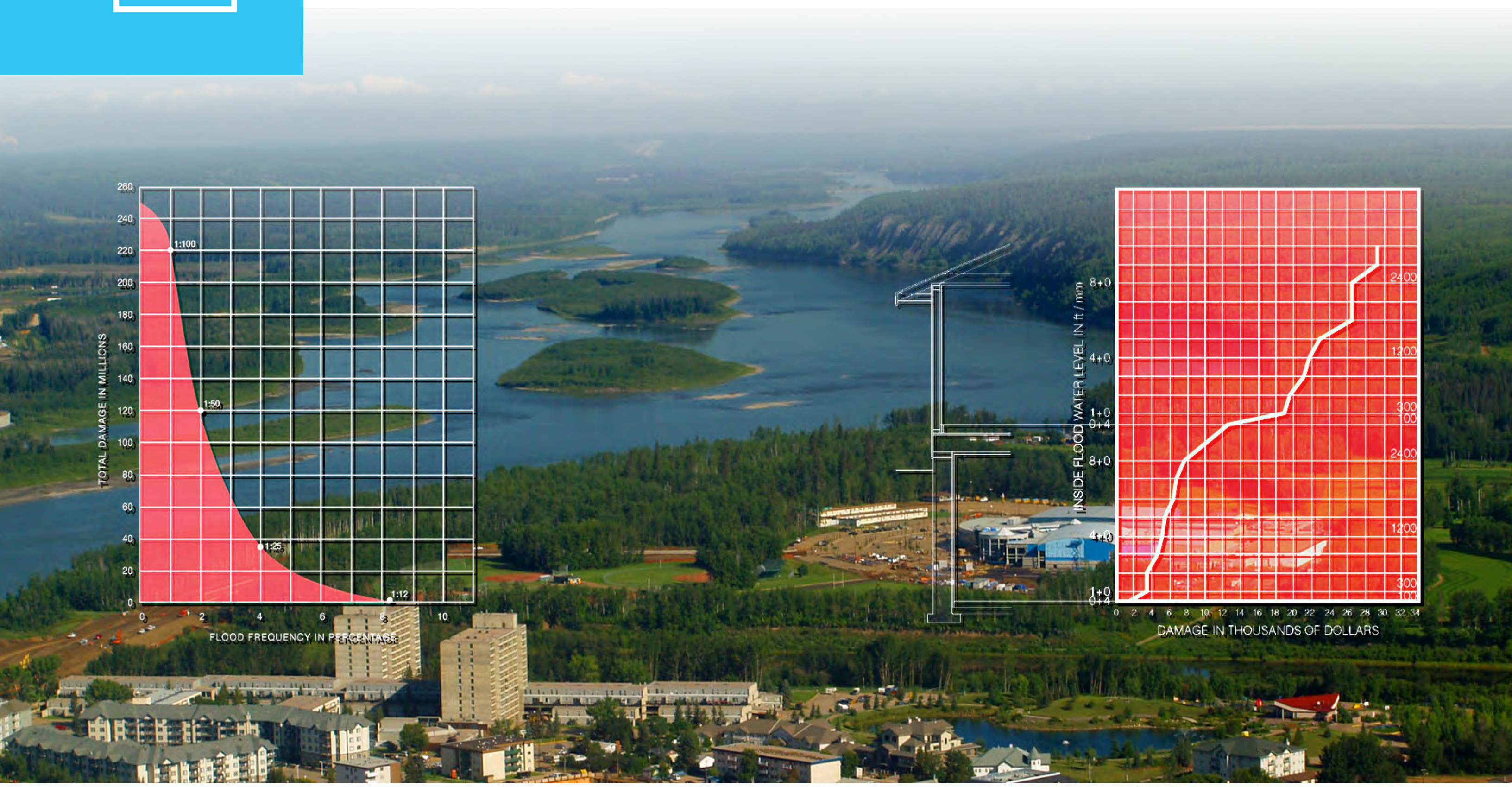

REPORT

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

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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.

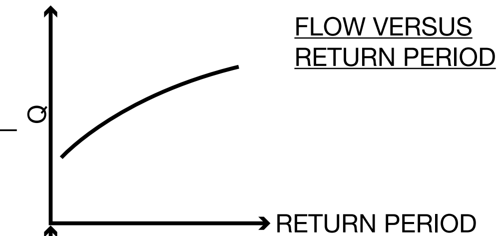
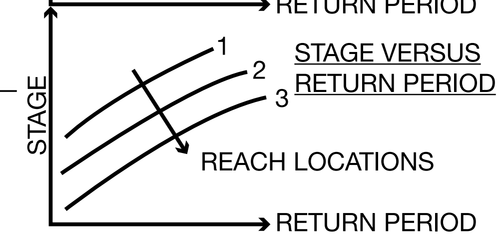
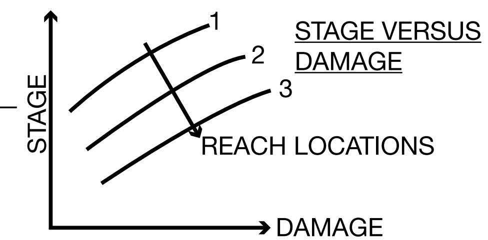
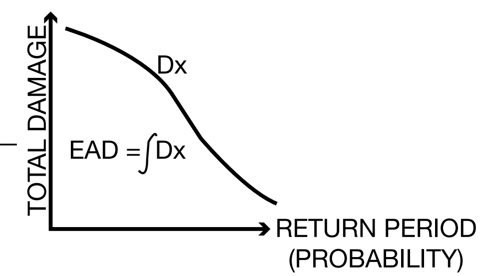
Damages incurred are proportional to depth of flooding which is, in turn, dependent upon the hydraulic characteristics of the watercourse and floodplain and the magnitude of the flood flow. Therefore, definition of flood damages for a particular flood first involves the prediction of flows for return 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

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	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	
- 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)	

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].

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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

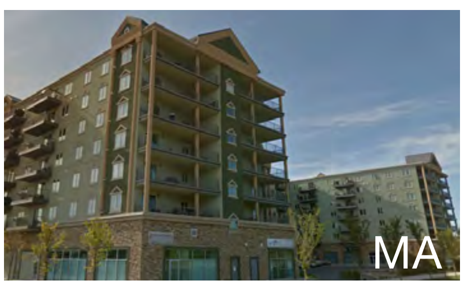
* 1, 2, 3 denotes above average, average and below average quality within the A, B and C categories. This differentiation was later dropped for sampling purposes.

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 FIA. 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

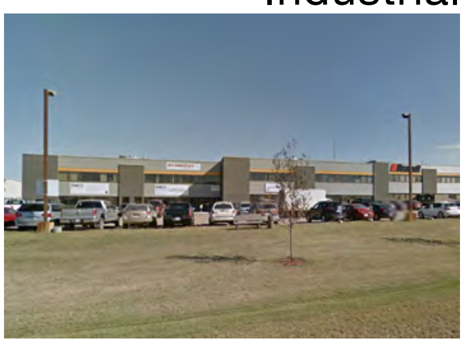
Industrial

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.

[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.

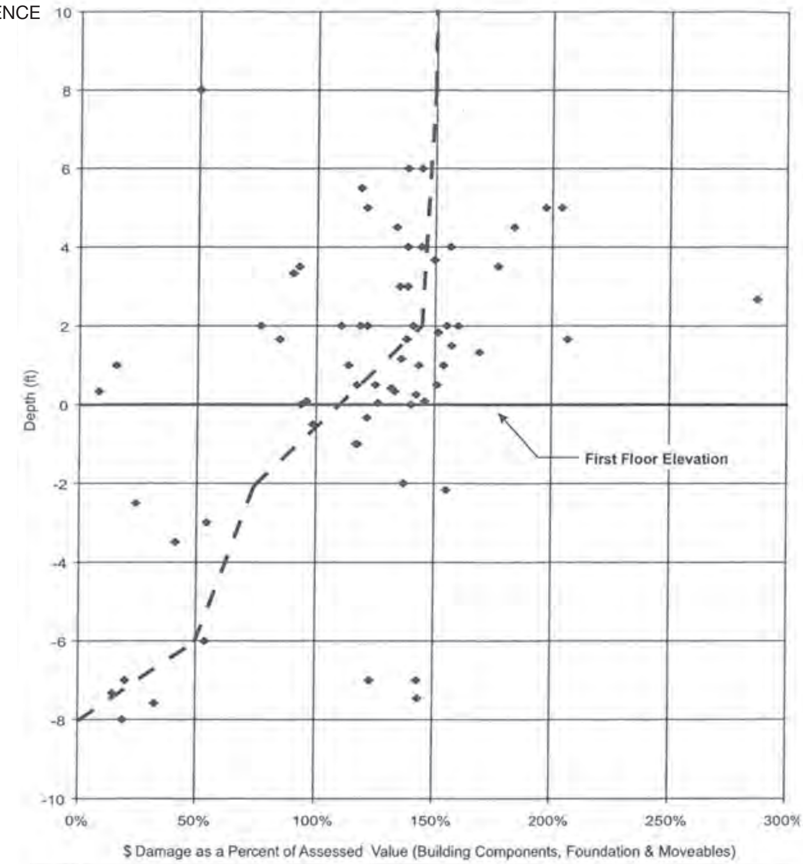
2.3.5.3 Depth-Damage Relationships

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.

