DETAILED STUDY SITES FOR THE COASTAL PERFORMANCE INDICATORS

Prepared for:

BUFFALO DISTRICT UNITED STATES ARMY CORPS OF ENGINEERS

Prepared by:

W.F. BAIRD & ASSOCIATES COASTAL ENGINEERS LTD.
MADISON, WISCONSIN

DEC. 31, 2006
Detailed Study Sites for the Coastal Performance Indicators

Reporting History

<table>
<thead>
<tr>
<th>Version No</th>
<th>Date</th>
<th>Status</th>
<th>Comments</th>
<th>Reviewed by</th>
<th>Approved by</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dec 1 ‘06</td>
<td>Draft</td>
<td></td>
<td>PJZ</td>
<td>RBN</td>
</tr>
<tr>
<td>2</td>
<td>Dec 31, ‘06</td>
<td>Final</td>
<td></td>
<td>PJZ</td>
<td>RBN</td>
</tr>
</tbody>
</table>

For further information please contact
Pete Zuzek, 905-845-5385

This report was prepared by W.F. Baird & Associates Coastal Engineers Ltd. for the Buffalo District USACE. The material in it reflects the judgment of Baird & Associates in light of the information available to them at the time of preparation. Any use which a Third Party makes of this report, or any reliance on decisions to be made based on it, are the responsibility of such Third Parties. Baird & Associates accepts no responsibility for damages, if any, suffered by any Third Party as a result of decisions made or actions based on this report.
# TABLE OF CONTENTS

## 1.0 INTRODUCTION

1.1 Coastal Performance Indicators

1.2 Lake Levels

1.2.1 Historical Lake Ontario Water Levels

1.2.2 Lake Levels for Legacy Plans with Historic Supplies

1.2.4 35 Year Climate Change Lake Levels (preliminary data)

1.2.5 Climate Change Supplies with Pre-Project Conditions

1.2.6 Lake Levels for Candidate Plans (as of August 2005)

1.3 Shore Units, Counties and Regional Municipalities

1.4 Detailed Study Sites

1.5 Flood and Erosion Prediction System

1.6 Lakewide Assessment with FEPS

1.7 Linkage to the Shared Vision Model

## 2.0 FLOODING SITES

2.1 Runup and Overtopping Calculations with the FEPS

2.2 Site #1 – Payne Beach

2.3 Site #2 – Sandy Harbor Beach

2.4 Site #4 – Edgemere Drive

2.4.1 Detailed Survey Data for Individual Land Parcels

2.4.2 Overtopping Simulations for Legacy Plans

2.4.3 Overtopping Simulations for a 2.14 m Crest Elevation

2.4.4 Overtopping Simulations for a 2.54 m Crest Elevation

2.4.5 Flow Pathway Analysis

2.5 Site #3 – Sandy Point, Sodus Bay

## 3.0 EROSION SITES

3.1 Site #5 – Maumee Bay

3.1.1 Profile Data

3.1.2 Lake Level Data

3.1.3 Wave Data

3.1.4 Ice Data

3.1.5 COSMOS Model Calibration

3.1.6 COSMOS Model Verification

3.2 Site #6 – East of 20 Mile Creek
4.1 Site #16 (Walkers to Appleby Line) and #17 (Coronation Park) ........................................108
4.1.1 Design Water Levels .....................................................................................................111
4.1.2 Shore Protection Data ....................................................................................................112
4.1.3 Material Costs ...............................................................................................................121
4.1.4 Conceptual Designs for Shore Protection ......................................................................122
4.1.5 Maintenance and Replacement Costs .............................................................................125
4.1.6 Detailed Cost Estimate ....................................................................................................125
4.1.7 Sensitivity Analysis ........................................................................................................129
4.1.8 Summary of Results for Study Site #17 .........................................................................133
4.2 Site #18 - Wilson Area .......................................................................................................135

5.0 SEDIMENT BUDGET SITES .....................................................................................140
5.1 Site #12 – CND8 Sediment Budget ....................................................................................141
5.1.1 Rates of Sediment Supply for Different Regulation Plans ...........................................143
5.1.2 Economic Function to Quantify the Value of Eroded Sediment ....................................145
5.1.3 Benefits and Costs of Regulation for the Port Hope to Presqu’ile Littoral Cell ..............146
5.2 Site #13 – Eastern Lake Ontario Sediment Budget ............................................................148
5.2.1 Post Glacial Evolution at ELO Site ...............................................................................152
5.2.2 Modern Geology and Geomorphology ........................................................................152
5.2.3 Sediment Sources and Sinks ......................................................................................160
5.2.4 Regional Sediment Transport Patterns .......................................................................182
5.2.5 Bypassing Analysis at the Salmon River Jetties ............................................................185
5.2.6 Sediment Budget Findings .........................................................................................191
5.2.7 Impacts of Lake Level Regulation at ELO ....................................................................191

6.0 BARRIER BEACHES AND DUNES ..........................................................................193
6.1 Braddock’s Bay Barrier Beach Case Study ........................................................................193
6.2 Site #13 – North Pond Barrier Beach, Eastern Lake Ontario ............................................199
6.2.1 Wave Climate ..............................................................................................................200
6.2.2 Beach and Dune Profiles ..........................................................................................201
6.3 Site #14 – North and South Colwell Pond, Eastern Lake Ontario ....................................207
6.4 Site #15 – Huyck’s Bay Barrier Beach .............................................................................213
6.4.1 Long Term Shoreline Change Rates ..........................................................................218
6.4.2 Lake Bottom Profiles ..................................................................................................219
6.4.3 Beach Profiles ............................................................................................................219
6.4.4 Waves and Hydrodynamic Modeling at Huyck’s Bay ...................................................221

7.0 BEACH ACCESS PERFORMANCE INDICATOR ............................................225
7.1 Site #11 Beaches .................................................................................................................. 225
  7.1.1 Presqu’ile Provincial Park .................................................................................................. 225
  7.1.2 Sandbanks Provincial Park .............................................................................................. 226
  7.1.3 Southwick Beach State Park .......................................................................................... 227
  7.1.4 Hamlin Beach State Park ............................................................................................... 228
7.2 Economic Impacts of Beaches ............................................................................................... 230
7.3 Sandbanks and Hamlin Beach Survey .................................................................................. 231

REFERENCES .......................................................................................................................... 238
**LIST OF TABLES**

