IBI

GOLDER

Alberta

Photo: Flatiron Building, RETROactive

Photo: thelacombecityhallblog.blogspot.com

Photo: Karlie Marrazzo

Report #112835

Provincial Flood Damage Assessment Study – City of Lacombe: Damage Estimates

Submitted to Alberta Environment and Parks
by IBI Group and Golder Associates Ltd.
March 2019

Alberta Government

Provincial Flood Damage Assessment Study – City of Lacombe: Damage Estimates

IBI

GOLDER

Prepared for Alberta Environment and Parks
by IBI Group and Golder Associates
March 2019

Table of Contents

Table of Contents (continued)

Executive Summary

Introduction

Background

Flood damage estimates are required for evaluating the cost effectiveness of projects designed to alleviate flood impacts. In 2014, IBI Group developed the Provincial Flood Damage Assessment Tool (PFDAT) for the Province of Alberta. This tool enables the standardized calculation of flood damages for varying levels of inundation within a community.

Purpose and Scope

The purpose of this project is to use the PFDAT to develop community-specific damage models for different flood frequencies for the City of Lacombe. The scope is as follows:

a. Updating of residential, commercial, and industrial synthetic depth-damage curves to current economic values.

b. Updating of adjustment indexes for use in Lacombe.

c. Creation of an inventory of all structures located in the flood hazard area.

d. Application of the PFDAT to this inventory to develop community-specific damages for different flood frequencies.

e. Application of the PFDAT to damage models where mitigation is in place.

f. Preparation of a final risk assessment report for each community describing direct and indirect damage for various flood frequencies, as well as damage estimates for mitigation scenarios, both working and failing.

Methodology

Direct Damages

Damages for residential, commercial, and industrial units are estimated by employing the updated synthetic depth-damage curves developed for general usage in Alberta in combination with community-specific property and flood elevation data.

Each building was coded for use class, structure type, main floor area, presence of basement or underground parking, main floor elevation from grade, and elevation of grade at the building.

The source of flood elevation data for the Lacombe study was the Lacombe Flood Risk Mapping Study, prepared by Alberta Environmental Protection in 1996 as part of the Canada-Alberta Flood Damage Reduction Program.

Indirect Damages

Indirect damages are additional costs beyond the physical damage to property that arise as a result of flooding. This includes residential displacement and business interruption. There is also an increasing awareness of the severity of intangible costs such as stress, anxiety, and community disruption. These costs have typically been acknowledged and applied as a percentage of direct damage. For this study, additional depth-damage functions were created for business interruption and residential displacement. Intangible costs were assigned per household with direct damage based on the results of willingness-to-pay studies.

City of Lacombe

Background

The City of Lacombe is located in central Alberta, approximately 25 km north of Red Deer. Lacombe lies within the Battle River watershed, which is part of the larger Saskatchewan River Basin. Flooding concerns in the area arise from Wolf Creek, much of which runs adjacent to the Canadian Pacific Rail line along the southeast portion of town.

History of Flooding

Flooding of Wolf Creek in the City of Lacombe typically occurs in the open water season, either as a result of spring runoff in March and April, or from heavy rainfall events in June and July. Prior to channelization, Wolf creek had a history of overtopping its banks, particularly in spring runoff events. The channelization was intended to reduce the frequency and duration of such events on adjacent agricultural land, but is only effective for up to 1:5 year flows.

Stormwater flooding has been an issue in Lacombe when heavy rain events exceed the capacity of the sewer system. Concurrent high creek levels could exacerbate this issue. Ice jam flooding does not appear to be a problem in Lacombe.

Floodplain Mapping

The 1996 Flood Hazard Identification Study mapped the 1:100-year open water flood on Wolf Creek. This map can be found in Appendix A. For the purposes of this study, open-water flood elevation mapping for all return periods provided were create to show where the flood elevation was higher than grade. The flood elevation was obtained by extending the cross sections from the 1996 study and producing a surface between them. The grade elevation was obtained from the bare-earth digital elevation model provided by Alberta Environment and Parks. The results of this mapping is contained in Appendix D.

Inventory of Buildings

Within the Lacombe study area, a total of 471 buildings were classified, 156 of which were non-residential and 315 of which were residential. Of the residential buildings, only one was an apartment-style building. There were no mixed-use buildings with classes differing between the main floor and upper floors.

Damage Estimates

The flood damage estimates reflect total potential damages for the various return periods. Damages are presented as being caused by overland flooding and sewer backup/groundwater flooding. Overland flooding is caused when the modeled river flood elevation is greater than that of the ground surface.

Sewer backup or groundwater flooding is caused when the modeled flood elevation is below the ground surface, within 75 m of overland flooding, at the location of a basement. Sewer backup can occur when the river rises and enters the system or causes groundwater infiltration. High groundwater during a flood may also directly infiltrate basements through foundation walls or penetrations.

Total damages for each return period are summarized in Exhibit 3.11.

Exhibit 3.11: Total Damages

Damage Category		Return Frequency, in Years			
		2	10	50	100
Residential	Direct Overland	$0	$2,206,760	$5,426,324	$6,685,288
	Indirect Overland	$0	$702,949	$1,473,558	$1,759,905
	Direct Sewer/ Groundwater	$851,646	$8,362,823	$16,634,183	$17,120,332
	Indirect Sewer/ Groundwater	$232,985	$1,931,180	$3,835,888	$3,813,065
	Subtotal	$1,084,631	$13,203,712	$27,369,953	$29,378,590
Non-Residential	Direct Overland	$0	$375,756	$1,009,749	$2,264,770
	Indirect Overland	$0	$301,974	$926,240	$2,074,107
	Direct Sewer/ Groundwater	$0	$3,789	$232,708	$625,264
	Indirect Sewer/ Groundwater	$0	$0	$0	$0
	Subtotal	$0	$681,520	$2,168,698	$4,964,141
Infrastructure		$0	$445,484	$1,110,223	$1,543,885
Flood Fighting and Emergency Response		$0	$129,126	$257,443	$358,002
Total	Direct Overland	$0	$3,028,001	$7,546,295	$10,493,943
	Indirect Overland	$0	$1,129,030	$2,637,064	$4,188,188
	Direct Sewer/ Groundwater	$851,646	$8,366,611	$16,866,892	$17,745,596
	Indirect Sewer/ Groundwater	$232,985	$1,931,180	$3,835,888	$3,813,065
	Total	**$1,084,631**	**$14,454,823**	**$30,886,140**	**$36,240,791**

Average Annual Damage

Average Annual Damage (AAD) is the cumulative damage occurring from various flood events over an extended period of time, averaged for the same timeframe. The AAD is obtained by calculating the area under a damage-probability curve, which depicts total damage versus probability of occurrence.

The unmitigated total potential flood damages amount to $5.3 million in AAD. Of this, approximately $3.7 million is a result of sewer backup or groundwater infiltration risk. The relatively high proportion of sewer backup or groundwater damage amounts indicates potential vulnerability for basement flooding as a large number of homes have developed space below adjacent overland flood risk.

The flood damage estimates and associated AAD for overland and groundwater flooding presented in this report illustrate the potential risk due to modelled flood elevations. These estimates can be used to prioritize mitigation efforts or serve to illustrate the value of maintaining current infrastructure, such as stormwater outfall gates, as well as homeowner awareness about basement flooding potential. Most importantly, the PFDAT methodology provides a consistent basis for assessing flood risk and mitigation projects across the province.

Damages with Mitigation

At this time, the City of Lacombe does not have any flood mitigation in place, nor does the City have any plans for flood mitigation measures. As such, no calculations were performed to weigh the benefits and costs of any such mitigation.

1 Introduction

1.1 Background

Flood damage estimates are required for evaluating the cost effectiveness of projects designed to alleviate flood impacts. In 2014, IBI Group developed the PFDAT for the Province of Alberta. The PFDAT enables the standardized calculation of flood damages for varying levels of inundation within a community. This is accomplished by employing three sets of data: inundation damage curves; community-specific property data; and community-specific flood elevation data.

The PFDAT permits comparative benefit/cost analyses of proposed flood mitigation measures to be performed within communities for which the community models have been developed.

The original Provincial Flood Damage Assessment Study can be found at the following link:

https://open.alberta.ca/publications/7032365

1.2 Purpose

The purpose of this project is to use the PFDAT to develop community-specific damage models for different flood frequencies for Lacombe.

1.3 Scope and Deliverables

a. Updating of residential, commercial, and industrial synthetic depth-damage curves to current economic values.

b. Updating of adjustment indexes for use in the flood prone community.

c. Inventory of all structures located in the flood hazard area (private and publically owned).

d. Application of the PFDAT to develop community-specific damage models for different flood frequencies.

e. Application of the PFDAT to estimate damage reduction where mitigation is in place.

f. Preparation of a final risk assessment report for each community describing direct and indirect damage for various flood frequencies and mitigation scenarios.

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.

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 keep study costs within reason.

In a first principles approach, damages for residential, commercial, and industrial units are estimated employing updated depth-damage curves developed for general usage in Alberta. In the absence of actual damage costs for each event in a community, synthetic depth-damage functions are the standard approach based on repair estimates for various flood levels within a typical structure for each category. Content damage functions are based on a statistically significant survey of Alberta households.

On an ongoing basis, curves are indexed to current values employing Consumer Price, Household Expenditure, and Construction Cost indexed 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 business income due to disruption of business activities and transportation routes
- Administrative costs
- Flood fighting costs
- General inconvenience
- Stress and anxiety

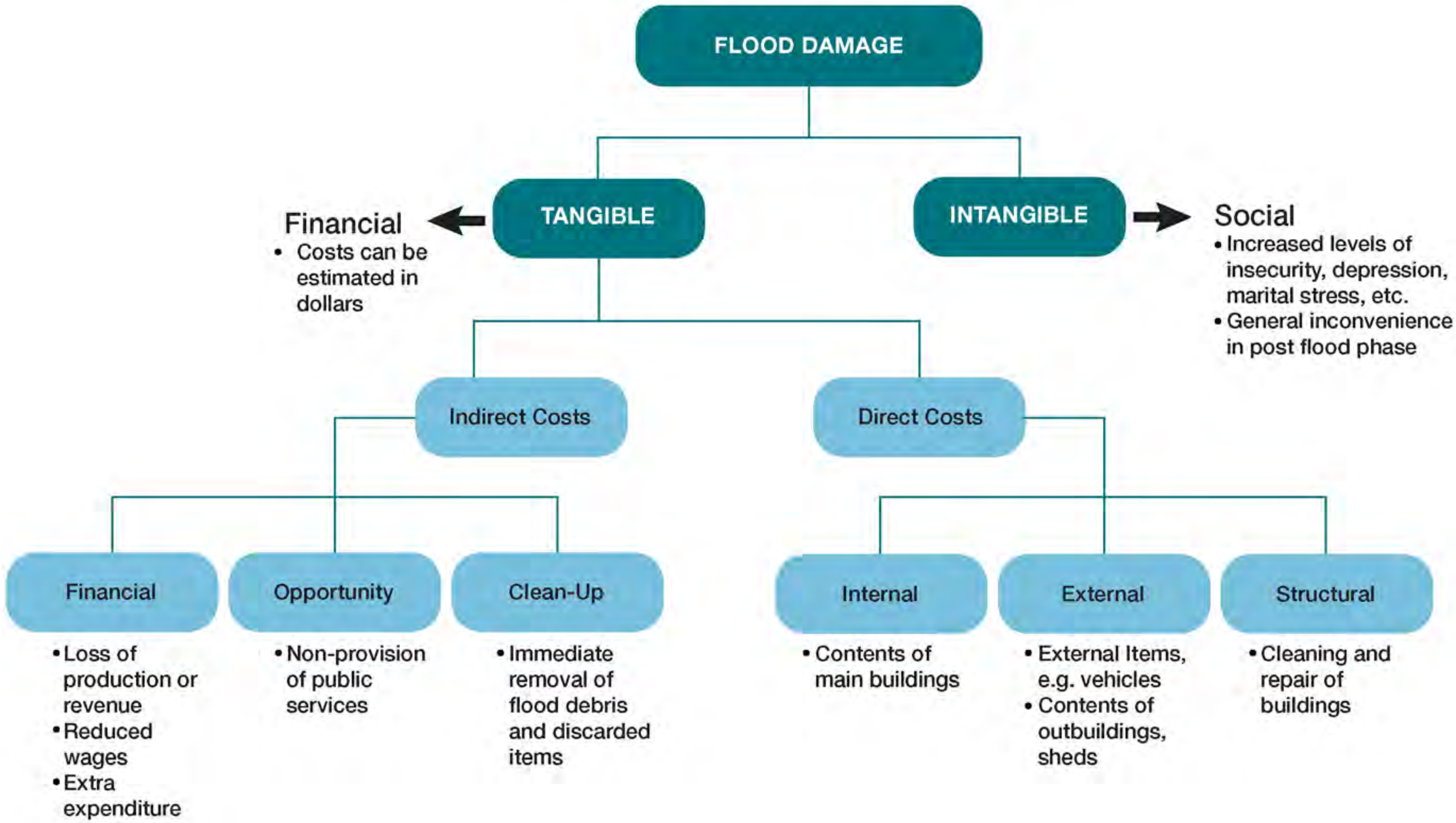
Finally, and most importantly, flooding may represent a threat to human life and well-being, not only for those residing directly within the floodplain, but also for those individuals who may work within the area as well as those volunteers and professionals who are involved in flood fighting activities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

Types of Flood Damage



- 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.

The source of flood elevation data for the Lacombe study was the Lacombe Flood Risk Mapping Study, prepared by Alberta Environmental Protection in 1996 as part of the Canada-Alberta Flood Damage Reduction Program. (See **Appendix A** for the 1:100-year flood hazard mapping from that study).

GIS cross-sections and bare-earth DEM elevations were provided by Alberta Environment and Parks. The DEM source was 1 meter resolution bare earth LiDAR collected in 2007. Golder Associates prepared flood elevation surfaces and inundation extent polygons based on the elevations in the cross section files for each return period (1:2, 1:10, 1:50, and 1:100-year floods). The cross-sections were extended, where necessary, to fully cover the study area.

2.3 Floodway/Flood Fringe

The accompanying exhibits (**Exhibit 2.2** and **Exhibit 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: Aerial View of Flood Hazard Area (Alberta Environment and Parks, 2017)

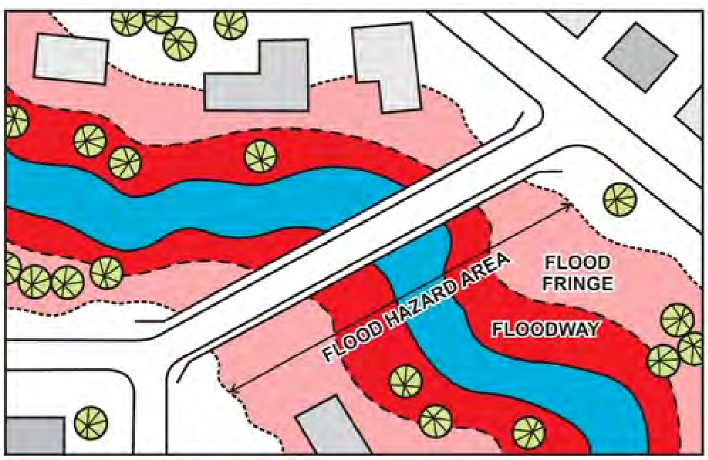
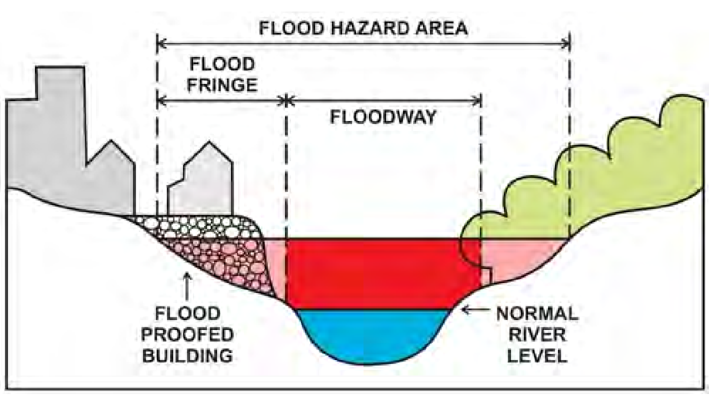


Exhibit 2.3: Cross-Section of Flood Hazard Area (Alberta Environment and Parks, 2017)



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 overland inundation edge for each return period. Essentially, with the sewer backup condition, basements with floor elevations lower than the floodwaters are susceptible to sewer backup and will generate damages in this model. Basement flooding in areas adjacent to overland flooding is a common occurrence in Alberta. Particularly for less frequent floods that overtop the banks, basements can flood directly from groundwater seepage or infiltration of storm and sanitary lines. **Exhibit 2.4** depicts this relationship. Determining the influence of floodwaters on groundwater and infrastructure in Lacombe is beyond the scope of this study. Therefore, this is a conservative approach, illustrating the potential damages to property that is below the flood elevation.

2.5 Direct Damage Estimates

For the purposes of computing direct damage estimates for the study area all residential, commercial, industrial, and institutional structures within the identified flood hazard area are inventoried and damages computed employing the PFDAT developed specifically for Alberta. The inventory was compiled as described below.

2.5.1 Creation of the Building Inventory

Along with the depth-damage functions and a flood elevation table, the building inventory is one of the major inputs for the PFDAT program. In addition to the location and identifying attributes, the building inventory must, at a minimum, contain the following information for each building or parcel to be assessed:

- Use classification
- Structural classification
- Main floor area
- Presence of basement or underground parking
- Main floor elevation relative to grade
- Elevation of grade at building

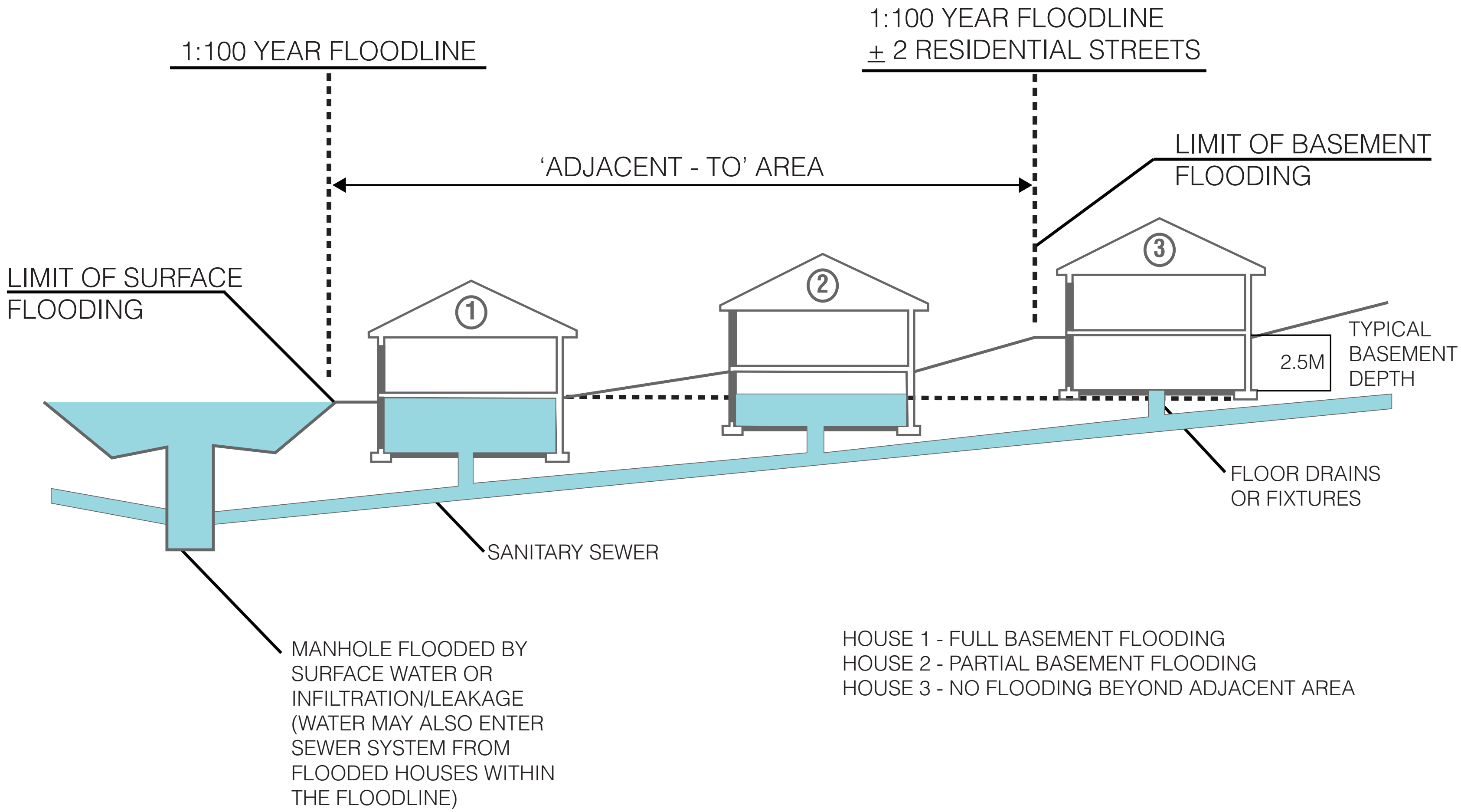
2.5.1.1 Data Sources

Available data included building and parcel shapefiles provided by the City of Lacombe, high resolution orthophotos, and Google Street View verification. The building footprint shapefiles did not contain all buildings in the study area so additional buildings were added in GIS using the orthophotos as a base-map.

