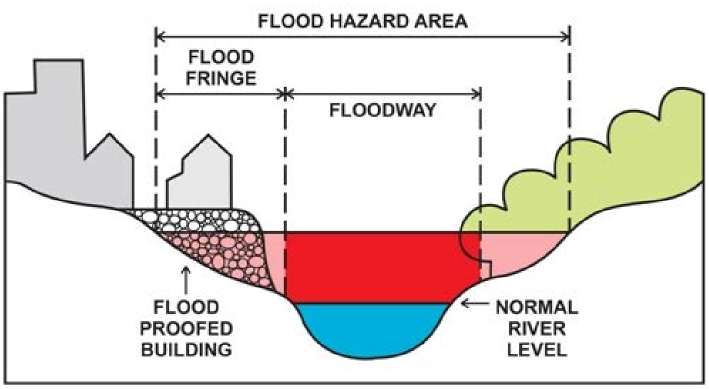
2.3 Floodway/Flood Fringe

The accompanying exhibits (see **Exhibit 2.2** and **2.3**) describe the criteria employed in defining the floodway/flood fringe and adjacent-to area. The floodway is typically defined as the area of deepest and fastest flows, with the flood fringe being that area within the overall floodplain which may suffer only shallow flooding and consequently may accommodate development with the provision that floodproofing measures are implemented.

Exhibit 2.2: Flood Hazard Area



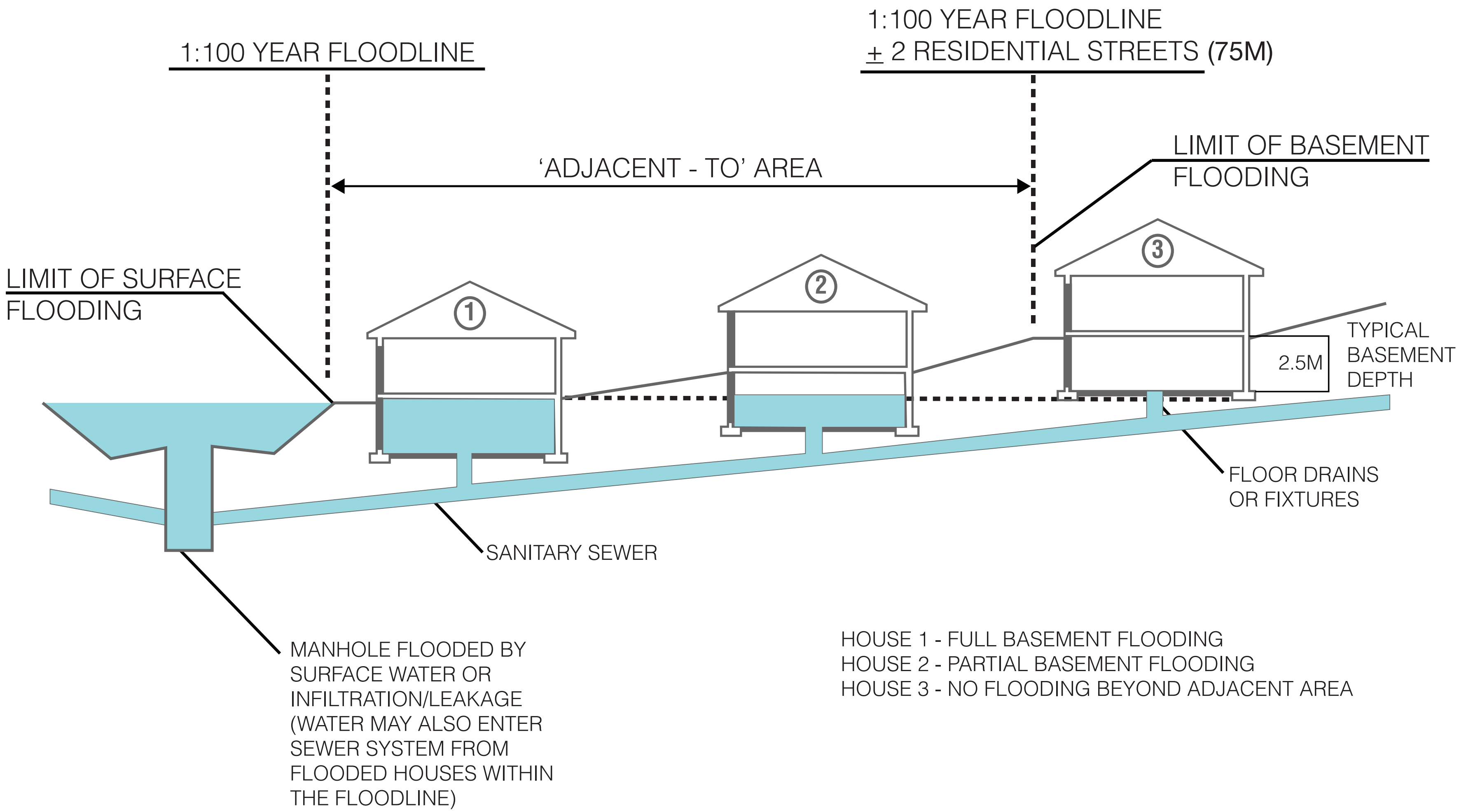
Cross-Section of Flood Hazard Area



2.4 Adjacent-To Areas

Areas outside the floodplain can be subjected to basement sewer backup flooding, primarily through seepage of floodwaters into the sanitary sewer system. To account for this potential flood damage, an adjacent-to area was delineated based on a distance of two dwelling units or ±75 m from the 1:100 year flood line. Essentially, with the sewer backup condition, basements with floor elevations lower than the floodwaters will automatically suffer damages. Exhibit 2.3 depicts this relationship.

Adjacent-To Area Definition Diagram



THE 'ADJACENT - TO' AREA IS THE AREA ADJOINING THE FLOODED SURFACE AREA IN WHICH BASEMENTS MAY BE FLOODED BY BACKED UP SANITARY SEWERS

2.5 Direct Damage Estimates

For the purposes of computing direct damage estimates for the study area all residential and commercial/industrial/institutional structures within the identified flood hazard area are inventoried and damages computed employing the Rapid Flood Damage Assessment Model developed specifically for Alberta.

Infrastructure damages (highways, bridges, railroads, utilities, etc.) are typically determined by the Municipality, or alternatively, a percentage of direct damage is applied to represent potential damages to infrastructure.

2.6 Indirect Damages

Indirect damages include such things as costs of evacuation, employment losses, administrative costs, net loss of normal profit and earnings to capital, management and labour, general inconvenience, etc., and are generally calculated as a percentage of direct damages. Values can range from 10% to 45% for specific land use categories but are commonly calculated as being 20% of direct damages. Kates (1965) analyzed a number of studies by the Corps of Engineers to find values of 15% for residential damage, 37% for commercial, 45% for industrial, 10% for utilities, 34% for public property, 10% for agriculture, 25% for highway, and 23% for railroads.

Indirect damages are best evaluated by developing a checklist of potential effects and methodically assessing each one. The checklist would logically include the amount of use and the duration of interruption of transportation and communication facilities, the number of workers and farmers depending on closed plants and the amount of business lost through a flood emergency. The magnitude of each effect may be estimated by interviewing those affected during recent floods and unit economic values may be assigned by market analysis. Finally, the results may be summed to render a total value for indirect damages.

The complexity of the above evaluation process has led agencies to estimate indirect damages from direct damages based on percentages as discussed previously. The Canada-Saskatchewan Flood Damage Reduction Program uniformly applied an indirect damage calculation of 20% of all categories (combined) of direct damages. This figure is in keeping with guidelines developed by the U.S. Soil Conservation Services who in the past suggested the following ranges for indirect damages:

- Agricultural 5% to 10%
- Residential 10% to 15%
- Commercial/Industrial 15% to 20%
- Highways, Bridges, Railroads 15% to 25%
- Utilities 15% to 20%

The approach employed on the Provincial Flood Damage Assessment Study involved a review of the current situation within the flood study area, i.e., major transportation routes affected by flooding, percentage of industries and businesses affected by flooding, number of residences affected by flooding, and average duration of flooding event, and the application of the appropriate percentage to reflect the relative severity (high, medium or low) of the flood event. In the case of Calgary, for instance, a value of 323% was estimated for commercial indirect damage due to the unusually high concentration of economic activity and hence GDP creation in the flood hazard area.

2.6.1 Residential Indirect Damage

The literature surveyed consistently indicates a value of 15% of direct residential damages for computing indirect damages.

2.6.2 Commercial/Industrial Indirect Damage

The range in this category is broad and varies from 10% to 45% of direct damages.

2.6.3 Utilities Indirect Damage

Values in this category range from 10% to 25% but in general are between 15% and 25%.

2.6.4 Highways Indirect Damage

Values in this category range from 10% to 25%.

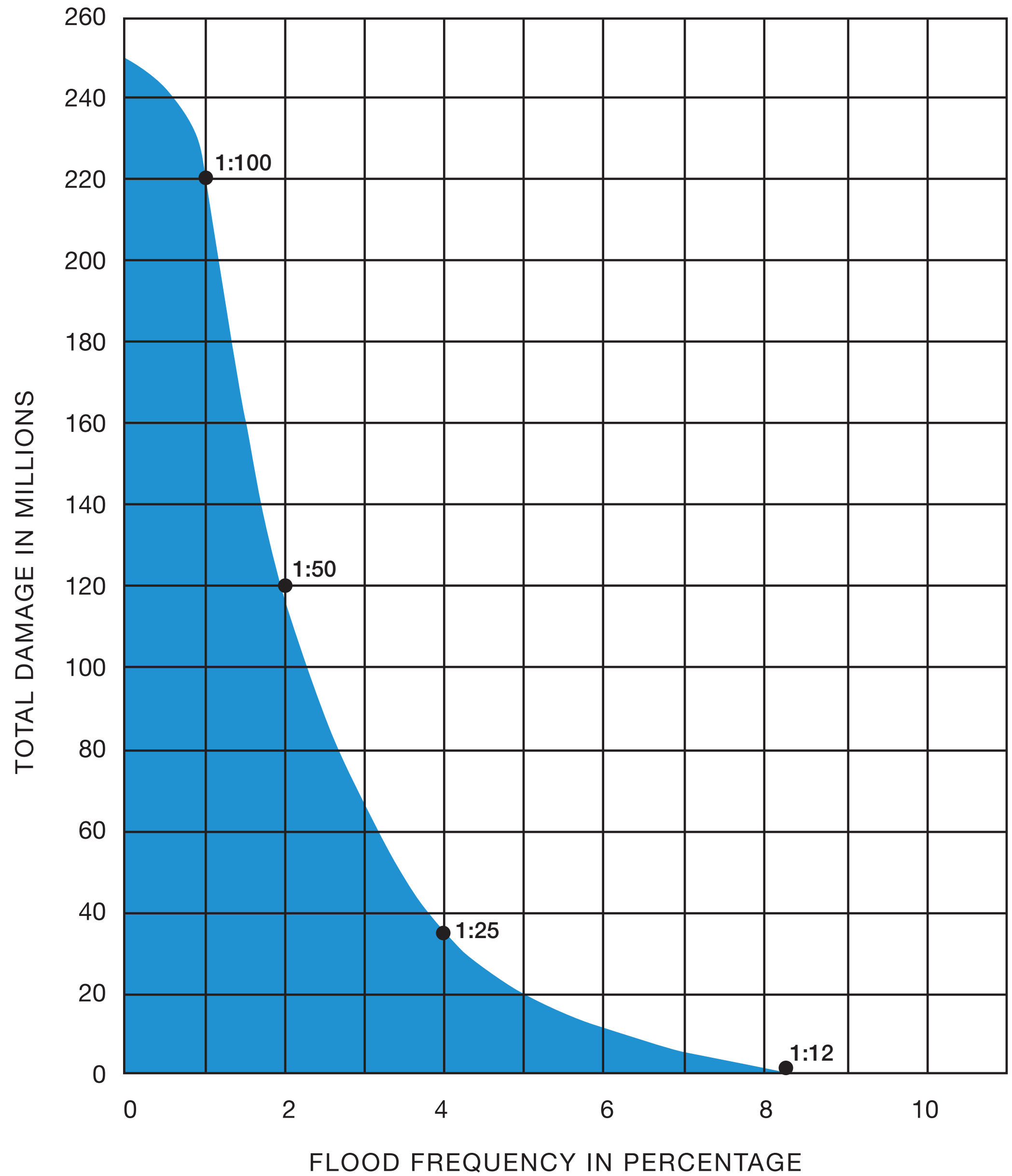
2.7 Total Damage Estimates

Total flood damages for each of the return floods (where available) are estimated employing the methodologies as previously described. These damages include direct damage to residential, commercial/industrial/institutional, utilities/infrastructure and highways, as well as indirect damages.

2.8 Average Annual Damages

Average annual damages are the cumulative damages occurring from various flood events over an extended period of time averaged for the same timeframe. The average annual damage is obtained by integrating the area under the damage-probability curve which depicts total damage versus probability of occurrence (see an example curve in **Exhibit 2.4**).

Example of Damage Probability Curve



FLOOD	FLOOD DAMAGE MILLION DOLLARS
1:25	35.0
1:50	118.5
1:100	220.3

AVERAGE ANNUAL DAMAGE = $5,750,000

3 Calgary

3 Calgary

3.1 Background

The City of Calgary is the largest city in Alberta and the third largest municipality and fifth largest Census Metropolitan Area (CMA) in Canada. It is situated at the confluence of the Bow River and the Elbow River in the southern part of the Province, in an area of foothills and prairie, approximately 80 km (50 miles) east of the front ranges of the Canadian Rockies.

According to the 2011 Census, the City of Calgary had a population of 1,096,833 residing in 423,417 of its 445,848 total dwellings. According to the City of Calgary 2014 Municipal Census the population was 1,195,194, a 3.3% increase over the 2013 Municipal Census population of 1,156,686.

The economy of Calgary includes activity in the energy, financial services, film and television, transportation and logistics, technology, manufacturing, aerospace, health and wellness, retail and tourism sectors. The Calgary CMA is home to the second-largest concentration of corporate head offices in Canada amongst the country's 800 largest corporations.

The City is large in geographic area, consisting of an inner-city surrounded by communities of various densities. Unlike most cities with a sizable metropolitan area, most of Calgary's suburbs are incorporated into the City proper.

Calgary experiences a dry humid continental climate (Köppen climate classification Dfb). Calgary averages more than 22 days per year with thunderstorms, with most all of them occurring in the summer months.

There are two major rivers that run through the City. The Bow River is the largest and flows from the west to the south. The Elbow River flows northwards from the south until it converges with the Bow River at the historic site of Fort Calgary near downtown.

3.2 Context

Exhibit 3.1 depicts the City in a provincial context and **Exhibit 3.2** in a regional context.

3.3 History of Flooding

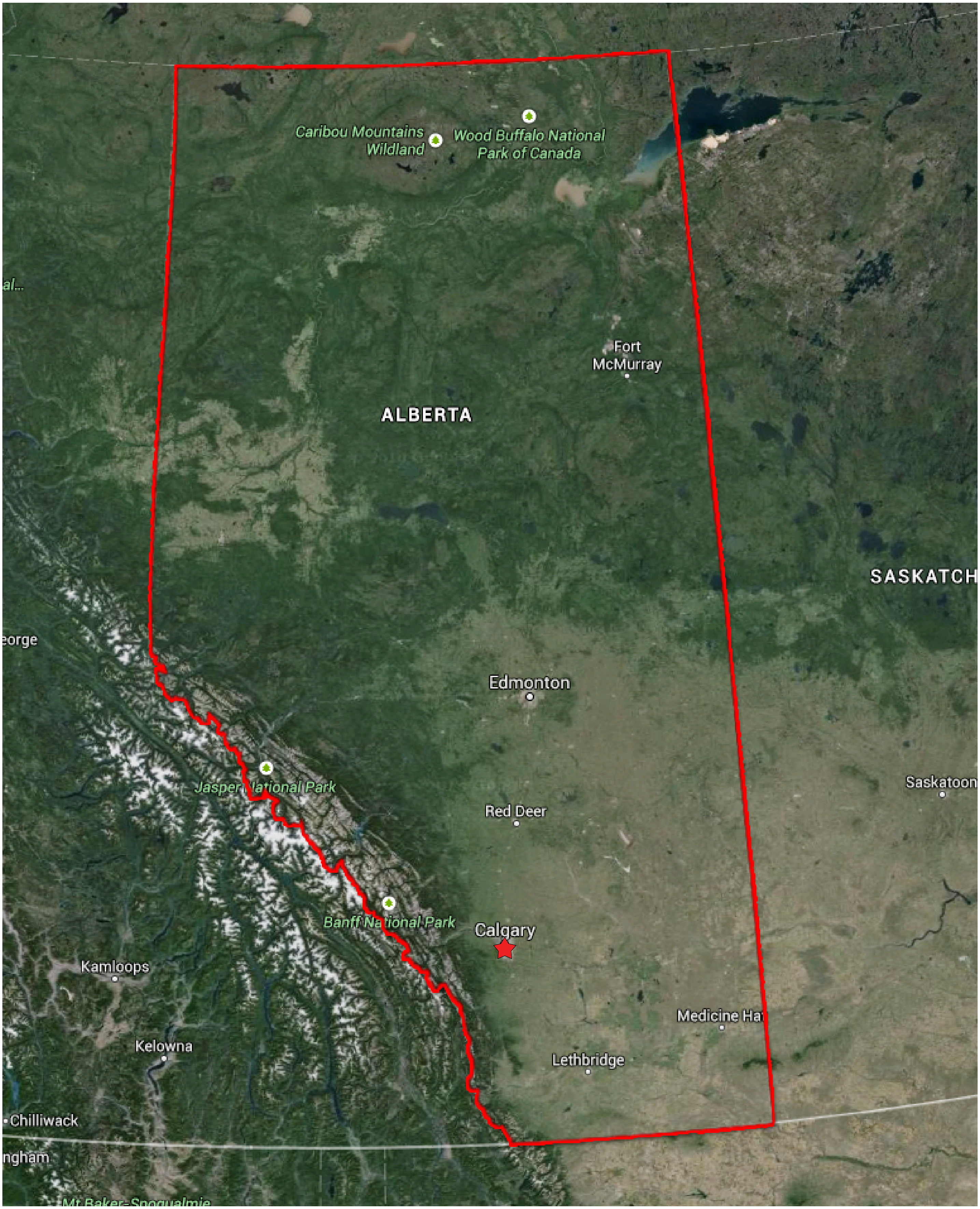
Major floods have occurred on the Bow River in 1902, 1915, 1929, 1932 and 2013. Major floods have occurred on the Elbow River in 1915, 1923, 1929, 1932, 2005 and 2013. These are traditionally summer floods caused by a combination of snowmelt and saturated ground conditions, in combination with heavy storms.

There is a continuous record from 1911 of Bow River flows at Calgary; the three largest known floods all occurred before 1911 – in 1879, 1897 and 1902. Reasonably reliable estimates are available for the floods of 1897 and 1902. The fourth-highest known flood at Calgary occurred in 1932. Due to the fortunate coincidence that the just-constructed Glenmore Reservoir, its reservoir still dry, stood in the path of that flood, the damage and disruption caused was much less than might have been expected.

The 2013 peak flows were recorded as follows:

- Elbow River above Glenmore Dam = 1,200 m^3/s
- Elbow River below Glenmore Dam = 700 m^3/s
- Bow River above the Elbow River confluence = 1,740 m^3/s
- Bow River below the Elbow River confluence = 2,450 m^3/s

Regional Context



IBI | Golder Associates | Alberta Government

Provincial Flood Damage Assessment Study

February 2015

EXHIBIT 3.1

Local Context

According to the 2014 Hydrology Update Report, the peak flows below the Glenmore Dam on the Elbow River approximate a 1:90 year return, with a similar return period for the Bow River both above and below the Elbow River confluence.

3.4 Floodplain Mapping

Exhibit 3.3 depicts the flood hazard area for the Bow and Elbow Rivers through the City of Calgary. Larger scale flood hazard mapping is contained in **Appendix B**. Nine flood elevations were employed to compute flood damages, including the 1:2, 1:5, 1:10, 1:15, 1:20, 1:50, 1:100, 1:200, 1:500, and 1:1000 year flood events. Flood elevation data was based on the hydraulic output of the HEC-RAS Model provided by the City of Calgary and based on the Bow and Elbow River updated hydraulic model project by Golder Associates dated April 2012.

Return flood elevations by zone and reach are detailed in the damage input/output files enclosed under separate cover.

3.5 Inventory of Buildings

Within the identified flood hazard area, which includes the 1:100 year design flood plus a 75 m buffer, the number of buildings totals approximately 7,200 (excluding outbuildings such as garages and storage sheds) and is comprised of 5,620 single-family residential dwellings; 728 semi-detached, triplex and townhouse-style dwelling units; 275 multi-family apartment buildings; and 564 non-residential (commercial/industrial/institutional) buildings.

3.6 Direct Damage Estimates

The flood damage estimates reflect total potential damages for the various return periods and do not consider any adjustments for structural or non-structural measures currently in place. The unadjusted values allow for the evaluation, including benefit/cost analyses, of both current and proposed mitigation options.

3.6.1 Residential Damages

Residential damages by return period are detailed in **Exhibit 3.4,** which expresses damages to both commercial and residential buildings with no sewer backup for the Elbow and Bow Rivers separately and for the entire flood hazard area.

Exhibit 3.5 expresses the same information but with the sewer backup condition which takes into consideration those units within the adjacent-to area that would suffer basement damage. As evidenced, under the sewer backup condition, 1:100 year damages within the flood study area equate to some $686.7 million. Residential damages along the Elbow River equate to $299.7 million or 44% of the total residential damages.

3.6.2 Commercial Damages

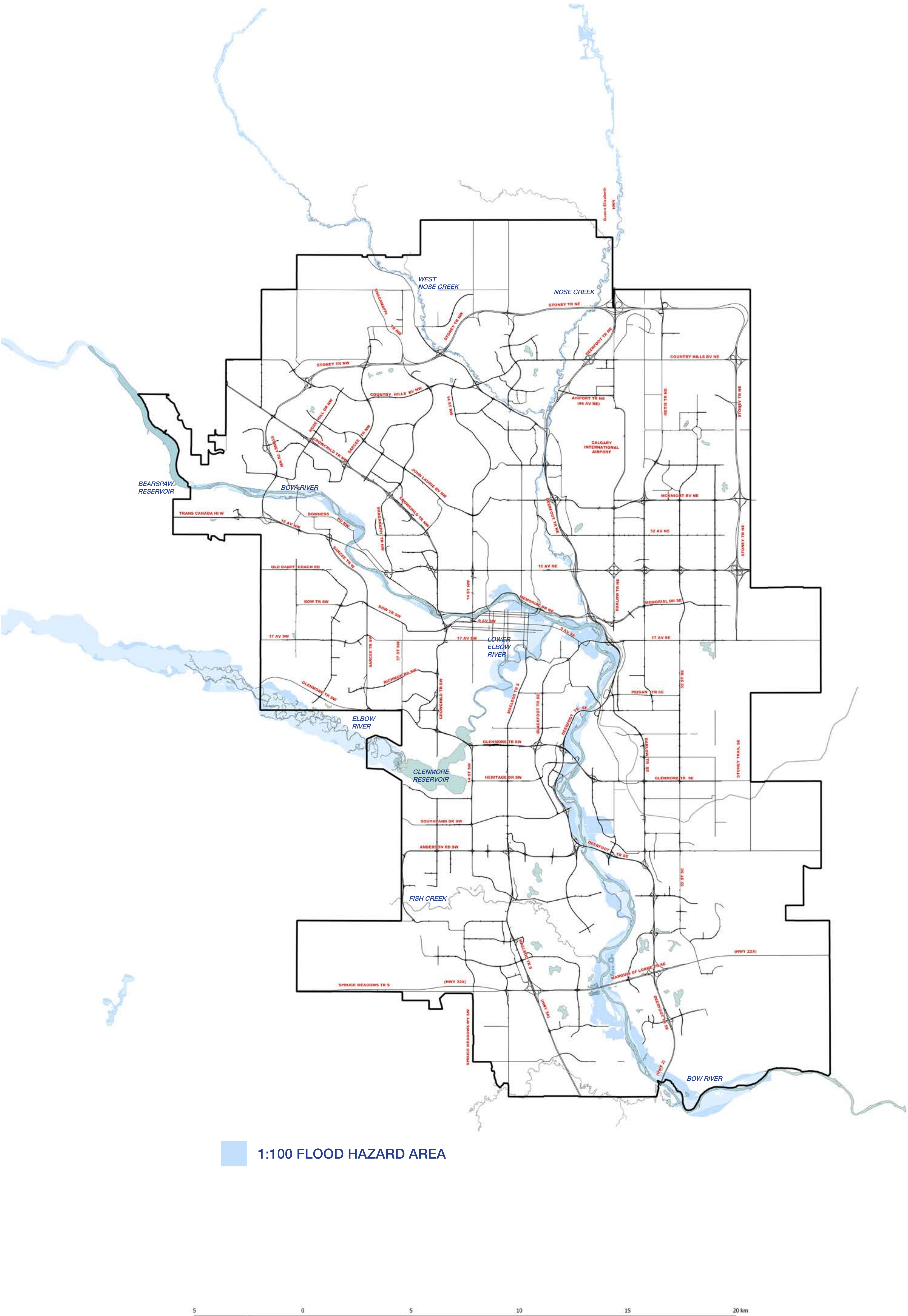
Total direct commercial damages for the entire study area for the 1:100 year flood are estimated at $111.0 million, with some $100.9 million or 91% within the Bow River flood hazard area.

Total commercial and residential building damage for the 1:100 year flood within the Bow and Elbow flood hazard areas equates to some $798 million.

3.6.3 Infrastructure Damages

Flood damages to City infrastructure were estimated by various City Departments based on the 2013 flood and total $372 million. Detailed costs by specific project are contained in **Appendix C** and summarized by category as follows:

Extent of Study Area - Flood Hazard Area



Damages to Commercial and Residential Buildings Without Sewer Backup

River basin	Land use	Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Bow River	Low density residential	$0	$0	$0	$9,852,000	$57,562,000	$181,641,000	$353,261,000	$568,375,000	$669,010,000
	High density residential	$0	$0	$0	$25,974,000	$42,993,000	$65,954,000	$123,652,000	$222,294,000	$224,537,000
	Commercial	$0	$0	$0	$15,128,000	$36,965,000	$100,874,000	$256,774,000	$471,284,000	$539,790,000
	Total	$0	$0	$0	$50,955,000	$137,520,000	$348,468,000	$733,685,000	$1,261,953,000	$1,433,338,000
Elbow River	Low density residential	$0	$0	$0	$5,086,000	$43,971,000	$195,729,000	$279,587,000	$338,215,000	$408,261,000
	High density residential	$0	$0	$0	$6,937,000	$16,521,000	$33,440,000	$40,112,000	$48,753,000	$56,590,000
	Commercial	$0	$0	$0	$82,000	$481,000	$10,205,000	$15,216,000	$22,540,000	$32,817,000
	Total	$0	$0	$0	$12,104,000	$60,973,000	$239,375,000	$334,916,000	$409,507,000	$497,667,000
Bow and Elbow	Low density residential	$0	$0	$0	$14,938,000	$101,533,000	$377,370,000	$632,848,000	$906,590,000	$1,077,271,000
	High density residential	$0	$0	$0	$32,911,000	$59,514,000	$99,394,000	$163,764,000	$271,047,000	$281,127,000
	Commercial	$0	$0	$0	$15,210,000	$37,446,000	$111,079,000	$271,990,000	$493,824,000	$572,607,000
	Total	$0	$0	$0	$63,059,000	$198,493,000	$587,843,000	$1,068,601,000	$1,671,460,000	$1,931,005,000

* No actual damages occur at these flow levels
** Flood Flow primarily contained within the river

Damages to Commercial and Residential Buildings With Sewer Backup

River basin	Land use	Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Bow River	Low density residential	$0	$0	$0	$141,764,000	$204,556,000	$321,121,000	$458,830,000	$668,941,000	$766,774,000
	High density residential	$0	$0	$0	$25,974,000	$42,993,000	$65,954,000	$123,652,000	$222,294,000	$224,537,000
	Commercial	$0	$0	$0	$15,128,000	$36,965,000	$100,874,000	$256,774,000	$471,284,000	$539,790,000
	Total	$0	$0	$0	$182,867,000	$284,515,000	$487,949,000	$839,255,000	$1,362,518,000	$1,531,101,000
Elbow River	Low density residential	$0	$0	$0	$94,078,000	$150,728,000	$266,276,000	$325,192,000	$389,213,000	$448,463,000
	High density residential	$0	$0	$0	$6,937,000	$16,521,000	$33,440,000	$40,112,000	$48,753,000	$56,590,000
	Commercial	$0	$0	$0	$82,000	$481,000	$10,205,000	$15,216,000	$22,540,000	$32,817,000
	Total	$0	$0	$0	$101,096,000	$167,730,000	$309,921,000	$380,520,000	$460,506,000	$537,870,000
Bow and Elbow	Low density residential	$0	$0	$0	$235,842,000	$355,284,000	$587,397,000	$784,022,000	$1,058,154,000	$1,215,237,000
	High density residential	$0	$0	$0	$32,911,000	$59,514,000	$99,394,000	$163,764,000	$271,047,000	$281,127,000
	Commercial	$0	$0	$0	$15,210,000	$37,446,000	$111,079,000	$271,990,000	$493,824,000	$572,607,000
	Total	$0	$0	$0	$283,963,000	$452,245,000	$797,870,000	$1,219,775,000	$1,823,024,000	$2,068,971,000

* No actual damages occur at these flow levels
** Flood Flow primarily contained within the river

- buildings: $114 million
- roads, bridges, other structures: $164 million
- utilities (sewer, water, stormwater): $48 million
- parks and open space: $46 million
- river clean-up: $1 million

Discounting damages to buildings, which have been estimated under direct commercial damages, these equate to $258 million.

The Calgary Municipal Land Corporation also reported infrastructure damages totalling $2.461 million which have been broken down as follows:

- East Village infrastructure: $227,000
- RiverWalk: $318,000
- 4th Street underpass: $1.916 million

It should be noted that these damages have been included under City infrastructure damages at a slightly higher cost of $2.6 million. For the purposes of this estimate, the higher figure will be retained and is included under the City infrastructure estimate.

See **Appendix D** for damage details relative to the Calgary Municipal Land Corporation assets.

Similarly, the Calgary Stampede reported infrastructure damage of $54 million. Discounting damages to buildings, which have been estimated under damages to Stampede Park, these equate to $24.5 million (see **Appendix E** for damage details). It should be noted that some $11.2 million are related to mitigation costs including the rebuilding of floodwalls, bridges, etc. Business interruption equated to some $785,000 or 1.5% of the total direct damage estimate.

Damages to other franchise utilities have been estimated as follows:

- Enmax $9.6 million
- Telus $7.0 million
- Shaw n/a (requested, but not available at time of writing of report)
- ATCO n/a (requested, but not available at time of writing of report)

Total infrastructure damages for the 2013 flood equate to $299.1 million.

3.6.4 Damages to Stampede Park

3.6.4.1 Introduction

Stampede Park, and in particular the associated annual Calgary Exhibition and Stampede, represents a unique circumstance as it relates to flood damage estimates, so much so that the previous study of the Elbow River treated Stampede Park as a standalone element in the assessment of overall flood damages.

3.6.4.2 Damage Assessment – 1986

The purpose of this component of the 1986 study was to assess the potential economic loss which would be caused by a 1:100 year flood at Stampede Park.

The flood risk period was identified as occurring between May 15 and September 15. As utilization of the park varies widely through the May to September flood hazard interval, three independent flood loss cases were examined:

- The first, or base case identified the potential economic loss suffered through flood damage to permanent structures and facilities, and through the impairment of ongoing operations and activities.
- The second case examined potential economic losses associated with the range of other events typical of the use of Stampede Park on an "average" (i.e., non-Stampede) spring or summer day.
- Finally, the third case specified those additional potential economic losses to facilities, operations and activities which would be associated with a flood during the 11 day period of the annual Calgary Exhibition and Stampede.

Thus, the three cases singly or in combination represented the range of economic losses which could be associated with a 1:100 flood of Stampede Park.

Content Depth-Damage Curves

Potential content damages were assessed by combination of a visual inspection of various premises, and discussions with senior management and day-to-day facilities' users.

Structural Depth-Damage Curves

In conjunction with the content damage assessment, all available plans, elevations and cross sections of permanent structures and facilities were acquired. Qualified architectural personnel reviewed the various facility plans, and then verified the structural characteristics of the facilities through field inspections. The 44 buildings on site were categorized into five primary construction types based on construction classification, cost and use.

Damage estimates were based on the then-current City of Calgary costs for materials, labour and service. Structural damage and restoration cost estimates were also based on the characteristics of a 1:100 year flood event, assuming a 1.5 day recession period. The estimates also assumed virtually no damage to walls or slabs through hydrostatic pressure, as exterior forces were assumed to be balanced by water backup through drains and leakage through vents, etc.

Annual Stampede Depth-Damage Curves

Flood damage estimates were calculated by interviewing Stampede officials, and exhibitors, operators and owners of the numerous concessions and displays which constitute the exhibition. For selected high value or unique operations, every available operator was interviewed, while a sample of operators of specific types of facilities were interviewed. For example, 16 of 179 food concessionaires were interviewed with respect to flood damages.

Approximately 85 personal and telephone interviews were conducted to assemble the data required to estimate the flood damages associated with the Annual Stampede. A standard interview format was established to direct the data collection efforts.

Essentially, concessionaires were asked questions concerning: the structure that the concession was operated from (e.g., its dimensions, age, construction materials used, value); and the contents of the structure (e.g., equipment, furnishings, merchandise, total value and salvageability of these). In addition, the concessionaires were asked to estimate the extent of the damage that would occur to the structure and contents at incremental flood levels.

The various uses were classified by functional type and location as either inside or outside a permanent structure. Each standard curve was broadly applicable to a functional use, e.g., food services or shows. In total, six functional categories were identified; however, certain of these uses did not occur in both locations, hence 10 standard depth-damage curves were generated (4 common by function to both locations = 8 standard curves; and 1 specialized function to each location = 2 standard curves). Damage curves were also generated for specialized uses, such as mobile television studios, the Indian Village, etc.

Direct Damage Estimates

The accompanying exhibit (**Exhibit 3.6**) describes direct damages to Stampede Park by return flood for the three cases selected for analysis. Case 1, or the base case, identifies the potential economic losses suffered through flood damage to permanent structures and facilities and ongoing operations and activities. Case 2 details potential economic losses associated with a typical day at the Park exclusive of the Annual Exhibition and Stampede. Finally, Case 3 details the potential economic losses to facilities; operations and activities associated with the Annual Exhibition and Stampede. For the 1:100 year event damages range from $4.8 million for Case 1 to $12.6 million for Case 3. For the purposes of estimating direct damages for the overall study area it was decided to employ Case 2 as being most representative given the limited probability of a flood occurring within the eleven day Stampede period and the fact that with sufficient warning time and a well organized evacuation procedure, the Park could be cleared of all temporary uses with damages restricted to permanent structures and contents as per Case 1.

Exhibit 3.6: Stampede Park Potential Direct Damages by Return Flood in 1985 Dollars

	1:17 Year	1:20 Year	1:50 Year	1:100 Year
Case 1	$1,368,000	1,728,000	3,471,000	4,857,000
Case 2	$1,368,000	1,728,000	3,536,000	5,034,000
Case 3	$1,371,000	1,839,000	7,605,000	12,673,000

Indirect Damages

Indirect damages include items such as employment losses, administrative costs, loss of normal revenues, general inconvenience, etc., and are generally calculated as a percentage of direct damages. However, in the 1986 analysis, it was possible to employ centralized accounting records for the Park as a whole in order to more accurately estimate indirect damages.

Financial statements for the years 1983 and 1984 were examined and relevant line items were averaged between the two years in order to reduce the effect of year-to-year fluctuations. Discussions with the Controller indicated that these results were expected to closely parallel the 1985 operating year results. At that time, during the course of the Stampede, the principal source of revenue was gate admissions, followed by midway-generated revenue, grandstand revenue, and rodeo revenue. Horse racing did not take place at the Park during Stampede.

Revenues which accrue to facility users and concessionaires were additional to the gross revenue realized by the Calgary Exhibition and Stampede. The additional revenues were conservatively estimated to be equivalent to 300% of the total revenue generated by the rental of Park facilities. Thus, indirect damages to facility users and concessionaires were accounted for in the 1986 estimates.

In summary, the estimated average daily indirect damages which would have been suffered as a result of the complete closure of the Park during the course of the Stampede were as follows:

Exhibit 3.7: Stampede Park Average Daily Indirect Damages Related to Annual Exhibition and Stampede

Item	Damage Estimate
Gate	$234,100
Midway	903,700
Grandstand	165,000
Rodeo	121,000
Casino	114,600
Lotteries	370,900
Independent Midway	185,600
Saddledome	72,600
Indoor Exhibits	103,800
Food Fair	61,700
Skyride	9,400
Daily Total	**$2,342,400**

As an illustration of the relative scope of indirect damage, a total (10 day) loss of $23,400,000 is equivalent to 185% of the estimated direct damages in the Case 3 1:100 year event.

3.6.4.3 Stampede Park Flood Damages – 2014

The Calgary Stampede and Exhibition reported infrastructure damage of $54 million, with damages to actual infrastructure equating to $24.5 million and the remaining damage to buildings and contents (excluding the Saddledome) constituting $29.5 million. The flood at that location approximated a 1:100 year event.

The Saddledome was flooded to the roof of the event level, corresponding to Row 10 in the arena section. The Calgary Flames Organization reported resulting direct damages to the Saddledome structure of $26.9 million; damages to contents totaled $11.2 million including some $4.0 million in damages to electronic equipment. The salvage value for contents was virtually zero, and it proved necessary to arrange secure disposal of contaminated memorabilia to prevent unauthorized and potentially hazardous re-use of those items. Indirect damages totalled $4.4 million as the Saddledome was closed for 74 otherwise available revenue days while repairs were completed; this was the net indirect loss, as it was possible to reschedule some events.

The reported 2013 damages have been employed to adjust the combined Stampede Park stage-damage curves and indirect damages to 2014$ values. This adjustment was calculated by factoring up the 1985 damage amounts for the other flood return periods in proportion to the observed difference for the 1:100 year event. This adjustment accounts for the changes to the building environment at the park since 1985 (e.g., addition of the Casino and BMO Centre, removal and replacement of barns, etc.). It also accounts for the increased intensity of use – and thus increased indirect damages.

Total Direct Damages

Estimated total direct damages for Stampede Park by return period are detailed in **Exhibit 3.8** with the Case 3 assumptions, assuming the flood event occurs prior to the annual Stampede and Exhibition, causing its cancellation. This worst case indirect damage estimate assumes that the entire 10 day event is lost.

Exhibit 3.8: Stampede Park Potential Direct Damages by Return Flood in 2014 Dollars

	1:17 Year	1:20 Year	1:50 Year	1:100 Year	1:200 Year
Case 3	$7,600,000	$10,200,000	$42,200,000	$68,900,000	$91,900,000

Indirect Damages

Estimated total indirect damages for Stampede Park by return period are detailed in **Exhibit 3.9** for Case 3. The indirect damages are estimated as a percentage of direct damages, reflecting the 2013 event experience.

Exhibit 3.9: Stampede Park Potential Indirect Damages by Return Flood in 2014 Dollars

	1:17 Year	1:20 Year	1:50 Year	1:100 Year	1:200 Year
Case 3	$14,100,000	$18,900,000	$78,000,000	$127,400,000	$169,900,000

Total Damages

Estimated total direct and indirect damages for Stampede Park by return period are detailed in **Exhibit 3.10** for Case 3.

Exhibit 3.10: Stampede Park Potential Total Damages by Return Flood in 2014 Dollars

	1:17 Year	1:20 Year	1:50 Year	1:100 Year	1:200 Year
Case 3	$21,700,000	$29,100,000	$120,200,000	$196,300,000	$261,800,000

3.6.5 Indirect Damage Estimates

3.6.5.1 Commercial Indirect Damages

Lost Hours Worked and GDP

Following the June 2013 flooding in Southern Alberta, Statistics Canada conducted a special Labour Force Survey that included questions about the impact of the flood on hours worked. They found that a total of 5.1 million hours were lost in Alberta. This survey collected data for only the last two weeks of June. Many additional hours were spent as a result of the flood, however all industries except utilities and public administration experienced a net loss during those two weeks.

The Calgary portion of lost hours in June 2013 provides a basis for estimating economic losses that would be experienced (without substitution) in the city at a 1:100 year flood. An estimate of lost GDP can be made using each industry's labour productivity amount multiplied by the industry's lost hours.

Labour productivity data for Alberta in 2013 is the latest available at this time. Real productivity is expressed in chained 2007 dollars. Productivity is not measured for the public sector and no associated losses have been included. To express the total in 2014 dollars, the average of the implicit price deflator for the first three quarters of 2014 is used. The implicit price deflator is equal to current dollar output divided by real output.

Exhibit 3.11: Estimated Lost Work Hours, Labour Productivity, and Real GDP Lost for 1:100 Year Flood in Calgary

Industry	Estimated Hours Lost	2013 Real GDP/Hr	Real GDP Lost
Agriculture	2,900	$44.30	$128,470
Forestry, fishing, mining, quarrying, oil and gas	738,000	$260.30	$192,101,400
Utilities	-18,400	$182.60	-$3,359,840
Construction	263,500	$46.60	$12,279,100
Manufacturing	208,100	$61.70	$12,839,770
Trade	69,700	$42.67	$2,974,099
Transportation and warehousing	86,600	$56.10	$4,858,260
Finance, insurance, real estate and leasing	314,300	$113.75	$35,751,625
Professional, scientific and technical services	758,400	$52.60	$39,891,840
Business, building and other support services	220,900	$32.70	$7,223,430
Information, culture and recreation	129,300	$82.70	$10,693,110
Accommodation and food services	121,300	$23.30	$2,826,290
Other services	78,400	$33.60	$2,634,240
		Total (2007 dollars)	$320,841,794
		Total (2014 dollars)	**$359,070,600**

Commercial Indirect Damages as a Percentage of Commercial Direct Damages

According to this estimate, lost GDP resulting from a 1:100 year flood would total $359 million dollars. Assuming total lost GDP is an appropriate estimate of commercial indirect damages, this equates to 323% of direct damages. This amount of commercial indirect damages in Calgary is exceptionally high in relation to direct damages; the primary reason is the concentration of high production value employment in commercial towers in the downtown core. The direct damage to the main and sub-grade levels of an office building is typically far less than the value of the sum of lost hours on all floors due to the building being closed.

3.6.5.2 Residential Indirect Damages

Evacuations

During a flood event, neighbourhoods are evacuated due to the risk of rising floodwater, the loss of essential services, and the loss of safe access. Therefore, evacuation includes homes that are not directly flooded. Between June 20 and 23, 2013, approximately 75,000 Calgarians were evacuated from their homes. Many of these residents would have incurred expenses from being unable to return to their homes during the flood. Assuming an average extra expense of $100 per person over a 48 hour period, this would amount to $7.5 million in indirect damages.

In addition to evacuated homes, the evacuation of institutions will incur expenses for residents within and beyond the flood affected areas. Patients of hospitals and residents of senior citizen homes may require additional and costly support. Children in affected schools and daycare facilities will require alternative care. During the 2013 floods, all Calgary schools were closed and Diploma Examinations were cancelled.

Further evacuations can also be expected due to hazards created during or after a flood. For example, flood evacuations were ordered downstream of the Bonnybrook bridge after a flood-damaged piling collapsed, causing a train carrying hazardous petrochemicals to derail.

Temporary Accommodation Costs for Flooded Buildings

After a flood event, residents of buildings directly impacted will require alternative accommodation for a period dependent on the amount of damage to their homes. At a 1:100 year flood level in Calgary, there is an estimated 6,600 residential dwelling units in affected buildings. The following assumptions have been made to estimate accommodation costs:

- Residents of structures suffering only sewer backup do not require alternative accommodation.
- Residents of single and attached homes with basement flooding will be displaced for an average of one week.
- Residents of single and attached homes with main floor flooding will be displaced for an average of three months.
- All residents of a flooded apartment building will be displaced for an average of one week.
- Residents of an apartment unit directly flooded will be displaced for an average of three months.
- 50% of all displaced households will find accommodation with friends or family.
- All households requiring other accommodation will stay in a hotel for the first week.
- Households requiring accommodation for longer than one week will find rental apartments.
- The average hotel room rate in Calgary is $168 (*Alberta Accommodation Outlook 2014*).
- The average apartment rental rate in Calgary is $1,290 (*CMHC Rental Market Report, Spring 2014*).
- Displaced residents will spend an average of $50 per person per day for meals and incidentals during the week spent at a hotel.
- Single-family houses have an average of 3 occupants and apartments have 1.7 (*The City of Calgary 2014 Census*). The weighted average of flooded units is 2.056 occupants.

Exhibit 3.12 indicates the temporary accommodation costs according to the assumptions listed above.

Exhibit 3.12: Temporary Accommodation Costs

Number of Days Displaced	Number of Households	Daily Accommodation Cost	Daily Incidental Cost	Total Cost
7	3300	$168	$103	$6,255,000
90	929	$43	n/a	$3,595,000
			Total	**$9,850,000**

Loss of Public Services

During and after a flood event, there is significant disruption to public services that adds to the indirect damages incurred by residents.

Damage to or temporary closure of social service facilities such as shelters, food banks, counselling, addiction treatment, etc. has a significant impact on residents who depend on these services.

A large portion of the City's parks, pathways, and other recreation facilities are located adjacent to the rivers. Damage to these amenities during the summer months would result in the cancellation of many community events. During the 2013 floods, 30 Calgary parks were flooded and major events such as Aboriginal Awareness Week, MEC Paddlefest, Park Market, and Sled Island Music Festival were cancelled.

Disruption of transit routes impacts residents throughout the city. A major flood would require cancellation of LRT service in the city centre, severing connections between city quadrants. Alternative transportation expenses could be significant to those who rely on the service. Closure of roadways causes major congestion on alternative routes with traffic delays costing residents significant amounts of time.

Flood Fighting and Clean Up

Neighbours and other volunteers perform a large part of residential flood preparation, fighting, and clean up. After the 2013 floods, thousands of Calgarians assisted homeowners in cleaning up. Some volunteers are organized through agencies such as Samaritans Purse while others were self-organized, bringing their own supplies.

Trauma, Stress, and Anxiety

Research into the effects of severe flooding on residents has shown that the physical and mental health impacts are serious. People who suffered flooding even regard the intangible effects of flooding to be higher than their direct material damage. Intangible effects include loss of memorabilia, psychological stress during the flood and during recovery, where discussions with insurance companies are specifically mentioned.[1]

Residential Indirect Damages as a Percentage of Commercial Direct Damages

Given the aforementioned, a value of 15% was selected for residential indirect damages.

3.6.5.3 Stampede Indirect Damages

Stampede indirect damaged have been calculated at 185% of direct damages.

3.6.5.4 Infrastructure Indirect Damages

Infrastructure indirect damages were estimated at 20% of direct damages.

3.6.6 Total Damages

Total flood damages for each of the return floods have been estimated for the entire study area. These damages include direct damage to residential, commercial/industrial/institutional, infrastructure, Stampede Park, as well as indirect damages. The results are summarized in **Exhibits 3.13 through 3.15.** As evidenced, total damages on the Bow and Elbow Rivers with sewer backup equate to some $1.8 billion for the 1:100 year flood event, increasing to $3 billion for the 1:200 year event and $5.6 billion for the 1:1000 year event.

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[1] Zevenbergen et al., *Urban Flood Management* Leiden: CRC Press, 2011.

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

The Bow River accounts for approximately 59% of the total damages under a 1:100 year flood. Indirect damages by themselves constitute some $649 million or 56% under 1:100 year flood conditions. (Indirect damages equate to a higher proportion of direct damages for the lower frequency floods; the unweighted average indirect share is 73% across the range of events.)

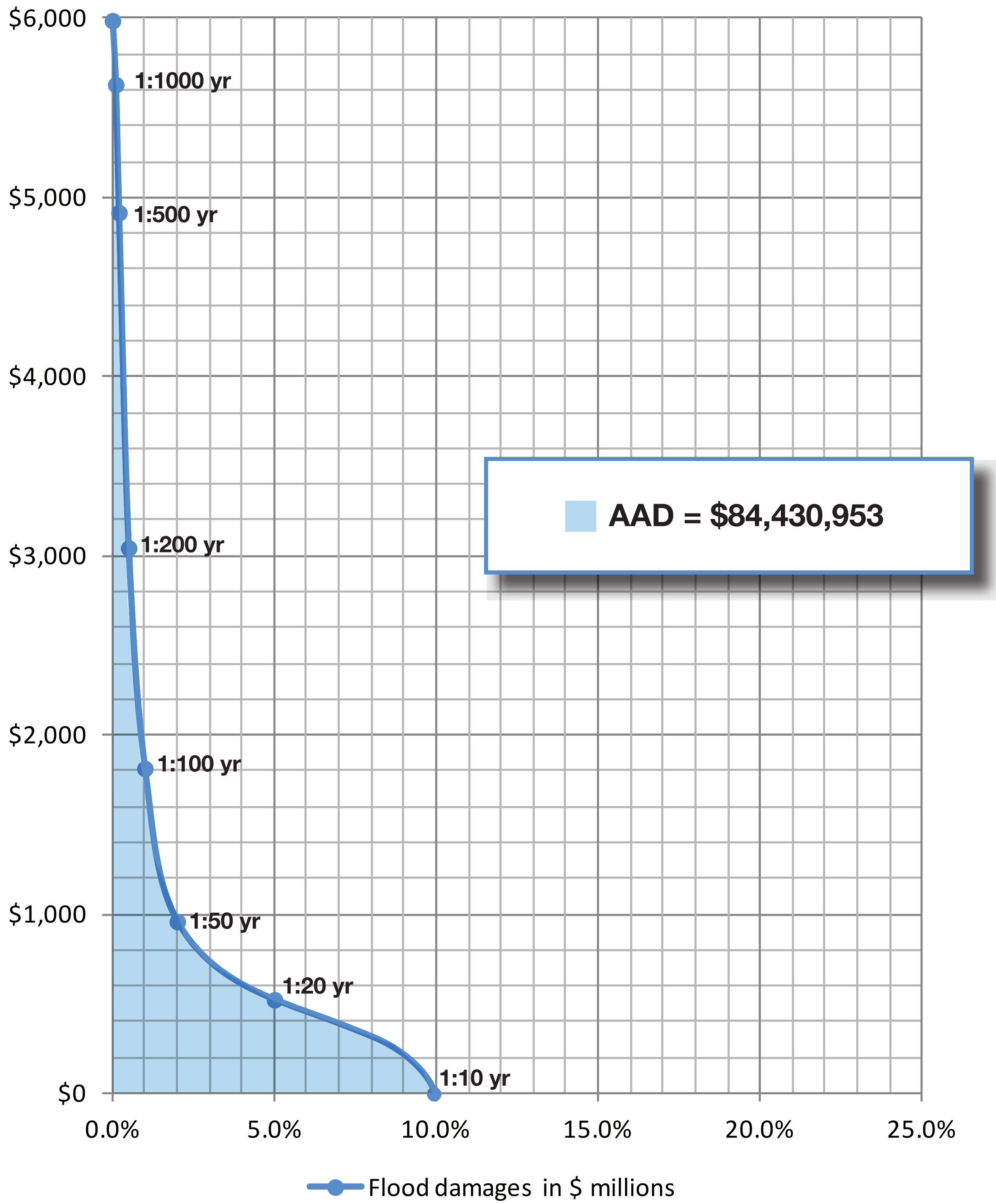
3.6.7 Average Annual Damages

Average annual damages are the cumulative damages occurring from various flood events over an extended period of time averaged for the same timeframe. The average annual damages are obtained by integrating the area under the damage-probability curve which depicts total damage versus probability of occurrence and is illustrated for the entire study area in **Exhibit 3.16**. The average annual damage for the study area is estimated at $84,431,000.

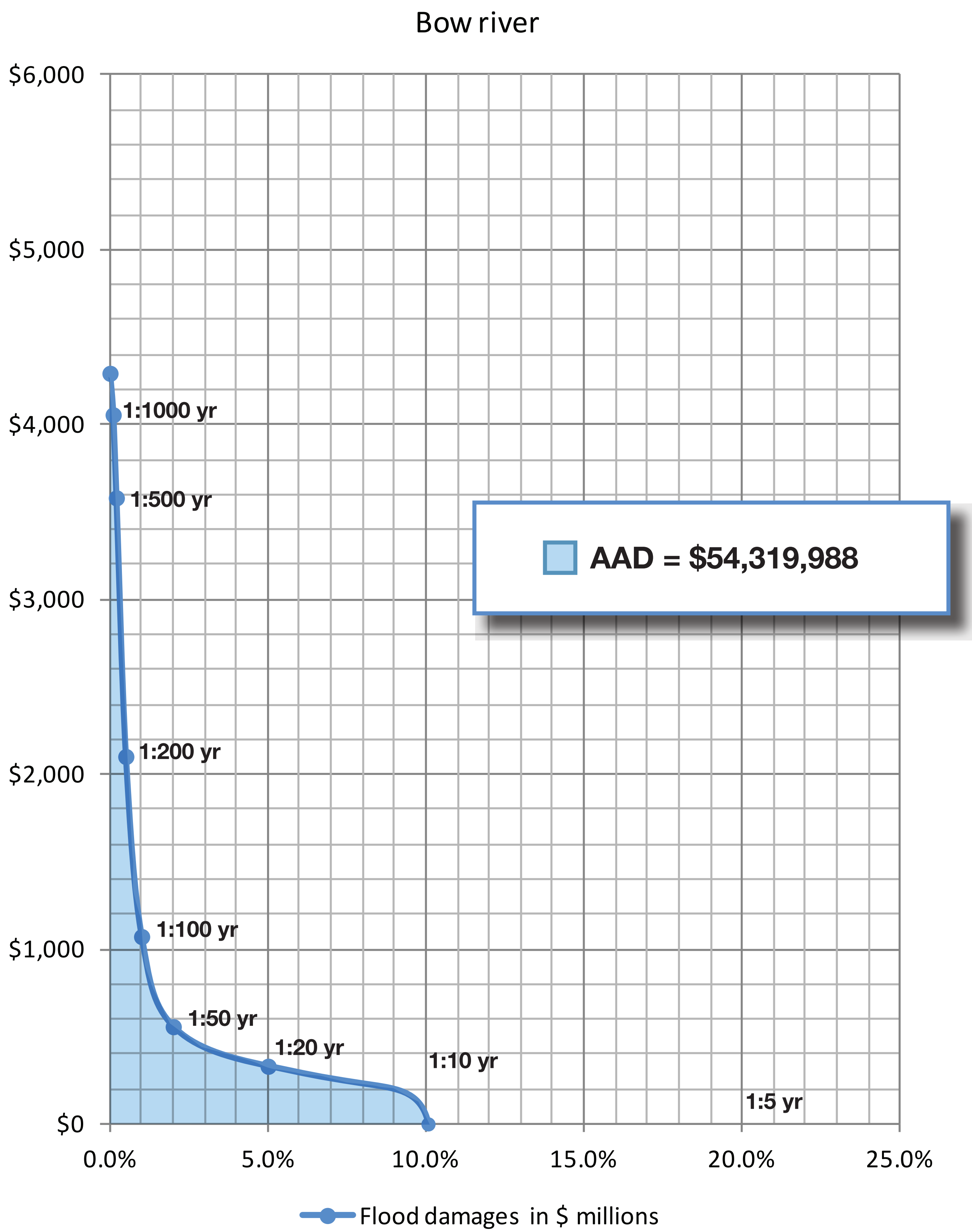
The average annual damage for the Bow River is $54,320,000 (see **Exhibit 3.17**). For the Elbow River flood hazard area the average annual damage is $30,111,000 (see **Exhibit 3.18**).

In terms of average annual damage, two damage scenarios were computed: (1) basement flooding only occurs when flood elevation exceeds grade elevation; and (2) basement flooding occurs when flood elevation exceeds basement floor elevation referred to as “sewer backup” condition. The average annual damage estimation is extremely sensitive to damages occurring at the frequent flood events. Assuming that all basements are flooded from sewer backup for the 1:10 year flood would skew the ADD results by a third. Since basement flooding has been historically minor at that flow event, basement flood damages below the 1:10 year event were not used to calculate average annual damage. By selecting the sewer backup condition for the other return periods, the results are quite conservative and erring on the high side of damages.

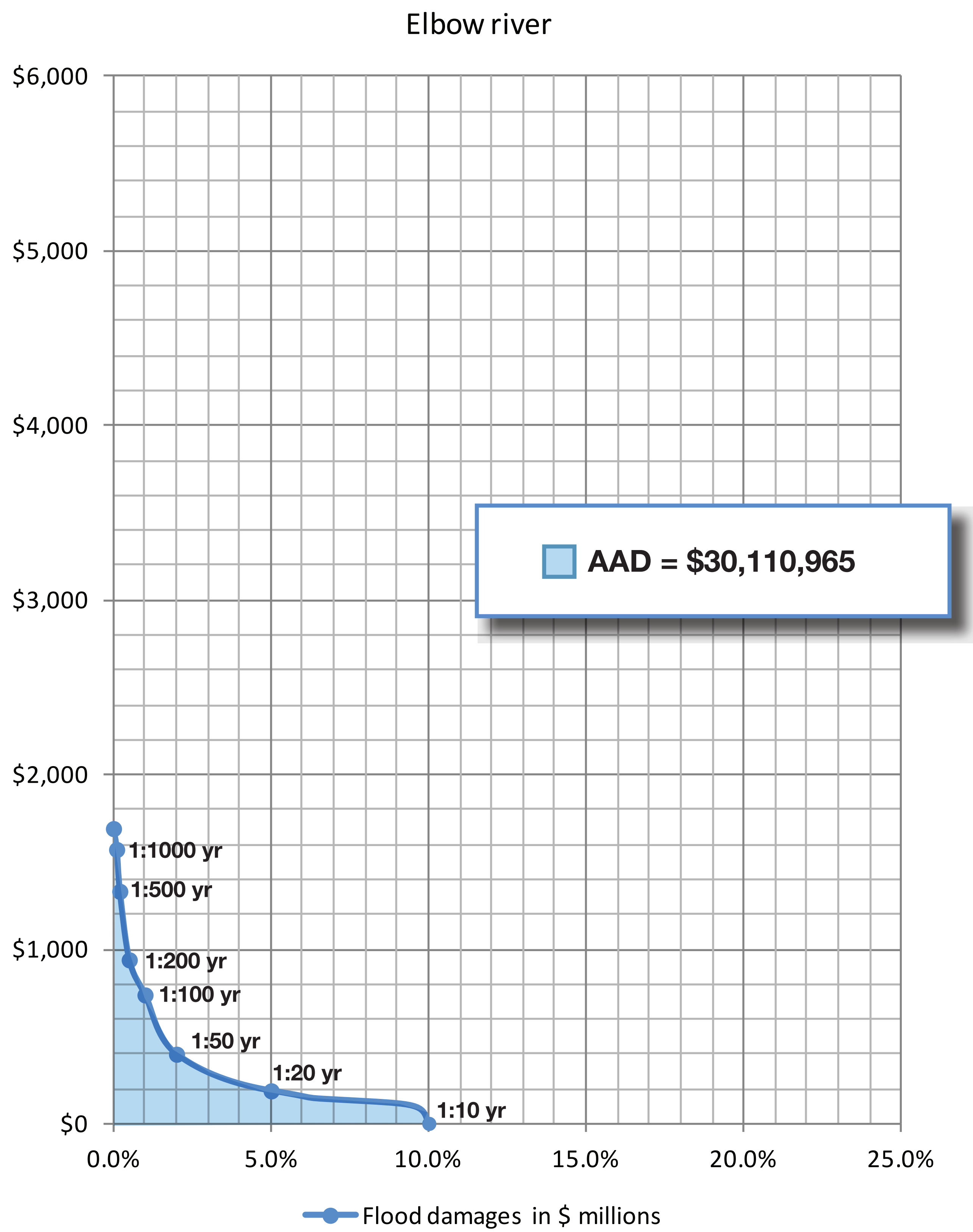
Flood Damages Probability Distribution, Bow and Elbow Rivers



Flood Damages Probability Distribution, Bow River



Flood Damages Probability Distribution, Elbow River



3.6.8 Alternative Damage Scenario

The previous damage assessment is reflective of worst case conditions, in particular as it relates to commercial indirect damages, Stampede indirect damages, and infrastructure damage, especially at the higher flood frequencies. An alternative damage scenario has been developed which reduces damage in these categories:

1. Commercial Indirect Damages – These costs were provided by the Conference Board of Canada and were based on a survey of productivity loss for a two week period immediately following the 2013 flood. This estimate of GDP loss did not account for post-flood economic recovery (substitution over time) nor geographic substitution of economic activity. For these reasons, the alternative damage scenario employed the more typical commercial indirect damage factor, in this case in the higher end of the range (45% versus 323%). Damages were also adjusted for the higher frequency events to reflect a greatly reduced impact on commercial operations, especially in the downtown.
2. Stampede Indirect Damages – These damages were based on the complete loss of the 10 day annual Calgary Exhibition and Stampede revenues, and while this loss could be experienced, depending upon the timing of the flood, the alternative scenario considers a more typical potential revenue loss during the non-Stampede timeframe. Accordingly, the indirect damage factor was reduced from 185% to 38%.
3. Infrastructure Damage – These damages were based on the City of Calgary's municipal infrastructure recovery list, but also include costs for mitigation projects that were implemented to prevent or ameliorate future damages. Infrastructure damage was adjusted to reflect a more typical percentage of other direct damages (residential and commercial). In addition, damages at higher frequencies were reduced to characterize anticipated losses at lower flow rates.

Exhibits 3.19 through **3.24** describe the reduced total damage and average annual damage estimates. Total damages for the Bow and Elbow Rivers for the 1:100 year event have been reduced from $1.815 billion to $1.237 billion with a concomitant reduction in average annual damage from $84,431,000 to $56,342,000. The average annual damage for the Elbow River is reduced from $30,111,000 to $21,729,000.

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

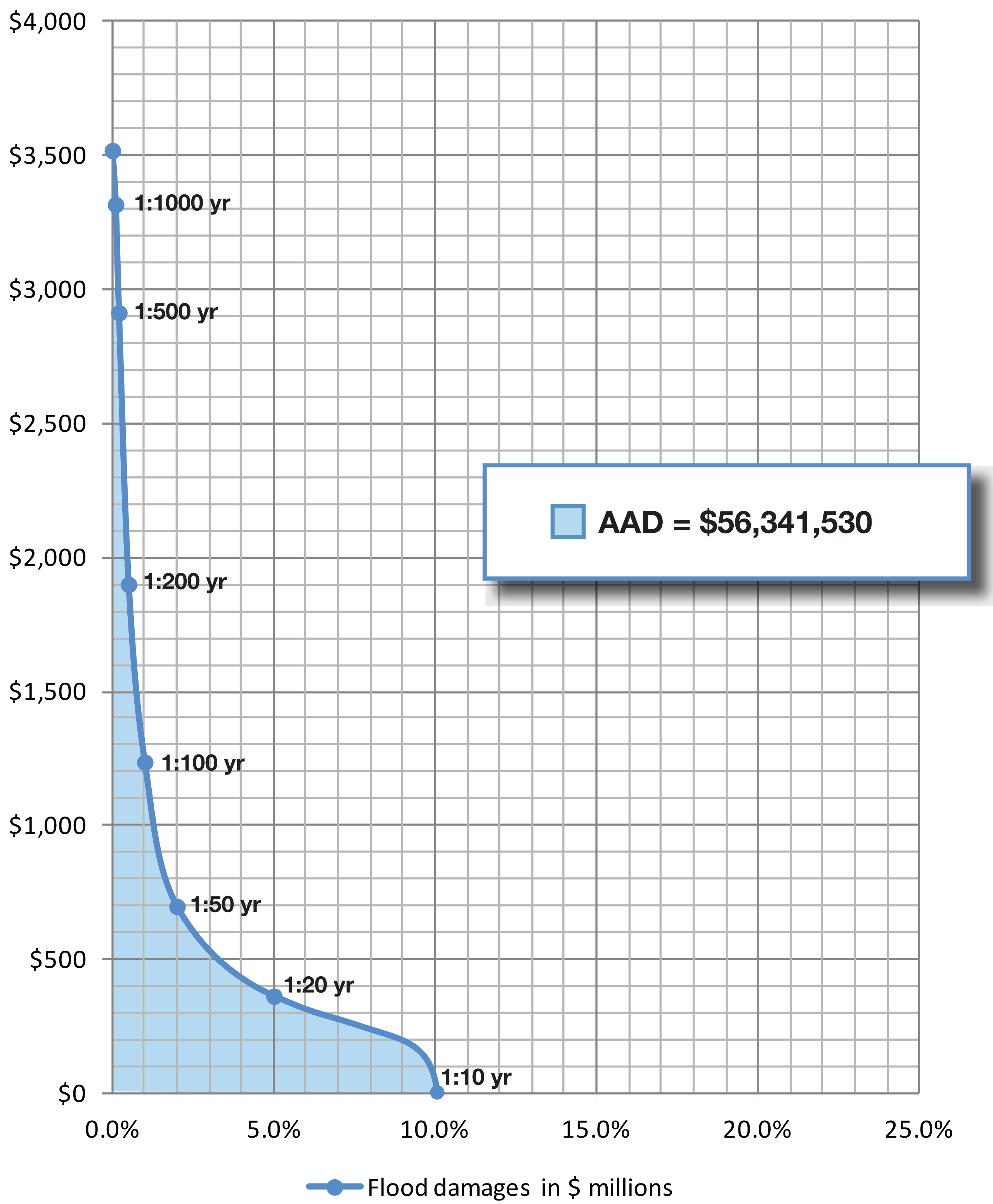
* No Actual damages occur at these flow levels
** Flood Flow primarily contained within the river

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

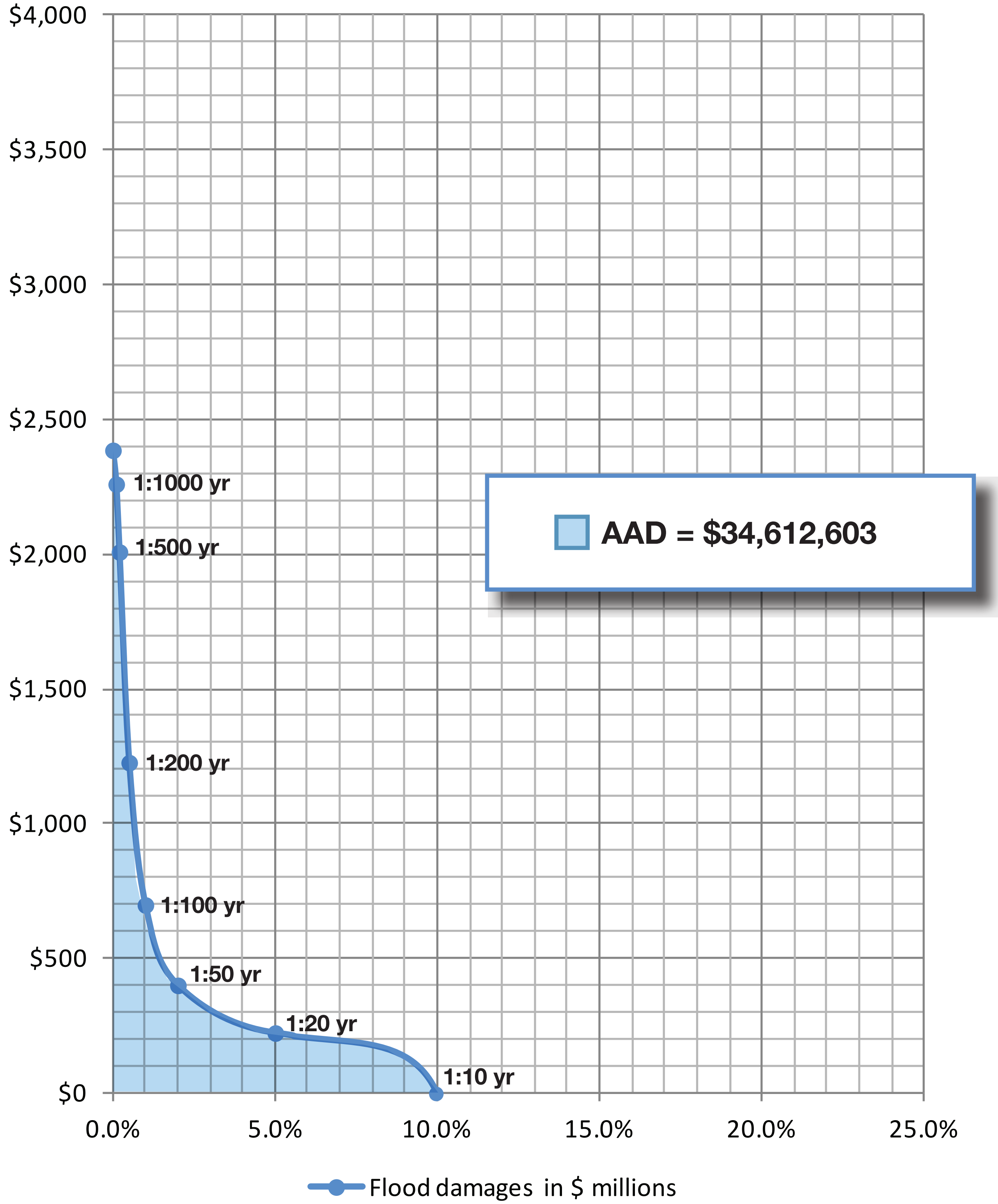
Categories of damage		Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Residential	Direct	$0	$0	$0	$101,015,000	$167,249,000	$299,716,000	$365,304,000	$437,966,000	$505,053,000
	Indirect 15%	$0	$0	$0	$15,152,000	$25,087,000	$44,957,000	$54,796,000	$65,695,000	$75,758,000
	Total	$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

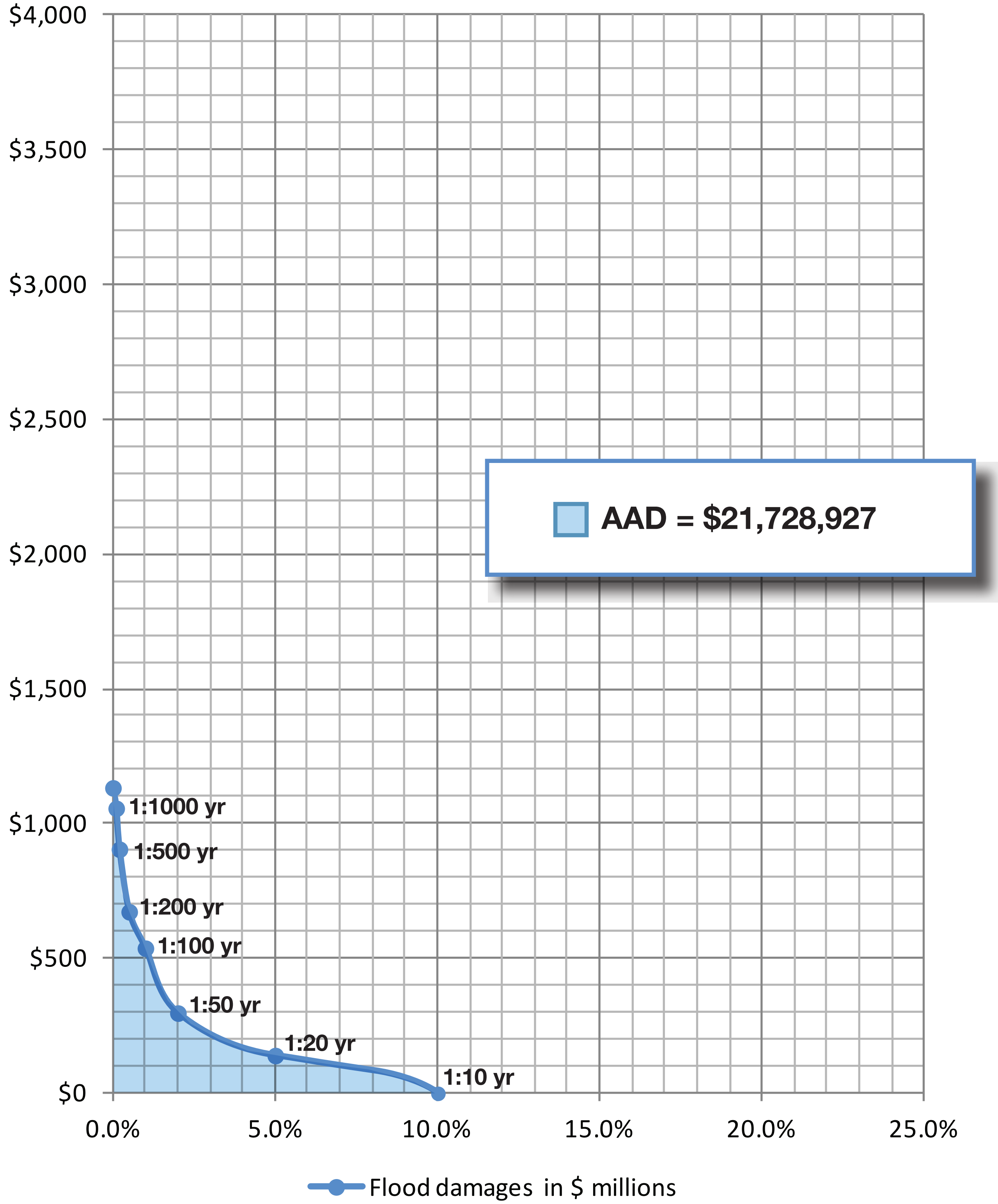
Alternative Damage Scenario - Flood Damages Probability Distribution, Bow and Elbow Rivers



Alternative Damage Scenario - Flood Damages Probability Distribution, Bow River

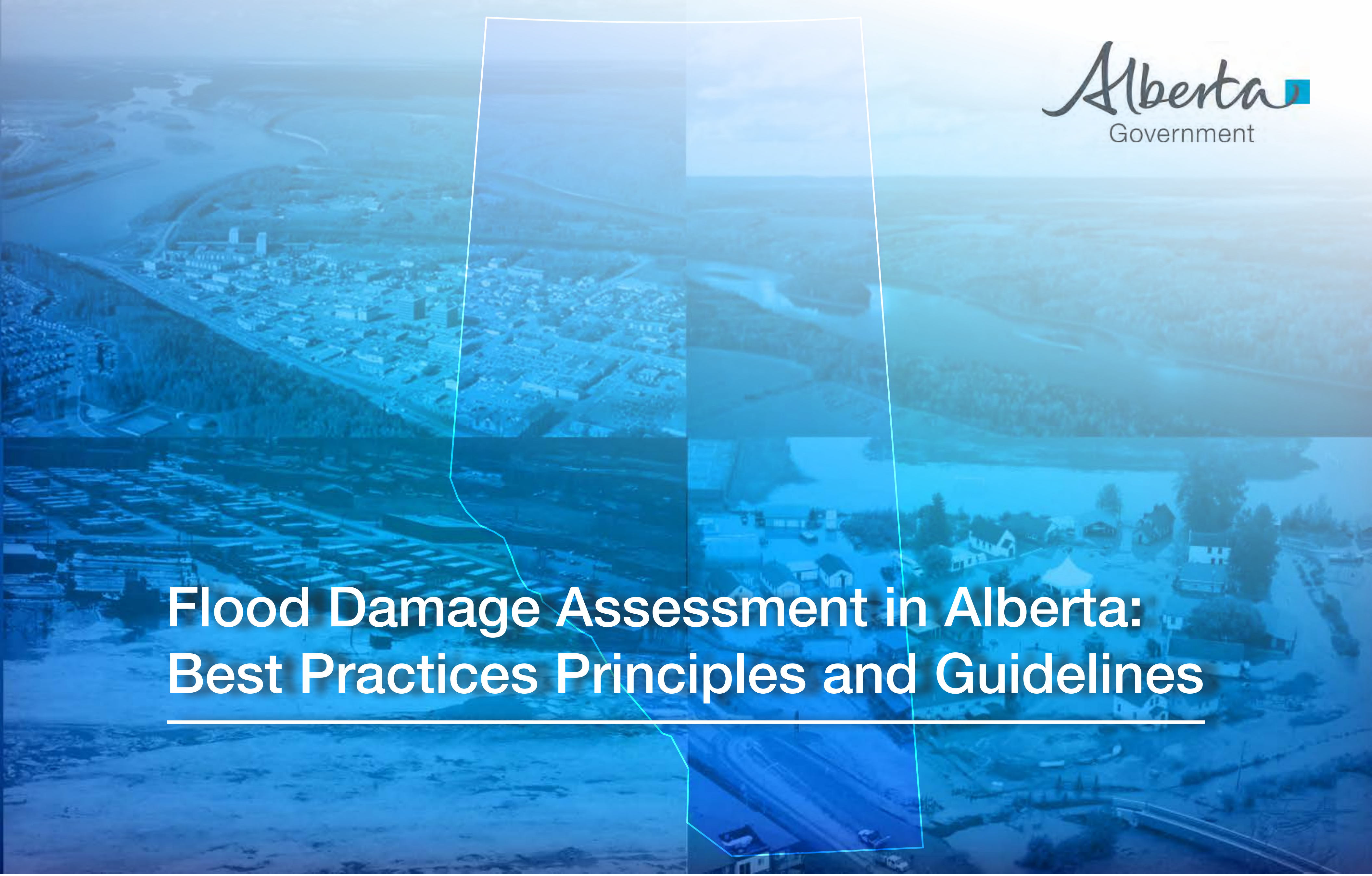


Alternative Damage Scenario - Flood Damages Probability Distribution, Elbow River



4 Appendices

Appendix A – Alberta Government Bulletin: Best Practices Principles and Guidelines



Flood Damage Assessment in Alberta: Best Practices Principles and Guidelines

Alberta Government

IBI

Prepared for Government of Alberta
ESRD - Resilience and Mitigation
by IBI Group
December 2014

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1 Introduction

1.1 Purpose

The following bulletin has been generated by the Government of Alberta to describe how flood damages are estimated within the Province, and how they are subsequently employed to evaluate the economic viability of flood mitigation projects.

