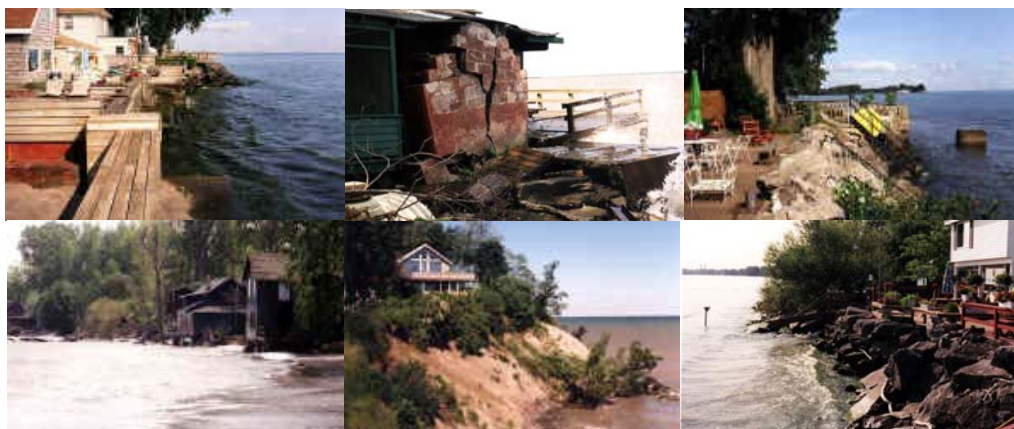


Task Summary Report
(Baird Phase II Task 5.3)
**Scoping Level Assessment of Available Historic
Flood and Erosion Damage Data**



**Coastal Task Working Group
International Joint Commission
Lake Ontario – St. Lawrence River Regulation Study**

November 2002

Prepared By



CHRISTIAN J. STEWART CONSULTING
1618 CANDELA PLACE, VICTORIA, BRITISH COLUMBIA, CANADA, V8N 5P4
PHONE: 250-472-1699 FAX: 250-472-1698
E-MAIL: CSTEWARD@CJSCONS.COM

Scoping Level Assessment, Historic Flood and Erosion Damage Data (Baird Phase II Task 5.3)

Status: This task is complete.

1.0 Introduction

This task forms part of a series of tasks being conducted for the Coastal Task Working Group (CWG) of the IJC Lake Ontario – St. Lawrence River Study by Christian J. Stewart Consulting (CJS) and W.F. Baird and Associates (Baird). Specifically this task comprises “Task 5.3 – Collect Flood Damage Data” in the June 14, 2002 Phase II proposal submitted to the CWG by Baird and CJS.

2.0 Purpose

The investigation of potential flood damage to shoreline riparians for the various alternative regulation plans will require specific data to calculate direct damages, including but not limited to: details on residential and commercial buildings (such as main floor elevation, lowest opening, content value, etc.); census block data where available; data from other agencies (such as FEMA); and data from existing reports that document historic flood or erosion damage.

Time and budget in the current LOSLRS did not allow for the basin-wide collection of new data of this type. As such, where existing data of this nature exists, it will need to be utilized as appropriate. In this light, there was a need to determine the extent and availability of such data for the Lake Ontario and St. Lawrence River shorelines with a particular focus, where possible, on the site specific areas being investigated by Baird. Acquisition, compilation and incorporation of this data into the Coastal Data Server and FEPS will take place in Phase III of the study.

3.0 Methods

This scoping level activity was comprised primarily of a literature review of available material on potential or actual Great Lakes flooding and erosion damages. This included but was not limited to data and information from:

a) Previous Reference Studies: The 3 past Great Lake Water Level Reference Studies (1964, 1977 and 1986-1993) all examined and made use of stage-damage relationships to determine and estimate potential flood damages. In developing these relationships various data were collected and utilized. This data and these relationships will be examined for applicability in this study;



b) Canada-Ontario Great Lakes Shore Damage Survey: provides historical flood damage data for the Canadian shoreline of Lake Ontario;

c) FEMA Flood Insurance Rate Maps and Flood Inundation Data: FEMA Q3 Digital Flood Data have been obtained and are being incorporated into the CDS. These maps are scanned versions of the Flood Insurance Rate Maps and show relevant flood hazard zones and structures at risk;

d) Property Assessment Data: Some relevant data (e.g., structure type, elevation) may be found in property assessment data collected in Task 1.10.

Additional information was also sought and obtained directly from County and Municipal offices in the U.S. and Conservation Authority offices in Ontario. For example, Oswego County in both their “Oswego County Data Book” and their “Comprehensive Plan” provide data on things like structure value, numbers of housing structures, etc. Similarly Niagara County has compiled damage data for a number of Townships along their shoreline.

4.0 Results

Tables 1 to 3 provide a summary of the key documents reviewed and lists them geographically according to County, Shore Unit and Reach definitions. An annotated bibliography of a number of these key documents is also provided below. A full list of documents reviewed can be found in the References.

4.1 New York State

United States Inundation and Erosion Stage Damage Relationships (De Cooke, 1991)

This report incorporates the inundation and erosion damage resulting from the high water of 1985-87 into the relationships developed by the International Lake Erie Regulation Study Board. The report is divided into two sections; inundation and erosion. Each section is divided by Shoreline Reach Number and describes the technique employed to update the existing relationships. There are erosion-damage and inundation-damage curves for each month (March to December) for each Reach (2001-2005) on the US shoreline of Lake Ontario. There are also Lake-wide erosion-damage and inundation-damage curves for each month (March to December) for Lake Ontario. Applying existing inundation and erosion models to the Lake Ontario level conditions, which existed in 1985-1987, produced damage estimates of \$2,519,000 and \$27,271,000 respectively.

Spatial Extent: Inundation damage relationships and erosion damage relationships for Reaches 2001, 2002, 2003, 2004, 2005 (US Lake Ontario shoreline).