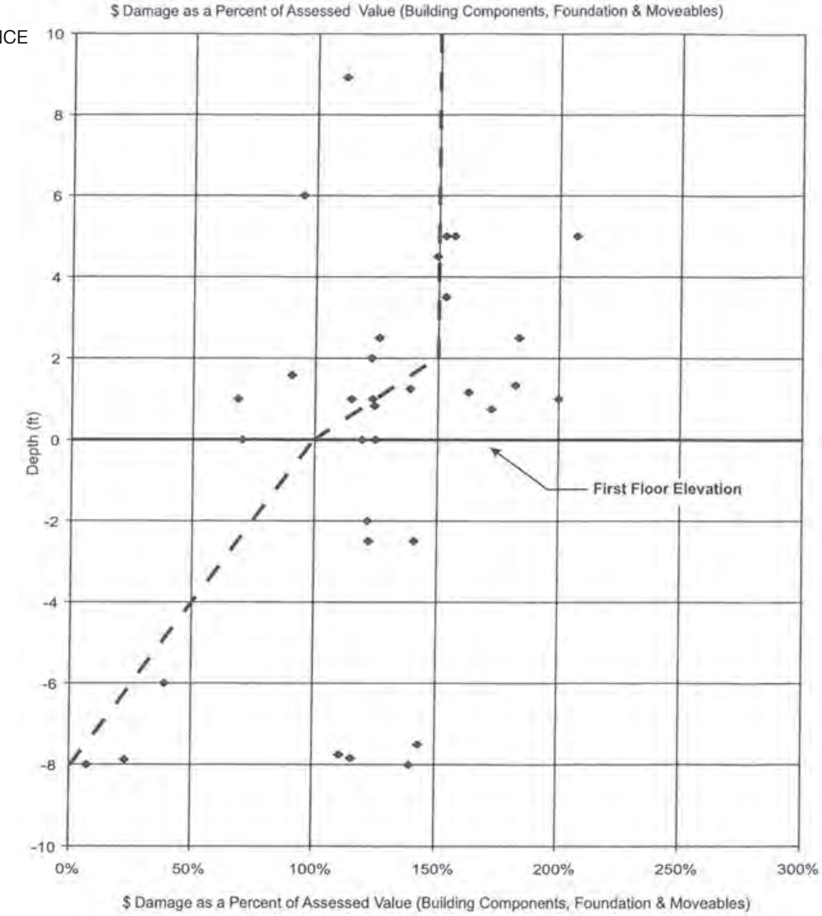
In general, the depth-damage relationships developed show that the damages exceed the market (assessed value) of the home as the flood depth increases beyond the first floor. This trend is consistent with previous studies, but the slope of the MEMO data relationship is greater than previous curves. As 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



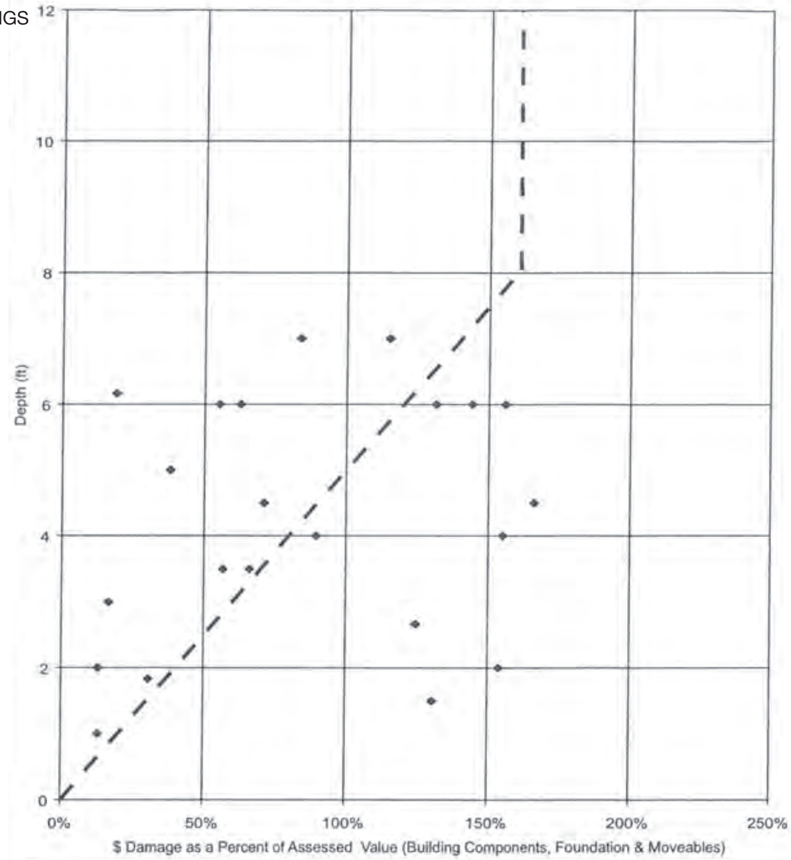
MULTIPLE STOREY RESIDENCE



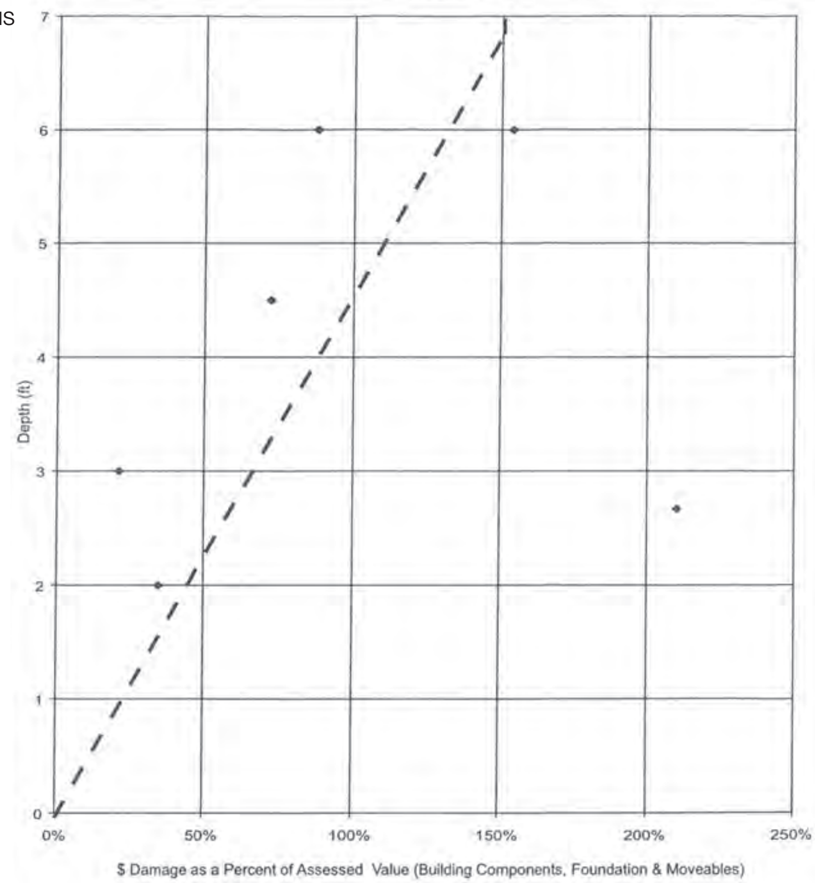
KGS Group, *Red River Basin Stage-Damage Curves Update and Preparation of Flood Damage Maps*, International Joint Commission, January 2000.