1.2 Preamble

Flooding is natural and essential to a healthy environment, but when severe events occur can cause human hardship and economic loss. In Canada, governments discourage flood-vulnerable development on the floodplain, and are involved in the mapping and designation of flood risk areas. From the mid-1970s until 1998, there was a national program of flood damage reduction involving mapping of floodplain areas and encouragement of land use controls within areas subject to risk of flooding. The Government of Alberta participated in this program in the 1980s and undertook studies to estimate flood damages in affected communities and propose mitigation alternatives where appropriate.

The Province of Alberta has mapped many of the communities that may be affected by flooding. Government of Alberta – Environmental and Sustainable Resource Development (ESRD) has posted the flood hazard mapping prepared for Alberta communities under the Flood Hazard Identification Program.

The website link is: http://maps.srd.alberta.ca/FloodHazard/viewer.ashx?viewer=Mapping.

In terms of assessing flood damages within flood affected communities, in 1982 the Government of Alberta commissioned a study of best practices and adopted a first principles approach employing Alberta-specific building practices and contents data. The resultant methodology and related tools were considered to be the leading edge of the field at the time.

Considerable time has passed since the original research was undertaken and the information was developed. In the interim, the type and value of household contents have changed dramatically, along with the use and level of improvement in typical basements. Given these substantial changes, it was considered prudent to update the flood damage estimation techniques to accurately reflect potential damages and hence provide a more reliable base for benefit/cost analyses and the ultimate selection of potential flood mitigation alternatives. Accordingly, in 2014 the Government retained the consultants who had undertaken the original work to update Provincial flood damage assessment techniques which are the subject of this bulletin.

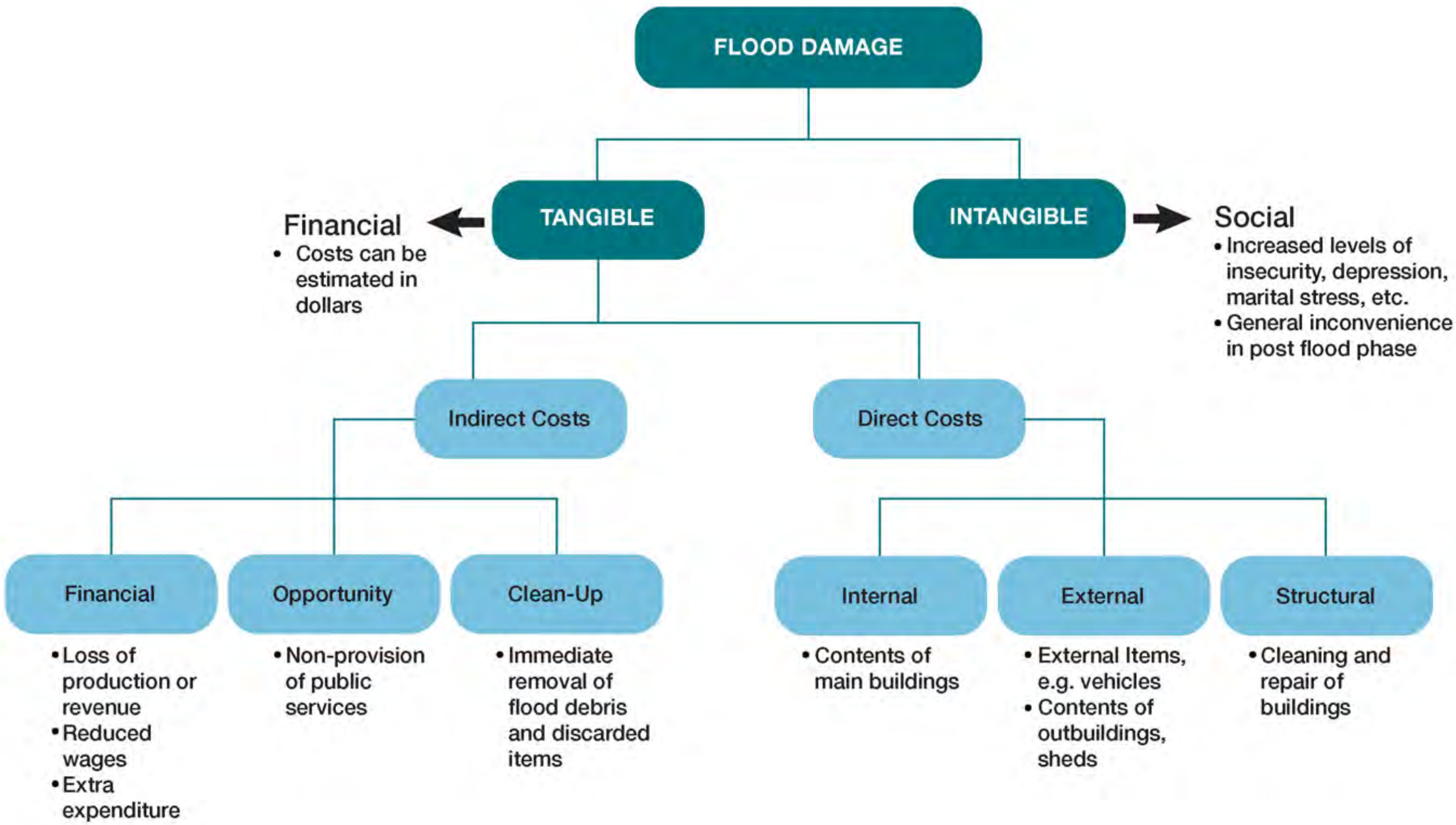
1.3 Types of Flood Damage

Damages resulting from major flood events can be broadly categorized as:

- Tangible damages – flood damages that one can attribute a dollar value to.
- Intangible damages – those that cannot be assessed in dollar terms, for example emotional stress or loss of life.

This bulletin will focus on tangible damages, which can be further categorized as direct damages and indirect damages. See **Exhibit 1** for a list of items covered.

EXHIBIT 1 - FLOOD DAMAGE



Tangible damages are those that can be readily measured in monetary terms. Damages to building structures and contents are considered tangible because they can be measured in terms of replacement or restoration costs.

Direct damages are those that occur immediately and can be directly attributed to the flood inundation. They include damage to both public infrastructure and private property.

Indirect damages also occur as a result of direct flood impacts but they are also more difficult to quantify. They include reduced economic activity and individual financial hardship, as well as adverse impacts on the social well-being of a community, and encompass disruptive impacts, including lost trading time and loss of market demand for products. Consequently indirect damages are often estimated as a percentage of direct damage.

1.4 Actual Versus Potential Damages

In many flooding situations the actual damages incurred are less than the potential damages because sufficient warning has been provided to the community such that mitigative measures, such as the removal of valuables, or the relocation of valuable contents to a higher level in the structure results in a reduction of the potential damages. Contingency measures including warning, flood fighting and individual adjustments within commercial and residential structures can result in reductions of up to 30% of damages.

It should also be noted that the communities suffering frequent flooding will have significantly reduced potential damages versus communities that have not been impacted by a severe flood in recent memory. Consequently, communities in flood prone areas with a high risk potential need to be reminded about the potential for flooding in their community from time to time.

1.5 Approaches to Flood Damage Assessment

There are a number of different approaches that can be taken to estimate tangible damages:

1. the first entails an examination of the floodplain immediately after the water recedes. If such estimates were available for every flood over a period of many years, a damage-frequency curve could be created;
2. an alternative method is to determine the damage caused by three or four recent floods whose hydrologic frequency can be determined and a smooth damage frequency curve plotted through these points; however, for most floodplains, changes in land use with calendar time prevent direct usage of a damage-frequency relationship from historical damages; and
3. the third method entails hydrologically determining various flood elevations for specific flood frequencies and deducing synthetically the damages that would occur given these flood events. This analysis provides a synthetic damage-frequency curve from which one can estimate average annual damages for a given study area.

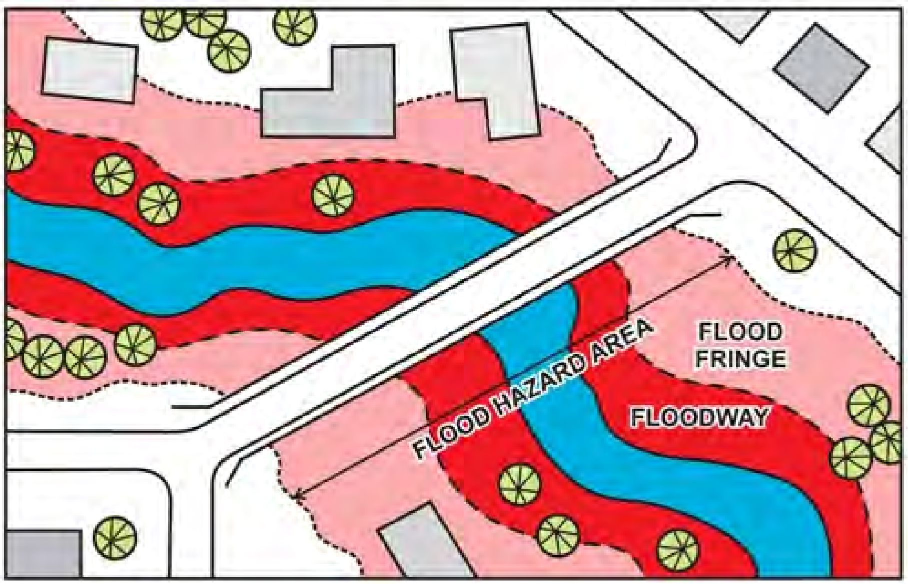
The third method is the one most frequently employed primarily due to a number of limitations inherent in the first two techniques. To reiterate, land use changes over time prevent the direct usage of damage-frequency relationships based on historical damages; this is particularly problematic for jurisdictions experiencing rapid growth. In addition, flood damage payments do not necessarily reflect real damages; however, they can serve as a useful check. Moreover, there are generally insufficient events to extrapolate from, and large voids in the data render the techniques susceptible to error.

In light of the above, the third methodology is considered the best approach for obtaining accurate and representative estimates of damages based on current economic factors and has been adopted for use in Alberta.

1.6 Terminology and Definitions

The following **Exhibits 2 and 3** provide an illustration of the terms and definitions below as it relates to flood hazard mapping and flood inundation mapping.

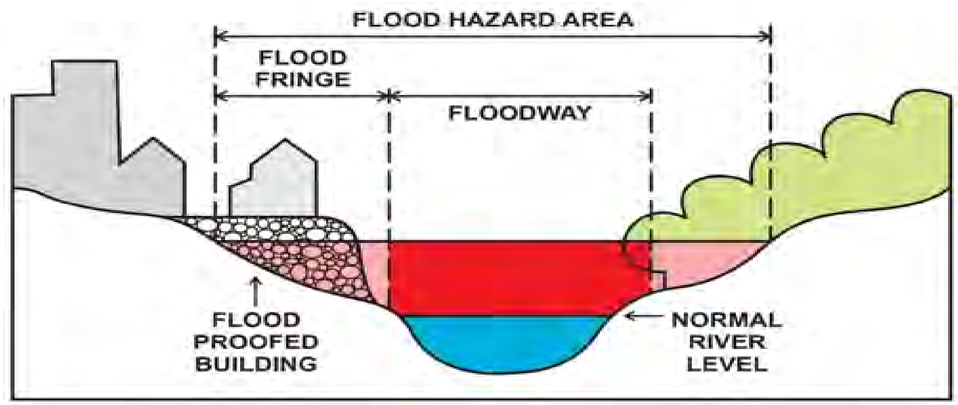
EXHIBIT 2 - FLOOD HAZARD AREA



Flood Hazard Mapping - Delineates the flood hazard area, showing the extent of a design flood event under encroachment conditions. Depending on the particular design flood scenario, the mapping may have associated design flood levels or be divided into multiple zones. Flood hazard mapping is typically used for long-term flood hazard area management and land-use planning.

Flood Hazard Area – The area affected by the design flood under encroachment conditions. The flood hazard area is typically divided into floodway and flood fringe zones, and may also include areas of overland flow.

EXHIBIT 3 - CROSS-SECTION OF FLOOD HAZARD AREA



Floodway – The portion of the flood hazard area where flows are deepest, fastest and most destructive. The floodway typically includes the main channel of a stream and a portion of the adjacent overbank area. The floodway is required to convey the design flood. New development is discouraged in the floodway and may not be permitted in some communities.

Flood Fringe – The portion of the flood hazard area outside of the floodway. Water in the flood fringe is generally shallower and flows more slowly than in the floodway. New development in the flood fringe may be permitted in some communities and should be floodproofed.

Overland Flow – Areas of overland flow are part of the flood hazard area outside of the floodway, and typically considered special areas of the flood fringe.

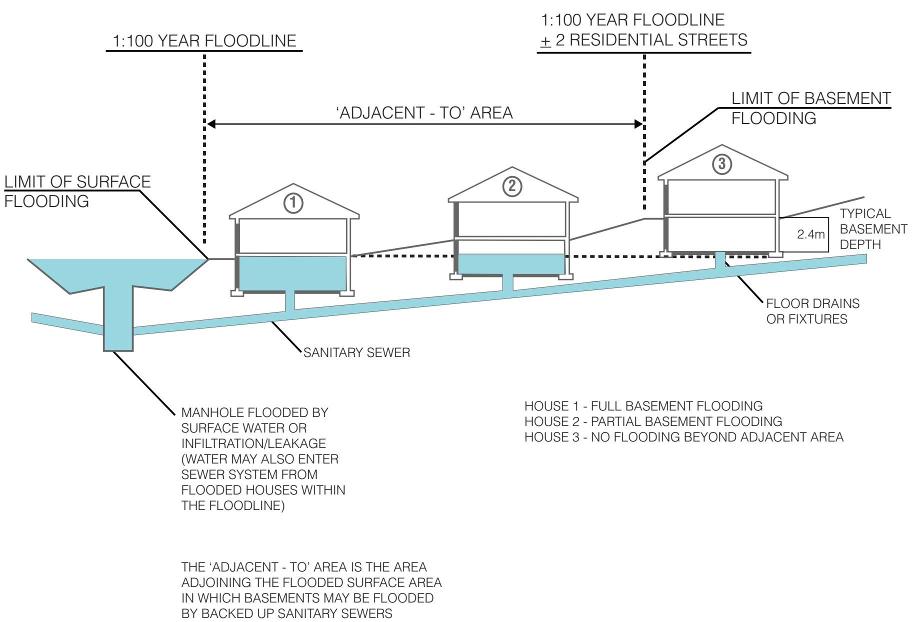
Design Flood – The current design standard in Alberta is the 100 year flood, determined when a flood hazard study is undertaken. A 100 year flood is defined as a flood whose magnitude has a one percent chance of being equaled or exceeded in any year. The design flood can also reflect a computed 100 year water level resulting from an ice jam or be based on a historical flood event.

Design Flood Levels – Flood hazard area water elevations computed to result from a design flood under encroachment conditions. Design flood levels do not change as a result of development or obstruction of flows within the flood fringe.

Encroachment Conditions – The flood hazard design case that assumes a scenario where the flood fringe is fully developed and flood flows are conveyed entirely within the floodway.

Adjacent-To Areas – Areas outside the floodplain can be subjected to basement sewer backup flooding, primarily through seepage of floodwaters into the sanitary sewer system. To account for this potential flood damage, an adjacent-to area is delineated based on a distance of two dwelling units or ±75 m from the 1:100 year flood line. Essentially, with the sewer backup condition, basements which are lower than the floodwaters will automatically suffer damages. **Exhibit 4** depicts this relationship.

EXHIBIT 4 - 'ADJACENT-TO' AREA



Flood Inundation Mapping - Delineates flood inundation areas, showing the extent of one or more flood scenarios under existing, non-encroachment conditions. Depending on the particular flood scenario, the mapping may have associated inundation flood levels or be divided into multiple zones. Flood inundation mapping is typically used for near real-time emergency response planning and operations.

Flood Inundation Area - The area inundated during a particular flood scenario under existing, non-encroachment conditions. The flood inundation area may be divided into multiple zones, including areas inundated due to dedicated flood protection structure failure and isolated areas of inundation due to groundwater seepage.

Flood Scenario - Flow conditions that describe a particular flood event. Flood scenarios typically represent a range of flows, based either on flood frequency analysis or set flow intervals. Typical flood frequency flows in Alberta include the 2-year, 10-year, 20-year, 50-year, 100-year, 200-year, 500-year and 1000-year flood events.

Inundation Flood Levels - Flood inundation area water elevations computed to result from a particular flood scenario under existing, non-encroachment conditions. Inundation flood levels may change as a result of development or obstruction of flows within the flood inundation area.

For more information about flood hazard mapping, contact Alberta Environment and Sustainable Resource Development via email at aenv-flood.risk-maps@gov.ab.ca.

2 Estimating Damages to Residential and Commercial Properties

The amount of flood damage a community suffers is directly proportional to the number of residential and commercial properties in the floodplain, and the depth of flooding these properties suffer as a result of the inundation. In addition to the depth of inundation, the velocity of the floodwaters will have an additional affect on the potential structural damage to a building.

2.1 Depth-Damage Relationships

The damage to residential and commercial properties and contents can be assessed using depth-damage curves. These curves describe the relationship between the depth of inundation and the amount of damage incurred as a result. These curves can be created by surveying damaged properties of a similar grouping over a range of flood depths, or by undertaking a detailed loss assessment with a representative sample of residential properties to create synthetic depth-damage curves.

To reiterate, in 1982 the Government of Alberta commissioned the development of synthetic depth-damage curves based on loss assessment of residential and commercial buildings in the City of Fort McMurray. Additional depth-damage curves were developed as a part of the Elbow River Flood Study in the City of Calgary in 1986. The stage-damage curves were subsequently indexed for use throughout other flood prone centres in Alberta. In 2014 updated residential depth-damage curves were developed based on a representative sampling of properties within the City of Calgary.

The original curves were developed and used in a computerized Flood Damage Database Management System application which was developed specifically for Alberta. This computer model has been replaced by the R-FDA (Rapid Flood Damage Assessment) model, which includes the new synthetic depth-damage curves. The depth-damage curves for the R-FDA model were developed for a range of building types and sizes and include those that represent:

- residential buildings for a range of single-family, multi-family, mobile home and apartment types, for contents and structure expressing damages on a per square metre basis; and
- commercial/retail/industrial and institutional buildings for a number of categories of non-residential use based on damages per square metre for both contents and structure.

2.2 Estimating Levels of Inundation of Affected Properties

It is typically an extreme historical flood event that causes severe inundation and hence damages in a community. However, damage can also be caused by less severe but higher frequency flood events. For benefit/cost purposes it is necessary to determine potential damages from a range of flood events. As a result, hydrologic studies are undertaken to establish the flood flows for different flood frequencies coupled with hydraulic analysis to establish the respective flood elevations in a given location to assist in estimating the levels of inundation on properties in that location. The following for each property is required:

- **Grade** of the property is established using the digital elevation model (DEM) from LiDAR. Alternatively the grade or ground elevation could also be obtained from traditional ground level surveys or detailed topographic maps.
- **Flood elevation** is derived from hydraulic flood modelling (HEC-RAS), or established from historical flood events.
- **Flood depth** at each property can be calculated using floor heights above grade, which can be established from building approval records, traditional field survey, or the use of videos/photography of street views from the location.

2.3 Estimating Flood Damages

The following steps are undertaken to estimate flood damages:

1. Hydrologic and hydraulic studies to establish the floodplain limits under different return flood events (i.e., 1:10 year, 1:25 year, 1:50 year, 1:100 year, 1:500 year, including floods that exceed the design flood).
2. Inventory and classification of all flood affected properties (including the adjacent-to areas) and the depth of inundation by individual property.
3. Selection of appropriate depth-damage curves to determine direct contents and structural damages to individual properties from the flooding.
4. Estimation of indirect damages including such things as costs of evacuation, employment losses, administrative costs, net loss of normal profit and earnings to capital, management and labour, general inconvenience, etc. These are generally calculated as a percentage of direct damages.
5. Calculation of total direct and indirect damages.

Step 1

Flood hazard mapping exercises predict the extent and depth of floodwaters for varying levels of flood severity and frequency. These flood maps provide the information to locate potential properties that may be affected by the flooding. With the use of the 3D DEM surface within the flood area, the grade, main floor elevation and flood depth can be established for each affected property.

Step 2

Flood damages for the affected properties in the floodway, flood fringe and adjacent-to area are estimated for each of the return flood events.

The first stage is to assess if the building property is in the floodway or flood fringe. Typically the floodway is part of the floodplain where the depth of flooding and velocity is greater than one metre and one metre per second respectively. Any properties in the floodway could be subjected to significant structural damage and may need to be relocated.

Basement damages could occur even if the property is outside of the flood hazard area because of sewer backup, or ground seepage. Consequently properties in an adjacent-to area should be included for damage estimates.

Step 3

The depth-damage curves developed for Alberta are divided into residential and commercial categories, and each set includes separate curves for contents and structure. In addition basement damage curves have been developed for the single family residential properties. Twenty-one different content and six structural damage curves have been developed for commercial properties. These are used for flood damage estimation.

<u>Estimate Direct Damages</u>

- Depth-Damage Curve Estimate
- Damage Curve Height = Flood Elevation – (Main Floor Height Above Grade + Grade Elevation)
- Main Floor Damage = Dollar Value On Curve Equal To The Damage Curve Height
- Total Damage = Basement Damage + Main Floor Damage

This process is repeated for all affected properties and a cumulative total for each return flood event is computed. The total potential direct damage resulting from a 1:100 year flood, 1:50 year flood, etc. is established.
Exhibits 6 and 7 illustrate this.

Step 4

Once an assessment of the potential direct damages to the affected properties has been made, the indirect damage can be estimated. It is common practice that the indirect damages for residential and commercial property be estimated as a percentage of the direct damage.
For example the following percentages were recommended for the City of Fort McMurray:

- Residential Indirect Damage - 20% of Direct Residential Damages
- Commercial/Institutional Damage - 41% of Direct Comm./Ind. Damages

In addition a percentage is also attributed to infrastructure, highways and utilities unless these damages can be estimated from first principles by the municipality. It should be noted that the indirect percentages should be re-assessed for each of the flood affected communities and they should be based on the local situation assessment. Indirect damages should be reassessed over time especially if new mitigation measures are proposed.

Step 5

The total damage cost for each return flood is the sum of all direct and indirect damages.

Total damages = direct damages + indirect damages

Exhibit 7 illustrates the input, tasks and output of the flood damage estimation methodology described

EXHIBIT 5 - EXAMPLE OF RESIDENTIAL CONTENT DEPTH DAMAGE CURVE

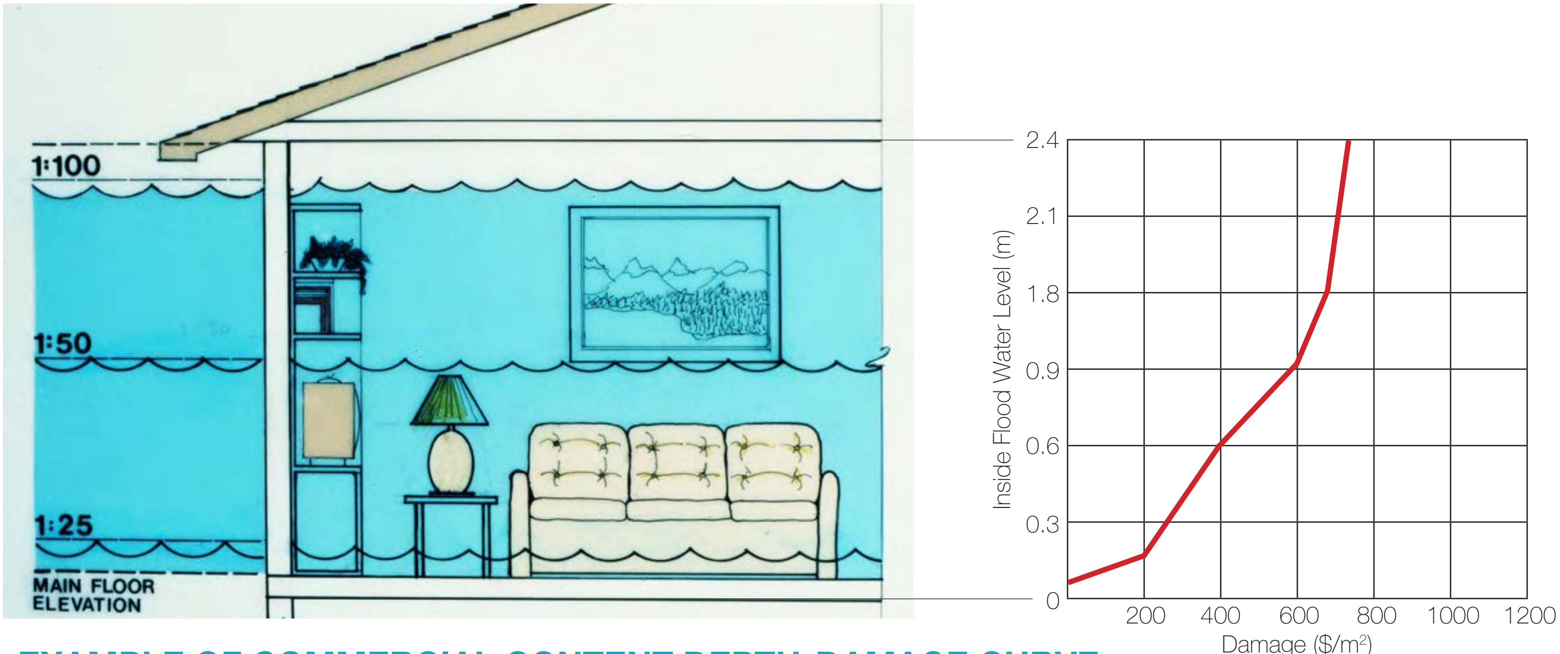


EXHIBIT 6 - EXAMPLE OF COMMERCIAL CONTENT DEPTH-DAMAGE CURVE

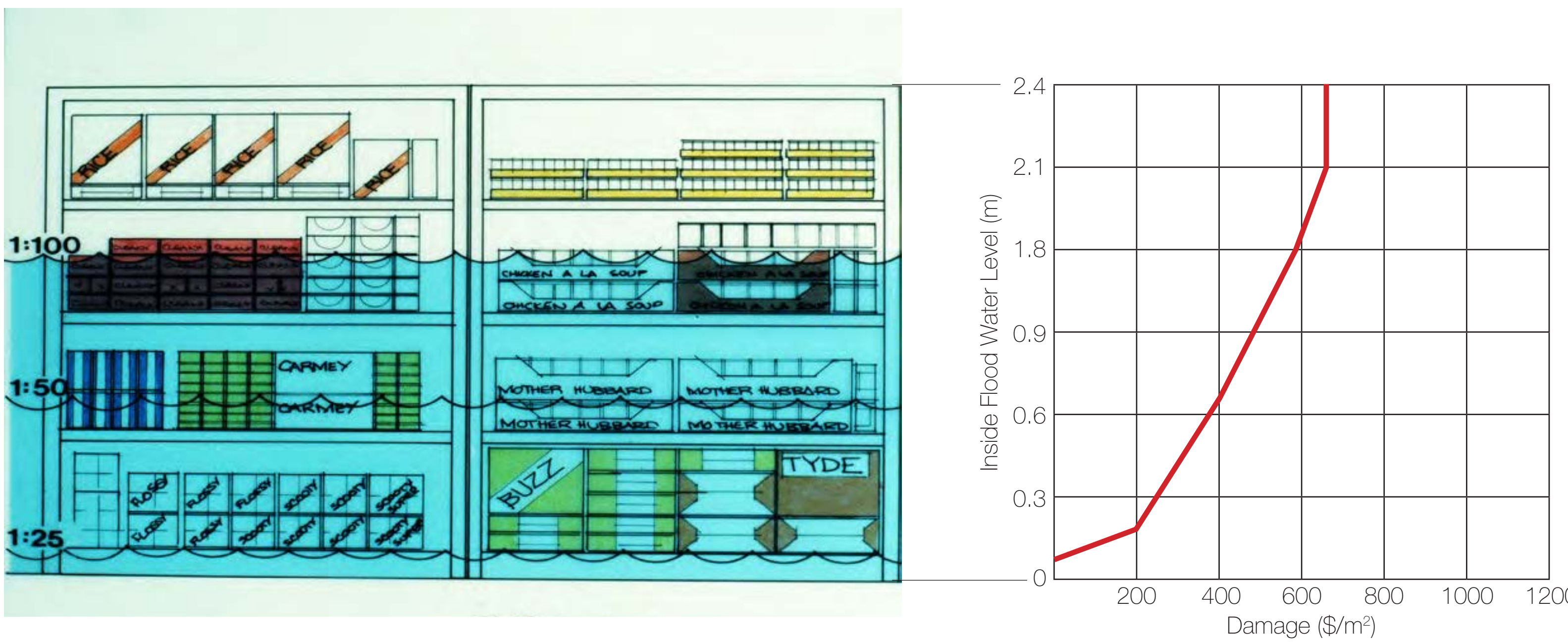
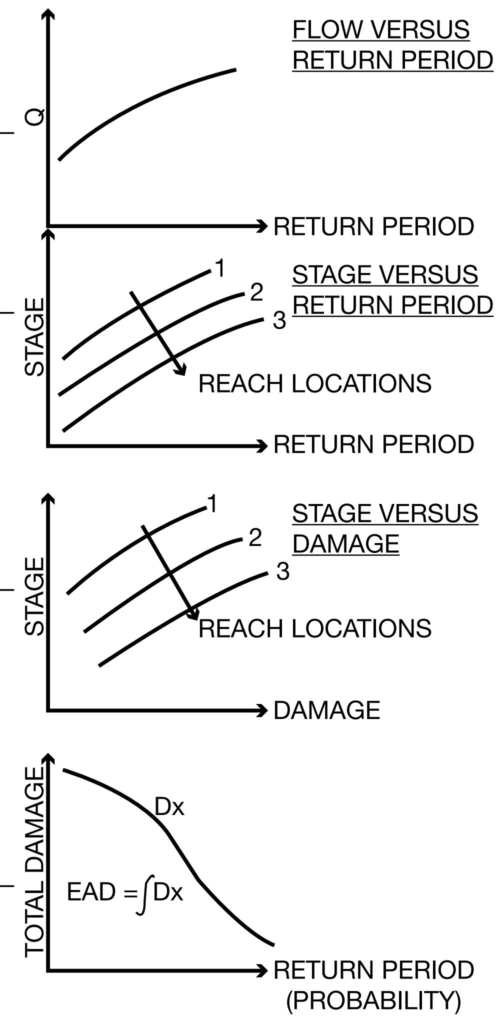


EXHIBIT 7 - GENERAL FLOOD DAMAGE ESTIMATION METHODOLOGY

INPUT	TASK	OUTPUT
	IDENTIFICATION OF DAMAGE CENTRE	
- DRAINAGE AREA - STEAMFLOW RECORDS - PAST STEAMFLOW ANALYSES	HYDROLOGIC ANALYSIS - SINGLE STATION FREQUENCY ANALYSIS - REGIONAL FREQUENCY ANALYSIS - TESTS FOR SUITABILITY OF LOW RECORD	FLOW VERSUS RETURN PERIOD
- CHANNEL AND FLOODPLAIN GEOMETRY - ROUGHNESS COEFFICIENTS - BRIDGE AND CULVERT DETAILS	HYDRAULIC ANALYSIS - BACKWATER PROFILES THROUGH DAMAGE CENTRE FOR ALL RETURN PERIOD FLOODS - SELECT DAMAGE REACHES - ESTIMATE STAGE (DEPTH) FOR EACH REACH RETURN PERIOD	STAGE VERSUS RETURN PERIOD
- TOPOGRAPHIC SURVEY OF STRUCTURES - SYNTHETIC/HISTORICAL STAGE DAMAGE CURVES - COMMERCIAL/INDUSTRIAL INVENTORIES - AGRICULTURAL	STAGE DAMAGE CALCULATIONS - SELECT TYPE OF DAMAGE CURVE FOR VARYING LAND USE - MODIFY OR ADD TO CURVES DEPENDING ON PROJECT SPECIFICS - ACCUMULATE DAMAGE ESTIMATES FOR STAGE INCREMENTS	STAGE VERSUS DAMAGE
	TOTAL DAMAGE CALCULATIONS - DETERMINE DAMAGE VERSUS RETURN PERIOD (PROBABILITY) AND ACCUMULATE OVER ALL REACHES - INTEGRATE UNDER DAMAGE VERSUS PROBABILITY CURVE TO ESTIMATE EXPECTED ANNUAL DAMAGE (EAD)	



Source: Paragon Engineering “Flood Damages: A Review of Estimation Techniques” - Ministry of Natural Resources (March 1984)

3 Estimating damage to other infrastructure

In addition to private property, there are a number of other assets that may be potentially exposed to flood damage. For example, direct and indirect damages may be caused to:

- **roads and transport infrastructure**
- **parks and recreational facilities**
- **hospitals, schools, and other government buildings**
- **water, sewerage and drainage systems**
- **communication networks**

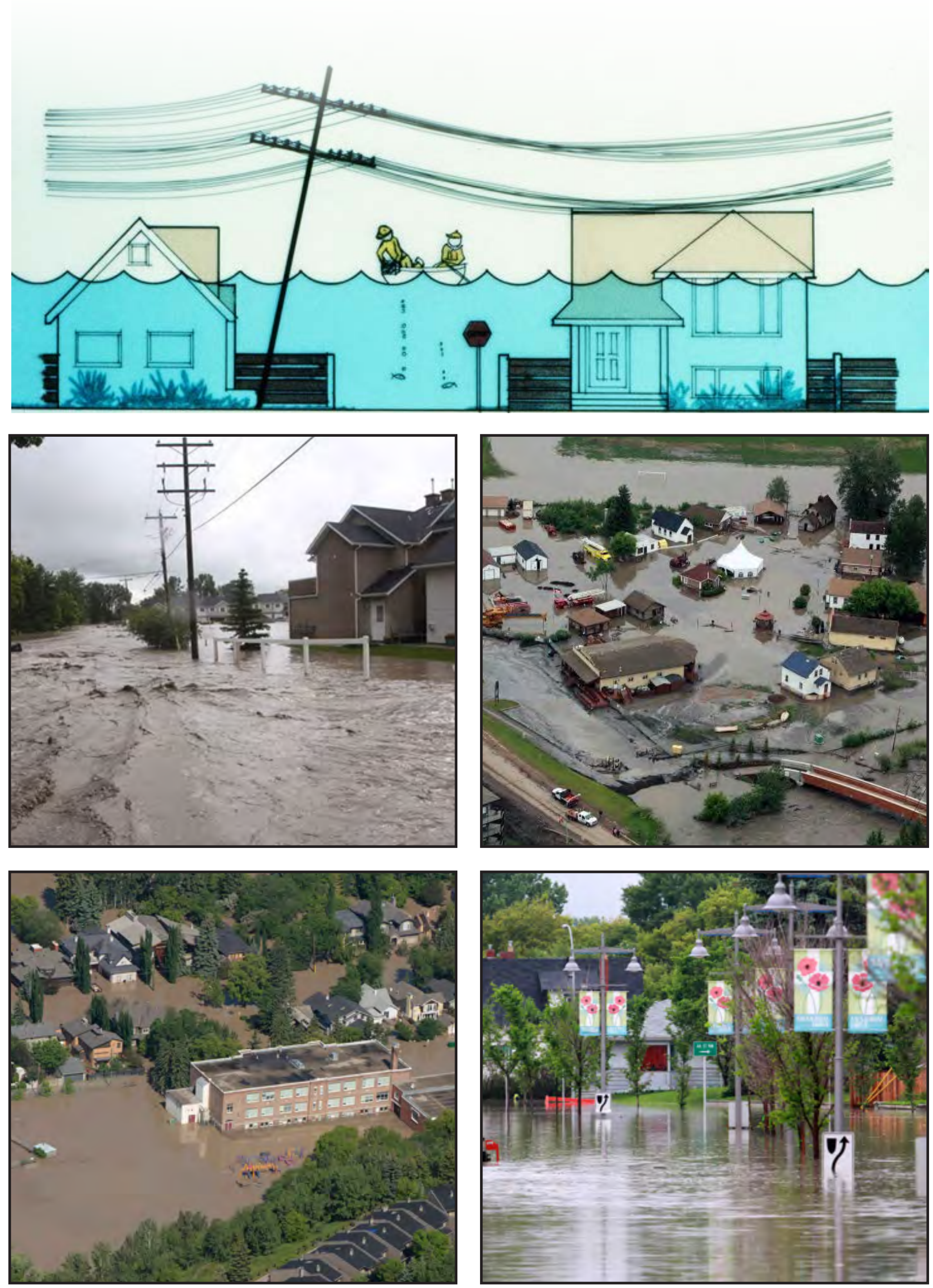
Traditionally, most of these were publicly owned; however, the increasing trend towards privatization of services may have an influence on the costing methodology used to assess damages.

3.1 Direct Damages to Infrastructure

In general the repair and replacement of roads and bridges is the largest component of damages to public assets. The amount of damage caused is a result of the flood-related factors and the ability of the road to withstand flood conditions. Relevant factors include both the initial repair cost and the possibility of a significant reduction in the overall life of the road surface as a result of the flood.

Generally annual maintenance costs and other documented historical costs can be used to develop locally specific damage costs. Where this information is not available then data from other studies may have to be used.

EXHIBIT 8 - INFRASTRUCTURE DAMAGE



3.2 Indirect Damages to Infrastructure

The indirect damages to services provided by government or community agencies should be based on the lost wages from downtime and disruption to operations. This may be calculated by multiplying lost working hours by wages.

Business or activities not provided by government or community agencies are profit driven. Accordingly, the calculation of their damages needs to be based on different assumptions. These indirect losses should be calculated only as the lost profit component.

4 Economic Assessment of Flood Mitigation Projects

The purpose of this section is to provide guidance on the economic assessment of flood mitigation projects based on their respective cost and benefits.

Depending on its size (or severity), each flood will cause a different amount of flood damage. The average annual damage (AAD) is the average damage in dollars per year that would occur in a designated area (i.e., the Drumheller area) from flooding over a very long period of time. In many years there may be no flood damage, in some years there will be minor damage (caused by small, relatively frequent floods) and, in a few years, there will be major flood damage (caused by large, rare flood events). Estimation of the average annual damage provides a basis for comparing the effectiveness of different floodplain management measures (i.e., the reduction in the annual average damage).

4.1 Average Annual Damages

The average annual damage (AAD) cost from flooding is a common performance indicator used to measure the level of potential flood damages. It expresses the costs of flood damage as a uniform annual amount based on the potential damages inflicted by a range of flood magnitudes.

The calculation of an AAD estimate requires potential damage costs for a number of flood events – the more the better (including the events greater than the design flood which is usually the 1:100 year flood).

To calculate AAD:

1. Estimate the potential flood damage costs from a range of flood events, including those greater than the design flood if possible.
2. Plot the graph of flood damages versus annual exceedance probability.
3. Calculate the average annual damages from flooding.
4. Calculate the reduction as a result of the proposed flood mitigation activities.
5. The net benefit is the difference of the two over the design life of the mitigation.

Step 1

To complete this step, it is necessary to have estimates of potential flood damages for a range of flood sizes.

Following is an example of flood damage costs that is used to illustrate the process used to calculate AAD. If the cumulative total of direct and indirect flood damages including residential, commercial, infrastructure, utilities and highways for the 25, 50 and 100 year annual recurrence interval (ARI) flood events are:

- Annual Recurrence Interval (ARI) 25 year 50 year 100 year
- Annual Exceedance Probability (AEP) 0.04 0.02 0.01
- Total Damages $ 35,082,000 $ 118,519,000 $ 220,323,000

Step 2

A graph of potential damage estimates versus annual exceedance probability is plotted. Potential damages in dollars are plotted on the vertical axis and the annual exceedance probability is plotted horizontally.

The annual exceedance probability for a given flood event is the inverse of the average recurrence interval:

- Annual exceedance probability = 1 / Average recurrence interval
- Using the example flood damage costs:
- 10 year ARI = 10%, AEP = 0.1
- 100 year ARI = 1%, AEP = 0.01

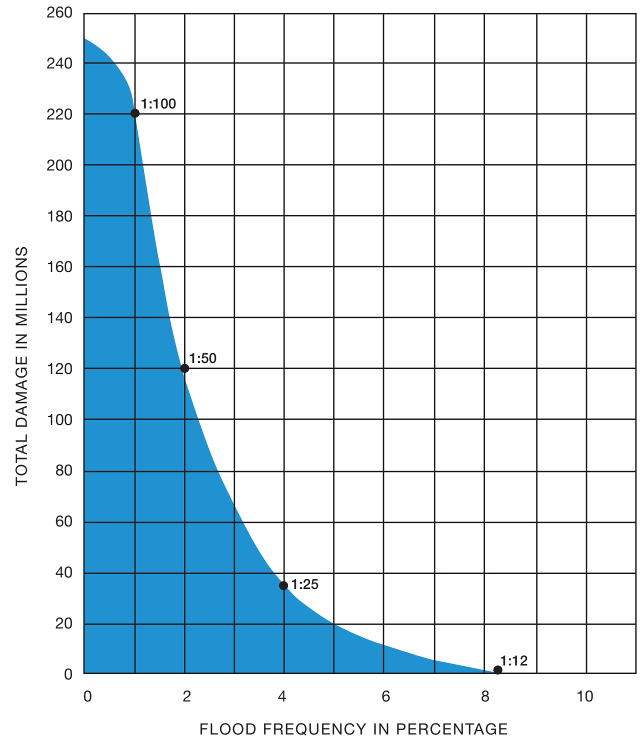
For the rarer flood events like the probable maximum flood, the annual probability of exceedance (AEP) approaches zero. **Exhibit 9** depicts a damage-probablity curve, which is used to calculate Average Annual Damage.

Step 3

The average annual damage cost is the area under the flood damage cost curve plotted in the graph. It is expressed in units of dollars per year.
Using the example:

- Each square unit in the graph = $ 20,000,000 * 0.01 = $ 200,000
- Cumulative area in blue in the graph = 28.75 units
- Therefore, average annual damage = $ 5,750,000

EXHIBIT 9 - DAMAGE - PROBABILITY CURVE



FLOOD	FLOOD DAMAGE MILLION DOLLARS
1:25	35.0
1:50	118.5
1:100	220.3

AVERAGE ANNUAL DAMAGE = $5,750,000

Step 4

The benefit that will accrue to a flood mitigation project is equal to the reduction in the AAD that can be realized by that project, and is calculated as:

- Reduction in AAD = AAD without project – AAD with project
- A project that protects the properties up to 100 year flood = 16.75 units
- Therefore, AAD with mitigation project = $ 2,400,000
- Reduction in AAD = $ 5,750,000 - $ 2,400,000
- Assuming a project life of 50 years and a discount rate of 4%

The benefit/cost will be positive if the flood mitigation project is less than $71,965,370 in terms of capital and operating costs over the life of the project.

4.2 Evaluation of Flood Mitigation Alternatives

This bulletin has been developed by Alberta Environment Sustainable Resources Development to provide stakeholders with guidance on the economic development of flood mitigation alternatives. It is intended that topics of social and environmental assessment also be covered in future bulletins.

5 Appendix

5.1 Acronyms

AE – Alberta Environment (now ESRD)

AAD – Average Annual Damage

AEP – Annual exceedance probability

ARI – Average recurrence interval

DEM – Digital elevation model

ESRD – Environment Sustainable Resource Development

FDA – Flood Damage Assessment

FDDBMS – Flood Damage Database Management System

FEMA – Federal Emergency Management Agency

HAZUS-MH – FEMA software for multi hazard loss estimation

HEC-FDA – USACE software for flood mitigation

HEC-RAS – USACE software for flood mapping

LiDAR – Light detecting and ranging remote sensing method

R-FDA – Rapid Flood Damage Assessment

USACE – U.S. Army Corps of Engineers

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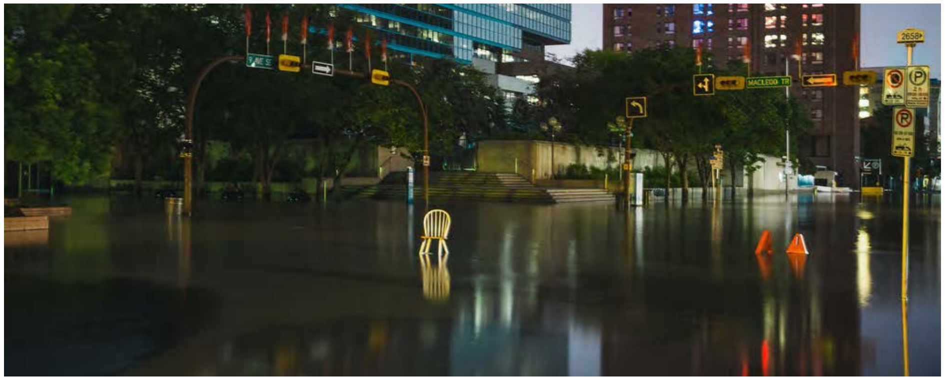

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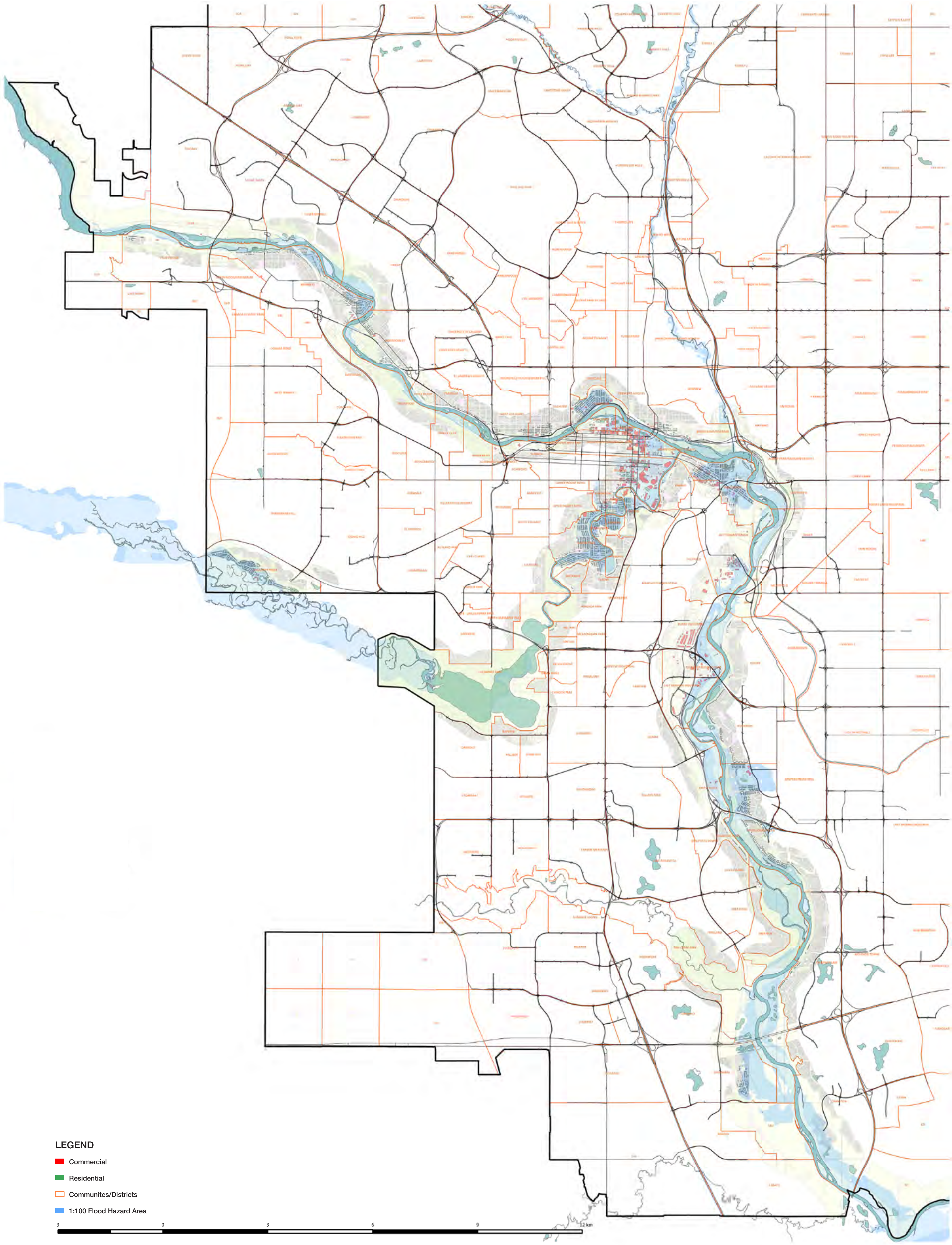
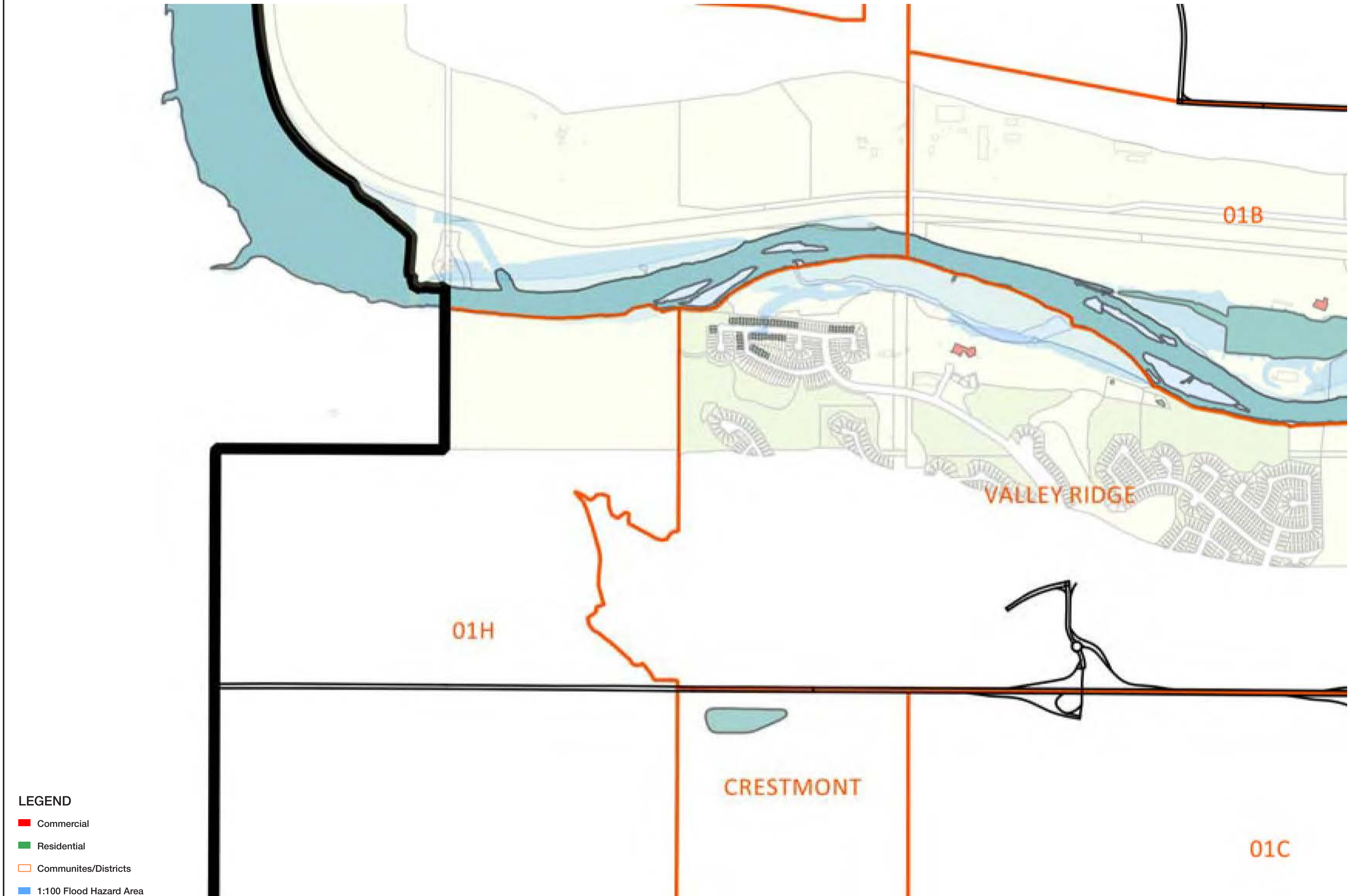
Appendix B – Flood Hazard Mapping

Calgary Flood Hazard Area



Calgary Flood Hazard Area



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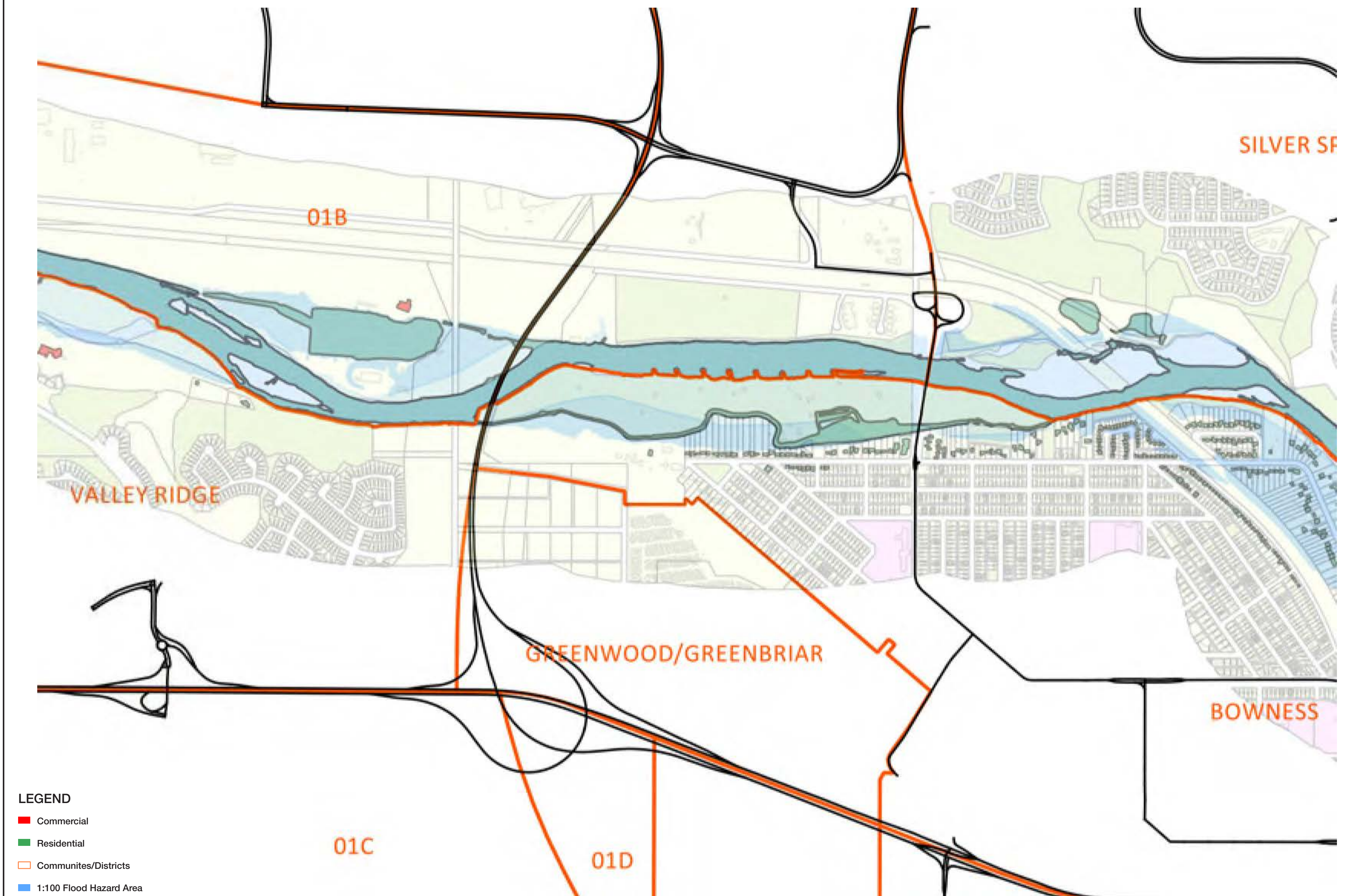

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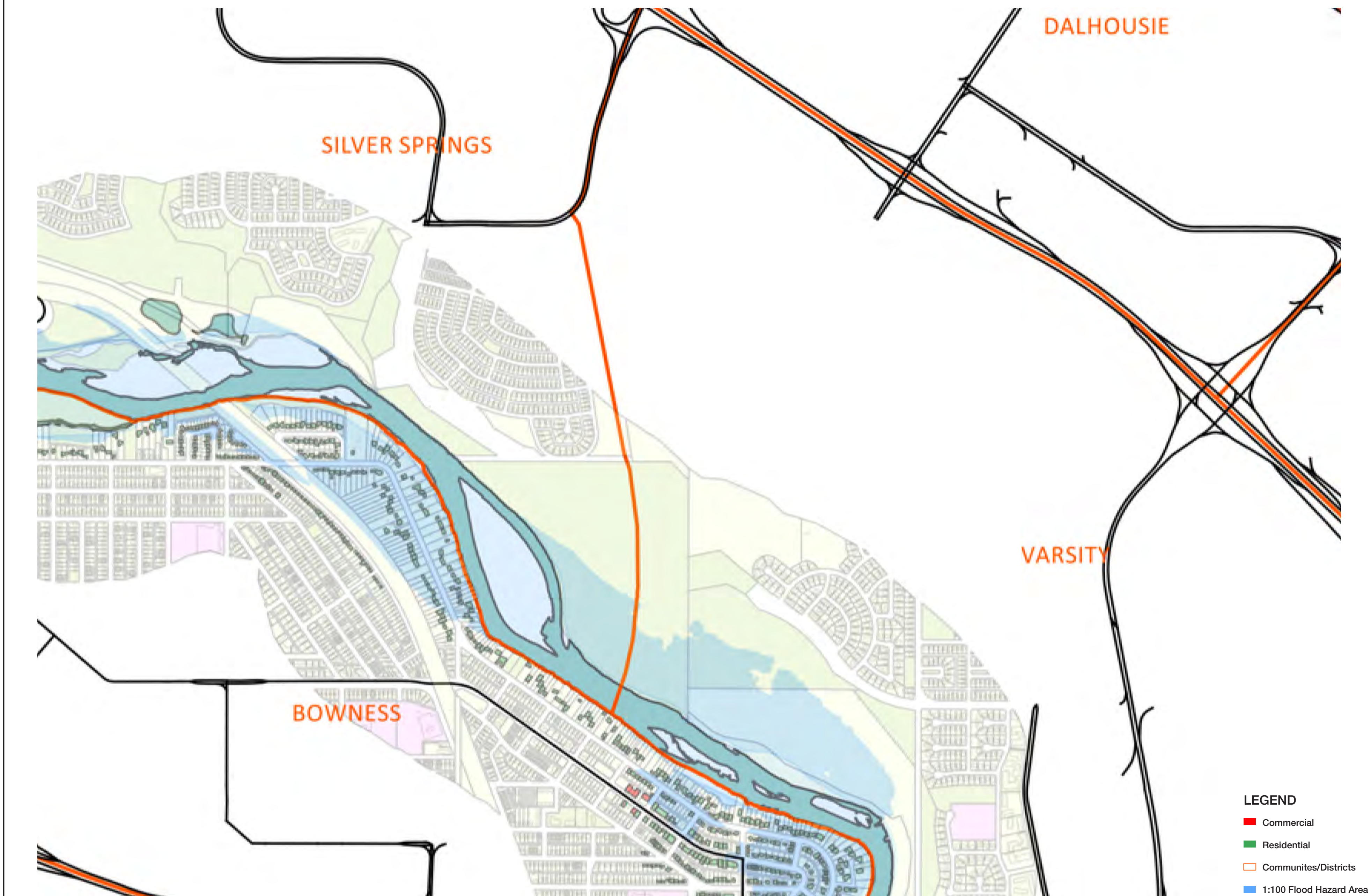

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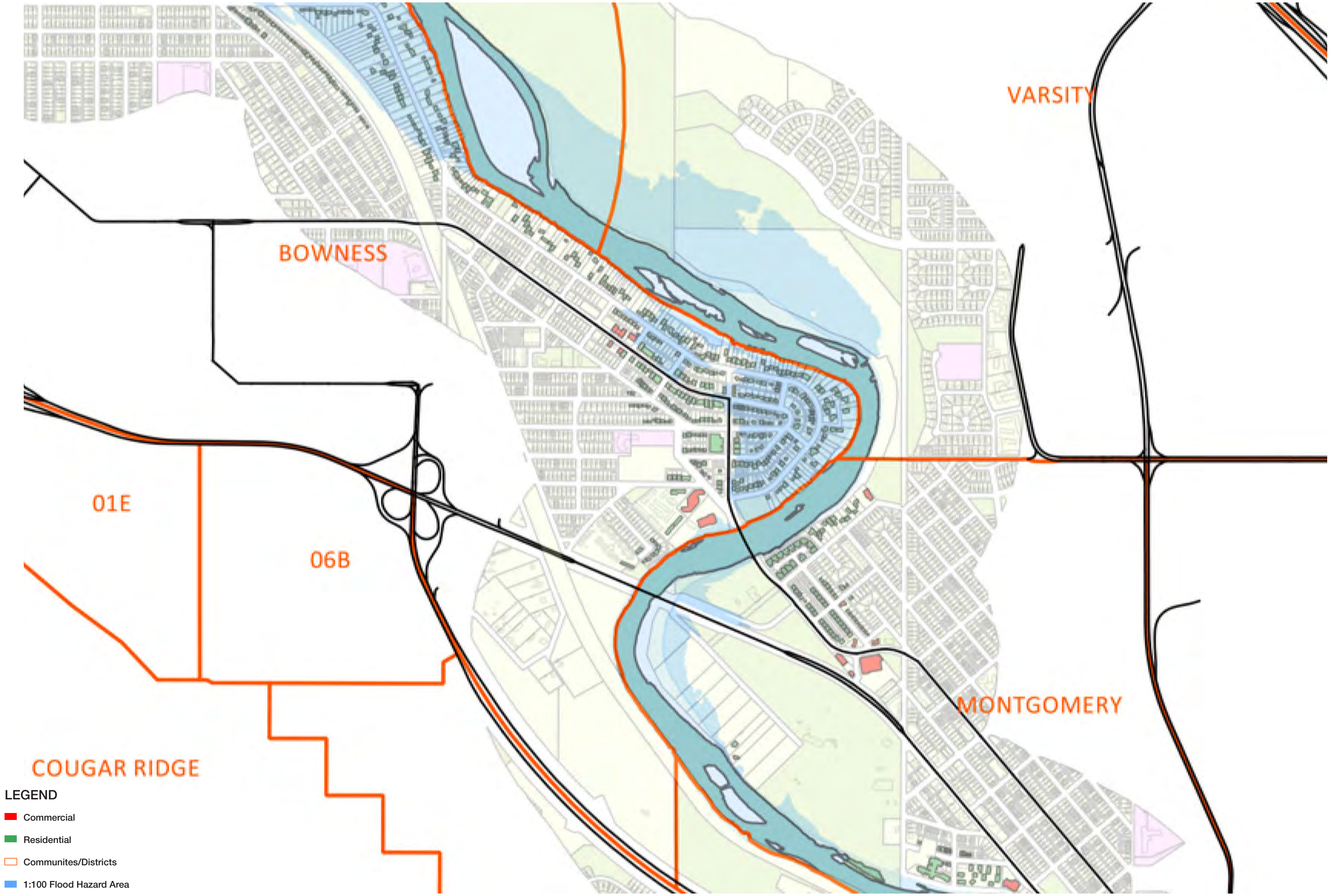
EXHIBIT B-4