Table 1 - Summary of Damage Documents Reviewed By Shore Unit and County - New York Shoreline

NEW YORK				
County	Shore Unit	Reaches	Report #	Report Title
St. Lawrence	R1-4	16-278	1	United States Inundation and Erosion Stage Damage Relationships (De Cooke, 1991)
			2	Great Lakes 1985-1987 High Water Levels U.S. Shoreline Damages, Modeling and Mapping, Situation Report (De Cooke, 1988)
			3	Regulation of Great Lakes Water Levels, Appendix C – Shore Property (International Great Lakes Levels Board, 1973)
Jefferson	R1, US7-8	279-669	1	United States Inundation and Erosion Stage Damage Relationships (De Cooke, 1991)
			2	Great Lakes 1985-1987 High Water Levels U.S. Shoreline Damages, Modeling and Mapping, Situation Report (De Cooke, 1988)
			3	Regulation of Great Lakes Water Levels, Appendix C – Shore Property (International Great Lakes Levels Board, 1973)
Oswego	US5-7	670-780	1	United States Inundation and Erosion Stage Damage Relationships (De Cooke, 1991)
			2	Great Lakes 1985-1987 High Water Levels U.S. Shoreline Damages, Modeling and Mapping, Situation Report (De Cooke, 1988)
			3	Regulation of Great Lakes Water Levels, Appendix C – Shore Property (International Great Lakes Levels Board, 1973)
			4	Potential Damages Task Group, IJC Levels Reference Study (Stewart and Kangas, 1993)
			5	Eastern Great Lakes Area Contingency Plan, Volume 3. A Geographic Response Plan for Oil Spills and Hazardous Substance Releases in Lake Ontario for the C
Cayuga	US4	781-818	1	United States Inundation and Erosion Stage Damage Relationships (De Cooke, 1991)
			2	Great Lakes 1985-1987 High Water Levels U.S. Shoreline Damages, Modeling and Mapping, Situation Report (De Cooke, 1988)
			3	Regulation of Great Lakes Water Levels, Appendix C – Shore Property (International Great Lakes Levels Board, 1973)
			4	Eastern Great Lakes Area Contingency Plan, Volume 3. A Geographic Response Plan for Oil Spills and Hazardous Substance Releases in Lake Ontario for the C
			5	Eastern Great Lakes Area Contingency Plan, Volume 3. A Geographic Response Plan for Oil Spills and Hazardous Substance Releases in Lake Ontario for the C
Wayne	US3-4	819-933	1	United States Inundation and Erosion Stage Damage Relationships (De Cooke, 1991)
			2	Great Lakes 1985-1987 High Water Levels U.S. Shoreline Damages, Modeling and Mapping, Situation Report (De Cooke, 1988)
			3	Regulation of Great Lakes Water Levels, Appendix C – Shore Property (International Great Lakes Levels Board, 1973)
			4	Eastern Great Lakes Area Contingency Plan, Volume 3. A Geographic Response Plan for Oil Spills and Hazardous Substance Releases in Lake Ontario for the C
			5	Eastern Great Lakes Area Contingency Plan, Volume 3. A Geographic Response Plan for Oil Spills and Hazardous Substance Releases in Lake Ontario for the C
Monroe	US2-3	934-1072	1	United States Inundation and Erosion Stage Damage Relationships (De Cooke, 1991)
			2	Great Lakes 1985-1987 High Water Levels U.S. Shoreline Damages, Modeling and Mapping, Situation Report (De Cooke, 1988)
			3	Regulation of Great Lakes Water Levels, Appendix C – Shore Property (International Great Lakes Levels Board, 1973)
			4	Eastern Great Lakes Area Contingency Plan, Volume 3. A Geographic Response Plan for Oil Spills and Hazardous Substance Releases in Lake Ontario for the C
			5	Eastern Great Lakes Area Contingency Plan, Volume 3. A Geographic Response Plan for Oil Spills and Hazardous Substance Releases in Lake Ontario for the C
			6	Analysis and Report on Stage-Damage Relationships for Selected U.S. Shoreline Reaches (C.A., Inc., 1992)
			7	Monroe County Damage Information - memos
			8	Lakeshore Interceptor Erosion Repair Project, Monroe County NY (Digital Report, 2000)
			9	Monroe County Emergency Management (International St. Lawrence River Board of Control Roundtable Discussion, 1997)
			10	Letter to the Chairs of the International St. Lawrence River Board of Control from County Executive Jack Doyle Re: Public Hearing, Sacketts Harbour, NY (Jun
Orleans	US1-2	1073-1133	1	United States Inundation and Erosion Stage Damage Relationships (De Cooke, 1991)
			2	Great Lakes 1985-1987 High Water Levels U.S. Shoreline Damages, Modeling and Mapping, Situation Report (De Cooke, 1988)
			3	Regulation of Great Lakes Water Levels, Appendix C – Shore Property (International Great Lakes Levels Board, 1973)
			4	Eastern Great Lakes Area Contingency Plan, Volume 3. A Geographic Response Plan for Oil Spills and Hazardous Substance Releases in Lake Ontario for the C
			5	Eastern Great Lakes Area Contingency Plan, Volume 3. A Geographic Response Plan for Oil Spills and Hazardous Substance Releases in Lake Ontario for the C
Niagara	US1	1134-1213	1	United States Inundation and Erosion Stage Damage Relationships (De Cooke, 1991)
			2	Great Lakes 1985-1987 High Water Levels U.S. Shoreline Damages, Modeling and Mapping, Situation Report (De Cooke, 1988)
			3	Regulation of Great Lakes Water Levels, Appendix C – Shore Property (International Great Lakes Levels Board, 1973)
			4	Eastern Great Lakes Area Contingency Plan, Volume 3. A Geographic Response Plan for Oil Spills and Hazardous Substance Releases in Lake Ontario for the C
			5	Eastern Great Lakes Area Contingency Plan, Volume 3. A Geographic Response Plan for Oil Spills and Hazardous Substance Releases in Lake Ontario for the C
			11	Niagara County New York Damage Information (1998 - with supplemental info 1999)
			12	Letter to Gerald Galloway, IJC from Joanne Ellsworth Re: Criteria Review for Regulation of Lake Ontario Niagara County Data Development (October 3, 2000)
			13	Letter to Tony Eberhardt, US Army Corps of Engineers, from Joanne Ellsworth Re:Electronic Data for Lake Ontario Shoreline (December 27, 2000)



Table 2 - Summary of Damage Documents Reviewed By Shore Unit and County - Ontario Shoreline

