Hurricane Hazel and Extreme Rainfall In Southern Ontario

by:

Cumming Cockburn Limited

November 2000

ICLR Research
Paper Series – No. 9

The Institute for Catastrophic Loss Reduction (ICLR) was established in 1998 with the mission to reduce the loss of life and property caused by severe weather and earthquakes through the identification and support of sustained actions to improve society's capacity to adapt to, anticipate, mitigate, withstand and recover from natural disasters.

For Further Information, please contact:
Institute for Catastrophic Loss Reduction
151 Yonge Street, Suite 1800
Toronto, Ontario, Canada M5C 2W7
Telephone: (416) 362-2031 – Extension 352
Fax: (416) 361-5952
E-mail: info@iclr.org www.iclr.org

Copies of this paper can be obtained from the Institute for $25 plus taxes, shipping and handling.

This paper was prepared by Cumming Cockburn Limited

For further information, please contact:
Harold Belore
Cumming Cockburn Limited
65 Allstate Parkway
Suite 300,
Markham, Ontario L3R 9X1
Tel: 905-475-4222
Fax 905-475-5051

INSTITUTE FOR CATASTROPHIC LOSS REDUCTION
HURRICANE HAZEL AND EXTREME RAINFALL IN SOUTHERN ONTARIO

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

HURRICANE HAZEL EXTREME RAINFALL
SOUTHERN ONTARIO CASE STUDY

EXECUTIVE SUMMARY

This case study was commissioned by the Institute for Catastrophic Loss Reduction to estimate the losses resulting from an extreme rainfall event similar to Hurricane Hazel affecting the area from Burlington to Ajax/Whitby in southern Ontario. Cumming Cockburn Limited focused on direct physical flood and water damage losses primarily to residential structures. Direct physical losses to infrastructure, crops, vehicles (plus indirect economic, human suffering, e.g., injury and fatality losses caused by flooding and wind) were not included in the study.

The October 1954 Hurricane Hazel tropical rainstorm dumped over 280 mm. (a total volume of 3.71 cubic kilometers) of rain in a 48-hour period and caused 81 deaths. It was the highest level of precipitation recorded in a 12-hour period anywhere in Ontario up to that time. The rainstorm, centred over the Humber River Watershed, affected a 30,000-square-kilometer area. It is unlikely, but possible, that a similar large rainstorm events could occur again at any time.

A survey of the key personnel at Conservation Authorities (Toronto & Region, Central Lake Ontario, Credit Valley and Halton Region) and Municipalities (Burlington, Milton, Oakville, Mississauga, Etobicoke, North York, Toronto, Scarborough, Pickering, Ajax and Whitby) in the study area was undertaken to obtain background information to estimate the potential for general water damage to basements and flood damage to structures located in flood hazard areas along streams and rivers.

The estimated total river related flood losses which might be associated with a Hurricane Hazel-type event moving through the study area was $240 million. It was suggested that this potential loss was significantly lower as a result of the excellent floodplain management adopted and enforced over the last 30 – 40 years by Conservation Authorities in order to prevent development and increased flood losses in these high-hazard areas.

In general, the survey revealed that the municipalities with a lower original design capacity, direct basement connections to storm and/or combined sewer systems had a higher potential for the number of structures to be affected by flooding during a severe tropical storm like Hurricane Hazel. The analysis indicated potential widespread basement flooding could exceed $400 million. The total flood and water damage loss in the study area could therefore exceed $640 million (not including other direct and indirect losses.

The potential for direct physical flood and water damage losses has grown in direct proportion to population growth. There is no reason to think that, without some intervention, that these losses will not continue to increase in the future as population continues to grow. The increased concentration of the population in urban centres will also lead to higher losses in the future. Losses will increase as the given the higher value of homes and household possessions. For example, in recent years an increased amount of high-value possessions are kept in basement recreation areas (televisions, computers, electronic entertainment centres, etc.), resulting in a significant increase in the potential for damages due to basement water damage. Also, as the infrastructure of urban centres continues to age, blockages can occur in the storm and sanitary sewers.

The proportional increase in potential flood damages along rivers and streams is likely somewhat less today than in 1954. This can be attributed directly to the excellent program for flood-proofing or prohibiting the re-building of flood-damaged structures in flood hazard areas, and to zoning regulations preventing new development in flood prone areas.

Significant flood events similar to Hurricane Hazel will recur. For example, Hurricane Floyd in September 1999 might be regarded as a "near miss". Other large events will continue to occur, exceeding existing system design capacities on a random basis (i.e., similar to the 1989 Harrow Storm – 450mm of rain, etc.).

On the other hand, the legacy of Hurricane Hazel has significantly reduced the potential for riverine-related flood damages in the study area and across Ontario. Since 1954, the implementation of flood plain management policies restricting development or re-building of flood damaged structures in flood hazard areas and flood proofing programs have helped reduce direct physical flood losses. These policies should continue to be enforced, and serious attention should be given to adopting similar zoning policies in other municipalities across Canada in order to reduce flood losses.

With respect to municipalities, a given level of design for the drainage system (sanitary or storm) always has an associated risk of exceedance, which can be estimated over a selected time period (e.g., over the lifetime of the infrastructure). The risk of system failure varies with design level. The design criteria have been found to vary with time and location in the study area. The selection and application of consistent design criteria would provide a common level of risk for the insurance industry. Some relevant elements of the design criteria include:

- Adoption of best management practices for storm water management.
- Similar design levels of protection (e.g., 5-year for the minor system).
- Adoption of consistent technical and calculation design procedures, which should include consideration of the potential impact of climate change.

Current problem areas could be addressed by implementing programs to improve the storm water management capacity of the existing infrastructure by:

- Replacing combined sewers with separate sanitary and storm sewer systems.
- Upgrading existing drainage systems (e.g., storage systems, inlet restrictions and retrofitting with backwater valves, etc.)
- Eliminating weeping tile connections to storm sewers.
- Discharging roof leaders to the ground surface instead of to the sewer system.
- Increasing regular maintenance and inspection programs to avoid drainage system blockages; especially in older developments.