Calgary Flood Hazard Area



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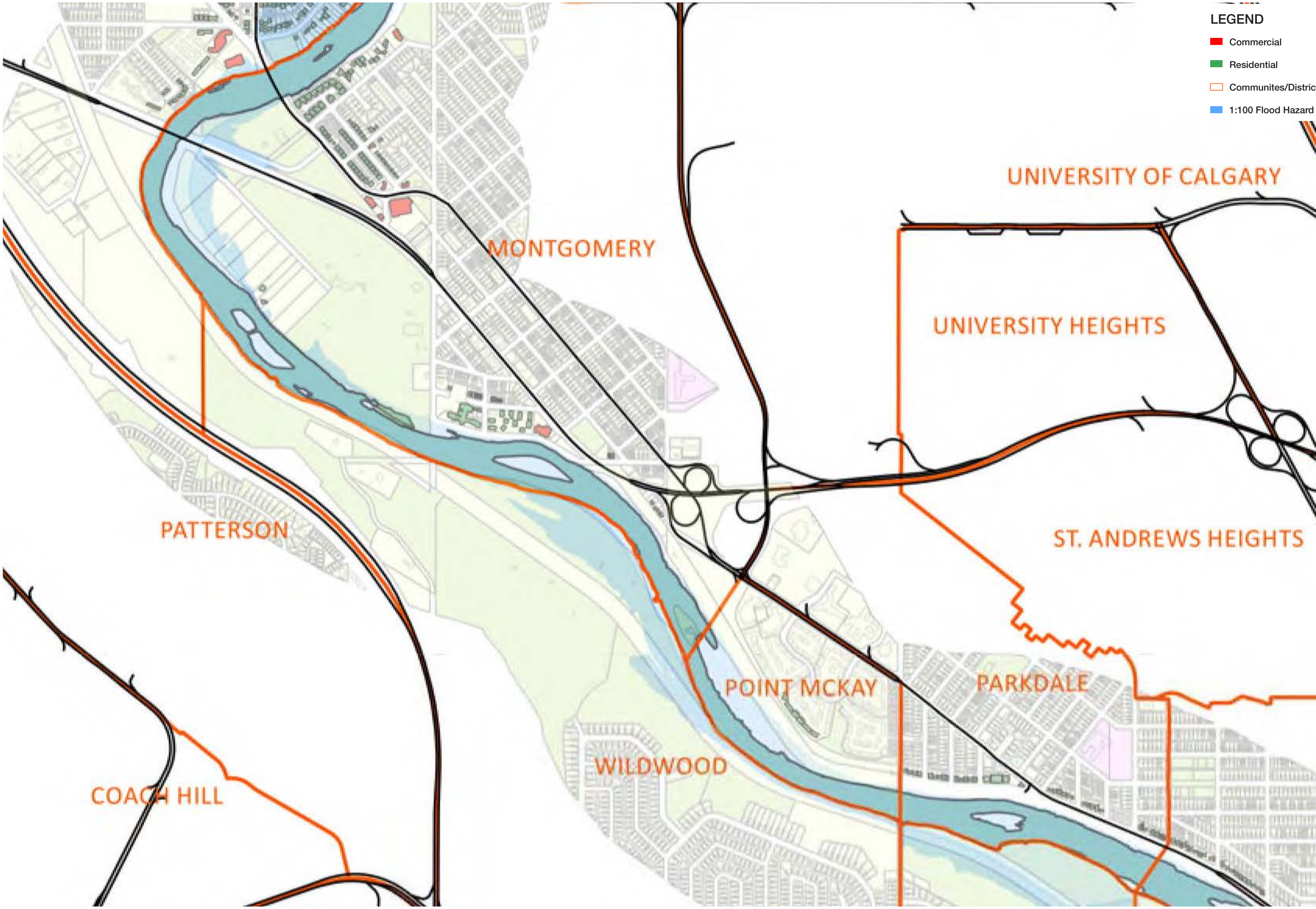
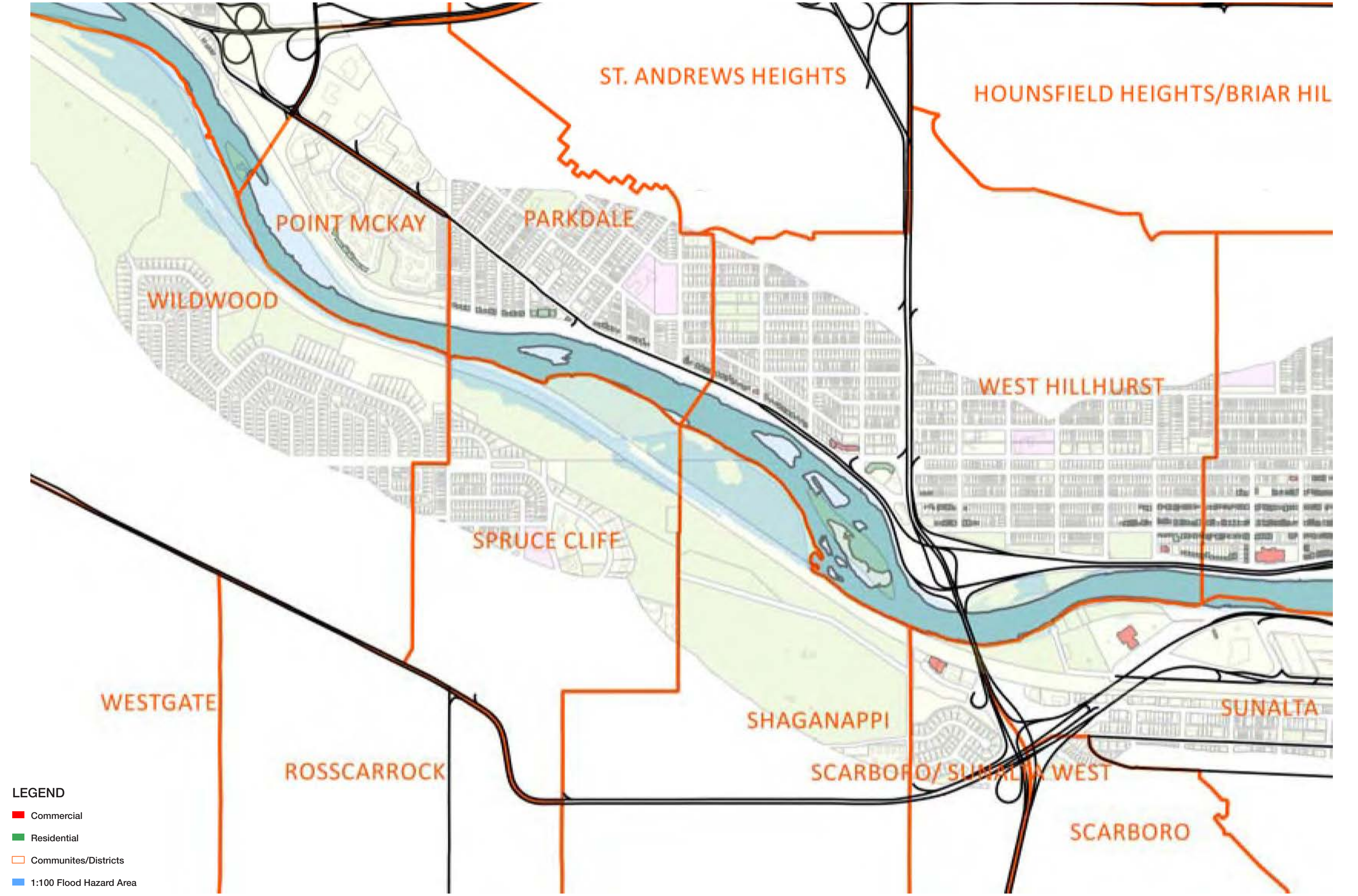


Calgary Flood Hazard Area



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Calgary Flood Hazard Area

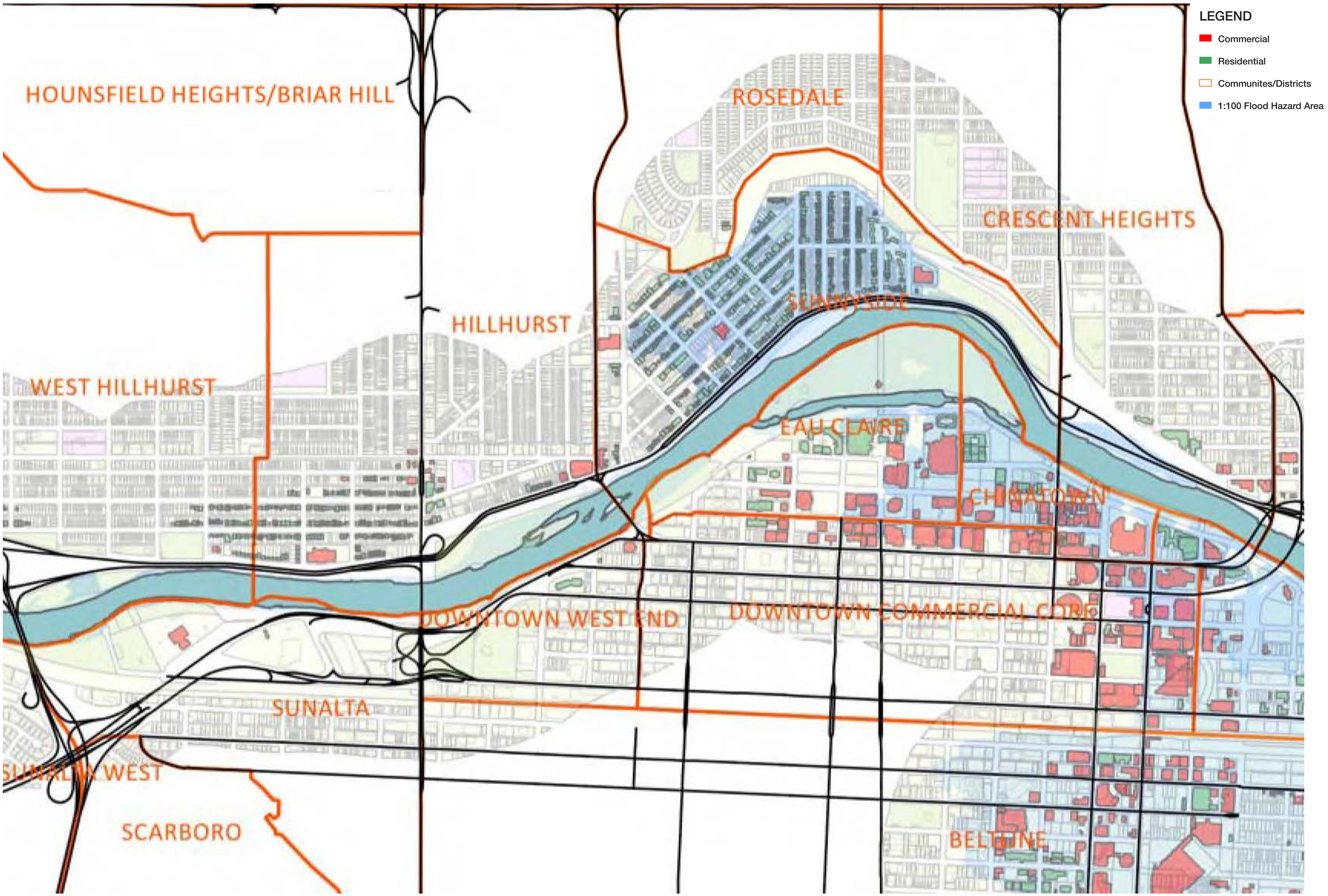

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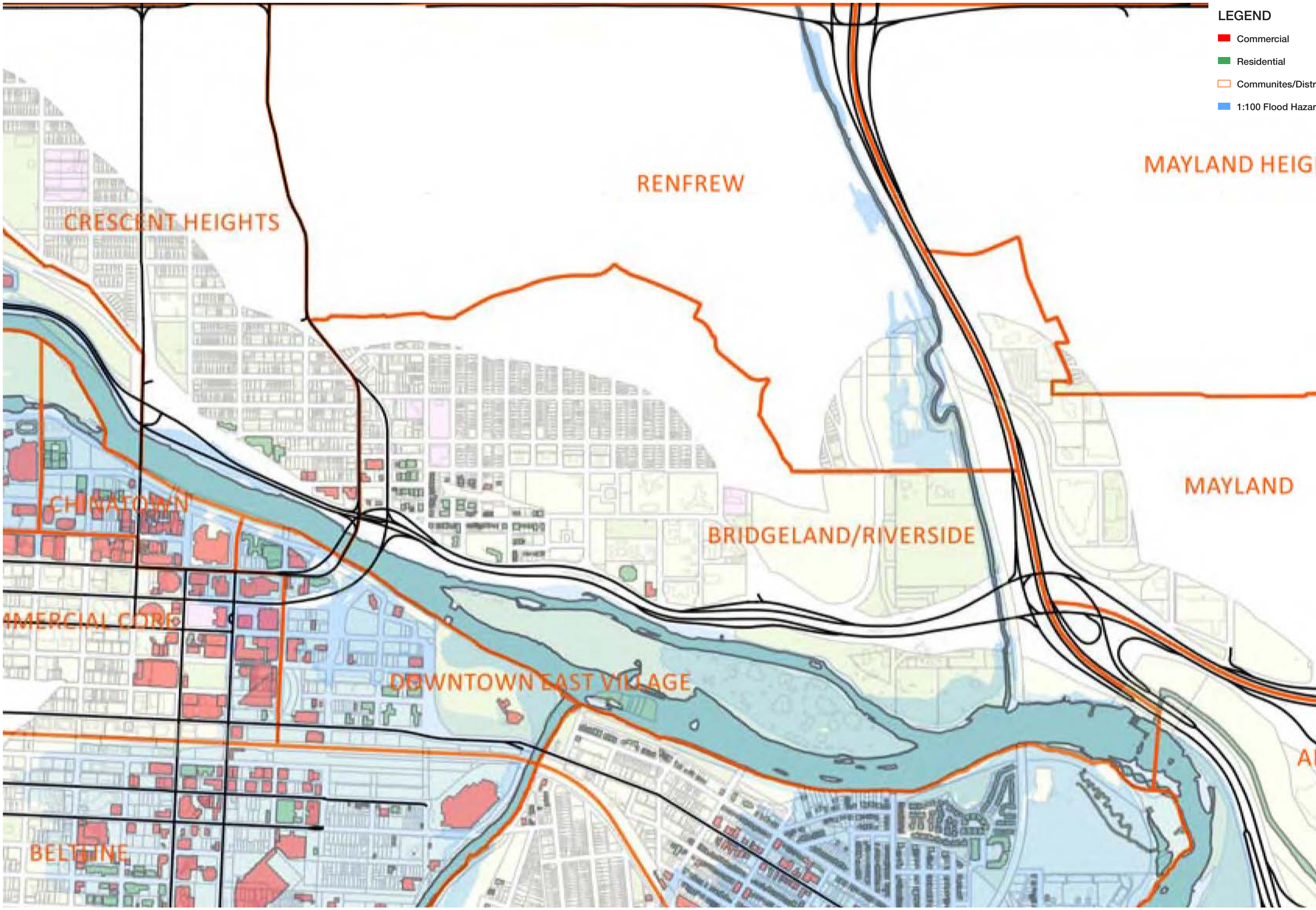
EXHIBIT B-8

Calgary Flood Hazard Area



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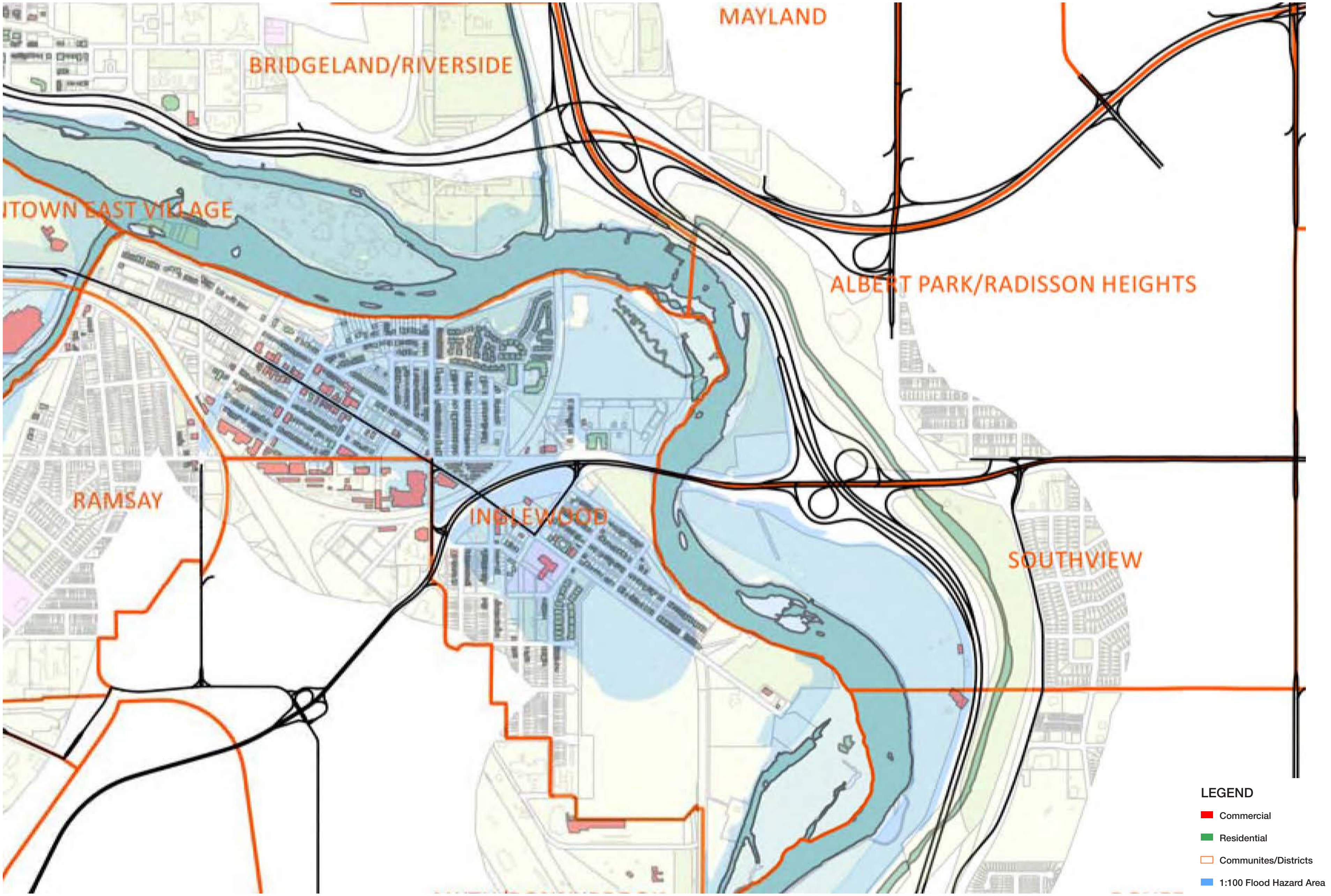

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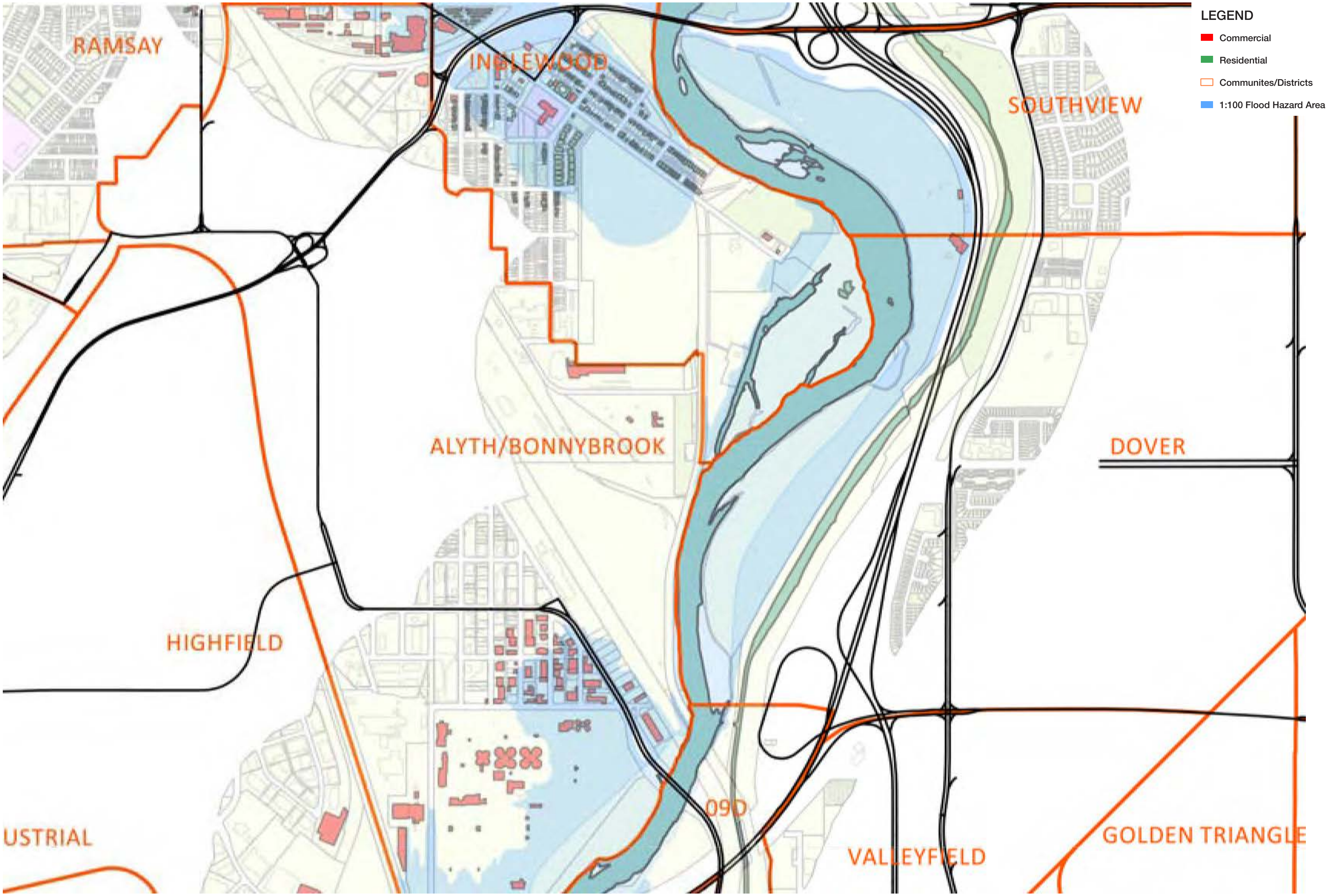

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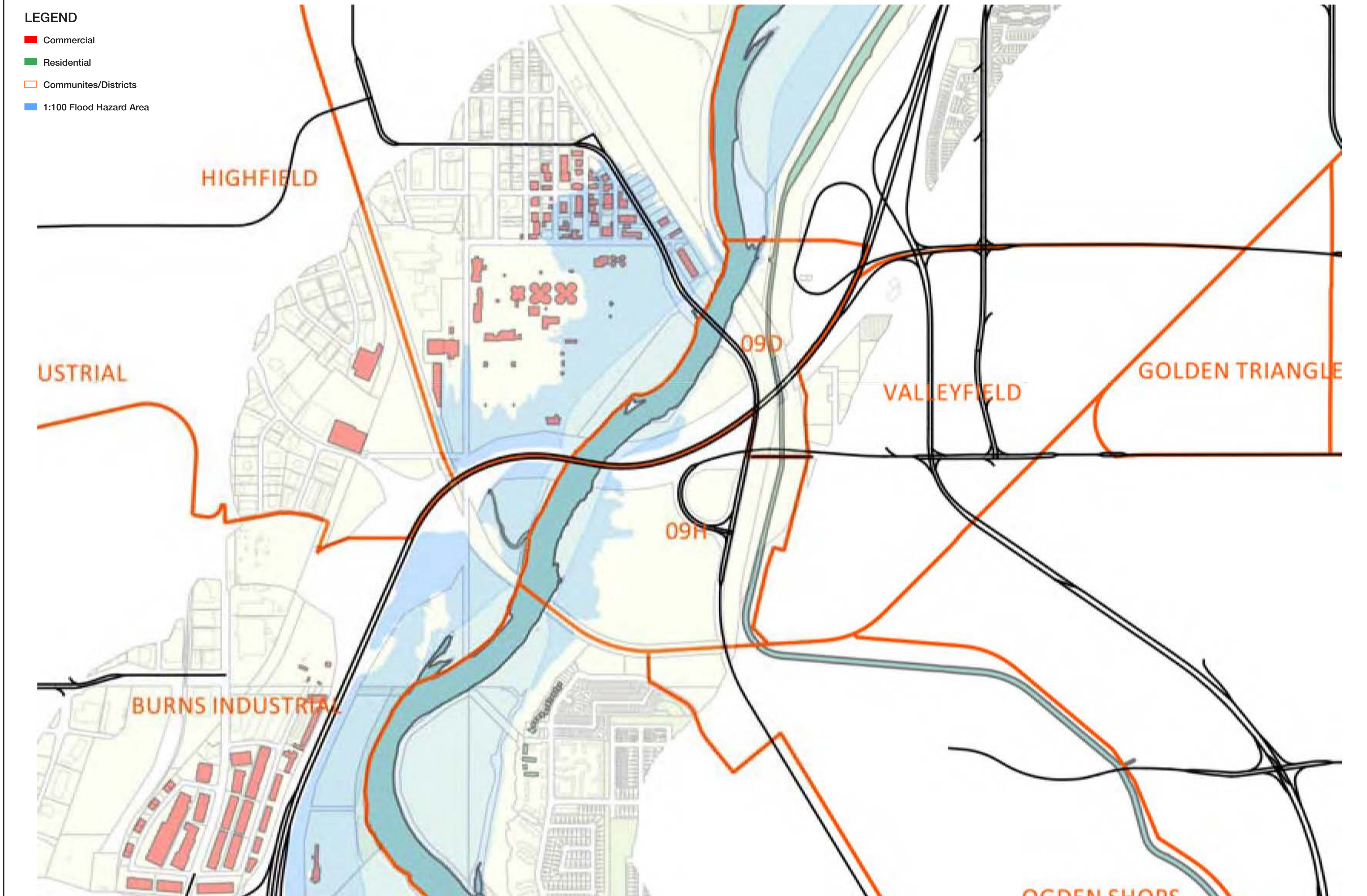

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EXHIBIT B-12

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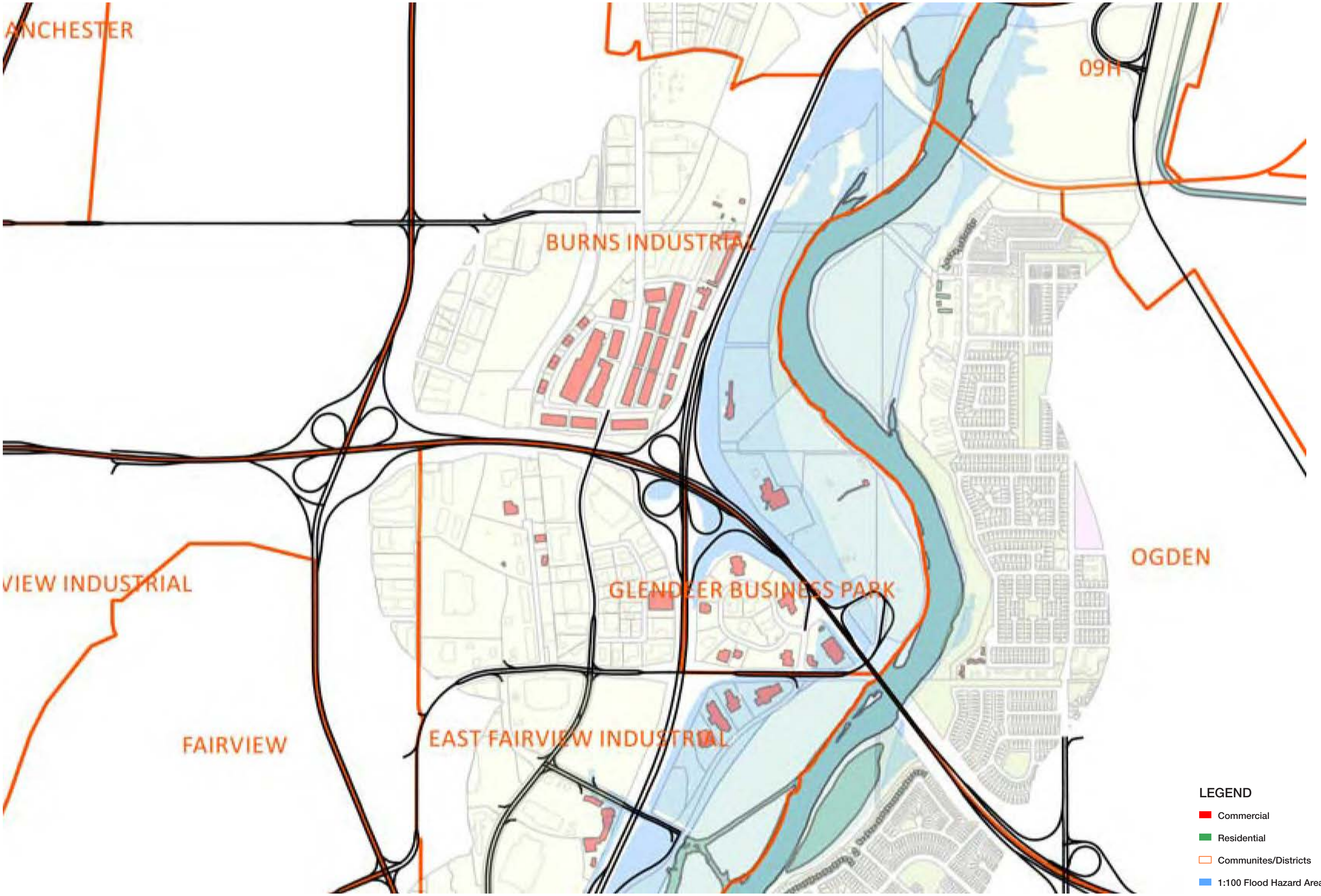

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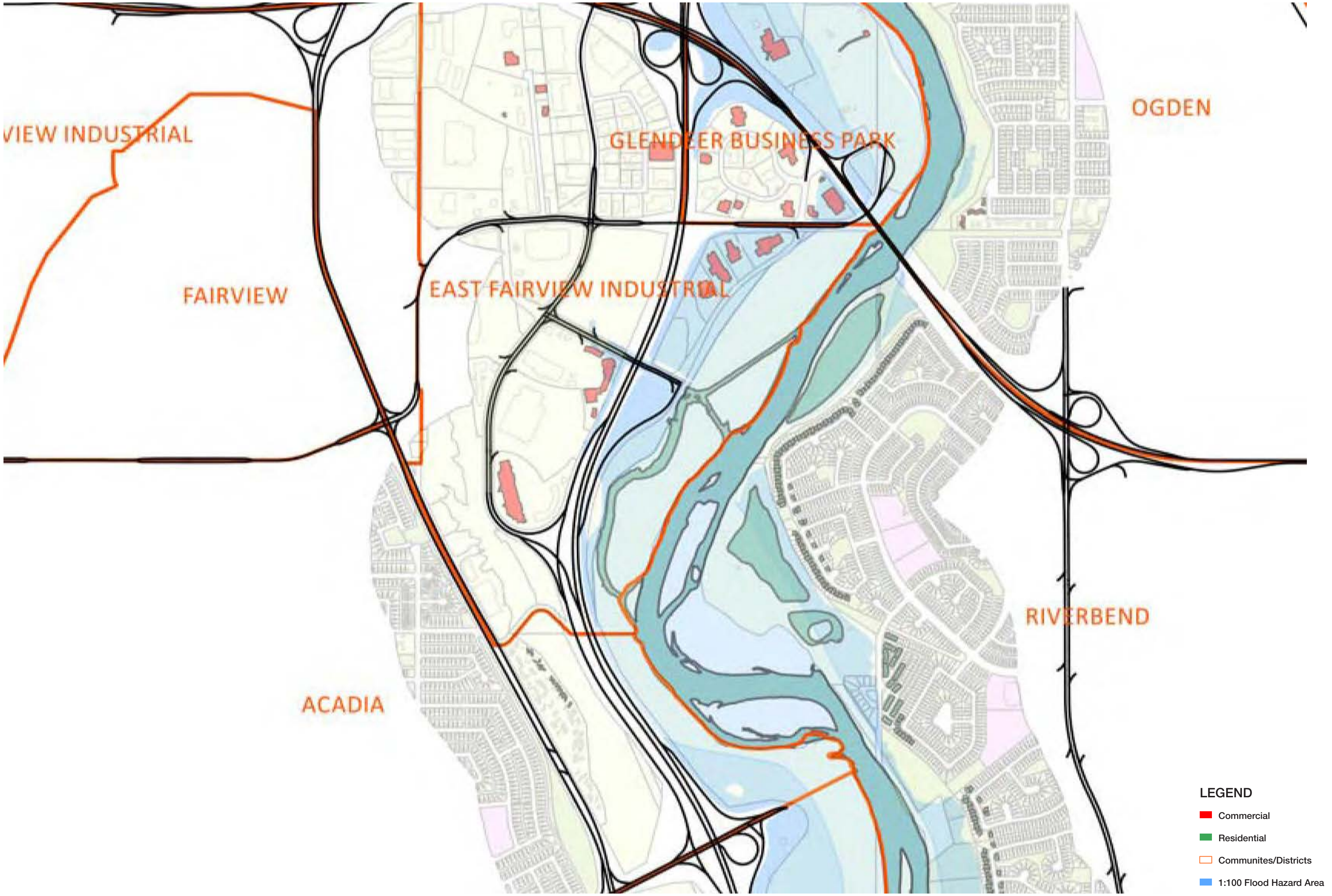

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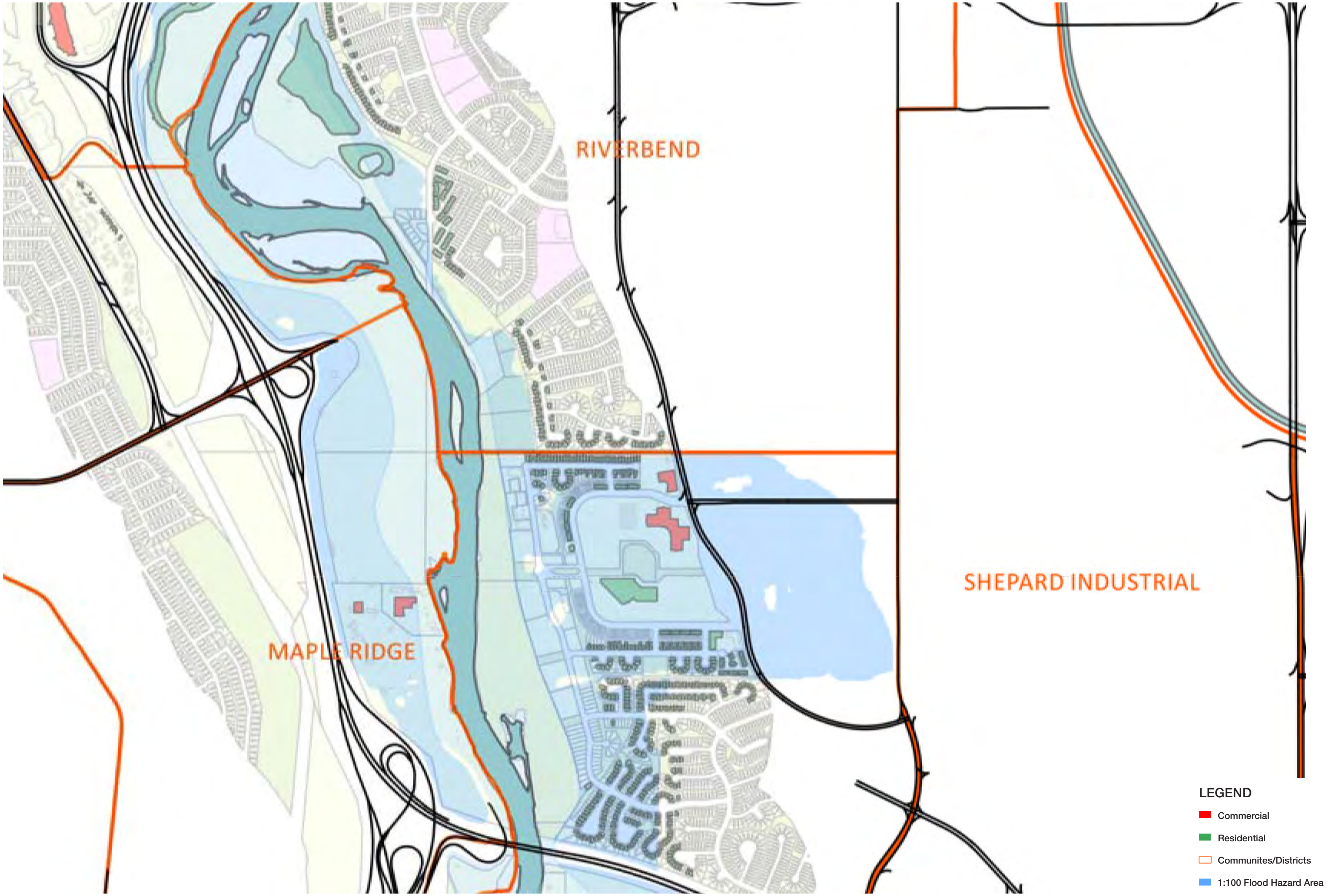

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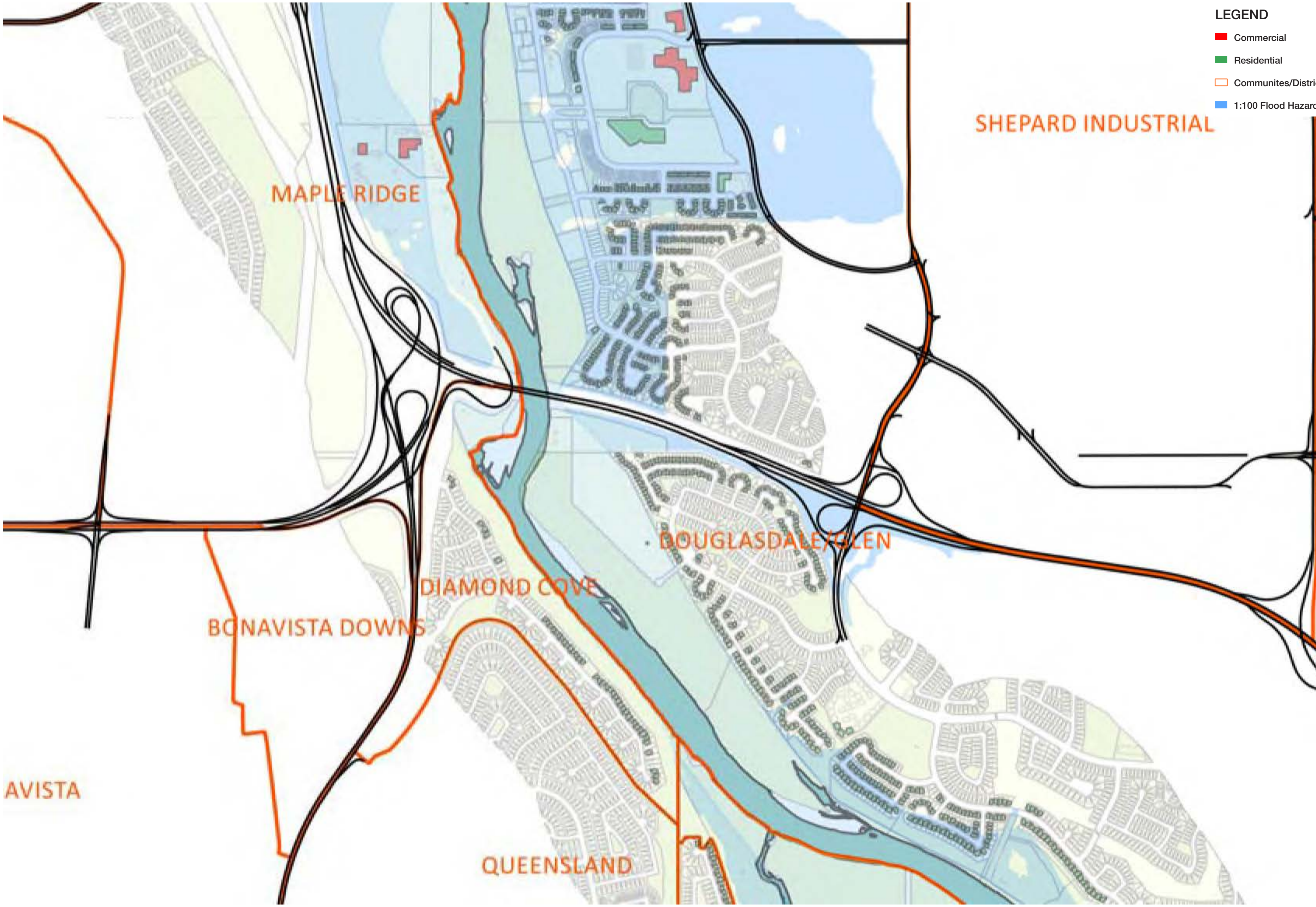
Calgary Flood Hazard Area



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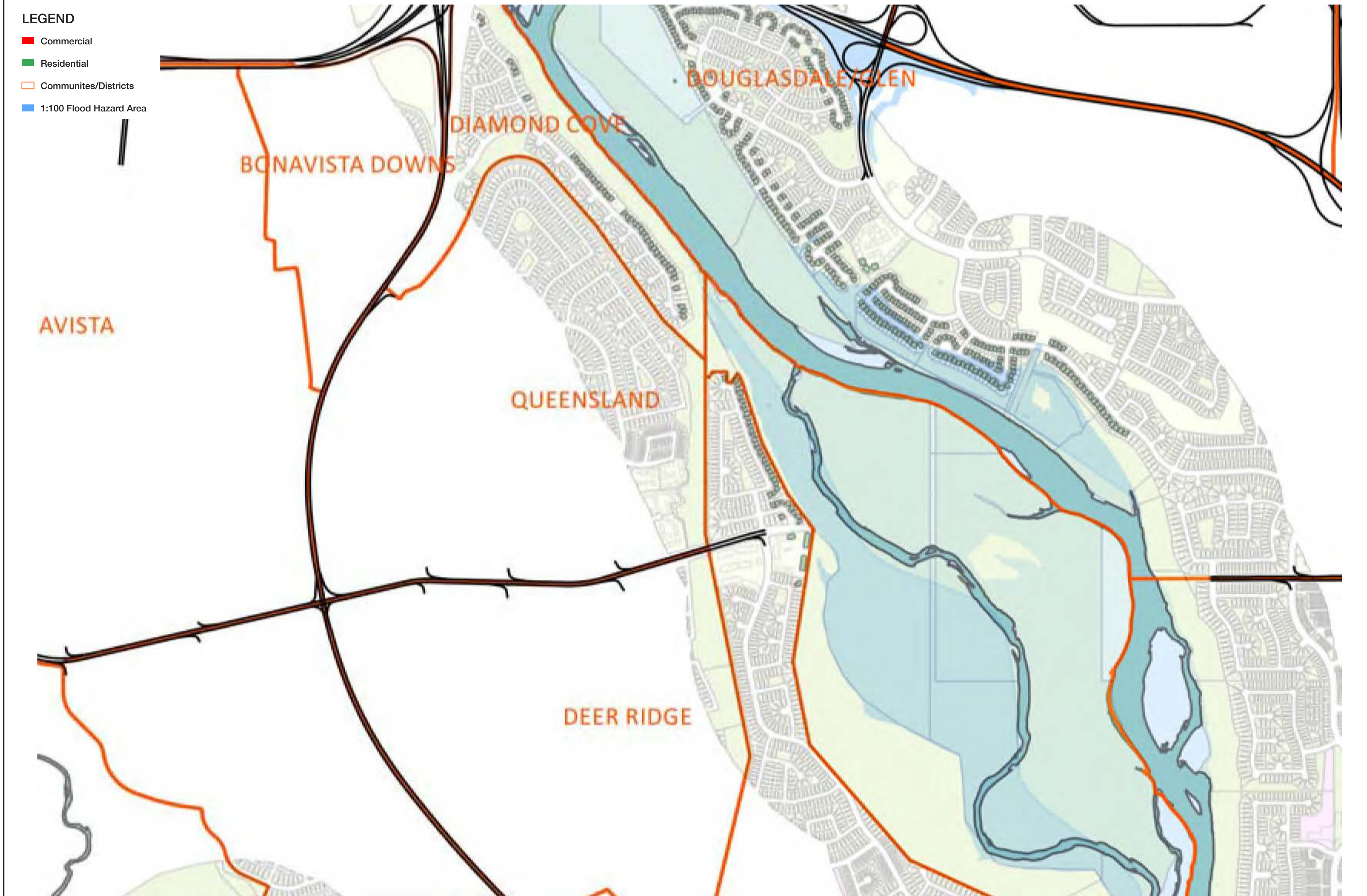

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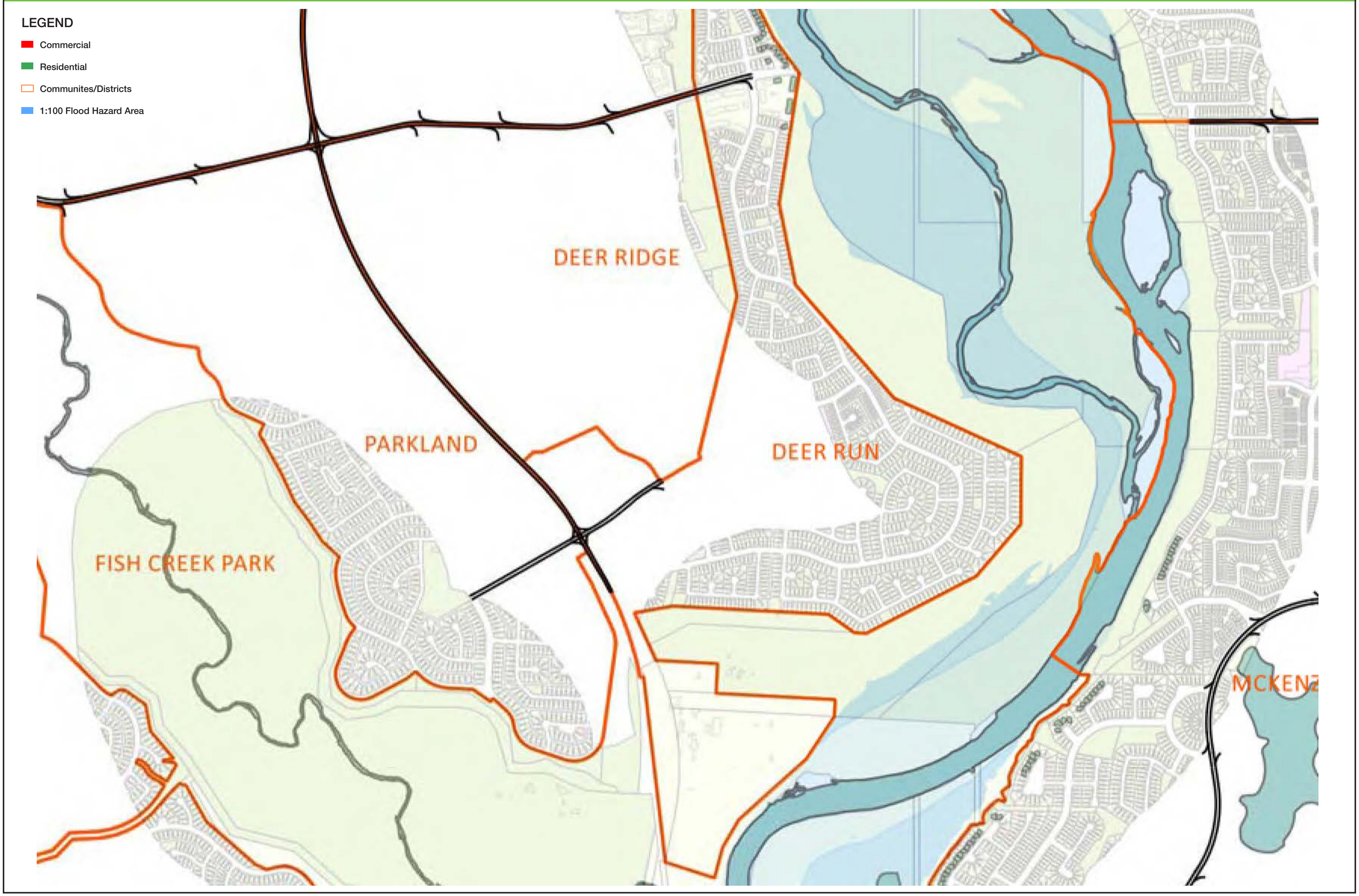

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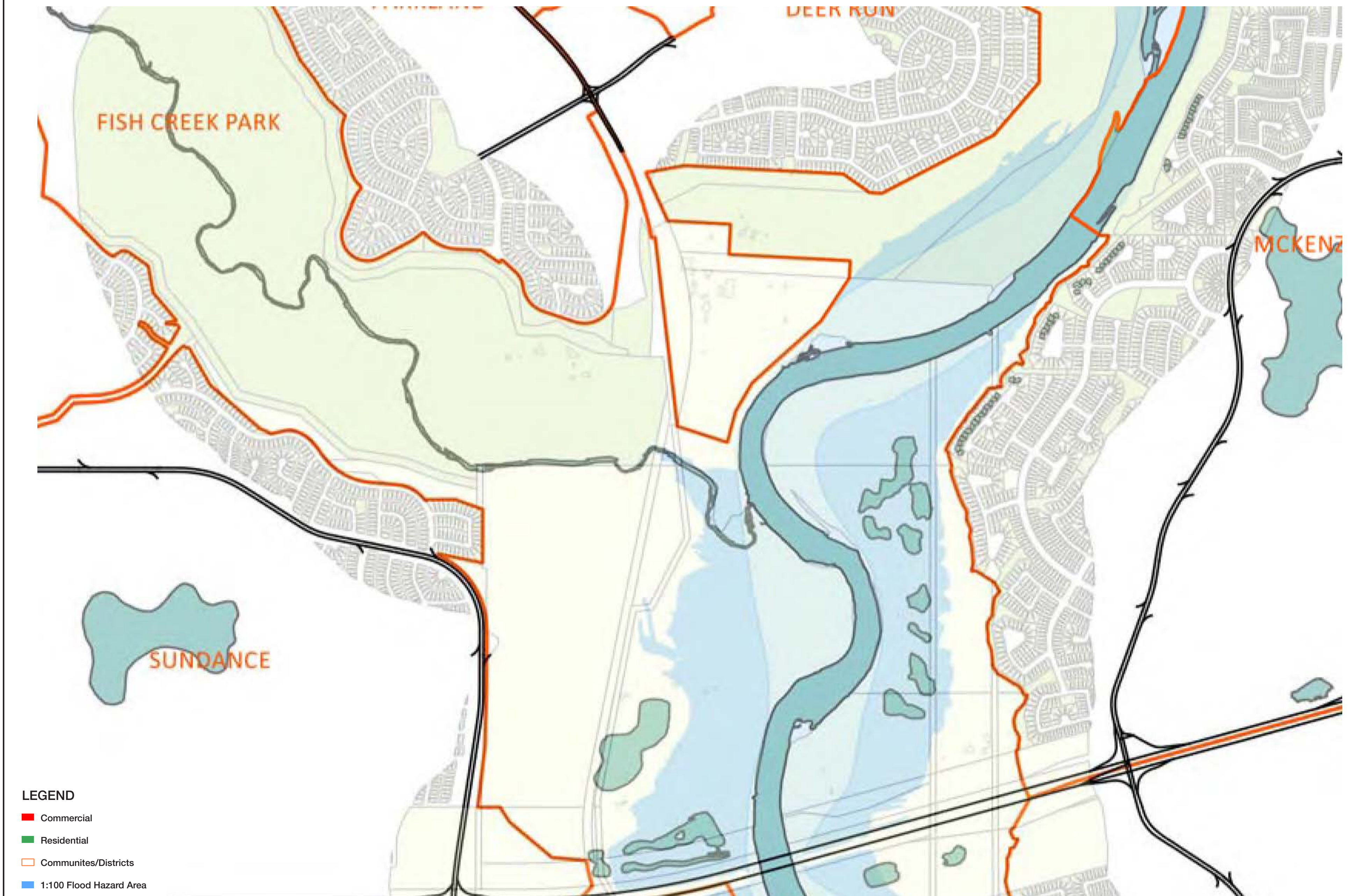
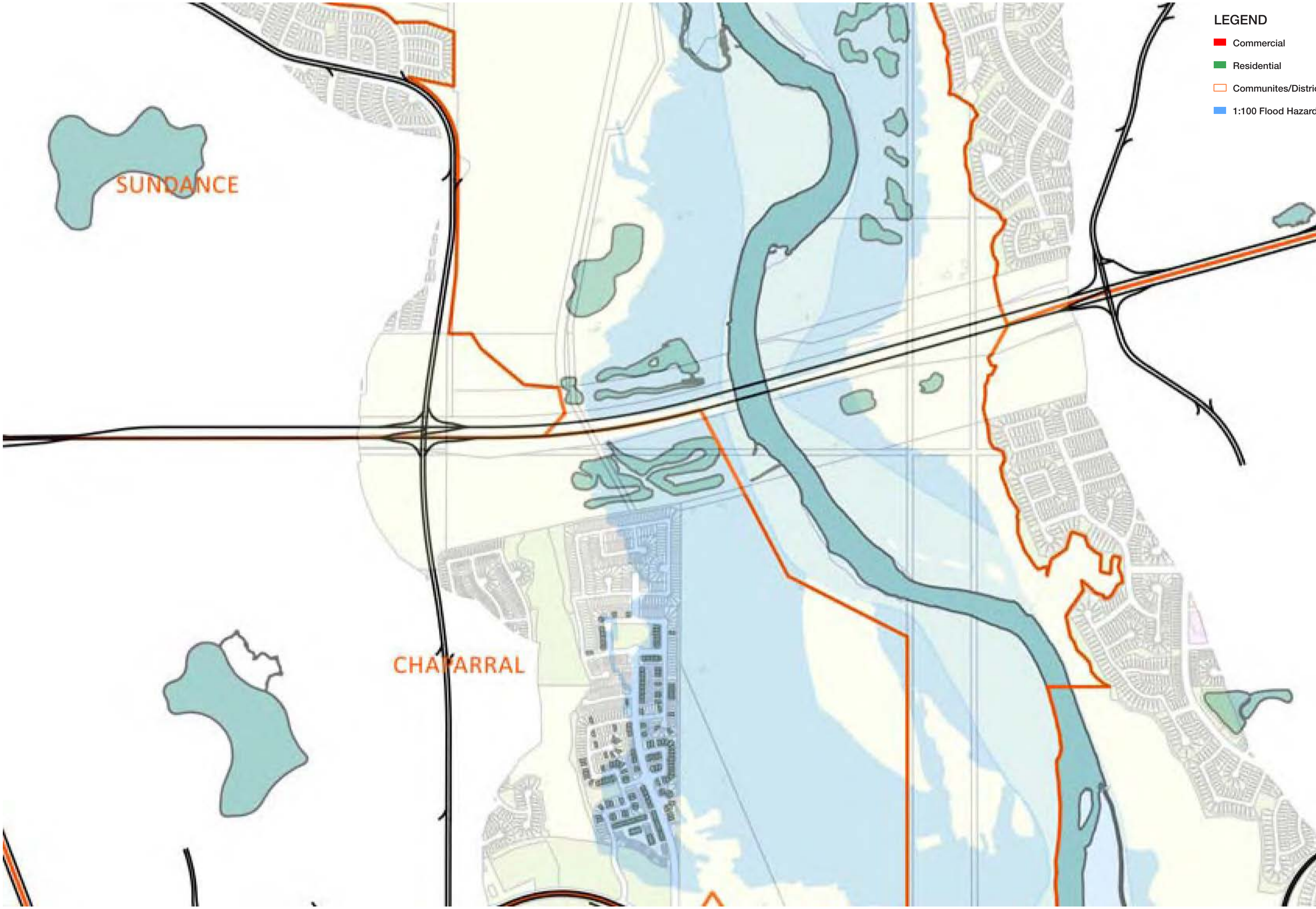


Calgary Flood Hazard Area



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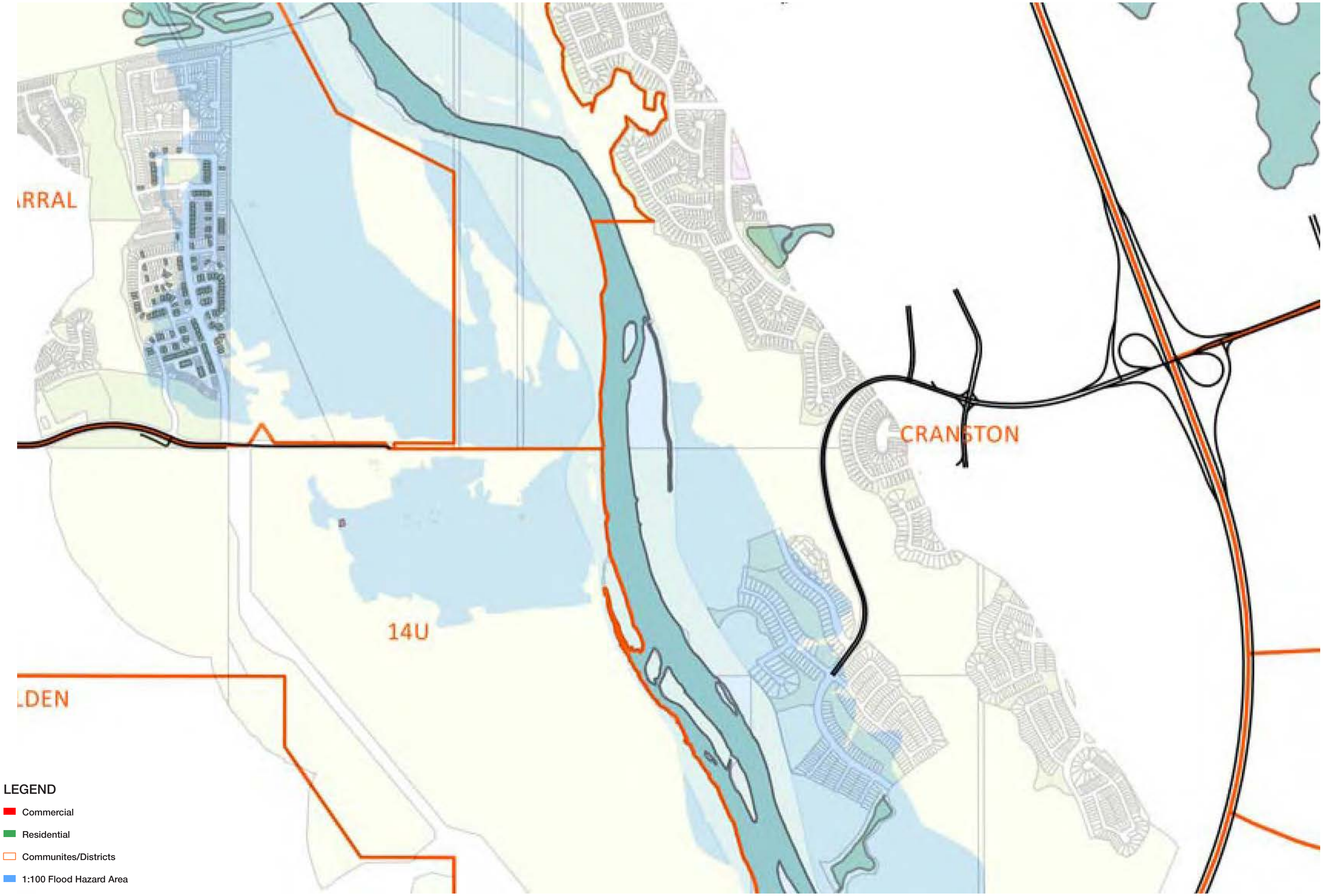

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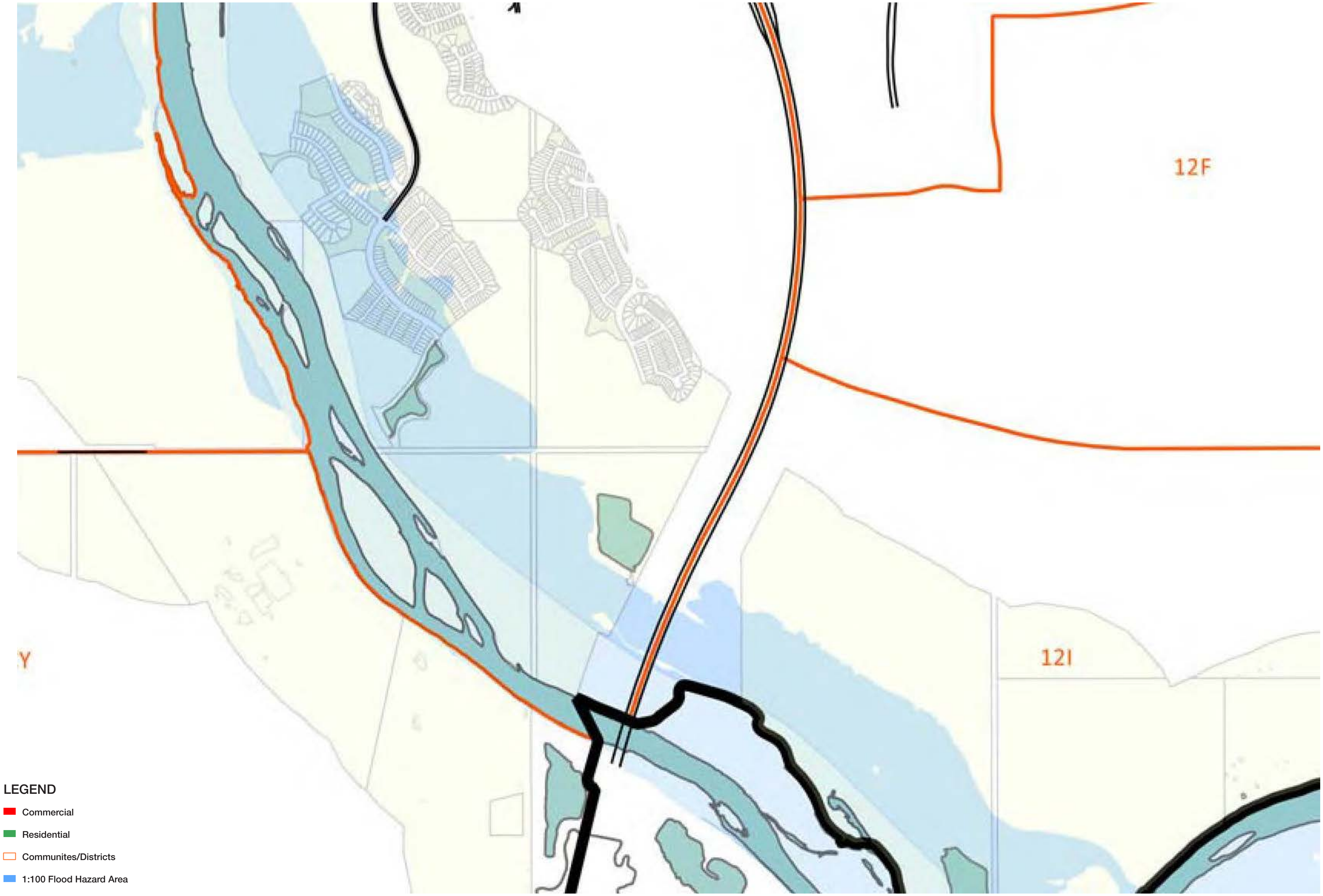
Calgary Flood Hazard Area



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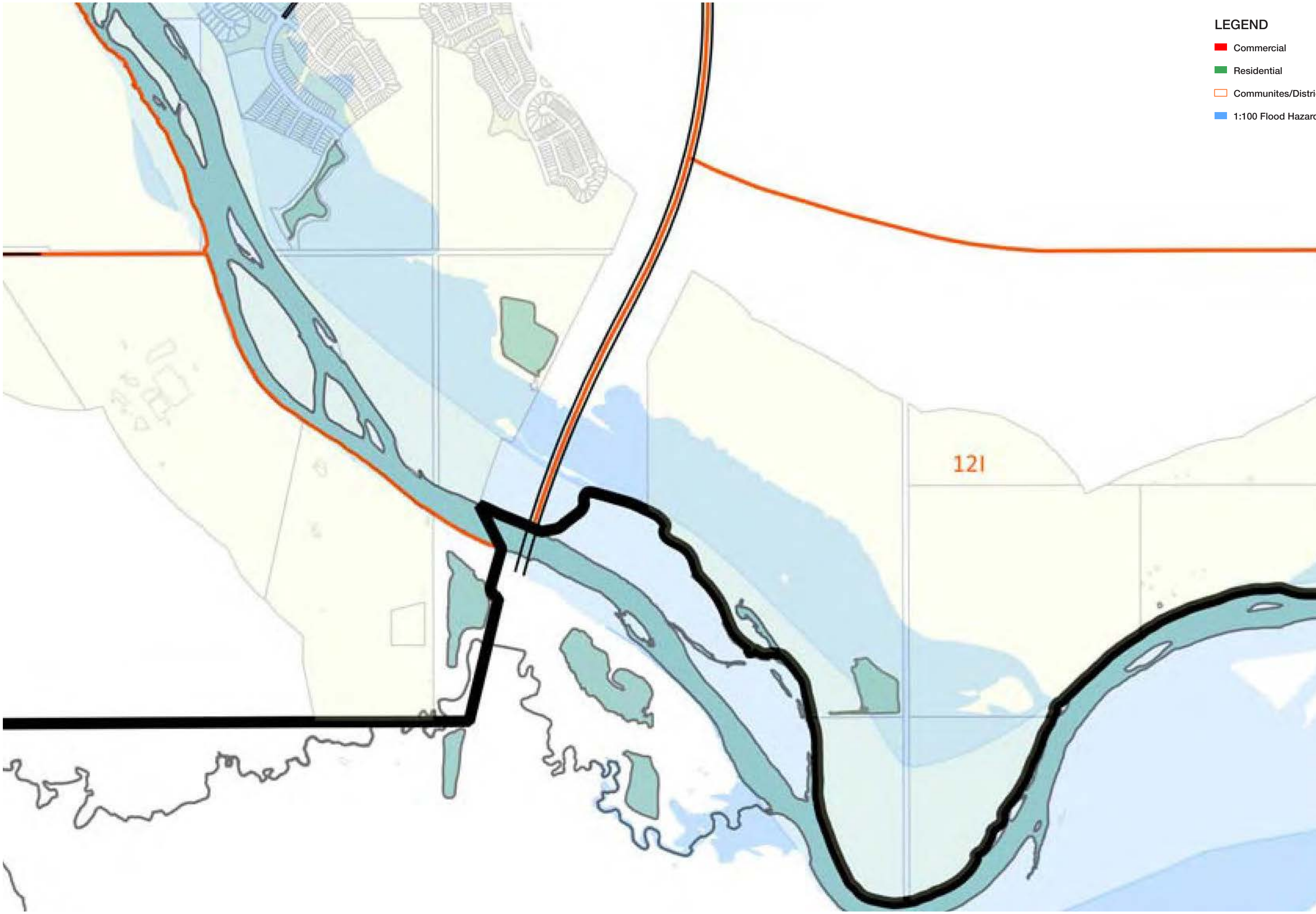
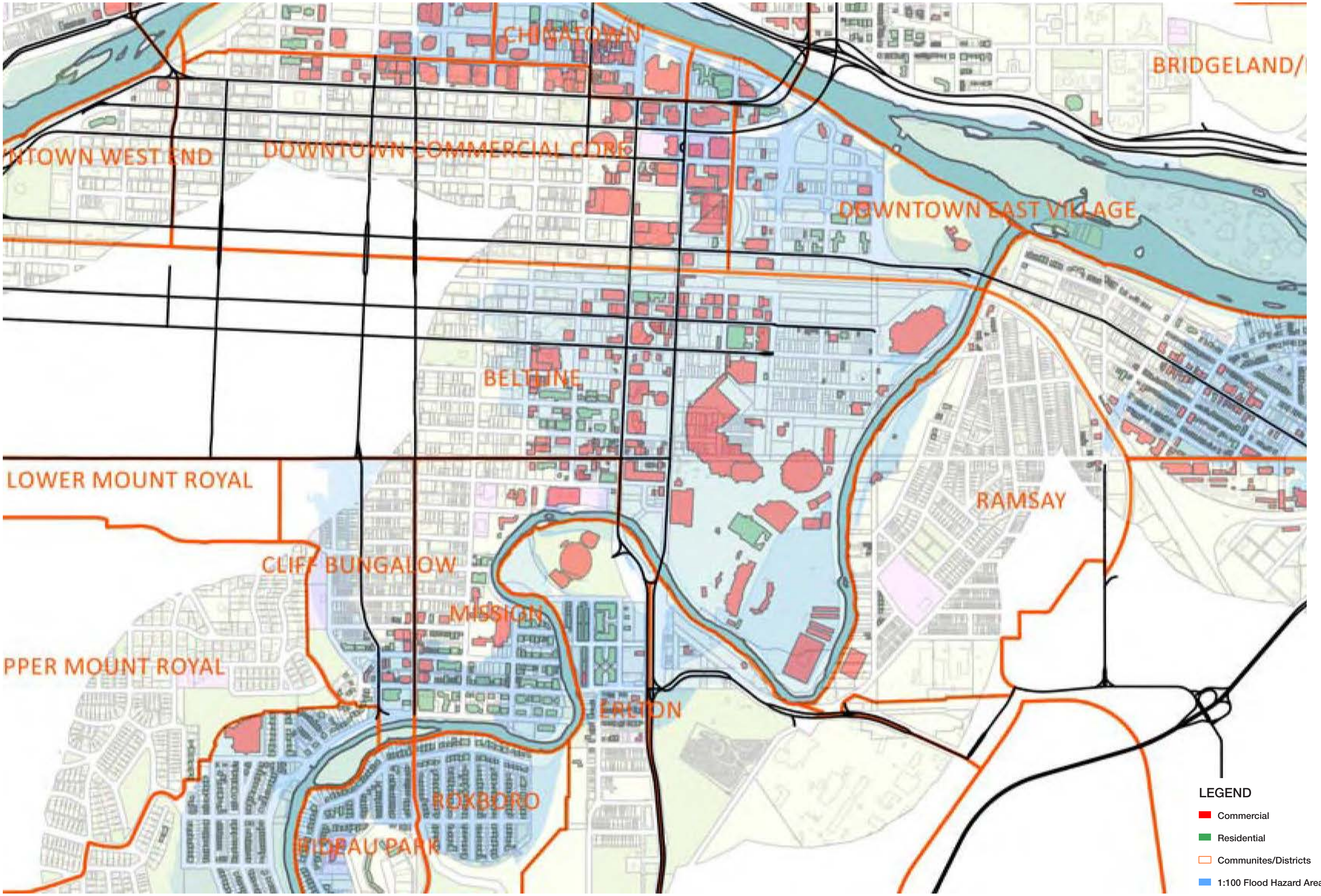