ONTARIO

Niagara R.M	CND1	14	Canada – Ontario Great Lakes Shore Damage Survey (Boulden, 1975)
		15	Report on Ontario Flood History (Water Network, 1991)
		16	Great Lakes Flood and Erosion Stage-Damage Curve Updates (Marshall Macklin Monaghan Ltd., 1992)
Hamilton-Wentworth	CND1-3	14	Canada – Ontario Great Lakes Shore Damage Survey (Boulden, 1975)
		15	Report on Ontario Flood History (Water Network, 1991)
		16	Great Lakes Flood and Erosion Stage-Damage Curve Updates (Marshall Macklin Monaghan Ltd., 1992)
Halton	CND2-4	14	Canada – Ontario Great Lakes Shore Damage Survey (Boulden, 1975)
		15	Report on Ontario Flood History (Water Network, 1991)
		16	Great Lakes Flood and Erosion Stage-Damage Curve Updates (Marshall Macklin Monaghan Ltd., 1992)
Peel	CND4	14	Canada – Ontario Great Lakes Shore Damage Survey (Boulden, 1975)
		16	Great Lakes Flood and Erosion Stage-Damage Curve Updates (Marshall Macklin Monaghan Ltd., 1992)
Metro Toronto	CND4-7	4	Potential Damages Task Group, IJC Levels Reference Study (Stewart and Kangas, 1993)
		14	Canada – Ontario Great Lakes Shore Damage Survey (Boulden, 1975)
		16	Great Lakes Flood and Erosion Stage-Damage Curve Updates (Marshall Macklin Monaghan Ltd., 1992)
		17	Potential Damage Estimates for Site Specific Areas (IJC Levels Reference Study Board, Paragon, 1993 – draft)
Durham	CND7	14	Canada – Ontario Great Lakes Shore Damage Survey (Boulden, 1975)
		16	Great Lakes Flood and Erosion Stage-Damage Curve Updates (Marshall Macklin Monaghan Ltd., 1992)
Northumberland	CND7-8	14	Canada – Ontario Great Lakes Shore Damage Survey (Boulden, 1975)
		16	Great Lakes Flood and Erosion Stage-Damage Curve Updates (Marshall Macklin Monaghan Ltd., 1992)
Hastings	CND9 & 11	14	Canada – Ontario Great Lakes Shore Damage Survey (Boulden, 1975)
		16	Great Lakes Flood and Erosion Stage-Damage Curve Updates (Marshall Macklin Monaghan Ltd., 1992)
Prince Edward	CND9-11	14	Canada – Ontario Great Lakes Shore Damage Survey (Boulden, 1975)
		16	Great Lakes Flood and Erosion Stage-Damage Curve Updates (Marshall Macklin Monaghan Ltd., 1992)
Lennox & Addington	CND11-12	14	Canada – Ontario Great Lakes Shore Damage Survey (Boulden, 1975)
		16	Great Lakes Flood and Erosion Stage-Damage Curve Updates (Marshall Macklin Monaghan Ltd., 1992)
Frontenac	CND12 & ??	14	Canada – Ontario Great Lakes Shore Damage Survey (Boulden, 1975)
Leeds & Grenville	??		
Montreal		4	Potential Damages Task Group, IJC Levels Reference Study (Stewart and Kangas, 1993)
		17	Potential Damage Estimates for Site Specific Areas (IJC Levels Reference Study Board, Paragon, 1993 – draft)
St. Lawrence		16	Great Lakes Flood and Erosion Stage-Damage Curve Updates (Marshall Macklin Monaghan Ltd., 1992)



Table 3 – Summary of General Damage Documents Reviewed

GENERAL

18	Development of Flood Depth-Damage Curves for Residential Homes in Ontario (Paragon Engineering, 1985)
19	A Review of Flood Damage Estimation Methodologies (Paragon Engineering, 1984)
20	Memo – From J.Y. Ding to Doug Brown dated Dec 12, 1986 Re: Flood Damages Report (Paragon, 1984) Updated Version
21	A Critical Review of Existing and Updated U.S. and Canadian Stage-Damage Curves (Yoe, 1992)
22	Flood Damages in Ontario, 1985 – 1988 (Conservation Authorities and Water Management Branch, Ministry of Natural Resources, 1990)
23	An Inventory of the US Shoreline of Lake Ontario and Evaluation of Structural Modifications for Damage Reductions, Lake Ontario Shore Protection Study (Ray and Sweeney, 1980)

Great Lakes 1985-1987 High Water Levels U.S. Shoreline Damages, Modeling and Mapping, Situation Report (De Cooke, 1988)

This report presents historic damage information as well as a rough assessment of 1985-1987 damage to the U.S. Great Lakes shorelines. The purpose of the report is to develop a rough assessment of damages which occurred to the Great Lakes US shoreline resulting from the high water levels which prevailed during the 1985-1987 period and to document both the hydrologic conditions and supporting information which can be employed for further evaluation of the problem. Data on shoreline damages due to storm events are reported and are presented here in Tables 4, 5, and 6. Estimated damage in dollars prevented due to protection structures are reported and presented here in Table 7. Newspaper clippings and real estate listings of property values along the US shoreline are also contained in the report.

Spatial Extent: US Lake Ontario shoreline, Reaches 2001-2005

Table 4 — Summary of Shoreline Damage, Lake Ontario 1951 to 1952

Reach #	Inundation		Other than Inundation		Total (\$)	1987 Total (\$) value adjustment
	Direct	Indirect	Direct	Indirect		
2001	28,100	15,000	692,800	300	736,200	4,580,000
2002	694,000	N/R	3,470,100	41,300	4,205,400	26,170,000
2003	319,000	10,000	952,500	35,000	956,500	5,950,000
2004	32,000	14,200	315,400	1,500	363,100	2,260,000
2005*	127,750	26,200	930,300	8,700	1,092,950	6,800,000
Total	1,200,850	65,400	6,001,100	86,000	7,354,150	45,770,000

* Includes St. Lawrence River

N/R = none reported



Table 5 — Summary of Shoreline Damage, Lake Ontario 1972 to 1976

Reach #	Erosion	Inundation	Total	1987 Total adjustment	Public and Private Mitigation	
					1975	1987
2001	4,229,000	28,600	4,257,600	8,440,000	7,701,000	15,270,000
2002	4,725,300	2,756,000	7,481,300	14,830,000	5,370,000	10,630,000
2003	3,928,900	547,200	4,476,100	8,870,000	1,610,000	3,190,000
2004	311,000	N/R	311,000	620,000	N/R	N/R
2005*	5,009,900	729,600	5,739,500	11,380,000	180,000	360,000
Total	18,204,100	4,061,400	22,265,500	44,140,000	14,870,000	29,450,000

* Includes St. Lawrence River
N/R = none reported

Table 6 — Summary of Shoreline Damage, Lake Ontario 1985 to 1987

Reach #	Erosion	Inundation	Total	Public and Private Mitigation
2001	N/R	N/R	N/R	No Construction
2002	300,000	168,800	468,800	2,664,000
2003	1,074,000	700,000	1,774,000	1,881,000
2004	N/R	90,000	90,000	2,124,000
2005*	100,000	63,000	163,000	2,295,000
Total	1,474,000	1,021,800	2,495,800	8,964,000

* Includes St. Lawrence River
N/R = none reported

Table 7 – Shoreline Protection Placed under Operation Foresight 1973-1974

Reach #	Cost (\$)	1974 Estimated Damage Prevented	1987 Level Cost (\$)
2001	442,000	928,000	950,000
2002	430,000	842,000	925,000
2003	349,000	723,000	750,000
2004	No construction	-	-
2005*	No construction	-	-
Total	1,221,000	2,493,000	2,625,000

* Includes St. Lawrence River



**Regulation of Great Lakes Water Levels, Appendix C – Shore Property
(International Great Lakes Levels Board, 1973)**

A documentation of the methodology developed to estimate in economic terms the effects of changes in water level regimes on erosion and inundation of the shoreline, marine structures and water intakes and sewer outfalls, and of detailed evaluations of selected regulation plans.