Depth-Damage Curves

DETACHED RESIDENTIAL BUILDINGS



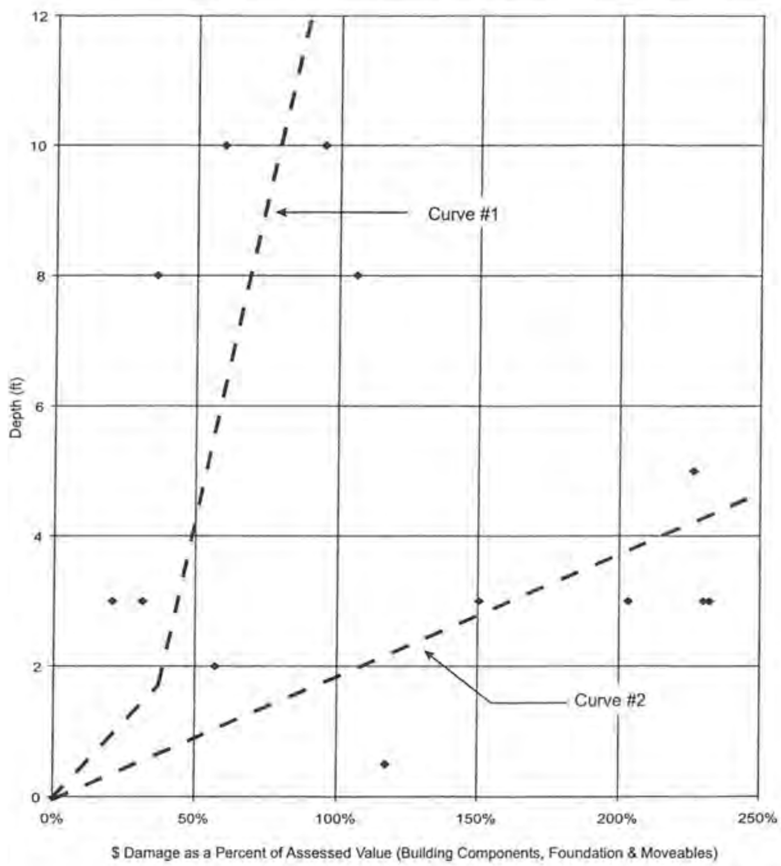
AGRICULTURAL BUILDINGS - BARNS



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

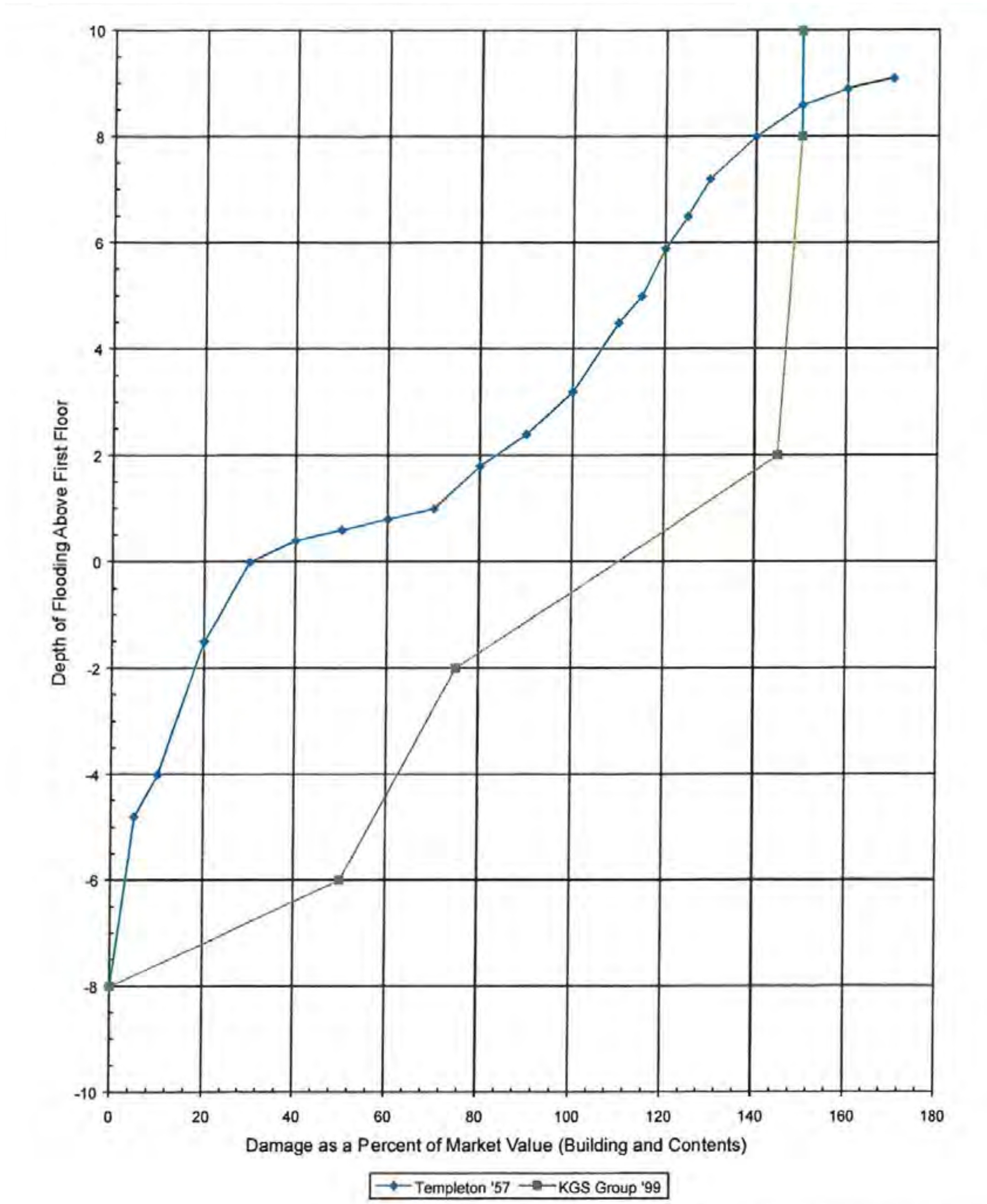
Depth-Damage Curves

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.