Calgary Flood Hazard Area



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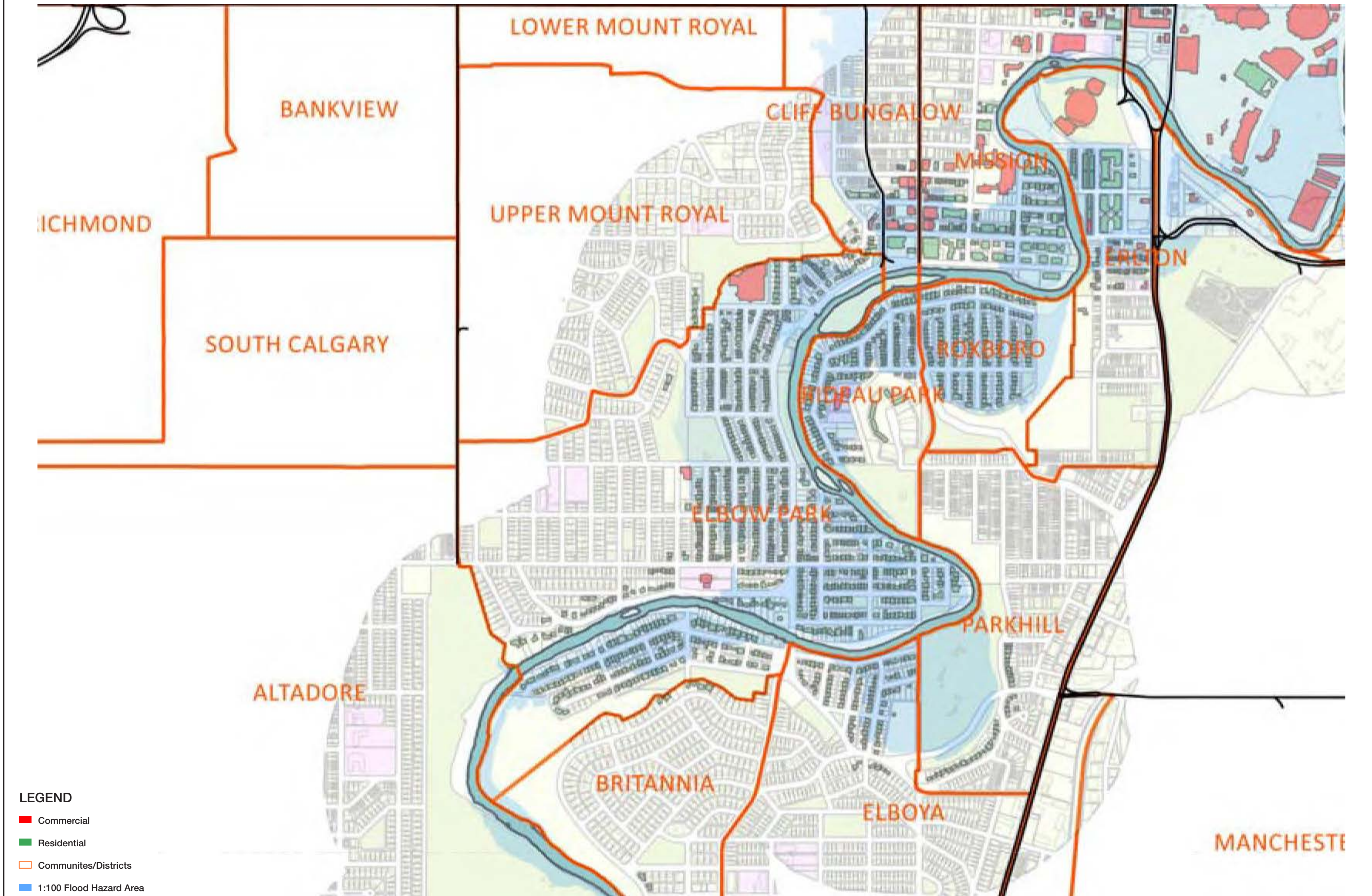
Calgary Flood Hazard Area



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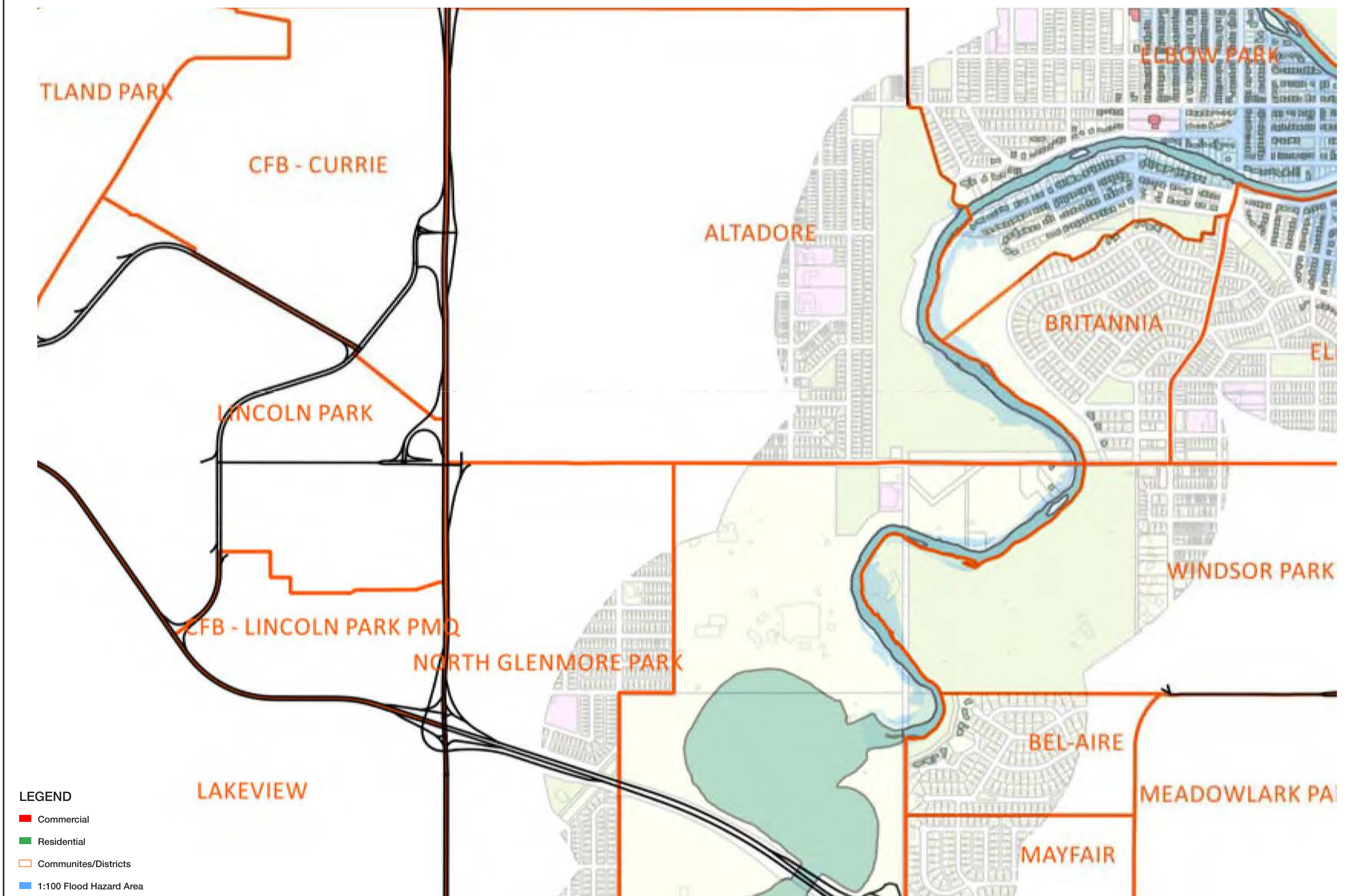
Provincial Flood Damage Assessment Study

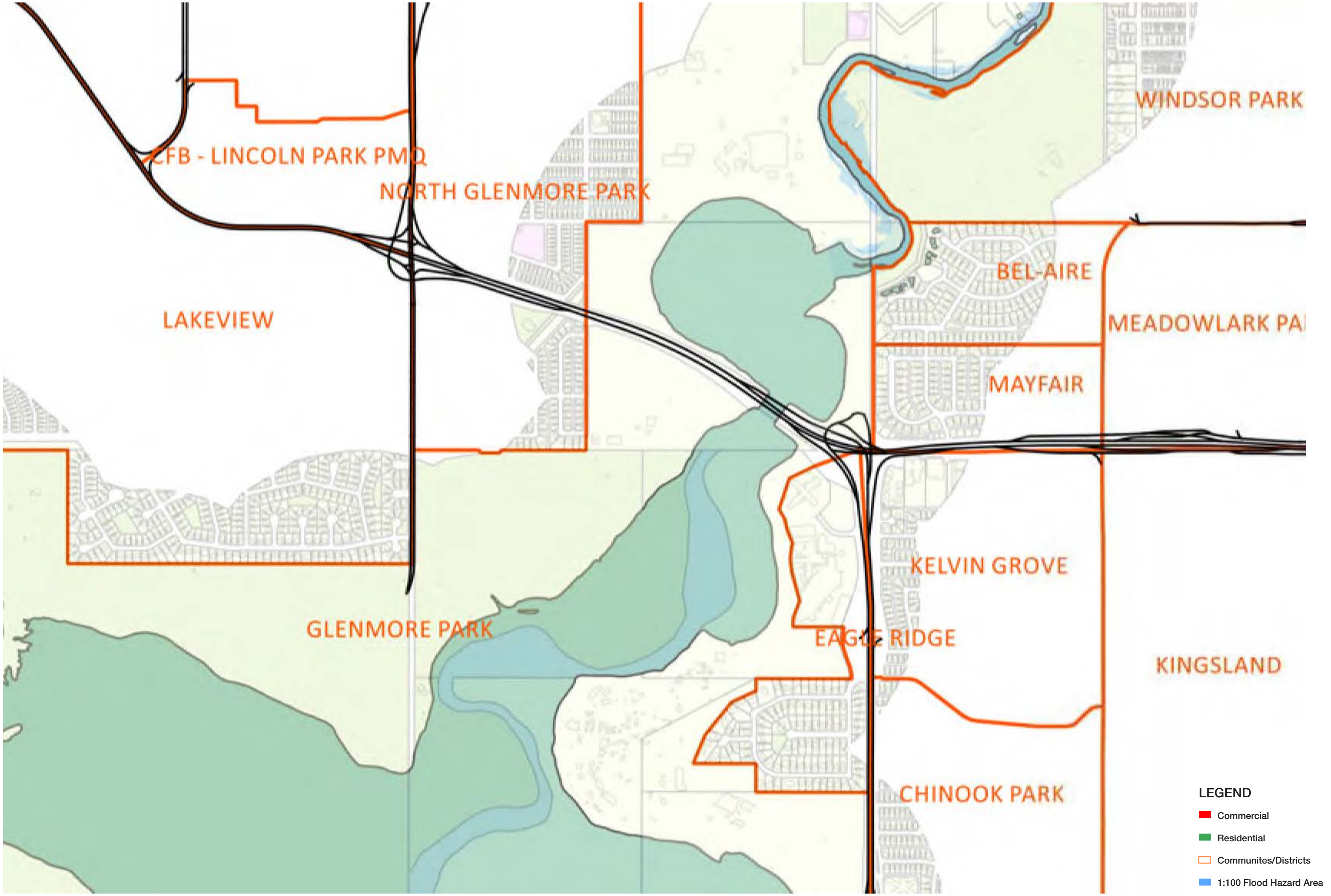
February 2015

EXHIBIT B-25

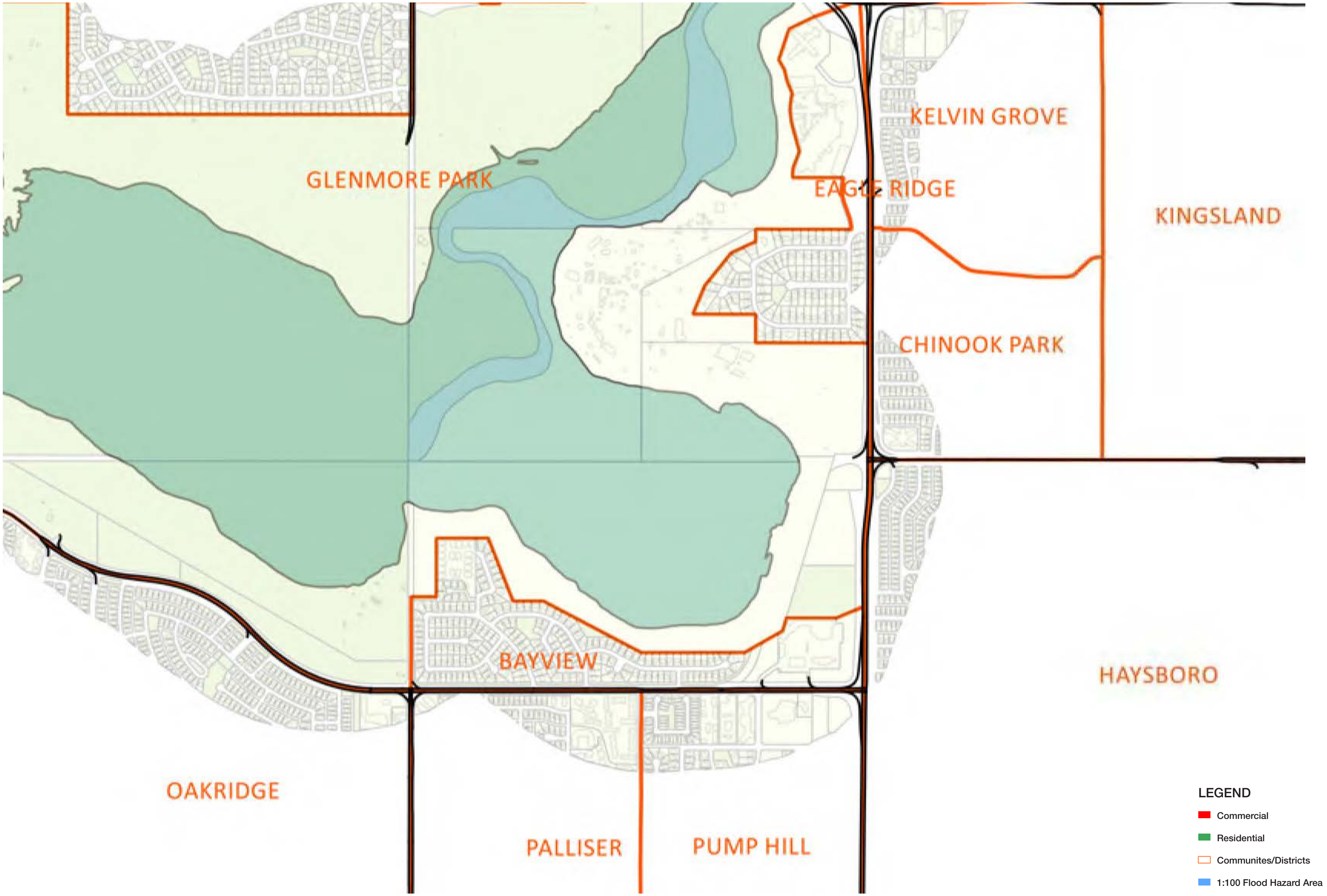
Calgary Flood Hazard Area



Calgary Flood Hazard Area



Calgary Flood Hazard Area



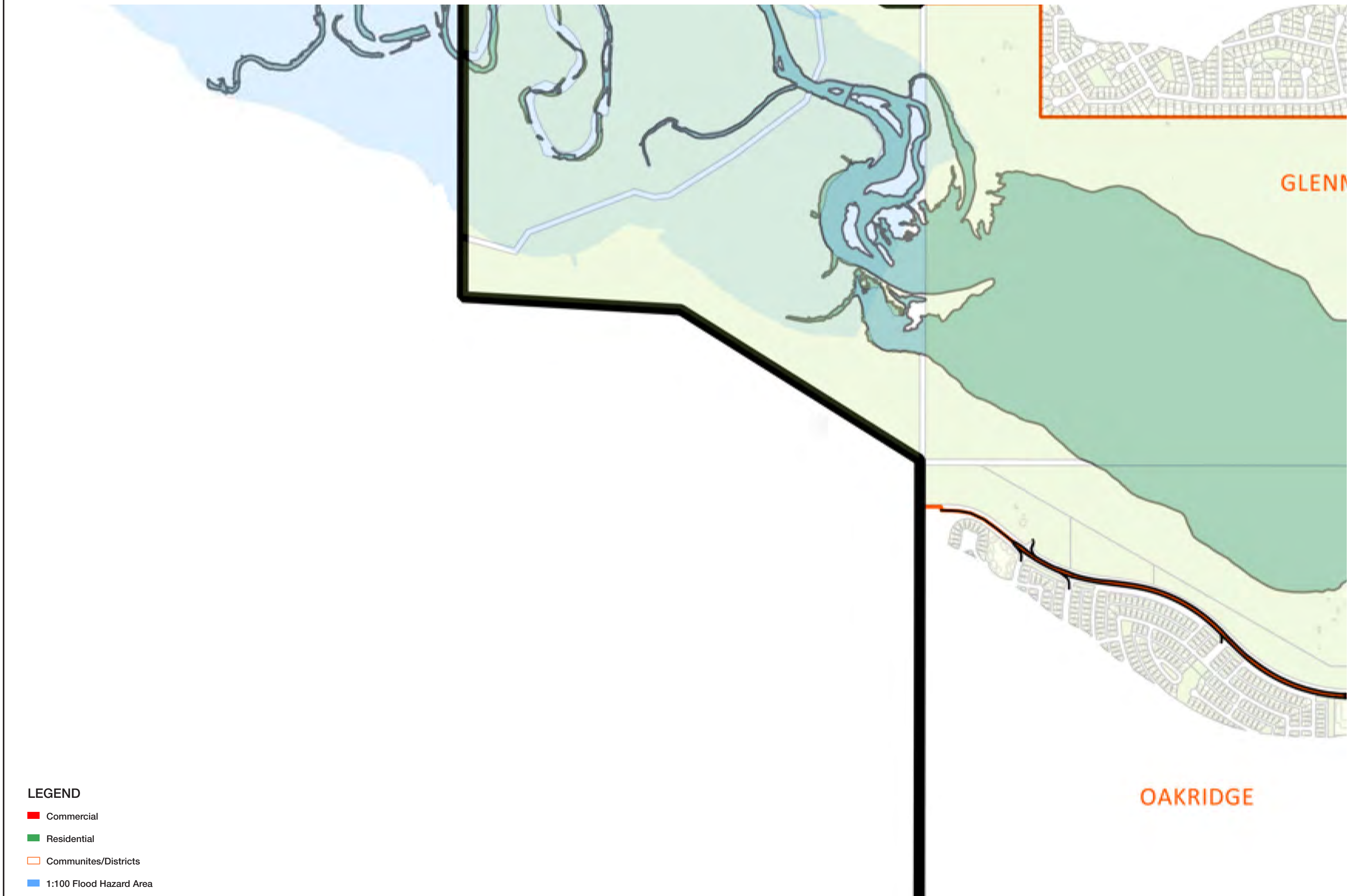
IBI Golder Associates Alberta Government

Provincial Flood Damage Assessment Study

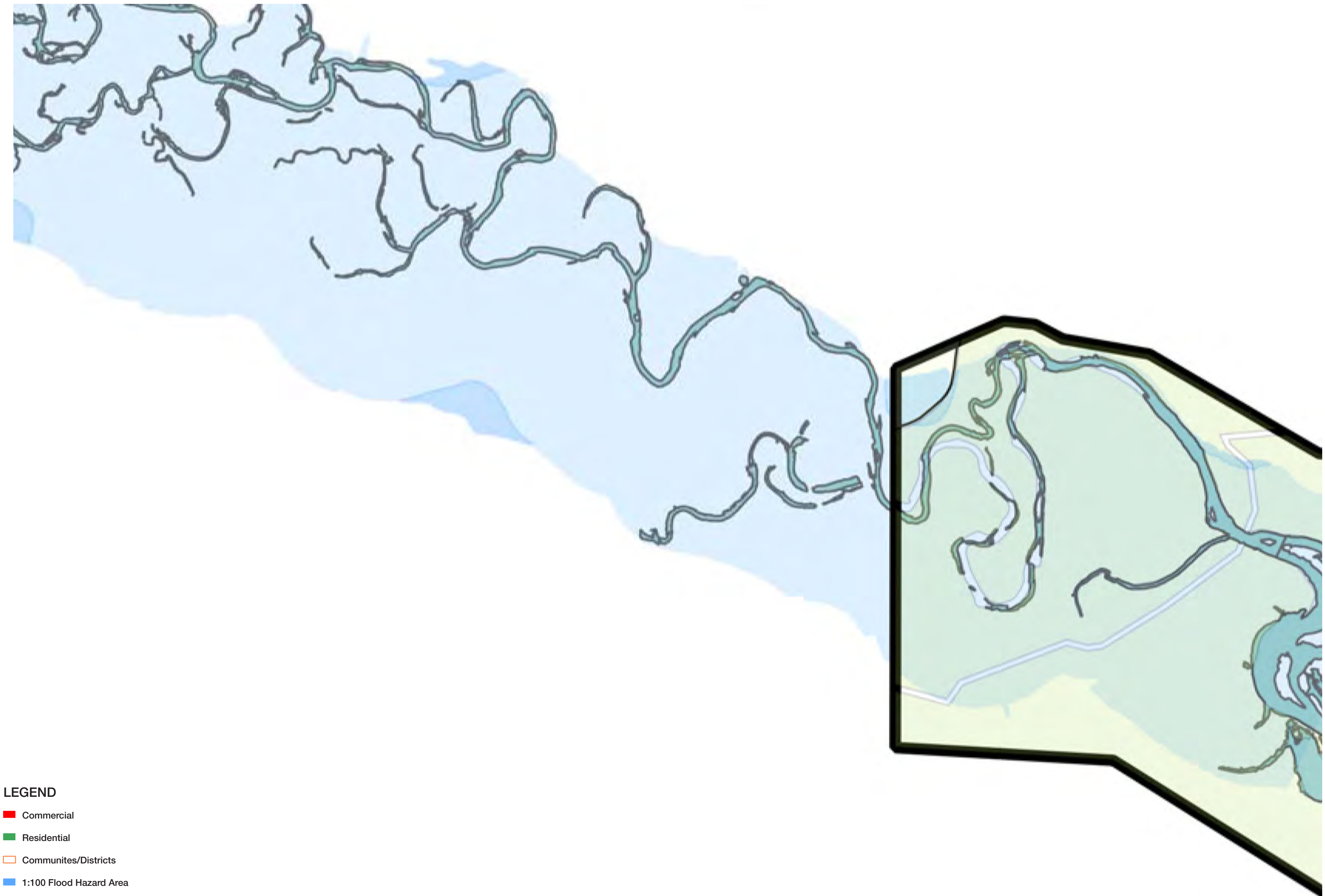
February 2015

EXHIBIT B-28

Calgary Flood Hazard Area



Calgary Flood Hazard Area



LEGEND

- Commercial
- Residential
- Communites/Districts
- 1:100 Flood Hazard Area

Calgary Flood Hazard Area

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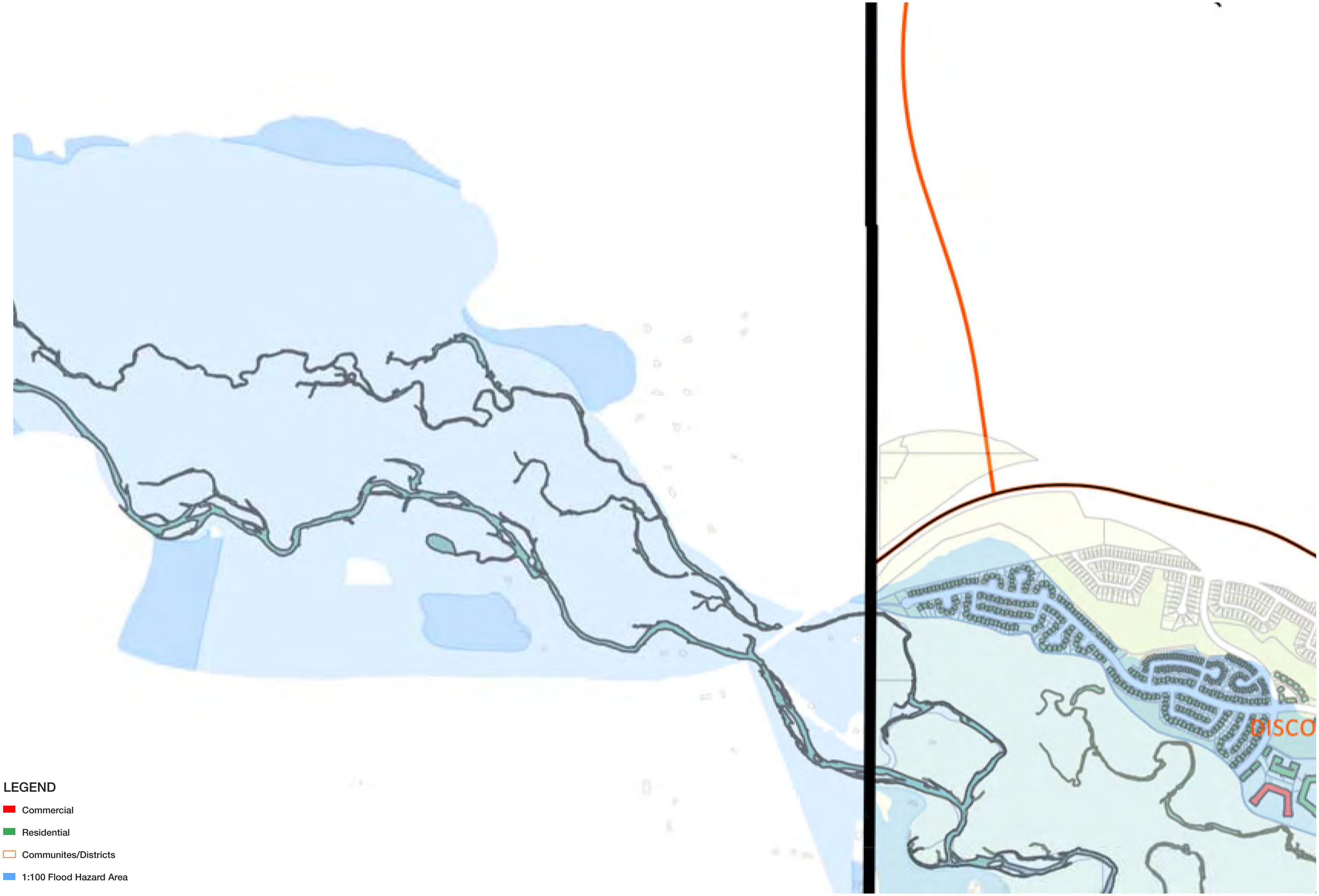
Calgary Flood Hazard Area



LEGEND

- Commercial
- Residential
- Communites/Districts
- 1:100 Flood Hazard Area

Appendix C – Municipal Infrastructure Recovery List

Municipal Infrastructure Recovery Project List with Cost Estimate (as of September 2014)

Buildings & Equipment | Roads, Bridges & Other Infrastructure | Utilities | Parks & Open Space | River Cleanup

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-AB-001	Centre City Team building repairs	8	Community Services & Protective Services	CS & PS.Animal & Bylaw Services	Repair and replace the flood-damaged equipment in basement and garage	$0.00
I-FL2013-CP-001	Pumphouse Theatre		Community Services & Protective Services	CS & PS.Civic Partners	Pumphouse has their own insurance on infrastructure. City to complete structural review and geotechnical testing to determine damage to basement.	$25,000.00
I-FL2013-CP-002	Talisman Centre		Community Services & Protective Services	CS & PS.Civic Partners	HVAC and other mechanical equipment damaged and requires replacement. Large scale cleaning and sanitization of facility required. Estimate closure of some amenities for 6 to 9 months.	$15,000,000.00
I-FL2013-CP-003	Calgary Zoo - Building		Community Services & Protective Services	CS & PS.Civic Partners	Extensive damage to buildings, elevators, electrical & IT damaged.	$35,800,000.00
I-FL2013-CP-004	Calgary Zoo - Clean Up		Community Services & Protective Services	CS & PS.Civic Partners	Extensive damage to lands	$10,900,000.00
I-FL2013-CP-005	Calgary Public Library - Central		Community Services & Protective Services	CS & PS.Civic Partners	Basement flooded and contents destroyed. Alarm system damaged. Public washrooms and meeting rooms in basement need to be restored.	$8,000,000.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-CP-007	Calgary Centre for the Performing Arts		Community Services & Protective Services	CS & PS.Civic Partners	Basement floor damage; cleaning &sandbags; sump pump connections, plumbing repairs & generator ventilation; service and maintenance of elevator.	$35,000.00
I-FL2013-CP-008	Fort Calgary - Dean House		Community Services & Protective Services	CS & PS.Civic Partners	Stock loss (Dean House) ; damage cost could be covered by insurance. No City involvement is required.	$0.00
I-FL2013-CP-009	Heritage Park		Community Services & Protective Services	CS & PS.Civic Partners	Damage to sewer pump; damage cost could be covered by insurance. No City involvement is required.	$0.00
I-FL2013-CP-010	Tourism Calgary		Community Services & Protective Services	CS & PS.Civic Partners	Replaced 3 boilers, electrical, pump system, inventory, etc. $690,317 in flood recovery costs estimated to date. Tourism Calgary has been reimbursed $486,537 to date; remainder of claims in progress. No City involvement is required.	$0.00
I-FL2013-FI-001	Station Flood Mitigation	1, 7, 8	Community Services & Protective Services	CS & PS.Fire	Implement flood prevention and mitigation measures at stations located with the flood plain (1, 2, 6, 15)	$0.00
I-FL2013-FI-002-01	Lifecycle Maintenance (Boat Launch Repairs) - 8th Street Boat Launch	8, 9	Community Services & Protective Services	CS & PS.Fire	8th Street Boat Launch	$80,526.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-FI-002-02	Lifecycle Maintenance (Boat Launch Repairs) - Cushing Bridge	8, 9	Community Services & Protective Services	CS & PS.Fire	Cushing Bridge	$80,526.00
I-FL2013-FI-002-03	Lifecycle Maintenance (Boat Launch Repairs) - Stoney Trail	8, 9	Community Services & Protective Services	CS & PS.Fire	Stoney Trail	$80,526.00
I-FL2013-FI-002-04	Lifecycle Maintenance (Boat Launch Repairs) - Fish Creek	8, 9	Community Services & Protective Services	CS & PS.Fire	Fish Creek	$0.00
I-FL2013-FI-002-05	Lifecycle Maintenance (Boat Launch Repairs) - Fort Calgary	8, 9	Community Services & Protective Services	CS & PS.Fire	Site to be abandoned. New lauunch to be constructed at Shouldice	$0.00
I-FL2013-FI-002-06	Lifecycle Maintenance (Boat Launch Repairs) - Graves Bridge	8, 9	Community Services & Protective Services	CS & PS.Fire	Project has been replaced by Shouldice/Quarry Park (I-FL2013-FI002-09/10)	$0.00
I-FL2013-FI-002-07	Lifecycle Maintenance (Boat Launch Repairs) - Shouldice	8, 9	Community Services & Protective Services	CS & PS.Fire	Project has been replaced by Shouldice/Quarry Park (I-FL2013-FI002-09/10)	$0.00
I-FL2013-FI-002-08	Lifecycle Maintenance (Boat Launch Repairs) - Bonnybrook	8, 9	Community Services & Protective Services	CS & PS.Fire	Project has been replaced by Shouldice/Quarry Park (I-FL2013-FI002-09/10)	$0.00
I-FL2013-FI-002-09	Boat Launches - Shouldice (new)	7, 8	Community Services & Protective Services	CS & PS.Fire	Relocation of existing Shouldice boat launch	$108,303.00
I-FL2013-FI-002-10	Boat Launches - Quarry Park (new)		Community Services & Protective Services	CS & PS.Fire	Relocation of existing Boat launch	$219,706.00
I-FL2013-FI-003	Communication Lifecycle		Community Services & Protective Services	CS & PS.Fire	Replacement of telecommunications equipment (Mike phones, radios, etc) lost / damaged in flood.	$0.00
I-FL2013-FI-004	Urban Search Rescue Equip		Community Services & Protective Services	CS & PS.Fire	Replacement of large capacity pumps damaged during the flood and purchase of inflatable dyking / berms for flood preparedness.	$100,000.00
I-FL2013-FI-005	Personal Protective Equipment		Community Services & Protective Services	CS & PS.Fire		$54,195.81

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-FI-006	Hazardous Materials Equipment		Community Services & Protective Services	CS & PS.Fire		$0.00
I-FL2013-FI-007	Light Fleet Lifecycle		Community Services & Protective Services	CS & PS.Fire	Project supports repair and replacement of support vehicles used during the flood.	$0.00
I-FL2013-FI-008	Emergency Units		Community Services & Protective Services	CS & PS.Fire		$200,000.00
I-FL2013-FI-009	Fire Equipment Lifecycle		Community Services & Protective Services	CS & PS.Fire	PFD replacement; replacement of portable generator / light plant damaged during the flood.	$40,000.00
I-FL2013-PA-001	Princess Island Park		Community Services & Protective Services	CS & PS.Public Art	Cracked Pot Foundation, Buffalo Grass and Tumbleweed" & Prairie collage" require professional cleaning & some patina worn off on collection.	$0.00
I-FL2013-PA-002	Calgary Zoo - Sundial		Community Services & Protective Services	CS & PS.Public Art	Sundial requires cleaning and waxing.	$0.00
I-FL2013-PA-007	City Hall		Community Services & Protective Services	CS & PS.Public Art	Some damage and removal of 25 works in Aldermanic offices & lobby, 27 works in Office of Mayor, 16 works in City Manager's Office, 2 works in IT, 1 work in lower level lobby.	$0.00
	Major Parks (Program)		Community Services & Protective Services	CS & PS.Parks	Programs including Major Parks projects from Parks	
I-FL2013-PK-001	Bowness Park	1	Community Services & Protective Services	CS & PS.Parks	Significant flood damage across entire park	$3,200,000.00
I-FL2013-PK-002	Prince s Island	7	Community Services & Protective Services	CS & PS.Parks	Flood damage to hard surface, furniture, landscaping, irrigation and electrical. East end wetland; bank failure, compromised	$3,604,344.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
	Other Parks (Program)		Community Services & Protective Services	CS & PS.Parks	Programs incluidng Major Parks projects from Parks (excluding Bowness & Prince's Island Park)	
I-FL2013-PK-003	12 Mile Coulee	1	Community Services & Protective Services	CS & PS.Parks	Habitat loss; Slope failures at two locations; Loss of capital infrastructure (hardened stream crossings).	$260,000.00
I-FL2013-PK-004	Amenities Repairs	City Wide	Community Services & Protective Services	CS & PS.Parks	resurfacing of 11 playgrounds throughout the city	$300,000.00
I-FL2013-PK-005	Baker Park	1	Community Services & Protective Services	CS & PS.Parks	Silt damaged turf in Sunbowl. Some minor riverbank damage.	$24,685.00
I-FL2013-PK-006	Beaver Dam Flats	9	Community Services & Protective Services	CS & PS.Parks	New river channel and banks, high siltation throughout. Significant landscape damage. Most infrastructure on lower park areas a complete replacement including regional pathways and a pedestrian bridge (Sapper's)	$625,000.00
I-FL2013-PK-007	Bowmont	1	Community Services & Protective Services	CS & PS.Parks	Lower Bowmont significantly damaged. New bank instability; river access lost; Lagoon channel altered; slope failures along access road. Regional pathway and trail damage, pedestrian bridge and gabion damaged, fencing and signage washed away.	$2,090,000.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-PK-008	Carburn Park	9	Community Services & Protective Services	CS & PS.Parks	Clean up of pathways, parking lot, gazebo repair, trails and reforestation. New damage occurred to pathway/riverbank in June 2014.	$600,000.00
I-FL2013-PK-010	Douglasdale Park	12	Community Services & Protective Services	CS & PS.Parks	Ball Diamond	$50,444.00
I-FL2013-PK-014	Graves Bridge Parking Lot Repairs	9	Community Services & Protective Services	CS & PS.Parks	Gravel parking lot repairs. Resurfacing, debris removal, erosion repairs, new gravel and re-grading	$123,309.00
I-FL2013-PK-015	Griffith Woods	6	Community Services & Protective Services	CS & PS.Parks	Damage to parking lot, gravel trails, boardwalks and culverts. ($675K - year round) $75K - misc cleanup, bioengeneering, trail replacement design	$1,300,000.00
I-FL2013-PK-016	Inglewood Bird Sanctuary (IBS)	9	Community Services & Protective Services	CS & PS.Parks	general cleanup needed throughout park, pedestrian bridges damaged, boardwalk damaged, pond filled in, viewing platforms destroyed, chainlink and post/cable fencing repair, pathway and trail damage	$3,930,000.00
I-FL2013-PK-018	Lindsay Park	9	Community Services & Protective Services	CS & PS.Parks	Extensive damage along Elbow shoreline and lower park area. Playground destroyed. Riverbank stabilization	$650,000.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-PK-019	North Bow R granular trail 4 St to 2 St NW	7	Community Services & Protective Services	CS & PS.Parks	This granular pathway suffered extensive damage including complete loss of surfacing, timber edging. some subgrade materials and general clean up and removal of debris.	$40,000.00
I-FL2013-PK-020	Nose Creek Confluence Bottomlands		Community Services & Protective Services	CS & PS.Parks	Heavy erosion by railroad tracks along creek; moderate erosion at meander points; unstable fence in WNCC; hanging culvert more exposed; trail damage. Pathway/gabion damage under Beddington Trail	$275,000.00
I-FL2013-PK-021	Peace Bridge Pathway	7	Community Services & Protective Services	CS & PS.Parks	Flood Damage to concrete, landscaping, irrigation, and electrical. (Sole $200, 000)	$25,000.00
I-FL2013-PK-022	Pearce Estate Park	9	Community Services & Protective Services	CS & PS.Parks	reconstruction of access road, regional pathway repair, small bridge repairs, picnic tables, benches damaged, general clean-up and trail reconstruction	$275,000.00
I-FL2013-PK-024	Poppy Plaza	7	Community Services & Protective Services	CS & PS.Parks	Flood Damage to Concrete, Wood Decking, Landscaping, Irrigation, and Electrical. (Sole)	$158,150.00
I-FL2013-PK-025	Reader Rock	9	Community Services & Protective Services	CS & PS.Parks	Minor landscape damage and trail damage. Additional clean-up adjacent to lower parking lot to be added to scope of DRP application	$10,000.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-PK-026	Rideau Roxboro Community Association	9	Community Services & Protective Services	CS & PS.Parks	Clean up of silt, debris, playground repair, turf damage.	$46,663.00
I-FL2013-PK-028	Sandy Beach Britannia Slopes	11	Community Services & Protective Services	CS & PS.Parks	Extensive damage, pedestrian bridges destroyed, picnic tables, clean-up, pathways damaged, trails, fencing damage	$1,715,000.00
I-FL2013-PK-029	Shouldice Park	1	Community Services & Protective Services	CS & PS.Parks	Mud and debris. Undercutting of bank. Damage to basketball and tennis courts.	$2,205.00
I-FL2013-PK-032	Stanley Park		Community Services & Protective Services	CS & PS.Parks	All park underwater at approximately 4 - 6 ft. Only riverbank with significant damage. Pathway damage, playgrounds, turf, silt deposits, major cleanup required.	$800,000.00
I-FL2013-PK-033	Sue Higgins Park	12	Community Services & Protective Services	CS & PS.Parks	Significant river re- channelling, sink holes, debris etc. Infrastructure damage to areas nearest the river the worse.	$1,600,000.00
I-FL2013-PK-034	Valley Ridge	1	Community Services & Protective Services	CS & PS.Parks	washed out trails and fence damage	$30,000.00
I-FL2013-PK-035	Weaselhead	11	Community Services & Protective Services	CS & PS.Parks	Flood Damage to include but not necessarily be limited to; post & rail fencing, wooden boardwalks (250m) pedestrian gates, service gates, gravel trails (1000m), regional pathway, post and rail fencing (150m), and general clean up and removal of debris.	$210,000.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-PK-036	Bridgeland Tennis Courts	9	Community Services & Protective Services	CS & PS.Parks	temporary repaired settlement and cleaned two tennis courts that were submerged during flood	$8,967.00
I-FL2013-PK-037	Edison Park (307 40 Avenue SW)	11	Community Services & Protective Services	CS & PS.Parks	Silt debris, irrigation repair, picnic table and signage damage.	$75,021.00
I-FL2013-PK-038	Nose Hill Park	4	Community Services & Protective Services	CS & PS.Parks	trail damage	$7,200.00
I-FL2013-PK-039	Royal Oak natural environment park	2	Community Services & Protective Services	CS & PS.Parks	trail damage	$25,000.00
I-FL2013-PK-040	Tuscany natural environment park	1	Community Services & Protective Services	CS & PS.Parks	trail damage	$1,807.00
I-FL2013-PK-091	Elbow Island Park	8	Community Services & Protective Services	CS & PS.Parks	Clean up of large debris and garbage from Elbow Island Park on Elbow River at 4 Street Bridge SW	$47,000.00
I-FL2013-PK-092	Jerry Shaw Park – Elbow Drive @ 30 Ave SW	8	Community Services & Protective Services	CS & PS.Parks	clean up of silt and sand from trails, turf, stairs and pathways along Elbow River @ 30 Ave SW and in pocket parks on west side of Elbow Drive SW	$52,000.00
I-FL2013-PK-095	South Highfield Pathway Birthplace Forest – Deerfoot Trail @ Glenmore SE	9	Community Services & Protective Services	CS & PS.Parks	Flood damage includes large silt deposits over tree beds, irrigation systems, access road and fence damage	$3,600,000.00
	Pathways (Program)		Community Services & Protective Services	CS & PS.Parks	Program that includes Pathways projects from Parks	
I-FL2013-PK-041	16 Ave NW to Hextall Bridge	1	Community Services & Protective Services	CS & PS.Parks	Underpasses at bridges damaged or washed away.	$1,782,000.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-PK-042	Alyth bridge path @ Ogden Rd	9	Community Services & Protective Services	CS & PS.Parks	Damaged and missing pathway sections. Water Resources to lead DRP application and repairs with Parks as liaison. Funding source TBD.	$25,000.00
I-FL2013-PK-048	Bowness Park - east of 85 Street	1	Community Services & Protective Services	CS & PS.Parks	Bridge dislocated; 10m bridge approach rebuild, 5 m silt cleanup.	$30,000.00
I-FL2013-PK-049	East Bowness Train Bridge Catwalk	1	Community Services & Protective Services	CS & PS.Parks	regional pathway washed away on either side of the train bridge catwalk on south side of Bow River across from Bowmont Park island. Major damage to catwalk structure	$600,000.00
I-FL2013-PK-051	Douglasdale - Pathway Enmax Substation @ Deerfoot south to Ball Diamonds	12	Community Services & Protective Services	CS & PS.Parks	GIS and photo estimates used for assessment. Pathway gone by substation and compromised going south. Water Resources / Enmax. $1.2 Million. $150 Temporary Pathway in 2014.	$650,000.00
I-FL2013-PK-052	Douglasdale - Bridge to Fish Creek (Sue Higgins Bridge)	12	Community Services & Protective Services	CS & PS.Parks	The transitions from the regional pathway to the bridge on both sides were scoured out by the high water.	$1,100,000.00
I-FL2013-PK-053	Douglasdale Park - Pathway South - 130 Ave SE	12	Community Services & Protective Services	CS & PS.Parks	Extensive pathway damages. Land lost west side of the pathway. GIS and photo estimates - $3 mil is bank rebuilding and sinkhole fill. Pathway stability compromised and parking lot. ($850 Sole)	$900,000.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-PK-054	Edworthy to Sovereign Cr SW	8	Community Services & Protective Services	CS & PS.Parks	Entire section of riverbank north of tracks gone. CPR reinforced track edge with rip rap and concrete block during flooding. Equipment damage to west pathway.	$6,034,000.00
I-FL2013-PK-055	Elbow River 9 Ave SE to 25 Ave SE (Stampede Bend-Severe)	9	Community Services & Protective Services	CS & PS.Parks	25-30% of pathway and bank completely damaged, entire length silted. TI leading delivery of project with Parks as liaison.	$4,600,000.00
I-FL2013-PK-057	Glenmore @ Heritage	9	Community Services & Protective Services	CS & PS.Parks	Repaving needed.	$29,931.00
I-FL2013-PK-062	Mt Alberta View	12	Community Services & Protective Services	CS & PS.Parks	This is a slope stability project which is being led by Roads. Full cost of the repair could be as high as $10 million and has not been approved for cost recovery under the DRP. The 2013 area of failure is adjacent to the area of failure claimed under	$1,500,000.00
I-FL2013-PK-066	Refinery Park	9	Community Services & Protective Services	CS & PS.Parks	Parks to submit DRP application for pathway and fence repairs and park clean up required south of Calf Robe Bridge and Water Resources to submit DRP/FRECP app for pathway and bank damage north of bridge.	$1,000,000.00
I-FL2013-PK-070	Stoney Trail underpass - north pedestrian connections	1	Community Services & Protective Services	CS & PS.Parks	North side connection to Stoney pathway bridge is missing; coordinate with Structures.	$125,000.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-PK-072	Sue Higgins Park Southland to Anderson Lafarge lands	12	Community Services & Protective Services	CS & PS.Parks	Bank missing for significant length of Lafarge property. GIS and Photo review - Full distance Southland to Anderson.	$2,800,000.00
I-FL2013-PK-073	Zoo Bridge Underpass @ 12 St SE - North Side	9	Community Services & Protective Services	CS & PS.Parks	Clean up of silt deposits and debris along regional pathway.	$51,000.00
I-FL2013-PK-079	Scollen Bridge park (Elbow River at 25 Avenue SW)	8	Community Services & Protective Services	CS & PS.Parks	fence, pathway and bench damage in pocket park adjacent to Scollen Bridge	$84,000.00
I-FL2013-PK-080	Bonnybrook natural area	9	Community Services & Protective Services	CS & PS.Parks	clean up of silt and debris from natural area	$10,000.00
	Parks Building (Program)		Community Services & Protective Services	CS & PS.Parks	Program that includes Buildings projects from Parks	
I-FL2013-PK-081	Baker Park - Depot	1	Community Services & Protective Services	CS & PS.Parks	Replacement for Bowness depot - emergency trailer.	$559,332.00
I-FL2013-PK-082	Bowness Park - Depot Washrooms and Facilities	1	Community Services & Protective Services	CS & PS.Parks	Depot fully compromised. Trucks & equipment lost. Three washrooms severely damaged.	$1,038,380.00
I-FL2013-PK-083	Carburn Park - Depot	9	Community Services & Protective Services	CS & PS.Parks	Approx. 4' of water, damage to depot main level, including bathrooms, oil pits, outbuildings and 5 wooden sheds.	$231,116.00
I-FL2013-PK-084	Griffith Woods - Washrooms	6	Community Services & Protective Services	CS & PS.Parks	Washroom building had 3' of water on exterior (plaster) with building and mechanical damage.	$136,862.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-PK-085	Inglewood Bird Sanctuary (IBS) - Col Walker House	9	Community Services & Protective Services	CS & PS.Parks	Basement had 3 inches of water sediment. Some mechanical impacts.	$13,571.00
I-FL2013-PK-086	Pearce Estates Park - Washrooms	9	Community Services & Protective Services	CS & PS.Parks	Washroom building has water damage.(cost included in larger park)	$62,903.00
I-FL2013-PK-087	Prince s Island (buildings)	7	Community Services & Protective Services	CS & PS.Parks	All buildings with some water damage ,electrical damage and interior restoration needed. Temp Ops trailer needed for PI/downtown staff.	$473,249.00
I-FL2013-PK-088	Sandy Beach - Rivers Edge Buildings	11	Community Services & Protective Services	CS & PS.Parks	Extensive water damage to a historical building	$50,850.00
I-FL2013-PK-089	Stanley Park (buildings)	9	Community Services & Protective Services	CS & PS.Parks	All buildings had some water damage (approx. 5'), including Pavilion and the Depot.	$986,000.00
I-FL2013-PK-009	Clearwater		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	no damage, no DRP application required	$0.00
I-FL2013-PK-011	Douglasdale Ridge - Slope Stability	12	Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	This is a slope stability project which is being led by Roads. Full cost of the repair could be as high as $10 million and has not been approved for cost recovery under the DRP. The same area of failure was claimed under the 2012 DRP. No DRP application	$0.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-PK-012	Edworthy Park and Lawrey Gardens		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	DRP application not required. Consolidated with PK-054.	$0.00
I-FL2013-PK-013	Fort Calgary		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Riverbank vegetation damage and scouring. To be assessed with CMLC and Ft Calgary.	$0.00
I-FL2013-PK-017	Laycock Park		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	NO DAMAGE, no DRP application required	$0.00
I-FL2013-PK-023	Point McKay		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	no damage, no DRP application required	$0.00
I-FL2013-PK-027	Riparian Misc for Elbow River and Bow River		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Bioengineering, clean up, trail repair and restoration. No DRP application required. This work tracked within other projects	$0.00
I-FL2013-PK-043	Beaver Dam Flats - Pathway (2013-F31)		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Regional pathway compromised.No DRP application required (consolidated with I-FL2013-PK-006 Beaverdam Flats)	$0.00
I-FL2013-PK-044	Bow River - under Langevin Bridge	9	Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Water Resources to lead DRP/FRECP applications for bank stabilization and pathway repairs with Parks as a liaison. Funding source TBD	$0.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-PK-045	Bowmont - Pathway 2013-F27		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	New pathway alignment needed . Trestle bridge assessment through Roads Bridges. Remainder in Bowmont Park.No DRP application required (consolidated with I-FL2013-PK-007 Bowmont Park)	$0.00
I-FL2013-PK-046	Bowness Park - East end @ 85 St NW Underpass - South Bow (2013-F07)	1	Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	100 lineal m of heavy debris cleanup, 300 l m of light silt.No DRP application required (consolidated with I-FL2013-PK-001 Bowness Park)	$0.00
I-FL2013-PK-047	Bowness Park - South Bank of Bow River Stoney Tr Pedestrian Bridge (2013-F40)		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Pathway at west end of park completely washed out.No DRP application required (consolidated with I-FL2013-PK-001 Bowness Park)	$0.00
I-FL2013-PK-050	Carburn Park (2013-F32)		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Regional pathway covered with heavy debris, silt deposits. No DRP application required. Consolidate with PK-08 (Carburn Park)	$0.00
I-FL2013-PK-056	Elbow River Macleod Trail Underpass LRT Underpass (2013-F11)		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	No DRP application required. Consolidated with PK-055.	$0.00
I-FL2013-PK-058	Inglewood 8 Av - 21 to 23 St (2013-F15)	9	Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	8th Avenue from 21st to 22nd Street will have to be On-Street. No Parks DRP required. Pathway to be captured under WR application.	$0.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-PK-059	Lindsay Park Talisman (25 Ave SW to Macleod Trail) (2013-F13)		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	No DRP application required. Consolidated with PK-18 (Lindsay Park)	$0.00
I-FL2013-PK-060	Memorial Dr at 19th Street NW (2013-F01)	7	Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Entire riverbank washed away - requires complete reconstruction of bank. Water Services rebuilding bank but may not be permanent solution.No Parks DRP required. Pathway to be captured under WR application.	$0.00
I-FL2013-PK-061	Montgomery Blvd NW		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	No DRP application required. Pathway relocation away from river was planned pre-flood. Sinkhole in pedestrian path, bank damaged.	$0.00
I-FL2013-PK-063	North Bow - 85 St Underpass	1	Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Water Resources to lead DRP/FRECP applications and repairs for bank stabilization and pathway repairs with Parks as a liaison	$0.00
I-FL2013-PK-064	Pearce Estate Park - Pathways Weir to Train Trestle		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Area close to river has damaged pathways. Regional Pathway gone, no bank no base for 100 lineal meters. (not costed) Cost dependent on Prov channel decisions. No DRP required. Consolidate with PK-22 (Pearce Estate)	$0.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-PK-065	Prince s Island Ped Bridge to Centre Street	7	Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Entire riverbank washed away - Water Services rebuilding bank but may not be permanent solution. No Parks DRP required. Pathway to be captured under WR application	$0.00
I-FL2013-PK-067	Riverdale Ave Underpass (Elbow Dr Underpass)	11	Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	no DRP application required. Work completed to be submitted as part of Stanley Park PK-32	$6,000.00
I-FL2013-PK-068	Sandy Beach (2013-F25)		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Pathway has minor damage only, cleanup needed.Consulting only, subject to furtner review. No DRP required. Consolidated with PK-28 (Sandy Beach/Britannia)	$0.00
I-FL2013-PK-069	Stanley Park (2013-F16)		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	30m2 sink hole along path - pathways mostly OK, require lots of clean up, 130m riverbank construction.No DRP required. Consolidated with PK-32 (Stanley Park)	$0.00
I-FL2013-PK-071	Sue Higgins Park Southland		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Heavy Debris and silting. River pathway gone, needs replacement. NO DRP required, consolidated with PK-33 (Sue Higgins Park)	$0.00
I-FL2013-PK-074	Zoo Bridge Underpass @ 12 St SE-South Side (2013-F22)		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Minor sinkholes and cleaning needed. Consolidated with PK-73	$0.00

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I-FL2013-PK-075	Zoo to Baines Bridge (2013-F04)		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Heavy Debris and silting.Consolidated with PK- 73	$0.00
I-FL2013-PK-076	Deane house pathway (Elbow River @ 9 Avenue SE)	9	Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Water Resources to lead DRP/FRECP applications for damaged pathway and riverbank failure with Parks as a liaison. Funding source TBD	$0.00
I-FL2013-PK-090	Sue Higgins Park - Washrooms		Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	Washroom building requires Interior replacements fixtures and clean. (NOT DAMAGED)	$0.00
I-FL2013-PK-093	Rocky Ridge natural environment park	1	Community Services & Protective Services	CS & PS.Parks (Consolidate Projects)	trail repairs complete. No photographs of flood damage prior to completion. Parks does not intend to pursue a DRP claim.	$0.00
I-FL2013-RC-001	Shouldice Artificial Turf Repairs		Community Services & Protective Services	CS & PS.Recreation	8 significant sinkholes found on river fields after flood event. Ground penetrating radar scan detected disturbance to subsoil structure. Artificial turf sinkholes have been temporarily repaired, currently closed for winter	$20,000,000.00

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I-FL2013-RC-002	Stanley Park Outdoor Pool Repairs		Community Services & Protective Services	CS & PS.Recreation	Mechanical infrastruture of facility heavily damaged. Asset requires complete replacement of HVAC system reconstruction of pool basin, drainage and landscaping. Full restoration of millwork within pool change room is needed. Detail design drawings ongoing.	$2,000,000.00
I-FL2013-RC-003	Maple Ridge River Pumphouse Repairs		Community Services & Protective Services	CS & PS.Recreation	Electrial & mechanical systems damaged and required replacement. Existing river intake has lost significant capacity to provide water supply to the irrigation system. Measures being taken to prevent disruption to 2014 season	$1,350,000.00
I-FL2013-RC-004	Shaganappi Pumphouse Repairs		Community Services & Protective Services	CS & PS.Recreation	Electrial & mechanical systems damaged and required replacement. Existing river intake has lost significant capacity to provide water supply to the irrigation system. Measures being taken to prevent disruption to 2014 season.	$1,700,000.00
I-FL2013-RC-005	Glenmore Reservoir Services Repairs		Community Services & Protective Services	CS & PS.Recreation	Includes Canoe & Row Club. Damage to docks & equipment.	$0.00
	14 Patrol vehicles		Calgary Police Service	Calgary Police Service	Replace Patrol Vehicles	$416,000.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
	Police Administration Building		Calgary Police Service	Calgary Police Service	Restoration of Administration Bulding	$4,850,000.00
I-FL2013-CMLC-001	4th Street Underpass		Calgary Municipal Land Corporation	Calgary Municipal Land Corporation	The underpass was a completed project not yet FAC'd to the City. The underpass was completely submerged and the pump station and other electrical systems sustained significant damage.	$1,476,000.00
I-FL2013-CMLC-002	RiverWalk		Calgary Municipal Land Corporation	Calgary Municipal Land Corporation	Structure was adjacent to the river. until ground water recedes, the full extent of damage from settlement will not be known.	$508,000.00
I-FL2013-CMLC-003	East Village Infrastructure		Calgary Municipal Land Corporation	Calgary Municipal Land Corporation	Damage throughout East Village was sustained as a result of the flooding.	$626,000.00
I-FL2013-CPB-001	Admin Building	7	Corporate Services	CS.CPB	Uninhabitable, gutting and rebuilding.	$6,635,000.00
I-FL2013-CPB-002	Alberta Trade Center	8	Corporate Services	CS.CPB	Damaged, rebuilding/replacement required.	$1,966,000.00

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I-FL2013-CPB-003	EMS 3 - Erlton	8	Corporate Services	CS.CPB	Damaged, rebuilding/replacement required.	$2,059,000.00
I-FL2013-CPB-004	Municipal Building	7	Corporate Services	CS.CPB	Electrical, mechanical, switch gears, elevators, fire system, east side concrete restoration, carpets	$12,262,000.00
I-FL2013-CPB-005	Old City Hall	7	Corporate Services	CS.CPB	Damaged, rebuilding/replacement required.	$1,306,000.00
I-FL2013-CPB-006	Real Estate Buildings		Corporate Services	CS.CPB	CHC and 3rd party CPB buildings	$250,000.00
I-FL2013-CPB-007	Furniture Related Equipment		Corporate Services	CS.CPB	Furniture, AV and specialized equipment for A&BS Staff	$980,000.00
I-FL2013-CPB-008	Other Flood Damage Related Projects		Corporate Services	CS.CPB	Demos/cleanup/UofC rent/other	$3,000,000.00
I-FL2013-CPB-009	Admin Building Basement	7	Corporate Services	CS.CPB	Damaged, redesign, rebuilding/replacement required.	$0.00
I-FL2013-CPB-010	Alberta Trade Center Basement	8	Corporate Services	CS.CPB	Damaged, redesign, rebuilding/replacement required.	$0.00
I-FL2013-FL-001	Fleet - 24 units		Corporate Services	CS.Fleet	TOTAL LOSS - Severe Damage from being submerged in water	$1,139,000.00
I-FL2013-IIS-001	Riverbanks - LiDAR		Corporate Services	CS.IIS		$375,000.00
I-FL2013-IIS-002	MSPS2010 - Flood Recovery Program Management System		Corporate Services	CS.IIS	Software require for the administrative and operational aspects of disaster response.	$345,000.00
I-FL2013-IT-001	Phone Restoration		Corporate Services	CS.IT		$5,000,000.00
I-FL2013-IT-002	Network Hardware Replacement		Corporate Services	CS.IT		$3,500,000.00
I-FL2013-IT-003	Network Restoration		Corporate Services	CS.IT		$500,000.00
I-FL2013-IT-004	Business Continuity		Corporate Services	CS.IT		$3,000,000.00
I-FL2013-OLSH-001	OLSH Assets City Owned and City Partnership		Corporate Services	CS.OLSH		$650,000.00
I-FL2013-OLSH-002	Additional City Owned Assets		Corporate Services	CS.OLSH		$11,000.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-OLSH-003	CHC Managed Assets		Corporate Services	CS.OLSH		$125,000.00
I-FL2013-CPA-001	Structure repairs		Transportation	Trans.CPA	Civic Plaza and McDougall parkades repairs.	$11,825,000.00
I-FL2013-CPA-002	Equipment and machinery		Transportation	Trans.CPA	Repair damage to pay machines, IT infrastructure	$263,000.00
I-FL2013-CPA-003	Surface lot repairs		Transportation	Trans.CPA	Repair water damage to crush base, sinkholes, paving	$11,000.00
I-FL2013-TI-001	Macleod Trail N bound (from 25th Ave to Victoria Bridge)	9	Transportation	Trans.TI	2 lanes washed out - bank erosion - debris	$885,000.00
I-FL2013-TI-002	25th Avenue - between Spiller Road and Macleod	9	Transportation	Trans.TI	Road repair and underground utility repair	$135,000.00
I-FL2013-TI-003	25 Ave (Scollen Bridge)	8, 9	Transportation	Trans.TI	Road repair adjacent to bridge, bridge repair and related structural, geotechnical and environmental consulting.	$1,250,000.00
I-FL2013-TI-004	Miscellaneous Road and Transit repairs (Program)	City Wide	Transportation	Trans.TI	Internal OT costs and misc internal costs for supplies during the state of Emergency - these should be allocated across the TI projects	
I-FL2013-TI-004-01	Structure Inspections and Sink Hole repairs		Transportation	Trans.TI	Rope access structural bridge inspection and debris removal	$45,270.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-TI-004-02	Highfield Road	9	Transportation	Trans.TI	Heavy rains resulted in approximately 30m of a bank along Highfield Road to collapse, resulting in a portion of the road structure to fail.	$23,831.00
I-FL2013-TI-004-03	Erlton Street - south of 25th Ave	9	Transportation	Trans.TI	Concrete side walk and roadway at 27 ave and Erlton Street was damaged. A gas line running under the sidewalk along Erlton street was exposed and destabilized.	$79,000.00
I-FL2013-TI-004-04	Erlton Road at 25th Ave	9	Transportation	Trans.TI	Repairs to the sidewalk due to the undermined soil underneath. The adjacent roadway developed a sinkhole and required remediation.	$9,166.00
I-FL2013-TI-004-05	Memorial Drive Crossover at 19th Street NW	7	Transportation	Trans.TI	Pathway and river bank adjacent to eastbound memorial drive was washed away and destabilized. To allow remediation work to progress, a transition was needed at Memorial Dr and 19st to allow eastbound traffic to crossover to the westbound lanes.	$38,297.00
I-FL2013-TI-004-06	22nd Avenue Cul de Sac	8	Transportation	Trans.TI	Repairs to holes that developed near cul de sac and removal of debris.	$2,750.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-TI-004-07	61st Ave and McLeod Trail Emergency bus stop		Transportation	Trans.TI	Transit implemented a BRT route along Macleod Trail to provide service similar to the south LRT and required temporary bus pads near existing south LRT stations.	$16,050.00
I-FL2013-TI-005	Pedestrian bridge replacement (Program)	City Wide	Transportation	Trans.TI	Reconstruction of 3 pedestrian bridges on the Elbow River including: demolition, utility relocations, regulatory approvals, design, construction, confirm funding sources, public engagment. Construciton right of way and access is limited.	$11,878,000.00
I-FL2013-TI-005-001	Sandy Beach Pedestrian Bridge	11	Transportation	Trans.TI	Reconstruction of Sandy Beach pedestrian bridge.	$0.00
I-FL2013-TI-005-002	Riverdale-Sifton Pedestrian Bridge	11	Transportation	Trans.TI	Reconstruction of Riverdale-Sifton Pedestrian Bridge.	$0.00
I-FL2013-TI-005-003	Rideau Park Pedestrian	8	Transportation	Trans.TI	Reconstruction of Rideau Park pedestrian bridge.	$0.00
I-FL2013-CT-001	Victoria Park Garage	8	Transportation	Trans.Transit	Entire site evacuated, extensive cleaning, cash processing,building repairs and equipment damaged.	$2,500,000.00
I-FL2013-CT-002	Erlton Vic Park LRT Stations	8, 9	Transportation	Trans.Transit	Extensive comm room & escalator damage, 2 ticket machines require replacement,repairs and cleaning of Lot 91	$1,500,000.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-CT-003	South LRT Corridor Recovery Area including track work damage	9	Transportation	Trans.Transit	CPR/Cemetery Hill Tunnels - completely flooded, extensive cleaning, pump station, signals, ventilation switch gear destroyed,LRT signals rebuild.	$8,200,000.00
I-FL2013-RD-001	Traffic Signals Street lighting and Underpass Lighting Restoration	City Wide	Transportation	Trans.Roads	Restoration of Signals and Streetlight Infrastructure - various locations	$70,000.00
I-FL2013-RD-002	Traffic Sign Replacement and Lane Marking Work	City Wide	Transportation	Trans.Roads	Critical sign and inventory replacement/Lane marking work - various locations	$10,000.00
I-FL2013-RD-003	Road Repairs and Sink Holes	City Wide	Transportation	Trans.Roads	Repairs to emergency sinkholes caused by flood; Work on building berms, cleaning roads and other roadway repairs - various locations	$2,857,000.00
I-FL2013-RD-004	Pavement and Sidewalk Reconstruction (Program)	City Wide	Transportation	Trans.Roads	The flood resulted in multiple sinkholes and safety hazard concerns relating to subsurface conditions. Will be split into 6 separate projects.	$15,535,000.00
I-FL2013-RD-004- 001	Pavement Sidewalks Macleod Trail NB	9	Transportation	Trans.Roads		$0.00
I-FL2013-RD-004- 002	Pavement Sidewalks Macleod Trail SB	9	Transportation	Trans.Roads		$0.00
I-FL2013-RD-004- 003	Pavement Sidewalks 11 Ave SE Olympic Wa	8	Transportation	Trans.Roads		$0.00
I-FL2013-RD-004- 004	Pavement Sidewalks 25 Ave SW Macleod	9	Transportation	Trans.Roads		$0.00
I-FL2013-RD-004- 005	Pavement Sidewalks38 Ave SW 8A St	11	Transportation	Trans.Roads		$0.00
I-FL2013-RD-004- 006	Pavement Sidewalks Pumphouse Snow Dump Site	8	Transportation	Trans.Roads		$0.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-RD-004- 007	Elbow DR SW 4 St SW to Riverdale Ave SW		Transportation	Trans.Roads	Repairs to settlements on Elbow Dr SW. Delivered by TI.	
I-FL2013-RD-005	Slope Rehabilitation (Program)	City Wide	Transportation	Trans.Roads	4 sites across the city; Inglewood site to be reported under Water Resources.	$6,600,000.00
I-FL2013-RD-005-01	Highfield Rd SE	9	Transportation	Trans.Roads		$700,000.00
I-FL2013-RD-005-02	Hill Road NE	9	Transportation	Trans.Roads		$56,000.00
I-FL2013-RD-005-03	5 Trafford Cr NW (north of McKnight Blvd)	4	Transportation	Trans.Roads		$200,000.00
I-FL2013-RD-005-04	5328 32 Ave NE (Klippert gravel pit road)	5	Transportation	Trans.Roads		$0.00
I-FL2013-RD-006	Heritage Drive Reconstruction (Program)	9	Transportation	Trans.Roads	Reconstruction of Heritage Drive, including environmental contamination assessment.	$2,500,000.00
I-FL2013-RD-006-01	Heritage Drive Major Road Reconstruction	9	Transportation	Trans.Roads	Project created for Partial Financial Submission. This projects refers to major reconstruction	
I-FL2013-RD-006-02	Heritage Drive Top Lift Paving	9	Transportation	Trans.Roads	Project split for Partial Financial Submission. This projects refers to top lift paving that will occur in 2015	
I-FL2013-RD-007	Guardrails Landscaping and Fences Repair Reconstruction	City Wide	Transportation	Trans.Roads	Repair/reconstruction of Guardrails, Landscaping, Boulevards and Fences.	$280,000.00
I-FL2013-RD-008	Bridge Remediation (Program for 3 projects)	City Wide	Transportation	Trans.Roads	Repair work to flood damaged bridges/structures including bank erosion and scour protection at various locations: Re-build head slopes, replace protection and install rip-rap at river piers (Various locations).	$1,491,000.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-RD-008- 001	Underwater bridge inspections and assessments	City Wide	Transportation	Trans.Roads	All Bow River traffic and pedestrian bridges.High flood water level in the Bow and Elbow river altered th course, geometry, and configuration creating potential for severe scour around/under bridge piers, abutment, dams and causeways.	$190,800.00
I-FL2013-RD-008- 002	Channel Scour and Remediation	City Wide	Transportation	Trans.Roads	High flood water level in the Bow and Elbow river altered the course, geometry, and configuration creating potential for severe scour around/under bridge piers, abutment, dams and causeways.	$1,000,000.00
I-FL2013-RD-008- 003	Centre St Bridge Deck Hangers Replacement	7	Transportation	Trans.Roads	Deck hangers replacement (Centre St Bridge). Lower deck support hanger rods bent and supporting structural concrete beams cracked.	$300,000.00
I-FL2013-WRS-001	Residential Blue and Black Carts		Utilities & Environmental Protection	UEP.Waste & Recycling	It is estimated that many single-family residents in the flood-plain lost there blue and/or black carts during the flood event. Replace, repair and delivery will be required to reinstate services in the impacted areas.	$0.00
	Bonnybrook		Utilities & Environmental Protection	UEP.Water	Recovery of the Bonnybrook wastewater treatment plant. Includes restoration of electrical, instrument, and mechanical components.	$17,331,000.00
	Lift Stations		Utilities & Environmental Protection	UEP.Water	Damage to10 sanitary lift stations and 2 storm lift stations.	$5,000,000.00
	River Clean Up		Utilities & Environmental Protection	UEP.Water	Clean up of Bow and Elbow River	$1,050,000.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-W0-001	6 Critical Erosion Sites (Program)		Utilities & Environmental Protection	UEP.Water	Erosion Program - 6 sites	$0.00
I-FL2013-W-001	Critical Erosion Sites - 52 Street NW Home Road		Utilities & Environmental Protection	UEP.Water	Critical Erosion site - restoration of riverbank along 52nd street NW.	$5,000,000.00
I-FL2013-W-002	Critical Erosion Sites - Inglewood	9	Utilities & Environmental Protection	UEP.Water	Critical erosion site - restoration of riverbank along 8 Ave SE. Work includes restoration of riverbank, road, pathway, water line, hydrant.	$5,920,000.00
I-FL2013-W-003	Critical Erosion Sites - Memorial Drive at Sunnyside (curling rink)		Utilities & Environmental Protection	UEP.Water	Critical erosion site - restoration of riverbank at Memorial Drive in Sunnyside. Work includes restoration of riverbank and pathway.	$4,089,000.00
I-FL2013-W-004	Critical Erosion Sites - Memorial Drive 19 Street		Utilities & Environmental Protection	UEP.Water	Critical erosion site - restoration of riverbank at Memorial Drive at 19 Street. Work includes restoration of riverbank and pathway.	$4,300,000.00
I-FL2013-W-005	Critical Erosion Sites - Douglasdale Riverbank restoration (adjacent to Enmax Power Station)		Utilities & Environmental Protection	UEP.Water	Critical erosion site. Restoration of riverbank downstream of Enmax Power Station. Design to be in conjuction with works at the power station (done by Enmax) and Diamond Cove.	$1,400,000.00
I-FL2013-W-006	Critical Erosion Sites - Diamond Cove		Utilities & Environmental Protection	UEP.Water	Critical erosion site. Protection of eroded riverbank at the toe of slope to protect from further erosion.	$5,931,000.00
I-FL2013-W-007	High Priority Erosion Sites (Program)		Utilities & Environmental Protection	UEP.Water	Program to repair 27 high priority erosion sites along the Bow and Elbow River.	$23,000,000.00
I-FL2013-W-007.H	Douglasdale River Crossing		Utilities & Environmental Protection	UEP.Water		

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-W-007.H	Lindsay Park High Priority Site		Utilities & Environmental Protection	UEP.Water	Repair of berm is critical to act as spillway across 22 Avenue SW during flood event. Close Proximity to Homes. Erosion during another event likely.	
I-FL2013-W-007.H	U S of Glenmore		Utilities & Environmental Protection	UEP.Water	Penelope Reid (ID) repairing outfall B4A. May need to repair remainder of eroded bank after outfall repair work completed. Erosion in future event probable.	
I-FL2013-W- 007.H001	Elbow River Water Survey Gauge Access		Utilities & Environmental Protection	UEP.Water	Part of High Priorities Sites. Only relocation and resurfacing of access is being applied for DRP	
I-FL2013-W- 007.H003	Langevin Bridge Bank and Pathway		Utilities & Environmental Protection	UEP.Water	High Priority Erosion Site	
I-FL2013-W- 007.H005	Alyth Yard Bridge		Utilities & Environmental Protection	UEP.Water	Priority for Parks, Damage to Pathway	
I-FL2013-W- 007.H006	Bonnybrook Landfill		Utilities & Environmental Protection	UEP.Water	Possible environmental issues if landfill becomes exposed. This section along the stretch of erosion is under most severe attack during next flood season so armouring is required.	
I-FL2013-W- 007.H007	St Marys High School		Utilities & Environmental Protection	UEP.Water	Retaining wall at St. Mary's High School at risk. Area is between two "hardened" surfaces (bridge and retaining wall) and therefore subject to future attack. Parks may want to place a pathway at this location.	
I-FL2013-W- 007.H009	South Highfield Outfall B4B and Bow Bank (US Lafarge)		Utilities & Environmental Protection	UEP.Water		

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I-FL2013-W- 007.H010	Parkdale Ave Westmount Blvd		Utilities & Environmental Protection	UEP.Water	May qualify for DRP as existing bank protection was lost. West Memorial Sanitary Trunk at risk if further erosion continues. Close Proximity to Memorial Drive. Pathway loss (with easy detour).	
I-FL2013-W- 007.H011	Pine Creek WWTP		Utilities & Environmental Protection	UEP.Water	Long stretch of erosion that is at risk in future event. Pine Creek WWTP may eventually be at risk if erosion continues.	
I-FL2013-W- 007.H012	Under 85th Street		Utilities & Environmental Protection	UEP.Water	Pathway loss. Remediation costs are small (easy win). Large section of pathway could be opened due to fix.	
I-FL2013-W- 007.H014	Pathway at Calf Robe (Outfall B4C)		Utilities & Environmental Protection	UEP.Water	Needs to be protected to accommodate potential future changes in discharge from Bonnybrook WWTP. Bridge and outfall from Bonnybrook also a concern. Potential pathway at this location for parks.	
I-FL2013-W- 007.H015	16 Avenue Outlet		Utilities & Environmental Protection	UEP.Water	Highly visible erosion scar. Erosion protection for major outfall required. Erosion is between two "hardened" structures and is therefore at further risk of erosion.	
I-FL2013-W- 007.H015	Deane House		Utilities & Environmental Protection	UEP.Water	Important for Grand Openings in area. Public Support. High profile Pathway.	