Information on flood and water damage losses should be assembled annually in a consistent format by a single agency. The information will help to confirm flood and water damage losses by type of severe precipitation, level and intensity of precipitation and other event characteristics. This information base will assist in the identification of problem areas and the prioritization of long-term flood damage mitigation programs.

Additional funding should be provided to Municipalities, Conservation Authorities and other key agencies to increase staffing and to help undertake flood damage mitigation programs such as relief sewer systems, updates to floodplain mapping, land acquisition in flood hazard areas, and flood control facilities, etc.

1.0 INTRODUCTION

1.1 General

This investigation was developed as a case study which focuses on estimating potential direct flood damages in a selected region of Southern Ontario. The potential flood damages which might occur as a consequence of the possible occurrence of a large rainstorm event (i.e. similar to the historical event commonly referred to as "Hurricane Hazel") were estimated for the study area. The damage estimates include losses due to basement flooding (e.g. losses due to sewer backups and other flood damage), and flood damage to residential and commercial structures along rivers and streams (referred to herein as "riverine" flood damages). The damage estimates did not include the following additional sources of losses: wind damages during severe rainstorm events; hail damage; overall economic losses (e.g. lost work time); health related costs or the potential for injuries or fatalities; damage to basic infrastructures (e.g. roads, bridges); other indirect flood damages (e.g. flood fighting and flood proofing costs, etc.).

"Canadians spent more than $3 billion in 1998 to repair damages caused by extreme weather. Disaster recovery payments by insurance companies and taxpayers have been doubling every five years throughout the 1980's and 1990's, an alarming trend that cannot be allowed to continue" (IBC National Strategy, 1999).

Floods are the number one natural disaster in Canada in terms of property damage. That was recently confirmed by a natural hazard inventory produced by the National Atlas of Canada, partly funded by the Insurance Bureau of Canada. Individual flood events can cause damages from $100 million upward to $1 billion at locations across Canada (National Atlas of Canada, 1998).

"Basement flooding is a problem which harasses property owners in practically every city in Canada, the northern part of the United States, and elsewhere in the world", (Ottawa, 1980). Basement flooding can be caused by sewer backup or other sources of water at almost any location.

The increasing cost of land has led to changes in the use of basements, which are no longer used exclusively for utilities and storage. The "finished basement" is frequently used for recreation rooms, entertainment and guest bedrooms. Older houses are also remodelled to provide this potential. Therefore basement flooding produces greater damages and inconvenience than in the past and this results in greater political pressure for remedial action.

Homes and businesses are also susceptible to flood damages when located in flood hazard areas along the floodplains of streams and rivers. These riverine related flood damages generally affect a smaller number of structures compared to the potential for a larger number of structures which may be susceptible to basement flooding in the overall community. However, at an individual residence or business, the higher flood depths and flow velocities associated with riverine flooding can result in higher damages to household contents (e.g. flood losses in the primary living areas in addition to basement flood damages) as well as the potential for structural damages, up to and including the total loss of the building. A higher potential for injury, loss of life, damage to infrastructure, and indirect flood damages is also associated with riverine flood losses during extreme weather conditions.

Flood damages can occur at any time of the year. The greatest number of flood events is associated mainly with the springtime flood events, caused by rain on snowmelt conditions. Figure 1 summarizes a frequency analysis of over 500 flood events that occurred in the province of Ontario from the 1850s up until about 1990. Most of the events causing flood damages were found to occur in the springtime. However, high-intensity, high-volume, hurricane-related, rainfall-driven flood events have also occurred (mainly in September and October). While such events do not occur frequently, they can cause very significant damages. Historically, the potential for hurricane-related flood damage has occurred east of Windsor, Ontario over to the Atlantic Provinces. The western part of Canada has not had an exposure to hurricane damages.

Over 1,500 municipalities have been found to be affected by flooding and flood damages in Ontario. For example, it is presently estimated that flood damages in Ontario exceed $30 million per year from a combination of events, including hurricane related storms and excluding losses to the insurance industry (Boyd, 2000). Figure 2 shows a summary of historical flood damages in Ontario (up to 1989), together with an illustration of the increase in population. (The Water Network, 1991.) The current population of Ontario is about 11.6 million (Annual flood damages after 1989 are no longer available in published form due to lack of staff resources at the Ontario Ministry of Natural Resources). The occurrence of the Hazel event in 1954 represented 50% of the total accumulated flood damages to that point in time. This particular event also resulted in a major turning point in political awareness and energy in terms of programs implemented with the objective of reducing future flood losses in Ontario. With reference to Figure 2, it is evident that the absolute potential for flood damages has grown in direct proportion to the population growth. There is no reason to think that, without some intervention, that flood losses will not continue to increase in the future as population continues to grow.

Hurricane Floyd (September 1999) cost the American insurance industry approximately $2 billion in damages, mainly attributed to an intensification of development and infrastructure associated with population increases along the track of the hurricane. The Canadian Hurricane Centre, in Halifax has advised that a severe tropical storm could occur in Southern Ontario sometime within the next 15 years. The flood damages which might be associated with the occurrence of such an event are not known, but the potential for significant economic loss is high.

1.2 Objective

The Institute for Catastrophic Loss Reduction is advocating the need for implementation of flood loss mitigation measures across Canada. The main objective of this investigation was to estimate the potential for flood damage which might be associated with occurrence of a tropical storm in Southern Ontario. The selected study area is between Hamilton to Oshawa. Significant damages associated with a previous tropical storm event (Hurricane Hazel) were documented in 1954. Some mitigation measures have been implemented since the occurrence of that event, but it is expected that the loss potential has increased considerably given population growth, increased urbanization and infrastructure, and the overall rise in economic prosperity.

The general characteristics of damage producing rainstorms were also identified, including intensity, volume and recurrence interval.

1.3 Types of Flood Damages

Flood damages can accrue due to a number of different sources, including local drainage problems, riverine-related flood damages along floodplains and damages along shorelines, including lakes and oceans. For example, in populated areas, this can include damage to the infrastructure itself, on roads and bridges and backups of sewers affecting basements. Undersized storm drains and blockage of storm and sanitary drains can also combine to create significant damages on an individual property basis or over wide areas if the surcharge is significant.