Table 3.1  **Historical Recession Rates for an Unprotected Section of Reach 1277** ..........................53
Table 3.2  **Historical Recession Rates for Unprotected Sections of Reach 1319** ..........................62
Table 3.3  **Historical Bluff Recession Rates for Reach 860** ............................................................71
Table 3.4  **Summary of Ten Erosion Sites from NYPA Study** .........................................................86
Table 4.1  **Peak Design Water Levels** ...........................................................................................112
Table 4.2  **HRCA Database for Study Site #16 (Walkers Line to Appleby Line, Burlington, Ontario)** ..................................................................................................................................113
Table 4.3  **HRCA Database for Study Site #17 (Coronation Park, Oakville, Ontario)** .................113
Table 4.4  **Summary of Structure Type as a Percentage of Frontage (length) for the Study Site** 120
Table 4.5  **Crest Height and Toe Elevation for all Structure Types at Study Sites** .......................120
Table 4.6  **Unit Costs for Shore Protection Construction Materials** .............................................121
Table 4.7  **Conceptual Design Details from Dominant Structure Types in Study Site #16** ..........123
Table 4.8  **Total Protection Cost and Potential Costs to Adapt Stability Only**
(crest and toe elevations unchanged) .............................................................................................127
Table 4.9  **Individual Parcel Costs and Potential Costs to Adapt Stability and Crest Elevation**
(toe unchanged) .............................................................................................................................128
Table 4.10 **Effect of Assumed Toe Elevation on Total Shore Protection Costs** ......................131
Table 4.11 **Effect of Assumed Crest Elevation on Total Shore Protection Costs** ..................133
Table 4.12 **Effect of Assumed Toe Elevation on Total Shore Protection Costs** ..................134
Table 6.1  **Wave Conditions for Two Historical Storms at ELO (conditions at 10 m depth contour)**201
Table 7.1  **Estimated Expenditures for Beach Visitors at Sandbanks Provincial Park in 2002**...230
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1.1</td>
<td>Schematic Map of Coastal Performance Indicators</td>
<td>1</td>
</tr>
<tr>
<td>Figure 1.2</td>
<td>Monthly Mean Water Levels for Lake Ontario</td>
<td>2</td>
</tr>
<tr>
<td>Figure 1.3</td>
<td>Legacy Plans for Historic Supplies from 1960 to 2000</td>
<td>3</td>
</tr>
<tr>
<td>Figure 1.4</td>
<td>Stochastic Supplies with Pre-project Conditions from 1900 to 2000</td>
<td>4</td>
</tr>
<tr>
<td>Figure 1.5</td>
<td>Three Climate Change Hydrographs Prepared by EC (2030, 2050 and 2090)</td>
<td>4</td>
</tr>
<tr>
<td>Figure 1.6</td>
<td>Lake Levels for Climate Change Supplies and Pre-Project Conditions</td>
<td>5</td>
</tr>
<tr>
<td>Figure 1.7a</td>
<td>Lake Ontario Water Levels for Candidate Plans and Historical Supplies</td>
<td>6</td>
</tr>
<tr>
<td>Figure 1.7b</td>
<td>Lake Ontario Water Levels for Candidate Plans and Historical Supplies</td>
<td>6</td>
</tr>
<tr>
<td>Figure 1.7c</td>
<td>Shoreline Units for Lake Ontario and the Upper St. Lawrence River</td>
<td>7</td>
</tr>
<tr>
<td>Figure 1.8</td>
<td>Counties and Regional Municipalities on Lake Ontario and the Upper River</td>
<td>8</td>
</tr>
<tr>
<td>Figure 1.9</td>
<td>Detailed Study Sites for the Coastal Technical Working Group</td>
<td>9</td>
</tr>
<tr>
<td>Figure 1.10</td>
<td>Flood and Erosion Prediction System (FEPS)</td>
<td>10</td>
</tr>
<tr>
<td>Figure 1.11</td>
<td>FEPS Simulation Builder for Linkage to the SVM</td>
<td>11</td>
</tr>
<tr>
<td>Figure 2.1</td>
<td>Variable Requirements for the Various Runup and Overtopping Equations</td>
<td>14</td>
</tr>
<tr>
<td>Figure 2.2</td>
<td>Nearshore Portion of a COSMOS Profile with Vertical Seawall</td>
<td>15</td>
</tr>
<tr>
<td>Figure 2.3</td>
<td>Sample of Runup Predictions in the FEPS Flooding Module for Study Site #2, Sandy Harbor Beach</td>
<td>16</td>
</tr>
<tr>
<td>Figure 2.4</td>
<td>Time Series Runup Predictions for Sandy Harbour Beach and Pre-project Lake Levels (runup elevations above LWD, m)</td>
<td>17</td>
</tr>
<tr>
<td>Figure 2.5</td>
<td>Sample of Overtopping Predictions for Edgemere Drive with the Flooding Module of the FEPS</td>
<td>18</td>
</tr>
<tr>
<td>Figure 2.6</td>
<td>Time Series Overtopping Predictions for Edgemere Drive and Pre-project Lake Levels (overtopping scale on Y2 axis)</td>
<td>19</td>
</tr>
<tr>
<td>Figure 2.7a</td>
<td>Aerial View of Study Site #1, Payne Beach (Reach 1045 and 1046)</td>
<td>20</td>
</tr>
<tr>
<td>Figure 2.7b</td>
<td>Aerial View of Study Site #1, Payne Beach (Reach 1045 and 1046)</td>
<td>21</td>
</tr>
<tr>
<td>Figure 2.8</td>
<td>Input Profile from the 2 m Depth Contour to the Road for Payne Beach</td>
<td>21</td>
</tr>
<tr>
<td>Figure 2.9a</td>
<td>Runup Events for 1958D with Deviations from 1981 to 1995</td>
<td>22</td>
</tr>
<tr>
<td>Figure 2.9b</td>
<td>Runup Events for Plan 1998 from 1981 to 1995</td>
<td>22</td>
</tr>
<tr>
<td>Figure 2.9c</td>
<td>Runup Events for Plan 1958D without Deviations from 1981 to 1995 (top ten)</td>
<td>23</td>
</tr>
<tr>
<td>Figure 2.9d</td>
<td>Runup Events for Pre-project from 1981 to 1995</td>
<td>23</td>
</tr>
<tr>
<td>Figure 2.10</td>
<td>Predicted Flow Pathways for New Estate Homes at Payne Beach</td>
<td>24</td>
</tr>
<tr>
<td>Figure 2.11</td>
<td>Study Site #2, Sandy Harbor Beach</td>
<td>25</td>
</tr>
<tr>
<td>Figure 2.12</td>
<td>Homes Located at the Edge of the Fillet Beach, Study Site #2</td>
<td>26</td>
</tr>
<tr>
<td>Figure 2.13</td>
<td>Portion of USACE Site Survey from August 2002</td>
<td>26</td>
</tr>
</tbody>
</table>
Figure 2.14  Typical Nearshore and Beach Profile at Sandy Harbor Beach ................................27
Figure 2.15  Storm Listing for Wave Runup at Sandy Harbor Beach (1981 to 1995 for 1958DD)28
Figure 2.16  Hourly Wave Runup Elevations from 1986 to 1990 for 1958DD ..........................28
Figure 2.17a  Wave Runup Storm Listing in Chronological Order for 1958D without Deviations (only first 10 storms) .............................................................................................................................29
Figure 2.17b  Wave Runup Storm Listing for Top Ten Storms for 1958D without Deviations ......29
Figure 2.18  Wave Runup Storm Listing for Top Ten Storms for Pre-project ..........................30
Figure 2.19  Plan View Map of Edgemere Drive (Reaches 1024 and 1025)..........................31
Figure 2.20  Wave Overtopping for a 1973 Storm, Edgemere Drive (image courtesy Dr. Martin)32
Figure 2.21  Waterfront Lots Along Edgemere Drive During Fair Weather ............................32
Figure 2.22  Structural Failure Due to Wave Attack (image courtesy Dr. Martin)......................33
Figure 2.23  Road Grade Below Home Foundation Elevations Along Edgemere Drive .................34
Figure 2.24  Street Flooding Along Edgemere Drive (image courtesy Dr. Martin) ......................34
Figure 2.25  Surveyed Seawall Crest Elevation and Surrounding Land Elevations .................35
Figure 2.26  Input Profile for COSMOS Menu with 2.14 m Crest and –0.33 m Toe for Seawall 36
Figure 2.27  Wave O/T Listing for 2.14 m Crest and Actual Rochester Gage WLS for 1973 ......37
Figure 2.28  1973 Time Series Plot of Predicted O/T (2.14 m Crest and –0.33 m Toe for Seawall)38
Figure 2.29  Wave O/T Listing for 2.54 m Crest and Actual Rochester Gage WLS for 1973 ......39
Figure 2.30  1973 Time Series Plot of O/T (2.54 m Crest and –0.33 m Toe for Seawall) .............39
Figure 2.31a  Results of Flow Pathway Analysis for Edgemere Drive ........................................40
Figure 2.31b  Regional Map of Sodus Bay and the Sandy Point Detailed Study Site (#3) ............41
Figure 2.32  Typical View of Sandy Point Shoreline (looking west) ........................................42
Figure 3.1  Erodibility Coefficients in the COSMOS Model ..................................................44
Figure 3.2  Location Map for Site #5, Maumee Bay, Lucas County Lake Erie ........................45
Figure 3.3  Repetitive Profile Data from 1981 to 1990 ............................................................46
Figure 3.4  Hourly Lake Level Data from the Toledo Gage, Jan. to Dec. 1987 (m, IGLD’85) ..46
Figure 3.5  December 15, 1987 Storm Surge and Draw-down Recorded at the Toledo Gage ....47
Figure 3.6  Wave Rose for Wind-Wave Hindcast Offshore of Maumee Bay ............................48
Figure 3.7  COSMOS Model Calibration for 1981 and 1985 ................................................49
Figure 3.8  COSMOS Model Verification, 1985 and 1990 ......................................................50
Figure 3.9  Location Map for Site #6, located East of 20 Mile Creek .......................................51
Figure 3.10 Oblique Aerial Photograph of Reach 1277 (August 9, 2003) looking southeast ......52
Figure 3.11 Ground Level Photograph of Reach 1277 (December 12, 2002) ........................52
Figure 3.12 Detailed Shoals Lakebed Profiles for CND1 / Niagara Regional Municipality ......54
Figure 3.13 Wave Height Rose for WAVAD Point 585 (10 m depth offshore of Site #6) ..........55
Figure 3.14 Annual Wave Energy at Study Site #6 (Joules per m$^2$) ..................................56
Table of Contents