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I-FL2013-W- 007.H017	DS Stanley Park (Outfall PR35 and PR36)		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W- 007.H018	Bowness Rail Bridge		Utilities & Environmental Protection	UEP.Water	Between two bridges. Erosion on steep bank with pathway adjacent is safety concern. Additional erosion likely.	
I-FL2013-W- 007.H018	Elbow Retaining Wall		Utilities & Environmental Protection	UEP.Water	Highly visible erosion site along Elbow Drive. Pathway loss with easy detour. Retaining wall has failed.	
I-FL2013-W- 007.H019	South Highfield		Utilities & Environmental Protection	UEP.Water	High Priority Erosion Site	
I-FL2013-W-007.M	Moderate Priority Erosion Site - 9th Avenue		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Bearspaw		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Beaverdam Flats		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Bowmont		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Centre Street		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Crowchild Trail Bridge		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Discovery Ridge		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Douglas Point Slope Stability		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Douglasdale Pathway		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Edworth at Lawrey		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Edworthy North		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Glenmore Dam Outlet		Utilities & Environmental Protection	UEP.Water		

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-W-007.M	Moderate Priority Erosion Site - Inglewood Golf Course		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - MacDonald Bridge		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Macleod Trail		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Memorial Off-Ramp (Crowchild)		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Montgomery		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Site - Shouldice		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-007.M	Moderate Priority Erosion Sites (program)		Utilities & Environmental Protection	UEP.Water	Program to repair 21 moderate priority erosion sites along the Bow and Elbow River.	$9,600,000.00
I-FL2013-W-008	Stormwater Ponds (Program)		Utilities & Environmental Protection	UEP.Water		$2,002,200.00
I-FL2013-W-008- 001	Burnsmed Storm Water Quality Retrofit		Utilities & Environmental Protection	UEP.Water	Damage to outfall channel, asphalt pathway, rip rap and safety railing.	$0.00
I-FL2013-W-008- 002	Deerfoot Trail Facility		Utilities & Environmental Protection	UEP.Water	Damage to access road, emergency overland escape route, debris deposit and pathway.	$0.00
I-FL2013-W-008- 004	Highway 22x-Marquis of Lorne South		Utilities & Environmental Protection	UEP.Water	Sediment and debris clean up around ponds, gabion basket well and outfall channel damage. Portion of gravel access road damaged.	$0.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-W-008- 007	Valley Ridge Wetland		Utilities & Environmental Protection	UEP.Water	Sediment and debris clean up , eroded and damaged outfall gate structure, eroded and separated concrete outfall pipe between ponds, eroded overland flow berms and destabilized riprap.	$0.00
I-FL2013-W-008- 010	Shepard Ditch Outfall		Utilities & Environmental Protection	UEP.Water	Major damage to stormwater infrastructure and riverbank.	$0.00
I-FL-2013-W-009	River Crossings (Program)		Utilities & Environmental Protection	UEP.Water	River Crossing - Damage unknown awaiting for water levels to receed Estimate is based on ASSESSMENT ONLY not repairs	$11,930,000.00
I-FL2013-W009-15st	San 15th Street NE Sanitary Sewer Siph		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-010	Outfalls (Program)		Utilities & Environmental Protection	UEP.Water	Repair of flood damaged outfalls on the Bow and Elbow river.	$7,850,000.00
I-FL2013-W-010	Storm Water Outfall B121		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-010	Storm Water Outfall B5A		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-010	Storm Water Outfall B5B		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-010	Storm Water Outfall B72		Utilities & Environmental Protection	UEP.Water		
I-FL2013-W-010- B101	Stormwater Outfall B101 (Bowness)		Utilities & Environmental Protection	UEP.Water	Outfall buried in gravel and sediment. No other damage.	$0.00
I-FL2013-W-010- B2B	Stormwater Outfal B2B		Utilities & Environmental Protection	UEP.Water	Outfall buried in gravel and sediment.	$0.00
I-FL2013-W-010- B3B	Stormwater Outfal B3B		Utilities & Environmental Protection	UEP.Water	Outfall buried in gravel and sediment.	$0.00

Province Unique Project Number	Project Name	Ward	Project Departments	Funding BU	Project Description	Overall Estimate
I-FL2013-W-010- B4A	Stormwater Outfall B4A (near Lysander)		Utilities & Environmental Protection	UEP.Water	Major loss of erosion exposing outfall pipe in the river. Need to install outfall structure and place rip rap.	$0.00
I-FL2013-W-010-B5	Stormwater Outfall B5 (Bonnybrook)		Utilities & Environmental Protection	UEP.Water	Safety railing damaged. Sediment and debris blocked outfall outlet.	$0.00
I-FL2013-W-010- B95	Stormwater Outfal B95		Utilities & Environmental Protection	UEP.Water	Outfall buried in gravel and sediment.	$0.00
I-FL2013-W-010-Be1	Stormwater Outfal E1		Utilities & Environmental Protection	UEP.Water	Outfall buried in gravel and sediment. Minor damage around the loss of riprap to be addressed.	$0.00
I-FL2013-W-010- G20C	Stormwater Outfal G20C		Utilities & Environmental Protection	UEP.Water		$0.00
I-FL2013-W-010-PC	Pine Creek Outfall		Utilities & Environmental Protection	UEP.Water	erosion protection lost, loss of riverbank, damaged outfall collar and pipe is dislodged.	$0.00
I-FL2013-W-10	Storm Water Outfall B37A		Utilities & Environmental Protection	UEP.Water		
Buildings & Equipment: Total Estimate						**$113,665,630.81**
Roads, Bridges & Other Infrastructure: Total Estimate						**$164,208,819.00**
Utilities: Total Estimate						**$47,578,200.00**
Parks & Open Space:						**$45,745,486.00**
River Cleanup						**$1,050,000.00**
Total Estimate						**$372,248,135.81**

Appendix D – Calgary Municipal Land Corporation Damages

East Village – June 20-24, 2013 Flood Damages

East Village June 20-24, 2013 Flood Damage - Underground

Phase	Location	FAC Underground Contract Value	Status of Completion	Repair Type	Timeframe	Rework as a Result of Flood
East village Phase 1	See Attached Phasing Plan for Phase Boundaries	$35,075.00	100%	City Owned	NA	$0.00
East Village Phase 1 Offsite	See Attached Phasing Plan for Phase Boundaries	$3,900.00	100%	City Owned	NA	$0.00
East Village Phase 2	See Attached Phasing Plan for Phase Boundaries	$9,510.00	100%	City Owned	NA	$0.00
East Village Phase 3 Offsite	See Attached Phasing Plan for Phase Boundaries	$2,550.00	100%	City Owned	NA	$0.00
East Village Phase 3	See Attached Phasing Plan for Phase Boundaries	$33,575.00	50%	Additional Flushing and Video may be required	2 Weeks	$16,787.50
4th Street North	See Attached Phasing Plan for Phase Boundaries	$16,935.00	50%	Additional Flushing and Video may be required	1 Week	$8,467.50
4th Street South	See Attached Phasing Plan for Phase Boundaries	$17,770.00	0%	Work has not begun so additional costs should be limited	NA	$0.00
4th Street South Part 2	See Attached Phasing Plan for Phase Boundaries	$4,380.00	0%	Work has not begun so additional costs should be limited	NA	$0.00
East Village Phase 6	See Attached Phasing Plan for Phase Boundaries	$22,605.00	80%	Additional Flushing and Video may be required	2 weeks	$18,084.00
East Village Phase 7	See Attached Phasing Plan for Phase Boundaries	$7,820.00	100%	Additional Flushing and Video may be required	1 Week	$7,820.00
East Village Phase 8	See Attached Phasing Plan for Phase Boundaries	$7,520.00	0%	Work has not begun so additional costs should be limited	NA	$0.00
East Village Phase 9	See Attached Phasing Plan for Phase Boundaries	$5,890.00	0%	Work has not begun so additional costs should be limited	NA	$0.00
East Village Phase 10	See Attached Phasing Plan for Phase Boundaries	NA	0%	Additional flushing may be required in the future	NA	$15,000.00
						$66,159.00

East Village June 20-24, 2013 Flood Damage - East Village Pond

Phase	Location	Area (m2)	lump sum/ each	Repair Type	Unit Price	Total
1- pond	ph 1 pond, west of forbay	900		topsoil and sod eroded	$50.00	$45,000.00
1- pond	ph 1 pond, west side forbay ret wall	8		sink hole	$500.00	$4,000.00
1- pond	ph 1 pond, southeast side forbay ret wall	8		sink hole	$500.00	$4,000.00
1- pond	ph 1 pond, control panel		1	replace control panel	$3,000.00	$3,000.00
1- pond	ph 1 pond, wier and valve		1	possible undemining , silt , rust	$2,000.00	$2,000.00
1- pond	cleanup debris and silt		1	clean silt and HWL debris from site	$5,000.00	$5,000.00
1- pond	dredge silt out of pond for FAC		1	dredge and resurvey	$20,000.00	$20,000.00
						$83,000.00

East Village June 20-24, 2013 Flood Damage - Roadways

1- Resand- sand the bricks from the top to fill in gaps.
2- Rebrick - lift bricks, resand under bricks to level, and replace bricks.
3- Repave- remove brick and pavement structure, fill in settlement and repave or pour and rebrick.
4- Redo Curb- remove and replace curb
5- Re----miscellaneous

Phase	Location	Area (m2)	Length (m)	Repair Type	Unit Price	Total
1	Confluence at Riverfront Ave	160		1- resand	$30.00	$4,800.00
1	Confluence at Riverfront Ave SE layby	24		1- resand	$30.00	$720.00
1	Riverfront Ave east of Riverfront Lane	60		1- resand	$30.00	$1,800.00
1	Riverfront Ave north of Confluence	9		3- repave	$400.00	$3,600.00
1	Riverfront Ave north of Confluence at sales center	9		3- repave	$400.00	$3,600.00
1	Confluence at 6th Ave	14		3- repave	$400.00	$5,600.00
1	Riverfront Ave (N-S) east of sales centre	12		3- repave	$400.00	$4,800.00
1	Riverfront Ave (N-S) south east of sales centre	12		3- repave	$400.00	$4,800.00
1	Confluence at Riverfront ave SE corner at hydrant	16		3- repave	$400.00	$6,400.00
1	Riverfront Ave and Confluence SE corner	9		3- repave	$400.00	$3,600.00
2	8th ave west of 5th st, north side	4		2- rebrick	$236.00	$944.00
2	8th ave west of 6th st, north side	6		2- rebrick	$236.00	$1,416.00
3	5th st between RF ave and 6th ave	90		1- resand	$30.00	$2,700.00
3	5th st just south of 6th ave, west sidewalk	8		2- rebrick	$236.00	$1,888.00
3	6th ave at 5th st at MH's	12		2- rebrick	$236.00	$2,832.00
3	5th st just south of 6th ave	9		3- repave	$400.00	$3,600.00
4th st North						
4th st South pt 2						
6	6th st south of 6th ave, west side walk	40		1- resand	$30.00	$1,200.00
6	6th st south of 6th ave, west side	40		1- resand	$30.00	$1,200.00
6	5th st between 8th and 9th ave north of lane	150		1- resand	$30.00	$4,500.00
6	6th st north of 7th ave, east side, at bus stop	115		2-rebrick	$230.00	$26,450.00
6	5th st north of 8th , west side at CB	12		2-rebrick	$230.00	$2,760.00
6	5th st north of 8th , east side at CB	9		2-rebrick	$230.00	$2,070.00
6	5th st south of 9th ave to lane, road crown	168		2-rebrick	$230.00	$38,640.00
6	6th st north of 7th ave, east side, at bus stop	4		3- repave	$400.00	$1,600.00
6	6th st south of 6th ave, west side	10		5- redo gravel under edge of brick	$100.00	$1,000.00
6	6th st at 7th ave, west side	10		3- repave at WCR and CB	$400.00	$4,000.00
6	6th st north of 7th ave, east side	8		3- repave	$400.00	$3,200.00
6	6th st at 9th ave, NW corner	18		3- repave at WCR	$400.00	$7,200.00
6	5th st at 9th ave, along conc band	9		3- repave	$400.00	$3,600.00
6	5th st between 8th and 9th ave by lane, east side	6		3- repave	$400.00	$2,400.00
6	5th st between 8th and 9th ave at lane (west side)	8		3- repave	$400.00	$3,200.00
7	4th st between 7th and 8th ave, north of lane	18		5- redo asphalt in road	$80.00	$1,440.00
7	4th st between 7th and 8th ave, north of lane at entrance	10		5- redo gravel under walk	$40.00	$400.00
8	8th ave at 4th st road and walk	50		1- resand	$30.00	$1,500.00
8	8th ave at 4th st road and walk	12		3- repave	$400.00	$4,800.00
9	Riverfront Ave walk east of RFLane	24		1- resand	$30.00	$720.00
9	Riverfront Ave walk at RFLane	60		1- resand	$30.00	$1,800.00
9	Riverfront Lane south end of art wall	160		1- resand	$30.00	$4,800.00
9	Riverfront Lane north of south planter	15		3- repave	$400.00	$6,000.00
9	Riverfront Lane along LRT at south planter	40		5- redo mulch, clean LRT gravel	$30.00	$1,200.00
10	5th st between 6th and 7th ave south of lane	90		1- resand	$30.00	$2,700.00
10	6th ave North side at Riverfront lane	60		1- resand	$30.00	$1,800.00
10	5th st between 6th and 7th ave north of lane	9		1- rebrick	$230.00	$2,070.00
10	5th st between 6th and 7th ave south of lane	17		1- rebrick	$230.00	$3,910.00
10	5th st between 6th and 7th ave at lane	15		3- repave	$400.00	$6,000.00
10	5th st between 6th and 7th ave south of lane	32		3- repave	$400.00	$12,800.00
10	Lane south of 7th ave between 5th and 6th st	24		3- repave	$400.00	$9,600.00
10	7th ave between 5th and 6th st	32.2		5- redo porous asphalt in road	$170.00	$5,474.00
10	7th ave between 5th and 6th st		26	4- redo curb	$150.00	$3,900.00
						$227,034.00

RiverWalk – June 2013 Flood Damage Evaluation Report

RiverWalk

June 2013 Flood Damage Evaluation Report

July 17, 2013
Calgary, AB

Stantec

Table of Contents

Introduction

Following the June 2013 floods events, the Calgary Municipal Land Corporation (CMLC) engaged Stantec Consulting to review and assess damages caused to the completed phases of RiverWalk. Stantec was directed to work with CMLC, the construction manager Marmot Concrete, and river hydrologists from Matrix Solutions to prepare an inventory of the damages, provide recommendations and strategies for mitigation, and an opinion of probable cost for the required repairs and rehabilitation construction works.

Site evaluations were conducted throughout the first two weeks of July 2013 by Stantec landscape architecture, electrical engineering, structural engineering, and geotechnical engineering. It was determined that the damages were not substantial within the context of the overall project. Areas where the river bank vegetation was well established proved to increase stability and limit erosion. The greatest damages were evident in Phase 3 and areas of Phase 1.

Stantec landscape architecture was responsible for coordinating all evaluations, compiling reports from all disciplines and providing an overall review of RiverWalk Ph1, Ph2 and Ph 3. The landscape evaluation focuses on damages caused to soft landscape areas, riverbank erosion, and miscellaneous cleanup items. Damages to the riverbank may require approvals from regulatory agencies prior to rehabilitation construction. Stantec will provide info to Matrix Solutions who will be responsible for corresponding with regulatory agencies and obtaining the necessary approvals.

The objective of the electrical engineering evaluation was to determine whether the electrical system suffered damaged due to flooding and evaluating the general condition of panels, conductors, and components installed within flood affected areas. Enmax feeds are exempt from the evaluation as Stantec does not have authorized access to Enmax equipment. Please note that submerged electrical equipment due to floods can be extremely dangerous if simply re-energized. Flood water contains contaminants such as chemicals, sewage and other substances that affect the integrity and functionality of the equipment and degrade service life.

The structural review focused on the river outlooks and decks that may have been submerged during the flood event and under high levels of force due to the volume and velocity of the river. The main areas of concern were the low decks in Fort Calgary, and the 6th St. outlook as they were known to have been partially submerged in the river.

The objective of the geotechnical evaluation was to observe areas where pathways and retaining walls were undermined and provide recommendations to ensure integrity to the base structure during mitigation construction. The geotechnical evaluation should be referenced for any mitigation work in the vicinity of pathways, retaining walls or landscape structures.

Landscape Report

Notes

- Survey extent of damage on bank.
- Survey top of path.
- Draft cross-section for Matrix review and design.
- Cut back damaged asphalt.
- Build up bank with compacted clay fill and gravel for pathway base.
- Patch asphalt.
- Rehab slope with loam & eco-blanket. Seed at 200kg/ha.
- Note - may require regulatory approvals.

Notes

- Remove debris.
- Clean up temporary pathway.

Notes

- Cut asphalt.
- Fill with compacted clay fill and gravel.
- Patch asphalt.
- Loam and seed with eco-blanket 200kg/ha.

Notes

- Top dress with 50mm loam and overseed with eco-blanket.

Notes

- Strip area and remove silt.
- Salvage good materials.
- Re-use existing surface, mix with binder material.
- Add protective perimeter willow planting.
- Add vegetative protection up-stream sides of large rocks.
- Reconstruct.

Notes

- Clean up subgrade.
- Rehab soft landscape with 150mm loam and seed with eco-blanket, 200kg/ha; or, fescue sod.
- Review and increase extents of rip-rap around decks.
- Decks did not appear to be damaged.
- Pull deck board to ensure subsurface drainage is functional.
- Ensure that deck board spaces are free of silt and debris for ventilation.

Notes

- Loam top dress 100mm.
- Seed with eco-blanket 200kg/ha; or, fescue sod.
- Clay fill and compact around light standard bases.

Notes

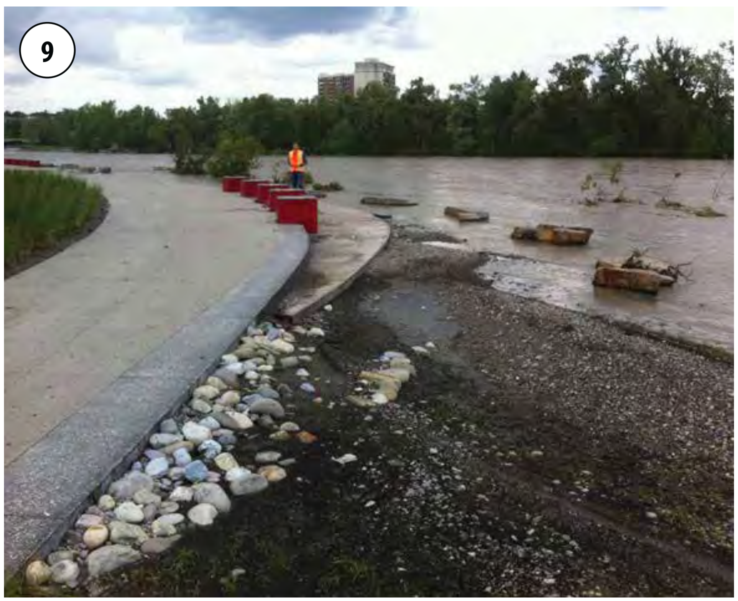
- Fill void with clay and compact to 98% SPD.
- Gravel base under pathway and compact.
- Where compaction becomes constrained due to space, fill with mud jack grout to fill voids. Refer to geotechnical evaluation.
- Ensure 400mm of loam depth in plant bed.
- Fill in grasses as per initial approved plans.

Notes

- Fill void with clay and compact to 98% SPD.
- Gravel base under pathway and compact.
- Where compaction becomes constrained due to space, fill with mud jack grout to fill voids. Refer to geotechnical evaluation.
- Ensure 400mm of loam depth in plant bed.
- Fill in grasses as per initial approved plans.
- Red cubes - refer to electrical notes.

Notes

- Clean up subgrade.
- Rehab eroded areas with 150mm loam.
- Seed with eco-blanket, 200kg/ha; or, fescue sod.
- Extend rip-rap around entire deck.



Notes

- Survey extents of bank erosion and new top of bank.
- Prepare cross-section for Matrix review and design.
- Re-build bank with clay fill and armor with rip-rap.
- Regulatory approvals may be required.

Notes

- Repair/replace landscape fabric.
- Fill in/replace Class II rip-rap.

Notes

- Some minimal scouring on established river bank.
- Top dress thin areas with 50mm of loam and overseed.
- Refill voids between steps with basalt chips.

Notes

- Clean off hard surfaces.
- Gently wash plant material and assess.
- Top up mulch where washed away or covered in silt.

Notes

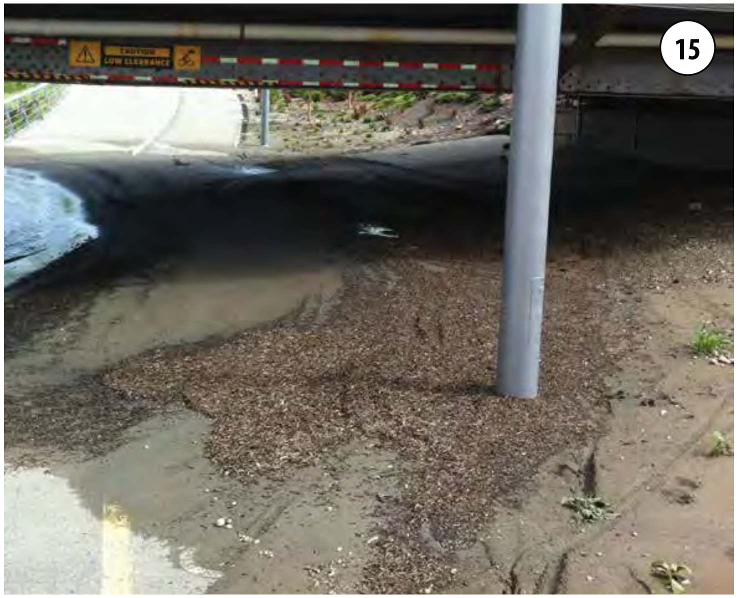
- Survey extents of wash out.
- Create cross-section for Matrix review and design.
- Remove slumped boulders.
- Replace void with compacted clay fill and Class II rip-rap.
- Armor with Class II rip-rap.
- May require regulatory approvals.

Notes

- Survey extents of wash out.
- Create cross-section for Matrix review and design.
- Remove slumped boulders.
- Replace void with compacted clay fill and Class II rip-rap.
- Armor with Class II rip-rap.
- May require regulatory approvals.

Notes

- Clean off silt.
- Replace plant material in silt covered area and re-mulch.



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Notes

- Clean up silt.
- Top dress with loam and overseed.

17

Notes

- Fill in plant bed voids with loam and re-mulch.

18

Notes

- Review retaining walls for voids caused by erosion.
- Repair filter fabric where possible.
- Fill voids with drainage rock.
- Refer to geotechnical evaluation.

19

Notes

- Clean debris off pathway.

Notes

- Clean off steps.

Notes

- Clean off steps.

Notes

- Clean debris from railing.

Notes

- Clean beds and re-mulch.
- Plant material was dead prior to flooding and should be replaced under contractor warrantee.

Notes

- Top dress and overseed scoured areas on riverbank.

Notes

- Fill voids with loam and ecolog to protect ends of steps.

Notes

- Refill voids in steps with crush basalt.

Notes

- Fill in rip-rap where it was washed away.

Notes

- Monitor wall for sloughing.

Electrical Report

MAIN DISTRIBUTION PANEL 3A

The main distribution panel servicing RiverWalk Phase 3 lighting system appears to have settled from recent floodwater. While components, including concrete base, do not appear to have any damage from water, the existing panel will require new fill and compaction to prevent any further settlement. It is recommended that the following work be completed on the panel:

- Support existing panel and hydrovac base down to compacted gravel.
- Investigate all ground rods for disturbance and ensure connection points are maintained. Megger test existing ground connection.
- Backfill existing panel to original specification. Refer to the appendix for additional photos.

RIVERWALK CUBES

The cubes have been submerged in their entirety and most of the electronics show signs of water damage. One of the LED panels was field tested and while operational at this time, the time before failure contrasted to its original service life due to taking on water is questionable. In addition, the bonding agent applied to red film to adhere it to the LED panels may be compromised and result in the film lifting in the coming years. It is recommended that the following work be completed on all cubes:

- Existing LED drivers be removed, disposed of, and replaced in kind with new models.
- LED Panels be removed, disposed of, and replaced in kind with new panels. New panels to have Aztech Film as per original specification.
- All field splices in panels to drivers be reconnected.

JUNCTION BOXES

The junction boxes exist along the river's edge and appear relatively undamaged. Most of the splices have taken on water or been completely submerged. Accordingly, it is recommended that each splice is taken apart and reconnected. Junction boxes should be cleared of any accumulated debris that will impede drainage through the bottom drain plate Ground connections should be brushed clean and wires cut back and re-terminated with fresh copper.

HESS NIGHT ELEMENTS

The Hess Night Elements do not appear to show major damage from the water due to their profile and general arrangement with the majority of equipment located higher in the pole. Hand holes show signs of dirt and debris accumulation with water seepage entering from the conduit. Splicing remains relatively undamaged, however, it is recommended that splicing be reconnected to ensure no accumulation of moisture within which will degrade the connection point over time. Some ground connections require moderate clean up, however, appear to be in functioning order.

The ground has been eroded at a number of locations and additional backfill and compaction is required to ensure proper support of foundations for the Hess Night Elements.

BURIED ELECTRICAL CABLES AND CONDUITS

Inspection of the cables and conduits within the system cannot be completed due to their nature of installation, however, given the water level it is anticipated that a number of conduits may have filled with water. Upon re-energization of the system a number of issues with cables may be found should insulation have been damaged. In addition, excess water accumulated in the ducts such as those for the ITS conduits may cause future issues pulling cables as duct work may break in winter once frozen. There is a relatively low probability that this will impede the operation of the system and its intended use, however, future work may be required following the 2013 winter.

We trust that the information contained above shall meet with you approval, however, should you have any questions or concerns please do not hesitate to contact the undersigned.

Photos of Flood Damage

Fig.1 - Panel settlement

Fig.2 - Main panel incoming conduits – Water level indicated by debris buildup

Fig. 3 - Main Breaker enclosure - Dry

Fig. 4 - Hess Night Element Base Erosion

Fig. 5 - Hess Night Element Hand Hole - Submerged

Fig. 6 - Hess Night Elements - Water in conduit

Fig. 7 - Cube - Fully Submerged

Fig. 8 - Cube Driver - Fully submerged with condensation build up

Fig. 9 - Cube Driver - Fully submerged

Fig. 10 - Cube Foundation Erosion

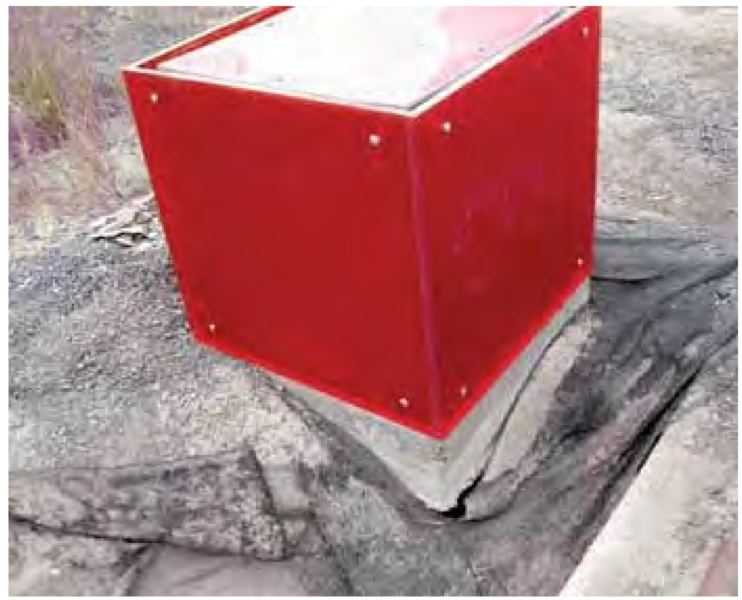

Fig.11 - Cube broke acrylic

Fig. 12 - In-Grade JB - debris buildup

Fig. 13 - In Grade JB - Mud accumulation

Fig. 14 - ITS Pull box erosion

Structural Report

EXISTING STRUCTURES

The RiverWalk stage 1 consists of several "outlook" structures, which consist of a concrete base, and steel truss outriggers supporting a platform for pedestrians to overlook the river. In addition to these structures, the site consists of concrete pathways, including timber decks supported on concrete grade beams, as well as several benches anchored to site concrete.

ASSESSMENT SCOPE AND METHODOLOGY

Stantec personnel conducted a visual assessment of the RiverWalk site. At the time of inspection, all areas of the site were accessible, as water levels of the bow had dropped considerably.

The structural components of the site that were reviewed included:

- Review of the outlook platforms along the southern bank of the bow river.
- General review of concrete pathways.
- General reviews of timber decks & supporting grade beams.
- Review of benches anchored to concrete.

OBSERVATIONS

Portions of the concrete pathways have had the supporting grade washed out, undermining the sidewalk by as much as 300-400mm. The foundations for timber decking appeared to have minimal scouring, and appeared to be generally unaffected.

The timber planking supporting various walkways appeared to have warped from the excess moisture, with a small percentage of the planking warping and raising slightly.

There appeared not to be any cracking for the anchorage of the bench structures to the existing concrete, however, in the "cube" benches, there was significant silt left behind on the inside of the structures due to the flooding.

Debris was found in between outlook structures, including tree branches and tree trunks, however, there did not appear to be any signs of deterioration of the structures, including cracking at the steel to concrete connection points. There did not appear to be any excessive scouring of the concrete foundations.

CONCLUSIONS AND RECOMMENDATIONS

Generally, there were no indications of significant movement or structural distress in any of the concrete or steel elements for the pathways, outlook platforms or anchorage of benches to the concrete elements that can be attributed to the flood event observed. All of these elements appear to be generally unaffected.

The timber planking supporting various walkways that appeared to have warped does not pose a structural concern at this time. It is understood that there is drainage below the decking, however, the decking should be monitored for any rot due to the excessive moisture that was sustained. For areas of the concrete pathway that have been undermined, it is recommended that the subgrade missing is replaced as per geotechnical recommendations.

Geotechnical Report

EXISTING STRUCTURES

The Riverwalk stage 1 consists of several "outlook" structures, which consist of a concrete base, and steel truss outriggers supporting a platform for pedestrians to overlook the river. In addition to these structures, the site consists of concrete pathways, including timber decks supported on concrete grade beams, as well as several benches anchored to site concrete.

ASSESSMENT SCOPE AND METHODOLOGY

Stantec personnel conducted a visual assessment of the RiverWalk site. At the time of inspection, all areas of the site were accessible, as water levels of the bow had dropped considerably.
The structural components of the site that were reviewed included:

- Review of the retaining structures / outlook platforms along the southern bank of the bow river.
- General review of asphalt and concrete pathways.
- Review of the light standard bases along the RiverWalk

OBSERVATIONS

In general the RiverWalk structures along the Bow River received minimal disturbance. Minor erosion was identified within the steps leading down to the river. However, a portion of the river bank (landscaping/rock and rip-rap) was lost beneath the fly-overs (4th St., 5th St. and LRT).

One section of the asphalt pathway and embankment just downstream of 9th Avenue was partially washed away due to the flood waters. Portions of the concrete pathways were undermined by as much as 300-400mm. The foundations for timber decking appeared to have minimal scouring, and appeared to be generally unaffected.

Some minor scouring was observed at various light standard bases, typically less than 300 mm of scour.

Debris was found in between outlook structures, including tree branches and tree trunks, however, there did not appear to be any signs of scouring or deterioration of the structures foundations.

CONCLUSIONS AND RECOMMENDATIONS

In areas where minor erosion was observed it recommended that repairs be in accordance with the original design. Backfill material required to reconstruct the riverbank beneath the fly-overs should be in accordance with the original design recommendations. A non-woven geotechnical fabric should be placed between the backfill material and rip-rap.
Rip-rap should be in accordance with the hydro-technical engineer's recommendations.

For areas of the concrete pathway that have been undermined, it is recommended that the subgrade and shoulder material be replaced with materials which conform to the original design. Following the placement of the backfill material adjacent to the pathway it is recommended that the undermined section of the concrete pathway be grout injected to fill the void. This may be achieved by hand excavating adjacent to the concrete pathway and inserting the grout injecting nozzle. It is recommended that this be completed at maximum 2 m spacing along the pathway.

In areas where the asphalt pathway has been damaged / lost it is recommended that these areas be rebuilt to the pre flood conditions.
It is recommended that loose of soft deleterious materials be removed from the impacted area prior to replacement. In areas where an exposed/ vertical face is observed within the pathway structure it is recommended that the contractor remove 150 mm of existing structure and rebuild. It is anticipated that the subgrade and embankments could be rebuilt using site excavated material (gravels).

Scouring at the light standards should be backfilled using pit run or site excavated gravel. Compaction requirements should be in accordance with the original design.

The foundations at the outlook platforms did not appear to be affected by the flood event.

FLOOD DAMAGE MITIGATION
PRELIMINARY OPINION OF PROBABLE COSTS - FOR INTERNAL USE ONLY

Assumptions contained herein are based on past projects.
Estimates are based on conventional construction access to sites.
Estimate assumes loam and fill materials will be imported.
All work conforms to City of Calgary Specifications.

	Item	Quantity	Unit	Price	Amount
	PHASE 1 & 2				
1.0	**Misc Works** Basic repairs and touch ups throughout the site, includes re surfacing washout areas, repairs to rip-rap, inspections/cleaning of the storm systems, silt removal, re-install plant material, reloaming and seeding.	1	l.s.	$ 15,000.00	$ 15,000.00
2.0	**Repair Chief Cliff Wall Under Fly Over**	1	l.s.	$ 105,000.00	$ 105,000.00
				SUBTOTAL	**$ 120,000.00**

PHASE 3

1.0	<u>**Rough Grading**</u>						
	Compacted Fill	350	c.m.	$	25.00	$	8,750.00
2.0	<u>**Subgrade Preparation**</u>						
		4000	s.m	$	0.50	$	2,000.00
3.0	<u>**Loaming & Fine Grading**</u>						
	Topdressing (50mm depth)	30	c.m.	$	20.00	$	600.00
	100mm Depth	140	c.m.	$	20.00	$	2,800.00
	150mm Depth	540	c.m.	$	20.00	$	10,800.00
4.0	<u>**Seeding c/w Eco Blanket**</u>						
	Specialty Seed	4500	s.m	$	6.50	$	29,250.00
	Note: Application Rate of 200 kg/ha. For specialty seeds contact seed supplier to confirm pricing.						
5.0	<u>**Riverbank Rehabilitation**</u>						
	Supply, install and compact fill material	825	c.m.	$	30.00	$	24,750.00
6.0	<u>**Plant Material (Supply & Install w/ 1 year Warranty)**</u>						
	Perennials						
	15cm pot	250	ea.	$	25.00	$	6,250.00
7.0	<u>**Area Asphalt**</u>	30	s.m	$	65.00	$	1,950.00
8.0	<u>**Miscellaneous**</u>						
	Rip Rap						
	Class 1	150	c.m.	$	150.00	$	22,500.00
	Class 2	310	c.m.	$	150.00	$	46,500.00
	Pathway Cleanup	1	l.s.	$	5,000.00	$	5,000.00
	Interperative Area	1	l.s.	$	25,000.00	$	25,000.00
	Replace damaged cube	1	l.s.	$	5,500.00	$	5,500.00
9.0	<u>**Shrub Bed**</u>						
	Topdressing and mulch	682	s.m	$	10.00	$	6,820.00
				SUBTOTAL		**$**	**198,470.00**
			TOTAL			**$**	**318,470.00**

4th Street Underpass Restoration Budget

Neil MacKimmie

From: Anderson, Brian (Calgary) <Brian.Anderson@stantec.com>
Sent: Monday, July 15, 2013 3:59 PM
To: Neil MacKimmie
Cc: Sawchyn, Brian; Birkle, Gerd; Roberts, Ryan; Furlong, James; Wynker, Mark; Loewen, Conrad; Rozsa, Francis; Bonnett, Ron; Darling, Dennis; More, Craig; Henderson, George; Tromposch, Eric; Monteith, Eric
Subject: 4th Street Underpass Restoration (DRAFT)
Attachments: 4th St Flood Restoration budget.pdf

Neil,
The following is a breakdown of anticipated cost for the restoration of the 4th street underpass to its original pre-flood condition. Cost has been received from Graham Infrastructure and their original sub-contractors (see attached quote). We have requested, as per our last meeting, an effected asset list, so that we can further assess the costs provided. Within the Graham costs there are items that remain a liability (lighting related) and we are working to assign values to these items.

1. Costs to date for emergency response to assess damage to lift station, restore temporary pumping, review structures, review roads and electrical.

    - *Graham Infrastructure & Subs - $ 30,000+/-
    - Stantec Consulting Ltd. - $ 12,000 +/-
    - **Total** $ 42,000 +/-

    *Still awaiting costs, so have made an assumption of cost.

2. Rebuild as per original design

    - Graham Infrastructure (Pump Station)
        - Electrical - $ 438,900
        - Mechanical- $ 206,580
        - Graham (Own Forces)- $ 80,273
    - Graham Infrastructure (External Restoration)
        - Electrical - $ 434,170
        - Graham (Own Forces) - $ 14,816
    - Graham Infrastructure (Contingent Items)
        - Pumps (if no warranty) - $ 93,500
        - Allowance type 112 light covers - $ 100,000
    - Stantec Consulting Ltd.
        - Water Resource Group - $ 26,000
        - Buildings (HVAC) - $ 10,000
        - Buildings (Electrical) - $ 10,000
        - Buildings (Structural) - $ 5,000
        - Urban Development - $ 15,000
    - **Total** **$1,434,239**

With respect to potential cost for raising the lift station control room to the street level above the underpass and above the underpass flood level, we provide an order of magnitude incremental cost allowance as follows. This would assume a building being positioned directly above the current control room, adjustments to the existing structure to close/move venting and hatches, re-arrange the same equipment in new building, connect to the existing wet well and infrastructure, design changes and submissions.

- Building allowance - $350,000
- Engineering
    - Architecture - $ 25,000
    - Buildings (HVAC) - $ 25,000

- Buildings (Structural) - $ 15,000
- Buildings (Electrical) - $ 20,000
- Urban Development - $ 5,000

- **Total** **$440,000**

Brian Anderson
Principal
Stantec
Ph: (403) 716-8216
Fx: (403) 716-8059
Cell: (403) 462-3048
Brian.Anderson@stantec.com
stantec.com

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Please consider the environment before printing this email.

Appendix E – Stampede Damages

Calgary Exhibition and Stampede
2013 Flood Loss Spending to September 30, 2014

Facility	Total Costs for Recovery	Mitigation Costs	Total
Grand Stand	15,103,130	295,311	15,398,441
Big Four Building	8,737,711	462,762	9,200,474
Other	6,394,506		6,394,506
Calgary Stampede Administration	5,627,668		5,627,668
Riverbanks – Floodwalls[1]		3,711,337	3,711,337
Bridge		2,130,681	2,130,681
Barns	1,098,469	534,097	1,632,566
Parking	1,228,412		1,228,412
Agriculture Livestock Building	1,175,442	5,347	1,180,789
BMO Centre	832,394		832,394
Business Interruption	784,729		784,729
Casino	547,985		547,985
Inventory: Liquor, Merchandise & Uniforms	596,330		596,330
Agrium Western Event Centre	307,954		307,954
Expansion Properties	141,602		141,602
Art	85,139		85,139
Corral Building and Boyce Theatre	9,246		9,246
Unidentified & Uninsured	---	4,099,209	4,099,209
Total	**42,670,718**	**11,238,745**	**53,909,463**

1. Does not include spending recovered from the City of Calgary.

APPENDIX 3-3 BENEFIT/COST ANALYSIS OF FLOOD MITIGATION PROJECTS FOR THE CITY OF CALGARY: SPRINGBANK OFF-STREAM FLOOD STORAGE (2015), ENVIRONMENT AND SUSTAINABLE RESOURCE DEVELOPMENT. PREPARED BY IBI GROUP.

Appendix 3-3 Benefit/Cost Analysis of Flood Mitigation Projects for the City of Calgary: Springbank Off-Stream Flood Storage (2015), Environment and Sustainable Resource Development. Prepared by IBI Group. June 2020

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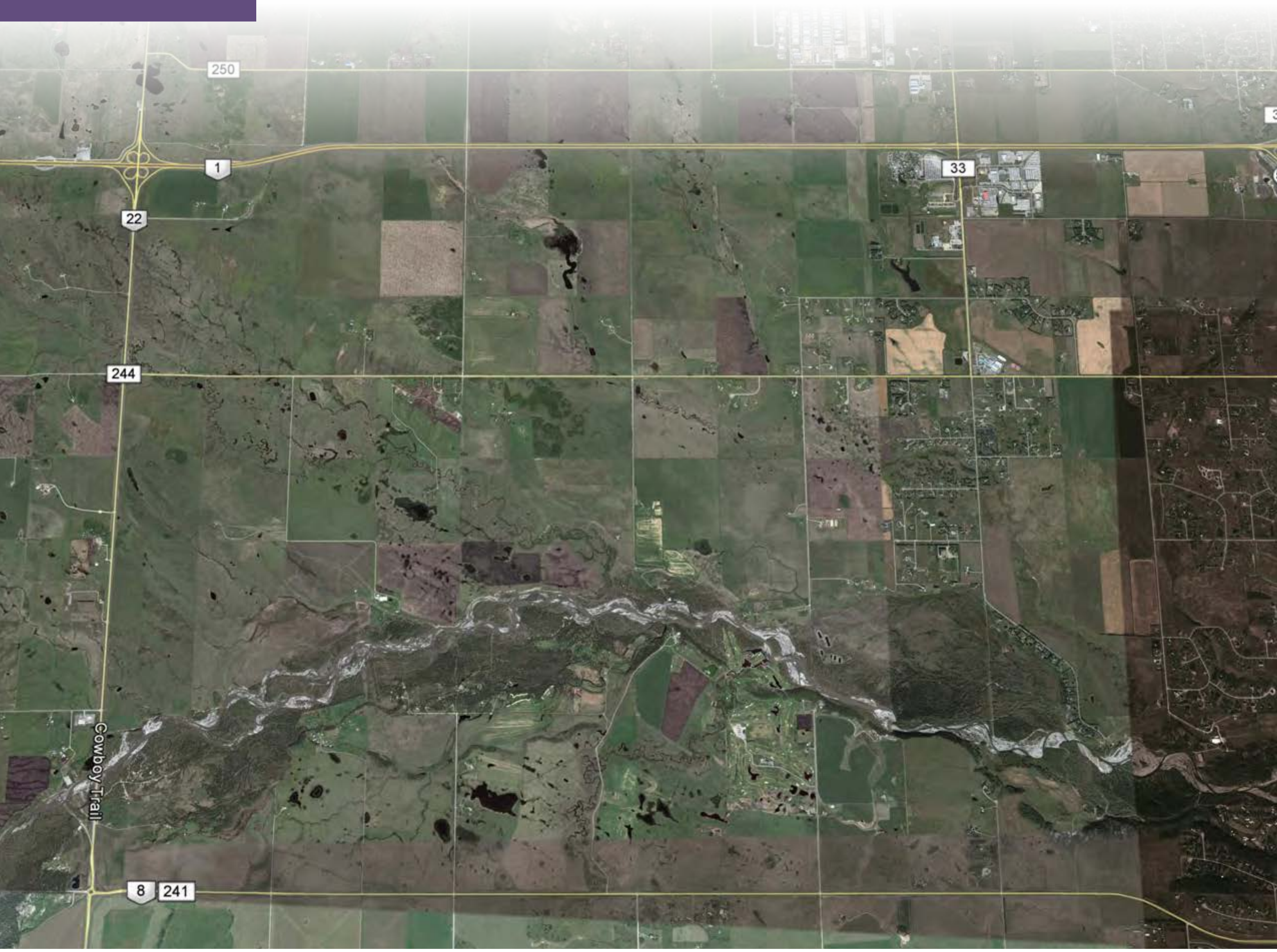
Alberta Government



REPORT

Benefit/Cost Analysis of Flood Mitigation Projects for the City of Calgary: Springbank Off-Stream Flood Storage

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

IBI GROUP
400 – Kensington House, 1167 Kensington Cres NW
Calgary AB T2N 1X7 Canada
tel 403 270 5600 fax 403 270 5610
ibigroup.com

February 18, 2015

Ms. Heather Ziober
Project Manager, Strategic Integration and Projects
Government of Alberta
Environment and Sustainable Resource Development
205 J.G. O'Donoghue Building
7000 - 113 Street
Edmonton, AB T6H 5T6

Dear Ms. Ziober:

BENEFIT/COST ANALYSIS OF FLOOD MITIGATION PROJECTS FOR THE CITY OF CALGARY: SPRINGBANK OFF-STREAM FLOOD STORAGE

Enclosed please find the draft final report for the aforementioned assignment. The report describes the benefit/cost analysis undertaken for the Springbank Off-Stream 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 Springbank Off-Stream Flood Storage Project ranks first.

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

Yours truly,

IBI GROUP

Stephen Shawcross
Director

Augusto Ribeiro, P.Eng.

SS/mp

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

J:\36910_PrvnFldDmgSt\10.0 Reports\10.5 Text\Benefit Cost Reports\Springbank\PTL-Ziober-GovofAB-BenefitCost-Springbank_2015-02-18.docx\2015-02-18\MP

IBI Group is a group of firms providing professional services and is affiliated with IBI Group Architects Engineers

Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary: Springbank Off-Stream Flood Storage

Submitted to Government of Alberta
ESRD - Resilience and Mitigation
by IBI Group

February 2015

Study Team Members

IBI Group

Stephen Shawcross

Augusto Ribeiro

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David Sol

Melinda Tracey

Michele Penn

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Michael Valenzuela

Golder Associates Ltd.

Wolf Ploeger

Carmen Walker

Table of Contents

Executive Summary

Key Metrics

Project Costs

Item	Cost
Project Construction	$159,768,000
Upstream Mitigation	$8,900,000
Land Acquisition	$40,000,000
Total 1:100 Year Protection	**$208,668,000**
Additional Cost for 1:200 Year Protection	$55,000,000
Total 1:200 Year Protection	**$263,668,000**
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)	$255,098,000	$309,607,000	$255,098,000	$309,607,000
Benefit/Cost Ratio	1.87	2.07	1.32	1.32
Net Present Value	$221,801,000	$330,336,000	$81,749,000	$99,294,000
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 in Springbank.

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 Springbank Off-Stream 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.

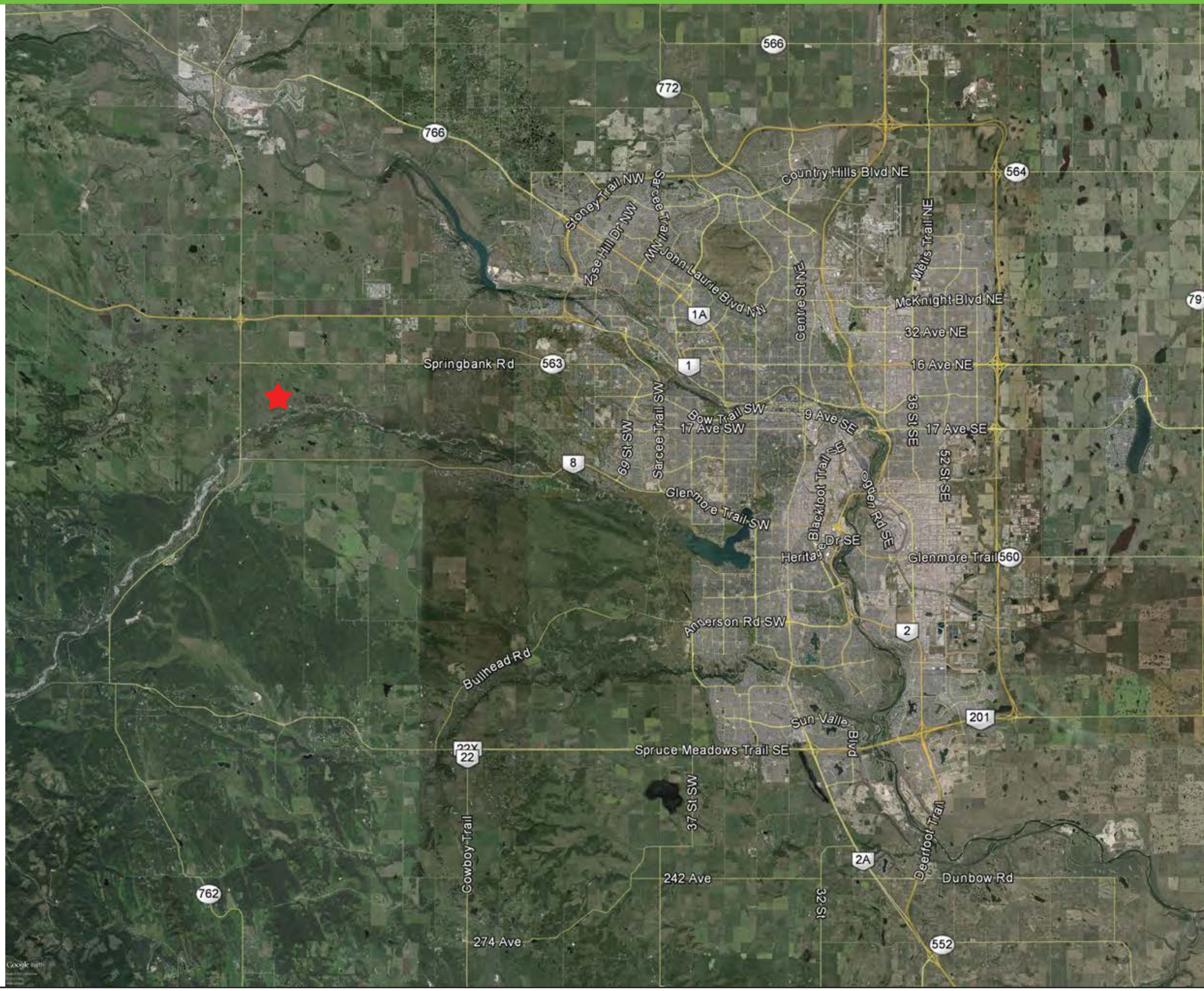
1.3 Scope

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 Springbank Off-Stream 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 off-stream storage project.

Regional Setting



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Alberta Government

Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary: Conceptual Design of the Springbank Off-Stream Flood Storage Site

February 2015

EXHIBIT 2.1

Local Setting

Alberta Government

Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary: Conceptual Design of the Springbank Off-Stream Flood Storage Site

February 2015

EXHIBIT 2.2

3 Project Description

The project consists of three basic components:

1. a river diversion structure;
2. a diversion channel and reservoir inlet structure; and
3. an off-stream storage dam and reservoir.

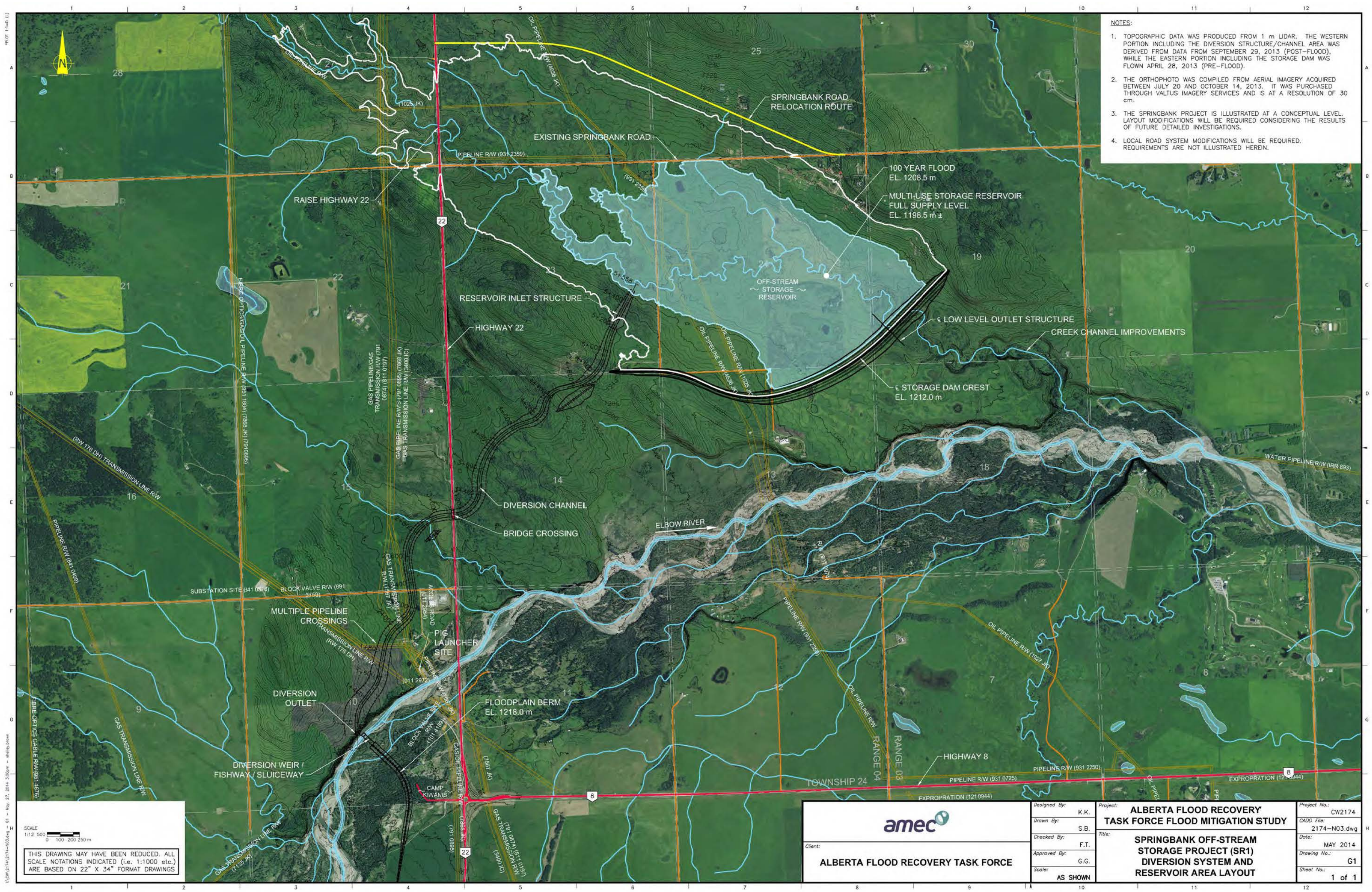
The diversion structure system would consist of a concrete overflow weir section crossing the Elbow River, a gated concrete sluiceway/fishway located adjacent to the left side valley abutment with its invert at the river thalweg level, and a gated diversion outlet structure located in the left valley abutment immediately upstream of the sluiceway. A conceptual design layout for the diversion structure system is provided in **Exhibit 3.1**. Additional structure details are provided in **Exhibit 3.2**, **Exhibit 3.3** and **Exhibit 3.4**.

The proposed diversion channel profile and a typical channel section are illustrated in **Exhibit 3.5**. 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 is designed with a 24 m bottom width, three horizontal to one vertical side slopes and a 3.6 m water depth.

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 **Exhibit 3.6**. 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 dam system will include a gated low-level outlet structure. The 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 centreline as illustrated in **Exhibit 3.7**. 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.

Springbank Off-Stream Storage Project (SR1) Diversion System and Reservoir Area Layout



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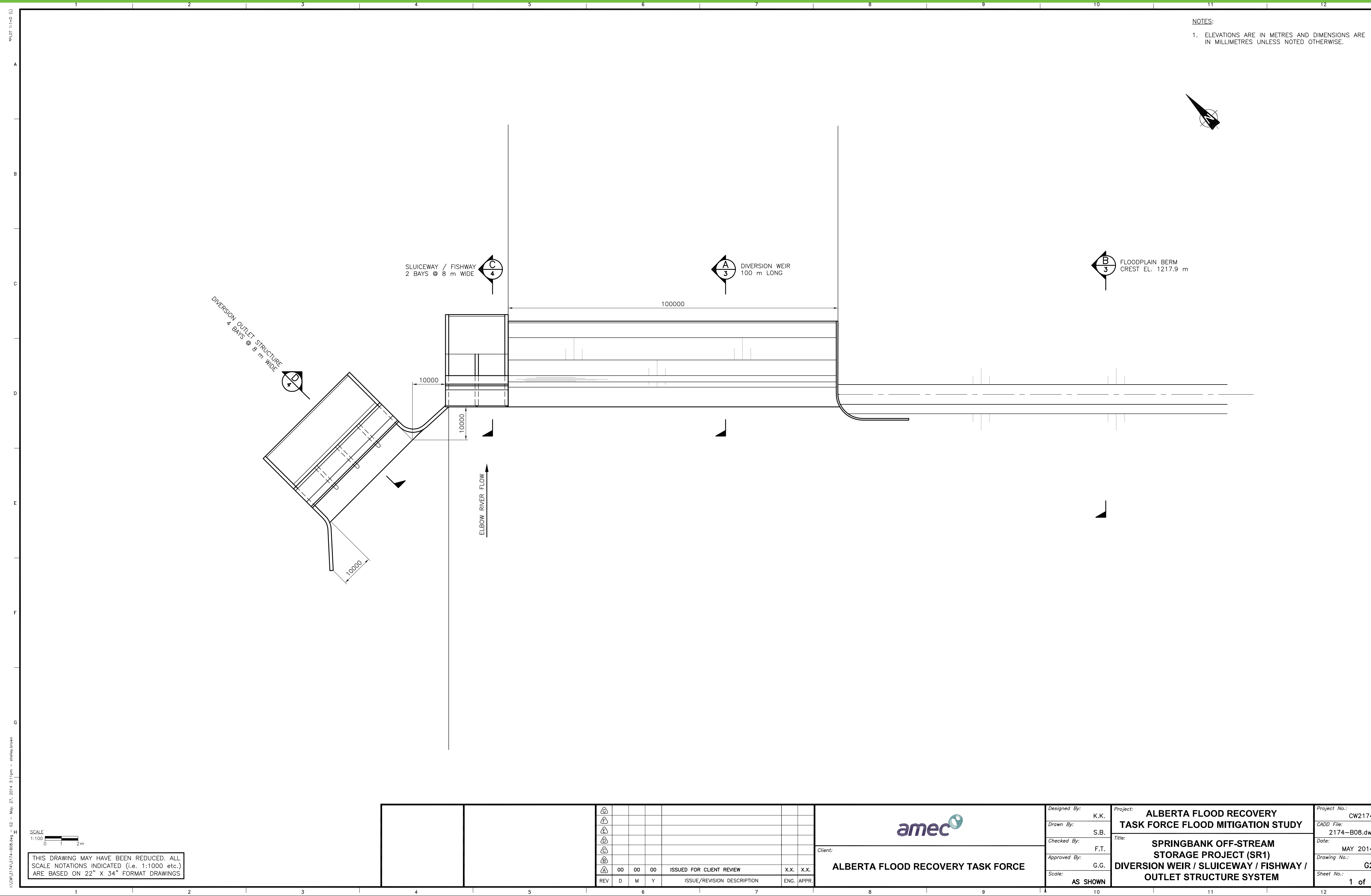
Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary: Conceptual Design of the Springbank Off-Stream Flood Storage Site

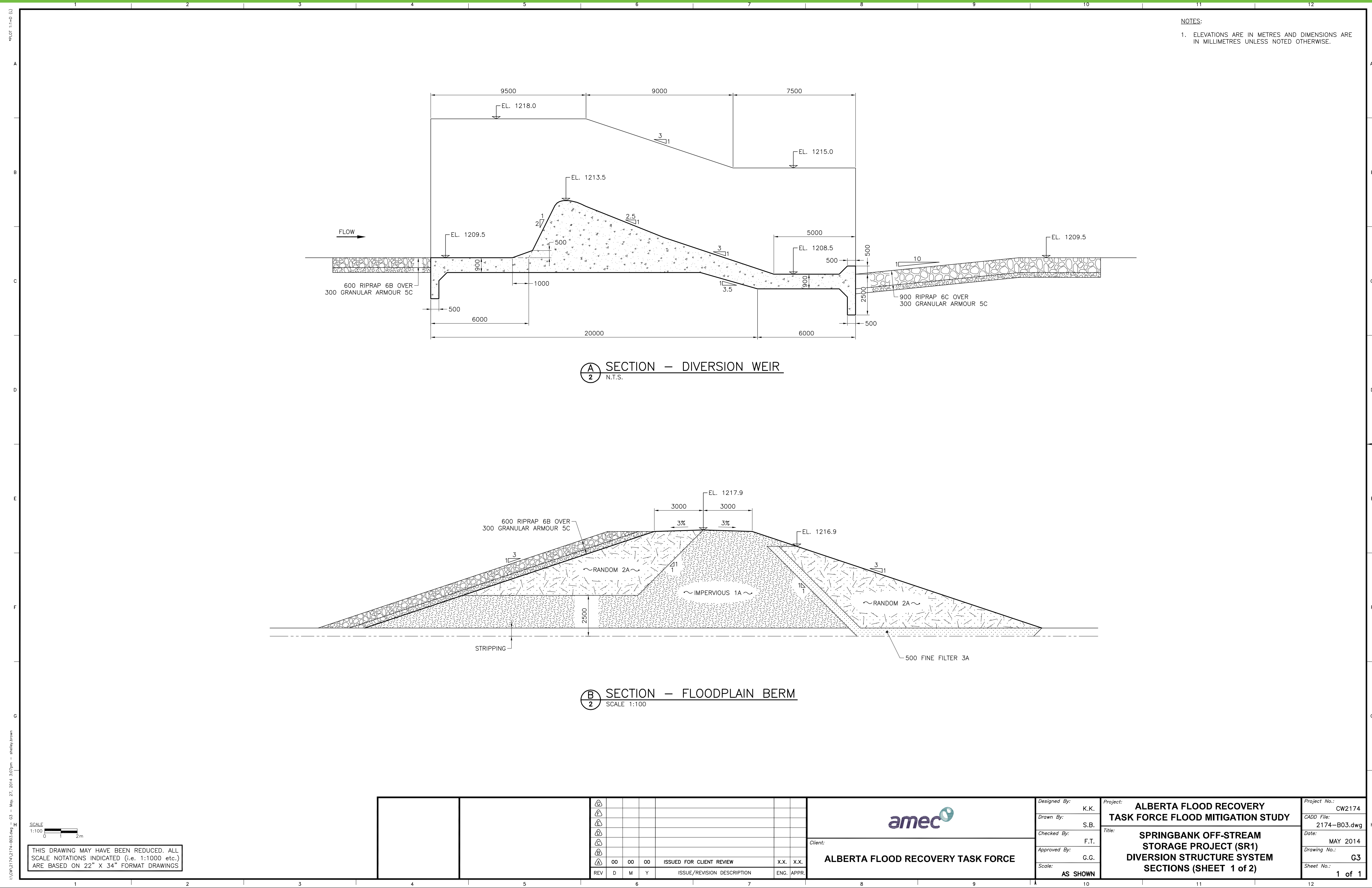
February 2015

EXHIBIT 3.1

Details - Springbank Off-Stream Storage Project (SR1) Diversion Weir / Sluiceway / Fishway / Outlet Structure System

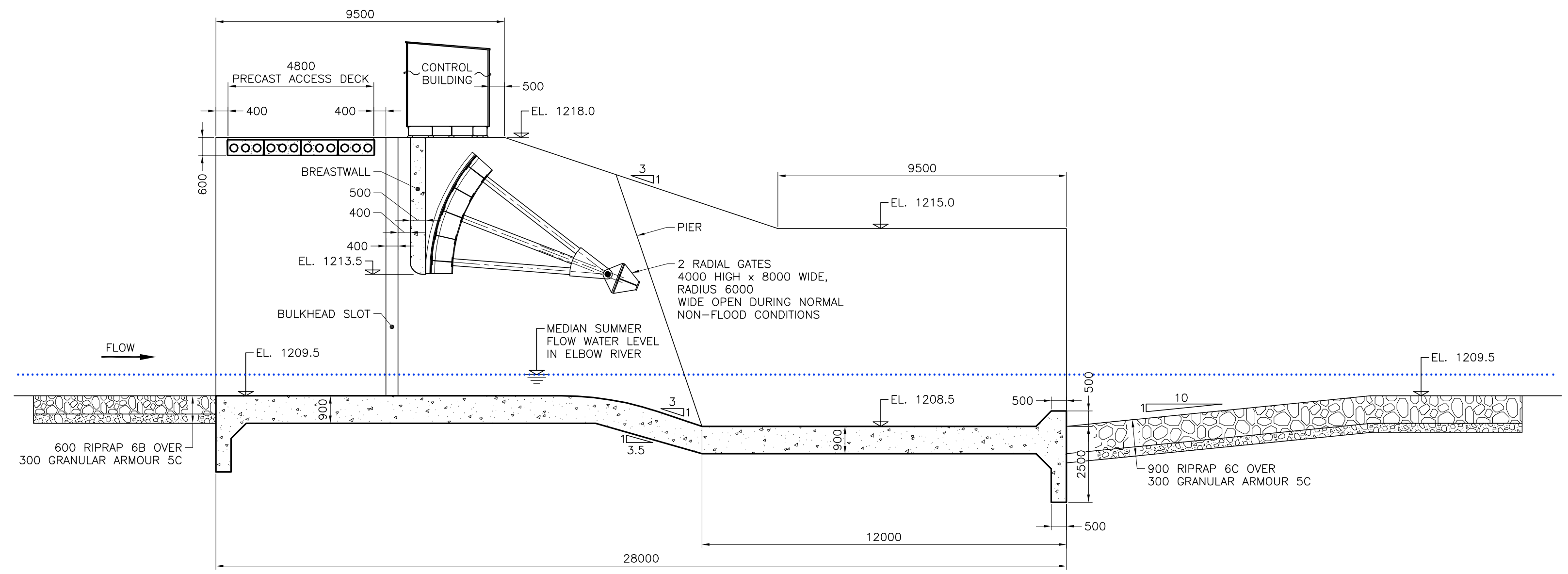


Details - Springbank Off-Stream Storage Project (SR1) Diversion Structure System Sections (Sheet 1 of 2)



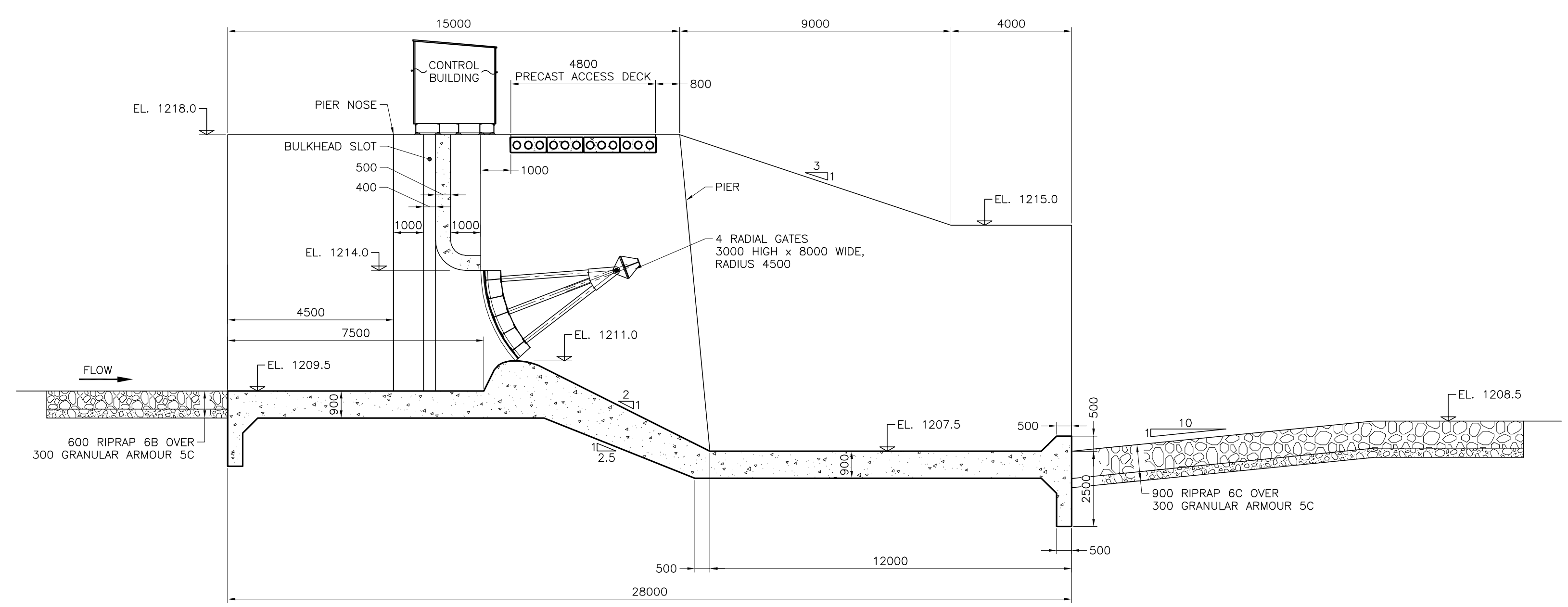
NOTES:

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 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.
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