The storm drainage system in an urban area can be thought of as two main components. The major component is comprised of the flow systems of the rivers and channels, and is normally referred to as the major drainage system. The major flow system is usually designed to handle flows up to the 20 or 100 year recurrence interval events; in other words, events that would occur on average 5% or 1% of the time. In urban areas, part of the major flow system can be the street surface which may be designed as part of the drainage system to convey flow to the receiving stream.

The minor flow system is generally comprised of storm drains designed to handle smaller and more frequently occurring events such as the 2 or 5 year events (i.e. the latter event would be equalled or exceeded in magnitude on average one year in every five years or 20% of the time on an annual basis). The major-minor drainage system for stormwater (see Figure 3) is now the most common design for new development (MOEE, 1994).

TABLE 1

TYPICAL CAUSES OF BASEMENT FLOODING AND WATER DAMAGE

STORM DRAINAGE SYSTEM	SANITARY SEWER SYSTEM
♦ Storm exceeds design capacity ♦ Backups from sewers and ditches ♦ Depressed driveways ♦ Leaks: • cracks in basement walls • cracks in floors • low door sills • leaky basement windows • inadequate window wells ♦ Improper lot drainage	♦ Storm water inflow to sanitary system resulting in backups: • backups through basement floor drains • inflow at sanitary manhole ♦ Seepage to sanitary system ♦ Pipe blockages (e.g. roots, debris) ♦ Connection of foundation drains to sanitary system ♦ Broken pipes

Flood damage may also occur where inappropriate land use has occurred in natural floodplain areas along rivers and streams. Such areas are a natural part of the major flow system required to safely discharge the runoff generated from severe flood events. Regulations have been in place in Ontario for over 30 years to prevent new development from being constructed in natural floodplain areas (see Figure 4a). Floodplains are regulated by Conservation Authorities, Municipalities and the Ministry of Natural Resources, enforced under the Conservation Authorities Act and the Planning Act.

New development is prohibited within the flood hazard zone as identified by the level of the Regional Flood. The definition of the Regional Flood varies across Ontario (see Figure 4b). In the study area, the Regional Flood is defined as the flood level which would be associated with the occurrence of Hurricane Hazel over the watershed. The procedures for determining the flood levels for the purposes of regulation are well documented (Ontario Ministry of Natural Resources, (MNR), Technical Guidelines). The implementation of floodplain regulations has significantly reduced the potential for future flood damages in the study area. However, some residual areas of development which were located in flood prone areas prior to the implementation of zoning regulations continue to present an ongoing flood hazard at sites in the study area.

In some cases (mainly in areas of older development) a combined system (sanitary and storm flow system) has been constructed (see Figure 5). The combined system efficiently transfers sewage flows (plus some capacity for storm flow) to downstream sewage treatment plants. However, when excess storm water enters the system, backups and overflows can occur. Back-ups to basement can also occur due to lack of maintenance and design capacity constraints. Some typical causes of basement flooding are listed in Table 1.

When high intensity rainfall events exceed design levels, the design capacity of the drainage system may be exceeded resulting in local or area wide flood damages. Local flood damages are generally associated with the minor drainage system and more frequent events, while area wide flood damages may be associated with the exceedance of the design capacity of the major drainage system which can then also result in backups to the minor system.

High water levels, storm surge, and wind and wave action along shorelines can also result in significant flood damages. This component of flood damage is not included in the present study, although additional information on potential shoreline flooding may be obtained from the local Conservation Authority.

It should also be noted that flood damages can be expressed as an average damage per year, taking into account all damages from large and small storm events. (This calculation is undertaken by weighting each event by its probability of occurrence. On this basis, the mean annual damage component attributed to the Hazel event might be on the order to 1 – 3 million per year, depending on the damages and recurrence interval assigned to the event). The mean annual flood damages in Ontario are currently estimated at about $30 million dollars (Boyd, 2000) from events of all size and type (riverine only) across the Province. Corresponding figures for basement flooding are not available from municipalities nor from the insurance industry.

The available information on flood losses (whether riverine, basement flooding or other) is not available in a consistent format or on a province-wide basis from a single source. This makes it difficult to identify damages by flood type and event characteristics and to prioritize problem areas from the viewpoint of long-term flood mitigation programs.

2.0 DATA COLLECTION

2.1 General

Information describing the rainfall characteristics of extreme events was obtained primarily from the Meteorological Service of Canada, Environment Canada (see Section 2.2.1).

Postal code boundaries and population statistics were provided by Canada Post.

Information describing the potential for basement flooding was provided by each municipality, where available (see Section 2.2.2 and Appendix A).

Flood damage estimates for major drainage systems were obtained from various Conservation Authorities (see Section 2.2.3).

2.2 Background Data

2.2.1 Extreme Rainstorms

The remnants of a tropical storm associated with the occurrence of Hurricane Hazel produced significant flood damages in the Toronto area in 1954. Since that time, at least 18 tropical storms have tracked over the region (Toronto Region Conservation Authority, (TRCA), personal communication, 2000) although none have caused damages similar to the 1954 event. In addition, a number of localized, but severe thunderstorm events have occurred at various locations. Indeed, it may be safe to say that a general perception of the public is that severe rainstorm events are occurring on a more frequent basis.

The rainfall associated with the Hurricane Hazel event resulted in the largest 12-hour rainstorm at any location in Ontario up to 1954, and the worst flood conditions over a period of about 200 years. The area affected by rainfall covered some 30,000 square kilometres, more or less centred over the Humber River Watershed. The storm resulted in over 280 mm of rain in a 48-hour period (a total volume of about 3.71 cubic kilometres).

While infrequent, such an event could occur again at any time. For example, during the period September 7-14, 1999, weather forecasters were issuing statements describing Hurricane Floyd as "developing along a pattern and storm track similar to that of Hurricane Hazel in 1954" (see Figures 6 and 7). However, by September 15, Floyd had changed directions and proceeded to move away from the forecasted track towards Southern Ontario and instead moved up the eastern seaboard, causing significant damages in the United States. Billions of dollars of damage occurred in the U.S.

over 14 states during the occurrence of Hurricane Floyd was one of the largest hurricanes to strike the U.S. in recent history. In the U.S. the vulnerability to damage has increased where population densities are higher resulting in more infrastructure prone to flood losses. (An average of 14 billion dollars per year in the period 1992 – 1996.)