Baird & Associates

Figure 3.15  Annual Wave Energy at Study Site #6 (Joules per m²).................................56
Figure 3.16  COSMOS Model Calibration at Reach 1277 (1961 to 2000).........................57
Figure 3.17  Estimate of Bluff Recession at Reach 1277 for Legacy Plans and Climate Change Water Levels .................................................................58
Figure 3.18  Cumulative Bluff Recession at Site #6 for Legacy Plans and Climate Change........59
Figure 3.19  Location Map for Site #7, Cherry Beach .........................................................60
Figure 3.20  Oblique Digital Photograph of Reach 1319 (August 9, 2003)..........................61
Figure 3.21  Ground Level Photograph of Eroding Bank at Reach 1319 (Dec. 13, 2002) ....61
Figure 3.22  Lakebed Profiles for Reaches 1308 to 1320 Based on 2001 SHOALS Data ......63
Figure 3.23  Wave Rose for Reach 1319 (10 m depth) .........................................................63
Figure 3.24  Calibration of COSMOS at Reach 1319 (1961 to 2000 waves).......................64
Figure 3.25  Lakebed Downcutting and Bank Recession at Reach 1319 .........................65
Figure 3.26  Cumulative Bank Recession for a 35 Year Simulation at Reach 1319 ............66
Figure 3.27  Map of Study Site #8, East Bay, Wayne County, New York .........................67
Figure 3.28  Eroding Bluffs and Residential Development at East Bay (taken August 6, 2003)68
Figure 3.29  Ground Level Photograph of Site #8 Looking East (taken April 11, 2002) .......68
Figure 3.30  Beach and Nearshore Lakebed Conditions at Site #8 (taken April 11, 2002) ....69
Figure 3.31  1973 and 2002 Bluff Crest Lines and Recession Measurements for Site #8 ....70
Figure 3.32  2001 SHOALS Profiles, Reaches 860 to 866 ..................................................71
Figure 3.33  1961 to 2000 Wave Data Offshore of Site #8, East Bay, Wayne County ......72
Figure 3.34  Results from COSMOS Model Calibration at Reach 860, 1973 to 2002 ........73
Figure 3.35  Results from COSMOS Simulation for Legacy Plans at Reach 860 (1961 to 1995)74
Figure 3.36  Cumulative Bluff Recession at Reach 860 for the Legacy Plans and Climate Change Water Levels..................................................................................75
Figure 3.37  Cumulative Bluff Recession at Reach 860 for Candidate Plans .....................76
Figure 3.38  101 Year Estimate of Future Top of Bluff for Candidate Plans at Reach 860 ......77
Figure 3.39  Location Map for Detailed Study Site #9, Newcastle to Port Granby ............78
Figure 3.40  Oblique Aerial Photograph of Reach 1695 ....................................................79
Figure 3.41  Typical Beach and Bluff Conditions from the waterline, November 28, 2002 ......79
Figure 3.42  1954 and 2000 Top of Bluff Lines and Recession Transects .........................80
Figure 3.43  Lakebed Profiles from Detailed SHOALS Bathymetry Collected in 2001 ........81
Figure 3.44  Offshore Wave Rose for Reach 1695 ...............................................................82
Figure 3.45  Target Profile and COSMOS Prediction for Reach 1695 (1954 to 2000) .........83
Figure 3.46  35 Year Prediction of Future Bluff Recession for Legacy Plans and Climate Change .............................................................83
Figure 3.47  101 Year Simulation at Reach 1695 Candidate Plans (A to D) .......................84
Figure 5.10  US7 Shore Unit Map and 1 km Reach Classification..............................................150
Figure 5.11  Eastern Lake Ontario with Place Names (from Woodrow et al., 2002)..............151
Figure 5.12  Shelving Bedrock Immediately North of Black Pond and Stony Creek.............153
Figure 5.13  Eroding Bedrock Cliff Near Nine Mile Point.......................................................153
Figure 5.14  Surficial Lakebed Cliff Near Nine Mile Point.......................................................153
Figure 5.15  Surficial Lakebed Mapping for ELO (from Woodrow et al, 2002) ......................155
Figure 5.16  Salmon River Jetties and Adjacent Beaches.........................................................156
Figure 5.17  Marsh and Barrier Beach at the Deer Creek Wildlife Management Area ............157
Figure 5.18  Portion of Rainbow Shores Development Located on Top of an Eroding Drumlin157
Figure 5.19  Eroding Relic Dunes Along the Southern Barrier Beach at North Pond...............157
Figure 5.20  Modern Inlet to North Pond ..................................................................................158
Figure 5.21  Montario Point Community and Cranberry Pond.................................................158
Figure 5.22  Development on the Dunes North of Southwick Beach State Park .........................159
Figure 5.23  Black Pond Inlet and Barrier Dunes .....................................................................159
Figure 5.24  Shoreline Change Rates from 1960 to 2002 (based on toe of dune measurements)161
Figure 5.25  Eroding Drumlin at Rainbow Shores (note pebble/cobble sized material in the till)163
Figure 5.26  2001 SHOALS Lakebed Profiles from Stony Point to Jefferson Park Community166
Figure 5.27  2001 SHOALS Lakebed Profiles from Stony Point to Jefferson Park Community166
Figure 5.28  2001 SHOALS Lakebed Profiles from Southwick State Park to Inlet at Lakeview167
WMA .......................................................................................................................................167
Figure 5.29  2001 SHOALS Lakebed Profiles from Inlet at Lakeview WMA to Inlet to North167
Pond .......................................................................................................................................168
Figure 5.30  2001 SHOALS Lakebed Profiles from South Barrier Beach at North Pond to169
Brennan Beach (adjacent to north jetty at Salmon River).........................................................169
Figure 5.31  2001 SHOALS Lakebed Profiles from South Fillet Beach at Salmon Inlet to 7.5 km170
south of Salmon River .............................................................................................................170
Figure 5.32  1948 to 2001 Lakebed Profile Comparison for Reach 628 (Lakeview WMA) ........172
Figure 5.33  1948 to 2001 Lakebed Profile Comparison for Reach 661 (Montario Point) ........173
Figure 5.34  1948 to 2001 Lakebed Profile Comparison for Reach 664 (North Barrier for North174
Pond) .......................................................................................................................................174
Figure 5.35  1948 to 2001 Lakebed Profile Comparison for Reach 693 (South Barrier for North175
Pond) .......................................................................................................................................175
Figure 5.36  1948 to 2001 Lakebed Profile Comparison for Reach 698 (Deer Lake WMA) ......176
Figure 5.37  Profile B Comparison from 1878 to 2001 at North Pond (0 on the x-axis178
corresponds to south) ...............................................................................................................178
Figure 5.38  Large Depositional Lobe of Sand on the Backside of Sandy Island Beach...........181
Figure 5.39  Cross-shore Distribution of Longshore Sediment Transport (Lakeview WMA) ....182
Figure 5.39  Regional Longshore Sediment Transport Estimates for Eastern Lake Ontario (average annual rates) ..........................................................184