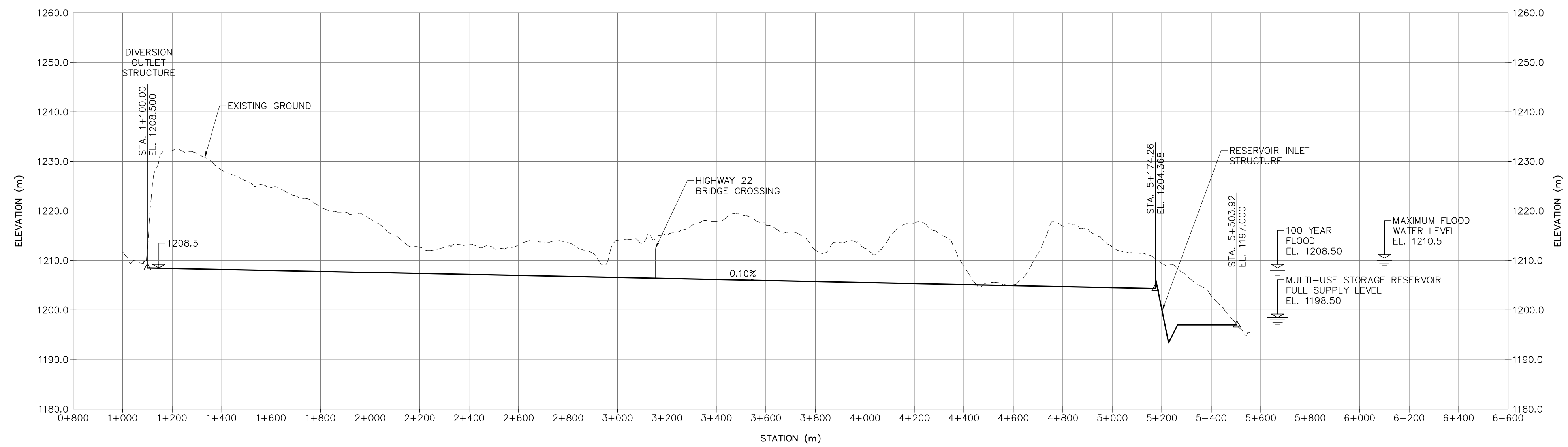
Title: SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) DIVERSION STRUCTURE SYSTEM SECTIONS (SHEET 2 of 2)

Project No.:	CW2174
CADD File:	2174–B05.dwg
Date:	MAY 2014
Drawing No.:	G4
Sheet No.:	1 of 1

Details - Springbank Off-Stream Storage Project (SR1) Diversion Channel

NOTES:

1. ELEVATIONS ARE IN METRES AND DIMENSIONS ARE IN MILLIMETRES UNLESS NOTED OTHERWISE.



DIVERSION CHANNEL PROFILE

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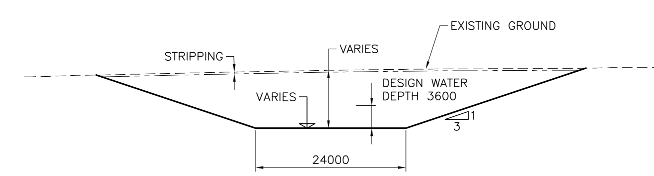
VER. 1:500



DIVERSION CHANNEL TYPICAL CROSS SECTION

SCALE 1:500

SCALES 1:10 000 0 100 200m; 1:500 0 5 10m

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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: 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

Details - Springbank Off-Stream Storage Project (SR1) Off-Stream Storage Dam & Low Level Outlet

NOTES:

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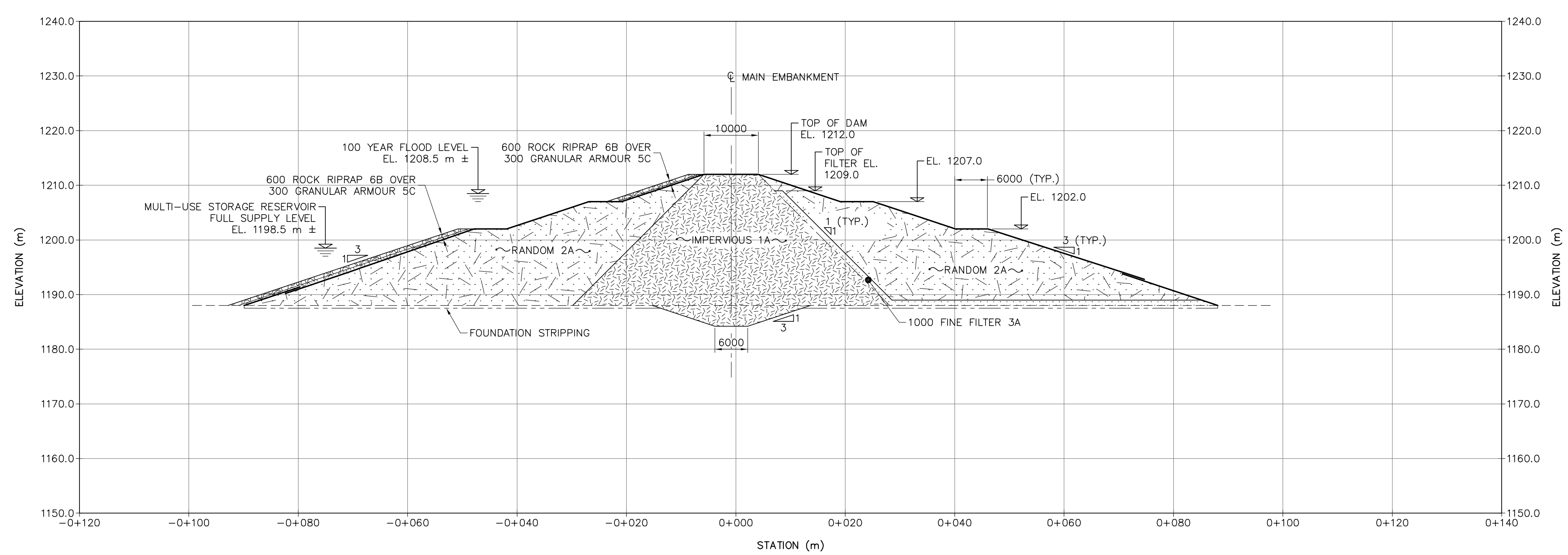
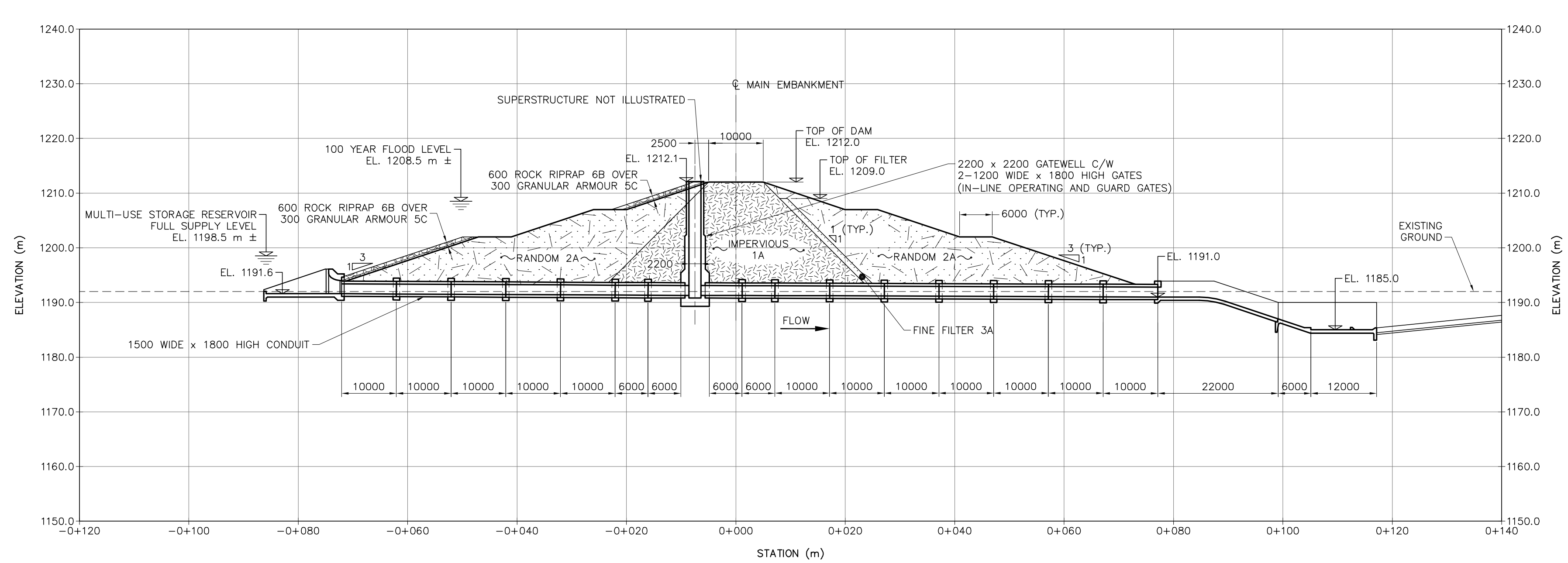


OFF-STREAM STORAGE DAM

SCALE 1:500



LOW LEVEL OUTLET STRUCTURE

SCALE 1:500

SCALE 1:500

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.
	00	00	00	ISSUED FOR CLIENT REVIEW	X.X.	X.X.

amec

Client: ALBERTA FLOOD RECOVERY TASK FORCE

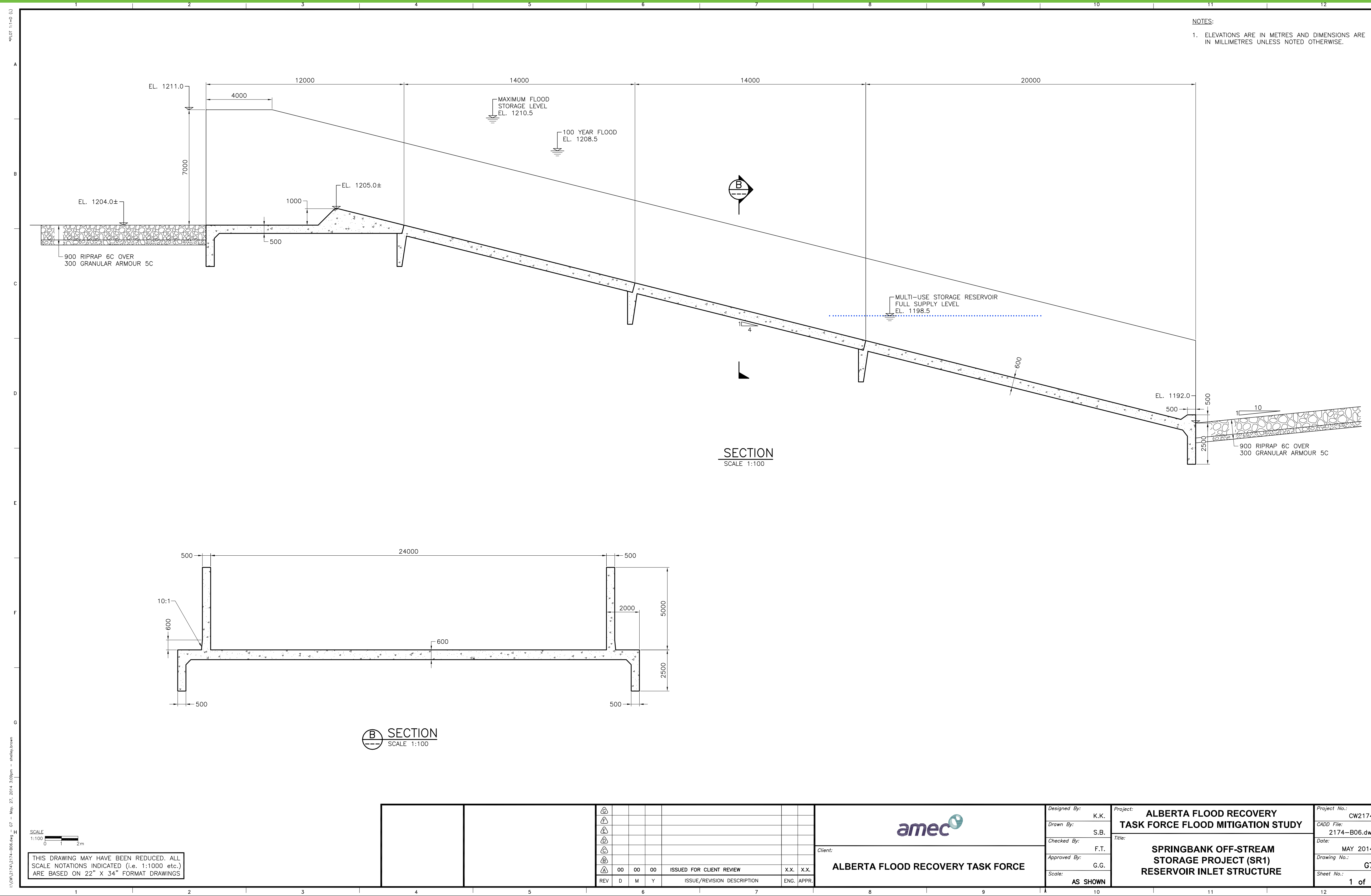
Designed By: K.K.
Drawn By: S.B.
Checked By: F.T.
Approved By: G.G.
Scale: AS SHOWN

Project: ALBERTA FLOOD RECOVERY TASK FORCE FLOOD MITIGATION STUDY

Title: SPRINGBANK OFF-STREAM STORAGE PROJECT (SR1) 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

Details - Springbank Off-Stream Storage Project (SR1) Reservoir Inlet Structure



4 Cost Estimate

A detailed cost estimate is provided in **Exhibit 4.1A/B**[1]. The project cost is estimated to be $159,768,000. This price does not include the cost of land acquisition. 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.

4.1 Land Acquisition

Land requirements were based on the conceptual design footprint including the diversion, storage reservoir to contain a 1:100 year event, and dam, and equated to some ±1,760 acres.[2] Currently, this land is under cultivation or pasture. In terms of planning status, the land is currently designated Ranch and Farm District (RF) according to the Rocky View County Land Use Bylaw. The purpose and intent of this land use designation is to “provide for agricultural activities as the primary land use on a quarter section of land or on a large balance of lands from a previous subdivision” (Rocky View County Land Use Bylaw, 1998).

There are no Area Structure Plans in place for the area and according to the County’s Growth Management Strategy, the area has not been recognized as a location for future growth (see **Appendix A**).

To establish potential land acquisition costs, 2014 MLS sales transactions for raw land and country residential style lots within the Springbank area (see **Exhibit 4.2**) were analyzed along with data from country residential developments including Watermark, Silverhorn and Harmony (see **Appendix B**). In addition, real estate brokers were solicited for opinions on potential land values in the general area.

Typical agricultural land values vary considerably depending upon soil quality, crop potential, etc. and vary from $4,000 to $8,000/acre. Larger transactions of farmland (±120 acres) have ranged between $6,000 and $9,000/acre within the general area. Using the upper bound of say $10,000/acre, would equate to a land acquisition cost of $17.6 million.

Developable land values are considerably higher with larger land assemblies (±120 acres) ranging from between $22,000 and $105,000/acre and averaging $50,000/acre.

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1 AMEC Environmental & Infrastructure, *Southern Alberta Flood Recovery Task Force, Volume 4 – Flood Mitigation Measures, Appendix G – Springbank Off-Stream Storage Project*, May 2014.

2 Actual land requirements will vary based on the detailed design of the facility which is currently underway.

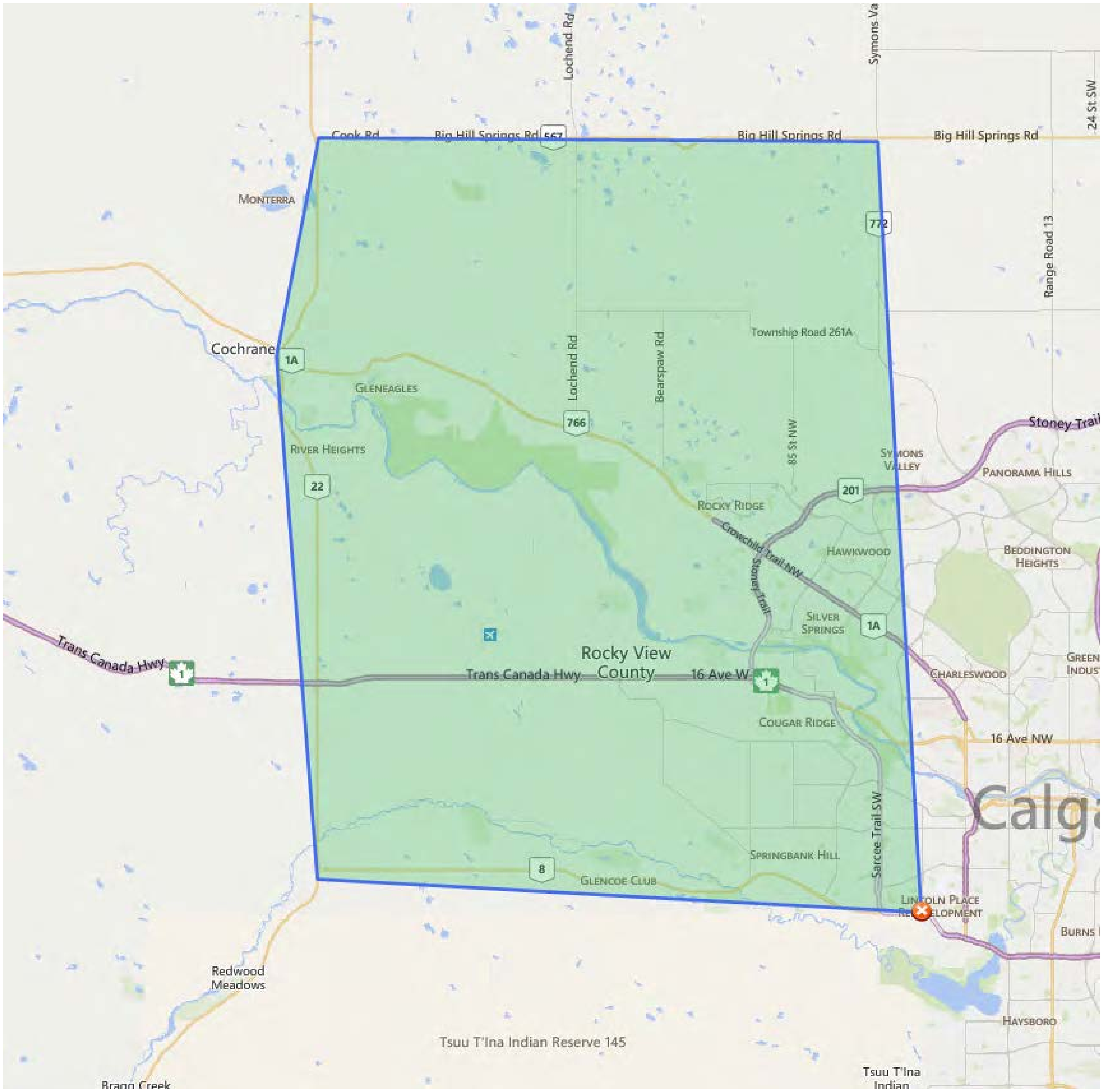
Off-Stream Storage Project (SR1) Cost Estimate (1 of 2)

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**

Item	Unit	Quantity	Unit Price	Extension
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**

Market Area Considered



Individual country residential lots sold within the market area range from $107,000 to $378,000/acre and average $193,000/acre. The latter reflects developed land value with the final sales prices reflecting the cost of raw land, servicing (roads, sanitary, storm and water), sales commissions, marketing, legal and developer profit.

The community of Harmony, located within the market area some 2 to 3 km to the north, is a 1,748 acre master-planned community, featuring a 140 acre lake, golf course, village centre and mixed residential community (see **Appendix C**). Assuming approvals were obtained for a similar type of development on the site in question, with an acquisition price of $50,000/acre, total land acquisition under these assumptions would equate to $88 million; however, given the size of the acquisition it is likely that this value would be discounted to reflect the anticipated absorption over a long timeframe. At a discount rate of 4% and a projected 20 year life expectancy for the development, the acquisition cost would be $40.163 million in 2014$.

If the current land owners choose to develop rather than sell the land to a third party developer, then the value of the ultimate project (depending upon a large number of factors) could be worth considerably more than the land value as stated.

In summary, land acquisition costs range from a low of $17.6 million to a high of $40.1 million, depending upon the precise circumstances surrounding the negotiation and ultimate acquisition. For the purposes of this study the higher value, $40 million, is proposed for use in the benefit/cost analysis.

4.2 Flood Defences at Bragg Creek

The flood mitigation measures study for the Bow, Elbow and Old Man River basins recommended flood defences at Bragg Creek if flood protection infrastructure for the City of Calgary was located downstream of Bragg Creek. Protection of the Hamlet via dykes was proposed with a further recommendation that if a decision was made to proceed with SR1 as the preferred flood storage scheme for the Elbow River, then the detailed design and planning for the dykes of Bragg Creek should be initiated as soon as possible.[3] Costs for the dyke system were estimated at $6.2 million (see **Appendix D**).

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 E**. 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.

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[3] AMEC Environmental & Infrastructure, *Southern Alberta Flood Recovery Task Force, Flood Mitigation Measures for the Bow, Elbow and Oldman River Basins, Volume 1 – Summary Recommendations Report – Final,* June 2014.

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.

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 upstream of the Springbank Off-Stream Flood Storage project including Bragg Creek, Redwood Meadows and infrastructure within Rocky View County which would not be protected by the proposed Springbank Off-Stream Flood Storage 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 1987[4].

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 F**.

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 upstream of the Springbank Offstream Flood Storage project. Notwithstanding, in order to account for the other damages, and therefore additional costs that will be incurred by the SR1 project over the MC1 project, an additional $8.9 million in total costs are proposed to be added to the SR1 project.

5.2 With Mitigation Alternative

Implementation of the Springbank Off-Stream 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

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[4] *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 Springbank Off-Stream Flood Storage scenario to account for required mitigation measures upstream.
- 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

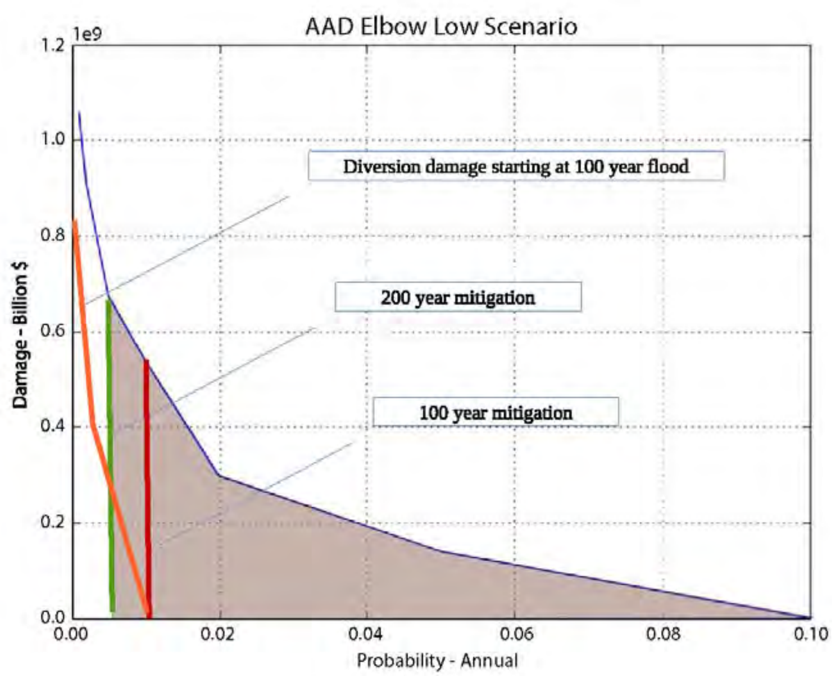
With respect to the Glenmore Reservoir Diversion it was possible to calculate the reduced damages that would be achieved as a result of the 500 and 700 CMS diversion. The incremental flow was passed downstream and damages based on the reduced flood flow were computed to determine the net benefits. Consequently, 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 of the Springbank Off-Stream 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 $255 million in costs, rendering a positive benefit/cost ratio of 1.87.

At the 1:200 year level of protection, the benefit/cost ratio increases to 2.07, an economically viable project with a very attractive benefit/cost ratio.

For the low damage scenario the 1:100 year present value of benefits is $337 million versus costs of $255 million, rendering a benefit/cost ratio of 1.32.

With the 1:200 year level of protection the benefit/cost ratio remains at 1.32, once again an economically viable project with a positive benefit/cost ratio.

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)	$255,098,000	$309,607,000	$255,098,000	$309,607,000
Benefit/Cost Ratio	1.87	2.07	1.32	1.32
Net Present Value	$221,801,000	$330,336,000	$81,749,000	$99,294,000
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

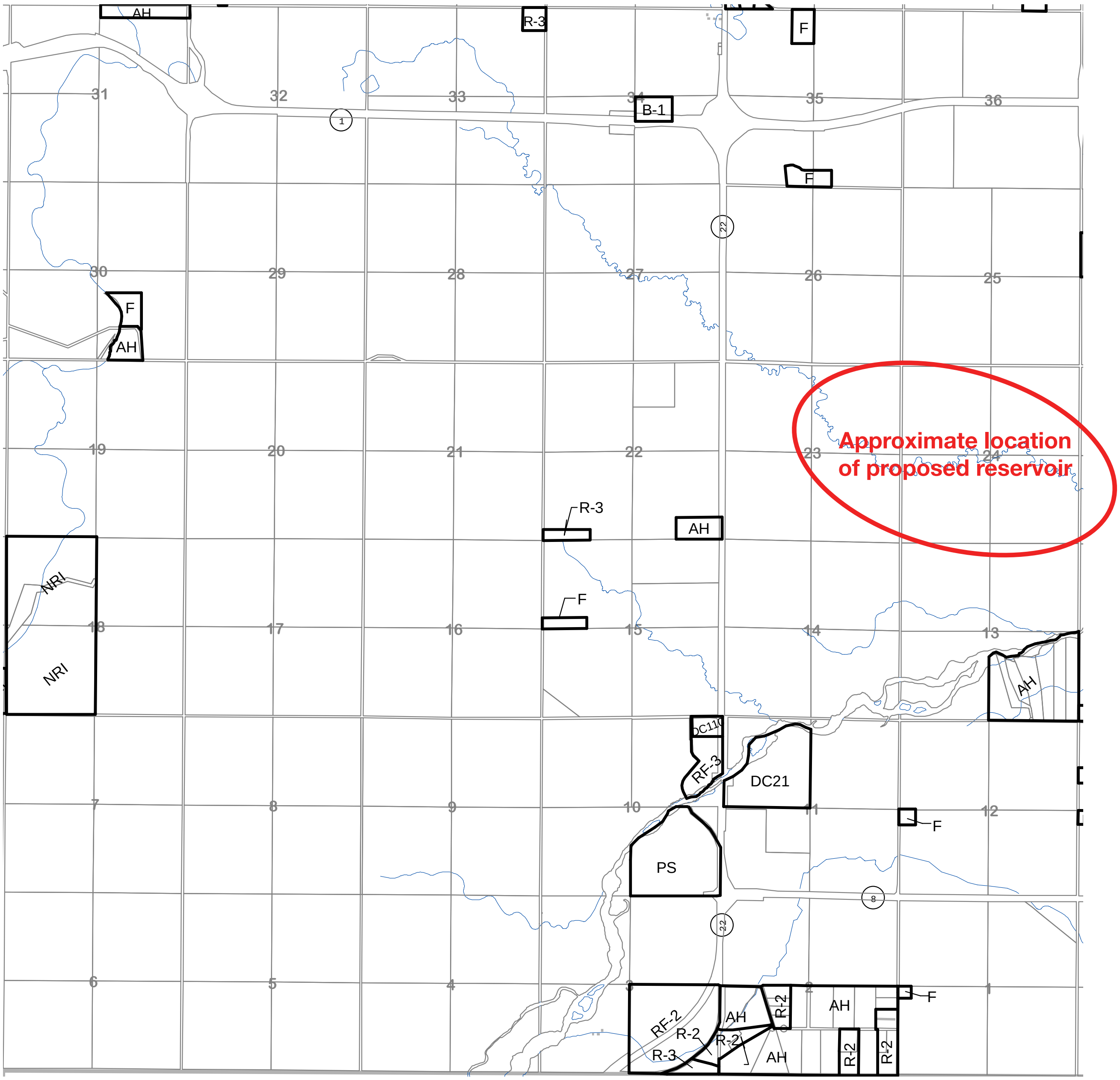
Mitigation Project	High Damage Scenario		Low Damage Scenario	
	1:100 Year Protection	1:200 Year Protection	1:100 Year Protection	1:200 Year Protection
SR1	1.87	2.07	1.32	1.32
MC1	1.43	1.65	1.01	1.05
Glenmore	1.21	1.20	0.81	0.83

The Springbank Off-Stream Flood Storage project achieves a positive benefit/cost ratio under all four scenarios and ranks first ahead of the other two mitigation projects with significantly higher benefit/cost ratios.[5]

[5] Refer to IBI Group Reports: *Benefit/Cost Analysis of Flood Mitigation Projects for the City of Calgary: McLean Creek Flood Storage (February 2015)* and *Benefit/Cost Analysis of Flood Mitigation Projects for the City of Calgary: Glenmore Reservoir Diversion (February 2015).*

Appendix A – Entitlement Status of Lands for Off-Stream Storage Project

Municipal District of Rocky View #44 - Land Use Map No. 48



ALL LANDS ARE DESIGNATED RF UNLESS NOTED OTHERWISE

RANCH AND FARM DISTRICT	RF
SEE EXCEPTIONS LISTED WITH THIS DISTRICT	RF *
RANCH AND FARM TWO DISTRICT	RF-2
RANCH AND FARM THREE DISTRICT	RF-3
AGRICULTURAL HOLDING DISTRICT	AH
FARMSTEAD DISTRICT	F
RESIDENTIAL ONE DISTRICT	R-1
RESIDENTIAL TWO DISTRICT	R-2
RESIDENTIAL THREE DISTRICT	R-3
HIGHWAY BUSINESS DISTRICT	B-1
GENERAL BUSINESS DISTRICT	B-2
LIMITED BUSINESS DISTRICT	B-3
RECREATION BUSINESS DISTRICT	B-4
AGRICULTURAL BUSINESS DISTRICT	B-5
LOCAL BUSINESS DISTRICT	B-6
HIGHWAY FRONTAGE BUSINESS DISTRICT	B-HF
BUSINESS CAMPUS BUSINESS DISTRICT	B-BC
INDUSTRIAL CAMPUS BUSINESS DISTRICT	B-IC

RECREATION DESTINATION BUSINESS DISTRICT	B-RD
LEISURE AND RECREATION BUSINESS DISTRICT	B-LR
AGRICULTURAL SERVICES BUSINESS DISTRICT	B-AS
POINT COMMERCIAL DISTRICT	C-PT
VILLAGE CENTRE COMMERCIAL DISTRICT	C-VC
LOCAL COMMERCIAL DISTRICT	C-LC
REGIONAL COMMERCIAL DISTRICT	C-RC
INDUSTRIAL ACTIVITY DISTRICT	I-IA
STORAGE AND SALES INDUSTRIAL DISTRICT	I-SS
NATURAL RESOURCE INDUSTRIAL DISTRICT	NRI
HAMLET RESIDENTIAL SINGLE FAMILY DISTRICT	HR-1
HAMLET RESIDENTIAL (2) DISTRICT	HR-2
HAMLET COMMERCIAL DISTRICT	HC
HAMLET INDUSTRIAL DISTRICT	HI
PUBLIC SERVICES DISTRICT	PS
AIRPORT DISTRICT	AP
DIRECT CONTROL DISTRICT	DC

N

MUNICIPAL DISTRICT OF ROCKY VIEW #44

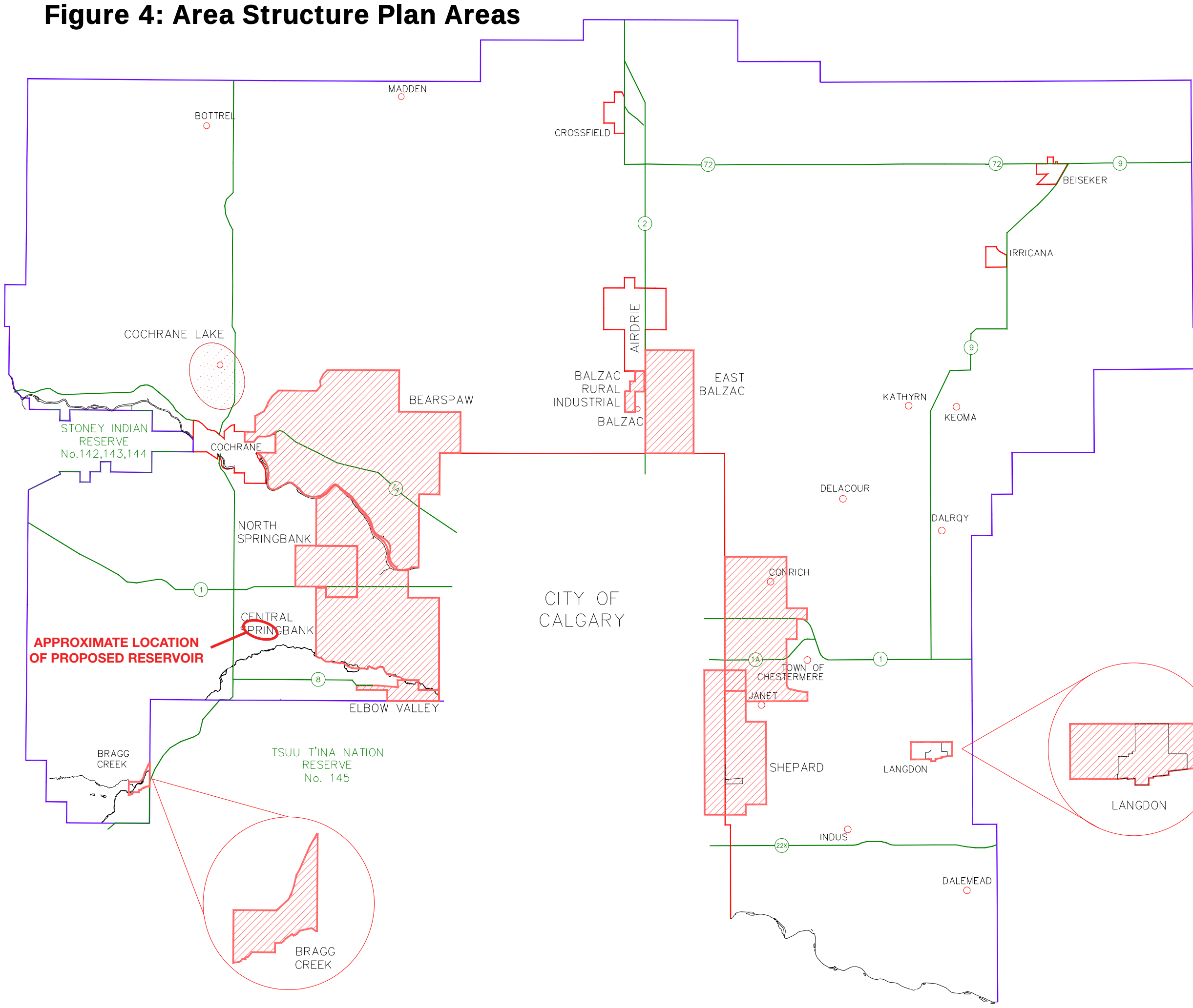
TWP. 24-4-W5M

LAND USE MAP No. 48

Part FIVE of the BYLAW No. C-4841-97

DATE: Mar 02, 2009

Figure 4: Area Structure Plan Areas



MUNICIPAL DISTRICT OF ROCKY VIEW No.44

SUGGESTED AND APPROVED AREA STRUCTURE PLANS

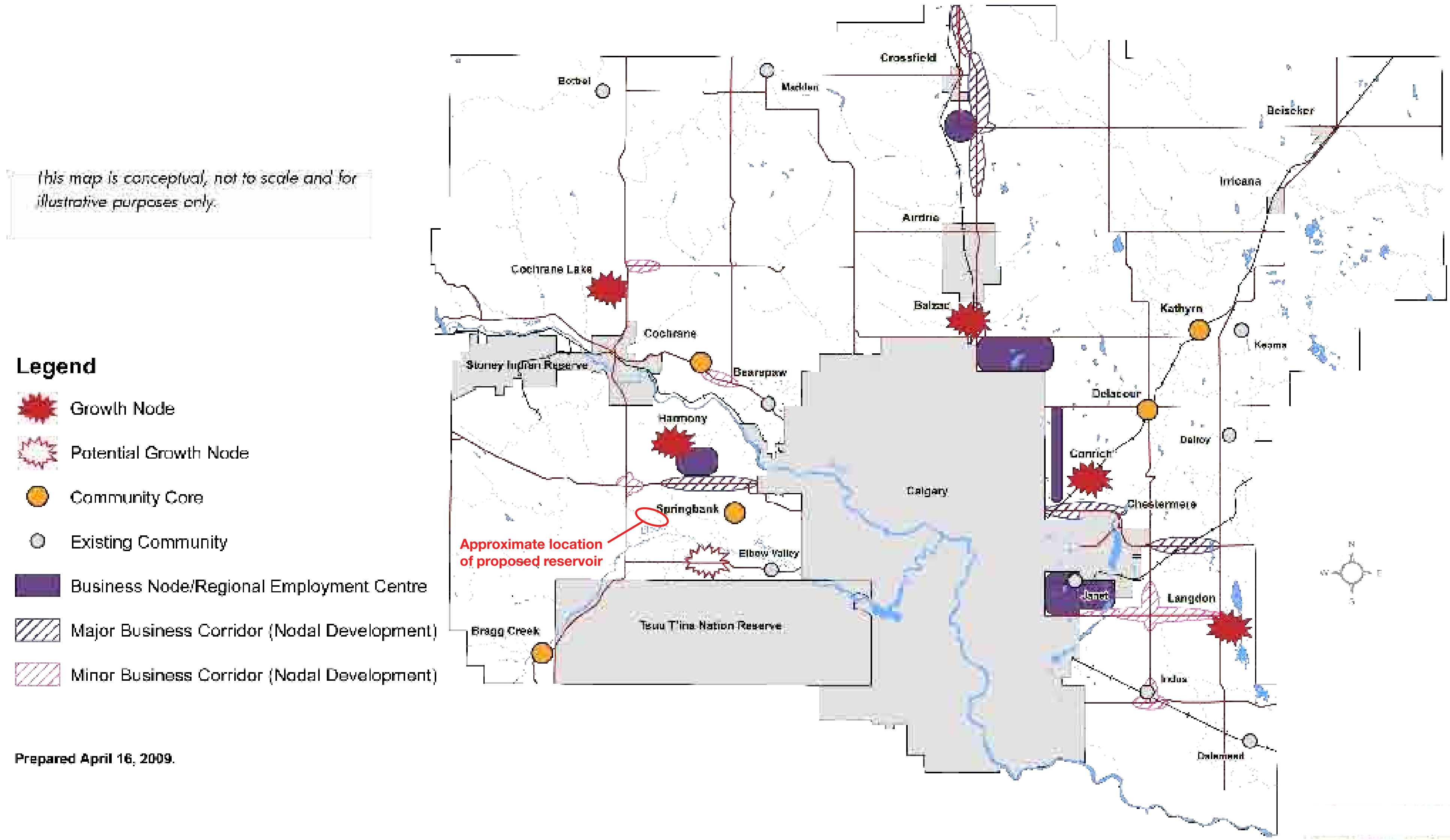
N

AREA STRUCTURE PLANS (EXISTING OR BEING PREPARED)

AREAS UNDER DEVELOPMENT PRESSURE

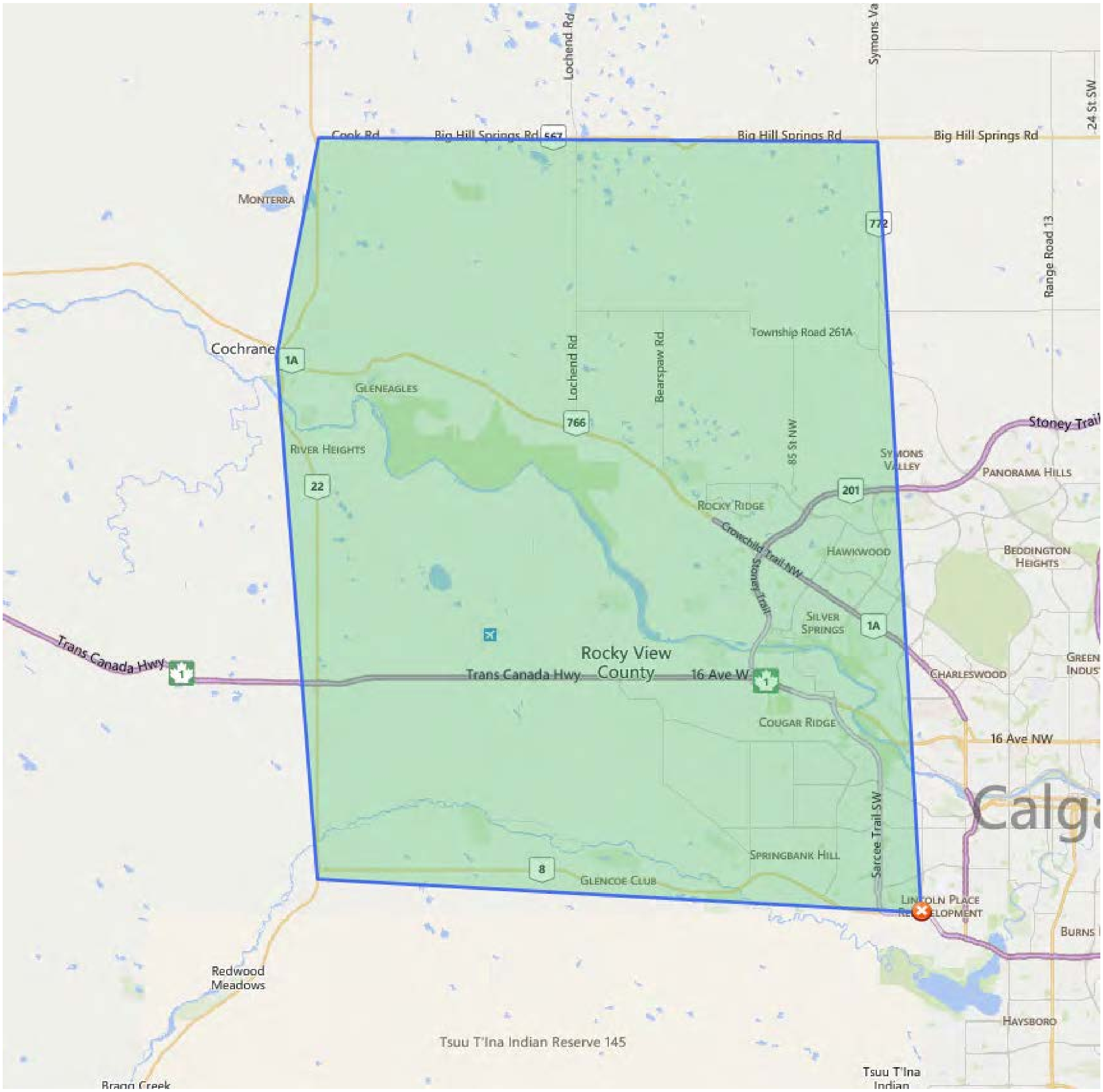
January 2003

Municipal District of Rocky View #44 - Growth Management Strategy Map



Appendix B – Springbank Area MLS Sales and Listing Data for 2014

Market Area Considered



Rocky View West Listing

Sta	ML Number	Address	List Price	Sold Price	Community Desc	List Date	Off Market Dat	Total Ac	Days c	Condo Name	Condo Type	Number of Parcels	Cummu	County	List Price / Acre	Sold Price / Acre	Postal Code
A	C3553126	227 CHURCH RANCHES WY NW	$ 719,000.00		Church Ranches	06/02/2013		3.43	650				800	ALBERTA	$ 209,620.99		T3R 1B2
A	C3586217	242258 Windhorse WY	$ 410,000.00		Springbank	19/09/2013		2.05	425				425	ALBERTA	$ 200,000.00		T3Z 0B4
A	C3586227	35 WINDHORSE GR	$ 435,000.00		Springbank	19/09/2013		2.03	425				425	ALBERTA	$ 214,285.71		T3Z 0B4
A	C3599739	Lochend RD NW	$ 8,000,000.00		Bearspaw_Calg	10/02/2014		158.85	281				281	ALBERTA	$ 50,361.98		T3L 2R2
A	C3604034	Highway # 22 North of Cochrane	$ 1,500,000.00		Cochrane Lake	10/03/2014		53.55	253				253	ALBERTA	$ 28,011.20		T4C 1A9
A	C3605546	124 WILLOW CREEK SU	$ 472,500.00		Bearspaw_Calg	21/03/2014		2.02	242				242	ALBERTA	$ 233,910.89		T3R 0K3
A	C3606704	116 GRIZZLY RI	$ 450,000.00		Bearspaw Country Estates	28/03/2014		4.05	235	Z-name Not Listed			235	ALBERTA	$ 111,111.11		T3Z 1H5
A	C3617284	67 CHEYANNE MEADOWS WAY	$ 699,000.00		Church Ranches	23/05/2014		2.34	179				179	ALBERTA	$ 298,717.95		T3R 1B6
A	C3629847	262 Lochend Road	$ 3,969,000.00		None	06/08/2014		157.56	104				104	ALBERTA	$ 25,190.40		T4C 0X0
A	C3631166	251095 WELLAND WY	$ 595,000.00		Bearspaw_Calg	14/08/2014		4.42	96	Z-name Not Listed			277	ALBERTA	$ 134,615.39		T3R 1L3
A	C3631295	41216 Camden Lane	$ 550,000.00		None	12/08/2014		3.95	98				98	ALBERTA	$ 139,240.51		T4C 1B1
A	C3629151	50 BLAZER ESTATES RG	$ 1,100,000.00		Bearspaw_Calg	01/08/2014		8.08	109				109	ALBERTA	$ 136,138.61		T3L 2N7
A	C3641919	116 BEARSPAW MEADOWS	$ 799,999.00		Lynx Ridge	23/10/2014		2.72	26				26	ALBERTA	$ 294,117.28		T3L 2M3
A	C3583465	108 AVENTERRA	$ 359,000.00		Springbank	30/08/2013		2.03	445				445	ALBERTA	$ 176,847.29		T3J 5J4
A	C3640329	31239 TWP RD 252	$ 675,000.00		Springbank	17/10/2014		4	32				32	ALBERTA	$ 168,750.00		T3Z 1E8
A	C3639338	24333 Meadow DR	$ 499,900.00		Bearspaw_Calg	08/10/2014		2	41				41	ALBERTA	$ 249,950.00		T3R 1G3
A	C3621718	10 BEARSPAW VALLEY PLACE	$ 499,900.00		Bearspaw_Calg	16/06/2014		1.96	155				155	ALBERTA	$ 255,051.02		T3G 3G3
A	C3642556	118 WINDHORSE CO	$ 384,900.00		Springbank	03/11/2014		2.05	15				303	ALBERTA	$ 187,756.10		T3Z 0B4
A	C3621729	18 BEARSPAW VALLEY PLACE	$ 499,900.00		Bearspaw_Calg	16/06/2014		1.93	155				155	ALBERTA	$ 259,015.54		T2E 2E2
A	C3575040	242244 WINDHORSE	$ 410,000.00		Springbank	27/06/2013		2.02	509				509	ALBERTA	$ 202,970.30		T3Z 0B4
A	C3637861	6 GLENDALE ESTATES MR	$ 459,000.00		Bearspaw_Calg	29/09/2014		1.98	50				212	ALBERTA	$ 231,818.18		T4C 1A2
A	C3613051	123 BROWN BEAR	$ 399,000.00		Bearspaw Country Estates	02/05/2014		2.08	200				200	ALBERTA	$ 191,826.92		T4C 0B5
A	C3629825	43 Big Hill Springs CV	$ 570,000.00		Bearspaw_Calg	06/08/2014		4.86	104				104	ALBERTA	$ 117,283.95		T4C 1A2
A	C3637529	22 GLENDALE ESTATES MR	$ 389,000.00		Bearspaw_Calg	25/09/2014		2	54	Z-name Not Listed			54	ALBERTA	$ 194,500.00		T3R 1G3
A	C3614265	31060 SWIFT CREEK	$ 494,900.00		Springbank	08/05/2014		2.08	194				194	ALBERTA	$ 237,932.69		T3Z 0B7
A	C3586173	31040 WINDHORSE DR	$ 460,000.00		Springbank	19/09/2013		2.03	425				425	ALBERTA	$ 226,600.99		T3Z 0B4
A	C3586195	12 WINDHORSE BA	$ 460,000.00		Springbank	19/09/2013		2	425				425	ALBERTA	$ 230,000.00		T3Z 0B4
A	C3586198	16 WINDHORSE BA	$ 410,000.00		Springbank	19/09/2013		2	425				425	ALBERTA	$ 205,000.00		T3Z 0B4
A	C3586221	43 WINDHORSE GR	$ 485,000.00		Springbank	19/09/2013		2	425				425	ALBERTA	$ 242,500.00		T3Z 0B4
A	C3586237	242162 WINDHORSE WY	$ 510,000.00		Springbank	19/09/2013		2	425				425	ALBERTA	$ 255,000.00		T3Z 0B4
A	C3586224	39 WINDHORSE GR	$ 485,000.00		Springbank	19/09/2013		2.05	425				425	ALBERTA	$ 236,585.37		T3Z 0B4
A	C3586243	242176 WINDHORSE WY	$ 435,000.00		Springbank	19/09/2013		2.01	425				425	ALBERTA	$ 216,417.91		T3Z 0B4
A	C3586234	242150 WINDHORSE WY	$ 510,000.00		Springbank	19/09/2013		2.02	425				425	ALBERTA	$ 252,475.25		T3Z 0B4
A	C3617248	31156 Township Road 251A	$ 749,800.00		Springbank	23/05/2014		10.63	179	Z-name Not Listed			179	ALBERTA	$ 70,536.22		T3Z 1E6
A	C3602240	21 SWIFT CREEK GR.	$ 588,000.00		Springbank	26/02/2014		2	265				265	ALBERTA	$ 294,000.00		T2Z 0B6
A	C3561891		$ 13,500,000.00		None	05/04/2013		121.37	592				1257	ALBERTA	$ 111,230.12		T3Z 2E4
A	C3633051	37 Westbluff PL	$ 2,450,000.00		Springbank	27/08/2014		10.01	83				83	ALBERTA	$ 244,755.25		T3Z 3P2
A	C3621724	14 BEARSPAW VALLEY PLACE	$ 499,900.00		Bearspaw_Calg	16/06/2014		1.95	155				155	ALBERTA	$ 256,358.97		T2E 2E2
A	C3595058	2 BEARSPAW VALLEY	$ 499,000.00		Bearspaw_Calg	29/12/2013		1.97	324				844	ALBERTA	$ 253,299.49		T3R 1A3
A	C3638507		$ 2,000,000.00		Glendale Meadows	02/10/2014		25.32	47				47	ALBERTA	$ 78,988.94		T4C 2G4
A	C3632325	35195 Springbank RD	$ 8,960,000.00		Springbank	22/08/2014		320	88				436	ALBERTA	$ 28,000.00		T3Z 3H3
A	C3603978	25151 ESCARPMENT RIDGE VW	$ 900,000.00		None	10/03/2014		2.31	253				253	ALBERTA	$ 389,610.39		T3Z 3M7
A	C3618112	Lochend RD	$ 3,080,000.00		Bearspaw_Calg	26/05/2014		138.97	176				176	ALBERTA	$ 22,163.06		T3L 2R2
A	C3593709		$ 3,950,000.00		Springbank	30/11/2013		73.95	353				353	ALBERTA	$ 53,414.47		A0A 0A0
A	C3593826	11 Rolling Range PL	$ 429,000.00		Rolling Range Est	29/11/2013		3.98	354				354	ALBERTA	$ 107,788.95		T4C 1A1
A	C3618530	19 MCKENDRICK PT	$ 684,900.00		Springland Estates	26/05/2014		2.3	176				208	ALBERTA	$ 297,782.61		T3Z 3K1
A	C3639339	24345 Meadow DR	$ 459,000.00		Bearspaw_Calg	08/10/2014		2	41				41	ALBERTA	$ 229,500.00		T3R 1G3
A	C3639342	24349 Meadow DR	$ 449,000.00		Bearspaw_Calg	08/10/2014		2	41				41	ALBERTA	$ 224,500.00		T3R 1G3
A	C3629788	45 BEARSPAW SUMMIT PL	$ 375,000.00		Bearspaw_Calg	06/08/2014		1.98	104				104	ALBERTA	$ 189,393.94		T3A 1G4
A	C3629992	40 Rolling Range DR	$ 3,600,000.00		None	03/08/2014		19.88	107				107	ALBERTA	$ 181,086.52		T4C 2A3
A	C3594983	Bearspaw 160 acres NW of Calgary	$ 1,900,000.00		None	24/12/2013		160	329				601	ALBERTA	$ 11,875.00		T3R 1C4
A	C3629125	251208 RGE RD 32	$ 864,000.00		Springbank	30/07/2014		12.31	111				111	ALBERTA	$ 70,186.84		T3Z 0X0
A	C3586216	31100 WINDHORSE DR	$ 410,000.00		Springbank	19/09/2013		2	425				425	ALBERTA	$ 205,000.00		T3Z 0B4
A	C3586180	4 WINDHORSE BA	$ 435,000.00		Springbank	19/09/2013		2.32	425				425	ALBERTA	$ 187,500.00		T3Z 0B4
A	C3586189	8 WINDHORSE BA	$ 460,000.00		Springbank	19/09/2013		2	425				425	ALBERTA	$ 230,000.00		T3Z 0B4

Rocky View West Listing

Sta	ML Number	Address	List Price	Sold Price	Community Desc	List Date	Off Market Dat	Total Ac	Days c	Condo Name	Condo Type	Number of Parcels	Cummu	County	List Price / Acre	Sold Price / Acre	Postal Code
A	C3586233	114 WINDHORSE CO	$ 460,000.00		Springbank	19/09/2013		2	425				425	ALBERTA	$ 230,000.00		T3Z 0B4
A	C3586239	242168 WINDHORSE WY	$ 460,000.00		Springbank	19/09/2013		2.01	425				425	ALBERTA	$ 228,855.72		T3Z 0B4
A	C3633344	30 GLENDALE ESTATES MR	$ 389,000.00		Bearspaw_Calg	28/08/2014		1.98	82				1015	ALBERTA	$ 196,464.65		T3R 1G3
A	C3629801	35 Big Hill Springs CV	$ 540,000.00		Bearspaw_Calg	06/08/2014		4.6	104				104	ALBERTA	$ 117,391.30		T4C 1A4
A	C3640579	24 GRANDVIEW PL	$ 525,000.00		Springbank	19/10/2014		1.98	30				30	ALBERTA	$ 265,151.52		T3Z 0A7
A	C3616382	24 Villosa Ridge PT	$ 389,000.00		None	20/05/2014		2.04	182				182	ALBERTA	$ 190,686.28		T3Z 1H2
A	C3637865	10 GLENDALE ESTATES MR	$ 499,000.00		Bearspaw_Calg	29/09/2014		2	50				1545	ALBERTA	$ 249,500.00		T3R 1G3
A	C3639734	5 MOUNTAIN GLEN	$ 425,000.00		None	12/10/2014		4	37				37	ALBERTA	$ 106,250.00		T4C 0G6
A	C3621144	34080 GLENDALE Road - TWP RD 260	$ 7,559,000.00		None	07/06/2014		134.5	164				164	ALBERTA	$ 56,200.74		T0L 0W0
A	C3627556	243081 Morning Vista WY	$ 405,000.00		None	21/07/2014		1.98	120				120	ALBERTA	$ 204,545.46		T3Z 0B2
X	C3574569	31119 GRANDARCHES DR	$ 735,000.00		Springbank	22/06/2013	15/11/2014	2.04	511				511	ALBERTA	$ 360,294.12		T3Z 0B6
X	C3627952	Glenbow RD	$ 398,500.00		None	24/07/2014	15/11/2014	3.7	114				114	ALBERTA	$ 107,702.70		T4C 2G4
X	C3626603	260084 GLENBOW	$ 1,498,850.00		None	14/07/2014	15/11/2014	22.6	124				124	ALBERTA	$ 66,320.80		T4C 2G4
X	C3545385		$ 555,450.00		Springbank	06/11/2012	06/11/2014	2.91	730	Z-name Not Listed			730	ALBERTA	$ 190,876.29		T3Z 3K1
X	C3634076		$ 499,900.00		None	02/09/2014	05/11/2014	4.3	64				64	ALBERTA	$ 116,255.81		T1T 1T1
X	C3625542	118 WINDHORSE CO	$ 395,000.00		Springbank	08/07/2014	31/10/2014	2.05	115				290	ALBERTA	$ 192,682.93		T3Z 0B4
X	C3587680	251092 WELLAND	$ 585,000.00		Bearspaw_Calg	27/09/2013	31/10/2014	4.25	399				399	ALBERTA	$ 137,647.06		T3R 1L3
S	C3586252	242230 WINDHORSE WY	$ 435,000.00	$ 388,000.00	Springbank	19/09/2013	28/10/2014	2.03	404				404	ALBERTA	$ 214,285.71	$ 191,133.01	T3Z 0B4
S	C3590964	Springbank Heights DR	$ 545,000.00	$ 535,000.00	Springbank	30/10/2013	27/10/2014	4.1	362				359	ALBERTA	$ 132,926.83	$ 130,487.81	T3Z 1C4
T	C3597033	120 GRANDVIEW WY	$ 499,900.00		Springbank	20/01/2014	07/10/2014	2.04	260				260	ALBERTA	$ 245,049.02		T3Z 0A8
X	C3613618	31038 SWIFT CREEK	$ 455,000.00		Springbank	06/05/2014	06/10/2014	2.04	153				153	ALBERTA	$ 223,039.22		T3Z 0B7
X	C3625066	25 SWIFT CREEK GR	$ 479,000.00		Springbank	05/07/2014	05/10/2014	2.01	92				92	ALBERTA	$ 238,308.46		T3Z 0B6
X	C3618522	24190 MEADOW	$ 529,000.00		Bearspaw Acres	29/05/2014	30/09/2014	2.2	124				124	ALBERTA	$ 240,454.55		T3R 1A8
X	C3588538	30032 LOWER SPRINGBANK RD	$ 539,900.00		Springbank	07/10/2013	30/09/2014	2.08	358				358	ALBERTA	$ 259,567.31		T3Z 3K7
X	C3606041	15 CORRAL VIEW	$ 510,000.00		Springbank	24/03/2014	28/09/2014	2.32	188				188	ALBERTA	$ 219,827.59		T3A 2B7
X	C3595970	10 GLENDALE ESTATES MR	$ 499,000.00		Bearspaw_Calg	10/01/2014	26/09/2014	2	259				1495	ALBERTA	$ 249,500.00		T3R 1G3
S	C3625546	242255 WINDHORSE WY	$ 394,900.00	$ 320,000.00	Springbank	08/07/2014	13/09/2014	2.93	67				242	ALBERTA	$ 134,778.16	$ 109,215.02	T3Z 0B4
S	C3586246	242190 WINDHORSE WY	$ 435,000.00	$ 391,500.00	Springbank	19/09/2013	12/09/2014	2	358				358	ALBERTA	$ 217,500.00	$ 195,750.00	T3Z 0B4
S	C3586248	242208 WINDHORSE WY	$ 410,000.00	$ 369,000.00	Springbank	19/09/2013	12/09/2014	2.02	358				358	ALBERTA	$ 202,970.30	$ 182,673.27	T3Z 0B4
S	E3361283	25006 TWP RD 264A	$ 1,500,000.00	$ 1,375,000.00	None	29/01/2014	09/09/2014	151.5	223				222	ALBERTA	$ 9,900.99	$ 9,075.91	T3R 1J6
S	E3361286	25006 TWP RD 264A	$ 1,300,000.00	$ 1,175,000.00	None	29/01/2014	09/09/2014	137.19	223				222	ALBERTA	$ 9,475.91	$ 8,564.76	T3R 1J6
S	E3361284	25006 TWP RD 264A	$ 1,300,000.00	$ 1,175,000.00	None	29/01/2014	09/09/2014	162.99	223				222	ALBERTA	$ 7,975.95	$ 7,209.03	T3R 1J6
S	E3361285	25006 TWP RD 264A	$ 1,300,000.00	$ 1,175,000.00	None	29/01/2014	09/09/2014	172.75	223				222	ALBERTA	$ 7,525.33	$ 6,801.74	T3R 1J6
X	C3623835	Bearspaw RD	$ 1,400,000.00		Bearspaw_Calg	27/06/2014	08/09/2014	20.02	73				73	ALBERTA	$ 69,930.07		T3R 1C4
X	C3623843	Bearspaw RD	$ 2,000,000.00		Bearspaw_Calg	27/06/2014	08/09/2014	20.02	73				73	ALBERTA	$ 99,900.10		T3R 1C4
X	C3598205	224 BROWN BEAR	$ 409,900.00		Bearspaw Country Estates	29/01/2014	31/08/2014	2.01	214	Z-name Not Listed			214	ALBERTA	$ 203,930.35		T4C 0B5
X	C3605262	Symons Valley Road	$ 2,595,000.00		None	15/03/2014	31/08/2014	103	169			1	169	ALBERTA	$ 25,194.18		T4B 2A3
X	C3613691	29 SWIFT CREEK GR	$ 425,000.00		Springbank	06/05/2014	31/08/2014	2	117	Z-name Not Listed			117	ALBERTA	$ 212,500.00		T3Z 0B7
X	C3617357	244230 OLD BANFF COACH	$ 1,288,888.00		Springbank	24/05/2014	30/08/2014	7.05	98				98	ALBERTA	$ 182,820.99		T2H 0K2
X	C3595707	30 GLENDALE ESTATES MR	$ 388,900.00		Bearspaw_Calg	08/01/2014	26/08/2014	1.98	230				934	ALBERTA	$ 196,414.14		T3R 1G3
X	C3616404	35195 Springbank RD	$ 8,960,000.00		Springbank	20/05/2014	20/08/2014	320	92				348	ALBERTA	$ 28,000.00		T3Z 3H3
S	C3621941	32050 KODIAK SPRINGS RD RD	$ 460,000.00	$ 425,000.00	Bearspaw_Calg	16/06/2014	15/08/2014	2.02	60	Z-name Not Listed			60	ALBERTA	$ 227,722.77	$ 210,396.04	T4C 1X2
X	C3602054	12 Cody Range WY	$ 529,900.00		Bearspaw_Calg	26/02/2014	01/08/2014	2.2	156				338	ALBERTA	$ 240,863.64		T3R 1C1
X	C3608525	31120 GRANDARCHES	$ 469,900.00		Springbank	08/04/2014	31/07/2014	2.03	114				114	ALBERTA	$ 231,477.83		T3Z 0C3
X	C3584175	243020 MORNING VISTA WY	$ 399,000.00		Springbank	05/09/2013	31/07/2014	2	329	Z-name Not Listed			329	ALBERTA	$ 199,500.00		T3Z 0B2
X	C3598421	251095 WELLAND WY	$ 639,000.00		Bearspaw_Calg	31/01/2014	31/07/2014	4.42	181	Z-name Not Listed			181	ALBERTA	$ 144,570.14		T3R 1L3
S	C3586219	242211 WINDHORSE WY	$ 410,000.00	$ 390,500.00	Springbank	19/09/2013	25/07/2014	2.04	309				309	ALBERTA	$ 200,980.39	$ 191,421.57	T3Z 0B4
S	C3597208	63 ROLLING ACRES PL	$ 1,050,000.00	$ 1,000,000.00	Bearspaw Acres	19/01/2014	18/07/2014	19.91	180				209	ALBERTA	$ 52,737.32	$ 50,226.02	T3R 1B8
S	C3623094	214 PARTRIDGE BAY	$ 369,900.00	$ 355,000.00	Partridge Heights	23/06/2014	17/07/2014	2	24	Z-name Not Listed			187	ALBERTA	$ 184,950.00	$ 177,500.00	T3Z 2B9
X	C3596752	232 BROWN BEAR PT	$ 399,500.00		Bearspaw_Calg	17/01/2014	17/07/2014	2.01	181				181	ALBERTA	$ 198,756.22		T3R 1G3
S	C3612237	185 SPRINGBANK HEIGHTS	$ 435,000.00	$ 410,000.00	Springbank	29/04/2014	09/07/2014	2.42	71				71	ALBERTA	$ 179,752.07	$ 169,421.49	T3Z 1C4
X	C3584193	243039 MORNING VISTA WY	$ 349,000.00		Springbank	05/09/2013	06/07/2014	1.98	304				304	ALBERTA	$ 176,262.63		T2Z 0B2
S	C3605365	30 WOODLAND GL	$ 398,700.00	$ 390,000.00	Bearspaw_Calg	20/03/2014	02/07/2014	1.98	102			1	102	ALBERTA	$ 201,363.64	$ 196,969.70	T3R 1G4
X	C3595607	118 WINDHORSE CO	$ 425,000.00		Springbank	07/01/2014	02/07/2014	2.05	176				175	ALBERTA	$ 207,317.07		T3Z 0B4
X	C3595610	242255 WINDHORSE WY	$ 399,900.00		Springbank	07/01/2014	02/07/2014	2.93	176				175	ALBERTA	$ 136,484.64		T3Z 0B4