The areal extent of the Hazel event is illustrated on Figure 8, which also compares the areal extent and magnitude of the following selected events (see also Table 2):

- Timmins Storm (1961)
- Harrow Storm (1989)
- Saguenay Storm (1996)

The Timmins storm event has been adopted as the Regional Event for flood hazard determination in Northern Ontario.

The Saguenay storm occurred in the Saguenay region of Quebec in July 1996 over a much larger area, although rainfall totals near the centre of the storm reached depths comparable to Hazel. The Saguenay storm resulted in several deaths and the evacuation of approximately 16,000 people. The flood damages totalled over $800 million including damage to over 1300 homes and significant damage to roads, bridge, dams and other infrastructure. (Brooks, et al, 1999)

The highest rainfall intensity for the Saguenay flood was 12.7 mm/hour (compared to over 52 mm/hour highest intensity for Hazel). The total rainfall for the events was quite similar (279 mm for Saguenay over a period of 72 hours of more or less steady rainfall).

The potential for significant damages from high intensity storms covering smaller areas is illustrated with reference to the Harrow storm event of 1989. While this convective type storm occurred over a significantly smaller area, total rainfall depths exceeded those near the centre of the Hazel and Saguenay events. Storms of this type have the potential to cause significant localized damages in urban areas.

This small sample of historical events is summarized in Table 2 and Figure 8, and illustrates that rain storm events similar to Hurricane Hazel can occur at any time and location in the Province with the potential to produce significant damages.

2.2.2 Concepts of Probability and Risk

If an annual storm event of a given magnitude is found to occur on average twenty percent of the time, (or probability P = 0.2), it may be said to have a recurrence interval (T = 1/P) of once in every 5 years. Similarly the recurrence interval associated with the magnitude of other storms can be determined (see Table 3 for example).

A design storm event with a recurrence T = 100 years has a 1% chance (P = .01) of occurrence in any given year (P = 1/T). Such an event could occur at any time or several times over a given time period and then not occur again for a long period of time. The probability of a 1% chance of occurrence therefore expresses the *average* chance of occurrence in any given year over a long period of time. The average probability of non-occurrence of this event in any given year is 99% (1 – P or 1 – 1/T).

TABLE 2
COMPARISON OF LARGE RAINSTORM EVENTS

	YEAR	AREA (Km^2)	DURATION (hour)	VOLUME (Km^3)
Hazel	1954	30,000	48	3.71
Timmins	1961	9,500	12	0.69
Harrow	1989	700	30	0.13
Saguenay	1996	170,000	48	14.14

TABLE 3
COMPARISON OF TYPICAL DESIGN STORM CHARACTERISTICS

STORM	TOTAL RAINFALL DEPTH (mm)(1)			MAXIMUM ONE HOUR INTENSITY (mm/hour)	DRAINAGE SYSTEM DESIGN COMPONENT
	3 HOUR DEPTH	12 HOUR DEPTH	48 HOUR DEPTH		
Hazel	104	212	285(2)	52.5	Major System
100 Year(3)	66	94	118	50.0	Major System
5 Year(3)	42	56	78	30.0	Minor System
2 Year(3)	30	42	59	22.0	Minor System

Notes: (1) Design values vary by municipality due to spatial and statistical variations in recorded rainfall amounts
(2) Over areas up to 25 km^2 (124 mm over an area of 30,000 km^2)
(3) Based on Toronto Recording Rain Gauge Data

Each part of the drainage infrastructure is designed according to the magnitude of the design event and resulting peak flows associated with the recurrence interval T. However, during the normal operating lifetime of the project, it is possible (statistically) that the design event may be exceeded, and therefore the capacity of the drainage system may be exceeded, causing flooding on a random basis. This is due strictly to the random nature of the meteorological and hydrological processes. The associated risk of occurrence over the expected useable lifetime (or service period) of the drainage facility (or any other selected period of time = n years), can be estimated according to the following logic. The probability of non-occurrence of the design event is one (certainty) minus the probability of occurrence (P = 1/T) or expressed as the following:

$$q = 1 - 1/T$$
$$= \text{probability of non-occurrence in any given year}$$

Over a service period of n years, the total probability of non-occurrence (Q) is:

$$Q = (1 - 1/T)^n$$

For example, in a 5-year period of time, the probability that the 100 year event will not occur is estimated from the above to be:

$$Q = (.99 \times .99 \times .99 \times .99 \times .99) = .95$$

It therefore follows that the <u>*risk*</u> of occurrence of the 100 year event during this 5-year service period is 1 – .95 = .05, or 5%. The general expression for estimating the risk of occurrence (R) of an event over a given number of years (n) is therefore:

$$R = 1 - (1 - 1/T)^n$$

This expression is shown graphically on Figure 9, which summarizes the variation of risk with the selected recurrence interval of the design event and the service period of the infrastructure. It is clear that as the service period of the drainage infrastructure increases, the risk of occurrence of exceeding its design capacity also increases. In other words, the older you are, the more chance you have to observe large flood events and their consequences. Bearing this in mind, there is, at any time, a certain risk of random *"failure"* of the drainage infrastructure, which may be associated with the recurrence interval that has been selected for the basis of design.

2.2.3 Data Source for Basement Flooding

A survey of municipalities in the study area was undertaken to determine the statistical criteria which forms the basis for drainage infrastructure design. The results of the survey are given in Appendix A and are summarized in Table 4. Generally, the design levels for system components were found to be standardized across the study area (i.e. T = 5 year for minor system drainage components, T = 100 year for major system drainage components and the use of Hurricane Hazel flood lines for floodplain management). However in Toronto, North York and Etobicoke, the minor drainage systems (e.g. storm sewer pipes, etc.) were found to be designed at the 2-storm capacity. Therefore, it might be expected that more frequent flooding problems would be reported in these areas since the risk of exceeding the system capacity would be greater, as discussed above.

As indicated in Table 4, some municipalities (Scarborough, Toronto, North York, Etobicoke) also utilize combined sewer systems in some areas. The direct house connections combined with a lower level of design capacity would also likely increase the risk of occurrence of basement flooding and associated damages in these areas. The locations of these areas are shown on Figure 10.