Table 8 – Damage to the US shoreline for the period May 1951 through April 1952

	Damage due to Inundation*	Damage due to Wave Action*	Total Damage*
Lake Ontario (including Lower Niagara River and St. Lawrence River to International Boundary)	\$1,266,300	\$6,087,900	\$7,354,000

*1952 price level

Spatial Extent: US shoreline of Lake Ontario (including Lower Niagara River and St. Lawrence River to International Boundary).

Potential Damages Task Group, IJC Levels Reference Study (Stewart and Kangas, 1993)

The Potential Damages Task Group of the Levels Reference Study conducted a number of detailed damage investigations including an assessment of damages associated with various water level scenarios, the evaluation of damages at a series of site specific study areas including Toronto and Montreal (Paragon Engineering, 1993), Oswego County and Alexandria Bay, NY, an evaluation of expenditures on shoreline protection (Ecologistics Limited, 1992) and the avoided costs of shoreline protection (Baird & Associates, 1993).

Flood and erosion stage-damage curves were also updated (Marshall, Macklin, Monaghan, 1992), critiqued (Yoe, 1992) and applied to the shoreline using an uncertainty analysis methodology (Environment Canada, 1992; U.S. Army Corps of Engineers, 1992). These curves were used to calculate potential damage information for various water level scenarios under consideration and potential benefits that would be attained under water level management scenarios. Canadian private and public shore protection expenditures during 1985-1987 for:

Lake Ontario = **\$531,000** (loan supported shore protection)
 Lake Ontario = **\$3,838,000** (Total Riparian Property Protection Activities)
 St. Lawrence Seaway = **\$1,283,000** (Total Riparian Property Protection Activities)



Spatial Extent: Site-specific studies at Toronto, ON; Oswego County, NY (Reach 2003); Montreal, PQ; and, Alexandria Bay, NY (Niagara County).

Eastern Great Lakes Area Contingency Plan, Volume 3. A Geographic Response Plan for Oil Spills and Hazardous Substance Releases in Lake Ontario for the Counties of Niagara, Orleans, Monroe, Wayne, Cayuga, and Oswego in New York State (US Coast Guard, 1999)

The purpose of the report is to provide information for emergency spill response along New York State's shoreline along Lake Ontario. There is information regarding contacts in the above-named counties, types of shoreline/habitat, and wildlife/resources at risk. Series of maps of the shoreline of Lake Ontario (scale 1:62,500). Water intakes, nuclear intakes, recreation sites as well as flora and fauna locations are identified.

Spatial Extent: Niagara, Orleans, Monroe, Wayne, Cayuga, and Oswego Counties.

Analysis and Report on Stage-Damage Relationships for Selected U.S. Shoreline Reaches (C.A., Inc., 1992)

This report specifically analyzes and updates the prepared stage-damage relationships to better reflect costs of inundation and erosion damage that occurred over the high water period of the mid-1980s. It contains descriptions of damages along Lake Ontario shoreline Reach 2002. Primary purpose of the study is to determine the dollar damages caused by high water levels so that the stage-damage relationships can be used in comparing different lake regulation plans. This process is accomplished by applying a measure of damages, which is proven reliable by data obtained during the most recent high water period to a potential high water period. The measure of damages developed in 1981 is the 1975 damage curves.

The high water estimated damages for this reach are those provided for the 1975 damage curve and updated to 1986 costs and 1985-1986 water levels. The total estimated damage used for this Reach was approximately **\$5,500,000**; **\$1,100,000** for inundation and **\$4,400,000** for erosion. This is a liberal estimate for damage; however, any reduction in damage mitigated by protective works since the 1970s may be partially offset by unprotected development during the same time period.

Direct damages consist of: damage to existing protective structures; cost of protective structures built during high water period under investigation; damage to improvements on shore property and in the water, other than protective measures; value of land lost by erosion, depreciation in sale of land for the remainder of the



tract of land and improvement thereon; and, other direct damages. Indirect damages consist of: cost of emergency work during extreme high lake level conditions; loss of business including loss of business to commercial recreation beaches or increase in cost of business due to high lake levels; loss of wages due to high lake levels; and, increase in cost of rail or highway transportation due to high lake levees.

Spatial Extent: New York, Monroe County – Reach 2002. Covers a total length of ~54 km including: Greece Township, Hamlin Township, Parma Township, Rochester Township.

Monroe County Damage Information – memos

Descriptive memos regarding 1998-2001 damage to water and wastewater facilities, impacts to public infrastructure, and impacts of high lake level on town facilities and infrastructure in the Town of Greece.

Spatial Extent: Monroe County – Town of Greece

Lakeshore Interceptor Erosion Repair Project, Monroe County NY (Digital Report, 2000)

Report by MCDES on Lakeshore Interceptor Erosion Project regarding repairs to foundation of DES’ Irondequoit due to high lake level in Lake Ontario. In early 1998, the County received citizen notification of a shoreline erosion problem in proximity to a major interceptor between Lake Ontario and the adjacent homes on Lake Bluff Road in the Town of Irondequoit. Upon investigation it was determined that severe wave action in recent years had caused significant erosion and slumping of the 30 foot high bluffs in two main areas, and that if left unchecked, would soon threaten to undermine Pure Waters’ 25 year old Irondequoit Lakeshore Interceptor. Repairs to all five sites had a total cost of **\$195,155**.

Table 9 - Cost Summary

Contractor, Equipment and Labor	Armor Stone Prep & Transport - \$42,433. Site off load and placement - \$68,604. Restoration - \$17,910.	\$128,947
Materials	4200 Tons of surge stone & rip rap - \$44,122. Geo-textile Fabric - \$5,975.	\$ 50,097
Engineering	Design & Site Consultation	\$ 12,751
MC DES	140 hrs of project management & inspection	\$ 3,360
		Total Costs \$ 195,155



Spatial Extent: Monroe County

Monroe County Emergency Management (International St. Lawrence River Board of Control Roundtable Discussion, 1997)

Monroe County has 36.5 miles of shoreline assessed at more than \$86 billion. In 1993, residents and businesses filed property damage claims with their insurance carriers; and, when the County could not meet SBA requirements, people secured private financing. Business deriving income from marine interest was adversely impacted as states of emergency barred the usual opening of boating season. Government/municipal losses alone were hundreds of thousand of dollars for park structures and infrastructure, roads, drainage systems, water and wastewater structures.