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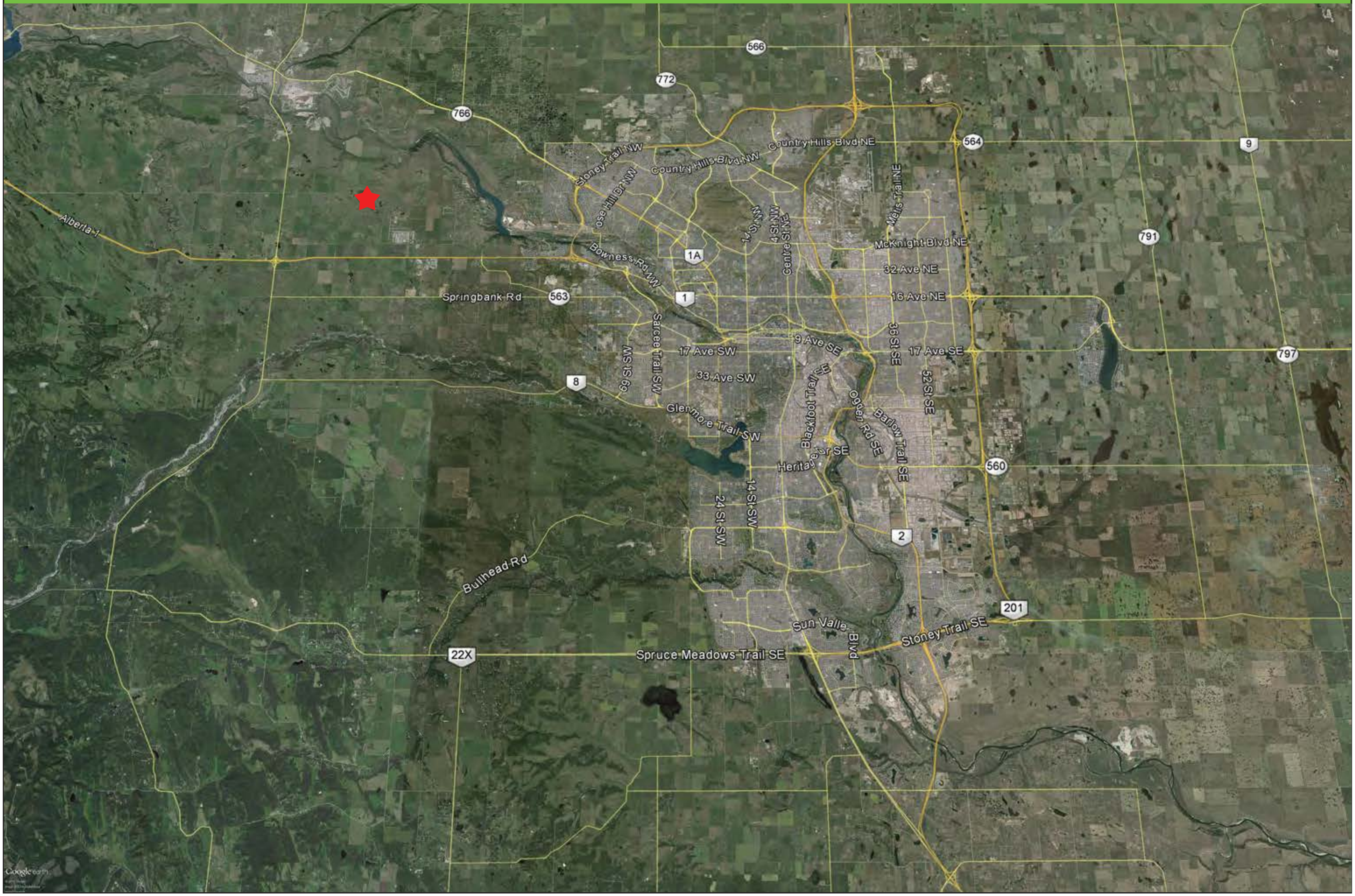
X	C3560024	# Lot 3 25205 Bearspaw PL	$ 474,900.00		Bearspaw_Calg	26/03/2013	01/07/2014	1.98	462				462	ALBERTA	$ 239,848.49		T3R 1H5
X	C3560021	# Lot 1 25205 BEARSPAW	$ 474,900.00		Bearspaw_Calg	26/03/2013	01/07/2014	1.98	462				462	ALBERTA	$ 239,848.49		T3R 1H5
X	C3607552	43 Big Hill Springs CV	$ 535,000.00		Big Hill Springs Est	02/04/2014	30/06/2014	4.86	89				89	ALBERTA	$ 110,082.31		T4C 1A2
X	C3595854	37 EMERALD BAY DR	$ 950,000.00		Springbank Links	09/01/2014	30/06/2014	2.05	172				172	ALBERTA	$ 463,414.63		T3Z 1E3
S	C3608674	31108 SWIFT CREEK TC	$ 499,800.00	$ 470,000.00	Springbank	09/04/2014	25/06/2014	2.06	77	Z-name Not Listed			77	ALBERTA	$ 242,621.36	$ 228,155.34	T3Z 0B7
S	C3620912	206 GRIZZLY	$ 350,000.00	$ 343,000.00	Bearspaw Country Estates	11/06/2014	24/06/2014	2.01	13				13	ALBERTA	$ 174,129.35	$ 170,646.77	T3L 2M7
S	C3585708		$ 319,900.00	$ 305,000.00	Springbank	16/09/2013	24/06/2014	2.84	281				281	ALBERTA	$ 112,640.85	$ 107,394.37	T3Z 2P8
S	C3595505	34 GLENDALE ESTATES MR	$ 399,000.00	$ 380,000.00	Bearspaw_Calg	06/01/2014	19/06/2014	1.98	164				1403	ALBERTA	$ 201,515.15	$ 191,919.19	T3R 1G3
X	C3608310	24039 Burma RD	$ 895,000.00		Bearspaw_Calg	07/04/2014	13/06/2014	15.81	67	Z-name Not Listed			126	ALBERTA	$ 56,609.74		T3R 1E3
S	C3608128	59 Big Hill Spings CV	$ 460,000.00	$ 460,000.00	Big Hill Springs Est	05/04/2014	11/06/2014	4.01	67				67	ALBERTA	$ 114,713.22	$ 114,713.22	T4C 1A2
X	C3595774	244119 PARTRIDGE	$ 470,000.00		Springbank	08/01/2014	08/06/2014	2	151				151	ALBERTA	$ 235,000.00		T3P 0R3
X	C3582915	244119 PARTRIDGE	$ 549,000.00		Springbank	26/08/2013	08/06/2014	2	286				286	ALBERTA	$ 274,500.00		T2P 0R3
X	C3594825	214 PARTRIDGE BA	$ 389,900.00		Partridge Heights	20/12/2013	01/06/2014	2	163	Z-name Not Listed			163	ALBERTA	$ 194,950.00		T3Z 2B9
X	C3584161	213 MORGANS WY	$ 429,000.00		Springbank	05/09/2013	31/05/2014	2	268	Z-name Not Listed			268	ALBERTA	$ 214,500.00		T3Z 0B9
X	C3568110	24 GRANDVIEW PLACE	$ 550,000.00		Springbank	14/05/2013	31/05/2014	1.98	382				382	ALBERTA	$ 277,777.78		T3Z 0A7
X	C3584203	206 MORNING VISTA VW	$ 479,000.00		Springbank	05/09/2013	31/05/2014	2	268				268	ALBERTA	$ 239,500.00		T3Z 0B2
S	C3605791	242091 RGE RD 32	$ 2,195,000.00	$ 2,195,000.00	Springbank	21/03/2014	27/05/2014	20	67				67	ALBERTA	$ 109,750.00	$ 109,750.00	T1X 0K1
S	C3589267	26 ELBOW RIVER RD	$ 549,000.00	$ 500,000.00	Elbow River Estates	15/10/2013	23/05/2014	4.08	220				435	ALBERTA	$ 134,558.82	$ 122,549.02	T3Z 2V2
S	C3575046	3 WINDHORSE	$ 435,000.00	$ 410,000.00	Springbank	27/06/2013	22/05/2014	2	329				329	ALBERTA	$ 217,500.00	$ 205,000.00	T3Z 0B4
X	C3600987	35195 Springbank Road	$ 8,960,000.00		Springbank	15/02/2014	18/05/2014	320	92				256	ALBERTA	$ 28,000.00		T3Z 3H3
S	C3596619	11 KODIAK SPRINGS CV	$ 435,000.00	$ 435,000.00	Bearspaw Country Estates	14/01/2014	17/05/2014	2	123				123	ALBERTA	$ 217,500.00	$ 217,500.00	T4C 0B5
S	C3613969	HAGGARD ROAD	$ 2,299,000.00	$ 2,100,000.00	Springbank	07/05/2014	16/05/2014	34.35	9				9	ALBERTA	$ 66,928.68	$ 61,135.37	T3Z 3P3
X	C3599346	31099 SWIFT CREEK	$ 749,000.00		Springbank	06/02/2014	14/05/2014	2	97				97	ALBERTA	$ 374,500.00		T3A 0J7
S	C3607356	24166 Old Banff Coach RD SW	$ 930,000.00	$ 825,000.00	NONE	01/04/2014	11/05/2014	6.61	39				39	ALBERTA	$ 140,695.92	$ 124,810.89	T3Z 3N4
S	C3586211	24 WINDHORSE BA	$ 410,000.00	$ 370,000.00	Springbank	19/09/2013	09/05/2014	2.06	232				232	ALBERTA	$ 199,029.13	$ 179,611.65	T3Z 0B4
S	C3581797	5 SWIFT CREEK GR	$ 499,800.00	$ 462,000.00	Springbank	15/08/2013	05/05/2014	2.01	263				263	ALBERTA	$ 248,656.72	$ 229,850.75	T3Z 0B6
S	C3607424		$ 1,500,000.00	$ 1,500,000.00	Bearspaw_Calg	01/04/2014	05/05/2014	73.11	34				34	ALBERTA	$ 20,517.03	$ 20,517.03	T4C 1A7
S	C3610858	116 Swift Creek CV SW	$ 459,900.00	$ 430,000.00	Springbank	22/04/2014	02/05/2014	2.07	10				826	ALBERTA	$ 222,173.91	$ 207,729.47	T3Z 0B6
S	C3603531	76 Eagle Butte Ranch	$ 549,000.00	$ 485,000.00	Springbank	06/03/2014	01/05/2014	2.03	56				126	ALBERTA	$ 270,443.35	$ 238,916.26	T3Z 1K3
S	C3541963	13 Country Meadows PL	$ 435,950.00	$ 430,000.00	Springbank	01/10/2012	30/04/2014	1.98	576				576	ALBERTA	$ 220,176.77	$ 217,171.72	T3Z 0C3
S	C3594713	251100 WELLAND WY	$ 680,000.00	$ 635,000.00	Bearspaw_Calg	18/12/2013	30/04/2014	4.84	133				629	ALBERTA	$ 140,495.87	$ 131,198.35	T3R 1L3
X	C3574240	8 Mountain Glen Close	$ 409,000.00		None	20/06/2013	30/04/2014	2	314				314	ALBERTA	$ 204,500.00		T0L 0W0
X	C3578466	21 Silverhorn VA	$ 625,000.00		None	23/07/2013	30/04/2014	1.98	281				281	ALBERTA	$ 315,656.57		T3R 1C8
X	C3598689	Glenbow RD	$ 399,500.00		None	31/01/2014	30/04/2014	3.7	89				89	ALBERTA	$ 107,972.97		T4C 2G4
S	C3485203	39 MORGANS COURT	$ 475,000.00	$ 488,250.00	Morgans Rise	21/07/2011	29/04/2014	2	1013	Z-name Not Listed			1013	ALBERTA	$ 237,500.00	$ 244,125.00	T3Z 0A5
S	C3593855	251225 Range Road 33	$ 279,900.00	$ 275,000.00	Springbank	02/12/2013	28/04/2014	2.13	147	Z-name Not Listed			147	ALBERTA	$ 131,408.45	$ 129,107.98	T3Z 1K7
X	C3589102		$ 469,000.00		None	09/10/2013	09/04/2014	4.05	182				182	ALBERTA	$ 115,802.47		T4B 2B7
X	C3599079	24039 Burma RD	$ 995,000.00		Bearspaw_Calg	05/02/2014	05/04/2014	15.81	59	Z-name Not Listed			59	ALBERTA	$ 62,934.85		T3R 1E3
S	C3541959	9 Country Meadows PL	$ 430,700.00	$ 422,000.00	Springbank	01/10/2012	26/03/2014	1.98	541				541	ALBERTA	$ 217,525.25	$ 213,131.31	T3Z 0C3
S	C3596982	31159 GRANDARCHES	$ 779,000.00	$ 750,000.00	Springbank	17/01/2014	25/03/2014	1.98	67				67	ALBERTA	$ 393,434.34	$ 378,787.88	T3Z 0A7
X	C3586641	116 Swift Creek CV SW	$ 459,900.00		Springbank	22/09/2013	23/03/2014	2.07	182				816	ALBERTA	$ 222,173.91		T3Z 0B6
S	C3601812	244131 PARTRIDGE	$ 549,000.00	$ 500,000.00	Partridge Heights	25/02/2014	17/03/2014	2.01	20				20	ALBERTA	$ 273,134.33	$ 248,756.22	T2P 0R3
T	C3604801	5 MOUNTAIN GLEN CL	$ 399,500.00		None	14/03/2014	17/03/2014	4	32				32	ALBERTA	$ 99,875.00		T4C 0G6
S	C3586229	31 WINDHORSE GR	$ 410,000.00	$ 380,000.00	Springbank	19/09/2013	13/03/2014	2.1	175				175	ALBERTA	$ 195,238.10	$ 180,952.38	T3Z 0B4
S	C3586253	31071 WINDHORSE DR	$ 435,000.00	$ 393,000.00	Springbank	19/09/2013	05/03/2014	2	167				167	ALBERTA	$ 217,500.00	$ 196,500.00	T3Z 0B4
S	C3598161	251116 WELLAND	$ 589,000.00	$ 579,000.00	None	29/01/2014	05/03/2014	4.5	35				35	ALBERTA	$ 130,888.89	$ 128,666.67	T3R 1L3
S	C3563563		$ 579,900.00	$ 549,900.00	None	17/04/2013	03/03/2014	3.98	320				653	ALBERTA	$ 145,703.52	$ 138,165.83	T3Z 2E3
X	C3561483	49 UPLANDS RIDGE	$ 849,900.00		Uplands	03/04/2013	03/03/2014	2	334	Z-name Not Listed			334	ALBERTA	$ 424,950.00		T3Z 3N5
X	C3576960	24166 Old Banff Coach Road RD	$ 1,200,000.00		None	12/07/2013	01/03/2014	6.61	232				232	ALBERTA	$ 181,543.12		T3Z 3N4
X	C3589835	Eagle Butte Ranch	$ 549,000.00		Eagle Butte Ranches	18/10/2013	28/02/2014	2.03	72				72	ALBERTA	$ 270,443.35		T3Z 1K3
X	C3466512	243238 HORIZON VIEW ROAD	$ 995,000.00		Horizon View Estates	18/03/2011	28/02/2014	5.27	1078	Z-name Not Listed			1078	ALBERTA	$ 188,804.55		T3Z 3M3
X	C3590765	164 GRANDVIEW WAY	$ 625,000.00		Springbank	28/10/2013	28/02/2014	1.99	123				123	ALBERTA	$ 314,070.35		T3Z 0A8
X	C3582467	12 Cody Range WY	$ 519,900.00		Church Ranches	22/08/2013	21/02/2014	2.2	183				183	ALBERTA	$ 236,318.18		T3R 1C1
X	C3581383	45 BEARSPAW SUMMIT PL	$ 390,000.00		Bearspaw_Calg	14/08/2013	14/02/2014	1.98	184				275	ALBERTA	$ 196,969.70		T3A 1G4
X	C3592535	35195 Springbank Road	$ 8,960,000.00		Springbank	15/11/2013	14/02/2014	320	91				168	ALBERTA	$ 28,000.00		T3Z 3H3

Rocky View West Listing

Sta	ML Number	Address	List Price	Sold Price	Community Desc	List Date	Off Market Dat	Total Ac	Days c	Condo Name	Condo Type	Number of Parcels	Cummu	County	List Price / Acre	Sold Price / Acre	Postal Code
X	C3581253		$ 1,000,000.00		Glenbow	12/08/2013	08/02/2014	4.27	180				180	ALBERTA	$ 234,192.04		T4C 0B7
S	C3592943		$ 2,250,000.00	$ 2,000,000.00	Springbank	20/11/2013	07/02/2014	34.32	79				79	ALBERTA	$ 65,559.44	$ 58,275.06	T3Z 3P3
X	C3580848	3 Cheyanne Meadows GA N	$ 588,000.00		Bearspaw Acres	09/08/2013	06/02/2014	1.98	181	No Name			181	ALBERTA	$ 296,969.70		T3R 1B7
X	C3327199	22 Highway, 4 miles north of Cochrane	$ 1,500,000.00		None	13/05/2008	31/01/2014	53.3	2089				2089	ALBERTA	$ 28,142.59		T4C 1A9
S	C3485205	35 MORGANS COURT	$ 425,000.00	$ 441,000.00	Morgans Rise	21/07/2011	20/01/2014	2	914	Z-name Not Listed			914	ALBERTA	$ 212,500.00	$ 220,500.00	T3Z 0A5
S	C3545360	25198 SPRINGBANK RD.	$ 2,185,000.00	$ 1,800,000.00	Springbank	05/11/2012	20/01/2014	20.29	441	Z-name Not Listed			441	ALBERTA	$ 107,688.52	$ 88,713.65	T3Z 3M8
T	C3594630	63 rolling acres PL NW	$ 1,200,000.00		Bearspaw Acres	16/12/2013	16/01/2014	19.91	31			1	31	ALBERTA	$ 60,271.22		T3R 1B8
S	C3587544	31147 GRANDARCHES DR	$ 799,000.00	$ 750,000.00	Springbank	23/09/2013	14/01/2014	1.98	113				113	ALBERTA	$ 403,535.35	$ 378,787.88	T3Z 0A7
S	C3595608	242163 WINDHORSE WY	$ 450,000.00	$ 417,000.00	Springbank	07/01/2014	14/01/2014	2.02	7				7	ALBERTA	$ 222,772.28	$ 206,435.64	T3Z 0B4
S	C3588038	228 Horizon View GL	$ 595,000.00	$ 550,000.00	Springbank	03/10/2013	13/01/2014	1.98	102				102	ALBERTA	$ 300,505.05	$ 277,777.78	T3Z 3M6
X	C3592381	262 Lochend RD	$ 4,410,000.00		None	08/11/2013	10/01/2014	157.56	63				63	ALBERTA	$ 27,989.34		T4C 2A3
X	C3575097	43 GRANDVIEW PL	$ 595,000.00		Springbank	27/06/2013	06/01/2014	2.03	193				193	ALBERTA	$ 293,103.45		T3Z 0A8
X	E3343728	25006 TWP RD 264A	$ 6,200,000.00		None	02/07/2013	06/01/2014	627.89	188			4	188	ALBERTA	$ 9,874.34		T3R 1J6
S	C3591083	ASPEN DRIVE	$ 500,000.00	$ 500,000.00	Aspen park	30/10/2013	05/01/2014	4	67				67	ALBERTA	$ 125,000.00	$ 125,000.00	T3R 1A5

Appendix C – Harmony Mixed-Use Development, Springbank

Regional Setting



IBI | Alberta Government

Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary:
Conceptual Design of the Springbank Off-Stream Flood Storage Site
February 2015

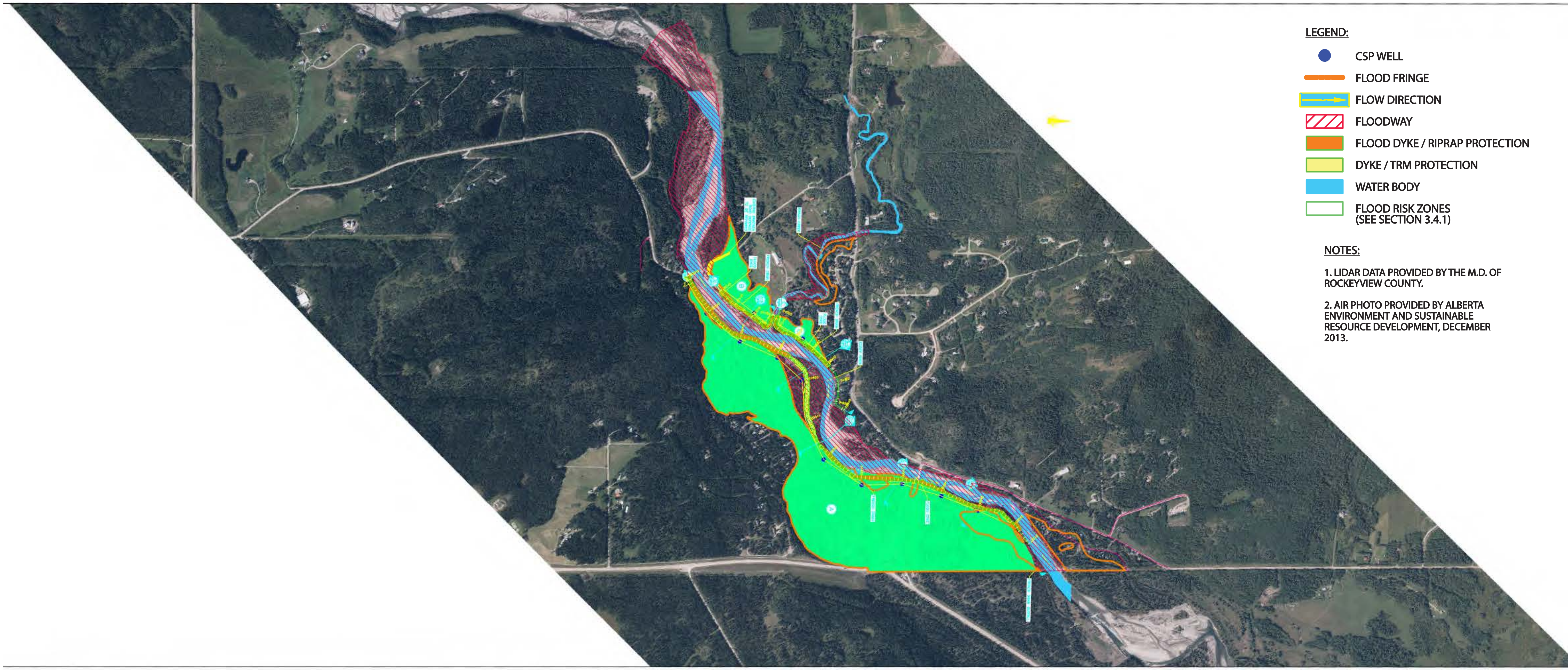
EXHIBIT C-1

Local Setting

Conceptual Master Plan - Harmony

Appendix D – Bragg Creek Proposed Dyke System

Bragg Creek Flood Risk Area and Proposed Dyke System



Source:
amec - Southern Alberta Flood Recovery Task Force
Flood Mitigation Measures for the Bow, Elbow and Oldman River Basins
Volume 4 - Flood Mitigation Measures - Final
June 2014

Elbow River at Banff Creek

Source:
amec - Southern Alberta Flood Recovery Task Force
Flood Mitigation Measures for the Bow, Elbow and Oldman River Basins
Volume 4 - Flood Mitigation Measures - Final
June 2014

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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	m^3	11315	$5.00	$56,577
6	Care of Water	L.S.	1	Lump Sum	$75,000
	EXCAVATION				
7	Common Excavation	m^3	13820	$6.50	$89,831
	FILL PLACEMENT				
8	Low Permeable Fill	m^3	56263	$10.00	$562,628
9	Common Fill	m^3	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	m^2	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	m^2	15390	$1.50	$23,084
18	Turf Reinforcement Mat	m^2	30779	$6.00	$184,674
19	Hydroseeding	m^2	30779	$3.50	$107,727
	SUBTOTAL				**$4,505,490**
	CONTINGENCIES @ 25%				**$1,126,373**
	ENGINEERING @ 12%				**$540,659**
	ESTIMATED TOTAL COST				**$6,173,000**

Source:
amec - Southern Alberta Flood Recovery Task Force
Flood Mitigation Measures for the Bow, Elbow and Oldman River Basins
Volume 4 - Flood Mitigation Measures - Final
June 2014

Appendix E – 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

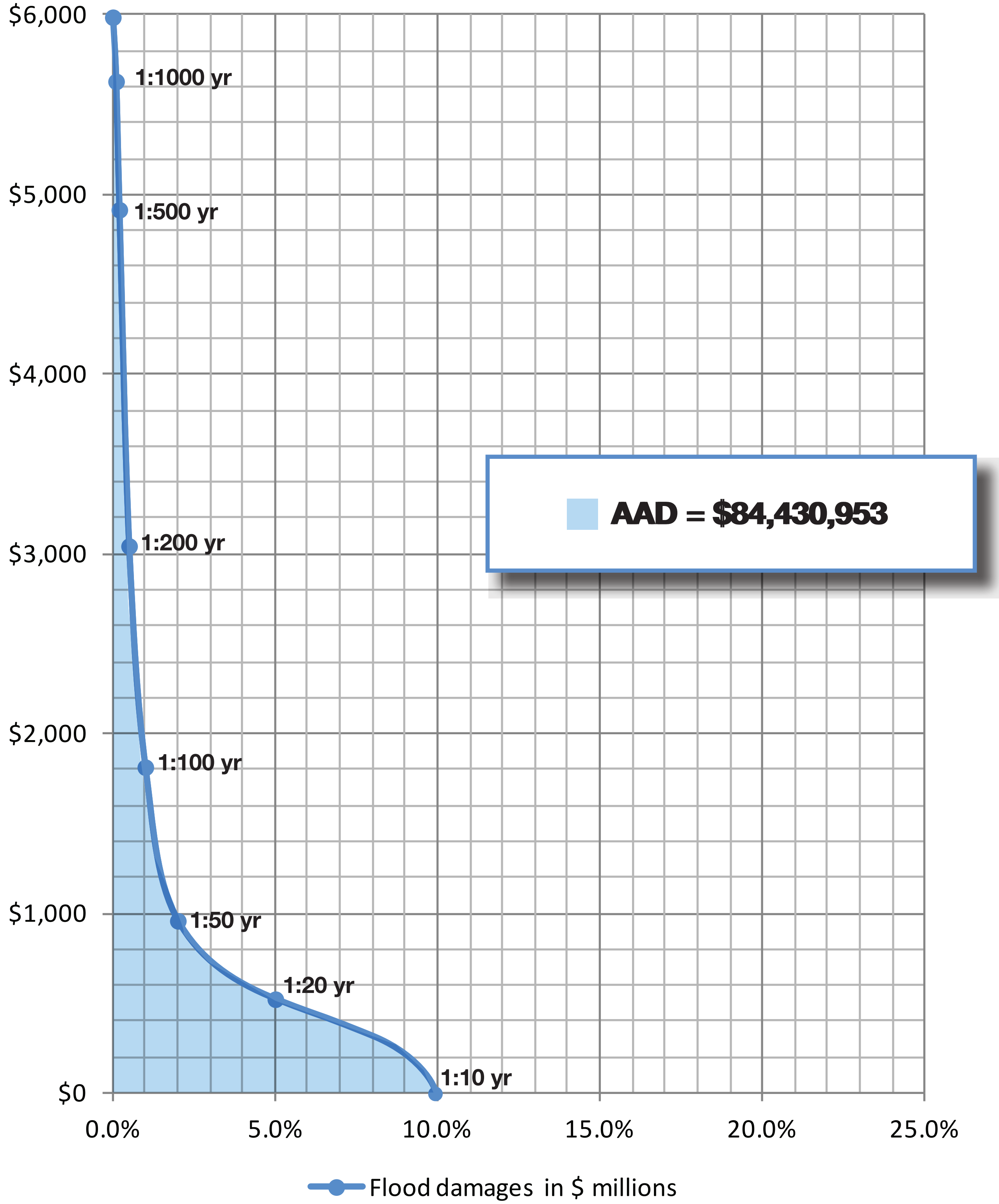
* No Actual damages occur at these flow levels
** Flood Flow primarily contained within the river

Total Damages, Elbow River, With Sewer Backup

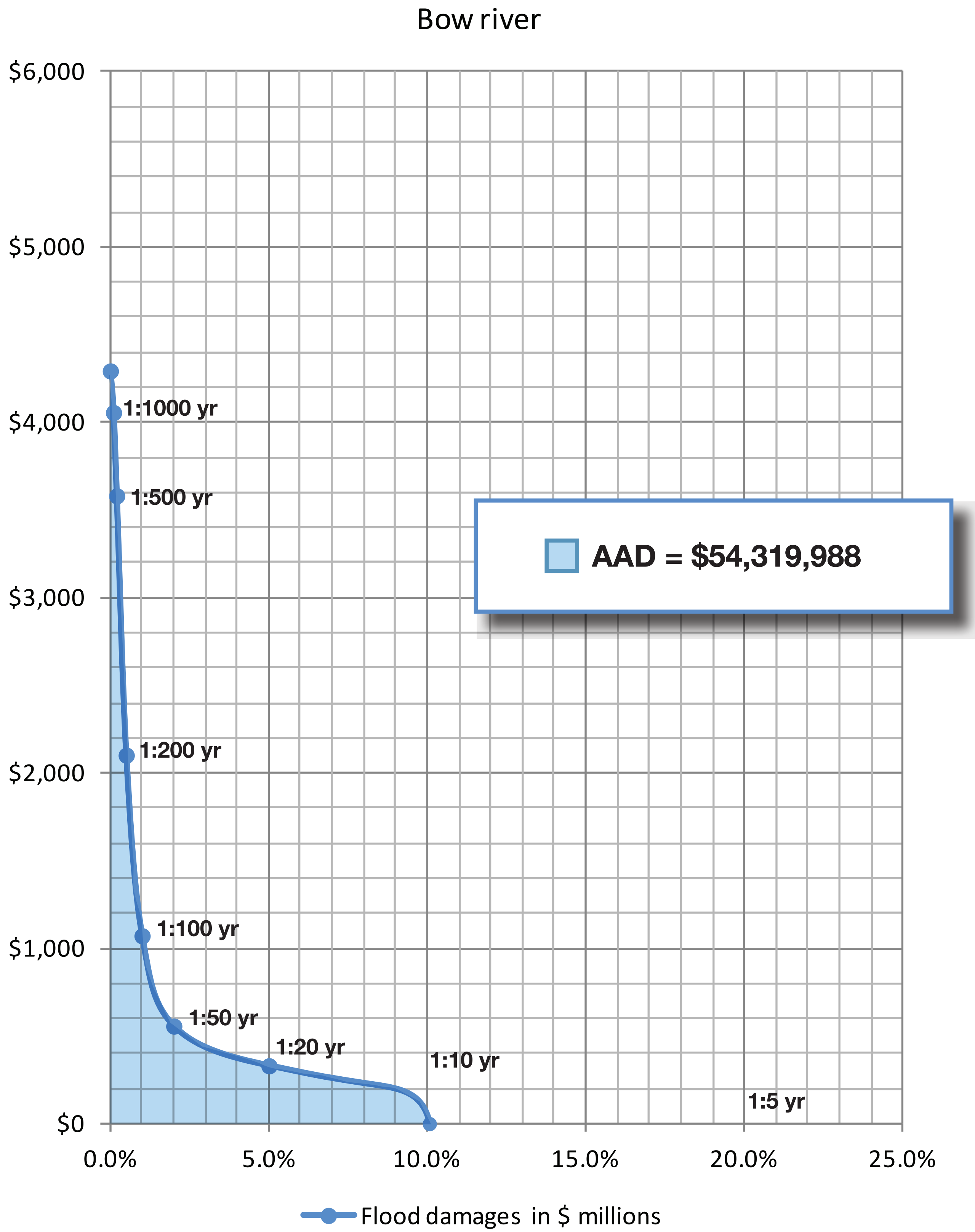
Categories of damage		Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Residential	Direct	$0	$0	$0	$101,015,000	$167,249,000	$299,716,000	$365,304,000	$437,966,000	$505,053,000
	Indirect 15%	$0	$0	$0	$15,152,000	$25,087,000	$44,957,000	$54,796,000	$65,695,000	$75,758,000
	Total	$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

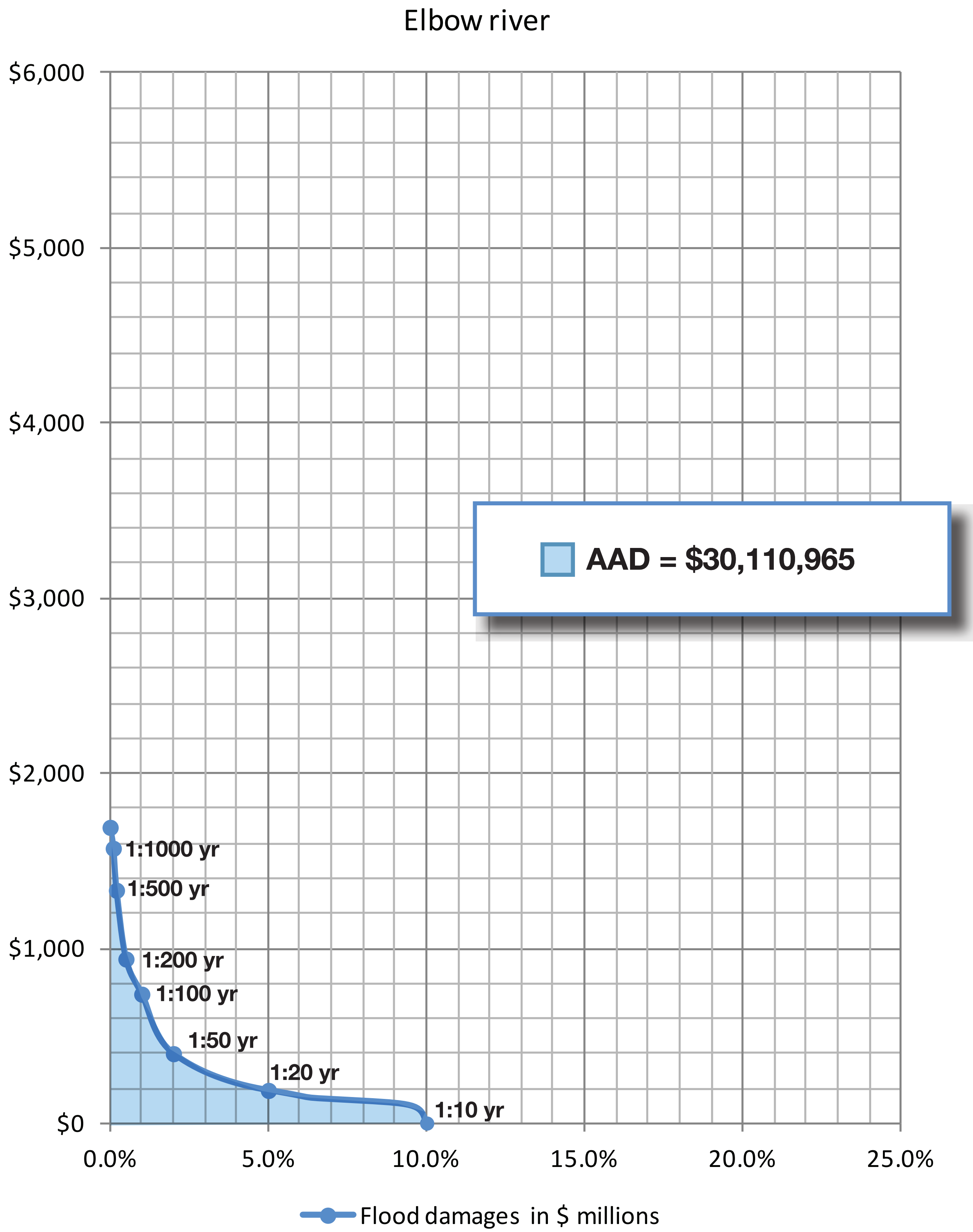
Flood Damages Probability Distribution, Bow and Elbow Rivers



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

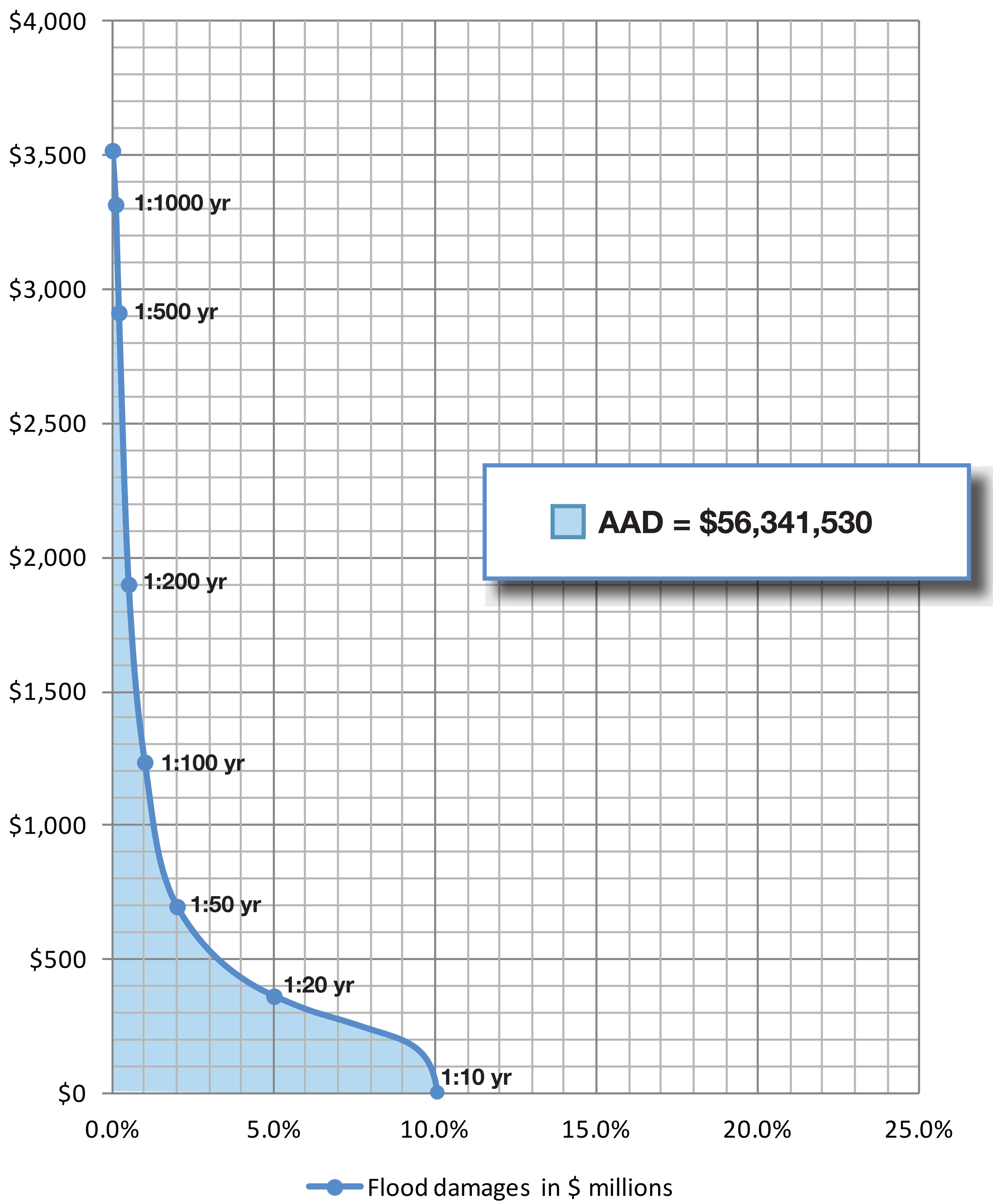
* No Actual damages occur at these flow levels
** Flood Flow primarily contained within the river

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

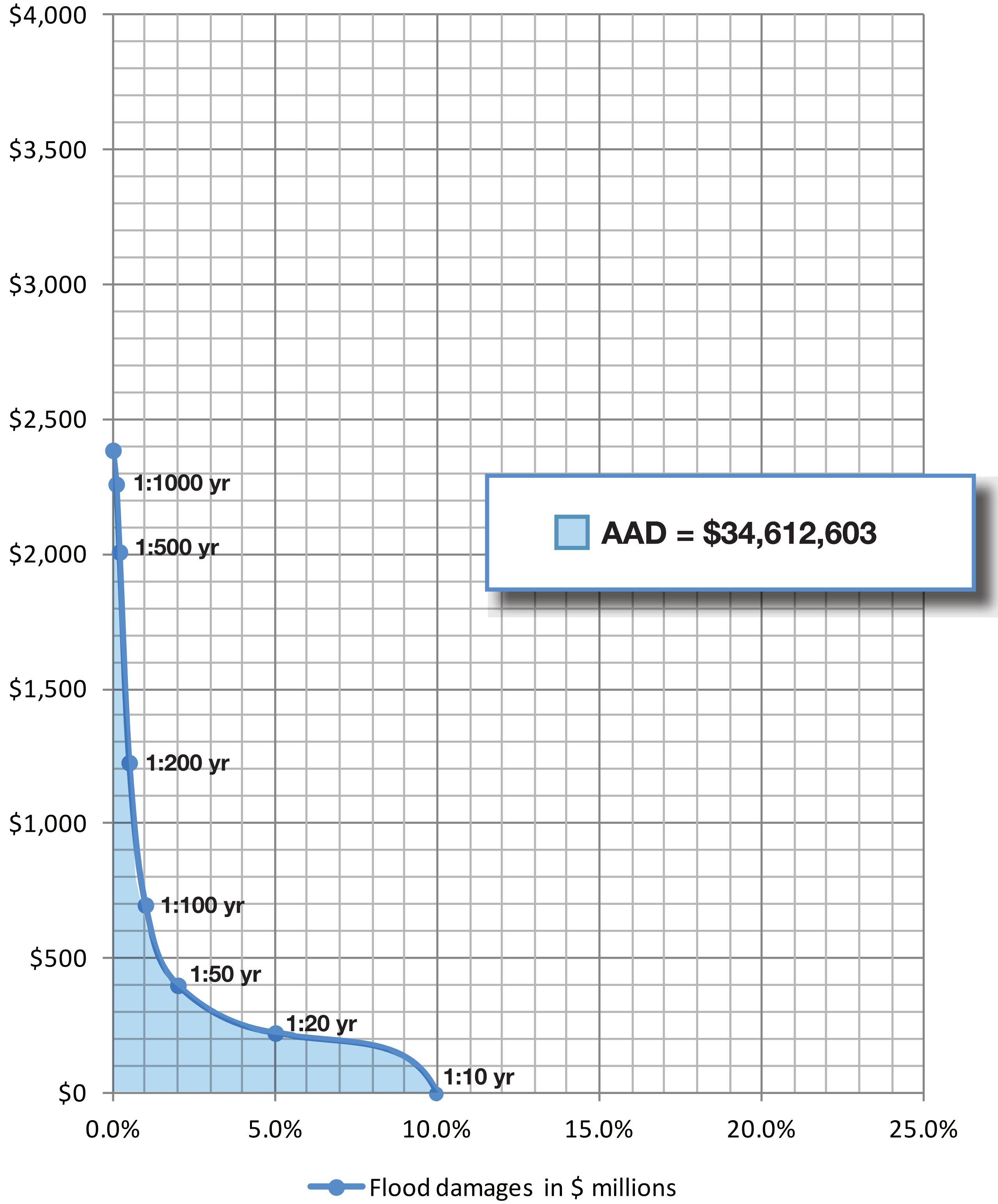
Categories of damage		Return frequency, in years								
		2*	5*	10**	20	50	100	200	500	1,000
Residential	Direct	$0	$0	$0	$101,015,000	$167,249,000	$299,716,000	$365,304,000	$437,966,000	$505,053,000
	Indirect 15%	$0	$0	$0	$15,152,000	$25,087,000	$44,957,000	$54,796,000	$65,695,000	$75,758,000
	Total	$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

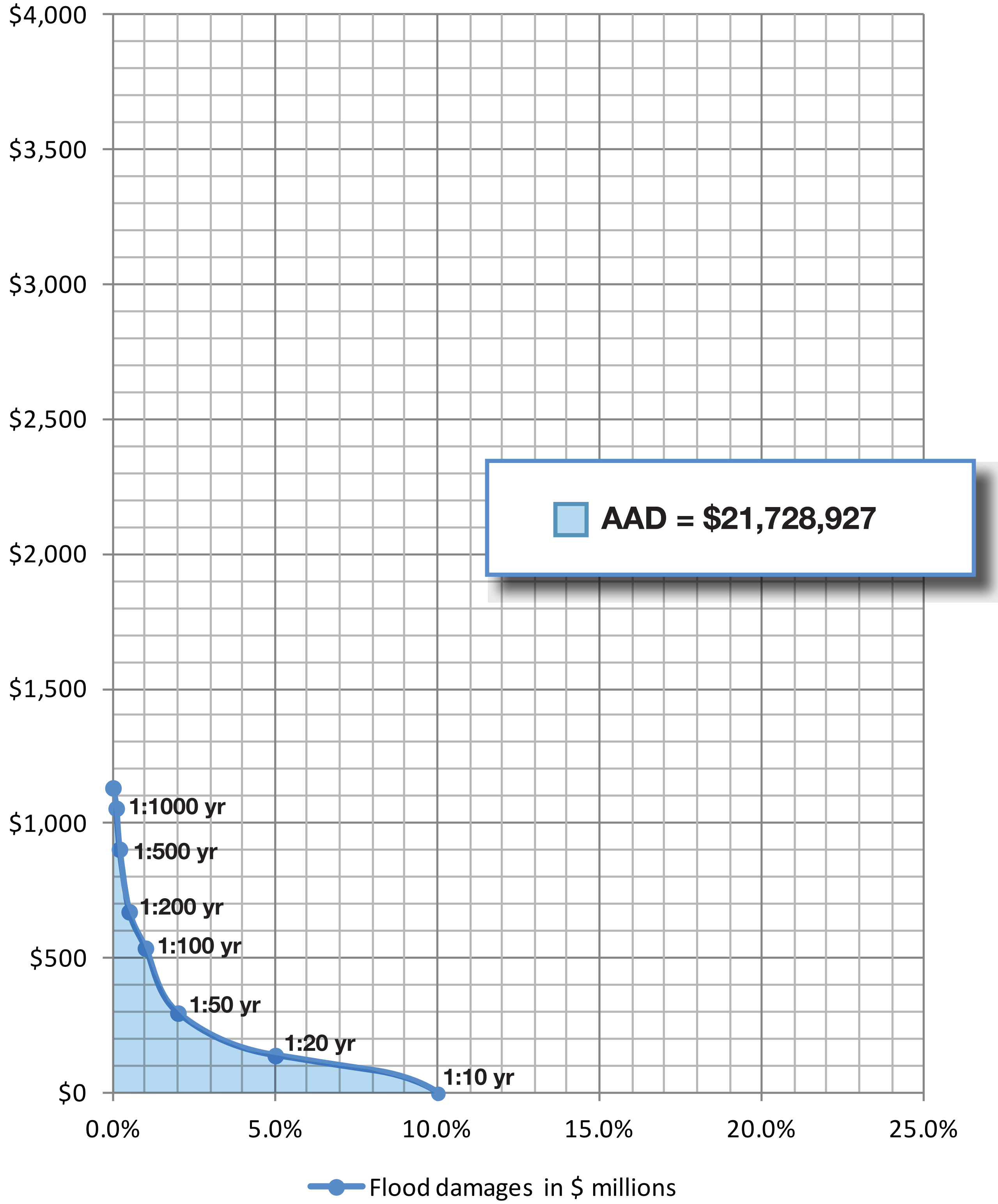
Alternative Damage Scenario - Flood Damages Probability Distribution, Bow and Elbow Rivers



Alternative Damage Scenario - Flood Damages Probability Distribution, Bow River



Alternative Damage Scenario - Flood Damages Probability Distribution, Elbow River



Appendix F – 2013 Southern Alberta Disaster Recovery Program

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					$1,083,770.00	

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

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**

APPENDIX 3-4 BENEFIT/COST ANALYSIS OF FLOOD MITIGATION PROJECTS FOR THE CITY OF CALGARY: MCLEAN CREEK FLOOD STORAGE (2015), ENVIRONMENT AND SUSTAINABLE RESOURCE DEVELOPMENT. PREPARED BY IBI GROUP.

Appendix 3-4 Benefit/Cost Analysis of Flood Mitigation Projects for the City of Calgary: McLean Creek Flood Storage (2015), Environment and Sustainable Resource Development. Prepared by IBI Group.
June 2020

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

IBI GROUP
400 – Kensington House, 1167 Kensington Cres NW
Calgary AB T2N 1X7 Canada
tel 403 270 5600 fax 403 270 5610
ibigroup.com

February 18, 2015

Ms. Heather Ziober
Project Manager, Strategic Integration and Projects
Government of Alberta
Environmental and Sustainable Resource Development
205 J.G. O'Donoghue Building
7000 - 113 Street
Edmonton, AB T6H 5T6

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

Augusto Ribeiro, P.Eng.

SS/mp

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

Submitted to Government of Alberta
ESRD - Resilience and Mitigation
by IBI Group

February 2015

Study Team Members

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Wolf Ploeger

Carmen Walker

Table of Contents

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.

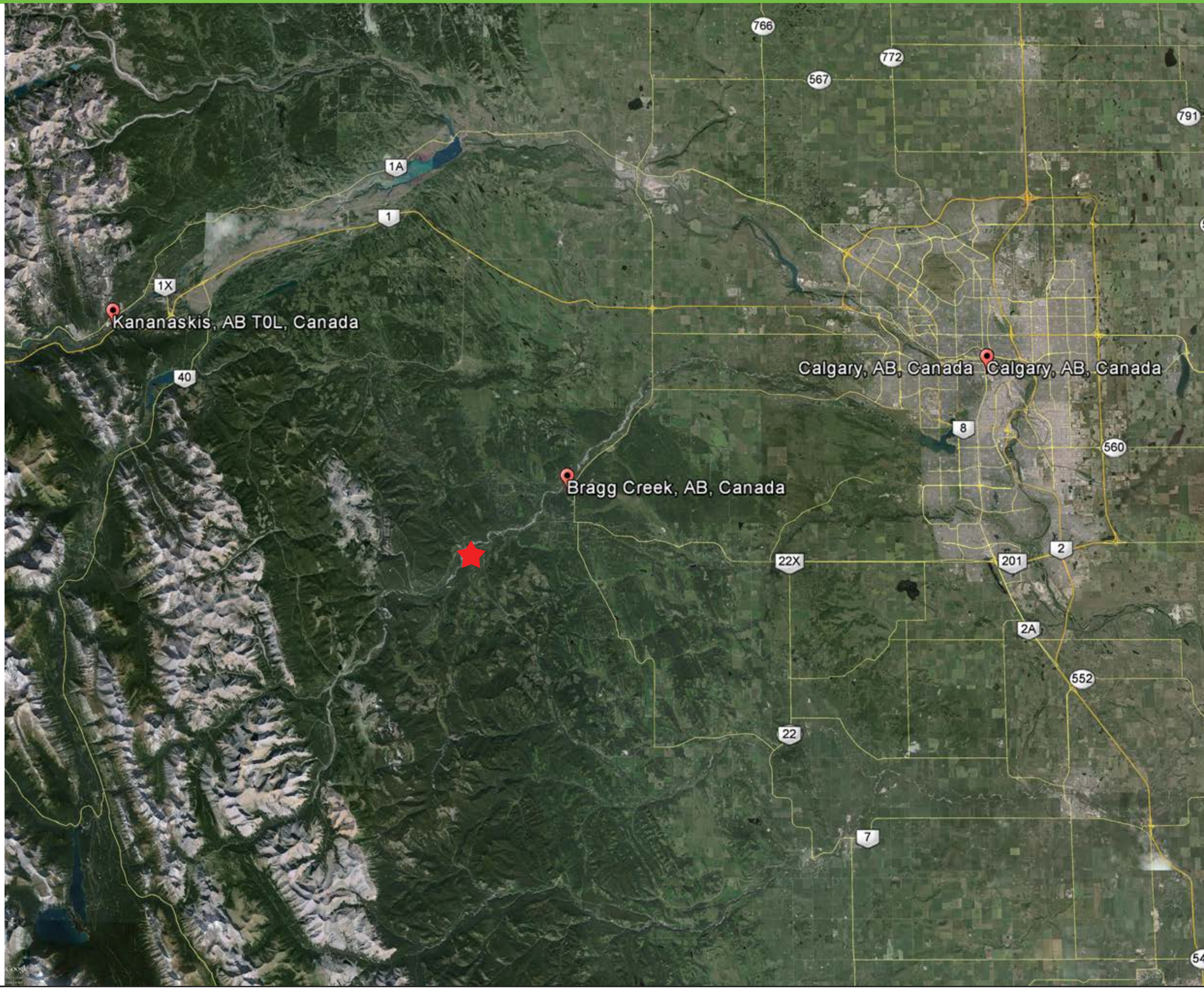
1.3 Scope

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

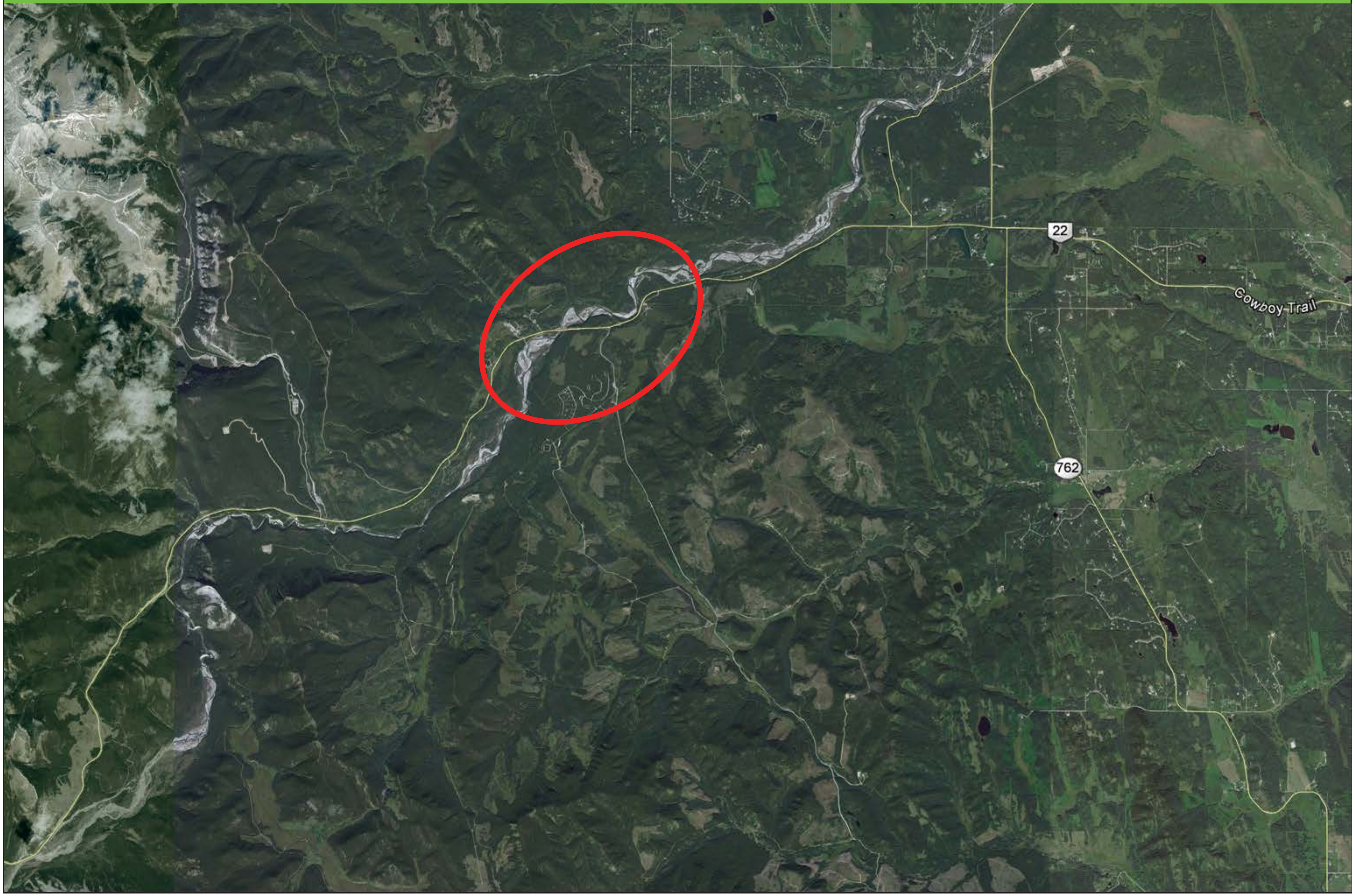


Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary: Conceptual Design of the McLean Creek Flood Storage Site

February 2015

EXHIBIT 2.1

Local Setting



IBI

Alberta Government

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

February 2015

EXHIBIT 2.2

3 Project Description

The Elbow River Dam at McLean Creek (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**.

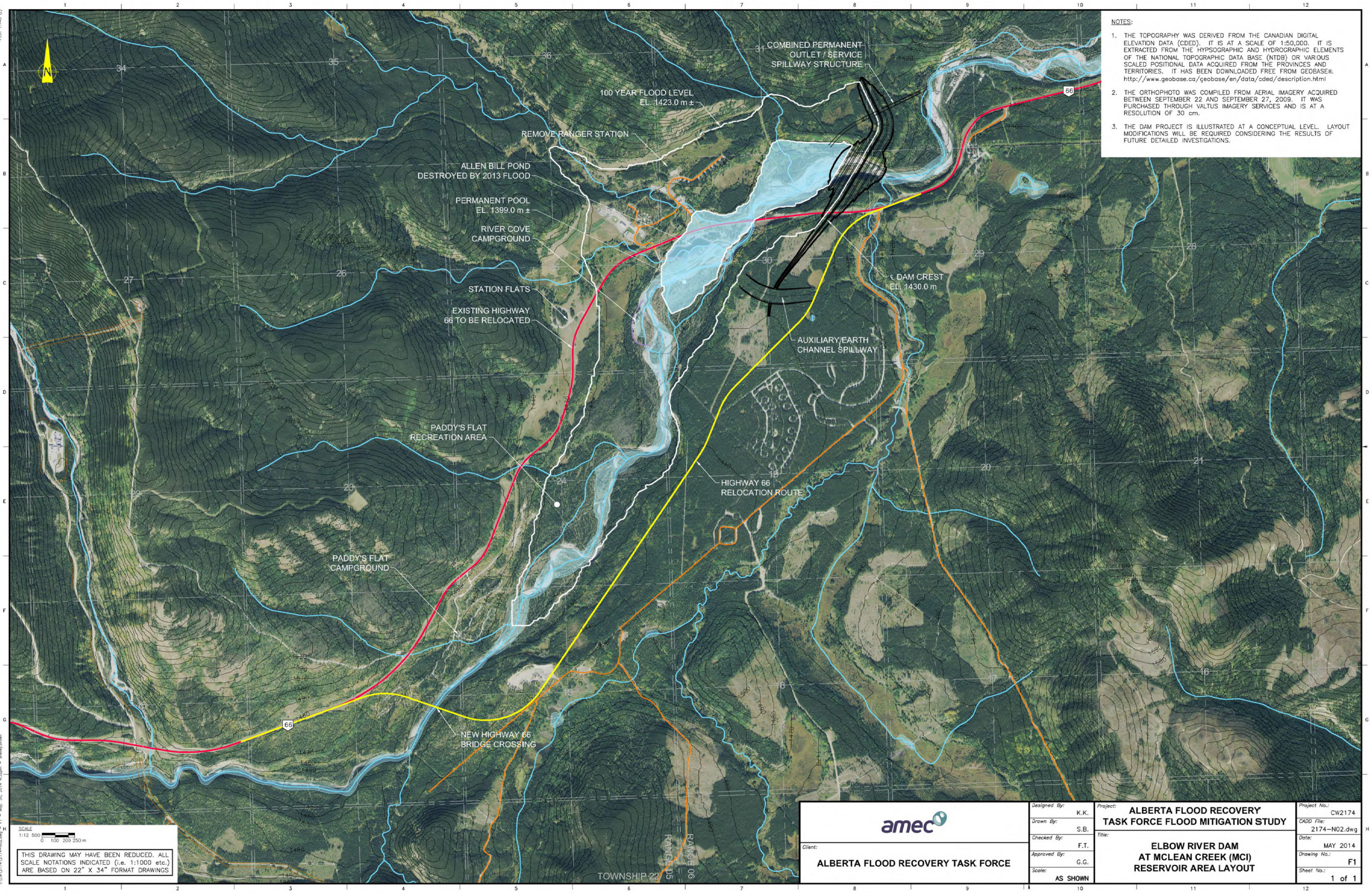
The proposed earth fill dam (main embankment) traverses a river gorge which is approximately 110 m wide at the base and is steep walled for a height of about 28 m (see **Exhibit 3.2**). The left abutment has a high knob-like feature falling away to an undulating plateau more-or-less equal to the height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

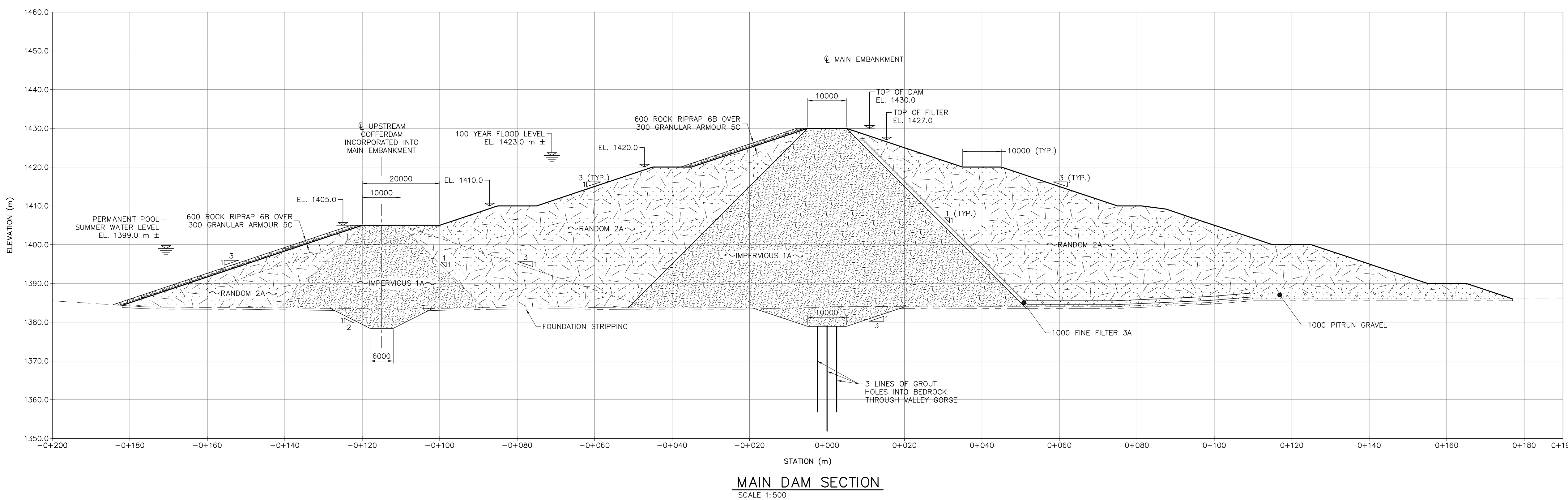
This conceptual design includes a small permanent pool in the valley bottom extending from river bottom elevation 1,379.0 m to the permanent outlet structure intake invert elevation 1,398.0 m, thereby permanently containing approximately 4,000 dam^3 of water as dead storage.

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.

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



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



Designed By:	K.K.
Drawn By:	M.H.
Checked By:	F.T.
Approved By:	G.G.
Scale:	AS SHOWN

Client: ALBERTA FLOOD RECOVERY TASK FORCE

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

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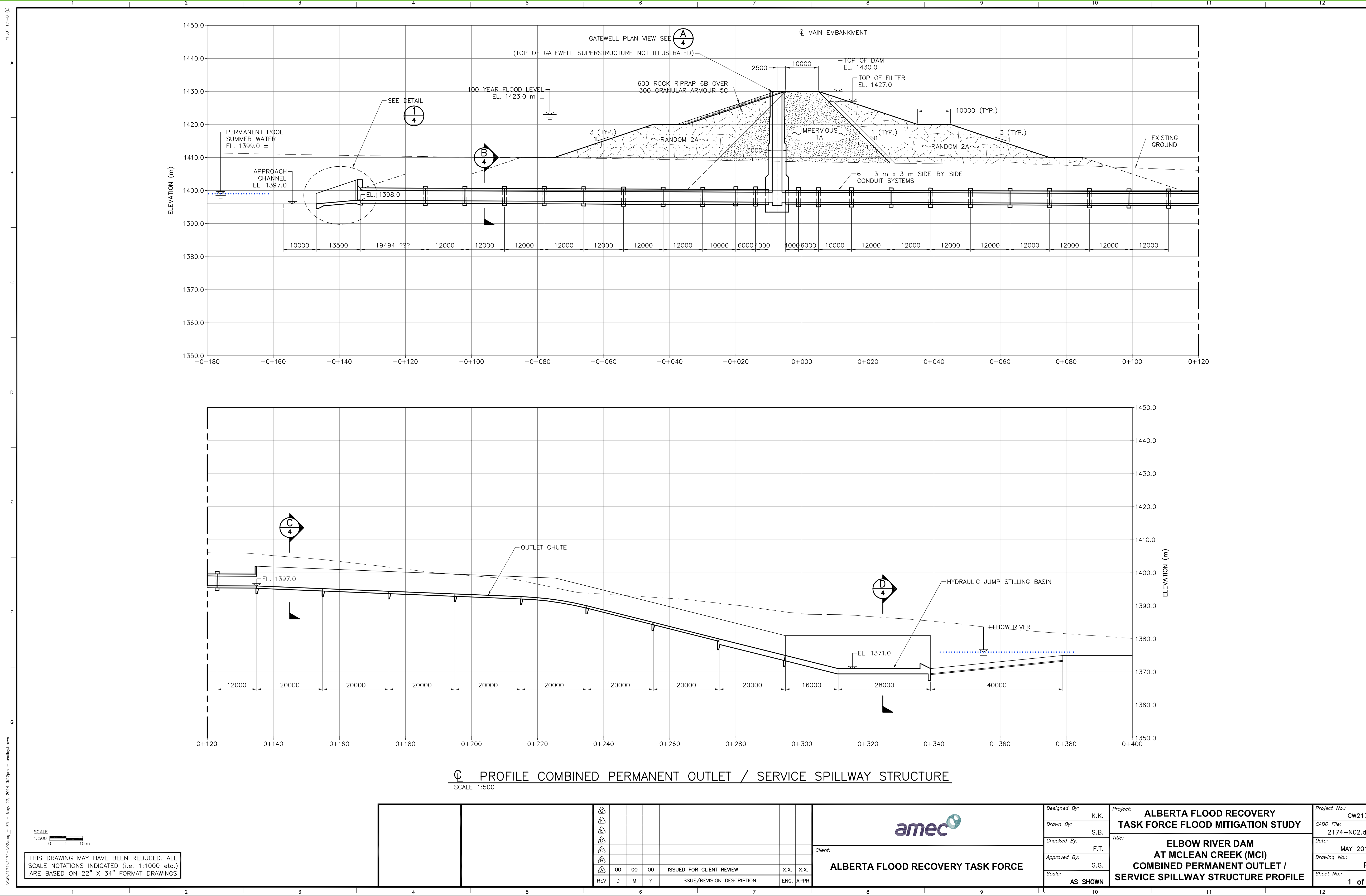
THIS DRAWING MAY HAVE BEEN REDUCED. ALL SCALE NOTATIONS INDICATED (i.e. 1:1000 etc.) ARE BASED ON 22" X 34" FORMAT DRAWINGS

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 Impacts[2]

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.

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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^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**

- 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 million[3]. In addition, the environmental impact assessment studies required to evaluate the project have been estimated at $4 million[4].

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.

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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 1987[5].