2.5.1.2 Populating the Inventory Fields

To facilitate the visual classification of buildings, IBI Group has developed a tool that allows entry of building attributes directly from Google Earth. The shapefile was converted to a KML file, a file suitable for importing into Google Earth Pro. In that file, one of the fields contains HTML code that creates a pop-up portal with the required fields when a user clicks on a building. The Google Earth tool is illustrated in **Exhibit 2.5.**

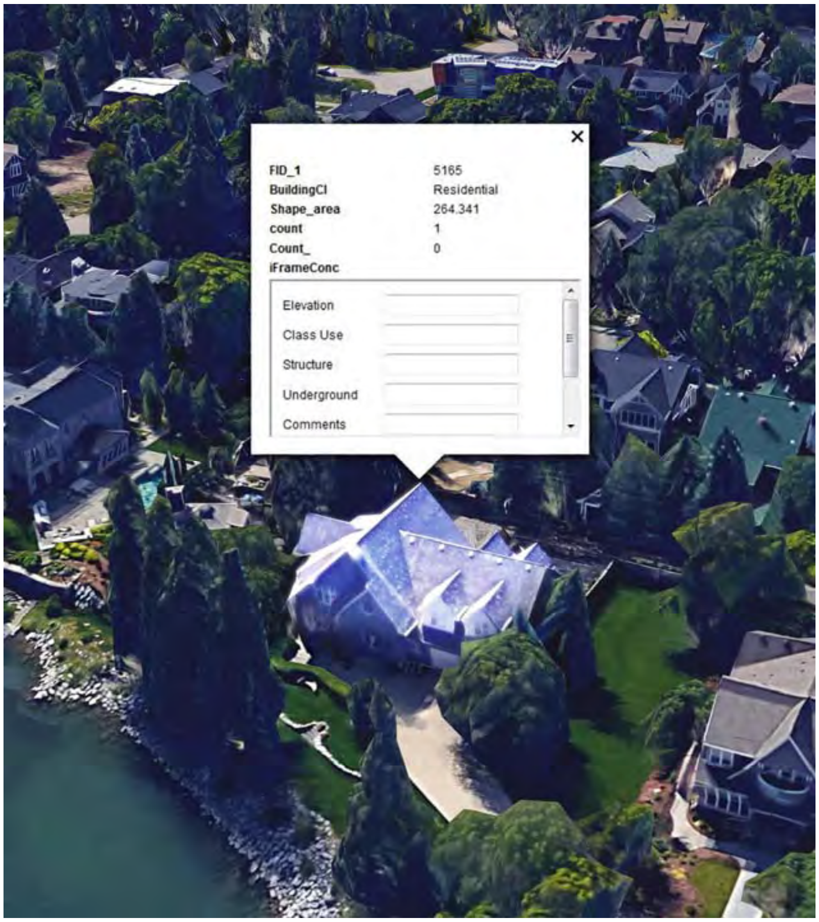
Adjacent-To Area Definition Diagram



HOUSE 1 - FULL BASEMENT FLOODING
HOUSE 2 - PARTIAL BASEMENT FLOODING
HOUSE 3 - NO FLOODING BEYOND ADJACENT AREA

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

Exhibit 2.5: Building Classification Tool in Google Earth



The following fields were used for this study:

- *Elevation*: the height of the main floor from grade
- *Class*: the use according to depth-damage curves. (See **Appendices B & C**)
- *Structure*: the structure type according to the depth-damage curves
- *Number of units*: the total number of residential dwelling units on the main and upper floors. This is used for the residential displacement function when a unit count is not available from assessment data
- *Number of storeys*: the number of commercial floors. This is used for the business interruption function
- *Basemen*t: "Yes" or "No" for the presence of a basement or underground parking
- *Comment*s: this is for special notes relating to the building, such as the need for further verification. Some buildings were obscured or otherwise difficult to assess in this manner due to trees or shrubs, locations behind other buildings or on private roadways, or construction activity.

2.5.2 Updating Stage-Damage Curves to Current Values

All synthetic depth-damage curves were updated to 2017 economic values using IBI Group's flood-specific methodology. As part of the 2014 Provincial Flood Damage Assessment Study, custom indexes were developed in recognition that existing commonly employed indexes were not sufficient to account for the specific type of damages caused by residential flooding. This custom index uses the Survey of Household Spending (SHS) to capture changes in content value more realistically than the Consumer Price Index (CPI), which measures goods of unchanging quality.

The original depth-damage curves were created using 2014 prices (see **Appendix C**). The SHS is annual but current-year results are not available. The 2017 survey was released December 12, 2018.[1] The Alberta values from this survey were used to update the residential content damages. Specific spending categories were weighted according to the distribution of contents that comprise the depth-damage curves. Non-residential content values were adjusted using the CPI special aggregate "Goods" for Alberta.[2]

Structural curves were updated using current construction price indexes specific to the type of building, accounting for price changes in materials, labour, overhead and profit. Construction price indexes are published quarterly by Statistics Canada. For both residential (building only) and non-residential construction, the Calgary price indexes indicate a slight reduction in costs compared to 2014.[3]

2.5.3 Updating Adjustment Indexes by Location

In addition to changes in time, there are regional variations across Alberta markets. Accordingly, IBI Group developed a spatial index for adjusting flood-specific residential content costs throughout the Province. As with the adjustments between years, a flood-specific "basket of goods" and weighting were used.

Government of Alberta Treasury Board and Finance publishes the Alberta Spatial Price Survey approximately every five years. The most recent survey was released in November 2016 containing prices from the spring of that year. The study compares the price of various goods across Alberta communities with a methodology similar to how the CPI compares goods across time. Lacombe was not included in the survey, so values for the City of Red Deer were taken instead. The results from Calgary and Red Deer were weighted and then indexed to produce a multiplier for the City of Lacombe.

Construction costs also vary between locations based on labour markets and material availability. However, there are no regularly published surveys for Alberta communities. Structural damages were adjusted according to the latest location factors from available sources including Alberta Infrastructure, the Alberta Disaster Recovery funding formula, and IBI Group's extensive industry experience in Alberta.

Exhibit 2.6 summarizes the combined spatial and temporal indexes used to apply the 2014 Calgary depth-damage curves to Lacombe.[4]

Exhibit 2.6: Lacombe Indexes

Category	Index
Residential Contents	0.9620
Non-Residential Contents	0.9821
House Structure	1.0241
Apartment Structure	1.0446
Office Structure	1.0268
Retail Structure	1.0270
Industrial Structure	1.0062
Institutional Structure	1.0282

1 http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3508
2 Statistics Canada Table 326-0021 Consumer Price Index, annual
3 Statistics Canada Table 327-0044 Price indexes of apartment and non-residential building construction, by type of building and major sub-trade group, quarterly & Table 327-0056 New housing price index, quarterly
4 In some instances, where local data were unavailable, data for Red Deer were substituted.

2.5.4 Infrastructure Damages

Infrastructure damages (such as highways, bridges, railroads, and utilities) are typically determined by the Municipality, or if unavailable, can be determined as a percentage of direct damages applied to represent potential damages to infrastructure. Infrastructure damages would also include property that is not represented by a building with a depth-damage function, such as campgrounds or golf courses. Specific damage amounts for Lacombe infrastructure were unavailable and a value of 17.25% of direct overland damages was used for this study. This amount is in the middle of the accepted range of damages based on a review of the proportion of structures and flooded land in the developed area.

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; and general inconvenience. 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, accounting for substitution and transactions that are merely delayed. 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 of direct damages. The ratios are chosen based on a review of the literature, empirical evidence, and expert opinion. For indirect damages that are associated with buildings, such as business disruption and residential displacement, another approach is to develop synthetic depth-damage curves.

2.6.1 Business Disruption Damage Curves

Businesses in buildings impacted by a flood will experience disruption of their normal operations. This may occur due to damage to the business' structure, equipment, and inventory; or because they have no access due to evacuations, road closures, or loss of utility services. The impact of a major flood event on businesses is complex and varied.

The major indirect loss results from disruption of business activities during the flood and restoration process. Estimating these tangible damages is described in the following sections. Other factors that may contribute to business losses are variable, such as the cost of loans vs. relief funds, or the relationship of the business to the specific location (foot traffic and attractions, among others) or to other affected services and suppliers.

2.6.1.1 Loss as Function of Productivity and Duration

Monetary business disruption losses can be modeled as loss of economic flows for a certain duration. Lost sales, revenues, or profits can be the most relatable indicator of impact and it is common to see reference to such figures; however, downtime reduces expenses, as well as profits. Sales, profits, and expenses are components of value added, which is a better measure for the net of flows in a company (FEMA, 2015).

A key principle of damage evaluation is to avoid summing stock and flow values. Doing so could be double counting because the value of a capital good is the present value of the income flow it generates over the rest of its useful life; however, in the case of a temporary business interruption, the loss of stocks (equipment, inventory), and the loss of flows (productivity during the interruption) can be summed because they each represent different components of damages (Messner, et al., 2007). Labour productivity is the ratio between an industry's value added and hours worked. It thus allows loss to be measured by duration.

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 in response to the flood, however, all industries except utilities and public administration experienced a net loss during those two weeks. In September 2013, the Government of Alberta issued an 'Economic Commentary' using this information as a basis for estimating business losses that were experienced. An estimate of GDP lost by the private sector was made using each industry's 2012 labour productivity amount multiplied by the industry's lost hours. The resultant loss estimate amounted to $485 million in 2007 dollars.[5]

While the estimate based on the labour force survey is informative, it does not provide a readily repeatable method and may not accurately reflect actual loss. Offices do not operate like a factory and the temporary closure of offices would not cause shutdown of related production. Using only the hours from such a survey does not consider time made up or work otherwise caught up after the flood. On the other hand, small businesses such as retail and restaurants that suffered direct inundation of their buildings would certainly experience loss for a greater period of time than the survey would capture.

With productivity and restoration time assumptions detailed below, a business interruption depth-damage curve was created and applied to each commercial building in the study area.

2.6.1.1.1 Productivity Values

Statistics Canada provides hourly labour productivity per worker for various industry classifications at the provincial level.[6] Daily productivity per square metre of floor area can be determined by dividing the employee productivity amount by the typical floor area per employee and then multiplying by the daily operating hours, as detailed in **Exhibit 2.7**.

Exhibit 2.7: Daily Productivity per Square Metre

Classification		m^2 per Employee	Productivity ($/hour)	Operating Hours/Week	Productivity/ Day/m^2
A1	General Office	23	$98.44	45	$20.72
C7	Retail	33	$35.11	65	$9.88
I1	Restaurant	33	$23.48	80	$8.13
L1	Warehouse/Industrial	70	$66.50	65	$8.82

The General Office productivity value for Lacombe was calculated as a weighted average based on the labour force composition of the town from the National Household Survey. The number of workers in each industry was multiplied by that industry's productivity value. The sum of those values was then divided by the total number of workers. Statistics Canada publishes productivity in chained base-year dollars. To express these in current dollars, the latest Implicit Price Deflator (provided quarterly) is used.[7]

Productivity is not a measure applied to the public sector. Damages associated with buildings identified as public (i.e., schools, government offices, and hospitals) should be considered as part of intangible impact evaluation.

[5] Statistics Canada publishes the productivity figures in a chained Fisher index, with 2007 as the base year.
[6] Statistic Canada CANSIM Table 383-0033: Labour productivity and related measures by business sector industry and by non-commercial activity consistent with the industry accounts, provinces and territories
[7] Statistics Canada CANSIM Table 380-0066 Price indexes, gross domestic product.

2.6.1.1.2 Duration of Business Disruption

An effective business interruption period was estimated using the building restoration time along with assumptions about the maximum business interruption time and the percentage of partial recovery at that time.

Building Restoration

Few methods of determining the average length of disruption have been suggested in the literature. Analysis of past events also indicates that restoration times vary greatly and are generally influenced by factors not directly attributed to flood damages such as additional improvements, changes, and pre-existing deficiencies. As with the direct damages, it is important to only consider the restoration to a previous state of operations.

One German study utilized telephone surveys among businesses in the Elbe and Danube catchments in 2003, 2004, and 2006 to determine mean interruption times. The study found that a water level of 20 cm led to a disruption of 16 days, and a depth of 150 cm led to a disruption of 59 days (Kreibich & Bubeck, 2013); however, the specific types of industries surveyed in the study are unknown. In the United States, FEMA's Hazus model contains tables for flood restoration time by building type. For retail trade, depths of zero to 1.2 m of floodwater indicate a rather large range of restoration times of between seven to 13 months. A flood level of several centimetres could be recovered from in much less than seven months. Furthermore, FEMA's total maximum reconstruction times range from 12 to 31 months. If a building required 25 months to rebuild, most businesses would be able to relocate and return to operations sooner. In another FEMA document, the business disruption days are provided in a table for each foot of flood depth.[8] It is a simple linear function, equating to 45 days per 30 cm of water. This is a more reasonable estimate when applied to lower levels of flooding, such as a nine-day disruption for six cm of floodwater.

For each building type, an estimated average restoration time was determined. For standard office and retail buildings it was assumed to be 150 days per metre of flooding. Warehouse and industrial buildings were assumed to have a shorter restoration period of 100 days per metre.

Business Loss Adjustments

The actual duration of complete productivity loss is not necessarily equal to the building restoration period. A maximum business interruption time must be assumed at which point a business would have logically relocated rather than wait for an extended building restoration period. Additionally, there may be partial business recovery within the maximum interruption time. If a business' space takes seven months to fully restore, its component resources, including staff, are unlikely to be completely lost to the economy for the entire period. A flood event is a disruption of operations, after which complex adjustments and alternate activities take place during recovery.

The loss of productivity decreases as the disruption time increases. The building disruption time variable was modified to produce a value for total business loss during the recovery process. Productivity days lost (*L*) for a building recovery period of *n* days was calculated as:

$$L = n \times (1 - \frac{n}{\left(\frac{d}{p}\right)})$$

Where *d* is the maximum number of disruption days; and *p* is the percentage of the maximum recovered productivity. **Exhibit 2.8** illustrates the results of this method with the following assumptions for a building type:

- The maximum business interruption period (*d*) is 240 days.
- At 240 days, 20% of previous productivity (*p*) will have been recovered.

[8] FEMA Benefit Cost Analysis Tool (v 4.5.5), 2009.

Exhibit 2.8: Building Restoration to Business Disruption Relationship

Building Restoration Days	Productivity Lost Days	Productivity/Building Loss Days
5	5	100%
151	132	87%
240	192	80%
300	192	64%

Office work is not as dependent on the physical space as a retail or manufacturing establishment. The work conducted in an office may be related to production outside the flood-affected area. It is also possible for many types of office work to be completed at another location, for example, working remotely or at another office location. To account for this, the overall productivity loss for an office closure was reduced. In Lacombe, no additional reduction due to office vacancy was considered.

In multi-storey buildings the impact on a retail business at ground level would be different than on an upper floor office. The retail business may suffer a disruption time of several months, while workers in an upper office may be able to return to the office in a matter of days if the utilities are restored and the lobby area deemed safe. Therefore, disruption times were also estimated for building space that has not been directly flooded (upper floors, evacuated buildings with no damage, and parkade damage only). It is normally not feasible to classify uses in upper floors so the blended general office productivity values were used. The floor area of the upper floor was estimated during the building inventory classification process.

2.6.1.2 Incorporation in Damage Model

The depth to productivity days lost estimates were combined with the daily productivity per-square-metre to create damage curves for each commercial use classification. To account for potentially different disruption times on upper floors, an additional curve is created for upper level office space. Costs associated with commercial buildings that are only evacuated (and not flooded) are not computed in the damage model.

2.6.2 Residential Displacement

Structural damage from floodwaters, loss of critical services, or lack of access due to evacuation and road closures can all lead to residential displacement. During and after a flood event, affected residents will have to find alternative accommodations and incur extra personal expenses. Expenses may include restaurant meals, daily essentials, hotel costs, and extra fuel. Residents of buildings that require substantial repairs will require alternative accommodation for a longer period and incur costs for moving and rent.

Residential displacement costs are not often explicitly estimated in flood damage assessments but the required assumptions are relatively straightforward. This section outlines the creation of depth-damage curves for the tangible costs of residential displacement. The intangible impact on houses is another aspect of displacement that is covered in Section 3.7.

2.6.2.1 Costs

Residential displacement costs are those that would not normally be incurred and are associated with the inability to return home for a period during and after a flood. Individual circumstances will have a great effect on the nature and amount of these costs. However, general assumptions about the population are made in order to estimate total costs.

The following is an example of the assumptions made to estimate the costs per household:

- Half of displaced households will find accommodation with friends, family, or a shelter.
- The costs associated with public shelters is included in the emergency operations calculation, and the costs associated with staying with friends and family is negligible.
- The remainder of households will spend up to 14 days in a hotel. Average daily hotel room costs in Lacombe are assumed to be $120.
- During the first 14 days, each individual will spend an extra $50 per day.
- The number of people per household is 2.6.[9]
- Households requiring alternate accommodation beyond 14 days will rent another unit of the same type. The average regional market rent for apartments and houses is assumed to be $876 and $1,295, respectively.[10]
- A one-time moving expense of $500 per household is included for households requiring accommodation beyond 14 days.

2.6.2.2 Displacement Period

Displacement times can vary greatly between buildings with similar inundation levels. As discussed above in regards to business interruption, the reconstruction process generally involves much more than restoring a building to its previous state.

Data on unofficial secondary suites in Lacombe was not available, but it is assumed that the majority of finished basements do not contain essential living spaces, such as kitchens, and a home with minor basement flooding will be largely inhabitable during its restoration. Basement flooding over 50 cm may affect electrical and mechanical equipment, and having an inspection completed can take longer than completing the actual repairs.

For multi-family units not directly damaged, restoration of electricity and life-safety systems determine the displacement duration. However, availability of specific mechanical equipment and a number of building-specific issues are highly variable. Re-entry of residents into multi-family buildings that only experienced flooded underground parking levels during the 2013 Calgary flood, ranged from a number of days to several weeks (IBI Group and Golder Associates, 2015).

It is recognized that as the number of buildings that are flooded increases, there may be issues with the availability of contractors, inspectors, and equipment. The estimated displacement duration considers the time to complete repairs plus general average expected delays including contractors, materials and equipment, and inspections for all return periods. Estimates are illustrated in **Exhibit 2.9**.

---

[9] Average household size, 2016 census
[10] Estimated from CMHC and local listings

Exhibit 2.9: Estimated Average Residential Displacement Periods[11]

Unit Type/Location	Depth (m)										
	0.1	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3
All apartments u/g parking	0	2	4	7	7	7	10	10	14	14	14
Upper level low-rise	35	35	90	90	120	120	180	180	180	180	180
Main floor units	60	90	120	180	180	180	210	240	270	300	300
Single/semi/row main floor	90	120	180	210	240	270	300	300	300	300	300
Single/semi/row basement	0	0	14	21	30	30	45	45	60	75	90

2.6.2.2.1 Rental Units

Several simple assumptions are required to account for the rent-related loss incurred when a unit is uninhabitable for a period greater than 14 days. If a rental unit is uninhabitable, the tenant will find other rental accommodation and continue being a renter, therefore, rent is not an additional flood damage to that household. However, the landlord of the flooded unit will lose the rental income. The loss of income will be for a duration equal to the estimated displacement times, so that the full displacement costs for all households regardless of tenure was used.