Soil erosion begins in the area when the lake level reaches 246.3'. On April 14th, thirteen feet of shoreline was eroded at Hamlin Beach State Park, costing **\$90,000** and prompting the Parks Department Regional Director to declare the area in a state of emergency. The Director estimates long-term protection measure is **\$800,000**. Newspaper articles capture stories of riparians who have suffered the ill-effects of erosion this season, losing property from several feet to 35 feet which includes out-buildings, septic systems, breakwalls, and trees/landscaping. Private property damage is estimated at several thousand dollars on the average. Flood insurance claims are not substantiated for erosion damages. The County expended **\$21,700** for 70,000 sandbags that were distributed to the six lakeshore municipalities on March 17th for property protection against rising water (lake level 246.16').

Spatial Extent: Monroe County, NY

Letter to the Chairs of the International St. Lawrence River Board of Control from County Executive Jack Doyle Re: Public Hearing, Sacketts Harbour, NY (June 16, 1998)

The letter and attached photos describe impacts of high water to public infrastructure including water treatment plants and pump station, roads, waste-water interceptor, parkland and facilities and environmentally sensitive land. High lake levels, exacerbated by wind action, have severely eroded two areas along the shoreline adjacent to Lake Bluff Road in Irondequoit threatening the Irondequoit Bay Pure Waters District's Lakeshore Interceptor. Preliminary estimates indicate that the repair work will cost approximately **\$250,000**. To date, the County has invested **\$2 million** to reconstruct Edgemere Drive from damage due to severe flooding from high lake level.



Spatial Extent: Monroe County, NY

***Niagara County Lake Ontario Shoreline Damage Property Assessment 1998
(with supplement for 1999)(Niagara County Department of Planning,
Development and Tourism, 1998)***

This report is a compilation of information, provided by the Lake Ontario shoreline property owners of Niagara County, to demonstrate the severity of damages incurred to shoreline erosion. No data existed regarding shoreline damages in Niagara County prior to 1998. A survey was developed to request this information from riparian property owners in Niagara County. Information provided on the survey responses is presented in the report as a table, listing damages by parcel number. The date of the damage occurrence was used to identify 1998 damages specifically, and generally, the total overall damages that have occurred over the history of the property. Shoreline property damage for 1998 is assessed at over **\$3.5 million**. Cumulative damages area assessed at **~\$8 million**. This report constitutes Niagara County's initial attempt to formalize shoreline property damage information.

Damage data has been compiled for the Towns of Newfane, Porter, Somerset and the Town of Wilson by the Niagara County Planning Department. This provides information on the cost of damages suffered by land parcels along the shoreline during high water periods and includes information on the types of protection structures for each town as well as a summary of all the townships. Shoreline property owners have experienced significant losses due to the 1997/98 weather conditions and wave action on the shoreline.

Table 10 – Damage Summary for Niagara County (as of June, 1999)

Municipality	1998 Damages	Total Damages
Newfane	\$ 669,129	\$ 976,320
Porter	\$ 1,980,202	\$ 3,647,540
Somerset	\$ 833,151	\$ 2,031,164
Wilson (Town and Village)	\$ 1,497,702	\$ 3,569,829
Total	\$ 4,980,148	\$ 10,224,853

Spatial Extent: Niagara County, Towns of Newfane, Porter, Somerset and Wilson



Letter to Gerald Galloway, IJC from Joanne Ellsworth Re: Criteria Review for Regulation of Lake Ontario Niagara County Data Development (October 3, 2000)

The letter and attached appendix/proposal address the issue of 'Creating a GIS of the Coastal Areas of Niagara County.' As part of the rationale for the proposal the following information is included:

Weather conditions during the winter of 1997-98, coupled with higher than normal lake levels resulted in severe erosion by storm waves and extensive damage to shoreline protective structures along the coast of Niagara County. Surveys were conducted by the Niagara County Department of Planning, Development and Tourism to determine the extent of the erosion and to assess the damages to dwellings, water lines, and septic/sewer systems, and to erosion control structures. Based on a survey response of 29%, property damage during the period was estimated at over **\$3.5 million**, and cumulative damages were assessed at over **\$8 million**.

Spatial Extent: Niagara County, NY

Letter to Tony Eberhardt, US Army Corps of Engineers, from Joanne Ellsworth Re: Electronic Data for Lake Ontario Shoreline (December 27, 2000)

A 3.5 disc contains a tabulated list, by parcel number, of lakeshore damages compiled in 1998 and updated in December 2000.

Spatial Extent: Niagara County, NY

4.2 Ontario

Canada – Ontario Great Lakes Shore Damage Survey (Boulden, 1975)

This report provides mapped shoreline damage information associated with high water levels in the early 1970s. The associated Coastal Zone Atlas provides mapping of both flood and erosion damages for various locations along the Lake Ontario shoreline. Recession rates for the Canadian shoreline of Lake Ontario were calculated and reported.



Table 11 - Lake Ontario Regional Shore Damage

Region on Lake Ontario	Shoreline (Km)	Total Damage (\$)	Immediate Potential Damage* (\$)
Niagara	49.09	648,457	219,592
Hamilton-Wentworth	18.31	130,418	81,132
Hamilton-Burl, Beach	0	47,123	0
Halton	26.90	707,811	124,136
Peel	14.72	532,757	43,397
Metro, Toronto	46.82	585,903	38,853
Durham	64.92	108,741	24,935
Northumberland	114.03	189,086	43,192
Prince Edward	289.54	127,319	14,890
Hastings	68.12	26,026	0
Lennox and Addington	156.59	45,561	31,229
Frontenac	212.92	91,749	100
Total	1,061.96km	\$3,240,951	\$621,456

*Immediate potential damage is defined as an estimate of the cost of measures necessary to prevent imminent damage.

Spatial Extent: Canadian Lake Ontario shoreline.

Report on Ontario Flood History (Water Network, 1991)

The primary purpose of the report is to provide an inventory of flooding in Ontario. Flooding is inventoried with regard to those events that were disruptive to people, as flood damage reduction programs concentrate upon avoiding or reducing flood damages to society.

Considerable variation in the quality of information is reflected in the estimates of flood damages. To ascertain damage estimates, data was collected from the Ontario Ministry of Natural Resources, some Conservation Authorities and newspaper clippings. The inventory data were collected and organized to allow information to be presented regarding the temporal history of the flooding, the spatial distribution of the flooding, the magnitude and causes of flooding, as well as damages and responses. Two limitations are noted regarding the Great Lakes damage estimates: newspapers reviewed did not provide comprehensive reporting of coastal flooding; and, difficulty in separating coastal flood and erosion damages.