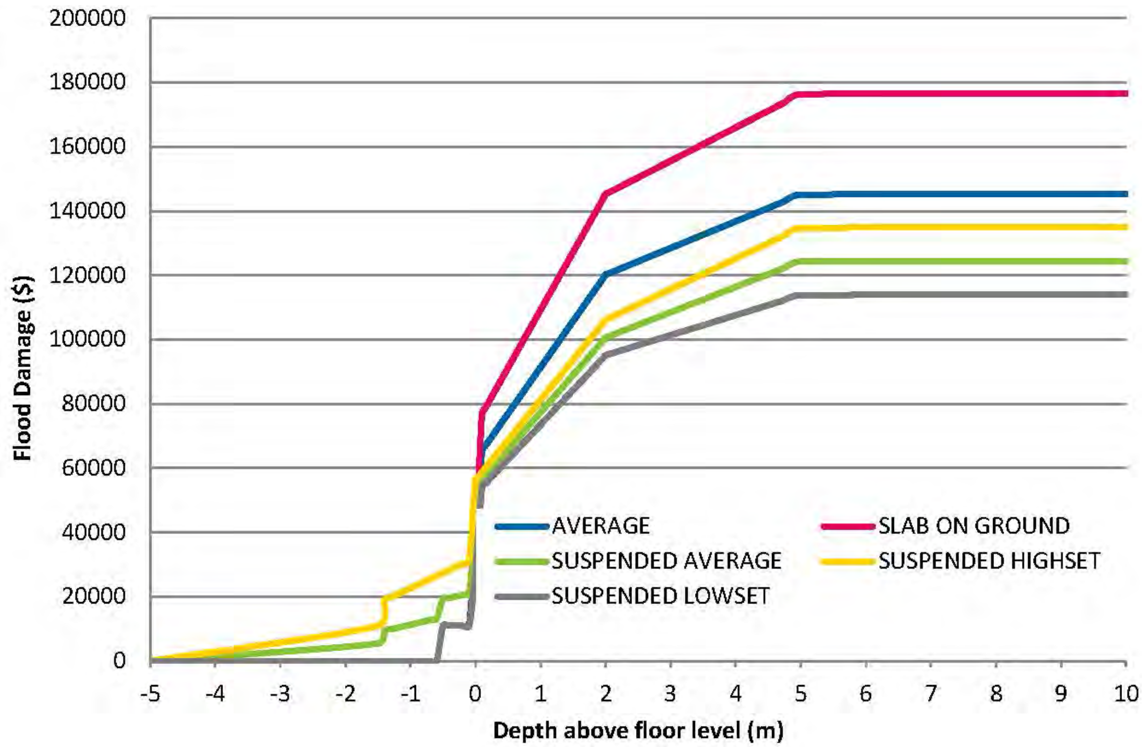
2.3.6.1.1 Residential

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

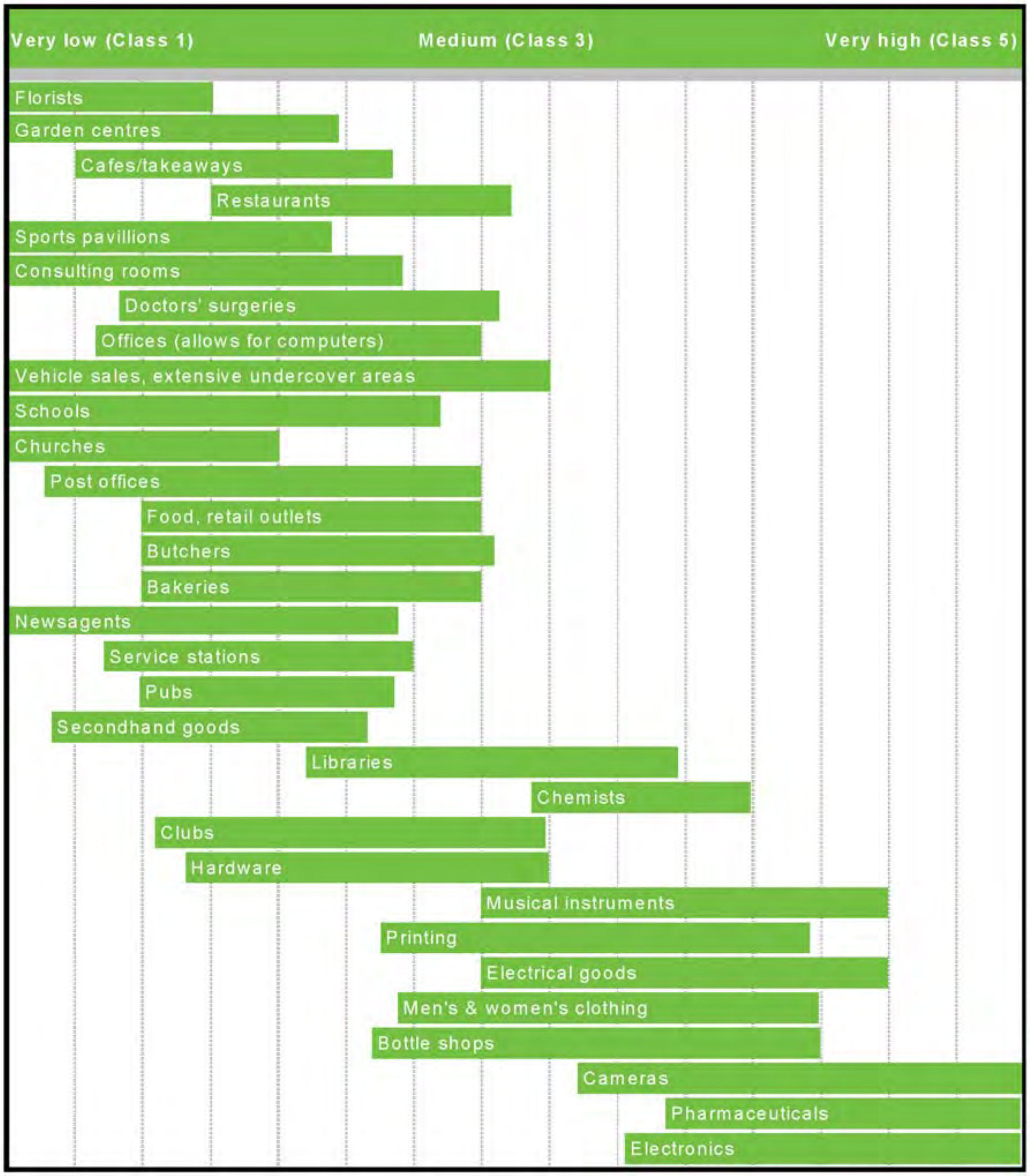
The Queensland DNRM methodology (DNRM, 2002), which is based on the stage-discharge curves developed by ANUFLOOD (Smith & Greenway, 1988) was adopted for the assessment of damages to commercial properties. This methodology utilizes various stage-damage curves based on both building size and contents 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

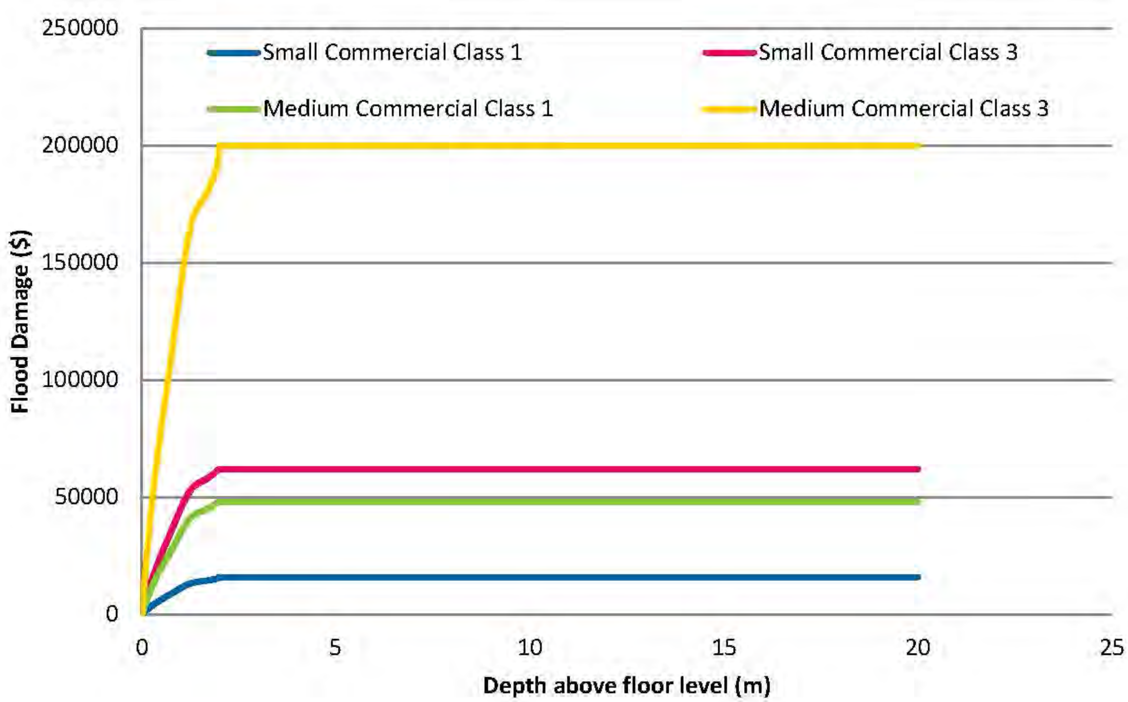
These stage-damage curves were updated to present day using CPI. It should be noted that curves for the small and medium sized buildings provide damages per property, while the large building curves provide damage estimates per unit of floor area (in this case m^2). These were used to estimate direct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

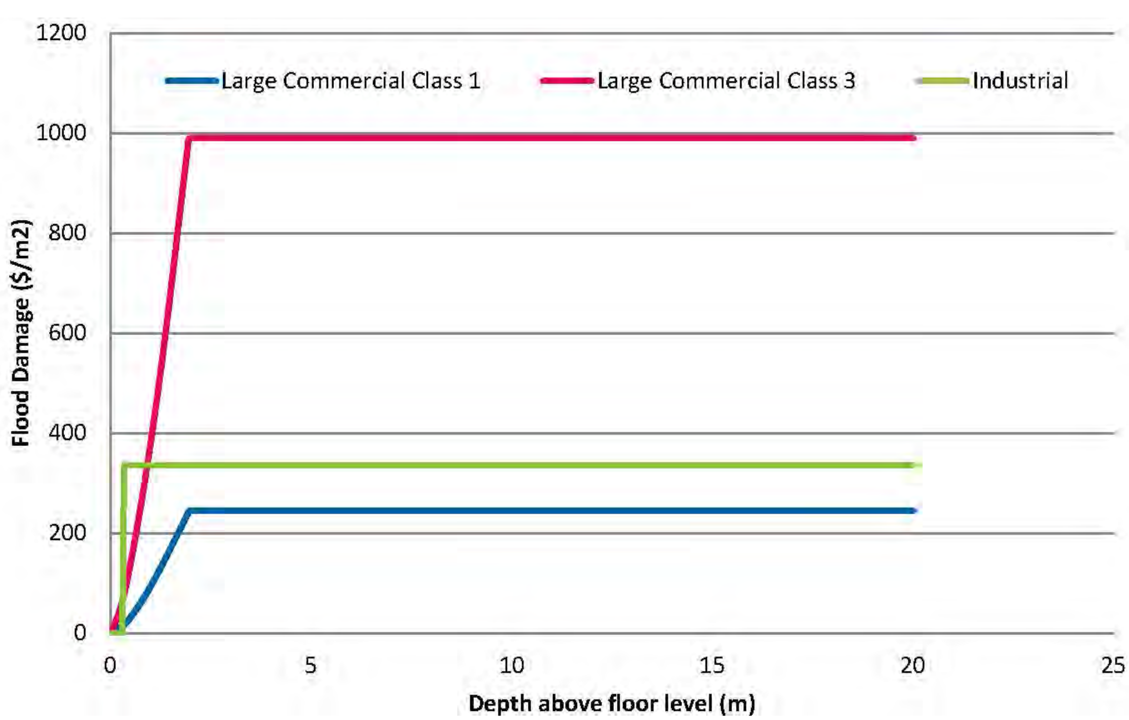


Stage-Damage Curve for Small and Medium Size Commercial Properties



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.