2.6.2.2.2 Incorporation in Damage Model

The depth-displacement-days estimates were combined with the daily costs per household to create damage curves for each housing type. To account for potentially different disruption times within apartment buildings, an additional curve is created for upper level units.

The damages were calculated on a per-unit basis, rather than for floor area. The total number of units in a multi-family building is not recorded in many assessment records. The number of units was estimated during the visual classification. Costs associated with residential buildings that are only evacuated (and not flooded) are not computed in the damage model.

2.6.3 Infrastructure, Flood Fighting, and Emergency Response

Damage to infrastructure can have many secondary indirect impacts. This may include traffic delays and business loss due to interruption of services (water, electricity, gas). No object-based utilities damage model has been developed. Estimated as a percentage of direct damage, values in this category range from 10% to 25%.

2.7 Intangible Damages

Intangible damages are those for which there is no market value. Human health impacts and damage to the environment all have intangible aspects. Quantification of these impacts for a flood event is challenging. Floods do not lend themselves well to controlled studies that connect population and flood characteristics to outcomes (Tapsell, Tunstall, & Priest, 2009). The intangible human impact of flooding is highly dependent on variables beyond the flood characteristics including an individual's prior health; income; family and community support; preparedness and experience; and a host of other social indicators or behaviours.

[11] Days due to underground parking and basement flooding are not added when main floor flooding occurs.

In 2015, The City of Calgary commenced an assessment of flood mitigations based on a Triple Bottom Line framework. This entailed an extensive literature review of intangible flood impacts and evaluation techniques. The impacts assessed included mortality; injury; disease; infection; exposure; mental health or quality of life; and environmental damage. A summary of the monetization method and the application of this value to Lacombe is provided in the following section.

2.7.1 Public Health & Quality of Life

There is little evidence to characterize most intangible outcomes of specific flood events/contexts. Nonetheless, attempts have been made to use appropriate quantitative means to estimate the probabilities for each factor, and then to convert this into a dollar value.

It was found that the process of quantifying the individual impacts relies on a high number of assumptions for each component variable. To then monetize these impacts requires further assumptions and transfer of values from other sources, most with no relation to flooding or the local context.

The available monetary values for all the impacts originate from various studies and contexts but in the end they are all assumptions based on willingness-to-pay surveys (WTP), or choices and preferences of people somewhere. Complex calculations could be created using these values, estimated probabilities, and flood and population characteristics to arrive at a value for each impact. However, this would only obfuscate the origin of the data and the assumptions it contains. The end result would have questionable meaning or relation to stakeholders.

Furthermore, the attempt to individually monetize impacts yielded values that were insignificant relative to the direct damages. In the simplest example, applying the recommended statistical value of life (in Canada this is approximately $8 million in 2015 dollars (Treasury Board of Canada Secretariat, 2007)) directly to the 2013 Calgary flood, in which one person died within the city, equates to approximately 0.4% of the 1:100-year flood damage estimate. Similarly low values were found for more complex attempts to quantify injuries, disease, infection, and exposure. This is not to suggest that these factors are not important, but the physical risks in this case are actually rather low.

The overall total impact on affected households, however, is obviously significant. There have been two WTP studies related to flooding conducted recently in the UK. The Department for Environment, Food & Rural Affairs (DEFRA) performed a comprehensive study on the intangible effects of flooding, the main objective of which was to determine a value to be used nationally for assessments (Department for Environment, Food and Rural Affairs, 2004). There was also a research paper with a similar methodology published in 2015 (Joseph, Proverbs, & Lamond, 2015).

In addition to a comprehensive health assessment, the 2002 DEFRA study included a survey of flooded households WTP to avoid all the intangible impacts. The overall mean WTP values for respondents whose residents were flooded was about £200 per household per year, or approximately $615 CAD. The 2015 study found a mean WTP value of £653 per household per year, or approximately $1,300 CAD. The more recent study results are significantly higher as the research was conducted after more severe flooding during 2007 and focused on a wider range of intangible impacts.

Because these studies elicit responses on a wide range of stress factors affecting the households, the result can be considered a single quality of life intangible value. The combination of physical and mental well-being would cover all the impacts, including but not limited to physical risk, worry, loss of services, community relations, or loss of enjoyment of the environment or historical assets.

To use a value from the UK is clearly a transfer in space and not Lacombe-specific. However, unlike the other available data and methods which would be a transfer in at least space, scale, and/or time, this value is directly from flood-affected households in a relatively comparable urban setting.

A major advantage of this model is that it is relatively easy to understand, verify, and adjust. Ideally, the values would be tested and adjusted in a public engagement process. Doing so is beyond the scope of this study, but the amounts can be adjusted for each at-risk community based on the available demographic data. The WTP studies include demographic profiles which, along with the evidence from the literature, can be used to make the initial judgements. Adjustments can be made according to the specific flood impact of the community. For example, two demographically similar communities may not experience equal impacts if one lost its school, community centre, and grocer to flooding while the other did not.

For Lacombe, an average value of $1,000 CAD per household per household was used. For apartment households, the value was reduced to $700 for main floor units and $250 for upper floor units. This was applied to all households estimated to incur over $10,000 in direct damages. A 100-year net present value at 4% discount rate was applied to the annual value to convert the annual rate into a sum consistent with the benefit/cost approach to using these damage estimates. It is the present value of protecting the household over the life of a typical mitigation project, discounted to account for future uncertainty and the time-value of money. A survey with 2,160 responses from Ph.D.-level economists found that 4% was the mean rate that should be used to discount benefits and costs of projects being proposed to mitigate the possible effects of global climate change (Weitzman, 2001).

2.8 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 and intangible damages.

2.9 Average Annual Damages

Average annual damage (AAD) is a common 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. In other words, AAD is the cumulative damage occurring from various flood events over an extended period of time averaged for the same timeframe. The AAD is obtained by calculating the area under the damage-probability curve which depicts total damage versus probability of occurrence.

3 City of Lacombe

3.1 Background

The City of Lacombe is located in central Alberta, approximately 25 km north of Red Deer. The location of Lacombe in a regional setting within the Province of Alberta is depicted in **Exhibit 3.1**. The entirety of the study area can be seen in **Exhibit 3.2**.

3.2 Context

Lacombe lies within the Battle River watershed, which is part of the larger Saskatchewan River Basin. Lacombe is situated in the Bigstone Sub-watershed, and fed by the Battle River, as depicted in **Exhibit 3.3**. The Battle River Watershed covers most of east-central Alberta with a portion lying in Saskatchewan. Unlike many other glacier-fed rivers in Alberta, Battle River itself is a prairie-fed river.

Flooding concerns in the area arise from Wolf Creek, much of which runs adjacent to the Canadian Pacific Rail line along the southeast portion of town. A long stretch of Wolf Creek has been channelized, helping to straighten and widen the creek close to the town in order to increase its conveyance capacity during spring runoff and also better handle effluent releases from the Town's sewage lagoons.

3.3 History of Flooding

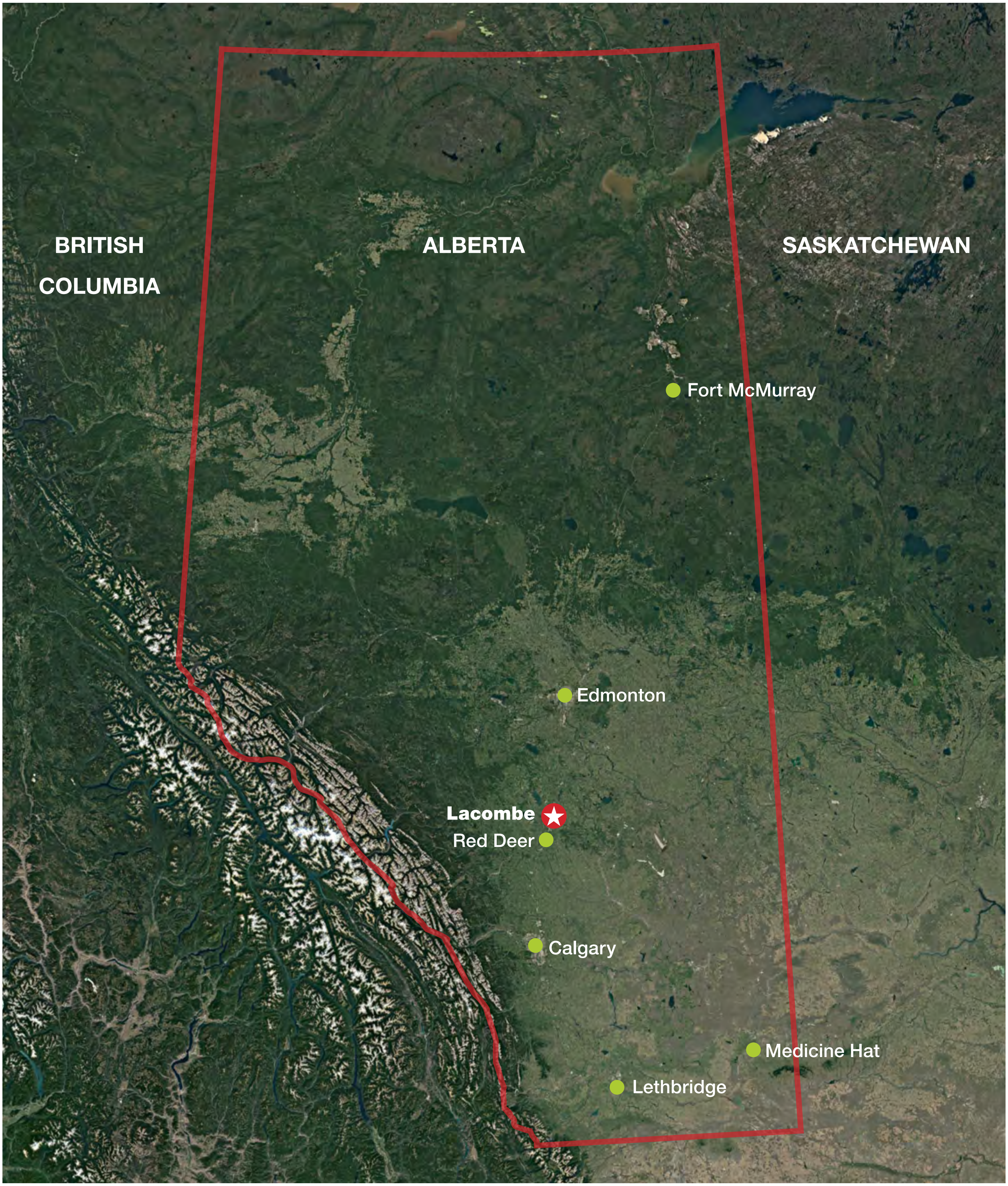
Flooding of Wolf Creek in the City of Lacombe typically occurs in the open water season, either as a result of spring runoff in March and April, or from heavy rainfall events in June and July. Prior to channelization, Wolf Creek had a history of overtopping its banks, particularly in spring runoff events. The channelization was intended to reduce the frequency and duration of such events on adjacent agricultural land, but is only effective for up to 1:5 year flows (Alberta Environmental Protection, 1996).

Storm water flooding has been an issue in Lacombe when heavy rain events exceed the capacity of the sewer system. Concurrent high creek levels could exacerbate this issue. Ice jam flooding does not appear to be a problem in Lacombe.

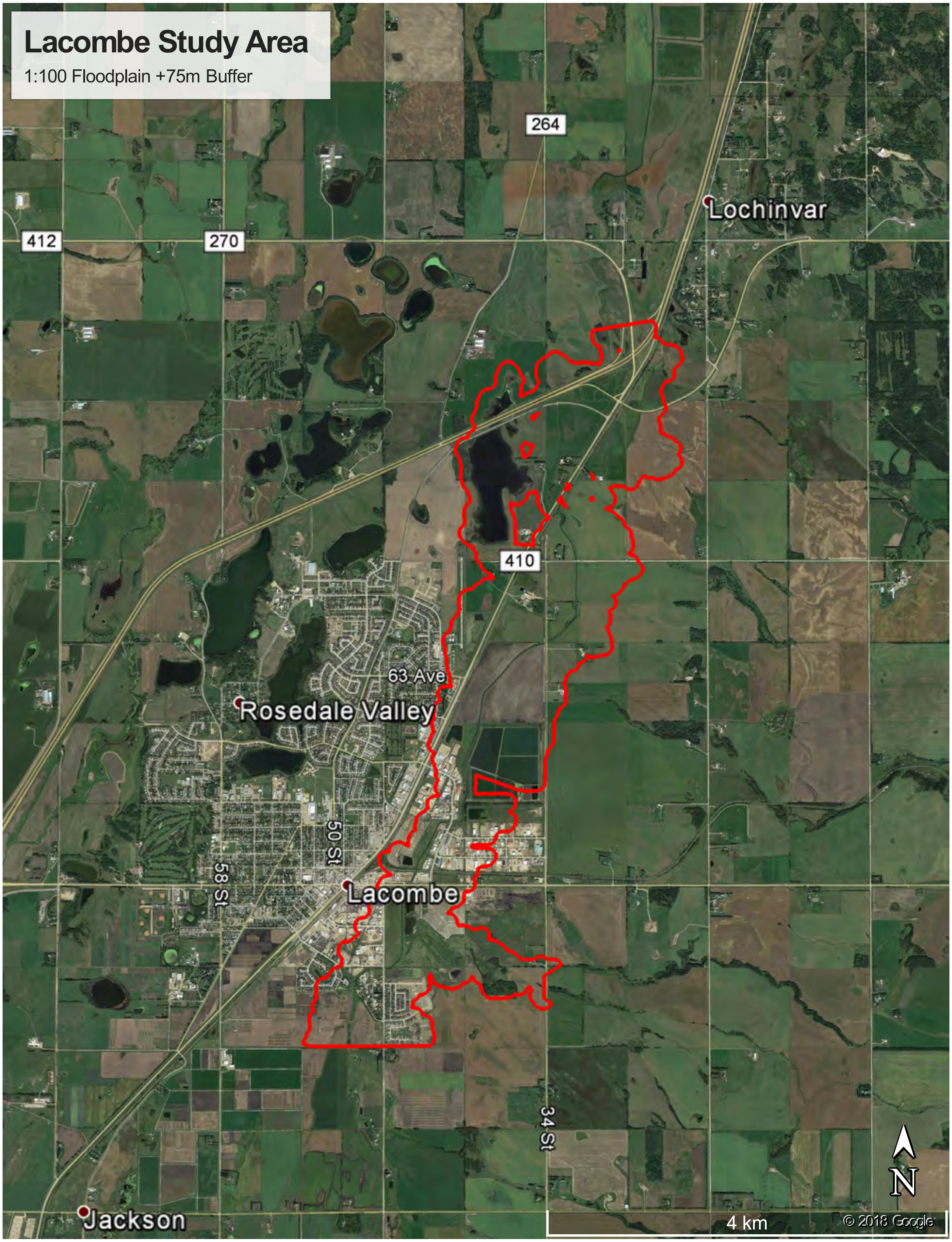
3.4 Floodplain Mapping

The 1996 Flood Hazard Identification Study mapped the 1:100-year open water flood on Wolf Creek. The results of the flood hazard mapping study can be found in **Exhibit 3.4**.

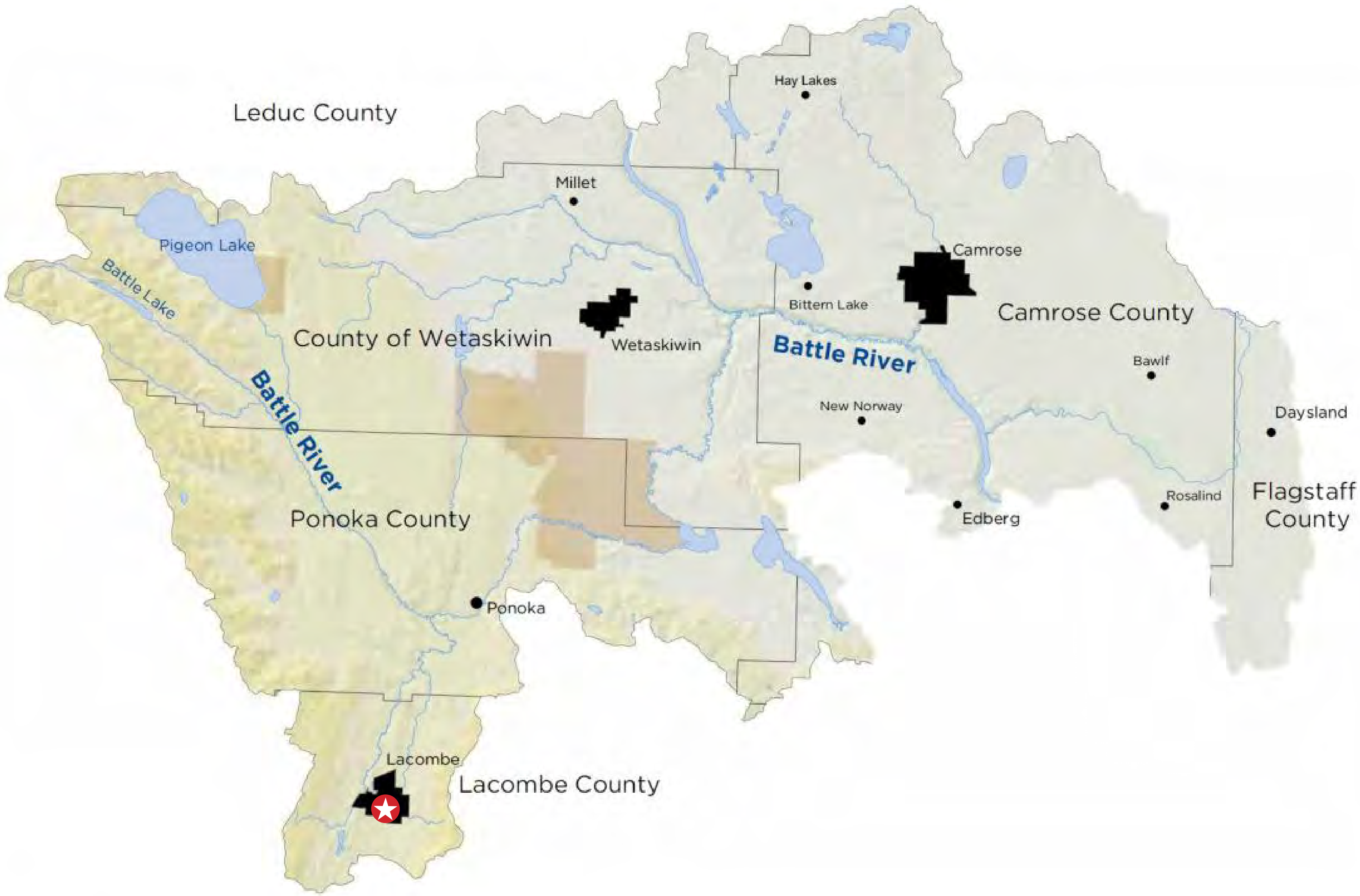
Regional Setting



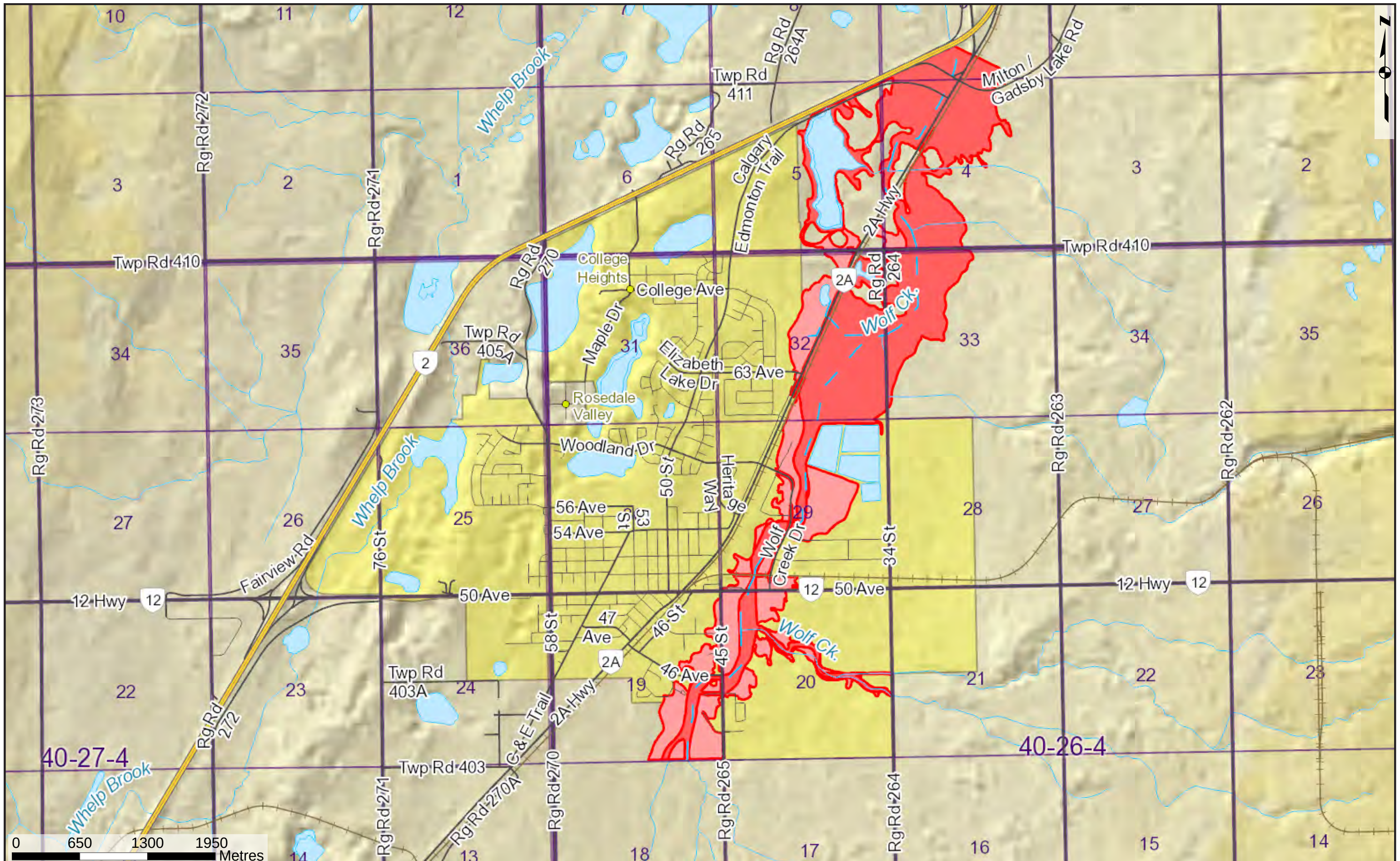
Lacombe Flood Study Area - Aerial



Location in Battle River Watershed



Lacombe Provincial Flood Hazard Map



Legend

Floodway	Overland Flow (Flood Fringe)
Flood Fringe	Under Review
855.09 m Cross Section and Design Flood Level	Water Body
First Nation Boundary	Municipal Boundary