Figure 5.40  Lakebed Contours and HYDROSED Model Grid (blue shading) ..................186

Figure 5.41  Current Predictions for 1.0 m Wave Height Approaching from 15 Degrees South of Normal .................................................................187

Figure 5.42  Current Predictions for 5.0 m Wave Height Approaching from 15 Degrees South of Normal .................................................................188

Figure 5.43  Estimates of Longshore Sediment Transport Across the Model Grid for Waves from the Southwest (south is represented by 0 on the x-axis, harbor jetties plotted as two vertical black lines) ..............................................189

Figure 5.44  Estimates of Longshore Sediment Transport Across the Model Grid for Waves from the Northwest (south is represented by 0 on the x-axis, jetties at approximately 2,000 to 2,200 m on the x-axis) ..............................................190

Figure 6.1  1902 Map of Braddock Bay (Tomkiewicz and Husted) ..................................193

Figure 6.2  Cottage Development along Lake Shore, near Rochester NY (Tomkiewicz and Husted) .................................................................194

Figure 6.3  Manitou Beach Trolley (Tomkiewicz and Husted) ........................................194

Figure 6.4  Manitou Beach Trolley (Tomkiewicz and Husted) ........................................195

Figure 6.5  Braddock Bay, Monroe County, South Shore of Lake Ontario from 1811 to 1928 (Old Maps from Tomkiewicz and Husted) ........................................................................196

Figure 6.6  Braddock Bay, Monroe County, South Shore of Lake Ontario from 1958 to 2001 197

Figure 6.7  North Pond Barrier Beach, Eastern Lake Ontario ...........................................199

Figure 6.8  Storm Climate Offshore of North Pond at 10 m Depth Contour (1961 to 2000 waves, 344 events) .................................................................200

Figure 6.9  Plan View of Profile Location for Photo 2080 and 2086 ..................................201

Figure 6.10 Location of Profile for Photo 2080 ...............................................................202

Figure 6.11 Location of Profile for Photo 2086 ...............................................................202

Figure 6.12 Profile 2080 Response to Average Summer Storm at 75.2 m (1.0 m above CD) ....203

Figure 6.13 Profile 2080 Response to Average Summer Storm at 75.7 m (1.5 m above CD) ....203

Figure 6.14 Profile 2080 Response to Severe Summer Storm at 75.2 m (1.0 m above CD) ....204

Figure 6.15 Profile 2080 Response to Severe Summer Storm at 75.7 m (1.5 m above CD) ....205

Figure 6.16 Profile 2086 Response to Severe Summer Storm at 75.7 m (1.5 m above CD) ....205

Figure 6.17 Study Site #14 ............................................................................................207

Figure 6.18 Inlet to South Colwell Pond, August 6, 2003 ..................................................208

Figure 6.19 Inlet to South Colwell Pond Temporarily Closed, April 12, 2002 ................208
Figure 6.20  Barrier Ridge and Channel Between North and South Colwell Pond, August 6, 2003 209

Figure 6.21  History of Barrier Ridge Growth and Migration at North and South Colwell Pond, 1878 to 1998 .................................................................................................................. 211

Figure 6.22  Typical View of the Beach and Dune Fronting North and South Colwell Pond, April 12, 2002 ................................................................................................................ 212

Figure 6.23  Study Site #15, Huyck’s Bay ................................................................. 213

Figure 6.24  Eroding Limestone Headland at South End of Huyck’s Bay, Sept. 15, 2002 .... 214

Figure 6.25  Close-up of Eroding Limestone Bank, Huyck’s Bay, Sept. 15, 2002 ........ 214

Figure 6.26  Study Site #15, Huyck’s Bay ................................................................. 215

Figure 6.27  Huyck’s Bay Marsh, Looking Northeast, Sept. 15, 2002 ....................... 215

Figure 6.28  Gravel Bar Across the Mouth of Huyck’s Bay ........................................ 216

Figure 6.29  Bay Water Draining Through the Gravel Bar due to Hydraulic Head .......... 216

Figure 6.30  Center of Barrier Beach Features a Sand Beach with Isolated Shingle ........ 217

Figure 6.31  Shelving Bedrock at the Waterline in the Northwest Corner of the Bay ...... 217

Figure 6.32  Pleasant Bay Inlet in the Northern Section of the Barrier ......................... 218

Figure 6.33  Bedrock Headland at the Northwest Corner of the Bay ......................... 218

Figure 6.34  Lake Bottom Profiles at Huyck’s Bay ..................................................... 219

Figure 6.35  Beach Profile Across Gravel Barrier at Huyck’s Bay Inlet ......................... 220

Figure 6.36  Beach Profile Across Sandy Barrier at Pleasant Bay Inlet ......................... 220

Figure 6.37  Wave Rose Offshore of Huyck’s Bay, 1981 to 2000 (deep water) ............... 221

Figure 6.38  Wave Propagation for HYDROSED Simulation (1 m Hs, 255 degrees) .... 222

Figure 6.39  Wave Propagation for HYDROSED Simulation (5 m Hs, 255 degrees) .. 223

Figure 7.1  View of Sand Beach at Presqu’ile Provincial Park .................................... 225

Figure 7.2  Beach Profiles Surveyed for the Study (all profiles aligned to 75.2 m on the Y-axis)226

Figure 7.3  Typical View of Sandbanks Provincial Park Beach, Looking South ............ 227

Figure 7.4  Southwick Beach State Park (northern beach, looking south) .................. 227

Figure 7.5  Southwick Beach State Park (southern beach, looking south) ................... 228