It should also be noted that older parts of the drainage system in some municipalities have been constructed to different criteria (e.g. 2 year) and may also include some combined sewers.

The detailed calculation procedures for sizing the drainage system also vary somewhat in different municipalities. These differences include spatial variations in the design event magnitude which may be statistical in nature. For example, the record length of available rainfall statistics is shorter at some recording stations, leading to statistical differences in the design rainfall amounts for the same recurrence interval T. The assumptions used for inlet time to the system, and pipe travel time may also vary, leading to somewhat different levels of design and associated flood risk. It is suggested that the design criteria calculation procedures, and design events should be standardized, where possible, in order to achieve a common level of design. Some additional discussion of hydrologic design considerations is given in Appendix B.

The survey also requested a summary of records documenting basement flooding in each municipality. However, in most cases detailed records were not available, and estimates of the potential for basement flooding assuming severe storm event conditions were provided based on historical floods and local knowledge of the drainage system. None of the municipalities were able to provide basement flooding data or estimates summarized by postal code area within the municipality. The City of Mississauga required that the request for information be processed through the Freedom of Information Act, and no useful data was received subsequent to this request.

The information received from the survey is summarized in Table 5. In general, the areas with a lower design capacity and basement connections are associated with a higher potential for the number of structures affected during a severe storm event like Hurricane Hazel. The areal distribution of anticipated basement flooding is illustrated on Figure 11. The approximate postal code boundaries are also depicted on Figure 11 by colour-coding Forward Sortation Areas (F.S.A's – which are labelled on Figure 13).

TABLE 4
MUNICIPAL STORM DRAINAGE CRITERIA FOR THE STUDY AREA

	DESIGN RECURRENCE INTERVAL (T IN YEARS)		
MUNICIPALITY	MINOR DRAINAGE SYSTEM	MAJOR DRAINAGE SYSTEM	FLOODPLAIN MANAGEMENT
Whitby	5	100	Hazel
Ajax	5	100	Hazel
Pickering	5	100	Hazel
Scarborough*	5	100	Hazel
Toronto*	2	100	Hazel
North York*	2	100	Hazel
Etobicoke*	2	100	Hazel
Mississauga	5	100	Hazel
Oakville	5	100	Hazel
Milton	5	100	Hazel
Burlington	5	100	Hazel
* Indicates that combined sewers are also present			

TABLE 5

SUMMARY OF RESULTS OF THE SURVEY OF BASEMENT FLOODING

MUNICIPALITY	ANY COMBINED SEWERS PRESENT?	ESTIMATED NUMBERS OF STRUCTURES*	RELEVANT COMMENTS ON BASEMENT FLOODING
Whitby		Nil	A report is available regarding a large event.
Ajax		Nil	Recent development and new drainage systems.
Pickering		0-10 say 8	Few problem areas; relatively new development.
Scarborough	Yes	844**	Most of the problems are in older areas. Many problems related to sewer blockages on public/private lands (50/50). About 8% of the system is combined sewers.
Toronto	Yes	10,000 - 175,000 say 92,500	Design level varies from 2-year to 5-year. Older, flatter areas of the City particularly south of St. Clair Avenue are the most frequently flooded problem areas. Many problems caused by tree roots blocking sanitary sewers (see also Appendix A and Appendix C).
North York	Yes	3,644	System design using 2-year event. Separate system but weeping tiles connected to storm sewers sanitary systems also cause back-ups; mostly in older areas of the City.
Etobicoke	Yes	459	Problems are restricted mainly to areas where the weeping tiles are connected to the sanitary sewer.
Mississauga	?	?	
Oakville		3,000 – 6,000 say 4,500	Main problems are in older areas of the City south of QEW. Few problems in new developments (mainly north of QEW 5-year design).
Milton		10+	Mostly newer development. Weeping tile to storm sewers. 5-year design.
Burlington		200 – 300 say 250	Older sections are problem areas where newer (5-year) design criteria were not used for storm system.

* Estimated potential during a Hurricane Hazel type rainfall event
** 50% attributed to problems on private land

2.2.4 Data Source for Riverine Flooding

The flood prone areas along the major streams and rivers in the study area are managed by local Conservation Authorities. The following Conservation Authorities were contacted for information on potential flood damage areas.

- Central Lake Ontario Conservation Authority (CLOCA)
- Toronto Region Conservation Authority (TRCA)
- Halton Region Conservation Authority (HRCA)
- Credit Valley Conservation Authority (CVCA)

Each municipality within the jurisdiction of the Conservation Authority provides representatives to the Authority to assist in managing flood prone locations and in the regulation of development.

The Conservation Authorities were asked to provide the following information under Hurricane Hazel flood conditions for each of the watercourses within the study area:

- Location of flood prone area
- Number and type of structures impacted
- Estimate of flood damages

A detailed Geographical Information System, (GIS), inventory of riverine flood sites was provided by the TRCA. This included site locations, type of structure affected and flood levels for various events including Hazel. The HRCA provided a spreadsheet with an accompanying map summarizing estimated damages for Hazel. The consultant visited the CLOCA offices to locate flood damage sites and identify structure location and types from available floodplain mapping although no existing flood damage estimates were available. The CVCA provided a background report produced under the Federal Provincial Flood Damage Reduction Program (FDRP) which identified riverine flood damage sites and provided an estimate of potential flood damages (Philips, 1987).

The available information from the various sources identified above was consolidated to identify the flood prone locations along the major streams and rivers, as summarized in Figure 12. The flood hazard sites are identified as potential sources of flood damage given the occurrence of a flood event similar to Hurricane Hazel.

2.3 Other Background Data

Postal code boundaries were provided by Canada Post (Canada Post Corporation, 1999, 2000). The relevant postal code boundaries are shown in Figure 13[1]. The following digital data were also obtained from Canada Post:

- Number of houses
- Number of apartments
- Number of businesses

A population breakdown by municipality was obtained from the Canada Census data.

It was not possible to directly relate the location of potential basement flooding problems to specific postal code areas due to the lack of detailed records obtained from the municipal survey. However, an approximate correlation between the centres of population, number of residences, and basement flooding problem areas is made with reference to Figure 14.