Information as depicted is subject to change, therefore the Government of Alberta assumes no responsibility for discrepancies at time of use.
Cadastral data provided by Alberta Data Partnerships Ltd. (ADP)
Base Map Data provided by the Government of Alberta under the Alberta Open Government License. November, 2014
National Framework Data © Department of Natural Resources Canada. All rights reserved.
Alberta Road Network data provided by GeoBase ®
Alberta Environment and Parks

Flood Hazard Map

Projection:	Datum:	Date:
ALBERTA 10TM	NAD 83	2018-Jul-26

maps.srd.alberta.ca/FloodHazard/

3.5 Inventory of Buildings

Within the Lacombe study area, a total of 471 buildings were classified, 156 of which were non-residential and 315 of which were residential (**Exhibit 3.5**). Of the residential buildings, only one was an apartment-style building. There were no mixed-use buildings with classes differing between the main floor and upper floors.

Exhibit 3.5: Residential Building Inventory Classification

Class	Total	One Storey	Two Storey	Split-Level	Basement
A	24	5	18	1	24
B	118	95	7	16	118
C	69	59	7	3	68
D	103	103	0	0	0
M	1	n/a	n/a	n/a	0

3.6 Direct Damage Estimates

The flood damage estimates reflect total potential damages for the various return periods. Damages are presented as being caused by overland flooding and sewer backup/groundwater flooding. Overland flooding is caused when the modeled river flood elevation is greater than that of the ground surface.

Sewer backup or groundwater flooding is caused when the modeled flood elevation is below the ground surface, within 75 m of overland flooding, at the location of a basement. Sewer backup can occur when the river rises and enters the system or causes groundwater infiltration. High groundwater during a flood may also directly infiltrate basements through foundation walls or penetrations.

3.6.1 Overland Flooding

Overland direct flood damages by return period are detailed in **Exhibit 3.6**.

Exhibit 3.6: Direct Overland Damages

Damage Category		Return Frequency, in Years			
		2	10	50	100
Residential	Direct Overland	$0	$2,206,760	$5,426,324	$6,685,288
Non-Residential	Direct Overland	$0	$375,756	$1,009,749	$2,264,770
	Total	**$0**	**$2,582,517**	**$6,436,073**	**$8,950,058**

Damages occurring at the 1:10-year flood elevation are primarily limited to structures along Wolf Creek south of 46 Ave. At the 1:10-year flood elevation, there are also some inundation of industrial properties along 45 St. At the 1:50 and 1:100-year flood levels, the same areas account for the majority of damages with increased depth and additional properties affected.

3.6.2 Sewer Backup/Groundwater Flooding

The sewer backup condition extends the water level for a distance of 75 m from the edge of above-ground flooding. This is the “adjacent-to” area described in Section 2.4 and illustrated in Exhibit 2.4. The actual mechanism for water infiltration in this area is unknown. Sanitary sewer lines may not be exposed to inundated areas; however, flooding can also occur due to groundwater movement or a high water table, as well as via storm water infrastructure. Damages due to sewer backup and/or groundwater flooding are detailed in **Exhibit 3.7.**

Exhibit 3.7: Direct Sewer Backup/Groundwater Damage

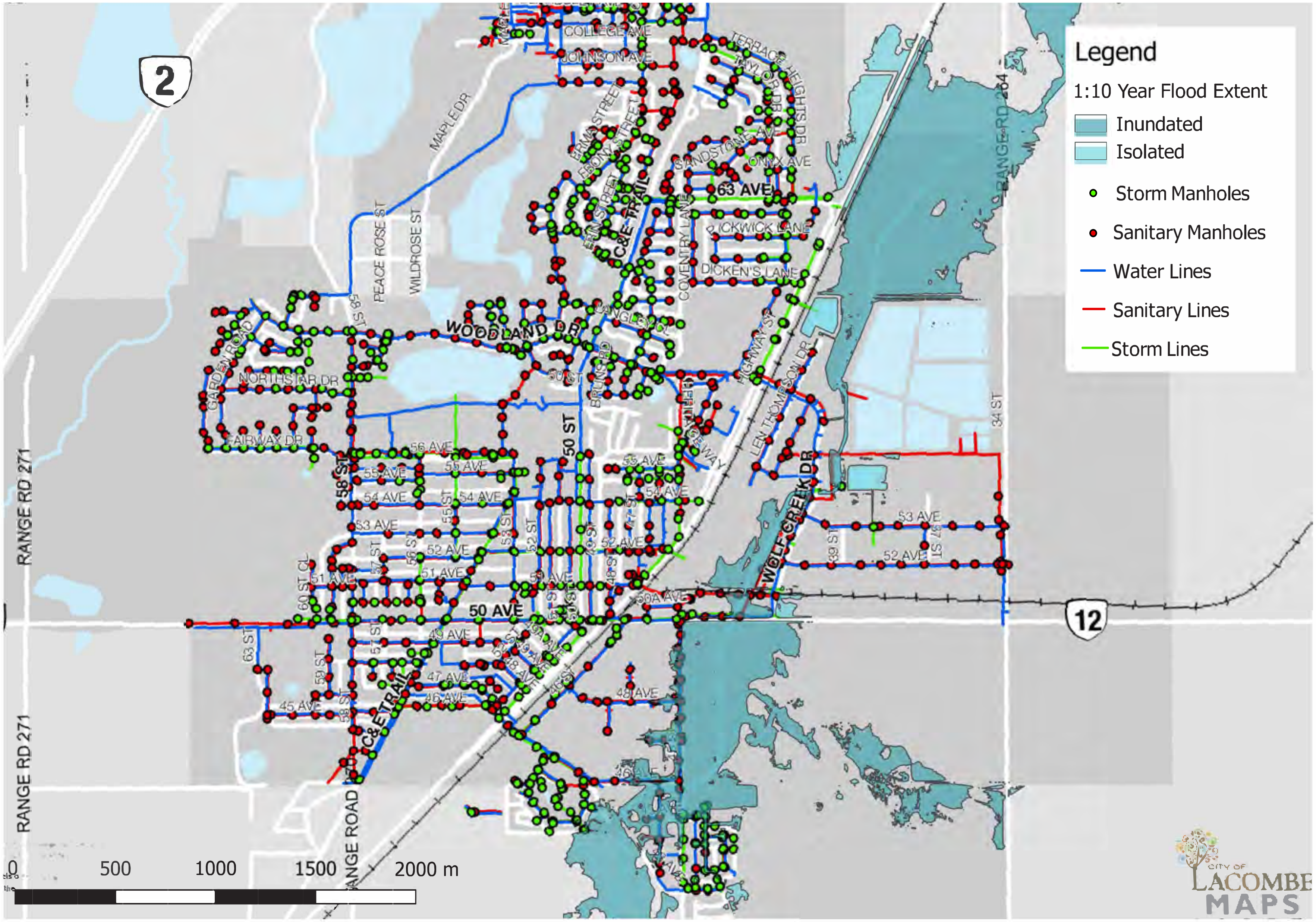
Damage Category		Return Frequency, in Years			
		2	10	50	100
Residential	Direct Sewer/ Groundwater	$851,646	$8,362,823	$16,634,183	$17,120,332
Non-Residential	Direct Sewer/ Groundwater	$0	$3,789	$232,708	$625,264
	Total	**$851,646**	**$8,366,611**	**$16,866,892**	**$17,745,596**

More research is required to determine the incidence of sewer backup and/or groundwater flooding in Alberta communities. Properties affected by the more frequent floods are likely to have implemented protective or adaptive measures. For example, a recent survey (April 2016) commissioned by the City of Calgary found that 50% of households at risk of flooding had sump pumps, 27% had a backup generator, and 29% had some form of private flood mitigation measure.

For the purposes of this study, groundwater damages for the more frequent events reflect an assumed level of mitigation or adaptation as well as an assumed probability of seepage impacts. Sewer and stormwater backup becomes a major issue once outfalls or manholes are inundated. For Lacombe, the inundation extents were overlaid on a map of underground utilities, including storm and sanitary lines and manholes. Inundation of this infrastructure is present at the 1:10-year event, as indicated in **Exhibit 3.8**.

The sewer backup/groundwater infiltration estimates are damages that could occur to properties adjacent to overland flooding where the basement structure is lower than the adjacent floodwaters. It assumes that water is entering the building from the flooded area or that storm and/or sewer water cannot drain due to backup.

Underground Infrastructure Inundated at the 1:10 Year Event



3.7 Indirect Damage Estimates

Indirect damage estimates were calculated as outlined in Sections 2.6 and 2.7. Because these damages are associated with direct damage to buildings, they are presented in the categories described above.

3.7.1 Commercial Indirect Damages – Business Interruption

Indirect damages due to business interruption are indicated in **Exhibit 3.9**.

Exhibit 3.9: Business Interruption Damages

Damage Category		Return Frequency, in Years			
		2	10	50	100
Non-Residential	Indirect Overland	$0	$301,974	$657,513	$2,004,518
	Indirect Sewer/ Groundwater	$0	$0	$0	$0
	Total	**$0**	**$301,974**	**$657,513**	**$2,004,518**

The business interruption damages are directly correlated with the direct damages and distributed similarly. In Lacombe, the business interruption losses are nearly equal to the direct damages for each return period. No business interruption costs were associated with sewer backup.

3.7.2 Residential Indirect Damages

The residential displacement and intangible damages are illustrated in **Exhibit 3.10**.

Exhibit 3.10: Residential Indirect Damages

Damage Category		Return Frequency, in Years			
		2	10	50	100
Residential	Displacement Overland	$0	$90,324	$199,298	$240,595
	Displacement Sewer/ GW	$14,891	$215,830	$429,693	$431,375
	Intangible Overland	$0	$612,625	$1,274,260	$1,519,310
	Intangible Sewer/ GW	$218,095	$1,715,350	$3,406,195	$3,381,690
	Total	**$232,985**	**$2,634,129**	**$5,309,446**	**$5,572,970**

It should be noted that mitigation of residential indirect damages can include community resiliency efforts in addition to flood protection.

3.8 Infrastructure, Flood Fighting, and Emergency Response

The Lacombe study area includes areas of maintained park space, water treatment facilities, and several road crossings. In the absence of specific cost estimates for flooding in Lacombe, the costs for these categories were determined by benchmark data from past events in various communities. The costs have been associated with direct overland flood damage values. For infrastructure, this amount is 17.25%. For flood fighting and emergency response, values between 6% and 4% were used, decreasing with flood magnitude. At the 1:100-year event, this amounts to $10.5 million for infrastructure and $2.3 million for flood fighting and emergency response.

3.9 Total Damages

Total damages for each return period are summarized in **Exhibit 3.11**

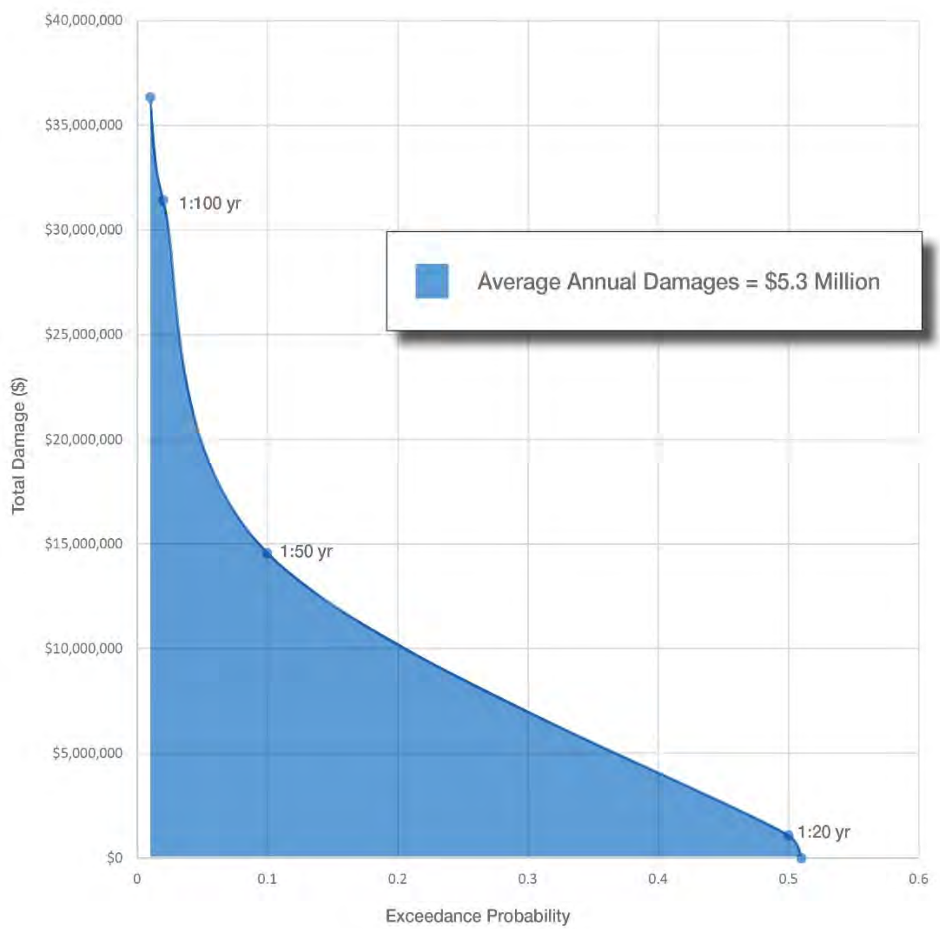
Exhibit 3.11: Total Damages

Damage Category		Return Frequency, in Years			
		2	10	50	100
Residential	Direct Overland	$0	$2,206,760	$5,426,324	$6,685,288
	Indirect Overland	$0	$702,949	$1,473,558	$1,759,905
	Direct Sewer/ Groundwater	$851,646	$8,362,823	$16,634,183	$17,120,332
	Indirect Sewer/ Groundwater	$232,985	$1,931,180	$3,835,888	$3,813,065
	Subtotal	$1,084,631	$13,203,712	$27,369,953	$29,378,590
Non-Residential	Direct Overland	$0	$375,756	$1,009,749	$2,264,770
	Indirect Overland	$0	$301,974	$926,240	$2,074,107
	Direct Sewer/ Groundwater	$0	$3,789	$232,708	$625,264
	Indirect Sewer/ Groundwater	$0	$0	$0	$0
	Subtotal	$0	$681,520	$2,168,698	$4,964,141
Infrastructure		$0	$445,484	$1,110,223	$1,543,885
Flood Fighting and Emergency Response		$0	$129,126	$257,443	$358,002
Total	Direct Overland	$0	$3,028,001	$7,546,295	$10,493,943
	Indirect Overland	$0	$1,129,030	$2,637,064	$4,188,188
	Direct Sewer/ Groundwater	$851,646	$8,366,611	$16,866,892	$17,745,596
	Indirect Sewer/ Groundwater	$232,985	$1,931,180	$3,835,888	$3,813,065
	Total	**$1,084,631**	**$14,454,823**	**$30,886,140**	**$36,240,791**

3.10 Average Annual Damage

AAD is the cumulative damages occurring from various flood events over an extended period of time averaged for the same timeframe. The AAD is obtained by calculating the area under a damage-probability curve which depicts total damage versus probability of occurrence, as illustrated in **Exhibit 3.12**.

Exhibit 3.12: Flood Damage Probability Distribution



As illustrated, the unmitigated total potential flood damages amount to $5.3 million in average annual damages. This is the AAD up to the 1:100-year flood as no data for greater floods is currently available. Of this, approximately $3.7 million is a result of sewer backup or groundwater infiltration risk. The relatively high sewer backup or groundwater damage amounts indicates potential vulnerability for basement flooding as a large number of homes have developed space below adjacent overland flood risk.

The flood damage estimates and associated AAD for overland and groundwater flooding presented in this report illustrate the potential risk due to modelled flood elevations. These estimates can be used to prioritize mitigation efforts or serve to illustrate the value of maintaining current infrastructure, such as stormwater outfall gates, as well as homeowner awareness about basement flooding potential. Most importantly, the PFDAT methodology provides a consistent basis for assessing flood risk and mitigation projects across the province.

3.11 Damages with Mitigation

At this time, the City of Lacombe does not have any flood mitigation in place, nor are we aware of any plans for flood mitigation measures. As such, no damage calculations were performed for any potential benefits of mitigation.

4 References

Alberta Environment and Parks. (2017, March 31). *Flood Hazard Mapping*. Retrieved from Flood Hazard Identification Program: http://aep.alberta.ca/water/programs-and-services/flood-hazard-identification-program/flood-hazard-mapping.aspx

Alberta Environmental Protection. (1996). *Lacombe Flood Risk Mapping Study.* Edmonton: Natural Resource Service, Alberta Environmental Protection.

Department for Environment, Food and Rural Affairs. (2004). *The Appraisal of Human-related Intangible Impacts of Flooding.* Flood and Coastal Defence R&D Programma. London: Defra; Environment Agency.

FEMA. (2015). Hazus-MH Technical Manual. Washington, D.C., USA: Department of Homeland Security.

IBI Group and Golder Associates. (2015). *Provincial Flood Damage Assessment Study.* Calgary: Government of Alberta, Environment and Sustainable Resource Development.

Joseph, R., Proverbs, D., & Lamond, J. (2015). Assessing the value of intangible benefits of property level flood risk adaptation (PLFRA) measures. *Nat Hazards*.