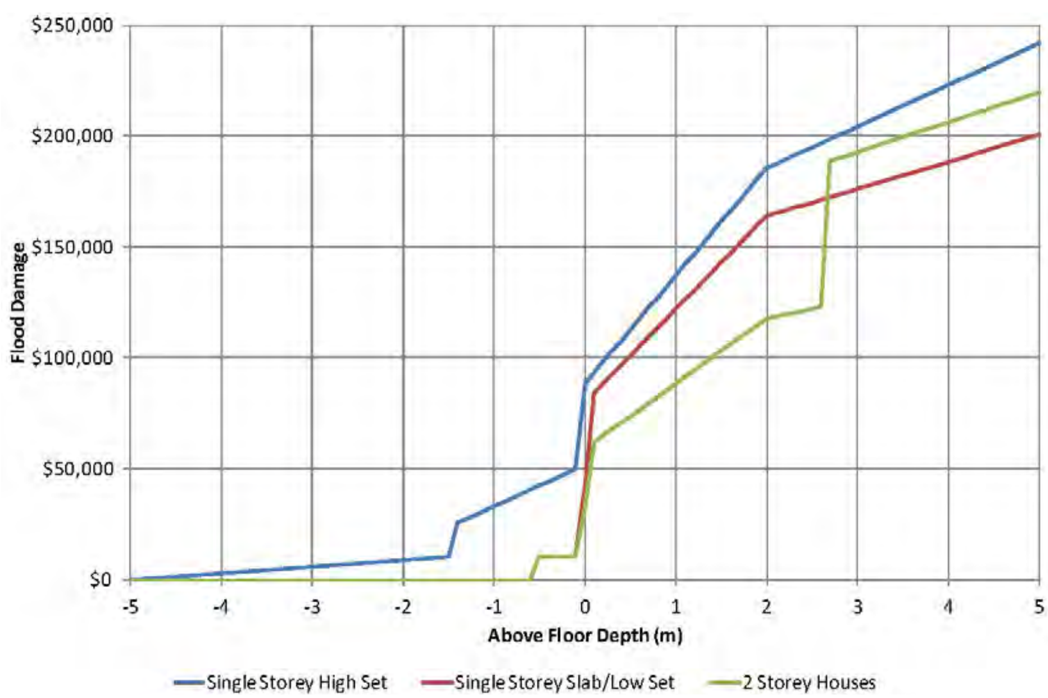
2.3.6.2 Ballina Floodplain Risk Management Study[14]

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

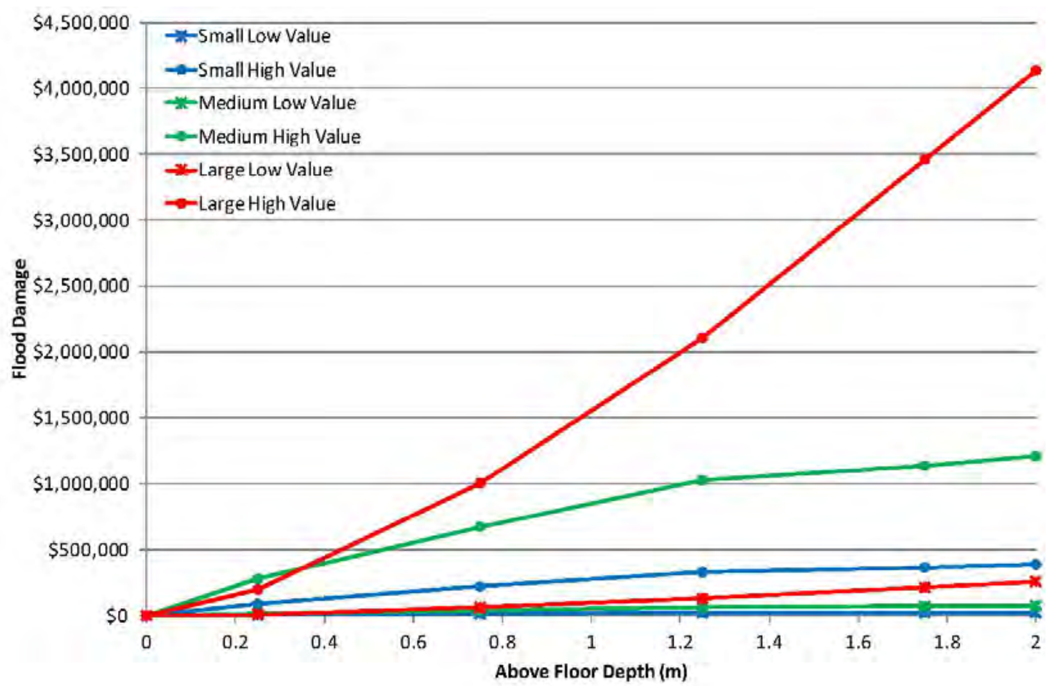
The Office of Environment and Water does not presently have specific NSW guidance on commercial flood damages. The Queensland NRM4 methodology was therefore adopted, as outlined in *Guidance on the Assessment of Tangible Flood Damages* (2002) and based on stage-damage curves developed for ANUFLOOD5.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

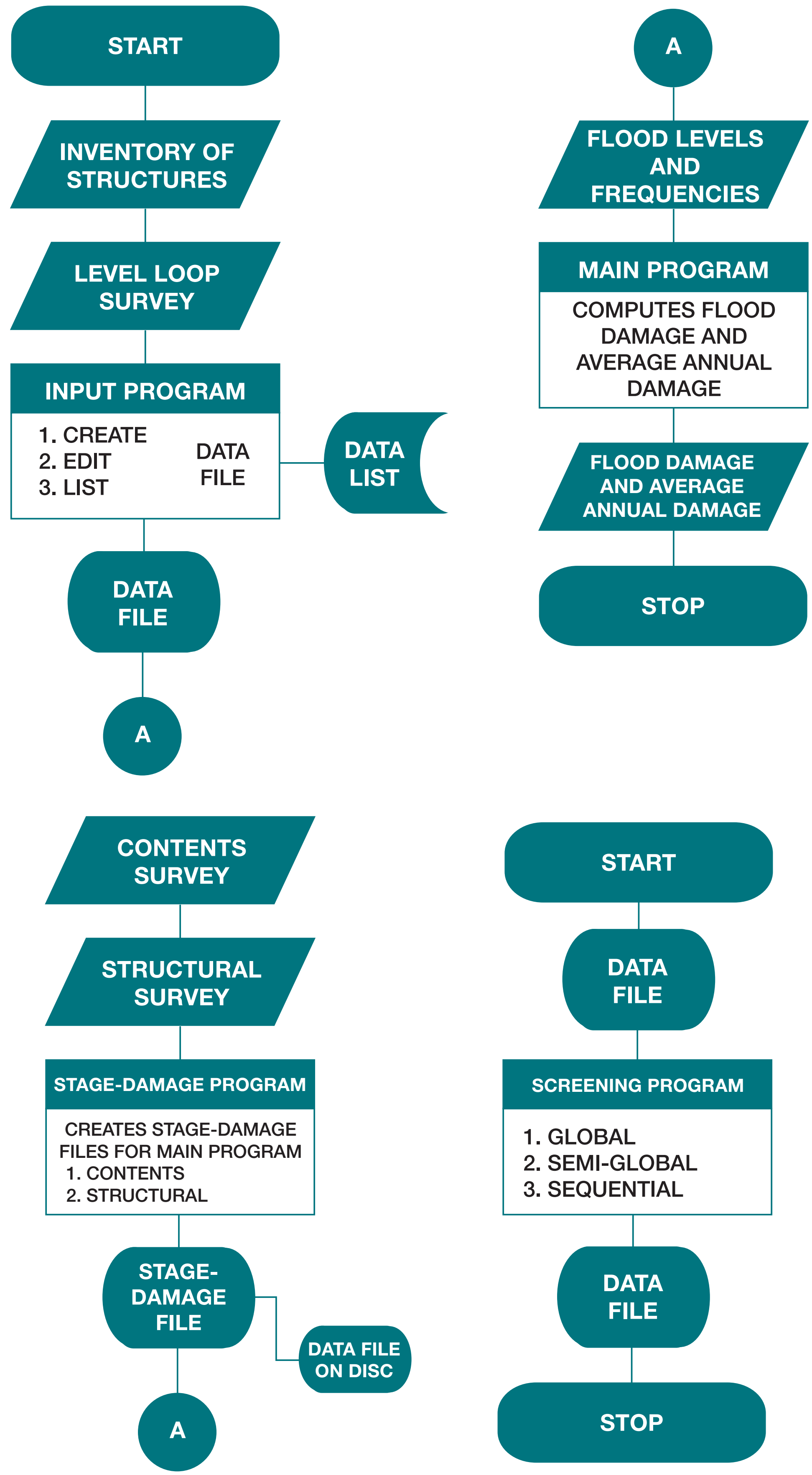
Comparative Flood Damage Estimation Program (CFDEP) was a modified version of FDDBMS designed to use the data base derived from the Flood Damage Survey Forms from seven communities in the Red River Valley and other adjacent watersheds in Manitoba. This data was collected by the Manitoba Flood Disaster 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