[1] Forward Sortation Area (FSA) boundaries were used. These represent the area location defined by the first 3 characters of the postal code.

3.0 ESTIMATED FLOOD DAMAGE

3.1 General

When Hurricane Hazel occurred in 1954, over 80 lives were lost, there were some 1,800 families left homeless and a significant amount of the infrastructure was destroyed in various municipalities. Various estimates of dollar damage have been made, ranging from over $150 million (National Atlas of Canada, 1998) to nearly one billion dollars. (The Water Network, 1991) (Figures adjusted by CPI to year 2000 dollars). These estimates were previously made based on limited data and there is some uncertainty as to the total amount of damage which occurred.

The historical flood damages in Ontario are illustrated on Figure 2. In general, the total flood damages increase in proportion to the affected population; and therefore much higher damages might be expected with a present-day occurrence of a Hurricane Hazel type event given the large population increase in Southern Ontario since 1954.

As developments have continued to occur, population centres have expanded, and a higher amount of flood damage is to be expected in urban areas. Also the infrastructure of urban areas continues to age, and blockages can occur in storm sewers and sanitary sewers. Increased flood damages can also be expected because of the increased value of real estate and household possessions. For example, in recent years an increased amount of high value possessions are kept in basement recreation areas (TVs, computers, electronic entertainment centres etc.), resulting in a significant increase in the potential for damages due to basement flooding.

On the other hand, the proportional increase in potential riverine flood damages is likely somewhat less today than in 1954. This can be attributed directly to the excellent program for flood proofing or prevention of re-building flood damaged structures in flood hazard areas, and for zoning regulations preventing new development in flood prone areas. (However, some residual flood damage areas still exist, as previously identified).

The benefit of flood plain zoning as a mitigative measure for flood damage reduction in Southern Ontario was recently described (Brown et al, 1997). Severe flooding events in Michigan and Ontario in 1986 caused $500 million and $500 thousand in total estimated flood damage respectively. The lower damages in Ontario were directly attributed to flood plain zoning, which prevents development from occurring in flood plain areas in Ontario.

Other studies have also shown quantifiable net benefits from the application of mapping and flood plain development restrictions. A comparison of the Saguenay and Hazel events (assuming both occurred over the Grand River Watershed) found that the peak flows which might be expected were similar for both events over the downstream parts of the watershed. It was also estimated that flood plain zoning reduced expected flood damages by 5 million dollars and that the existing flood control dykes in Cambridge, Galt and Brantford would have reduced potential flood damages by over 120 million dollars (Boyd, 1996).

Ontario has had an ongoing program for flood plain management since the occurrence of Hurricane Hazel. The application of the program has been province-wide and supported by provincial legislation. (Conservation Authorities Act, Planning Act). In 1978, this program was assisted by funding from the federal government through flood hazard mapping undertaken under the Canada-Ontario Flood Damage Reduction Program. It was concluded, (Brown et, al, 1997) that the residual damages that occurred in Ontario from the 1986 floods were significantly lower than those which might have been expected had a 30-year program of legislative flood plain management not been in place.

A detailed list of flood damage centres which were analysed in Ontario (over 270 communities) and other provinces (totalling over 900 communities) is available at http://www.ec.gc.ca/water/en/manage/flood/e-fdrp.htm. The list of communities for Ontario was extracted from this resource base and is provided in Appendix D.

Federal – Provincial flood mapping agreements were undertaken in Ontario and across Canada with the following policies in mind in regard to flood prone communities:

- No future federal or provincial government buildings or structures that are vulnerable to flood damage will be placed in the flood risk area.
- Funds from government sources, such as the Canada Mortgage and Housing Corporation will no longer be available for new buildings or structures placed in the flood risk area and subject to flood damage.
- Any buildings or structures vulnerable to flood damage placed in the flood risk area after designation will not be eligible for flood disaster assistance.
- The two governments will encourage local municipalities to adopt official plan policies and zoning restrictions on development in the flood risk area.

It has been indicated that "the benefits of long-term non-structural flood plain management can be enormous, possibly in the hundreds of millions of dollars saved in one year". "The benefits of non-structural flood plain management measures are cumulative and increase over time" (Brown et al, 1997).

With regard to basement flooding, the responsibility for controlling potential flood damage lies at the municipal level. In general, municipalities respond quickly to address individual basement flooding complaints where the problem originates on public lands. Various municipalities have also taken the initiative over the years to upgrade sewer systems in problem areas. Some municipalities also adopted general flood damage compensation programs to reimburse homeowners for flood damages (e.g. North York) or to provide one-time assistance for upgrading the local residential sewer connections (e.g. City of Toronto).

3.2 Riverine Flood Damages

Riverine flood losses can include flood damage to contents and damage to the structure up to and including total loss of the building. The existing flood damage sites were identified as discussed in Section 2.2.4 (see Figure 12). The riverine flood damages were estimated using the procedures recommended by the Ontario Ministry of Natural Resources (OMNR, 1984).

The total flood damages associated with the Hazel event for flood prone site on the Credit River were previously estimated (Philips, 1987) to total approximately $20 million (adjusted to current dollars). This was found to be equivalent to about $30,000 per structure. This is comparable to estimates by others based on the value of the structure and its contents (Johnson, 1985). Flood losses to commercial and industrial structures can vary widely depending on the specific business and are very difficult to estimate. Applying this damage value to the number of structures potentially affected by flooding in the jurisdiction of the Central Lake Ontario Conservation Authority resulted in a total damage estimate of about 30 million dollars.

The Halton Region Conservation Authority has undertaken flood damage estimates for the Hazel event at several locations (HRCA 1988; HRCA 1986). The forecasted flood losses were adjusted for inflation and the total flood losses for a Hazel type event was estimated to be approximately $40 million.

The TRCA has created a GIS database of information describing location and classification of flood prone sites along rivers and streams. This information includes site elevation and flood levels for various flood events, including Hazel. The database also includes descriptive comments on building types and flood characteristics at some sites. Direct estimates of flood damages were not available. However, based on the total number of structures potentially affected, it is estimated that flood damages would exceed $150 million. In our opinion, this estimate may be on the low side due to the number of institutional and commercial properties potentially affected by flooding.