Kreibich, H., & Bubeck, P. (2013). *Natural Hazards: Direct Costs and Losses Due to the Disruption of Production Processes.* Postdam: The United Nations Office for Disaster Risk Reduction; Flobal Assessment Report on Disaster Reduction.

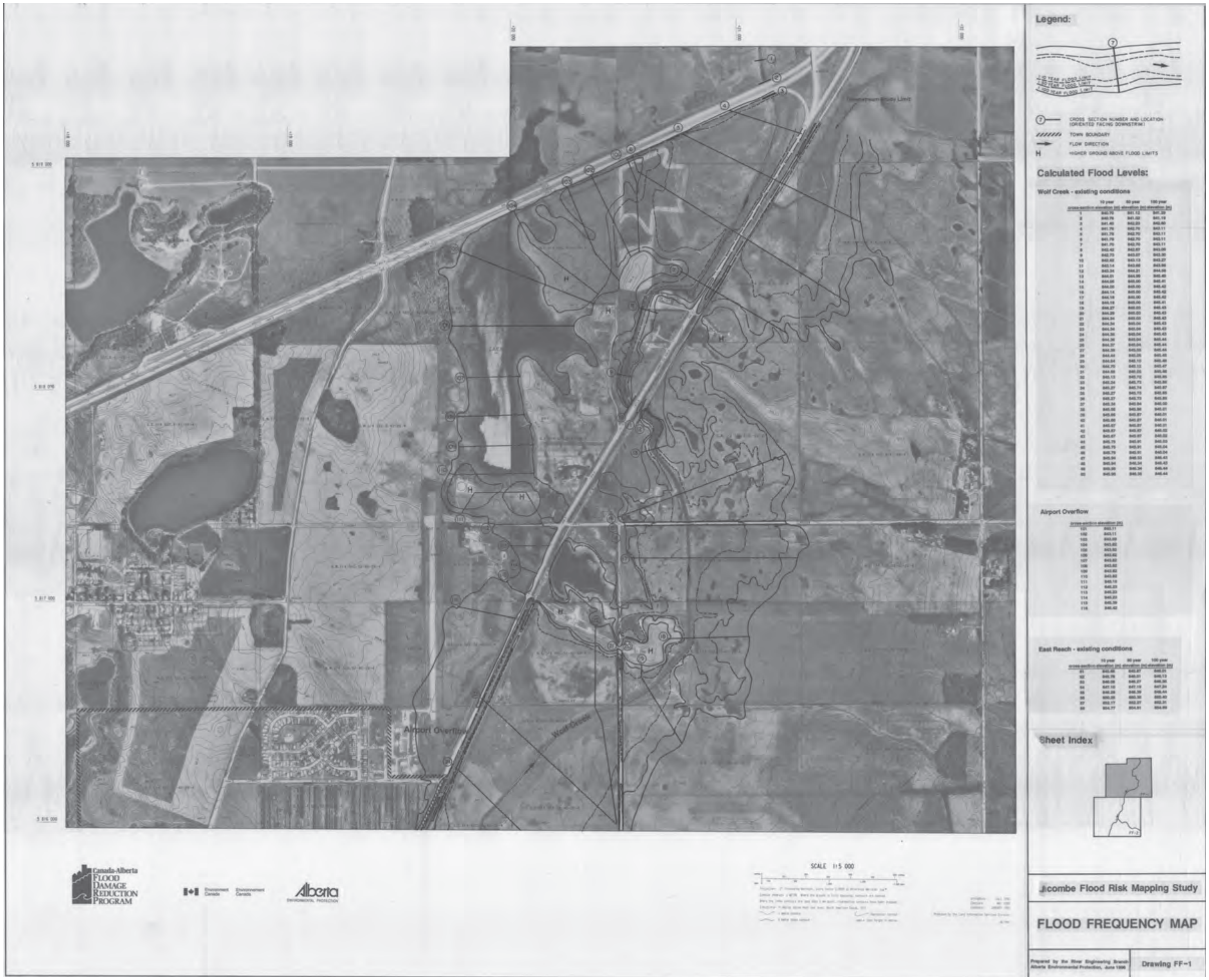
Messner, F., Penning-Rowsel, E., Green, C., Meyer, V., Tunstall, S., & van der Veen, A. (2007). *FLOODsite Report T09-06-01: Evaluating flood damages: guidance and recommendations on principles and methods.* Helmholtz: Helmholtz Centre for Environmental Research (UFZ).

Tapsell, S. M., Tunstall, S. M., & Priest, S. J. (2009). *Developing a conceptual model of flood impacts upon human health.* London: Middlesex University.

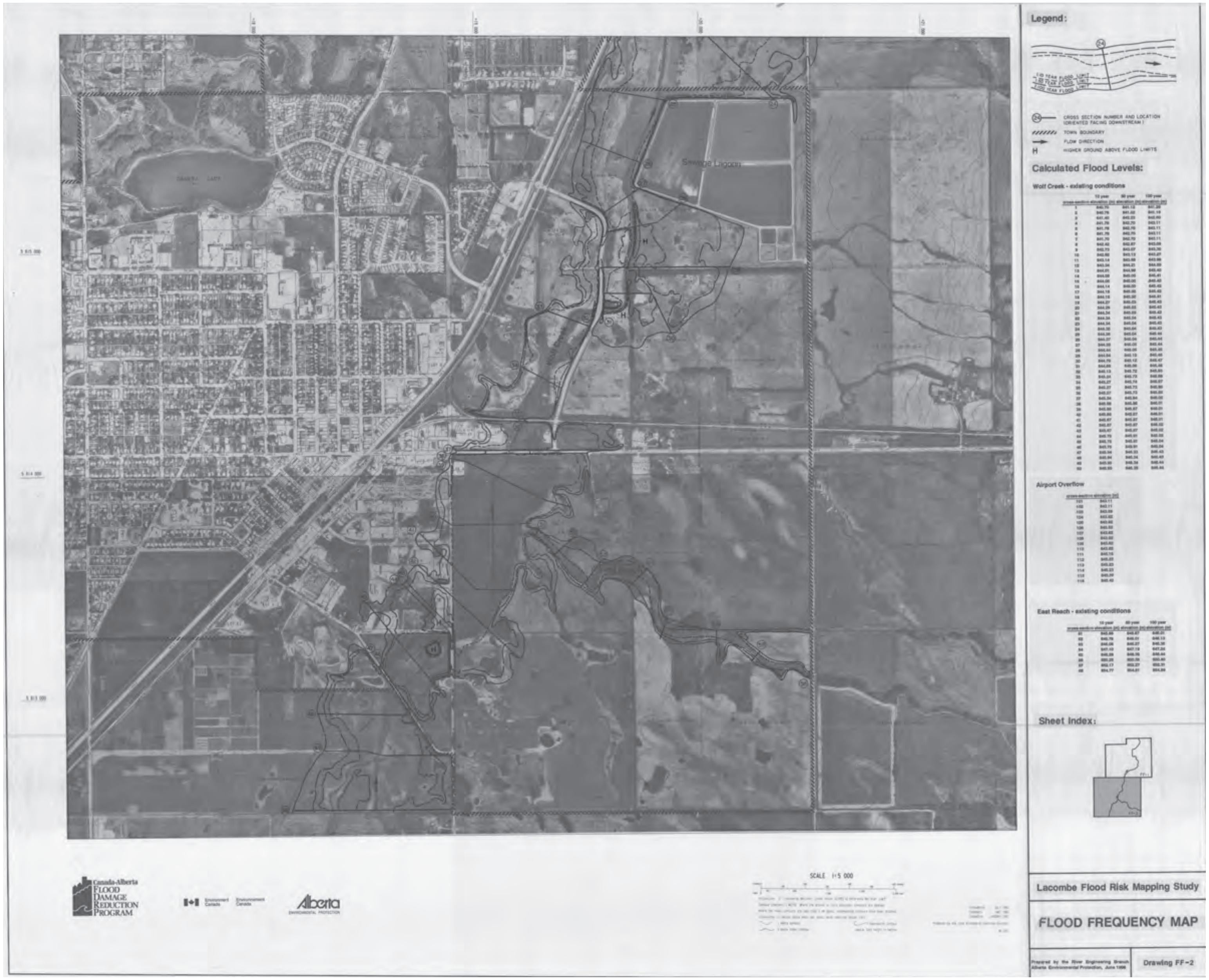
Treasury Board of Canada Secretariat. (2007). *Canadian Cost-Benefit Analysis Gudie: Regulatory Proposals.* Government of Canada.

Weitzman, M. L. (2001). Gamma discounting. *American Economic Review, 91*(1), 260-271.

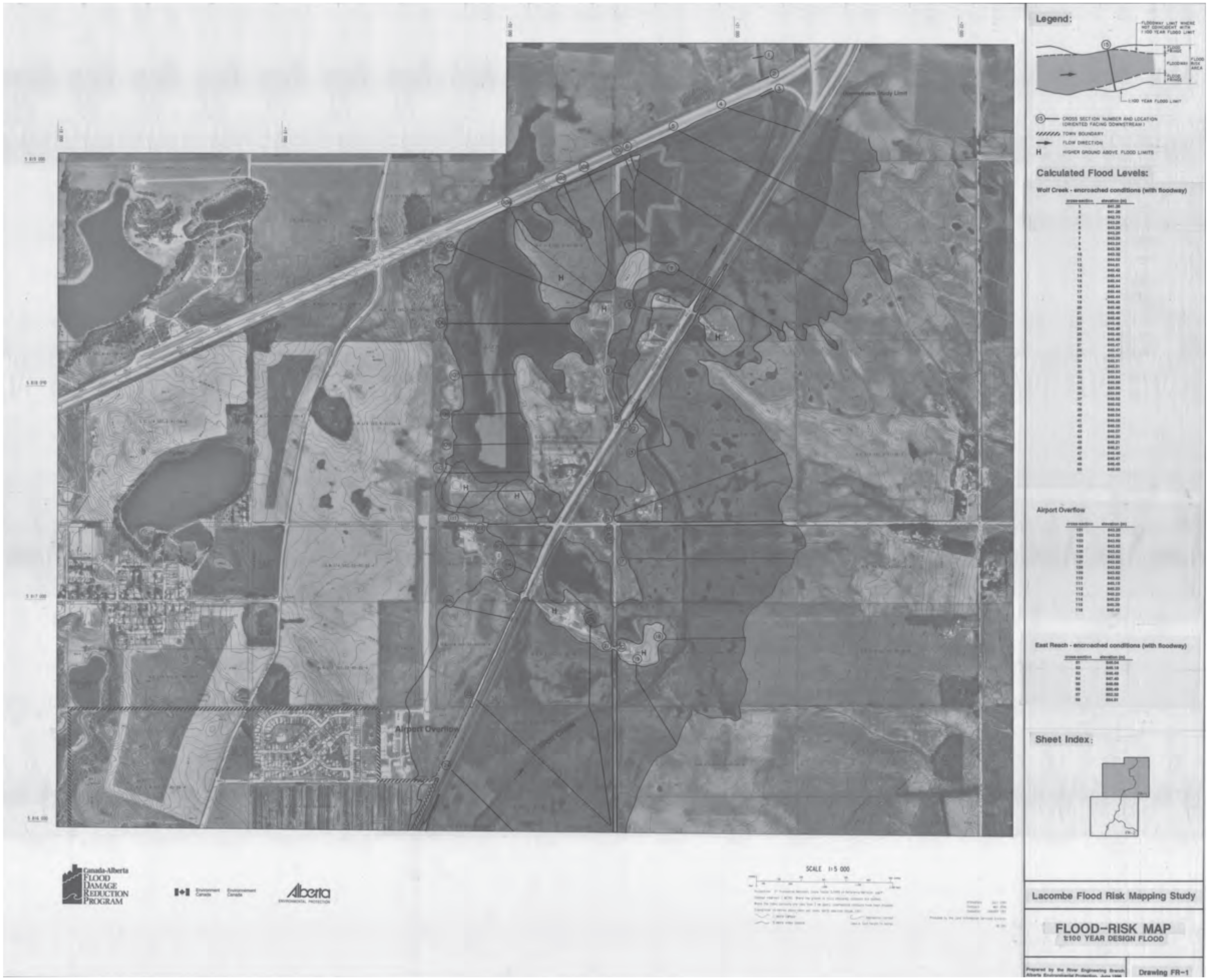
Appendix A – Lacombe Flood Hazard Mapping


Legend:
Calculated Flood Levels:
Wolf Creek - existing conditions
Airport Overflow
East Reach - existing conditions
Sheet Index
Airport Overflow
Wolf Creek
Canada-Alberta
FLOOD
DAMAGE
REDUCTION
PROGRAM
Alberta
SCALE 1:5 000
Lacombe Flood Risk Mapping Study
FLOOD FREQUENCY MAP
Drawing FF-1

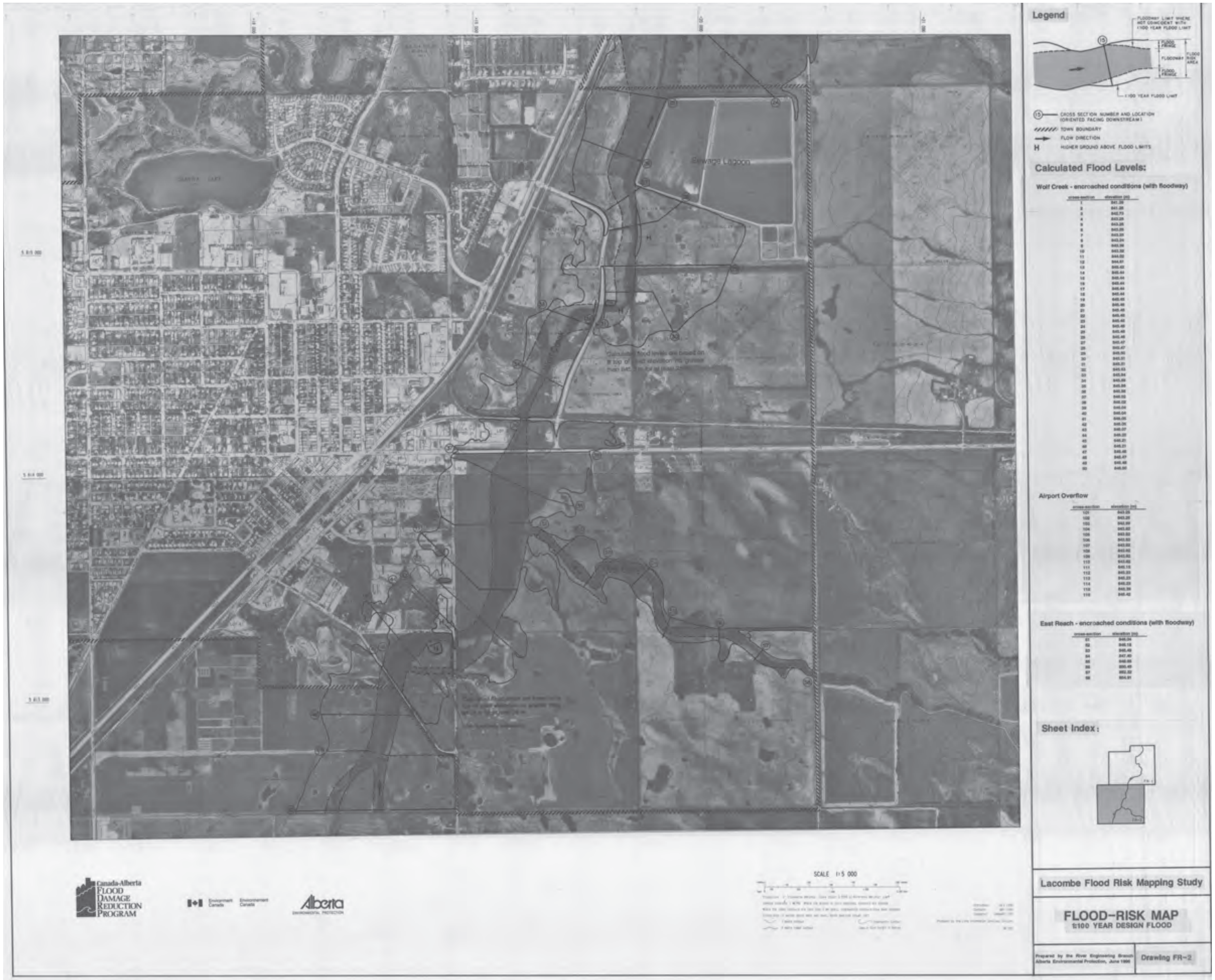
Wolf Creek Flood Hazard Mapping



Wolf Creek Flood Hazard Mapping



Wolf Creek Flood Hazard Mapping



Appendix B – Residential Classification Scheme

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.

Source: IBI Group, Golder Associates Ltd., *Provincial Flood Damage Assessment Study, Government of Alberta*, ESRD, February 2015.

Residential Classification - Typical Examples

AA

AA

A

A

B

B

Residential Classification - Typical Examples

D

D

MA

MA

MW

MW

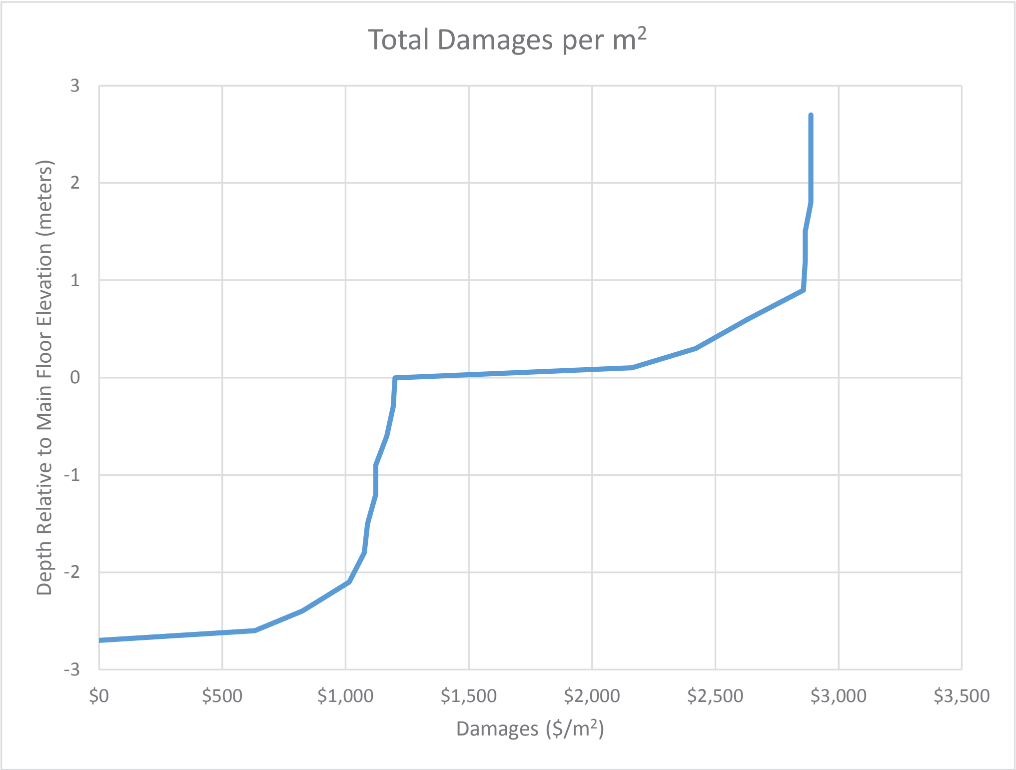
Appendix C – Depth-Damage Curves and Values*

* Calgary 2014 $

Class A - Residential One-Storey					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$400	$231	$632
-2.4	$0	$0	$554	$271	$825
-2.1	$0	$0	$715	$299	$1,015
-1.8	$0	$0	$778	$299	$1,077
-1.5	$0	$0	$784	$305	$1,090
-1.2	$0	$0	$786	$335	$1,122
-0.9	$0	$0	$788	$335	$1,123
-0.6	$0	$0	$810	$356	$1,167
-0.3	$0	$0	$836	$357	$1,193
0	$0	$0	$836	$365	$1,201
0.1	$373	$588	$836	$365	$2,162
0.3	$624	$594	$836	$365	$2,420
0.6	$758	$674	$836	$365	$2,633
0.9	$809	$848	$836	$365	$2,858
1.2	$816	$848	$836	$365	$2,865
1.5	$816	$848	$836	$365	$2,865
1.8	$839	$848	$836	$365	$2,888
2.1	$839	$848	$836	$365	$2,888
2.4	$839	$848	$836	$365	$2,888
2.7	$839	$848	$836	$365	$2,888