Table 12 – Lake Ontario Flooding Events By Decade

Decade	Flood Event Frequency
1850	1
1860	0
1870	1
1880	0
1890	1
1900	2
1910	1
1920	4
1930	0
1940	6
1950	6
1960	1
1970	2
1980	1

Table 13- Lake Ontario Flood and Erosion Damages by Conservation Authorities (1989 Dollars)

Conservation Authority	Nov 1972 – Oct 1973 (1989 \$)	County
Niagara (Ontario)	1,874,000	Niagara
Hamilton	513,000	Hamilton-Wentworth
Halton	2,046,000	Halton
Credit	1,540,000	Metro Toronto
Metro Toronto	1,939,000	Metro Toronto
Central Lake Ontario	68,000	Durham
Ganaraska	178,000	Northumberland
Lower Trent	334,000	Hastings / Lennox
Moira	51,000	?
Napanee	59,000	?
Prince Edward	368,000	Prince Edward
Catarquai	354,000	Frontenac / Leeds

Spatial Extent: Canadian Lake Ontario and St. Lawrence River shoreline.



Great Lakes Flood and Erosion Stage-Damage Curve Updates (Marshall Macklin Monaghan Ltd., 1992)

This report provides updated flood and erosion curves and forecasts damage estimates for various water level scenarios. The curves were updated for contents inflation, new development, removed structures, raised or moved structures, construction cost inflation, new shoreline protection, and property market value increases.

The Canadian shoreline of Lake Ontario was originally discretized into 12 reaches, although 3 of the 12 reaches have neither a flooding nor an erosion curve. The excluded reaches include Hamilton Harbour (reach 4) and the southern and southwestern portions of Prince Edward County. Flood damage curves exist for all of the reaches while erosion damage curves were developed for all of the reaches except for 9 and 12. Reach 9 includes the Bay of Quinte. The remaining reaches were delineated as:

Reach #	
1	Niagara on the Lake to Jordan Harbour
2	Jordan Harbour to Winona
3	Winona to Hamilton
5	Burlington to Oakville
6	Oakville to Humber Bay
7	Humber Bay to Port Hope
8	Port Hope to Presqu'ile Bay
9	Presqu'ile Bay to Point Petre
12	Deseronto to Kingston

The Canadian shoreline of St. Lawrence River was originally discretized into 5 reaches. The first four reaches are in the general vicinity of Montreal. These areas sustained significant damages during the 1974 and 1976 flooding events.

Reach #	
1	Lac des Deux Montagnes
2	des Mille Iles River
3	des Prairies River
4	Lac St. Louis
5	St. Lawrence River between Repentigny and Trois-Rivières

Spatial Extent: The Canadian shoreline of Lake Ontario and the of St. Lawrence River.



Potential Damage Estimates for Site Specific Areas (IJC Levels Reference Study Board, Paragon, 1993 – draft)

Detailed site descriptions for Toronto (Mississauga to Etobicoke) on Lake Ontario and Montreal (Verdun to Ste-Anne-de-Bellevue) on the St. Lawrence River are included in this report. At each site the following is presented: review and analysis of shoreline categorization; quantitative and qualitative estimates of past and potential damages due to flooding; quantitative and qualitative estimates of past and potential damages due to erosion; quantitative and qualitative estimates of past and potential damages due to extreme water events; and, estimates of the change in potential flood, erosion and low water damages that might occur with an overall reduction in the range of still water levels that have historically occurred.

This study dealt solely with damages and costs and residential areas. Inundation damages were calculated using the FLDAM computer program developed by Paragon Engineering Ltd. for the Canada/Ontario Flood Damage Reduction Program. Stage damage curves and damage estimates are provided for each scenario. In the SMHEO scenarios, no scenario resulted in a decrease in expected annual damages for either Toronto or Montreal.

Spatial Extent: Metro Toronto and Montreal.

Development of Flood Depth-Damage Curves for Residential Homes in Ontario (Paragon Engineering, 1985).

Objectives of the study are:

- to collect potential flood damage data by surveying homes at risk in the floodplains of Ontario;
- to analyze the survey results and produce a set of depth-damage curves associated with different housing styles;
- to develop computer application tools to facilitate the use of the damage curves; and,
- to develop recommendations for updating the flood damage curves.

Communities surveyed were selected to achieve a 'typical' cross-section of Ontario communities. The one community of interest with respect to Lake Ontario flood damages was Belleville. Damage curves were determined through the survey of damage approach. After specific flooding events, incidents-of-damage studies were conducted through household interviews and the depth-damage curves were established. All dollar figures are reported in 1984 dollars.



The questionnaire survey of households provided the base data from which damage curves were estimated. The report contains a sample of the questionnaire used for damage estimation. This raw data consisted on an inventory of the structural features and the contents that were subject to damage. Damage data includes; contents damages, structural damage, and total damage. The report contains summary statistics of damage data by category of building; contains damage curves and histograms for various types of structures (generally residential one story with basement). As well, the report considers various factors (flood warning, duration of flood, flooding with high velocity flows or ice, etc.) affecting damage values to provide first estimates of adjustment factors for the damage curves.

Spatial Extent: The Canadian shoreline of Lake Ontario.

Great Lakes System Flood Levels and Water Related Hazards (Conservation Authorities and Water Management Branch, Ontario Ministry of Natural Resources, 1989)

This report contains information on flood levels and water related hazards for the Ontario portion of the Great Lakes shoreline and connecting channels, excluding the St. Lawrence River. The information was prepared primarily to aid in identifying shoreline hazard areas. A thorough description of methods of calculation is included.

The following information is reported:

- 1) 100 Year flood levels and the sectors of Great Lakes shoreline for which they apply are reported. An accompanying 1:750,000 scale map of Lake Ontario delineates the shoreline into discrete parcels with 100-year instantaneous water levels (see Table 14 and 15);
- 2) Peak instantaneous water levels (IGLD) for recurrence intervals from 2 to 200 years;
- 3) Highest annual monthly mean lake levels (IGLD) for recurrence intervals from 2 to 200 years; and
- 4) Wind set-up values for recurrence intervals from 2 to 200 years.

Spatial Extent: The Canadian shoreline of Lake Ontario.