Figure 7.6  Oblique Aerial View of Hamlin Beach State Park (August 5, 2003) ............. 228

Figure 7.7  Ground Level View of Hamlin Beach State Park .................................... 229

Figure 7.8  Blue Flags at 0.5 m Contour Intervals at the Sandbanks Profile ................. 231

Figure 7.9  Survey Tent Setup at Sandbanks Provincial Park ..................................... 232

Figure 7.10a  Front Page of Beach Survey Handout (metric version) ......................... 233

Figure 7.10b  Back Page of Beach Survey Handout (metric version) ......................... 234

Figure 7.11  Impacts of Lake Levels on Future Beach Visitation if Advanced Knowledge was Available (Sandbanks Results) ........................................................................................................... 235
Figure 7.12  Waterline at Ontario Beach Park, August 17, 2004 ..............................236
Figure 7.13  Boardwalk at Ontario Beach Park, August 17, 2004.............................237
1.0 INTRODUCTION

The Coastal Technical Working Group completed a comprehensive evaluation of water level impacts on the coastal zone in support of the International Joint Commission (IJC) study on Lake Ontario and the Upper St. Lawrence River. This report reviews the coastal Performance Indicators (PIs) and the numerous detailed study sites that were investigated to evaluate water level impacts on these PIs.

1.1 Coastal Performance Indicators

A total of six performance indicators were developed to evaluate water level impacts on the coastal zone, including: erosion, flooding, shore protection, sediment budgets, beaches and dunes, and beach assess. The six indicators are presented graphically in Figure 1.1 in a schematic drawing of Lake Ontario.

![Figure 1.1 Schematic Map of Coastal Performance Indicators](image-url)
1.2 Lake Levels

Water levels on Lake Ontario and the Upper St. Lawrence River are controlled by the supply of water and the management of releases at the Moses Saunders Power Dam. For the study, a series of recorded and hypothetical supplies were considered, including the historical conditions between 1900 and 2000, stochastically generated supplies and hypothetical conditions under future climate change scenarios.

Regarding the operation of the dam, we have the current regulation plan, a series of older legacy plans developed in previous studies, new plans developed for this study and the hypothetical condition that the dam was never constructed, known as pre-project. Although pre-project is not a regulation plan, it will be referred to collectively with the other plans and resulting hydrographs.

1.2.1 Historical Lake Ontario Water Levels

Monthly mean water levels for Lake Ontario are presented in Figure 1.2. The Moses Saunders Power Dam was operational in 1960. Prior to 1960 the lake levels followed annual and multi-decade cycles of highs and lows. Following the construction of the dam, very low supplies in the 1960s resulted in very low lake levels. From the late 1970s to 2000, the supplies were closer to the long term average and the lake has generally been regulated within a 1.2 m or 4.0 ft range, from 74.2 to 75.4 m. There were a few exceptions, including the very high supplies in the early 1970s, 1993 and 1998.

![Figure 1.2 Monthly Mean Water Levels for Lake Ontario](image-url)
1.2.2 Lake Levels for Legacy Plans with Historic Supplies

A series of legacy plans were provided by the Plan Formulation and Evaluation Group (PFEG) in the early stages of the study to facilitate model testing and development. The Lake Ontario hydrograph for three of the plans, 1958DD (current operating rules with deviations), 1958D (no deviations from the written rules) and 1998 is presented below in Figure 1.3. The resultant hydrograph for the pre-project conditions is also included.

![Figure 1.3](image)

Figure 1.3 Legacy Plans for Historic Supplies from 1960 to 2000

1.2.3 Stochastic Supplies with Pre-Project Conditions

A ten thousand year time series of stochastically generated supplies was produced from the Great Lakes Watershed (Fagherazzi et al, 2005). These statistically generated supplies provide a broad range of potential future supplies to the watershed. Four of the 101 year segments of the stochastic time series were selected for the study to evaluate supply levels and alternative sequences to the historical conditions from 1900 to 2000. In other words, when evaluating plans, it is important to consider future supply sequences that are different than the historical conditions.

The four stochastic supply sequences were then used to generate 101 year hydrographs for the various legacy plans and pre-project. The resultant water levels for the pre-project scenario are presented in Figure 1.4. The Stochastic 2 supplies are very high for two periods of the 101 year record and result in water levels that exceed 76.5 m. Stochastic 1 supplies are very low and thus the resultant hydrograph for pre-project is very low in some years, including conditions 0.7 m below Chart Datum.
1.2.4 35 Year Climate Change Lake Levels (preliminary data)

A series of preliminary climate change water levels for Lake Ontario were available from a previous Environment Canada (EC) study (Mortsch et al., 2000). The data is plotted in Figure 1.5 for the three scenarios, 2030, 2050 and 2090. Since the actual climate change water levels generated by the IJC study were not available when the work was completed for some of the detailed modeling at the study sites, this EC information was used to test the predictive capabilities of the models for lower lake level hydrographs.
1.2.5 Climate Change Supplies with Pre-Project Conditions

A series of four climate change supplies were generated for the study (Croley, 2003) and then run through a routing model (Fan and Fay, 2003). The resultant water levels for the pre-project condition are presented below in Figure 1.6

![Stochastic and Climate Change Supplies with Pre-Project Conditions](image)

Figure 1.6 Lake Levels for Climate Change Supplies and Pre-Project Conditions

1.2.6 Lake Levels for Candidate Plans (as of August 2005)

Lake Ontario water levels for the four candidate plans, current as of August 2005, are presented in Figure 1.7a for the historical supplies from 1900 to 2000. The same hydrographs are also plotted for the final 50 years, from 1951 to 2000 in Figure 1.7b.

In general, Plans A and B feature water levels that are higher than those produced with 1958DD. Plan D is slightly higher and Plan C is approximately equal.

The impacts of the water levels for these candidate plans on the Coastal Performance Indicators is investigated at the detailed study sites summarized in Sections 2.0 to 7.0 of this report.
Figure 1.7a  Lake Ontario Water Levels for Candidate Plans and Historical Supplies

Figure 1.7b  Lake Ontario Water Levels for Candidate Plans and Historical Supplies
1.3 Shore Units, Counties and Regional Municipalities

In the early phases of the coastal investigation, the shoreline was sub-divided into a series of shore units to classify the physical properties, hazards, existing data and additional data requirements. There are three river shore units (R1 to R3), eight shore units along the US shoreline (US1 to US8) and twelve shore units for the Canadian shore (CND1 to CND12). Refer to Figure 1.7c for the spatial extent of the shore units.

![Figure 1.7c Shoreline Units for Lake Ontario and the Upper St. Lawrence River](image)

Summary of Lake Ontario and Upper St. Lawrence River Shoreline Classification

In addition to the spatial boundaries of the shore units, Figure 1.7c also includes a summary of the 1 km shoreline reach classification completed for the study (CJSC, 2002). This classification was completed for the continuous 1 km reach segments for the lake, river and embayments. It includes four tiers to characterize the shoreline geology, lakebed geology, presence of shore protection and land use.
As the study progressed and the Shared Vision Model (SVM) evolved, the regional classification focus shifted from the shore units to the legal boundaries of the counties and regional municipalities bordering the lake and river. Figure 1.8 maps and labels the various counties and municipalities bordering the study area.