[1]distance between floors is variable in model, 2.7m illustrated

[2]not all structures have basements and it is a separate calculation in the model

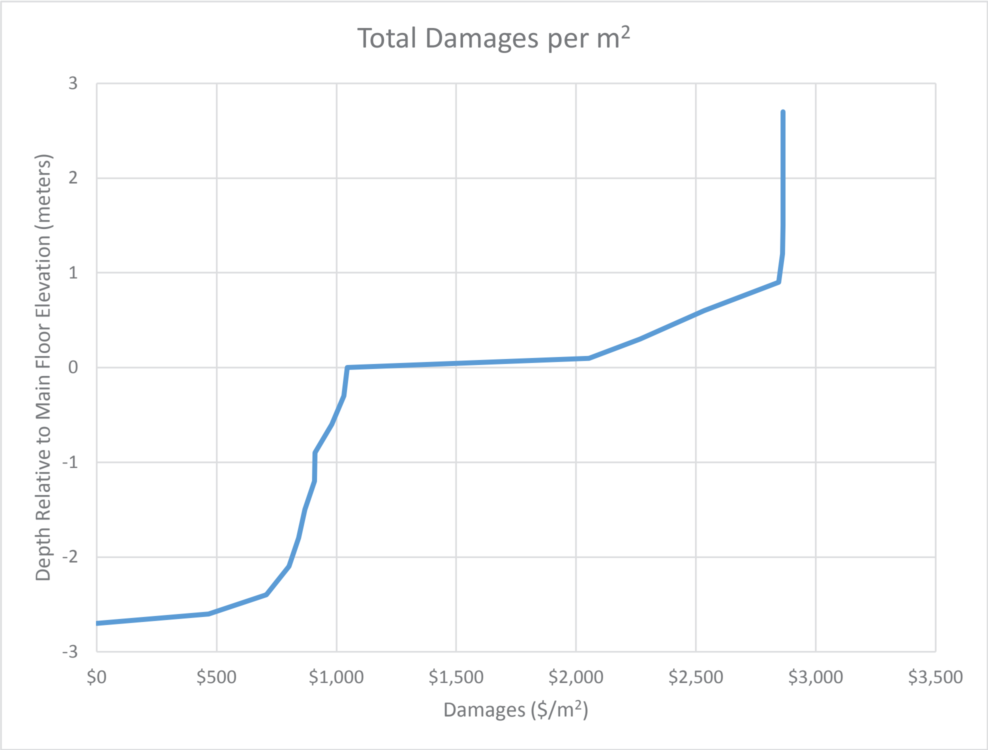


APPENDIX D - Damage Curves and Values - Class A - Residential Two-Storey

Class A -Residential Two-Storey					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$226	$241	$467
-2.4	$0	$0	$354	$354	$708
-2.1	$0	$0	$395	$406	$802
-1.8	$0	$0	$437	$406	$843
-1.5	$0	$0	$440	$429	$869
-1.2	$0	$0	$442	$466	$908
-0.9	$0	$0	$444	$466	$910
-0.6	$0	$0	$475	$506	$980
-0.3	$0	$0	$523	$507	$1,030
0	$0	$0	$523	$522	$1,045
0.1	$343	$665	$523	$522	$2,053
0.3	$545	$676	$523	$522	$2,266
0.6	$663	$826	$523	$522	$2,534
0.9	$748	$1,051	$523	$522	$2,845
1.2	$766	$1,051	$523	$522	$2,862
1.5	$767	$1,051	$523	$522	$2,863
1.8	$767	$1,051	$523	$522	$2,863
2.1	$767	$1,051	$523	$522	$2,863
2.4	$767	$1,051	$523	$522	$2,863
2.7	$767	$1,051	$523	$522	$2,863

[1]distance between floors is variable in model, 2.7m illustrated

[2]not all structures have basements and it is a separate calculation in the model

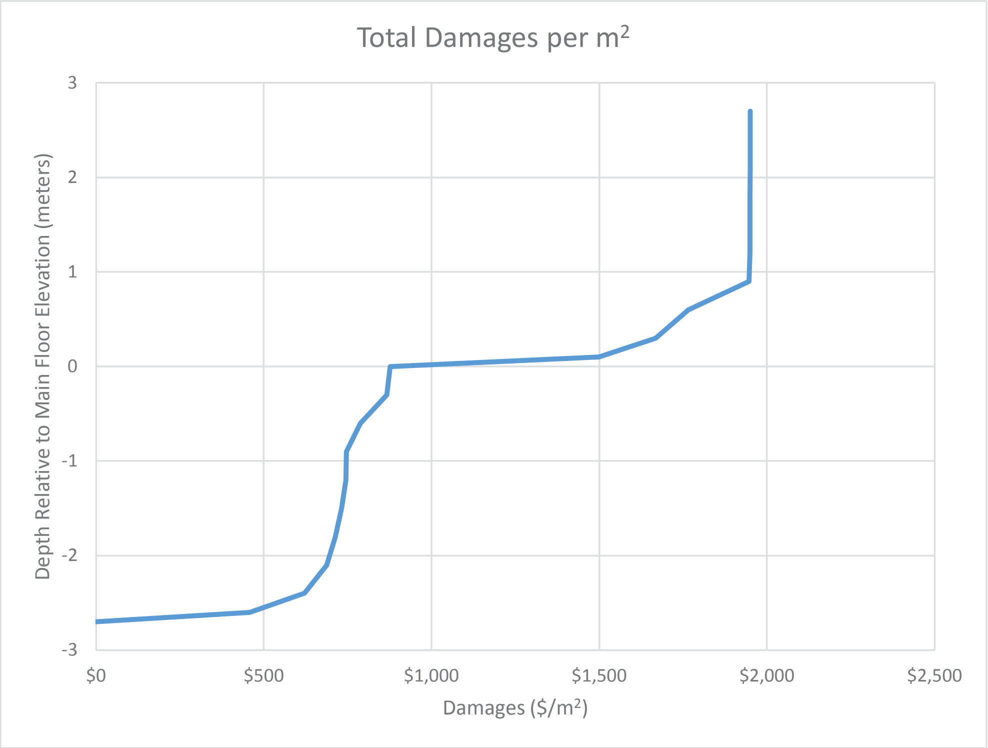


APPENDIX D - Damage Curves and Values - Class B - Residential One-Story

Class B - Residential One-Storey					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$226	$232	$458
-2.4	$0	$0	$339	$282	$621
-2.1	$0	$0	$375	$312	$687
-1.8	$0	$0	$401	$312	$713
-1.5	$0	$0	$410	$322	$732
-1.2	$0	$0	$411	$334	$745
-0.9	$0	$0	$412	$334	$746
-0.6	$0	$0	$426	$362	$788
-0.3	$0	$0	$504	$363	$867
0	$0	$0	$504	$374	$877
0.1	$221	$400	$504	$374	$1,498
0.3	$384	$407	$504	$374	$1,668
0.6	$431	$457	$504	$374	$1,765
0.9	$492	$578	$504	$374	$1,947
1.2	$494	$578	$504	$374	$1,949
1.5	$494	$578	$504	$374	$1,949
1.8	$495	$578	$504	$374	$1,950
2.1	$495	$578	$504	$374	$1,950
2.4	$495	$578	$504	$374	$1,950
2.7	$495	$578	$504	$374	$1,950

[1]distance between floors is variable in model, 2.7m illustrated

[2]not all structures have basements and it is a separate calculation in the model

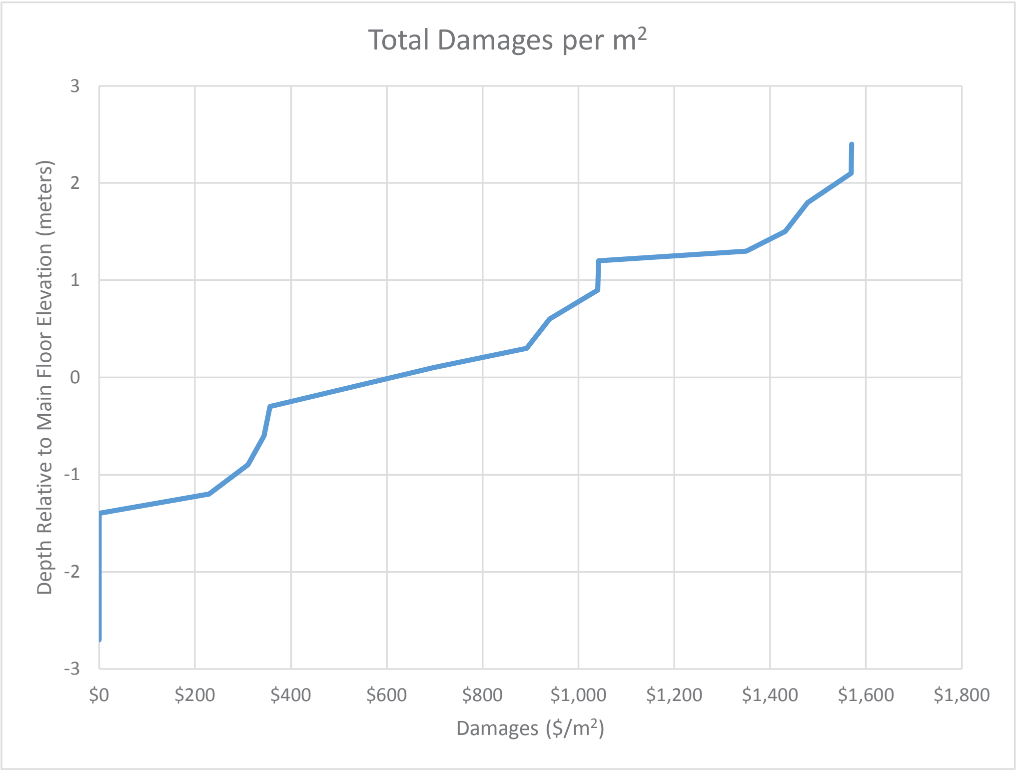


APPENDIX D - Damage Curves and Values - Class B - Residential Split Level

Class B - Residential Split Level					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$0	$0	$0
-2.4	$0	$0	$0	$0	$0
-2.1	$0	$0	$0	$0	$0
-1.8	$0	$0	$0	$0	$0
-1.5	$0	$0	$0	$0	$0
-1.4	$0	$0	$0	$0	$0
-1.2	$0	$0	$113	$116	$229
-0.9	$0	$0	$169	$141	$310
-0.6	$0	$0	$188	$156	$344
-0.3	$0	$0	$200	$156	$356
0.1	$108	$210	$219	$161	$698
0.3	$194	$217	$296	$185	$892
0.6	$217	$242	$296	$185	$940
0.9	$252	$302	$297	$190	$1,040
1.2	$253	$302	$297	$191	$1,043
1.3	$360	$502	$297	$191	$1,350
1.5	$441	$502	$297	$191	$1,431
1.8	$463	$527	$297	$191	$1,478
2.1	$494	$588	$297	$191	$1,569
2.4	$495	$588	$297	$191	$1,570

[1]distance between floors is variable in model, 2.7m illustrated

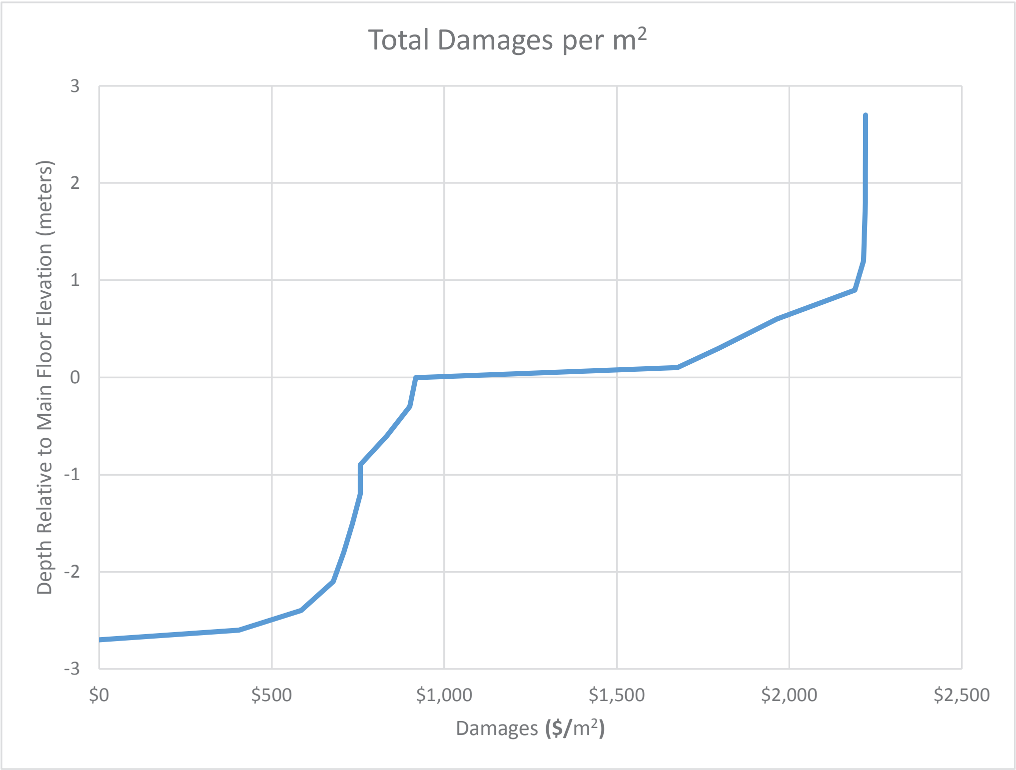
[2]not all structures have basements and it is a separate calculation in the model



Class B - Residential Two-Storey					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$163	$242	$405
-2.4	$0	$0	$255	$331	$586
-2.1	$0	$0	$294	$385	$678
-1.8	$0	$0	$324	$385	$709
-1.5	$0	$0	$332	$402	$735
-1.2	$0	$0	$336	$420	$756
-0.9	$0	$0	$336	$420	$756
-0.6	$0	$0	$364	$470	$833
-0.3	$0	$0	$427	$473	$900
0	$0	$0	$427	$490	$917
0.1	$235	$524	$427	$490	$1,676
0.3	$342	$536	$427	$490	$1,795
0.6	$422	$625	$427	$490	$1,964
0.9	$481	$792	$427	$490	$2,190
1.2	$507	$792	$427	$490	$2,216
1.5	$508	$792	$427	$490	$2,217
1.8	$511	$792	$427	$490	$2,220
2.1	$511	$792	$427	$490	$2,220
2.4	$512	$792	$427	$490	$2,221
2.7	$512	$792	$427	$490	$2,221

[1]distance between floors is variable in model, 2.7m illustrated

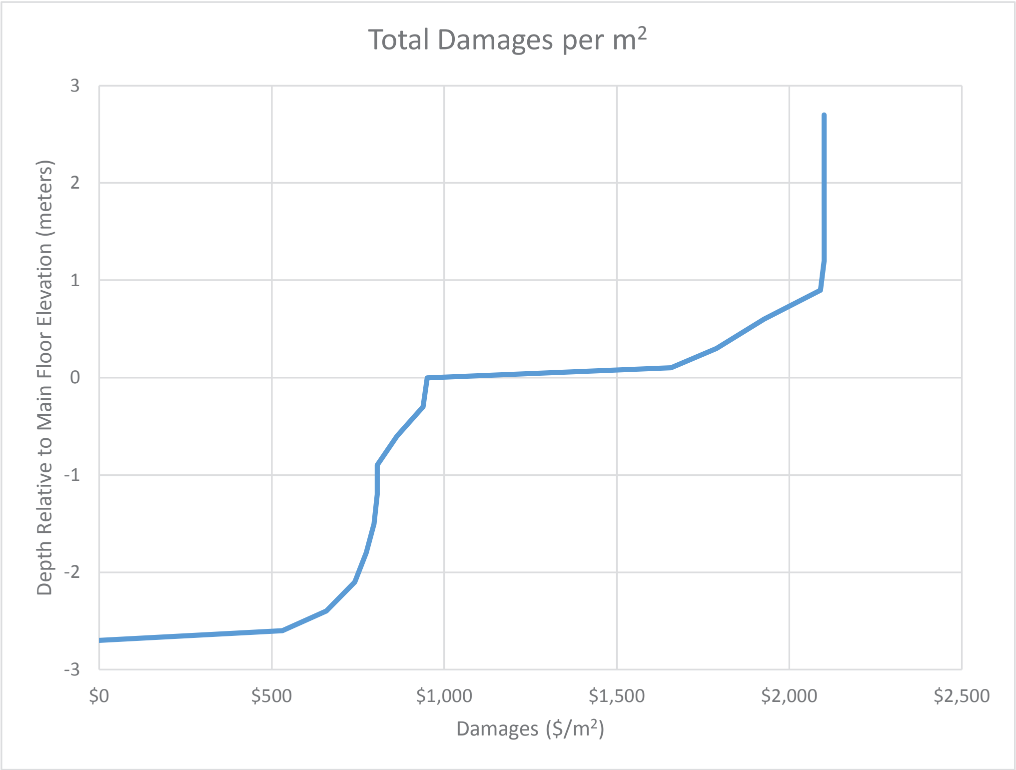
[2]not all structures have basements and it is a separate calculation in the model



Class C - Residential One-Storey					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$294	$237	$530
-2.4	$0	$0	$350	$309	$659
-2.1	$0	$0	$385	$356	$741
-1.8	$0	$0	$418	$356	$774
-1.5	$0	$0	$422	$374	$796
-1.2	$0	$0	$422	$383	$806
-0.9	$0	$0	$423	$383	$806
-0.6	$0	$0	$439	$424	$863
-0.3	$0	$0	$511	$427	$938
0	$0	$0	$511	$439	$950
0.1	$240	$467	$511	$439	$1,657
0.3	$360	$479	$511	$439	$1,789
0.6	$420	$557	$511	$439	$1,927
0.9	$468	$672	$511	$439	$2,090
1.2	$479	$672	$511	$439	$2,100
1.5	$479	$672	$511	$439	$2,101
1.8	$479	$672	$511	$439	$2,101
2.1	$479	$672	$511	$439	$2,101
2.4	$479	$672	$511	$439	$2,101
2.7	$479	$672	$511	$439	$2,101

[1]distance between floors is variable in model, 2.7m illustrated

[2]not all structures have basements and it is a separate calculation in the model

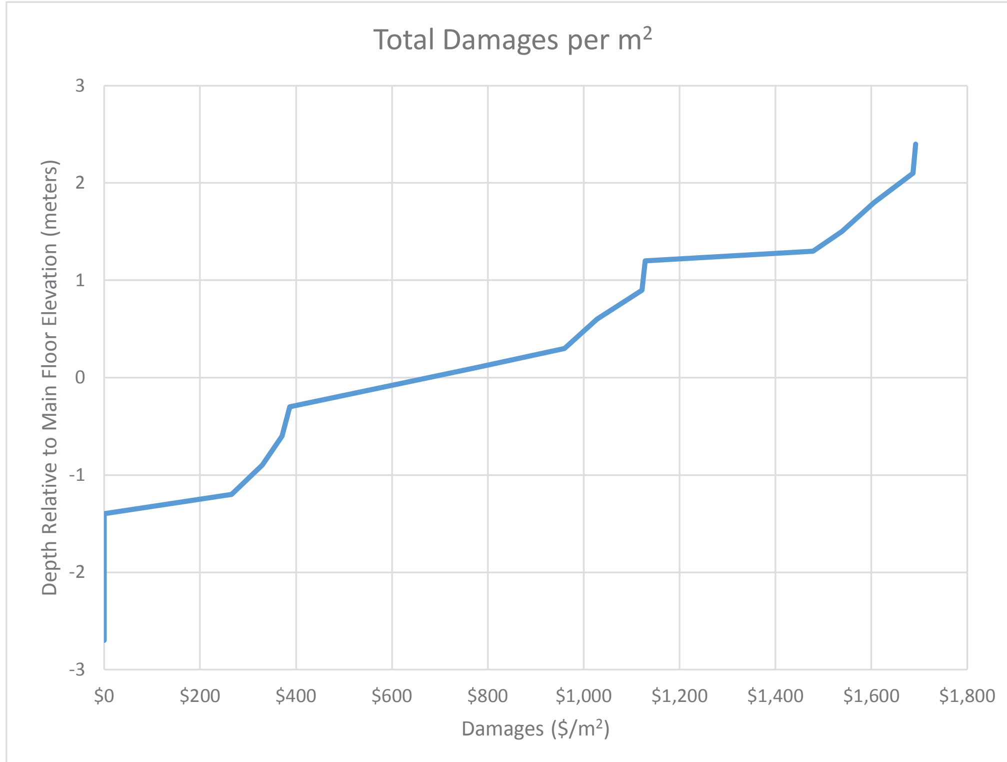


APPENDIX D - Damage Curves and Values - Class C - Residential Split Level

Class C - Residential Split Level					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$0	$0	$0
-2.4	$0	$0	$0	$0	$0
-2.1	$0	$0	$0	$0	$0
-1.8	$0	$0	$0	$0	$0
-1.5	$0	$0	$0	$0	$0
-1.4	$0	$0	$0	$0	$0
-1.2	$0	$0	$147	$118	$265
-0.9	$0	$0	$175	$154	$329
-0.6	$0	$0	$192	$178	$371
-0.3	$0	$0	$209	$178	$387
0.1	$117	$245	$225	$187	$774
0.3	$183	$257	$302	$218	$960
0.6	$212	$296	$302	$218	$1,028
0.9	$240	$354	$302	$225	$1,121
1.2	$245	$354	$302	$227	$1,128
1.3	$363	$587	$302	$227	$1,478
1.5	$423	$587	$302	$227	$1,539
1.8	$451	$626	$302	$227	$1,606
2.1	$475	$684	$302	$227	$1,687
2.4	$480	$684	$302	$227	$1,692