Table 14 – Lake Ontario Shoreline 100-Year Instantaneous Water Levels

OMNR Reach ID	LOSLR Shore Units	100-Year Peak Instantaneous Levels (m/GSC*)
Reach 0-1	CND1 (0-30km west from US1)	76.1
0-2	CND1 (remaining km) CND2 (all) CND4 (from CND2 to Burlington)	76.0
0-3	CND4 (Burlington to Mississauga)	75.9
0-4	CND4 (remaining) CND5 (Mississauga to Toronto)	75.8
0-5	CND5 (remaining) CND6 (all) CND7 (to Frenchman's Bay)	75.7
0-6	CND7 (Frenchman's Bay to Bowmanville)	75.6
0-7	CND7 (remaining) CND8 (all)	75.7
0-8	CND9 (to Wellington Bay)	75.7
0-9	CND9 (remaining)	75.7
0-10	CND10 (all) CND12 (~halfway point on Amherst Island)	75.8
0-11	CND12 (to Kingston)	76.0

* Geodetic Datum from the Geologic Survey of Canada

Table 15 – Lake Ontario Shoreline Sites 100-Year Instantaneous Water Levels

Lake Ontario Shoreline Sites	100-Year Peak Instantaneous Water Level	
	m(GSC)	m(IGLD)
Port Weller	76.1	75.99
Burlington	76.0	75.92
Oakville	75.9	75.82
Mississauga	75.8	75.72
Toronto	75.7	75.62
Oshawa	75.6	75.53
Cobourg	75.7	75.63
Wellington	75.7	n/a
Point Petre	75.7	n/a
Prince Edward	75.8	n/a
Kingston	76.0	75.86



Central Lake Ontario Shoreline Management Plan (Sandwell, 1994)

This shoreline management plan has been developed for the Central Lake Ontario, Ganaraska and Lower Trent Region Conservation Authorities. The results of the study have been summarized in report form with two sets of accompanying maps at 1:10,000 scale which cover the entire study area. The mapping identifies a number of items including land use, erosion set-back limits, 100-year floodline, environmentally sensitive areas, shoreline structures with photographic cross references, geological shoreline types, erosion rates, sediment characteristics, damage centers, erosion monitoring stations and littoral subcells and reaches.

Damage centers are defined as areas of high risk due to flooding and erosion potential. Seventeen such damage centers were identified and are summarized in Table 16. In each case the cause of the damage, potential for future damage and protective measures are reported.

Table 16 – Damage Centers, Central Lake Ontario Shoreline Management Plan

	Damage Center	Nature of Damage
1	Town of Whitby Lots 19-21. Broken Front Concession (Map 2.2) Reach #6	Area is prone to erosion
2	City of Oshawa Lots 10-12. Concession BF (Map 2.3) Reach #9	Area is prone to erosion
3	City of Oshawa Lot 8 Concession BF (Map 2.3) Reach #10	Area is prone to erosion
4	Port Darling Beach (Map 2.7) Reach #17	Area is at risk from riverine and lake flooding.
5	Newcastle (Map 2.8) Reach #25	Area is prone to flooding
6	Bouchette Point (Map 2.10) Reach #26, 27	Area is prone to erosion
7	Port Granby (Map 2.10) Reach #29	Low Level Nuclear Waste disposal site. Area is prone to erosion
8	Willow Beach (Map 2.11) Reach #31	Area is prone to erosion
9	Port Britain (Map 2.12) Reach #33	Area prone to flooding
10	Hope Township Lots 13-14 (Map 2.12) Reach #36	Area prone to flooding
11	Port Hope (Map 2.13) Reach #37	A number of structures are located below the 100-year flood level
12	Cobourg (Map 1.16) Reach #41-42	A number of structures are at risk due to flooding and erosion



13	Lakeshore Drive, Coburg (Map 2.16) Reach #43	Area prone to erosion. 33 homes at risk.
14	Lakeshore Pentacostal Camp (Map 2.17) Reach #44	Area prone to erosion
15	Haldimand Township, Lots 28-31. Concession A (Map 2.18) Reach #46	Area prone to erosion
16	Victoria Beach, loughbreeze (Map 2.21) Reach #54	Area prone to flooding during storm events
17	Stony Point to Barcovan Beach (Maps 2.26-2.28) Reach 61-65	Area prone to flooding

Spatial Extent: Central Lake Ontario Shoreline of Ontario.

Cramahe Shorelands Project (Lower Trent Conservation, 1997)

The Cramahe Shorelands Project Report is an integrated shoreline management plan for Cramahe Township, which is located in the Lower Trent Conservation watershed area. The report summarizes the current information base on the Cramahe Township shoreline, identifies key shoreline issues, identifies areas at risk from shoreline hazards, and identifies potential management and shoreline treatment options to overcome the hazards.

As part of the project a Flood Susceptible Areas Survey” was conducted and identifies, on hardcopy maps, individual structures and lists their lowest opening elevations, as well as the flooding hazard limit for that area of shoreline.

Spatial Extent: Cramahe Township, Ontario.

Lake Ontario Shoreline Management Plan, Niagara Peninsula Conservation Authority (Dillon, 1994)

This report presents a Shoreline Management Plan for the Niagara County, Ontario shoreline. The report includes descriptions of shoreline reaches that provide a general description of the shoreline, and information on environmental features, land use and flooding and erosion hazards.

Spatial Extent: Niagara County, Ontario



4.3 General Reports, Non-Specific Spatial Extent

A Review of Flood Damage Estimation Methodologies (Paragon Engineering, 1984)

The report provides a review and guidelines for estimating flood damages. In particular, it provides details of flood damage calculation procedures. This includes: the development of stage-damage data; residential, industrial, institutional and agricultural flood damages; public damages; and, indirect damages. The report also discusses the method for updating flood damage curves.

Memo – From J.Y. Ding to Doug Brown dated Dec 12, 1986 Re: Flood Damages Report (Paragon, 1984) Updated Version

There is an updated Guidelines for Estimation volume, which includes the new generic depth-damage curves for residential homes in Ontario. This update is for the 2-volume Flood Damages Report produced by Paragon in 1984.

A Critical Review of Existing and Updated U.S. and Canadian Stage-Damage Curves (Yoe, 1992)

The purpose of this Critical Review is to make recommendations about how established flood and erosion stage-damage curves might best be used given their strengths and weaknesses.

Flood Damages in Ontario, 1985 – 1988 (Conservation Authorities and Water Management Branch, Ministry of Natural Resources, 1990)

This report presents a summary of the damages and costs due to floods in Ontario for the period 1985 to 1988. A brief description of the damages and causes of the major flood events is given. Detailed damage tables by region are presented. However, as Lake Ontario did not experience extensive flooding during this period there is little data on Lake Ontario's shorelines.