Figure 1.8 Counties and Regional Municipalities on Lake Ontario and the Upper River

1.4 Detailed Study Sites

A total of 18 detailed study sites were selected to investigate water levels impacts for the six coastal performance indicators. A map of the 18 study sites is provided in Figure 1.9. These sites were selected for a variety of reasons, including existing datasets, ideal conditions to study the impacts for one or more of the performance indicators, and representative geographic coverage.

The analysis of water level impacts at these sites, such as erosion potential or flooding hazards, was a critical step in developing the knowledge of impacts of regulation on the six performance indicators. The results also provided the technical background to
develop the lakewide evaluation functions, which are discussed in separate reports (Baird, 2004a; Baird 2004b; Baird 2004c; and Baird 2005).

1.5 Flood and Erosion Prediction System

The Flood and Erosion Prediction System (FEPS) is a custom software application developed by Baird & Associates. The initial scoping study for the FEPS began in 1997, as part of the Lake Michigan Potential Damages Study (Baird, 1999). Subsequent phases of this study resulted in upgrades to the FEPS and expanded functionality (Baird, 2001; and Baird, 2003b).

The FEPS links GIS functionality with engineering models and custom software applications to investigate flooding and erosion hazards on the world’s oceans and lakes. From the onset, the FEPS was developed as a modular system that could be readily expanded and upgraded. Figure 1.10 provides a schematic diagram of the FEPS, as developed and applied for this study.

The following is a summary of the key functionality in the FEPS: graphical user interface, wave module, a suite of GIS tools, erosion and sediment transport modeling with the COSMOS module, wave runup and overtopping predictions, economic calculations for erosion, flooding and shore protection upgrades, and 2D/3D visualization. Data is stored in a conventional data server and in a relational database.
Figure 1.10  Flood and Erosion Prediction System (FEPS)
1.6  **Lakewide Assessment with FEPS**

The evaluation of the coastal performance indicators at the study sites provided a detailed and defensible assessment of water level impacts. In addition, this knowledge was used to develop the methodology for the lakewide or system wide assessment with the FEPS. In other words, the results from this detailed analysis were used to develop the algorithms that predicted lakewide impacts and the associated economic damages for over 20,000 individual property parcels in the FEPS relational database.

Several reports describe these lakewide algorithms for flooding, erosion, shore protection and beach access impacts (Baird, 2004a; Baird, 2004b; Baird, 2004c; and Baird, 2005).

1.7  **Linkage to the Shared Vision Model**

The Shared Vision Model (SVM) was developed to evaluate new alternative regulation plans, including economic impacts and environmental factors (Werick and Leger, 2005), in one software platform. Due to the complexity of the erosion, flooding and shore protection functions in the FEPS, it was not feasible to re-program the detailed functions in the SVM (as was done with many other performance indicators). Therefore, the FEPS was linked dynamically to the SVM. Figure 1.11 presents the Simulation Builder interface (left window) and the resulting output once the calculations are complete (right window and message box).

![Figure 1.11 FEPS Simulation Builder for Linkage to the SVM](image)
The FEPS user selects a local version of the SVM to obtain an appropriate water level file, selects the appropriate input parameters for the model, and executes the algorithms in the FEPS. Once the necessary calculations are complete in the FEPS and updated in the relational database, user is prompted with the text box. The economic calculations are then automatically uploaded to the SVM.
2.0 FLOODING SITES

Section 2.0 is dedicating to the investigation of lake level impacts on flooding. A total of four sites were selected to investigate flooding along the south shore of Lake Ontario in Monroe and Wayne Counties. The results are summarized below, along with an introduction to the runup and overtopping prediction capabilities that were added to the COSMOS module of the Flood and Erosion Prediction System.

2.1 Runup and Overtopping Calculations with the FEPS

The flooding module in the FEPS was enhanced for this study with the development of new functionality to predict wave runup elevations and wave overtopping volumes. The functionality was added directly to the COSMOS 2D profile model, which was already capable of transforming deep water wave conditions to shallow depths adjacent to development, such as housing.

The following equations were programmed into the COSMOS model to predict wave runup and overtopping:

- Van der Meer and Janssen (1995) for runup;
- Raubenheimer and Guza (1996) for runup;
- Ahrens and Heimbaugh (1988) for overtopping;
- Franco et al (1995) for overtopping;
- Schuttrumpf et al (1999) for overtopping; and
- Besley (1999) for overtopping.

When setting up the COSMOS model to predict wave runup or overtopping, the user must select a series of variables as summarized below in Figure 2.1. For example, if the structure type is a revetment, then the user must choose between an impermeable or permeable slope. Plus the distance on the x-axis that represents the toe and crest distance is required. When calculating the runup elevation for a natural beach slope, only the beach crest elevation is required. For a vertical wall, the distance on the x-axis corresponding to the toe and crest is also required. The code in the COSMOS model uses these variables to extract the necessary information to compute runup and overtopping, such as the vertical elevation of the beach crest and the toe elevation at the base of a seawall to compute freeboard for the overtopping calculation.
Figure 2.1 Variable Requirements for the Various Runup and Overtopping Equations

There are several advantages of programming these runup and overtopping calculations directly into the COSMOS model, including: 1) utilizing existing functionality to transform the hourly wave conditions (height, period and direction) from deep (10 m) to shallow water, 2) completing the calculations on an hourly basis for the duration of the simulation (e.g. one year to 50 years), 3) automated calculations for the equations based on water level, wave height and structure conditions, 4) results are exported and saved in a generic file format with metadata, 5) utilization of custom plotting applications in the FEPS to visualize the runup and overtopping predictions on an hourly basis and in an event listing sorted by date or runup characteristics; and 6) comparison of the results for the different equations.

A sample of a typical COSMOS profile used for overtopping calculations is presented in Figure 2.2. Only the nearshore portion of the profile is presented, however, the profile extends lakeward to the 10 m depth contour. As mentioned previously, the user must specify the location where the wave height is extracted for the calculations based on the toe and crest location on the x-axis. For example, in Figure 2.2 the toe of the vertical seawall is located at approximately 2,520 m on the x-axis.

By utilizing the existing time series functionality in COSMOS, it was also possible to complete the runup and overtopping predictions on an hourly basis. In other words, if the input wave file included ten years of hourly data, wave runup or overtopping could be predicted for each hour in the simulation, with the results stored in an output file generated by the model.
Figure 2.2 Nearshore Portion of a COSMOS Profile with Vertical Seawall

Once the COSMOS model simulations are completed, a series of custom plotting applications in the FEPS flooding module are used to visualize and interpret the results. For example, refer to Figure 2.3, which displays the user interface for processing the runup predictions and results for Study Site #2 (Sandy Harbor Beach) with the Pre-project lake levels from 1981 to 1995. Once the file is selected and read by the FEPS, the user can specify the temporal duration of the query (e.g. entire dataset or a sub-set), plus the runup equation (results for both are stored in the output file). Results can be visualized as tables, bar graphs or time series. The adjacent plot in Figure 2.3 presents the tabular listing of runup events, which can be sorted by date or runup elevation. Figure 2.4 presents a sample of the time series plot, which includes the time series water levels and runup elevation above Low Water Datum or Chart Datum (0.0 m).