The total riverine flood damages which might be associated with a Hurricane Hazel type event moving through the study area is estimated to be $240 million (see Table 6). This does not include intangible losses such as disruption to transportation, lost work hours and medical costs and other losses to the economy, etc.

As noted in Section 3.1 above, the potential for riverine flooding would be at least several hundred million dollars above the estimated value, if flood plain management regulations had not been put in place to regulate development in the flood prone areas of Ontario.

TABLE 6

SUMMARY OF ESTIMATED RIVERINE FLOOD DAMAGES**

AREA	ESTIMATED DAMAGE* ($ X 10)
Central Lake Ontario Conservation Authority	30
Toronto Region Conservation Authority	150
Credit Valley Conservation Authority	20
Halton Region Conservation Authority	40
Total Estimated Damages	$ 240 Million

* All figures in current dollars

** For Hurricane Hazel Type Event

3.3 Basement Flooding

The potential for basement flooding including sewer backups during a severe flood event such as Hazel was identified by using the results of the survey of the various municipalities. This was followed up by telephone discussions and meetings with municipal staff as necessary to clarify the questionnaire response and obtain additional data when available.

In general it was found that detailed lists or maps of problem areas are not available, although some municipalities have assembled data related to particular events. (Bob Quinn, Personnel Communication) Distribution of basement flooding data by postal code areas was not possible, however, estimates of the total potential number of problem areas were received from most of the municipalities surveyed. The survey results are summarized in Table 5.

The survey response identified that significant basement flooding problems resulted from severe rainstorm events which occurred on May 12 – 13, 2000. The May 12 event resulted in nearly 70 mm of rain in downtown Toronto, in a period of time less than 5 hours. Examples of the flooding-related problems created by this event include:

- Flooding along the Lower Don River
- Highway Closures
    - Don Valley Parkway
    - Bayview Avenue
    - Yonge & Sheppard
    - Finch near Signet
    - Wilson Avenue Keele to Murray
    - Highway 403 Oakville
    - Dundas Street Oakville
    - Culhan Street Oakville
    - 9th Line Oakville
    - Rebecca Street Oakville
- Port Credit Yacht Club
- Rail Services Disruptions
    - Go train
    - Subway
- Widespread basement flooding in Oakville, Toronto, Mississauga, North York, Etobicoke, Scarborough, Burlington (and at other locations in Ontario).

The former City of North York administers a grant program which compensates homeowners experiencing basement flooding problems. An amount of up to $3,000 per claim is available (see Appendix C). However, it is noted that this program may be repealed and it is unlikely that a similar program will be adopted for the new City of Toronto. The cost of such a program is considered to be "excessive and unpredictable, and the program would be in direct conflict with the legislative requirements under the Municipal Act [(2)] (see Appendix C).

The City of Toronto estimated that flood damages could be about $5,250 per claim (see Appendix C). This is consistent with the results of a previous basement flooding survey conducted in the Ottawa area in 1984 which reported an average residential damage of $3,000 (about $4,700 in current dollars) (Novatech, 1984).

The City of Toronto has a grant program in place, which is aimed at upgrading problematic service connections. A one-time grant amount of up to $1,500 per residence is available for this purpose.

The City of Toronto has estimated, using available records, that the potential loss per flooding incident is limited to approximately $5,250. On this basis, it was estimated that basement flood damages could easily exceed $50 million (assuming 10,000 units are affected) (Toronto Star, May 2000, see Appendix C).

Insurance claims for various basement flooding events were also summarized by the Institute for Catastrophic Loss Reduction (A. Pang, Personnel Communication). The data summarized in Table 7 represents typical residential claims over the 5-year period from 1994-1998 inclusive and does not represent total claims to all insurance companies. The data on water damage as summarized are not necessarily restricted to basement flooding as these may also be payments for leaky roofs, broken water mains, and escape of water from other sources such as plumbing, heating systems and domestic appliances, etc. However, it was assumed that the average value per claim ($2,300) is representative of typical insurance compensation for basement flooding. Including a typical deductible amount of $275 per claim, the total average damage is estimated to be $2,575 for the purpose of estimating potential basement flood damages.

Based on the various sources noted above, the potential range of flood loss is approximately $2,575 to an upper limit of $5,250 per basement flooded. The estimated number of structures potentially flooded in the study area during a severe rainstorm event could exceed 102, 215 (see Table 5). The corresponding potential damage could therefore range from $263 to $537 million dollars (mid point value equal to $400 million dollars).

Therefore, the total potential flood damages due to a severe event causing widespread basement flooding could exceed approximately $400 million dollars.

[(2)] Gutteridge, Barry, "No-Fault Flood Grant Program; Basement Flooding Damages and Clean-Up Costs", Works and Administration Committee, October 1999.

3.4 Total Flood Damages

The total estimated flood damages in the study area are as follows:

(a)	Riverine Flooding	$240 million
(b)	Basement Flooding	$400 million
	Total Estimated in excess of	**$640 million**

This estimate assumes widespread simultaneous flooding in the study area and does not include additional potential losses to the economy due to lost work hours, damages to infrastructure, transportation disruptions and other indirect costs related to flood damages or other losses such as potential loss of life, wind damage or other storm related damages.

3.5 Mitigation

Significant flood events similar to Hazel will continue to occur in the future. The occurrence of Hurricane Floyd in 1999 might be regarded as a “near miss”, other large events will continue to occur, exceeding existing system design capacities on a random basis (i.e. similar to the Harrow storm, etc.).

The potential for significant flood losses could be reduced by encouraging the implementation of various mitigation measures. The following identifies some mitigation measures which could be adopted to reduce riverine and basement flooding.

3.5.1 Riverine Flooding

The legacy of Hurricane Hazel has significantly reduced the potential for riverine-related flood damages in the study area and across Ontario. Since 1954, there has been less development in floodplains along rivers and streams than would have otherwise occurred due to the implementation of flood plain management policies restricting development in flood hazard areas. These policies should continue to be enforced, and serious attention should be given to adopting similar zoning policies in other municipalities across Canada in order to reduce the potential for an increase in future flood damages.