An Inventory of the US Shoreline of Lake Ontario and Evaluation of Structural Modifications for Damage Reductions, Lake Ontario Shore Protection Study (Ray and Sweeney, 1980)

This report identifies erosion and flood prone areas and provides structural modification plans for reducing erosion and flood damages. The total length of



shoreline studies was 289.6 miles, from the Niagara River to Tibetts Point. The entire shoreline is divided into 126 shore reaches. The identification of erosion areas was based on the measurement of short-term (less than 50 years) shoreline retreat rate from vertical aerial photographs taken during various time periods. Appendix II provides detailed locations of all areas discussed in the report.

5.0 Summary and Proposed Activities for Phase III

Information contained in these reports will be extracted and used as appropriate in conducting both site specific and lakewide analyses with the FEPS model.



REFERENCES and ADDITIONAL REPORTS REVIEWED

- Balogh, L.J., 1987. Report on Flood Contingency Planning in Ontario. Conservation Authorities and Water Management Branch, Ontario Ministry of Natural Resources.
- Boulden, R. S., Ed., 1975. Canada - Ontario Great Lakes Shore Damage Survey. Prepared for Environment Canada and the Ontario Ministry of Natural Resources, 97pp., plus Appendices.
- C.A., Inc., 1992. Analysis and Report on Stage-Damage Relationships for Selected U.S. Shoreline Reaches. Consulting Report Prepared for U.S. Army Corps of Engineers, Detroit District, 43pp., plus Appendices.
- DeCooke, B.G., 1988. Situation Report, Great Lakes 1985-87 High Water Levels U.S. Shoreline Damages, Modeling and Mapping. Consulting Report Prepared for the U.S. Army Corps of Engineers North Central Division and the U.S. Section of the International Joint Commission, 117pp., plus Appendices.
- DeCooke, B.G., 1991. Great Lakes Shoreline United States Inundation and Erosion Stage-Damage Relationships. Consulting Report Prepared for the United States Army Corps of Engineers, North Central Division, 355pp., plus Appendices.
- Environment Canada and Ontario Ministry of Natural Resources, 1987. Canada-Ontario Flood Damage Reduction Program Annual Review, 1986-1987, 43pp.
- Environment Canada, 1992. Uncertainty Analysis – Canadian Inundation Stage-Damage Curves. Report Prepared for the Potential Damages Task Group, Working Committee II, Phase II, IJC Levels Reference Study.
- Fisheries and Environment Canada and Ontario Ministry of Natural Resources, 1978. Canada-Ontario Great Lakes Flood and Erosion Prone Areas Mapping.
- Haras, W.S., and Tsui, K.K., 1976. Great Lakes Coastal Zone Atlas. Canada-Ontario Great Lakes Shore Damage Survey. Environment Canada and Ontario Ministry of Natural Resources.
- International Great Lakes Levels Board, 1973. Regulation of Great Lakes Water Levels, Appendix C, Shore Property. Report to the International Joint



Commission Under the Reference of October 7, 1964, 188pp., plus Appendices.

Lower Trent Conservation, 1997. Cramahe Shorelands Project. Shoreline Management Planning Report prepared for the Township of Cramahe, Ontario, 72pp., plus Appendices.

Marshall, Macklin, Monaghan, 1992. Great Lakes Flood and Erosion Stage-Damage Curve Updates. Report Prepared for the Potential Damages Task Group, Working Committee II, Phase II, IJC Levels Reference Study.

M. M. Dillon Limited, 1994. Lake Ontario Shoreline Management Plan Main Report. Report prepared for the Niagara Peninsula Conservation Authority, 150pp., plus Appendices.

Niagara County Department of Planning, Development and Tourism, 1998. Niagara County Lake Ontario Shoreline Property Damage Assessment, 1998 (with 1999 supplement). Presentation by Legislators.

Niagara Peninsula Conservation Authority, 1991. Flood Warning Manual. 21pp., plus Appendices.

Ontario Ministry of Natural Resources, 1989. Great Lakes System Flood Levels and Water Related Hazards. Conservation Authorities and Water Management Branch.

Ontario Ministry of Natural Resources, 1990. Flood Damages in Ontario, 1985-1988. Conservation Authorities and Water Management Branch Report Number CAWMB 90-1, July 1990, 48pp.

Ontario Ministry of Natural Resources, 1990. Delineation of Erosion Hazard Shorelands, Workshop Summary. Great Lakes Shoreland Management Workshop Series, Cleveland, Ohio, June 21-23, 1990.

Oswego County Department of Planning and Community Development, 1994. Oswego County Data Book. Oswego County Planning Board.

Oswego County Planning Board, 1997. Oswego County Comprehensive Plan.

Paragon Engineering Limited, 1984. Flood Damages Volume 1, A Review of Estimation Techniques. Consulting Report Prepared for Ontario Ministry of Natural Resources, 95pp.



- Paragon Engineering Limited, 1984. Flood Damages Volume 2, Guidelines for Estimation. Consulting Report Prepared for Ontario Ministry of Natural Resources, 35pp.
- Paragon Engineering Limited, 1985. Development of Flood Depth-Damage Curves for Residential Homes in Ontario, Volume 1 Technical Report. Prepared for Ontario Ministry of Natural Resources, 61pp., plus Appendices.
- Paragon Engineering Limited, 1993. Potential Damage Estimates for Site Specific Areas. Consulting Report prepared for the Potential Damages Task Group, IJC Great Lakes – St. Lawrence River Water Levels Reference Study, 25pp., plus Appendices.
- Ray, P.K., Sweeney, R.A., Kana, T.W., McCants, C.Y., Murday, M., and Galvin, C., 1980. Lake Ontario Shore Protection Study – An Inventory of the U.S. Shoreline of Lake Ontario and Evaluation of Structural Modifications for Damage Reduction. Report Prepared for the U.S. Army Corps of Engineers, Buffalo District, 66pp., plus Appendices.
- Sandwell Inc., 1989. Lake Ontario Shoreline Management Plan. Report Prepared for the Central Lake Ontario, Ganaraska Region, and Lower Trent Region Conservation Authorities.
- Stewart, C.J., and Kangas, J., 1993. Potential Damages Task Group Report. Submitted to Working Committee 2, IJC Great Lakes – St. Lawrence River Water Levels Reference Study, 135pp., plus Appendices.
- United States Army Corps of Engineers Detroit District, 1992. Uncertainty Analysis Methodology, Inundation Stage-Damage Curves. Report Prepared for the Potential Damages Task Group, Working Committee II, Phase II, IJC Levels Reference Study.
- The Water Network, 1991. A Report on Ontario Flood History. Report prepared for the Ontario Ministry of Natural Resources, 83pp.
- Yoe, C., 1992. A Critical Review of Existing and Updated U.S. and Canadian Stage-Damage Curves. Report Prepared for the Potential Damages Task Group, Working Committee II, Phase II, IJC Levels Reference Study.