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[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

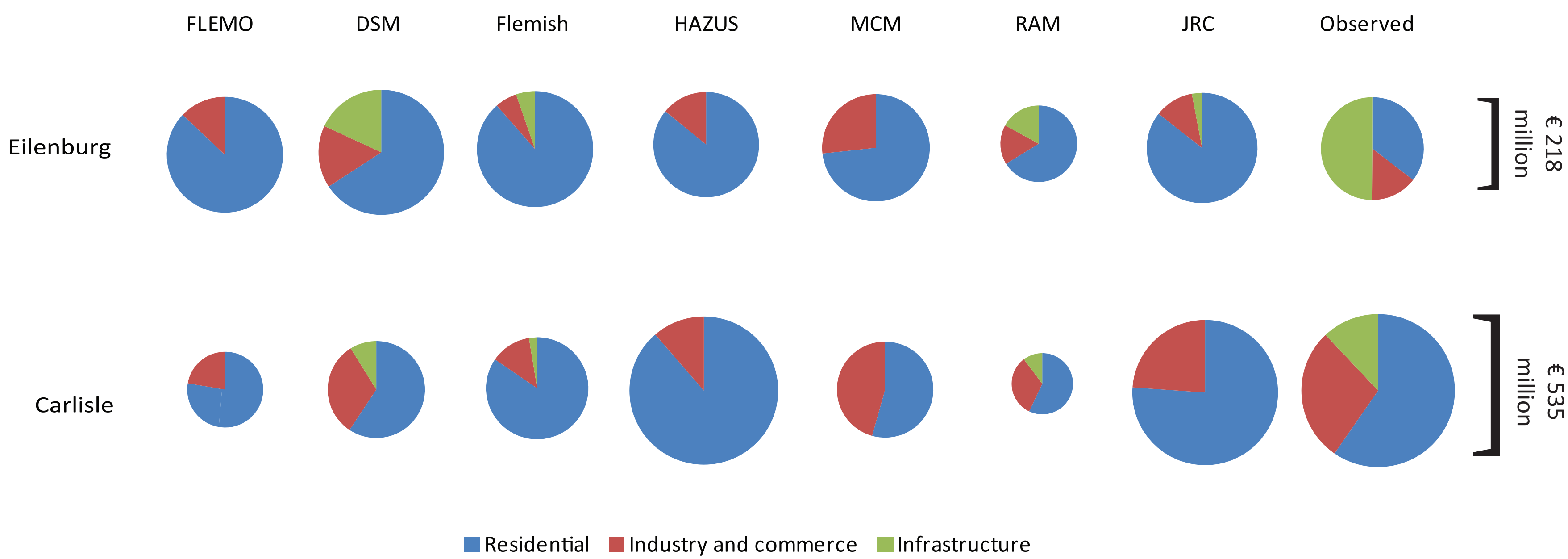
Inundation				Modelled damages (€millions)							Reported (€millions)
CLC Code	CLC Label	Inundated area (m^2)	Average depth (m)	FLEMO	DSM	Flemish	HAZUS	MCM	RAM	JRC	
111	Continuous urban fabric	0	0	0	0	0	0	0	0	0	77
112	Discontinuous urban fabric	2 211 425	1.71	130	252	494	128	174	67	165	
121	Industrial 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

[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

[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.

[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

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[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

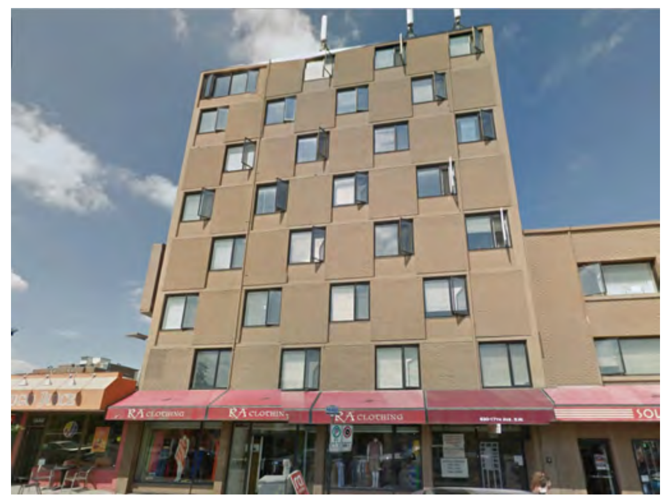
C

Residential Classification - Typical Examples

D

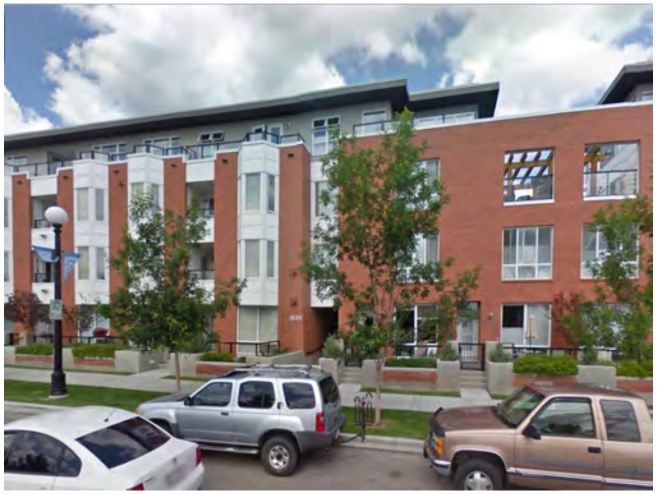
D

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 ________

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:

<u>Civic Plaza Parkade</u>

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$).

<u>McDougall Parkade</u>

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.