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

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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

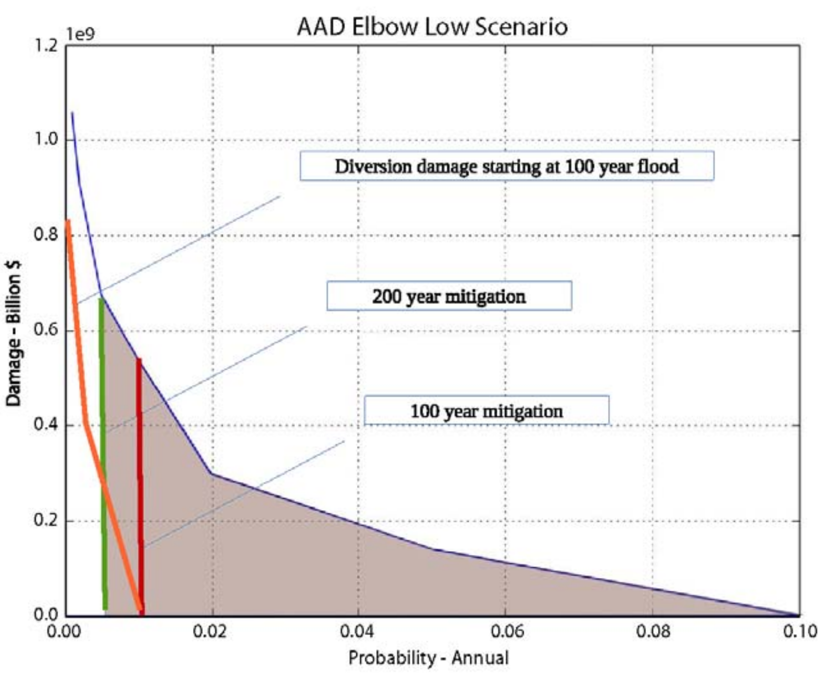
With respect to the Glenmore Reservoir Diversion it was possible to calculate the reduced damages that would be achieved as a result of the 500 and 700 CMS diversion. The incremental flow was passed downstream and damages based on the reduced flood flow were computed to determine the net benefits. Consequently, 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
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

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

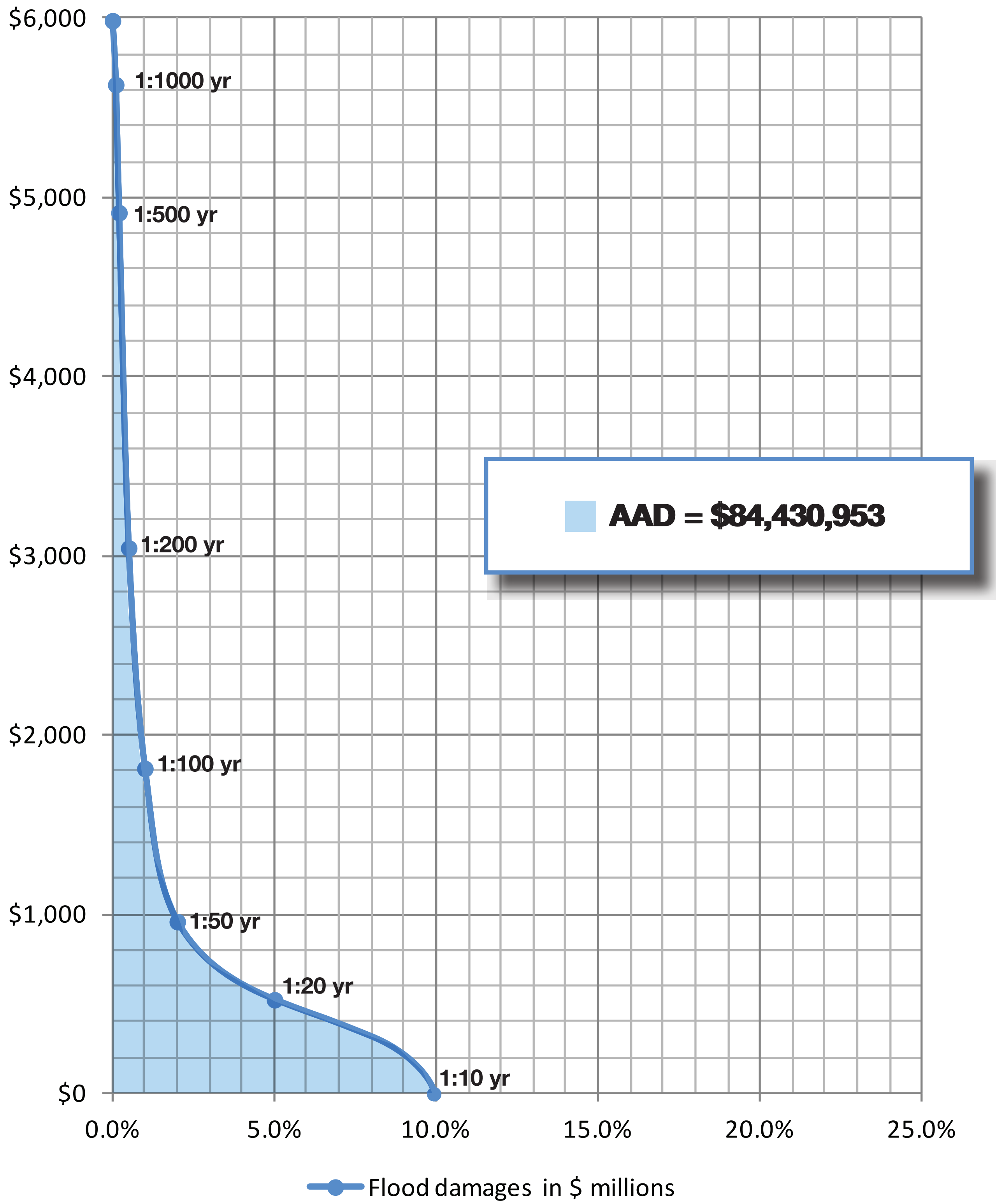
* No Actual damages occur at these flow levels
** Flood Flow primarily contained within the river

Total Damages, Elbow River, With Sewer Backup

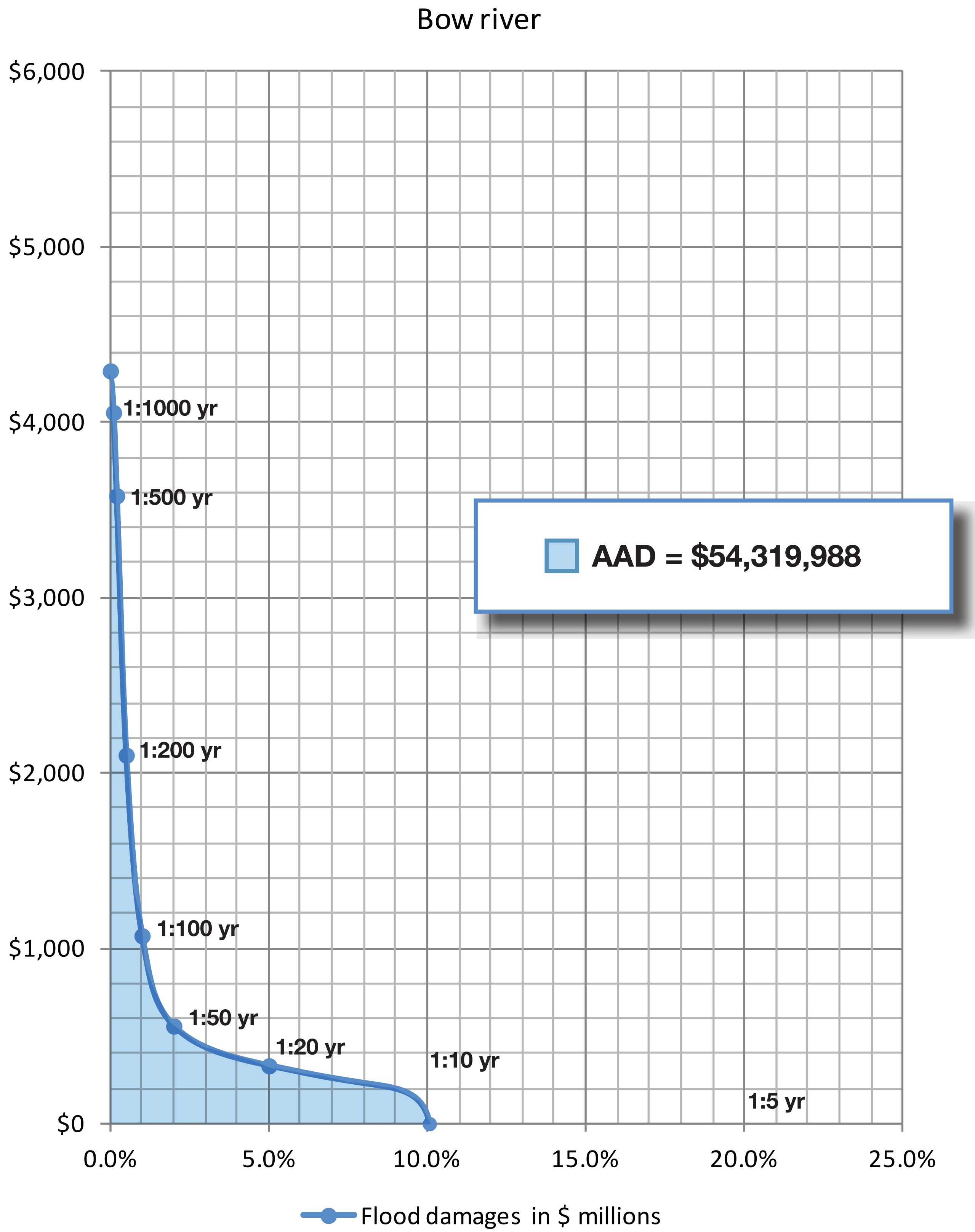
Categories of damage		Return frequency, in years								
		2 *	5 *	10 * *	20	50	100	200	500	1,000
Residential	Direct	$0	$0	$0	$101,015,000	$167,249,000	$299,716,000	$365,304,000	$437,966,000	$505,053,000
	Indirect 15%	$0	$0	$0	$15,152,000	$25,087,000	$44,957,000	$54,796,000	$65,695,000	$75,758,000
	Total	$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

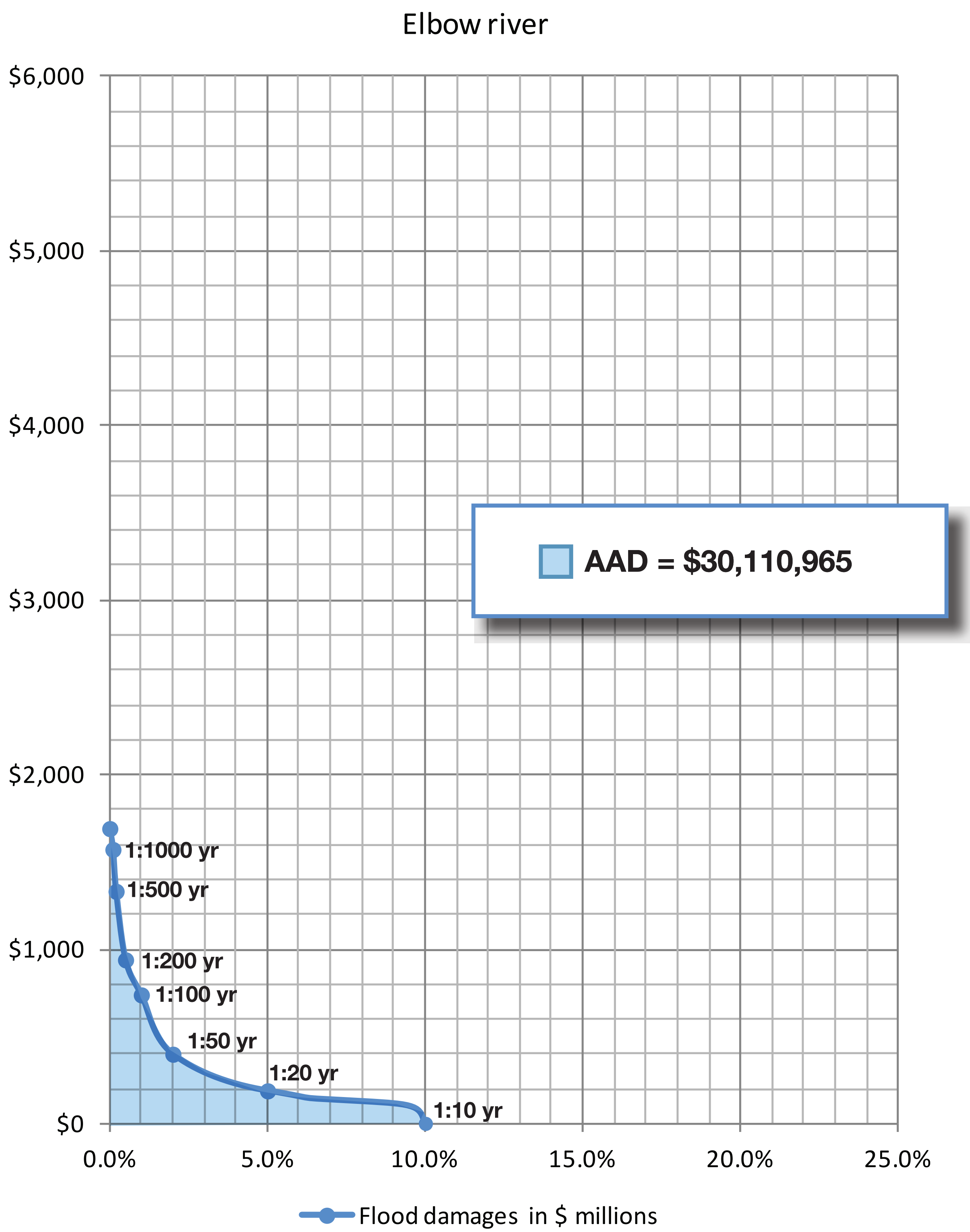
Flood Damages Probability Distribution, Bow and Elbow Rivers



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

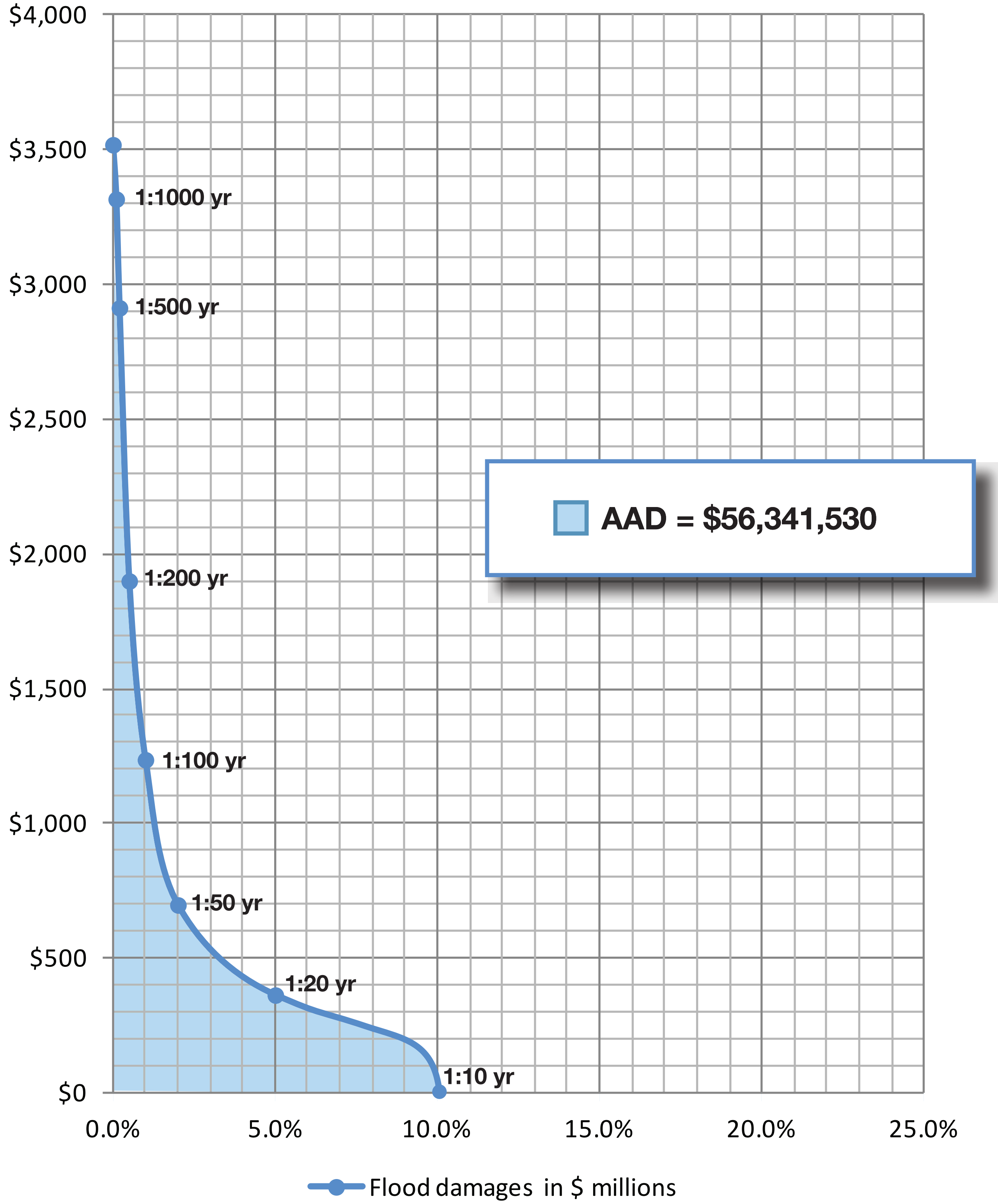
* No Actual damages occur at these flow levels
** Flood Flow primarily contained within the river

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

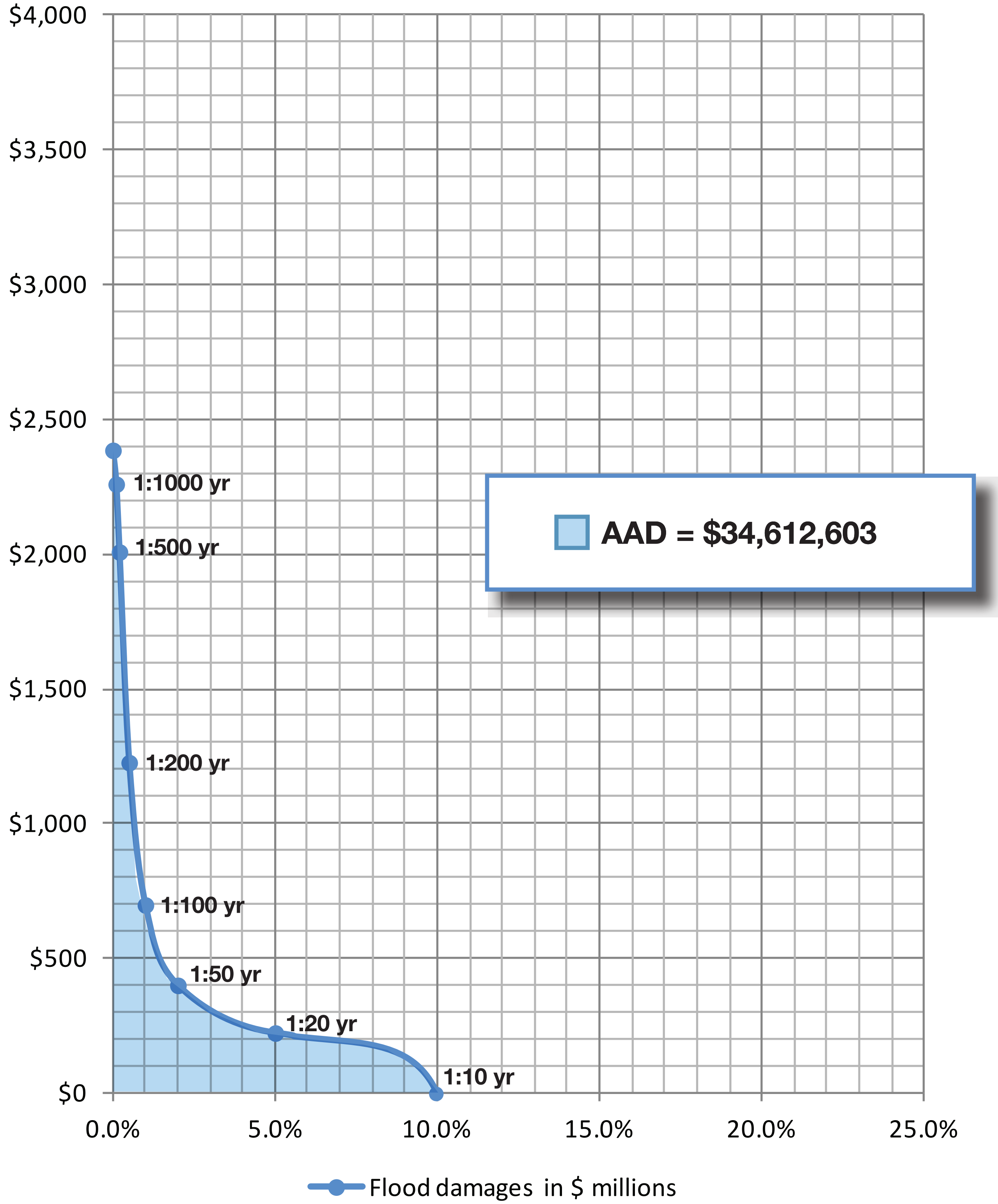
Categories of damage		Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Residential	Direct	$0	$0	$0	$101,015,000	$167,249,000	$299,716,000	$365,304,000	$437,966,000	$505,053,000
	Indirect 15%	$0	$0	$0	$15,152,000	$25,087,000	$44,957,000	$54,796,000	$65,695,000	$75,758,000
	Total	$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

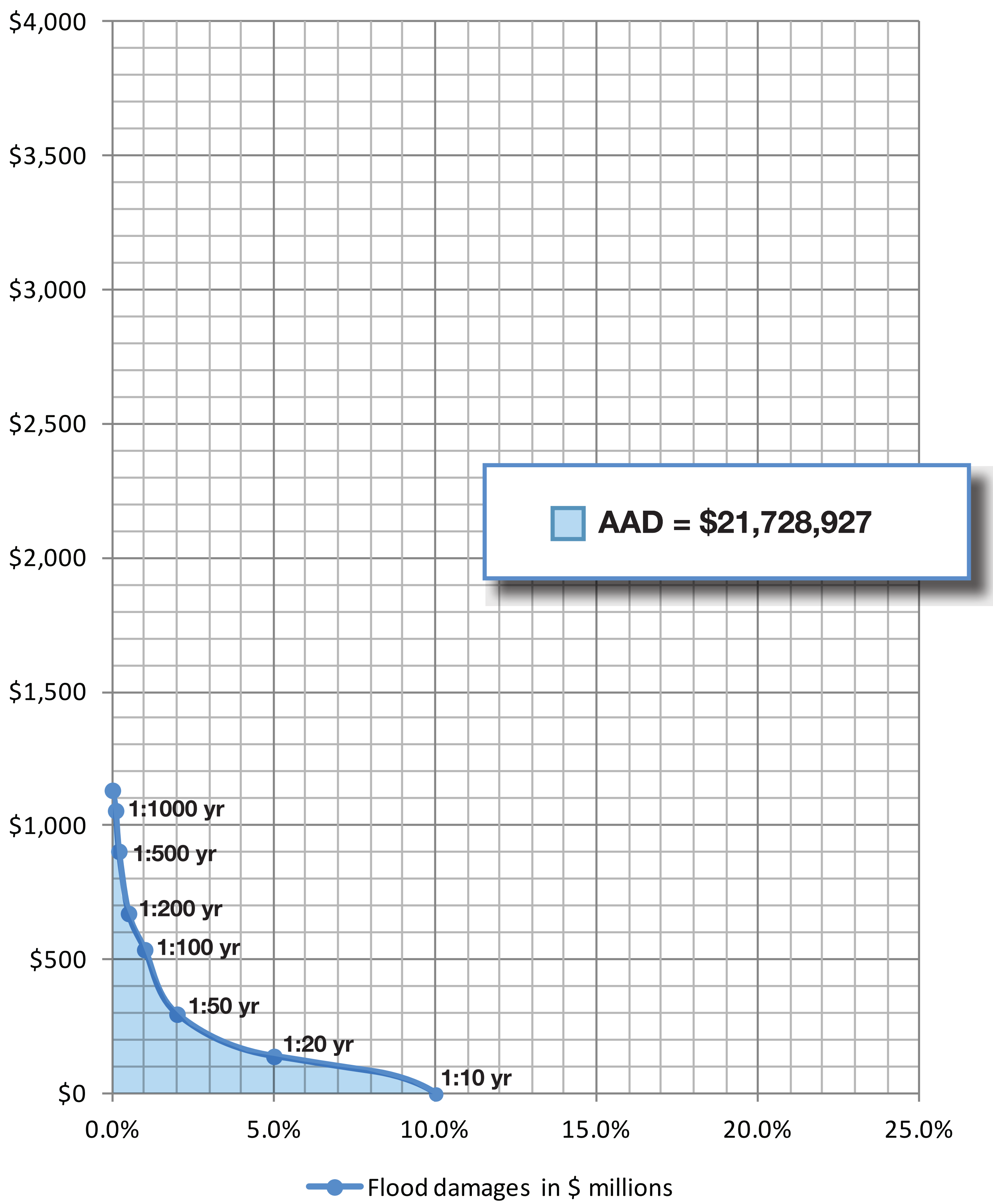
Alternative Damage Scenario - Flood Damages Probability Distribution, Bow and Elbow Rivers



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

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					$1,083,770.00	

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

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

APPENDIX 3-5 BENEFIT/COST ANALYSIS OF FLOOD MITIGATION PROJECTS FOR THE CITY OF CALGARY: GLENMORE RESERVOIR DIVERSION (2015), ENVIRONMENT AND SUSTAINABLE RESOURCE DEVELOPMENT. PREPARED BY IBI GROUP.

Appendix 3-5 Benefit/Cost Analysis of Flood Mitigation Projects for the City of Calgary: Glenmore Reservoir Diversion (2015), Environment and Sustainable Resource Development. Prepared by IBI Group.
June 2020

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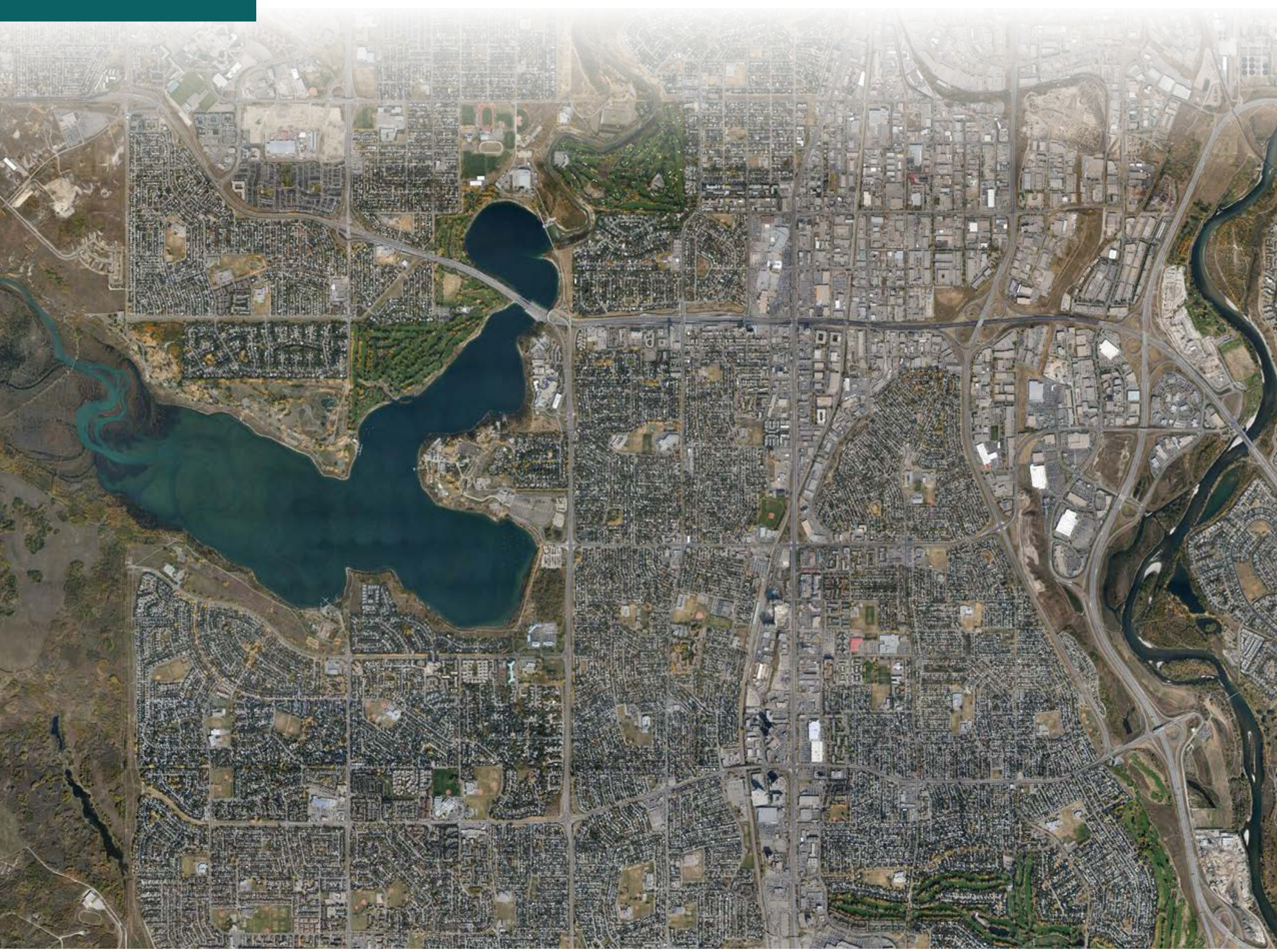
Alberta Government



REPORT

Benefit/Cost Analysis of Flood Mitigation Projects for the City of Calgary: Glenmore Reservoir Diversion

Prepared for Government of Alberta
ESRD - Resilience and Mitigation
by IBI Group

February 18, 2015

IBI GROUP
400 – Kensington House, 1167 Kensington Cres NW
Calgary AB T2N 1X7 Canada
tel 403 270 5600 fax 403 270 5610
ibigroup.com

February 18, 2015

Ms. Heather Ziober
Project Manager, Strategic Integration and Projects
Government of Alberta
Environmental and Sustainable Resource Development
205 J.G. O'Donoghue Building
7000 - 113 Street
Edmonton, AB T6H 5T6

Dear Ms. Ziober:

BENEFIT/COST ANALYSIS OF FLOOD MITIGATION PROJECTS FOR THE CITY OF CALGARY: GLENMORE RESERVOIR DIVERSION

Enclosed please find the draft final report for the aforementioned assignment. The report describes the benefit/cost analysis undertaken for the Glenmore Reservoir Diversion Flood 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 Glenmore Reservoir Diversion ranks third.

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

Yours truly,

IBI GROUP

Stephen Shawcross
Director

Augusto Ribeiro, P.Eng.

SS/mp

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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Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary: Glenmore Reservoir Diversion

Submitted to Government of Alberta
ESRD - Resilience and Mitigation
by IBI Group

February 2015

Study Team Members

IBI Group

Stephen Shawcross

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Golder Associates Ltd.

Wolf Ploeger

Carmen Walker

Table of Contents

Executive Summary

Key Metrics

Project Costs

Item	Cost
Project Construction	$458,600,000
Upstream Mitigation	$8,900,000
Total 1:100 Year Protection	**$467,500,000**
Additional Cost for 1:200 Year Protection	$39,600,000
Total 1:200 Year Protection	**$507,100,000**
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)	$621,715,000	$664,189,000	$416,313,000	$458,787,000
PV Costs (development & operating total cost)	$512,465,000	$551,960,000	$512,465,000	$551,960,000
Benefit/Cost Ratio	1.21	1.20	0.81	0.83
Net Present Value	$109,250,000	$112,229,000	-$96,152,000	-$93,173,000
Average Annual Damages	$25,370,933	$27,104,222	$16,988,895	$18,722,184

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 March of 2014 the City of Calgary retained Hatch Mott MacDonald (HMM) to prepare a detailed feasibility study to provide recommendations on a preferred tunnel diversion from Glenmore Reservoir aimed at routing flood flows away from that portion of the Elbow River between Glenmore Reservoir and the confluence with the Bow River.

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 recommended Glenmore Reservoir Diversion.

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 Glenmore Reservoir Diversion Feasibility Study dated July18, 2014.

2 Context

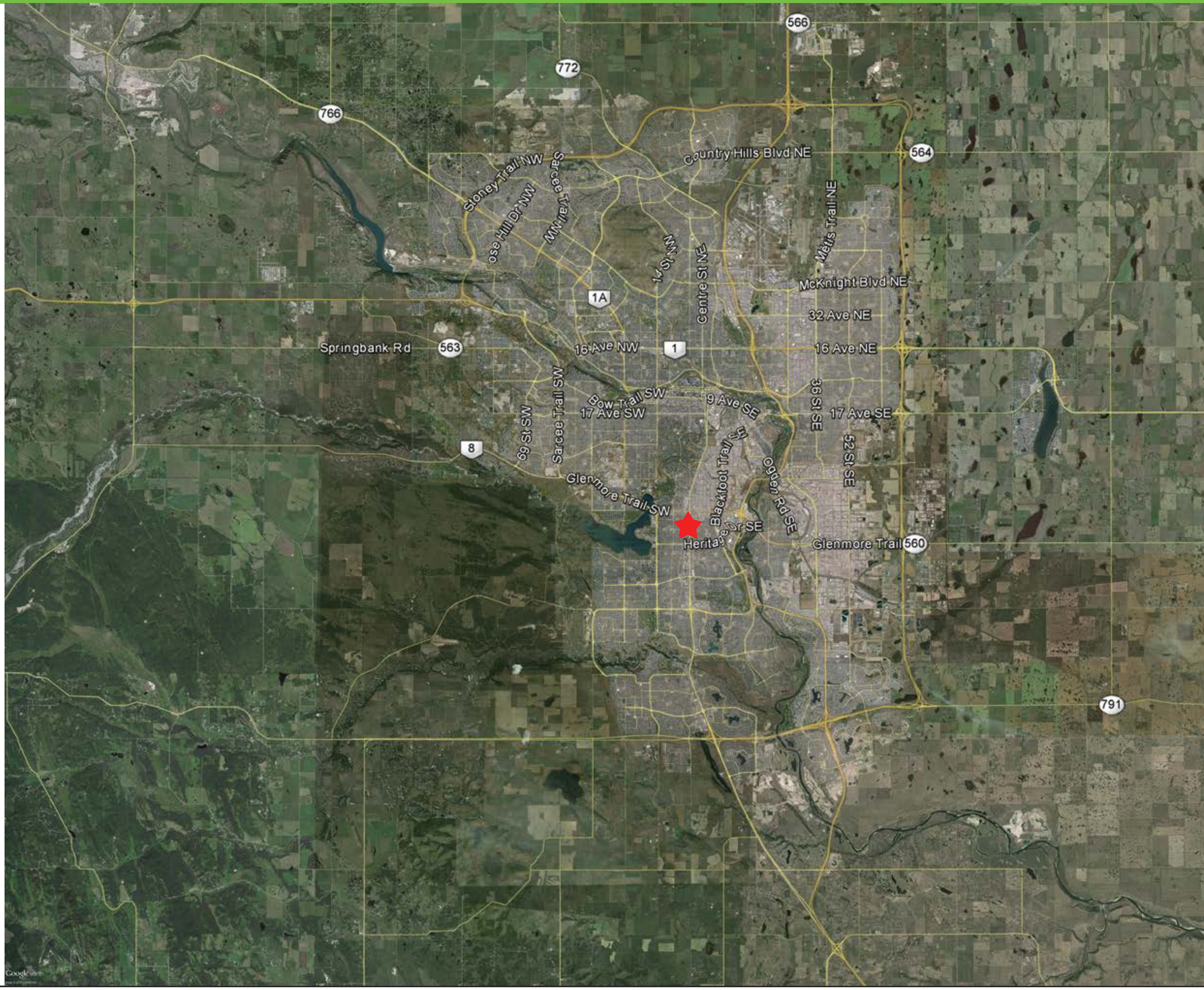
Exhibit 2.1 illustrates the study area, while **Exhibit 2.2** illustrates the location of the preferred alignment.

3 Project Description

Essentially, floodwater exceeding a 1:10 year event will be conveyed from the inlet structure to the outlet structure through a tunnel measuring approximately 4.2 km in length along the preferred Heritage Drive alignment. The geometry of the proposed flood diversion tunnel has been established based on two flow cases: 500 cm/s and 700 cm/s. The flow velocity is anticipated to be 10 m/s for both cases, meaning a tunnel cross-sectional area of 50 m^2 and 70 m^2 would be required for each flow case, respectively.

Exhibit 3.1 illustrates some of the details of the proposed tunnel structure.

Context - City of Calgary



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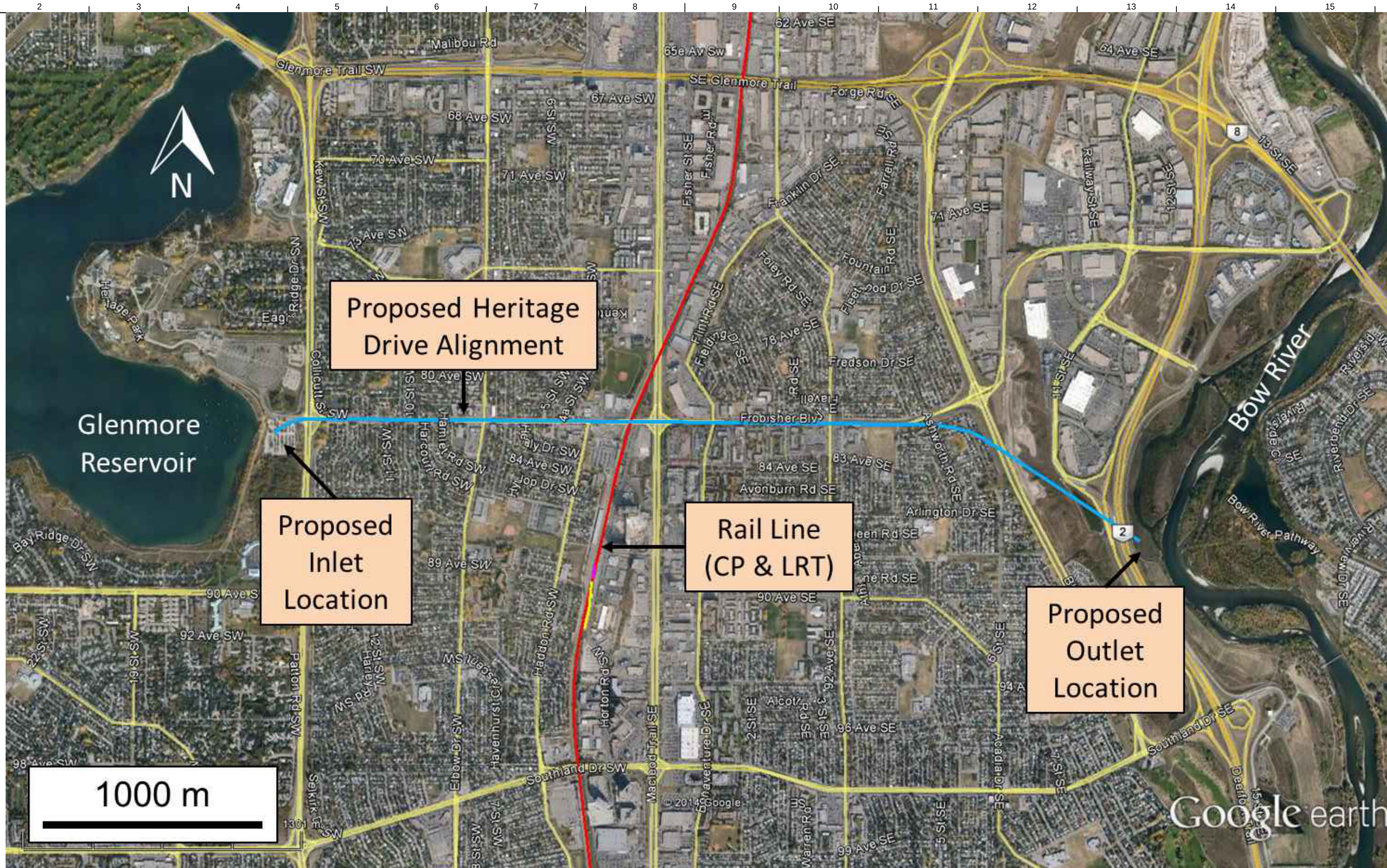
Alberta Government

Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary: Glenmore Reservoir Diversion

February 2015

EXHIBIT 2.1

Glenmore Reservoir Diversion Tunnel



FILE NAME: C:\Users\bro51532\Desktop\PDF\Misc\20140529 - Glenmore Diversion Tunnel - Sketch\334731-SK-01.dwg

USER NAME: Brockway, Chris

PLOT DATE: Monday, June 02, 2014 12:22:02

REFERENCE DRAWINGS

This document is issued for the party which commissioned it and for specific purposes connected with the captioned project only. It should not be relied upon by any other party or used for any other purpose. We accept no responsibility for the consequences of this document being relied upon by any other party, or being used for any other purpose, or containing any error or omission which is due to an error or omission in data supplied to us by other parties. This document contains confidential information and proprietary intellectual property. It should not be shown to other parties without consent from us and from the party which commissioned it.

ENGINEER STAMP:

NO.	DESCRIPTION	BY	YYYY/MM/DD
A	ISSUED FOR DISCUSSION	CL	2014/06/02

REVISIONS

Hatch Mott MacDonald

DRAWN: CSB 2014/06/02
DESIGN: CL 2014/06/02
CHECK:
REVIEW:

SCALE: AS NOTED AT ANSI D

CLIENT REF. DWG. No.: -

CLIENT: The City of Calgary — Glenmore Reservoir Diversion Tunnel

GLENMORE DIVERSION TUNNEL
HERITAGE DRIVE TUNNEL PROFILE

D | PROJECT/DWG No.: 334731-SK-01 | REV No: A

IBI | Alberta Government

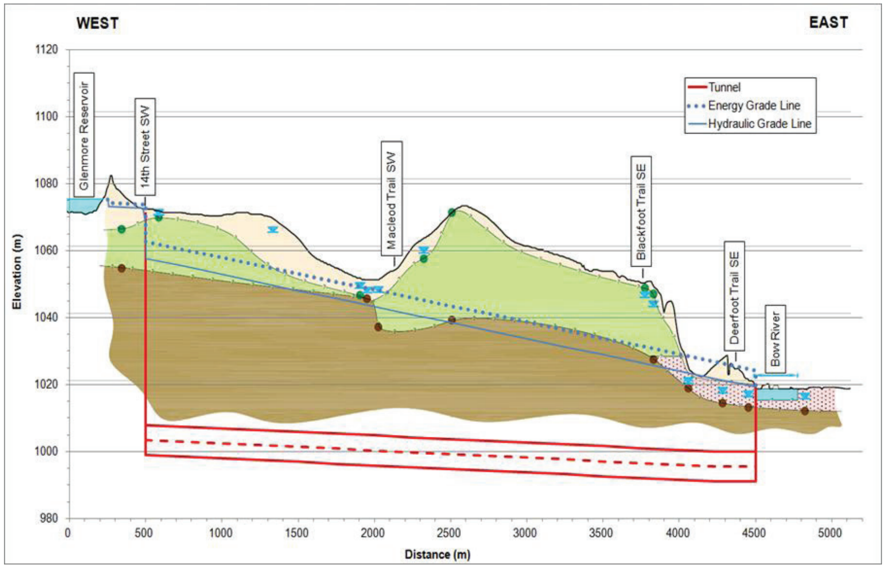
Benefit/Cost Analysis for Flood Mitigation Projects for the City of Calgary: Glenmore Reservoir Diversion

February 2015

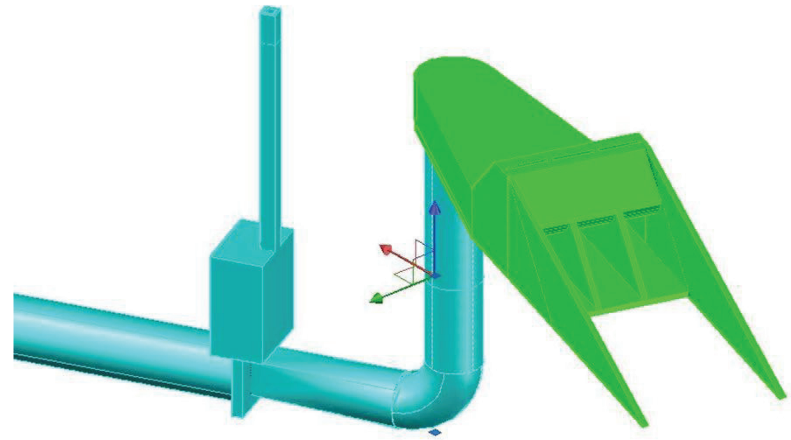
EXHIBIT 2.2

City of Calgary - Glenmore Reservoir Diversion Feasibility Study

HYDRAULIC GRADE LINE PLOT: HERITAGE DRIVE (500 m3/s)



ISOMETRIC VIEW OF TUNNEL AND INLET



TBM LAUNCH BOX FOR THE NIAGARA HYDROELECTRIC PROJECT IN ONTARIO

4 Cost Estimate

This estimate was prepared in Canadian dollars assuming a mid-2014 bid date. The focus of the estimate was placed primarily on the tunnelling and underground components as they dominate the overall cost and risk provisions. These costs were estimated, drawing from the HMM proprietary cost estimating method TED (tunnel estimating database), which adopts estimating methods similar to those used by tunnelling contractors.

4.1 Basis of Estimate/Assumptions

The cost estimate includes the following elements:

- Procurement and mobilization of equipment & materials.
- Site setup.
- Outlet launch box excavation in soil and rock (includes secant pile wall).
- Shield TBM bored tunnel (includes assemble and disassemble costs) with precast concrete tunnel lining.
- Inlet shaft excavation (includes secant pile wall).
- Inlet transition section.
- Control shaft excavation (includes secant pile wall).
- Control gate area excavation.
- Construction water (tunnel inflows) treatment facilities and disposables.
- Final concrete lining for inlet and control shafts.
- Transport and disposal of excavation muck.
- Excavation including topsoil removal.
- Construction of concrete inlet/outlet structures.
- Fabrication, installation and commissioning of all gates (includes guides, provisions for hydraulic and control system).
- Service shaft (includes consideration of ladder, dewatering system, air circulation fan and a housing).
- Indirect costs.
- Construction contingency.

A summary of the cost estimate for the Heritage Drive alignment is provided in the table below.

Summary of Total Project Costs for the Deep Tunnel Option Along the Heritage Drive Tunnel Alignment (millions of dollars)[1]

FLOW CASE	CONSTRUCTION CAPITAL COSTS	ENVIRONMENTAL MITIGATION	PROFESSIONAL SERVICES	RIGHT OF WAY	TOTAL
500 m^3/s	$ 362.4	$ 5.4	$ 90.6	$ 0.1	$ 458.6
700 m^3/s	$ 393.8	$ 5.9	$ 98.4	$ 0.1	$ 498.2

Notes:

1. All costs in millions of Canadian dollars and assume a mid-2014 bid date (excluding GST).
2. Operational and maintenance costs are expected to be between $1.8 to $2.0 million per year.
3. Refer to Appendix G of the HMM report for a breakdown of Construction Capital Costs.
4. Environmental mitigation costs are assumed to be 1.5% of the construction capital costs.
5. Professional services are assumed to be 25% of the construction capital costs and include final design services, construction management and additional costs to the owner (e.g., permit and agency fees for plan check, inspections and testing, and engineering fees for design consultants retained by city agencies or project stakeholders). This is based in part on The American Society of Civil Engineers Manual of Practice 45 “How to work effectively with consulting engineers”.
6. Right of Way costs for a temporary construction easement are assumed to be 5% of the assessed land value. This will need to be confirmed with the City of Calgary. The total area of subsurface easement is estimated at 3,000 m^2.

4.2 Flood Defences at Bragg Creek

The flood mitigation measures study for the Bow, Elbow and Old Man River basins recommended flood defences at Bragg Creek if flood protection infrastructure for the City of Calgary was located downstream of Bragg Creek. Protection of the Hamlet via dykes was proposed with a further recommendation that if a decision was made to proceed with a project located downstream of Bragg Creek, then the detailed design and planning for the dykes of Bragg Creek should be initiated as soon as possible.[2] Costs for the dyke system were estimated at $6.2 million (see **Appendix A**).

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.

1 Hatch, Mott, MacDonald Ltd., Glenmore Reservoir Diversion Feasibility Study – Final Report, July 18, 2014.

2 AMEC Environmental & Infrastructure, *Southern Alberta Flood Recovery Task Force, Flood Mitigation Measures for the Bow, Elbow and Oldman River Basins, Volume 1 – Summary Recommendations Report – Final,* June 2014.

The detailed analysis of City of Calgary flood damages is contained under separate cover; however, summary tables are contained in **Appendix B**. 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.

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 upstream of the Glenmore Reservoir Diversion project including Bragg Creek, Redwood Meadows and infrastructure within Rocky View County which would not be protected by the proposed Glenmore Reservoir Diversion 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 1987[3].

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 C**.

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 upstream of the Glenmore Reservoir Diversion project. Notwithstanding, in order to account for the other damages, and therefore additional costs that will be incurred by the Glenmore Reservoir Diversion project over the MC1 project (McLean Creek Flood Storage), an additional $8.9 million in total costs are proposed to be added to the Glenmore project.

5.2 With Mitigation Alternative

Implementation of the Glenmore Reservoir Diversion 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 = $25,370,933
- 1:200 year level of protection under the higher damage scenario = $27,104,222

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[3] *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.

- 1:100 year level of protection under the lower damage scenario = $16,988,895
- 1:200 year level of protection under the lower damage scenario = $18,722,184

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 scenario to account for required mitigation measures upstream.
- 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

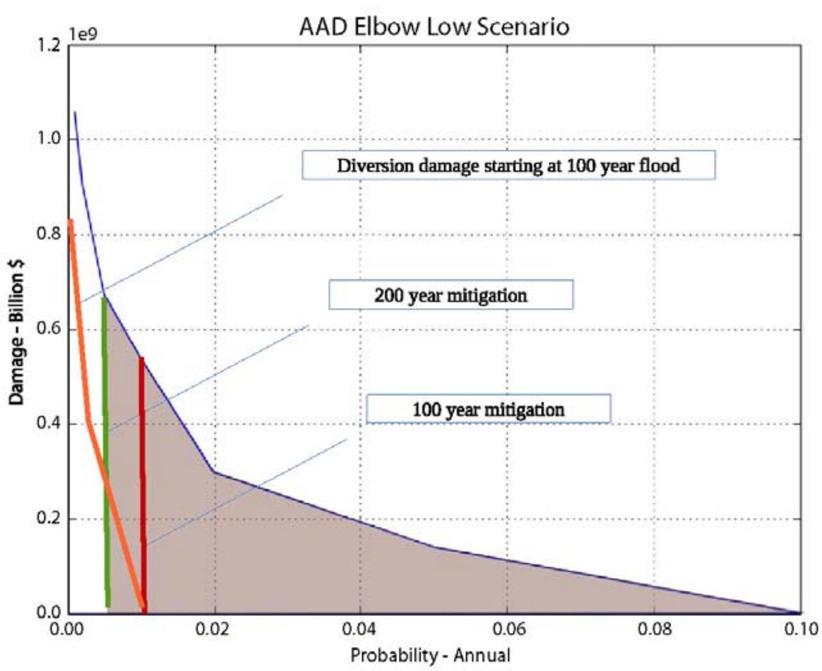
With respect to the Glenmore Reservoir Diversion it was possible to calculate the reduced damages that would be achieved as a result of the 500 and 700 CMS diversion. The incremental flow was passed downstream and damages based on the reduced flood flow were computed to determine the net benefits. Consequently, 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 of the Glenmore Reservoir Diversion project under the four cases as discussed.

For the 1:100 year level of protection under the high damage scenario, the present value of benefits is some $622 million versus $512 million in costs, rendering a positive benefit/cost ratio of 1.21.

At the 1:200 year level of protection under the high damage scenario, the benefit/cost ratio decreases slightly to 1.20, illustrating the economic viability of both alternatives.

For the lower damage scenarios, the 1:100 year present value of benefits is $416 million versus $512 million in costs, rendering a benefit/cost ratio of 0.81. At the 1:200 year level of protection, the benefit/cost ratio increases slightly to 0.83.

In summary, this project demonstrates economic viability under only two of the four cases considered.

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)	$621,715,000	$664,189,000	$416,313,000	$458,787,000
PV Costs (development & operating total cost)	$512,465,000	$551,960,000	$512,465,000	$551,960,000
Benefit/Cost Ratio	1.21	1.20	0.81	0.83
Net Present Value	$109,250,000	$112,229,000	-$96,152,000	-$93,173,000
Average Annual Damages	$25,370,933	$27,104,222	$16,988,895	$18,722,184

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

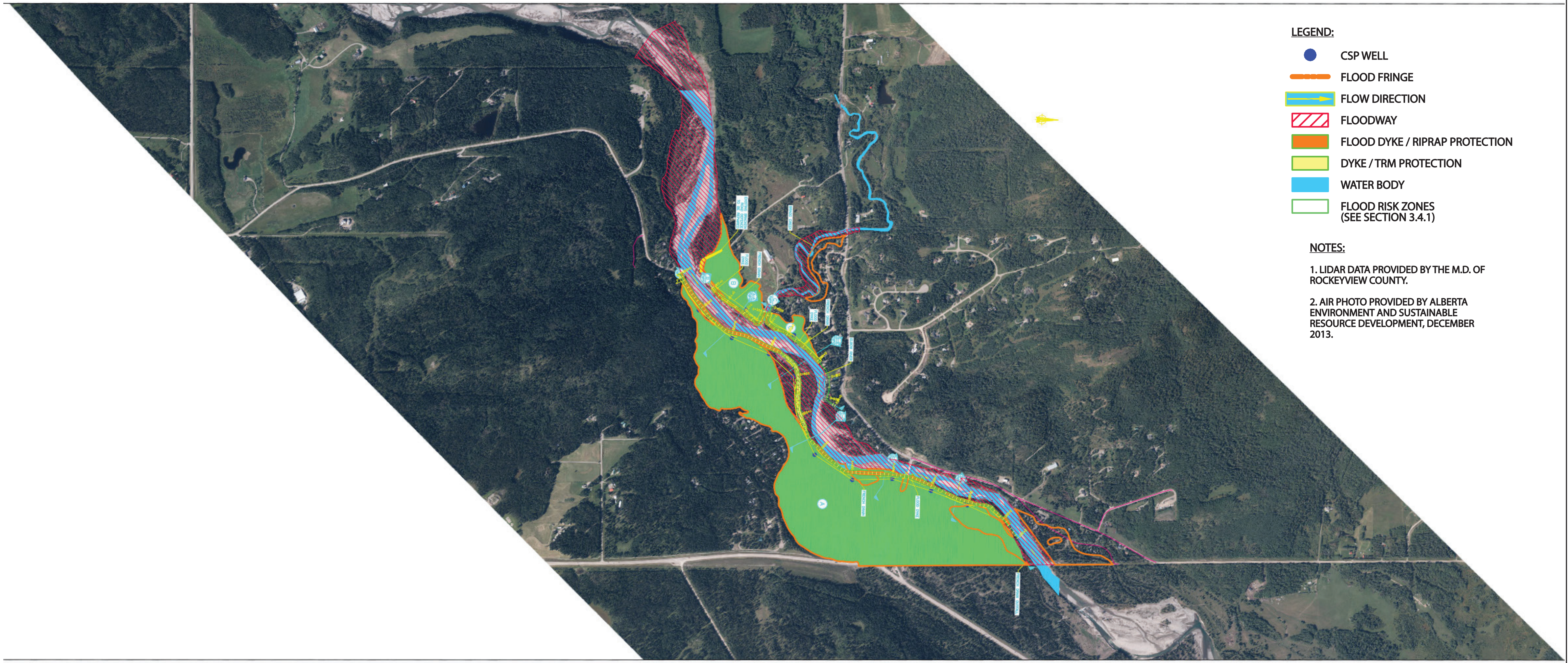
Mitigation Project	High Damage Scenario		Low Damage Scenario	
	1:100 Year Protection	1:200 Year Protection	1:100 Year Protection	1:200 Year Protection
SR1	1.87	2.07	1.32	1.32
MC1	1.43	1.65	1.01	1.05
Glenmore	1.21	1.20	0.81	0.83

The Glenmore Reservoir Diversion achieves a positive benefit/cost ratio in only two of the four scenarios and ranks third behind the other two mitigation projects.[4] In addition, of the three scenarios considered, the diversion project appears to have the highest level of uncertainty relative to costs. It relies upon new and relatively untested technology in the Alberta context versus the alternative storage solutions. The recent cost escalations associated with the City of Calgary airport runway tunnel (greater than two times the original estimate) provides a good example of the latter concern.

[4] 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: McLean Creek Flood Storage (February 2015).*

Appendix A – Bragg Creek Proposed Dyke System

Bragg Creek Flood Risk Area and Proposed Dyke System



Source:
amec - Southern Alberta Flood Recovery Task Force
Flood Mitigation Measures for the Bow, Elbow and Oldman River Basins
Volume 4 - Flood Mitigation Measures - Final
June 2014

Elbow River at Banff Creek f

Source:
amec - Southern Alberta Flood Recovery Task Force
Flood Mitigation Measures for the Bow, Elbow and Oldman River Basins
Volume 4 - Flood Mitigation Measures - Final
June 2014

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**

Source:
amec - Southern Alberta Flood Recovery Task Force
Flood Mitigation Measures for the Bow, Elbow and Oldman River Basins
Volume 4 - Flood Mitigation Measures - Final
June 2014

Appendix B – 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

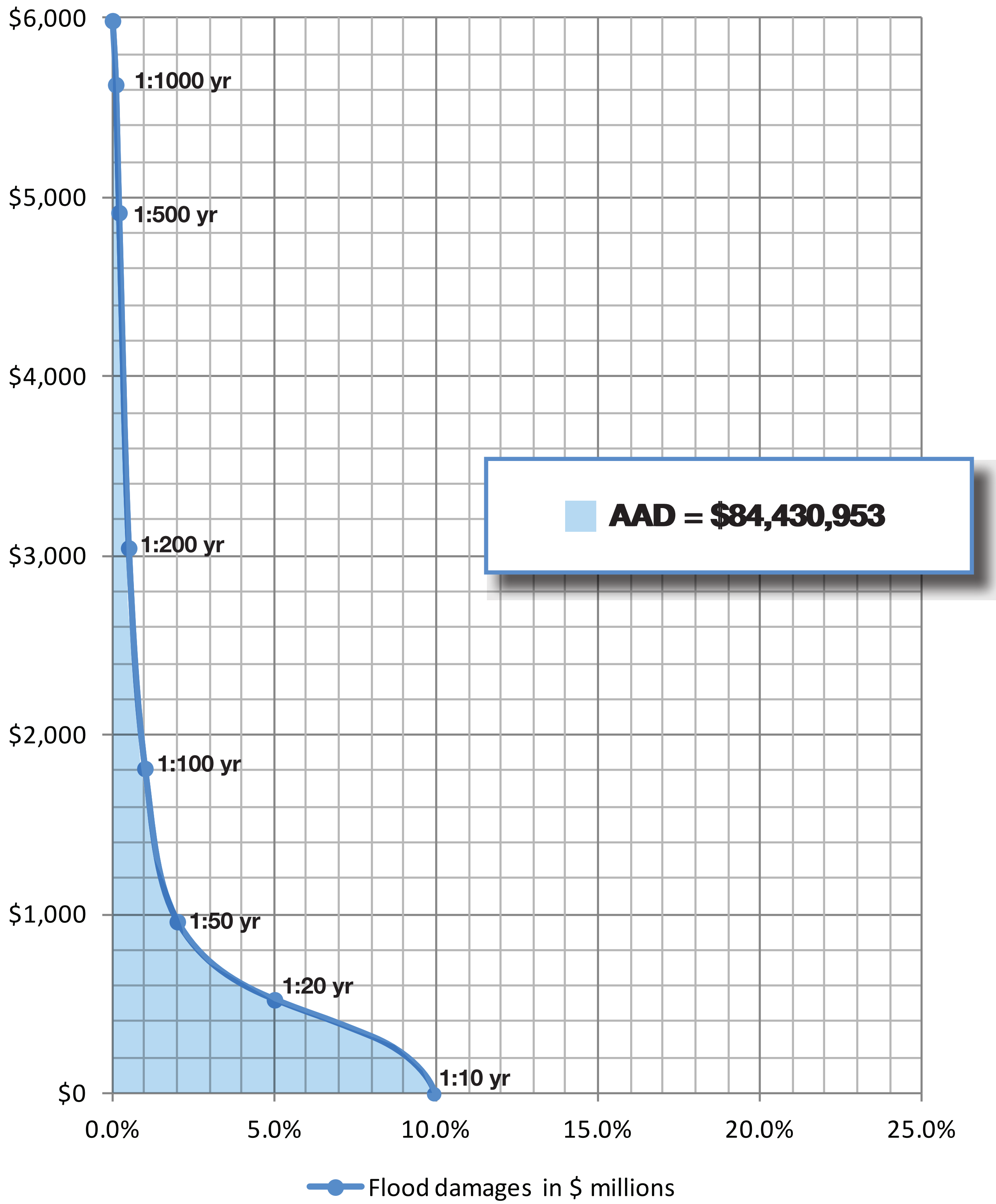
* No Actual damages occur at these flow levels
** Flood Flow primarily contained within the river

Total Damages, Elbow River, With Sewer Backup

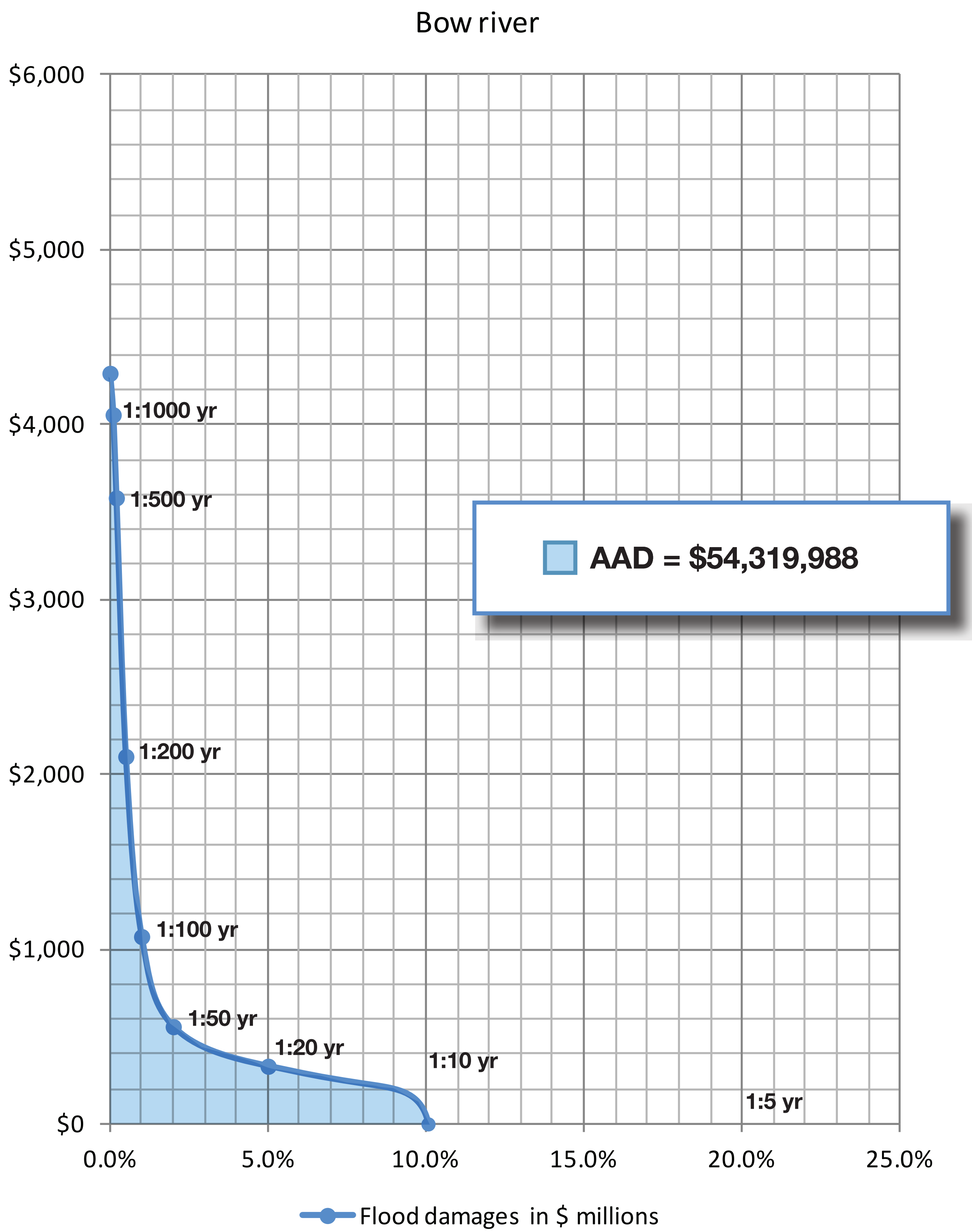
Categories of damage		Return frequency, in years								
		2 *	5 *	10 * *	20	50	100	200	500	1,000
Residential	Direct	$0	$0	$0	$101,015,000	$167,249,000	$299,716,000	$365,304,000	$437,966,000	$505,053,000
	Indirect 15%	$0	$0	$0	$15,152,000	$25,087,000	$44,957,000	$54,796,000	$65,695,000	$75,758,000
	Total	$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

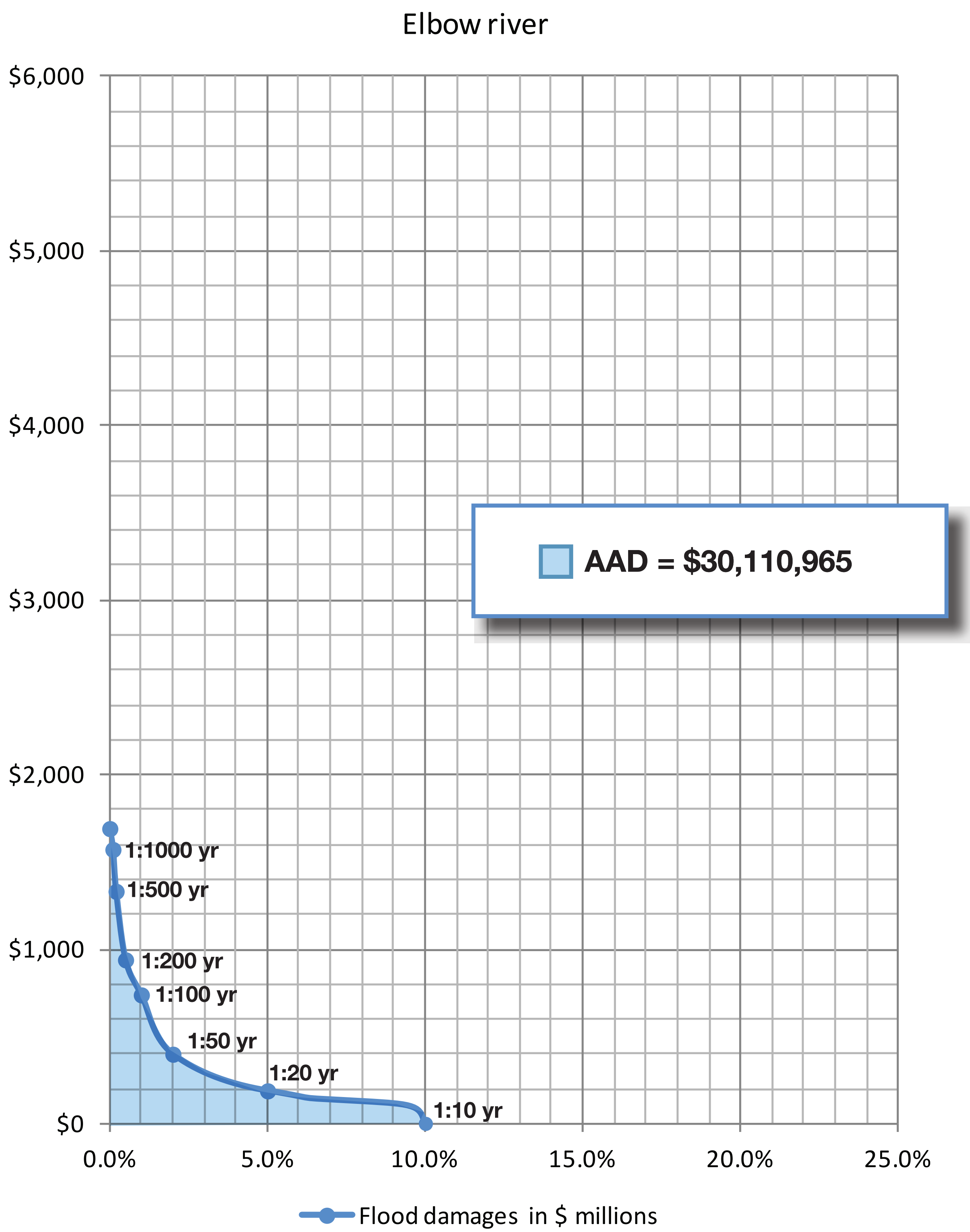
Flood Damages Probability Distribution, Bow and Elbow Rivers



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

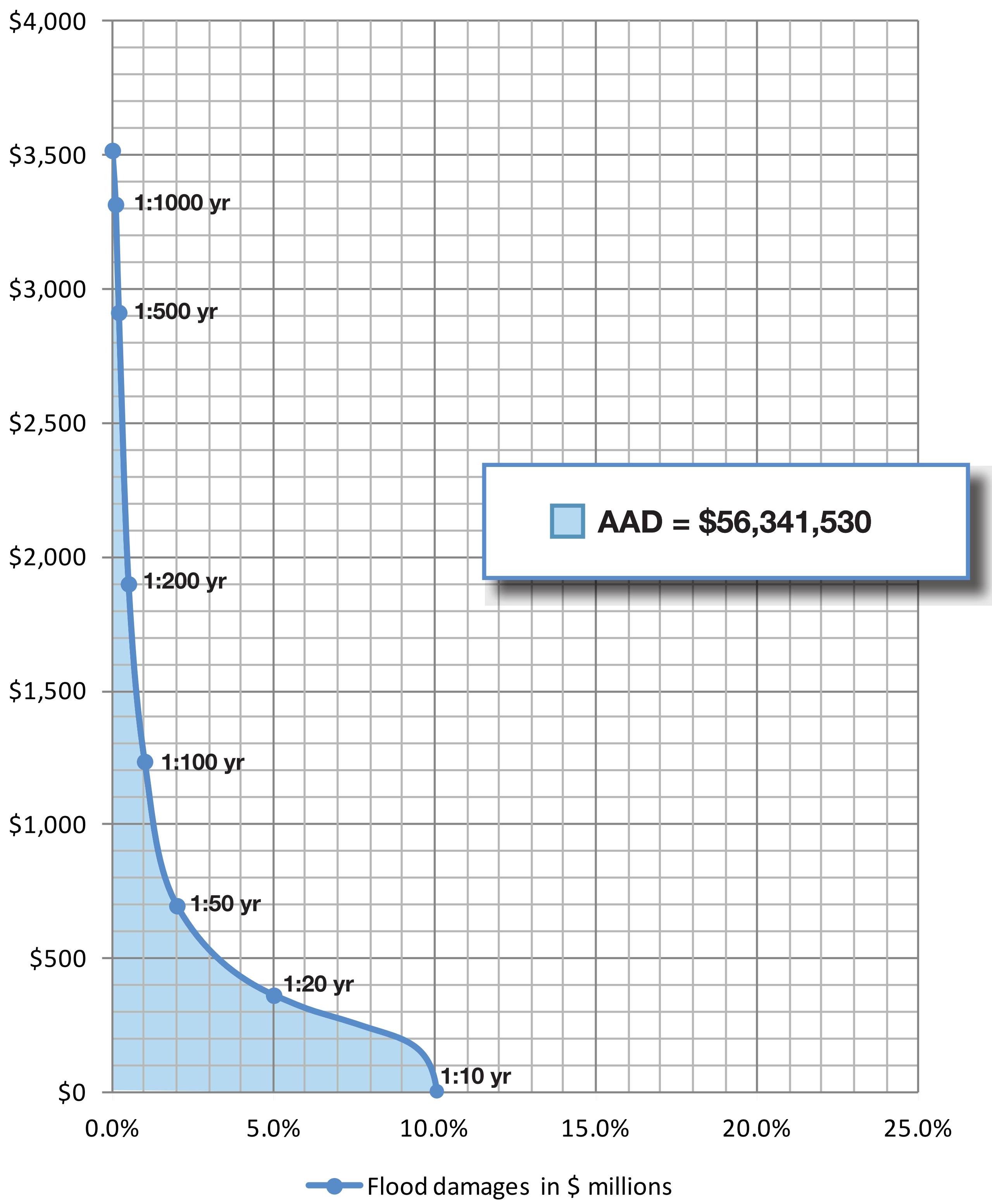
* No Actual damages occur at these flow levels
** Flood Flow primarily contained within the river

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

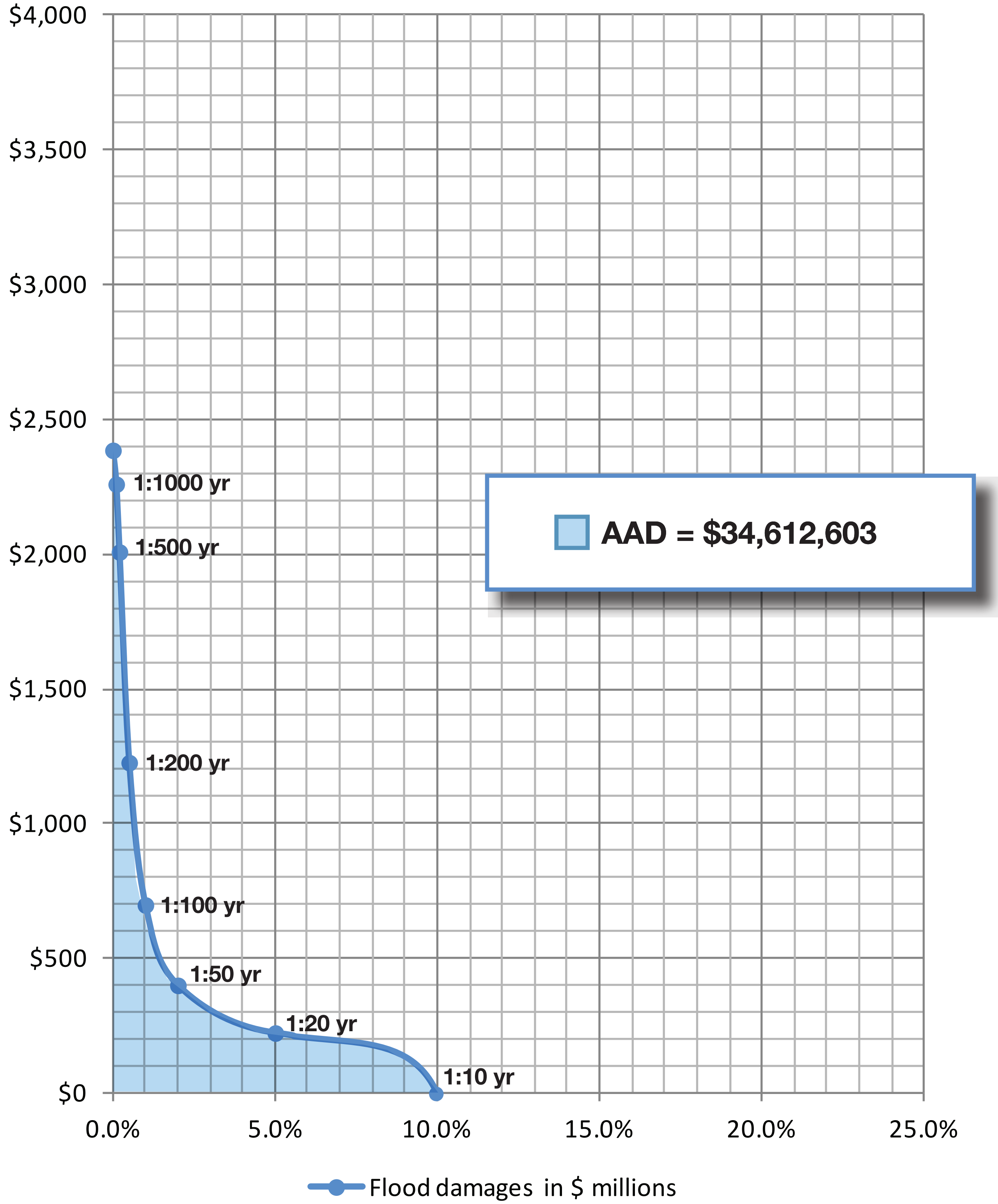
Categories of damage		Return frequency, in years								
		2 *	5 *	10 **	20	50	100	200	500	1,000
Residential	Direct	$0	$0	$0	$101,015,000	$167,249,000	$299,716,000	$365,304,000	$437,966,000	$505,053,000
	Indirect 15%	$0	$0	$0	$15,152,000	$25,087,000	$44,957,000	$54,796,000	$65,695,000	$75,758,000
	Total	$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

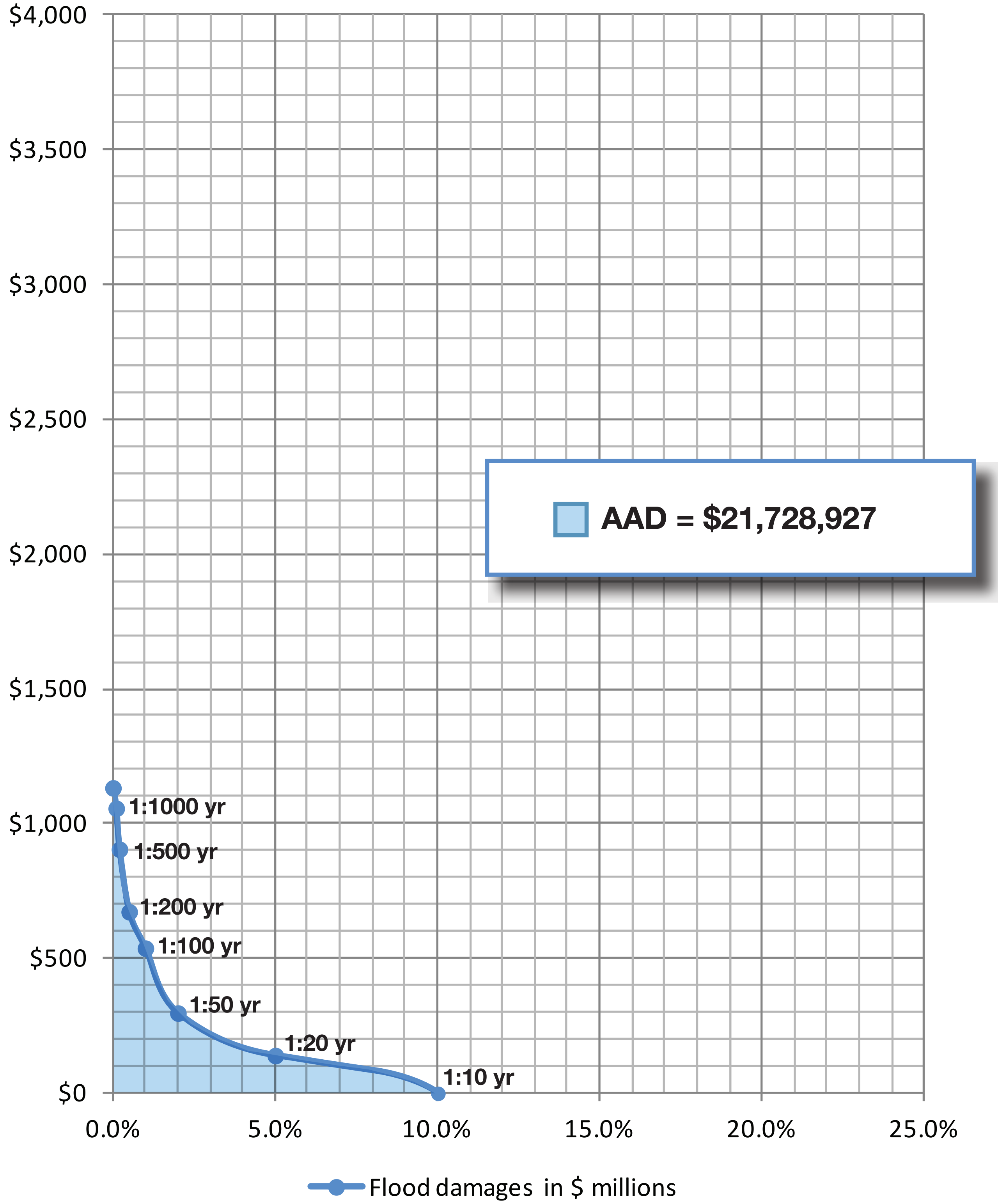
Alternative Damage Scenario - Flood Damages Probability Distribution, Bow and Elbow Rivers



Alternative Damage Scenario - Flood Damages Probability Distribution, Bow River



Alternative Damage Scenario - Flood Damages Probability Distribution, Elbow River



Appendix C – Southern Alberta Disaster Recovery Program

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					$1,083,770.00	

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

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**