A significant information resource already exists documenting riverine flood hazard areas across Canada (see Appendix D). This information should be updated and utilized by government agencies to reduce the potential for increased riverine flood damages across Canada.

Mean annual flood damage estimates have been undertaken at some locations in the study area. These estimates should be updated and utilized to prioritize locations where structures should either be flood proofed or acquired and removed from the hazard area.

The management of riverine flood damages should form part of a comprehensive water management program undertaken on an individual watershed basis (MOEE, 1993).

3.5.2 Basement Flooding

Typical causes of basement flooding in separated systems are illustrated on Figure 15.

A given level of design for the drainage system (sanitary or storm) always has an associated risk of exceedance, which can be estimated over a selected time period (for example, over the lifetime of the infrastructure). The risk of system failure varies with the design level selected. The design criteria have been found to vary with time and location in the study area. The selection and application of consistent design criteria would provide a common level of risk for the insurance industry. Some relevant elements of the design criteria include:

- Adoption of similar best management practises for storm water management.
- Similar design levels of protection (e.g. 5-year for the minor system).
- Adoption of similar technical and calculation procedures to provide design consistency.

Existing problem areas could be addressed by implementing programs to improve the existing infrastructure such as:

- Elimination of combined sewer systems.
- Upgrading existing drainage systems.
- Eliminating weeping tile connections to storm sewers.
- Discharge roof leaders to the ground surface; disconnection of existing roof leaders to the sewer system.
- Regular maintenance and inspection programs to avoid drainage system blockages; especially in older developments.

Various municipalities have undertaken improvement programs while at the same time recognizing that basement flooding problems cannot be totally prevented. In general, construction of relief sewers has been the most widespread measure adopted for reducing basement flooding in chronic problem areas.

Other measures for flood mitigation have also be implemented by various municipalities including:

- Design changes to limit surcharging
- Storage systems
- Flow diversion
- Inlet restrictions
- Retrofitting for use of backwater valves and sump pump systems

Information on flood losses (whether riverine, basement flooding or other) should be assembled in a consistent format on an annual basis by a single agency. This information base will help to confirm flood damages by flood type and event characteristics and will assist in the identification of flood problem areas and the prioritization of long-term flood damage mitigation programs.

Additional funding should be provided to Municipalities, Conservation Authorities and other relevant agencies to increase staffing and to help undertake flood damage mitigation programs.

4.0 LIST OF REFERENCES

- Bob Quinn, Personnel Communication
  "Basement Flooding Associated with Rainfall Events of May 12, 13, 2000,
  former City of Scarborough.

- Boyd, Ala, Personal Communication, Ontario Ministry of Natural Resources, 2000.

- Boyd, Dwight "Quantification of Impact of Saguenay Flood Assuming of its Occurrence over the Grand River Basin", Internal Report to GRCA Board, October 1996.

- Brooks, G.R., D. E. Lawrence
  "Geomorphic Effects and Impacts from July 1996 Severe Flooding in the Saguenay Area, Quebec", Natural Resources Canada, 1999.

- Brown, D.W., et. al
  "A comparison of Flooding in Michigan and Ontario: "Soft" Data to support "Soft" Water Management Approaches", Canadian Water Resources Journal, Volume 22, No. 2, 1997.

- Canada Post Corporation
  "The Canadian Postal Code Directory", 1999.

- Canada Post Corporation
  "The Canadian FSA Map", 1999.

- Canada Post Corporation
  "Householder Data" (CD ROM), 2000.

- Canadian Hurricane Centre
  Presented at Institute for Catastrophic Loss Reduction, Friday Forum, May 2000.

- City of Ottawa, "Report on Flooding of June 16 and July 1, 1979,"
  Department of Physical Environment, January 1980.

- Fox, R., Personal Communication, Ministry of Natural Resources Flood Forecast Centre, Sault Ste. Marie, 1999.

- Halton Region Conservation Authority
  "Milton Flood Damage Reduction Study", 1986.

- Halton Region Conservation Authority
  "Mill Grove/ Hidden Valley Flood Damage Reduction Study", 1988.

- Institute of Catastrophic Loss Reduction
  A. Pang, Personnel Communication, September 2000.

- Insurance Bureau of Canada, National Mitigation Strategy
  Protecting Canadian from Sever Weather and Earthquakes, 1999.

- Johnson, W.K., "Significance of Location in Computing Flood Damage",
  Journal of Water Resources, Planning and Management, 1985.

- MOEE, Ontario Ministry of Environment and Energy
  "Water Management on a Watershed Basis: Implementing an Ecosystem Approach",
  MOEE, MNR, 1993.

- MOEE, Ontario Ministry of Environment and Energy
  "Storm Water Management Practices, Planning and Design Manual", 1994.

- Ministry of Natural Resources, Ministry of Municipal Affairs and Housing
  "Flood Plain Criteria – A Policy Statement of the Government of Ontario on
  Planning for Flood Plain Lands", 1982.

- Ministry of Natural Resources
  "Technical Guidelines – Flood Plain Management in Ontario",
  Government of Ontario, MNR, MMAH, 1982.

- National Atlas of Canada
  "Emergency Preparedness Canada – National Hazards", SOREMA,
  National Resources Canada, The Weather Network, Insurance Bureau of Canada, 1998.

- Novatech, 1984, “Evaluation of Urban Drainage Methods for Basement Flood Proofing”, Canada Mortgage and Housing Corporation.

- OMNR, Ontario Ministry of Natural Resources
  “Flood Damages – Guidelines for Estimation”, 1984.

- Pang, Alan, Personal Communication
  Data provided by the Catastrophic Loss Reduction Institute of the
  Insurance Bureau of Canada, September 2000.

- Philips Planning and Engineering Limited
  “Credit River Flood Damage Reduction Study” Volume 1, Credit Valley
  Conservation Authority, Environment Canada, Ministry of Natural Resources, 1987.

- Statistics Canada
  “A National Overview – Population and Dwelling Counts”, April 1997.

- Toronto Region Conservation Authority (TRCA)
  Don Haley, Personal Communication, 2000.

- Toronto Star
  Article on “Basement Flooding in North York and the City of Toronto”, May 2000.

- Vandervink, G. et al, EOS, American Geophysical Union, 1991.