<u>Kensington House</u>

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

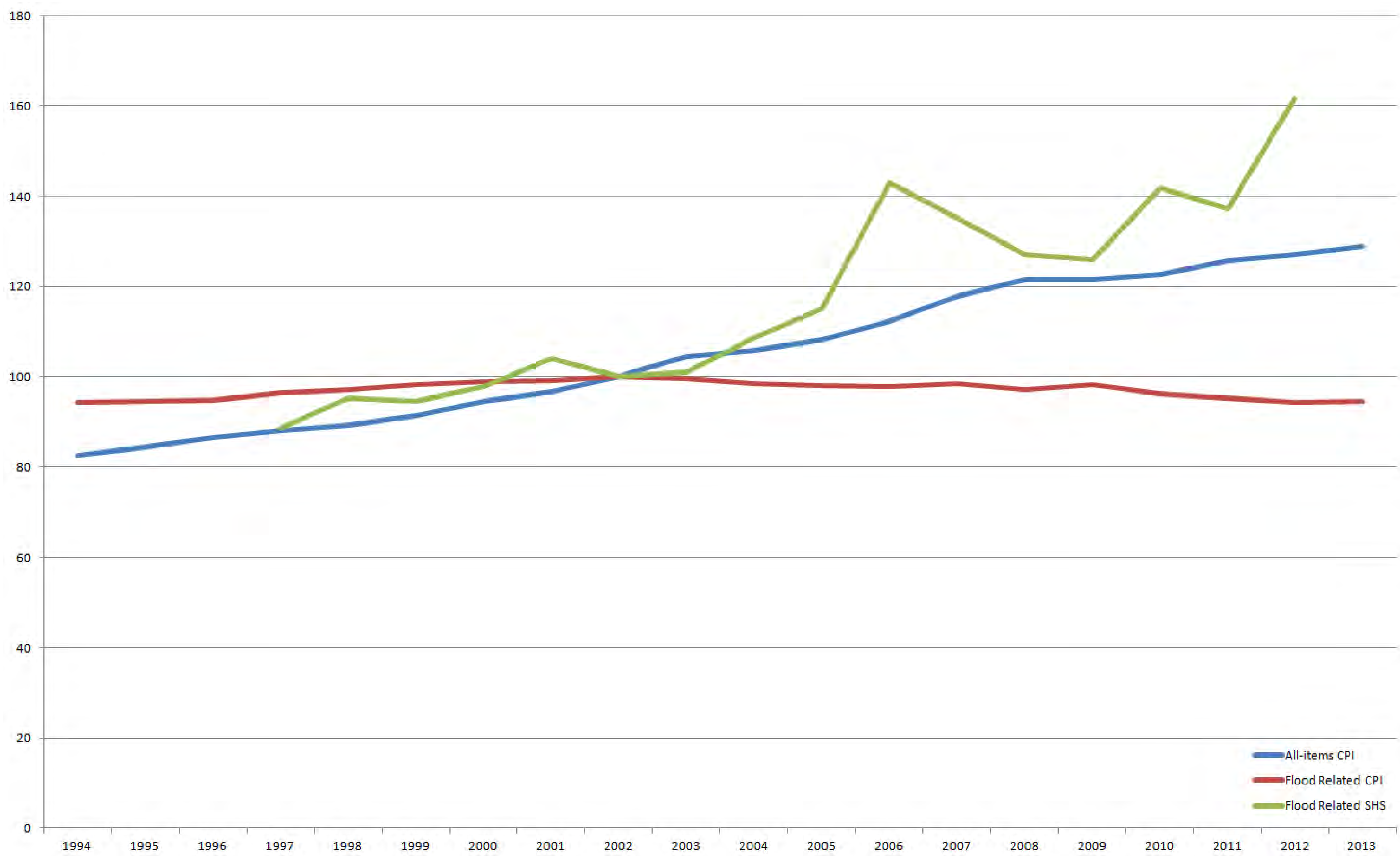
As with the residential buildings, the content of a commercial, industrial, or institutional building susceptible to flood damage is not reflected by the CPI basket in either composition or weighting. The problem with accounting for quality changes with category-specific index values is also present. 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%	$\text{2014 Damages} \times \dfrac{\Sigma\,((\text{current component expense}) \times (\text{weight}))}{\Sigma\,(\text{2014 component expense}) \times (\text{weight})}$
		Clothing & Accessories	21%	
		Recreation	20%	
Contents - Non-Residential	Consumer Price Index	Goods special aggregate		$\text{2014 Damages} \times \dfrac{\text{current goods index}}{\text{2014 goods index}}$
Structure - Residential - House	New Housing Price Index	N/A		$\text{2014 Damages} \times \dfrac{\text{current new housing index}}{\text{2014 new housing index}}$
Residential - Apartment	Apartment Building Construction Price Policy	N/A		$\text{2014 Damages} \times \dfrac{\text{current apartment index}}{\text{2014 apartment index}}$
Structure - Non-Residential	Non-Residential Building Construction Price Index	N/A		$\text{2014 Damages} \times \dfrac{\text{current non-residential index}}{\text{2014 non-residential index}}$

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.

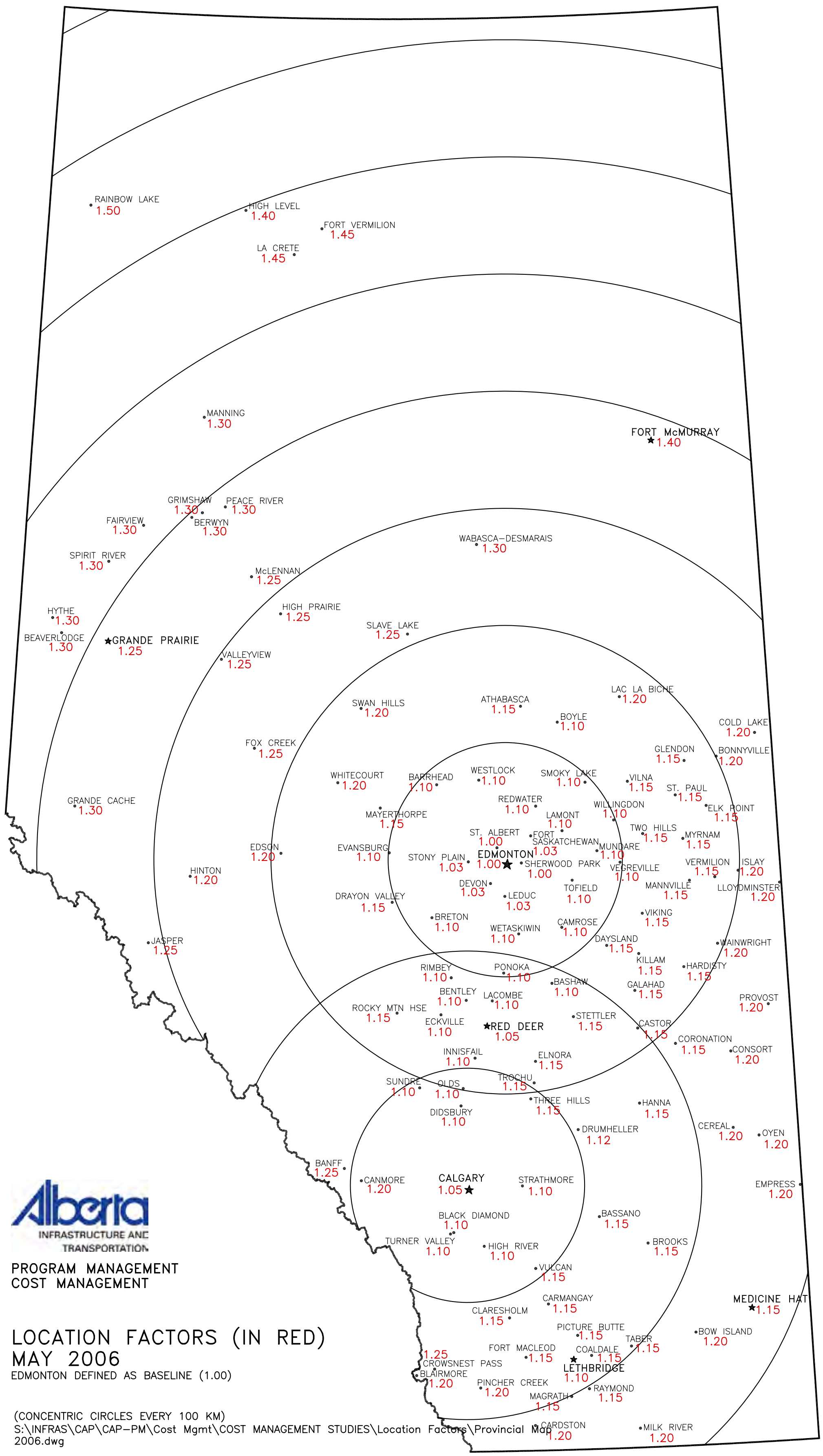
The following formula is used to adjust prices to other Alberta communities:

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.

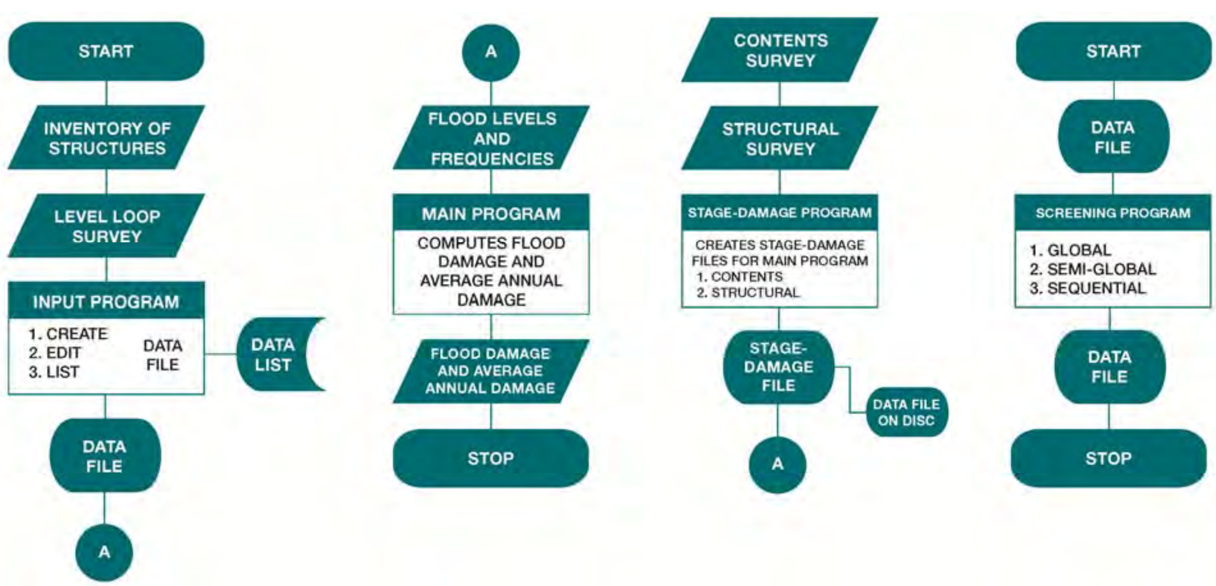
5.2 Flood Damage Database Management System

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.