Similar functionality was developed to import, query and visualize the wave overtopping predictions from COSMOS. Refer to Figures 2.5 for the interface and storm listing, while the time series overtopping results are plotted in Figure 2.6. It should be mentioned that these results are for the Pre-project lake levels, which were very high in 1987 and 1993 (close to 2.0 m above Chart Datum). Also, the labels for the Y1 and Y2 axis’ are reversed in Figure 2.6. Water level is plotted on the Y1 axis (although it is labeled for overtopping), while overtopping is plotted on the Y2 axis (although it is labeled for water level).
Figure 2.3 Sample of Runup Predictions in the FEPS Flooding Module for Study Site #2, Sandy Harbor Beach
Figure 2.4  Time Series Runup Predictions for Sandy Harbour Beach and Pre-project Lake Levels (runup elevations above LWD, m)
Figure 2.5 Sample of Overtopping Predictions for Edgemere Drive with the Flooding Module of the FEPS

<table>
<thead>
<tr>
<th>Start</th>
<th>End</th>
<th>Duration (hrs)</th>
<th>Peak O/T Vol. (m³/m³/hr)</th>
<th>Volume for Event (m³/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>06 Apr 1982 11AM</td>
<td>06 Apr 1982 05PM</td>
<td>7</td>
<td>7.76</td>
<td>7.54</td>
</tr>
<tr>
<td>08 Jun 1988 13AM</td>
<td>08 Jun 1988 13PM</td>
<td>13</td>
<td>11.53</td>
<td>67.03</td>
</tr>
<tr>
<td>29 Feb 1986 08PM</td>
<td>29 Feb 1986 04AM</td>
<td>9</td>
<td>9.69</td>
<td>80.71</td>
</tr>
<tr>
<td>04 May 1988 04AM</td>
<td>04 May 1988 09PM</td>
<td>12</td>
<td>26.42</td>
<td>209.98</td>
</tr>
<tr>
<td>29 May 1984 08PM</td>
<td>29 May 1984 08PM</td>
<td>24</td>
<td>125.79</td>
<td>1224.84</td>
</tr>
<tr>
<td>31 Mar 1985 10AM</td>
<td>01 Apr 1985 05AM</td>
<td>20</td>
<td>21.92</td>
<td>293.49</td>
</tr>
<tr>
<td>13 Apr 1985 05AM</td>
<td>14 Apr 1985 01AM</td>
<td>8</td>
<td>18.52</td>
<td>92.69</td>
</tr>
<tr>
<td>17 Apr 1985 12AM</td>
<td>17 Apr 1985 01PM</td>
<td>14</td>
<td>36.72</td>
<td>54.25</td>
</tr>
<tr>
<td>03 May 1985 11AM</td>
<td>03 May 1985 09PM</td>
<td>11</td>
<td>31.02</td>
<td>214.78</td>
</tr>
<tr>
<td>27 Jun 1985 06AM</td>
<td>27 Jun 1985 03AM</td>
<td>9</td>
<td>16.35</td>
<td>108.19</td>
</tr>
<tr>
<td>28 Nov 1985 03PM</td>
<td>29 Nov 1985 03AM</td>
<td>13</td>
<td>14.98</td>
<td>130.34</td>
</tr>
<tr>
<td>03 Dec 1985 04AM</td>
<td>03 Dec 1985 04PM</td>
<td>13</td>
<td>10.65</td>
<td>46.71</td>
</tr>
<tr>
<td>27 Jan 1986 06AM</td>
<td>28 Jan 1986 04AM</td>
<td>17</td>
<td>10.99</td>
<td>81.87</td>
</tr>
<tr>
<td>04 Feb 1986 06AM</td>
<td>04 Feb 1986 02PM</td>
<td>9</td>
<td>9.12</td>
<td>15.61</td>
</tr>
<tr>
<td>05 Feb 1986 12AM</td>
<td>06 Feb 1986 04AM</td>
<td>45</td>
<td>24.88</td>
<td>594.40</td>
</tr>
<tr>
<td>13 Mar 1986 05AM</td>
<td>13 Mar 1986 04PM</td>
<td>9</td>
<td>16.32</td>
<td>13.77</td>
</tr>
<tr>
<td>16 Apr 1986 07AM</td>
<td>17 Apr 1986 07AM</td>
<td>13</td>
<td>56.35</td>
<td>327.93</td>
</tr>
<tr>
<td>17 Apr 1986 05AM</td>
<td>18 Apr 1986 04AM</td>
<td>15</td>
<td>30.75</td>
<td>283.30</td>
</tr>
<tr>
<td>22 Apr 1986 01AM</td>
<td>22 Apr 1986 02PM</td>
<td>15</td>
<td>135.24</td>
<td>509.85</td>
</tr>
</tbody>
</table>
Figure 2.6  Time Series Overtopping Predictions for Edgemere Drive and Pre-project Lake Levels (overtopping scale on Y2 axis)
2.2 Site #1 – Payne Beach

Payne Beach is located along the south shore of Lake Ontario, west of the community of Greece, in Monroe County. An aerial view of the study site is provided in Figure 2.7. Between the centroid for Reaches 1046 and 1045, a vacant parcel of land north of the highway was recently converted to estate lots and developed. Since there are no hard engineering structures at the waterline and the land grades are gentle, it was selected as a study site to investigate lake level impacts on wave runup.

Figure 2.7a Aerial View of Study Site #1, Payne Beach (Reach 1045 and 1046)

A ground level view of the site is provided in Figure 2.7b. With the exception of some concrete rubble and stone at the waterline, the site does not feature any shore protection and a narrow gravel beach exists at the waterline. Profile 3 was centered on the white home in Figure 2.7b and this area will be the focus of the runup investigation.
Detailed elevation data was available for Study Site #1 from the bathymetric and topographic LIDAR collected for the study. A small portion of the profile data used for the COSMOS menu is presented in Figure 2.8. The beach face is steep from the waterline at 0.0 m (approximately 1,500 m on the x-axis) to the beach crest at 2.5 m. From the beach crest to the estate homes, the site features a gentle grade to approximately 3.2 m above CD.

Wave data from 1981 to 1995 was used to develop input conditions for the COSMOS menu at the 10 m depth contour. The waves were combined with the water levels from the four legacy plans, 1958DD, 1958D without deviations, Plan 1998 and Pre-project. Ice data was also combined with the time series waves and lake levels with the X-Wave module. Input files for the COSMOS model were exported.
A tabular summary of the runup events that breached (exceeded) the beach crest at Payne Beach, which is approximately 2.5 m above CD, is provided in Figures 2.9a to 2.9d for the legacy plans. The Van der Meer and Janssen (1995) equation is used for this comparison. For the current regulation plan and operational procedures (1958D with deviations), there were no events that featured runup elevations greater than 2.5 m above CD. Refer to Figure 2.9a. Therefore, no flooding is predicted for this plan from 1981 to 1995.

Summary of Runup Events (1981 to 1995) for 1958D with Deviations

<table>
<thead>
<tr>
<th>Start</th>
<th>End</th>
<th>Duration (hrs)</th>
<th>Peak Elev. above LWD (m)</th>
<th>Volume for Event (m³/m³)</th>
</tr>
</thead>
</table>

Figure 2.9a  Runup Events for 1958D with Deviations from 1981 to 1995

The same result was predicted for Plan 1998 from 1981 to 1995 at Payne Beach. No storm events produced a wave runup elevation that was higher than the crest of the beach (2.5 m). Refer to Figure 2.9b.