[1]distance between floors is variable in model, 2.7m illustrated

[2]not all structures have basements and it is a separate calculation in the model

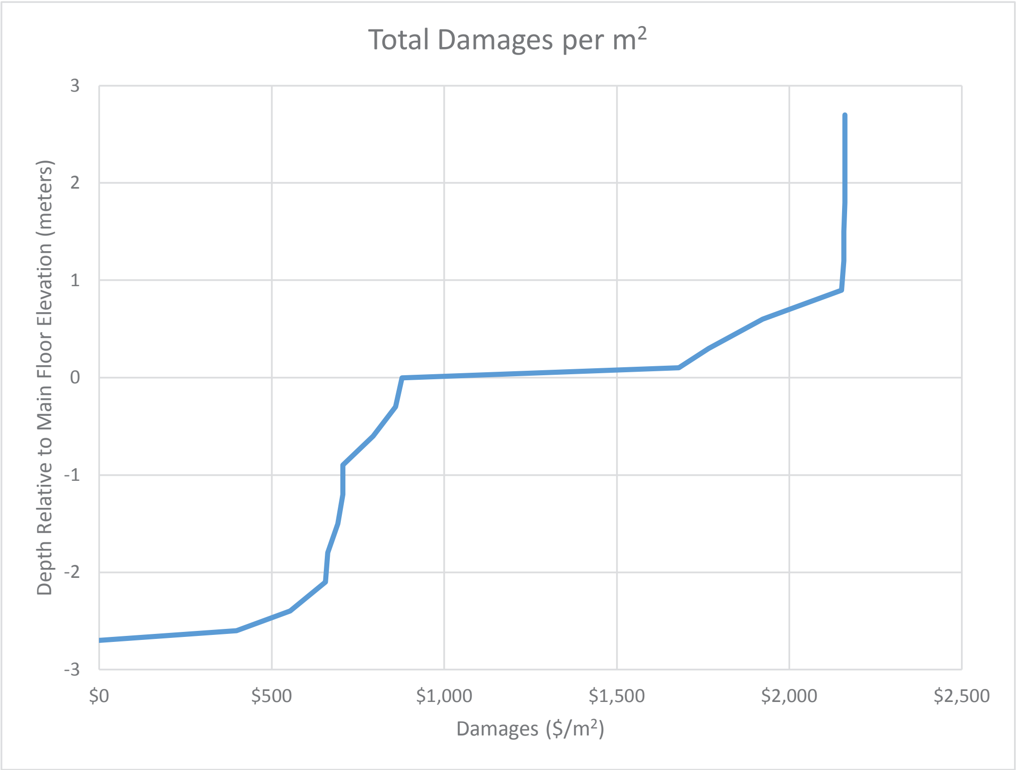


APPENDIX D - Damage Curves and Values - Class C - Residential Two-Storey

Class C - Residential Two-Storey					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$191	$207	$398
-2.4	$0	$0	$232	$322	$554
-2.1	$0	$0	$257	$399	$656
-1.8	$0	$0	$264	$399	$663
-1.5	$0	$0	$264	$428	$692
-1.2	$0	$0	$264	$442	$706
-0.9	$0	$0	$264	$442	$706
-0.6	$0	$0	$287	$508	$794
-0.3	$0	$0	$346	$512	$858
0	$0	$0	$346	$532	$878
0.1	$204	$599	$346	$532	$1,681
0.3	$271	$619	$346	$532	$1,767
0.6	$301	$744	$346	$532	$1,923
0.9	$376	$897	$346	$532	$2,152
1.2	$383	$897	$346	$532	$2,158
1.5	$384	$897	$346	$532	$2,159
1.8	$386	$897	$346	$532	$2,161
2.1	$386	$897	$346	$532	$2,161
2.4	$386	$897	$346	$532	$2,161
2.7	$386	$897	$346	$532	$2,161

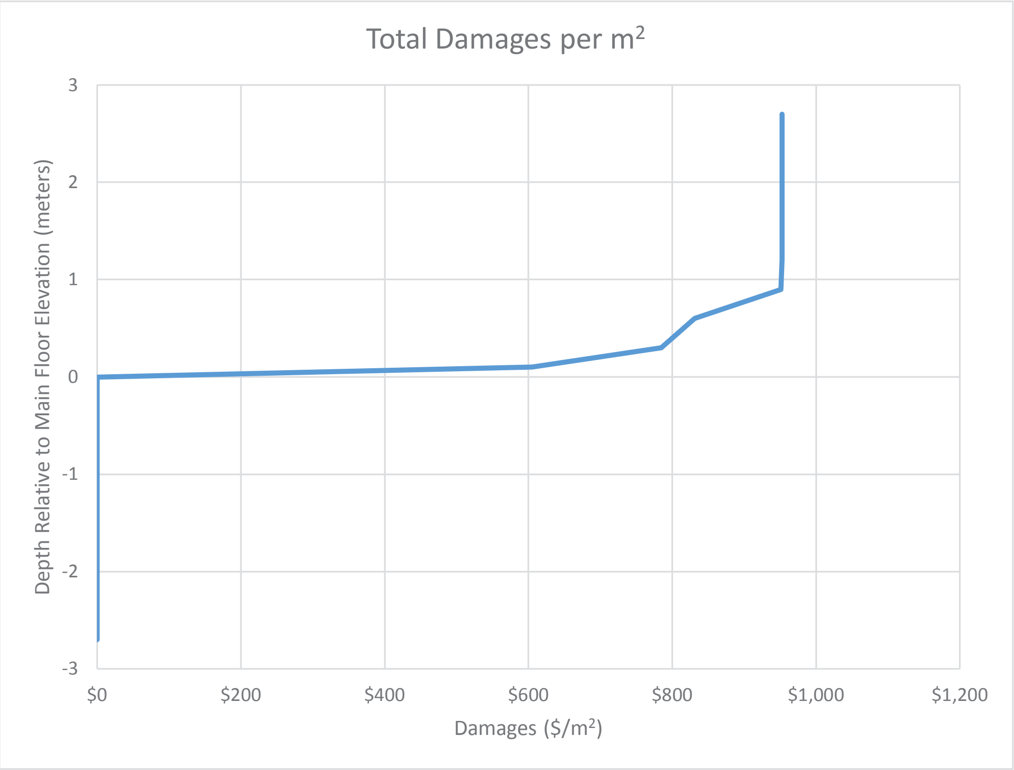
[1]distance between floors is variable in model, 2.7m illustrated

[2]not all structures have basements and it is a separate calculation in the model



APPENDIX D - Damage Curves and Values - One Storey Mobile Home (No Basement)

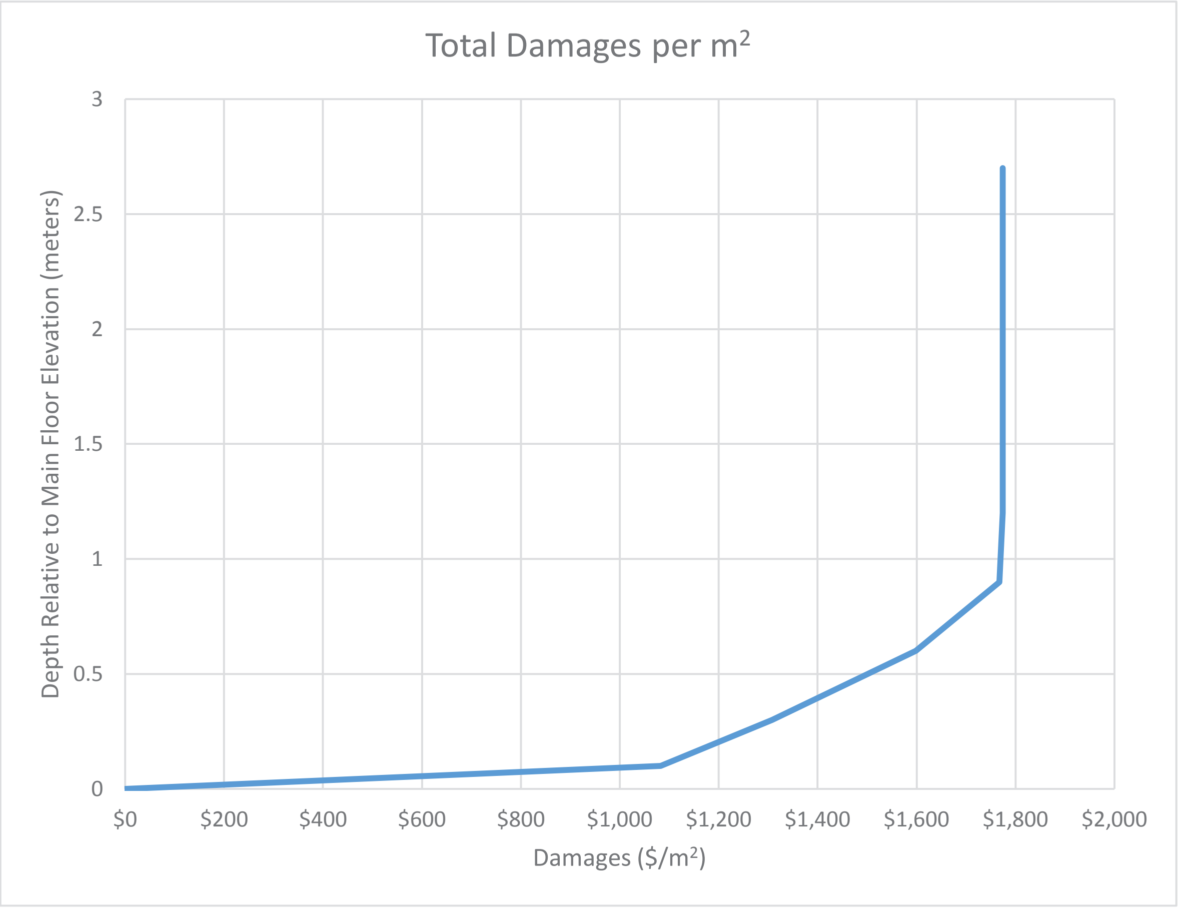
One Storey Mobile Home (No Basement)					
Depth relative to main floor	Main Floor Contents	Main Floor Structure	Basement Contents	Basement Structure	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$0	$0	$0
-2.4	$0	$0	$0	$0	$0
-2.1	$0	$0	$0	$0	$0
-1.8	$0	$0	$0	$0	$0
-1.5	$0	$0	$0	$0	$0
-1.2	$0	$0	$0	$0	$0
-0.9	$0	$0	$0	$0	$0
-0.6	$0	$0	$0	$0	$0
-0.3	$0	$0	$0	$0	$0
0	$0	$0	$0	$0	$0
0.1	$243	$362	$0	$0	$605
0.3	$379	$405	$0	$0	$785
0.6	$426	$405	$0	$0	$831
0.9	$481	$470	$0	$0	$951
1.2	$483	$470	$0	$0	$953
1.5	$483	$470	$0	$0	$953
1.8	$483	$470	$0	$0	$953
2.1	$483	$470	$0	$0	$953
2.4	$483	$470	$0	$0	$953
2.7	$483	$470	$0	$0	$953



APPENDIX D - Damage Curves and Values - Apartment Building with Four Floors or Less

Apartment Building with Four Floors or Less			
Depth relative to main floor	Main Floor Contents	Main Floor Structure	Total
0	$0	$0	$0
0.1	$260	$822	$1,082
0.3	$394	$914	$1,307
0.6	$494	$1,105	$1,599
0.9	$565	$1,203	$1,768
1.2	$571	$1,203	$1,774
1.5	$571	$1,203	$1,774
1.8	$571	$1,203	$1,774
2.1	$571	$1,203	$1,774
2.4	$571	$1,203	$1,774
2.7	$571	$1,203	$1,774

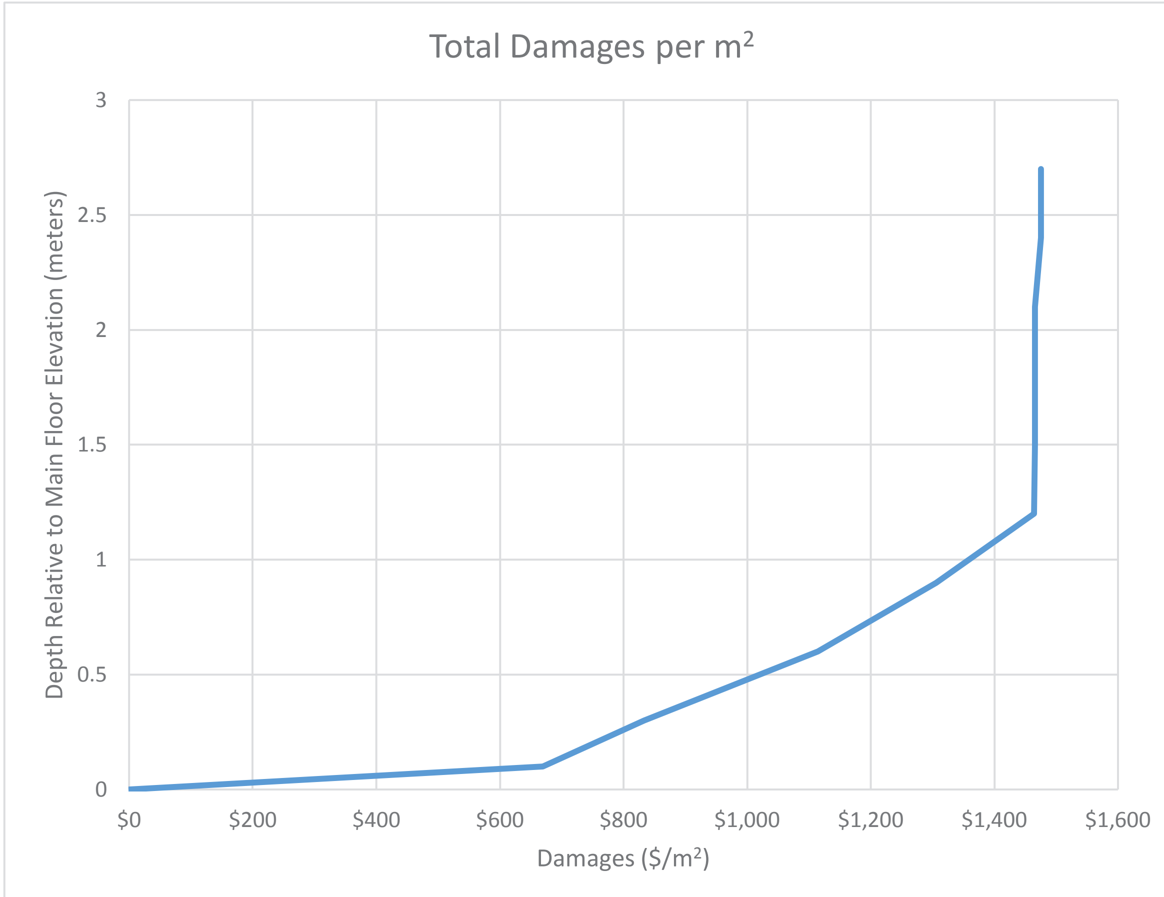
*Underground Parking damages are $215/m^2



APPENDIX D - Damage Curves and Values - Apartment Building with Five Floors or More

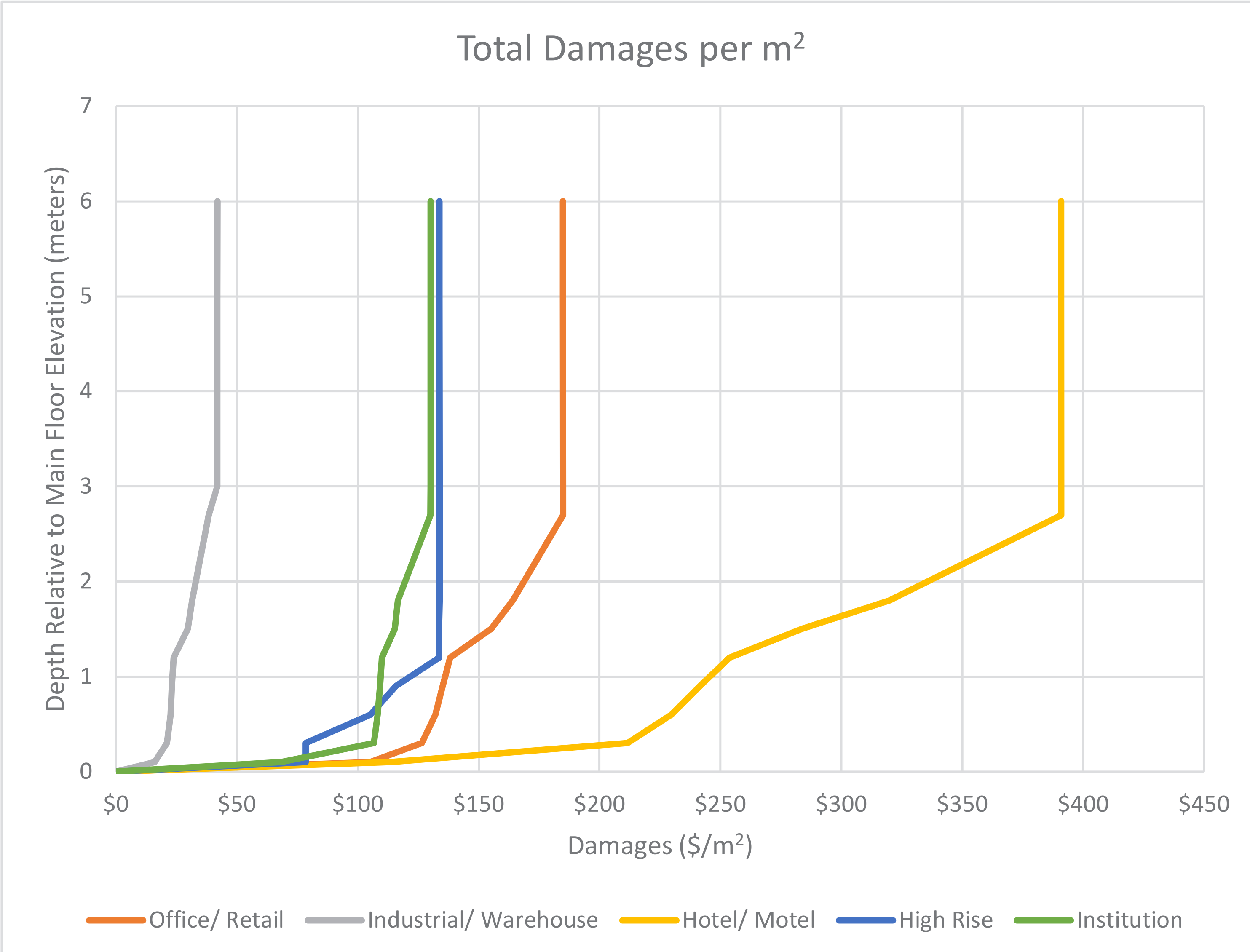
Apartment Building with Five Floors or More			
Depth relative to main floor	Main Floor Contents	Main Floor Structure	Total
0	$0	$0	$0
0.1	$221	$449	$670
0.3	$384	$449	$833
0.6	$435	$680	$1,115
0.9	$514	$792	$1,306
1.2	$527	$937	$1,464
1.5	$528	$937	$1,466
1.8	$528	$937	$1,466
2.1	$528	$937	$1,466
2.4	$538	$937	$1,475
2.7	$538	$937	$1,475