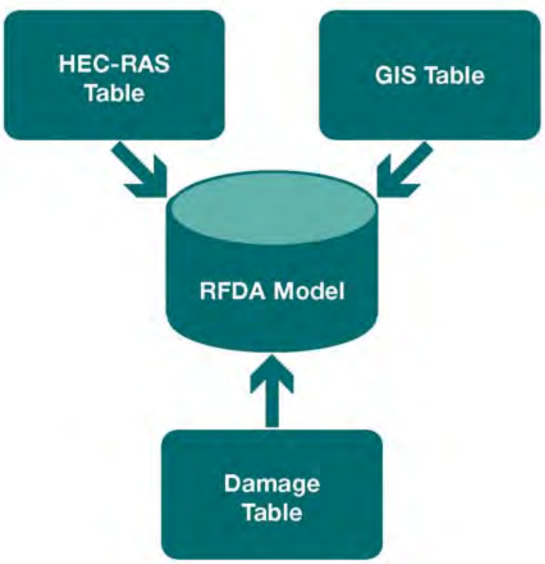
In addition to residential and commercial building structures in the floodplain the module contains a routine that can also compute basement flooding in adjacent-to areas.

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

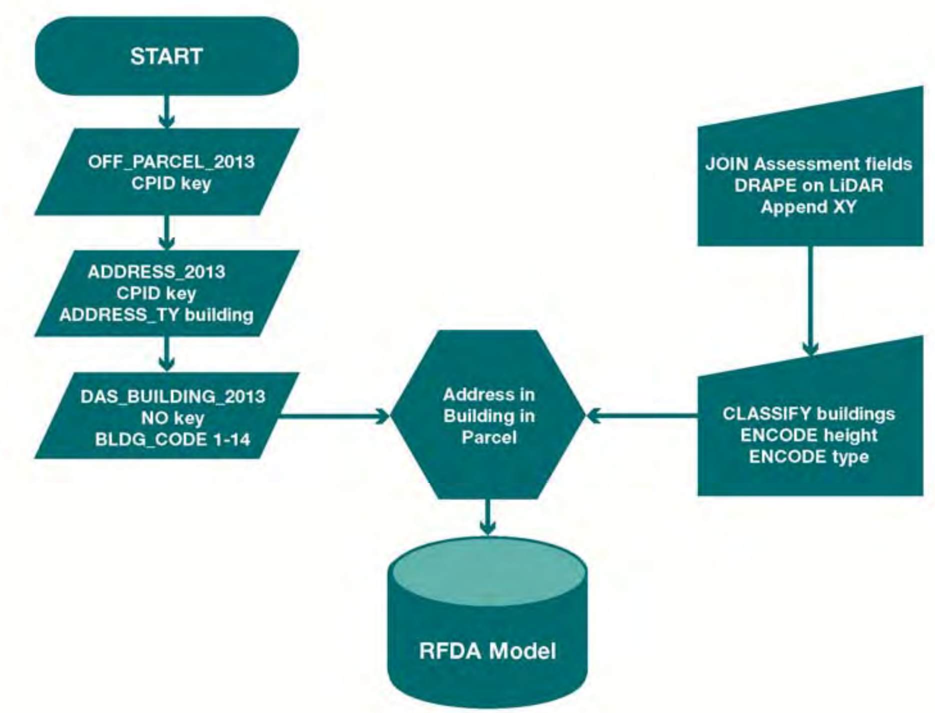


Municipalities in flood risk areas have access to high resolution satellite imagery, or orthophotos, which can clearly show the location of all buildings in their community. In addition they can overlay the images with property parcel boundaries. Many local governments have replaced contour mapping with 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'.

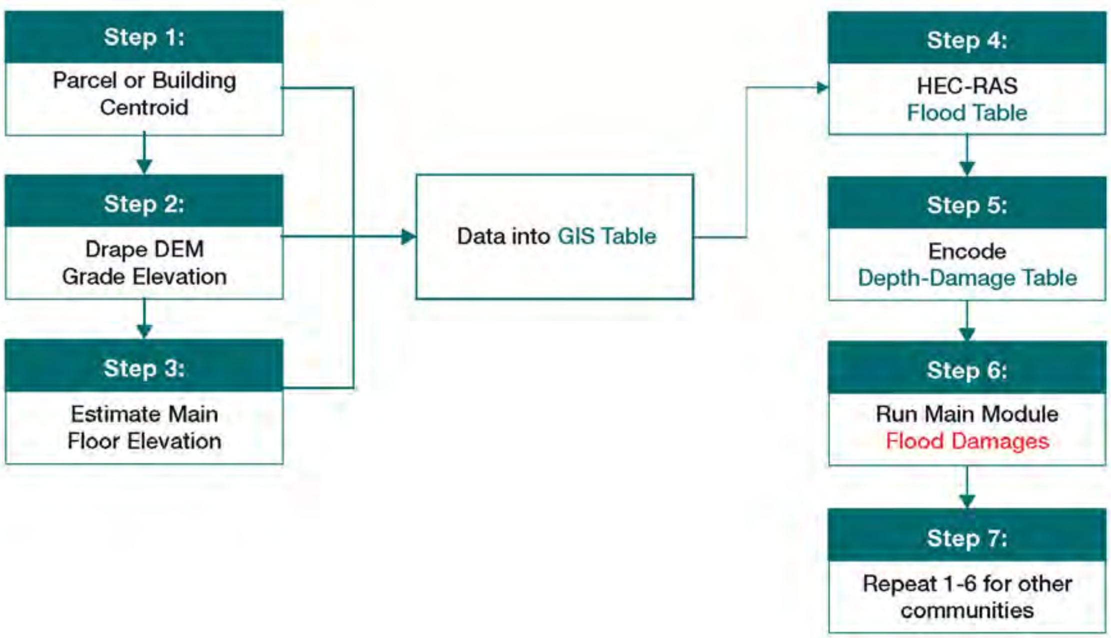
4. Use the HEC-RAS model sections to define floodplain zones in the community, include the adjacent to areas using a buffer zone on the left and right of the cross-sections. Input table of flood elevations for the different return flood levels that will be used for flood damage calculations. This can 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

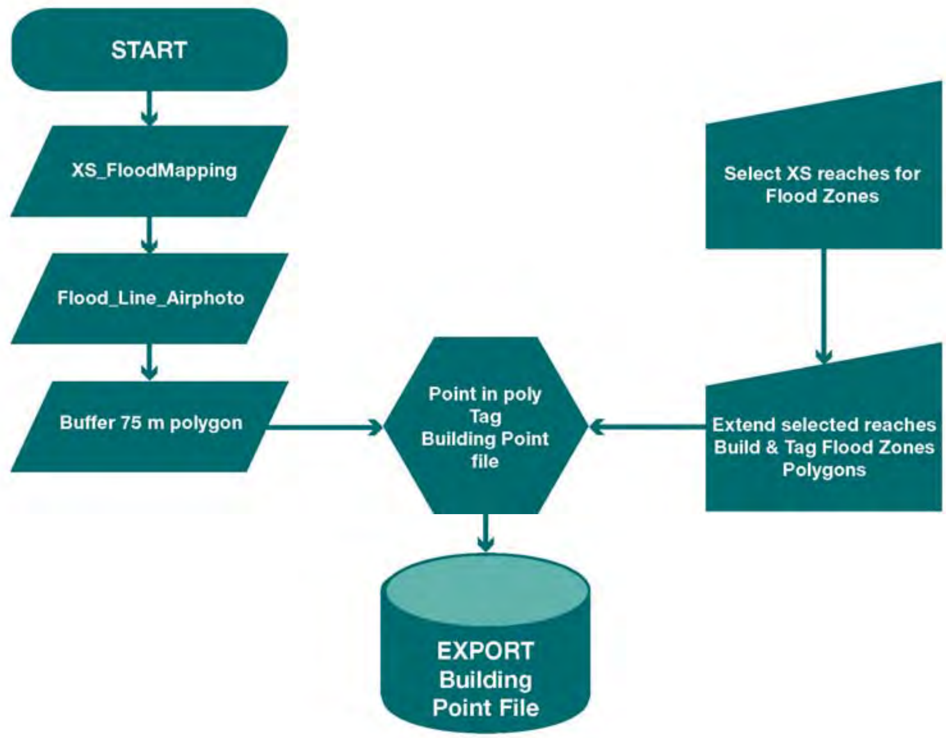


The conceptual design and detailed architecture has followed the basic structure of FDDBMS. However, refinements have been applied to take advantage of the new technology, including digital mapping and GIS. A detailed step-by-step tutorial will be available along with a user's manual that will allow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