*Underground Parking damages are $215/m^2



	S1	S2	S3	S4	S5
Relative Depth (m)	Office/ Retail	Industrial/ Warehouse	Hotel/ Motel	High Rise	Institution
0	$0	$0	$0	$0	$0
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
3	$185	$42	$391	$134	$130
5	$185	$42	$391	$134	$130
6	$185	$42	$391	$134	$130

*Underground Parking damages are $215/m^2


Total Damages per m²
Depth Relative to Main Floor Elevation (meters)
0
1
2
3
4
5
6
7
$0
$50
$100
$150
$200
$250
$300
$350
$400
$450
Damages ($/m²)
Office/ Retail
Industrial/ Warehouse
Hotel/ Motel
High Rise
Institution

	A1	B1	C1	C2	C3	C4	C5	C6
Relative Depth (m)	General Office	Medical	Shoes	Clothing	Stereos/TV	Paper Products	Hardware/ Carpet	Retail
0	$0	$0	$0	$0	$0	$0	$0	$0
0.15	$121	$150	$200	$187	$352	$96	$142	$209
0.3	$127	$450	$600	$385	$504	$183	$265	$408
0.6	$219	$900	$729	$572	$689	$366	$427	$636
0.9	$380	$1,350	$984	$1,314	$852	$557	$880	$844
1.2	$380	$1,380	$1,100	$1,425	$1,139	$740	$943	$1,072
1.5	$380	$1,425	$1,121	$1,705	$1,352	$810	$1,005	$1,252
1.8	$380	$1,500	$1,159	$1,862	$1,467	$906	$1,068	$1,366
2.1	$380	$1,500	$1,189	$1,862	$1,467	$906	$1,130	$1,366
2.4	$380	$1,500	$1,219	$1,862	$1,467	$906	$1,257	$1,366
2.7	$381	$1,500	$1,219	$1,862	$1,467	$906	$1,257	$1,366
3	$381	$1,500	$1,219	$1,862	$1,467	$906	$1,257	$1,366

*Underground Parking damages are $215/m^2

	C7	D1	E1	F1	G1	H1	I1	J1
Relative Depth (m)	Misc Retail	Furniture / Appliances	Groceries	Drugs	Auto	Hotels	Restaurant	Personal Services
0	$0	$0	$0	$0	$0	$0	$0	$0
0.15	$182	$138	$148	$50	$46	$20	$72	$37
0.3	$349	$198	$270	$350	$254	$39	$257	$74
0.6	$512	$306	$410	$505	$462	$52	$434	$167
0.9	$782	$345	$531	$610	$878	$65	$442	$260
1.2	$919	$376	$616	$715	$982	$104	$452	$278
1.5	$1,026	$408	$616	$820	$1,005	$131	$452	$408
1.8	$1,103	$439	$616	$897	$1,005	$144	$452	$687
2.1	$1,115	$439	$616	$897	$1,005	$144	$452	$696
2.4	$1,134	$439	$616	$897	$1,005	$144	$452	$705
2.7	$1,134	$439	$616	$897	$1,005	$144	$452	$705
3	$1,134	$439	$616	$897	$1,005	$144	$452	$705

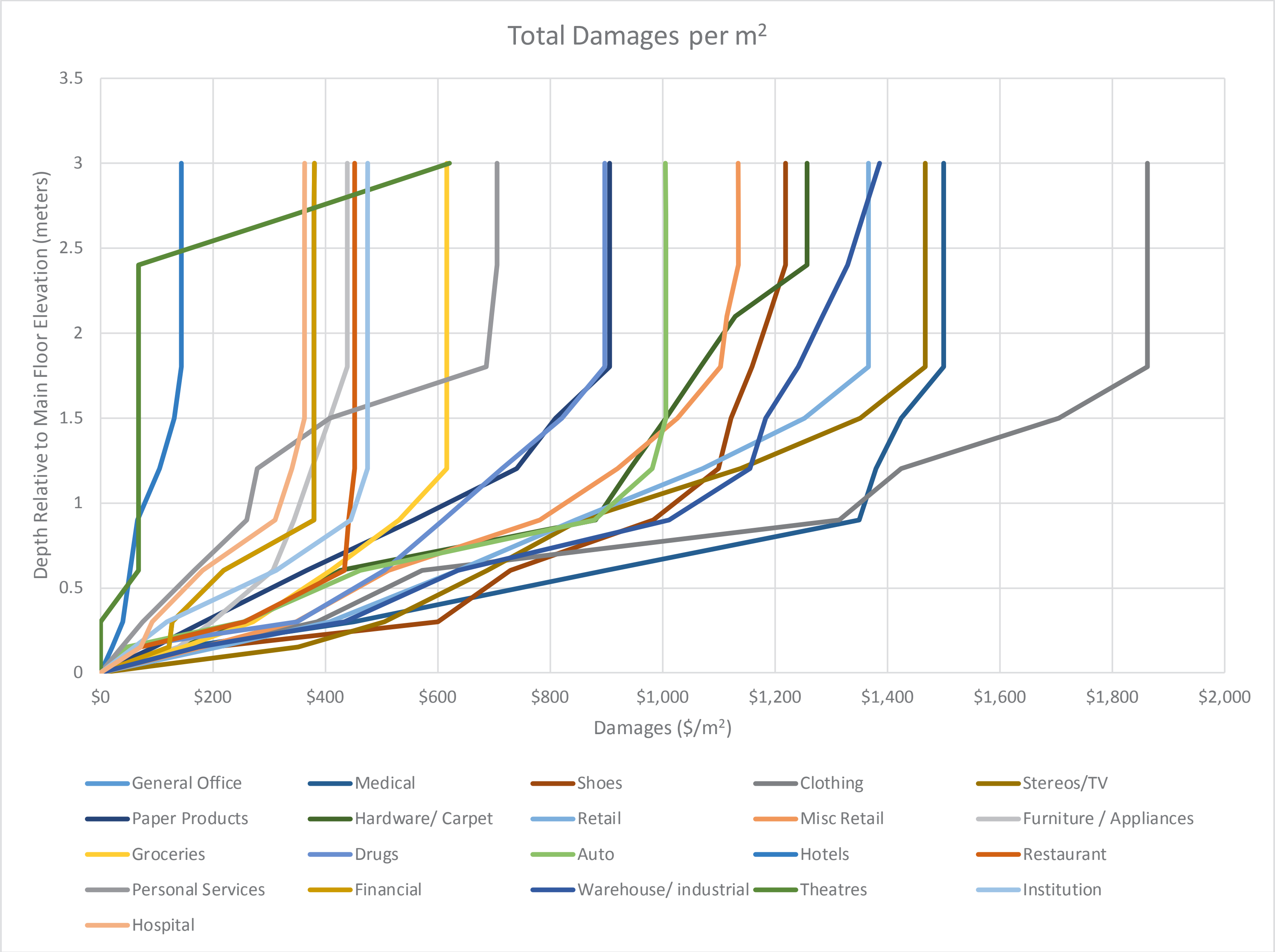
*Underground Parking damages are $215/m^2

APPENDIX D - Damage Curves and Values - Non-Residential Contents

	K1	L1	M1	N1	N2
Relative Depth (m)	Financial	Warehouse/ industrial	Theatres	Institution	Hospital
0	$0	$0	$0	$0	$0
0.15	$121	$173	$0	$59	$72
0.3	$127	$433	$0	$119	$92
0.6	$219	$635	$68	$312	$182
0.9	$380	$1,011	$68	$446	$311
1.2	$380	$1,155	$68	$475	$341
1.5	$380	$1,184	$68	$475	$363
1.8	$380	$1,242	$68	$475	$363
2.1	$380	$1,285	$68	$475	$363
2.4	$380	$1,328	$68	$475	$363
2.7	$380	$1,357	$344	$475	$363
3	$380	$1,386	$621	$475	$363

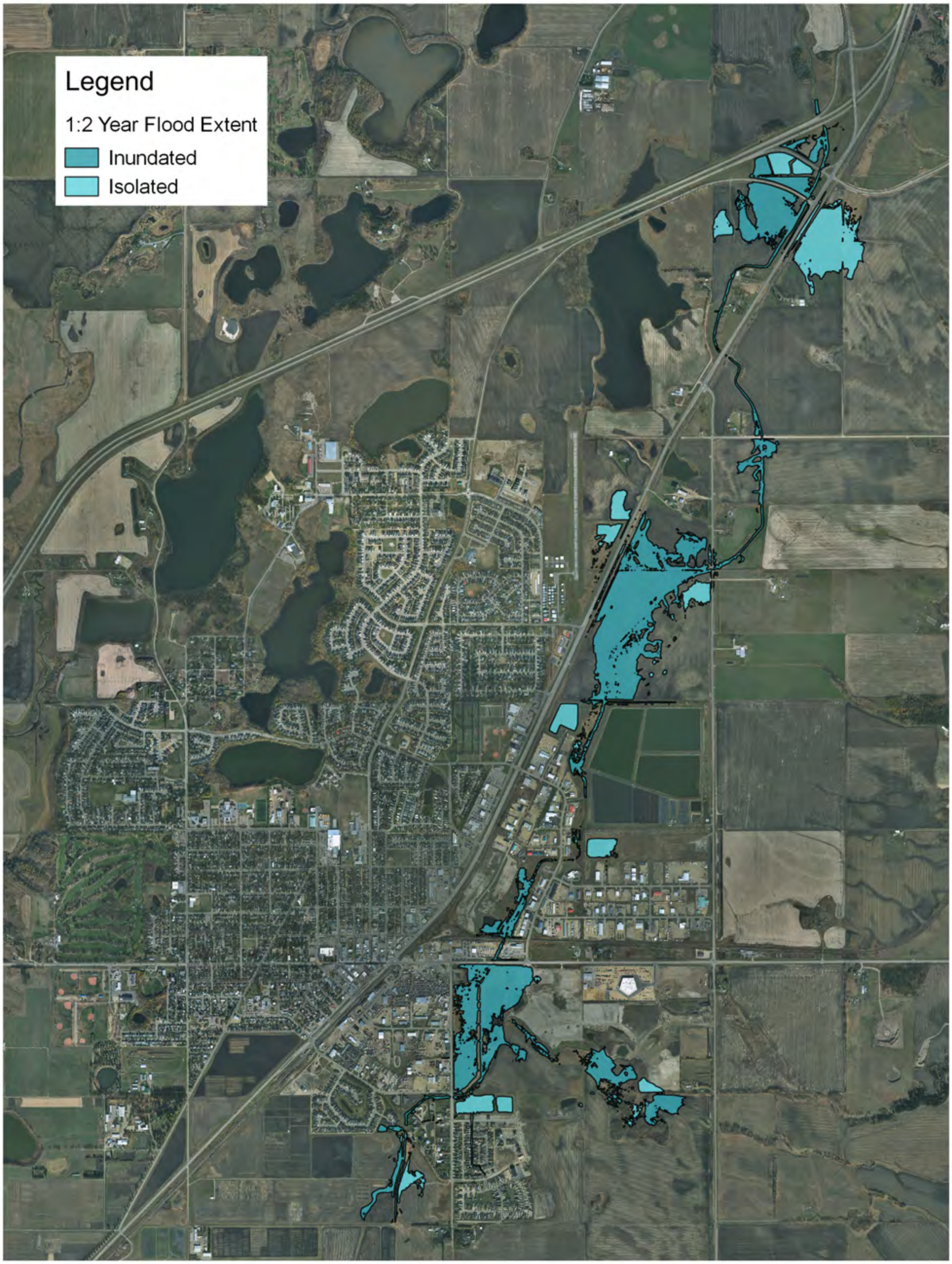
*Underground Parking damages are $215/m^2

APPENDIX D - Damage Curves and Values - Non-Residential Contents

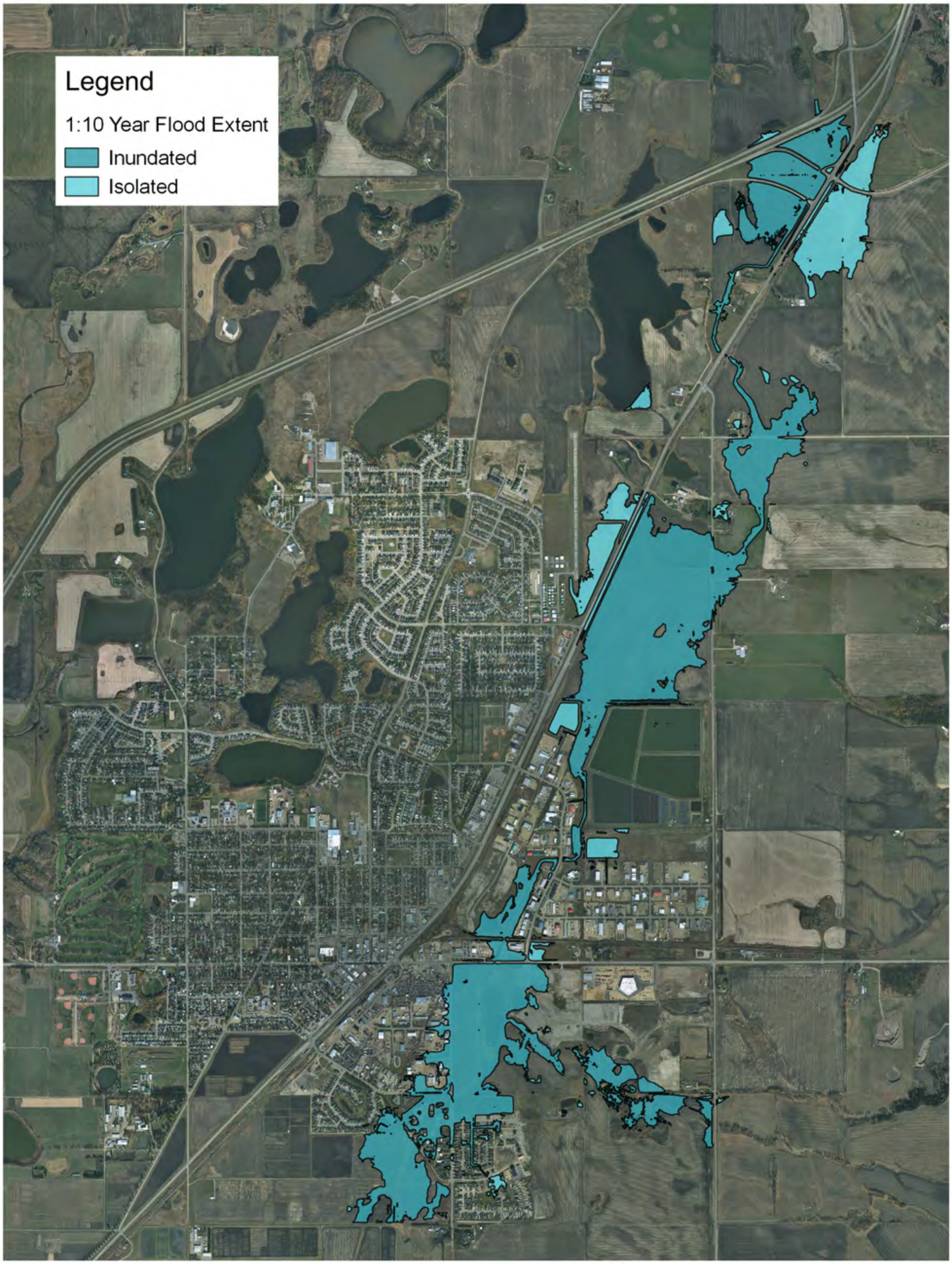


Appendix D – Lacombe Flood Extent Mapping

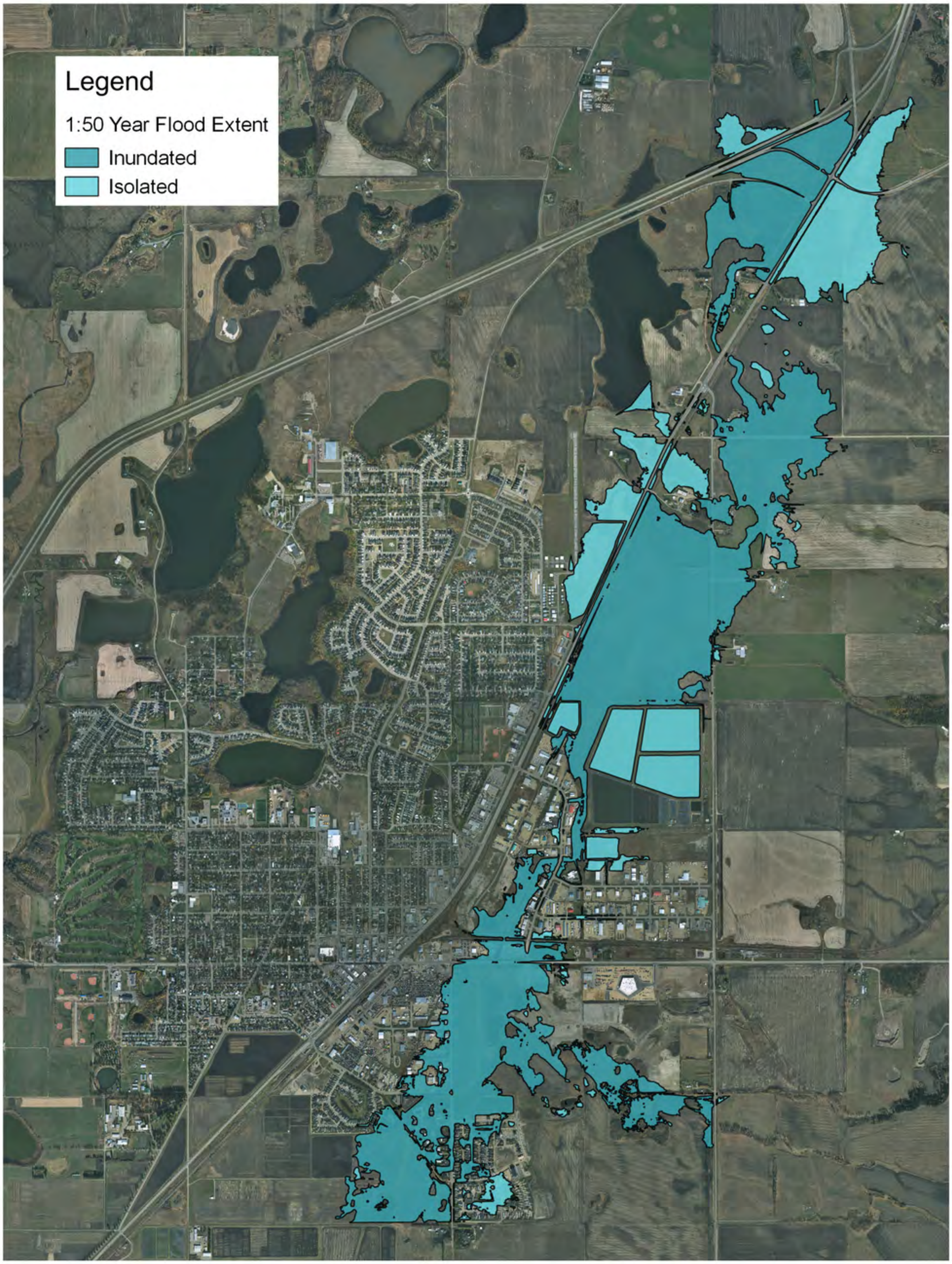
Lacombe Flood Elevation Mapping – 1:2 Year Flood



Lacombe Flood Elevation Mapping – 1:10 Year Flood



Lacombe Flood Elevation Mapping – 1:50 Year Flood



Lacombe Flood Elevation Mapping – 1:100 Year Flood