Summary of Runup Events (1981 to 1995) for Plan 1998

<table>
<thead>
<tr>
<th>Start</th>
<th>End</th>
<th>Duration (hrs)</th>
<th>Peak Elev. above LWD (m)</th>
<th>Volume for Event (m³/m³)</th>
</tr>
</thead>
</table>

Figure 2.9b  Runup Events for Plan 1998 from 1981 to 1995

The COSMOS simulation the lake levels associated with 1958D without deviations are presented in Figure 2.9c. The results are dramatically different for this plan, which featured significantly higher lake levels. A total of 83 events featured peak runup elevations that exceeded the beach crest at 2.5 m. The top ten events are listed in descending order in Figure 2.9c. The largest event was a multi-month storm in 1987. In reality this event was not a storm but an extremely high spike in the Lake Ontario water levels associated with this legacy regulation plan. The lake levels actually exceeded 2.5 m for several weeks during this hypothetical high lake level period.
Summary of Runup Events (1981 to 1995) for 1958D with Deviations

Source Data File: \StudySite\SiteC01 - Payne Beach\cosmos run\Site 1 Payne Beach\Modeled w/n 1985d.nc dev\Profile 3\runup.run

Selected Date Range: 01 Jan 1981 02AM to 31 Dec 1995 11PM

Maximum Ramp Elevation (m): 2.50  Minimum Event Duration (hr): 3  Number of Events: 83

Threshold Variables (hr): 3  Ramp: Van der Meer and Janssen (1995)

<table>
<thead>
<tr>
<th>Start</th>
<th>End</th>
<th>Duration (hrs)</th>
<th>Peak Elev. above LWD (m)</th>
<th>Volume for Event (m³/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 Jan 1987 07PM</td>
<td>30 Aug 1987 02PM</td>
<td>3444</td>
<td>4.13</td>
<td>29207.66</td>
</tr>
<tr>
<td>10 Jan 1987 12PM</td>
<td>14 Jan 1987 04AM</td>
<td>89</td>
<td>3.27</td>
<td>280.35</td>
</tr>
<tr>
<td>02 Jan 1987 06AM</td>
<td>04 Jan 1987 09AM</td>
<td>52</td>
<td>3.19</td>
<td>36931.27</td>
</tr>
<tr>
<td>07 Jan 1987 02PM</td>
<td>10 Jan 1987 12AM</td>
<td>59</td>
<td>3.14</td>
<td>50889.06</td>
</tr>
<tr>
<td>10 Dec 1986 01PM</td>
<td>11 Dec 1986 12PM</td>
<td>24</td>
<td>3.13</td>
<td>12738.86</td>
</tr>
<tr>
<td>04 Jan 1988 11PM</td>
<td>06 Jan 1988 09AM</td>
<td>35</td>
<td>3.12</td>
<td>7511.13</td>
</tr>
<tr>
<td>06 Oct 1986 08AM</td>
<td>06 Oct 1986 11PM</td>
<td>16</td>
<td>3.12</td>
<td>5372.50</td>
</tr>
<tr>
<td>09 Nov 1986 11PM</td>
<td>10 Nov 1986 05PM</td>
<td>23</td>
<td>3.08</td>
<td>9798.47</td>
</tr>
<tr>
<td>22 Dec 1986 03PM</td>
<td>23 Dec 1986 09PM</td>
<td>31</td>
<td>3.07</td>
<td>24906.04</td>
</tr>
<tr>
<td>13 Nov 1986 05AM</td>
<td>13 Nov 1986 11PM</td>
<td>19</td>
<td>3.04</td>
<td>5377.43</td>
</tr>
</tbody>
</table>

Figure 2.9c  Runup Events for Plan 1958D without Deviations from 1981 to 1995 (top ten)

The Pre-project hydrograph from 1981 to 1995 also featured periods of very high lake levels and the predicted runup elevations exceeded the 2.5 m beach crest a total of 32 times. The top ten events are listed in descending order in Figure 2.9d.

Summary of Runup Events (1981 to 1995) for Pre-project

Source Data File: \StudySite\SiteC01 - Payne Beach\cosmos run\Site 1 Payne Beach\Modeled w/o Pre-Project\Profile 3\runup.run

Selected Date Range: 01 Jan 1981 02AM to 31 Dec 1995 11PM

Maximum Ramp Elevation (m): 2.50  Minimum Event Duration (hr): 3  Number of Events: 22

Threshold Variables (hr): 3  Ramp: Van der Meer and Janssen (1995)

<table>
<thead>
<tr>
<th>Start</th>
<th>End</th>
<th>Duration (hrs)</th>
<th>Peak Elev. above LWD (m)</th>
<th>Volume for Event (m³/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23 Jan 1987 04PM</td>
<td>25 Jan 1987 06AM</td>
<td>29</td>
<td>2.58</td>
<td>2424.14</td>
</tr>
<tr>
<td>06 Oct 1986 11AM</td>
<td>06 Oct 1986 09PM</td>
<td>11</td>
<td>2.94</td>
<td>1273.36</td>
</tr>
<tr>
<td>09 Mar 1987 01PM</td>
<td>10 Mar 1987 07PM</td>
<td>31</td>
<td>2.92</td>
<td>790.00</td>
</tr>
<tr>
<td>04 Apr 1987 10AM</td>
<td>05 Apr 1987 12PM</td>
<td>27</td>
<td>2.88</td>
<td>2779.56</td>
</tr>
<tr>
<td>10 Dec 1986 04PM</td>
<td>11 Dec 1986 06AM</td>
<td>15</td>
<td>2.87</td>
<td>2813.23</td>
</tr>
<tr>
<td>10 Nov 1986 01AM</td>
<td>16 Nov 1986 03PM</td>
<td>15</td>
<td>2.85</td>
<td>1750.19</td>
</tr>
<tr>
<td>02 Dec 1986 06AM</td>
<td>03 Dec 1986 04AM</td>
<td>9</td>
<td>2.64</td>
<td>260.51</td>
</tr>
<tr>
<td>02 May 1986 06AM</td>
<td>02 May 1986 11AM</td>
<td>6</td>
<td>2.63</td>
<td>816.53</td>
</tr>
<tr>
<td>09 Feb 1987 04AM</td>
<td>09 Feb 1987 05PM</td>
<td>14</td>
<td>2.82</td>
<td>365.08</td>
</tr>
<tr>
<td>13 Nov 1986 09AM</td>
<td>13 Nov 1986 05PM</td>
<td>13</td>
<td>2.62</td>
<td>1297.89</td>
</tr>
</tbody>
</table>

Figure 2.9d  Runup Events for Pre-project from 1981 to 1995
The foundation elevations for the home in Figure 2.8 is approximately 3.2 m above Chart Datum. Therefore, the only flood event with runup elevations that actually reach the building foundation is the super high lake level spike for 1958D without Deviations. In short, although there is no shore protection and the grades near the lake are low, the new development is located far and high enough from the waters edge to avoid flood damages due to wave runup. The only exception is the large spike in the 1958D without deviations in 1987, when runup elevations of 4.13 m above CD were predicted.

A hydrologic model was used to investigate flow pathways around the newly constructed estate homes. The results are presented in Figure 2.10. Between the homes and the highway, any flood waters would be drained to the east, across the road and eventually to the lake. To the west of the homes, a similar drainage pattern is observed that appears to follow a local creek. Due to the slope of the land between the lake and the homes, any runup during a storm event would eventually run back down the slope into the lake. Therefore, the grading around the homes provides effective drainage during flooding events and should protect the homes from flood damage.

Figure 2.10  Predicted Flow Pathways for New Estate Homes at Payne Beach
2.3 Site #2 – Sandy Harbor Beach

Sandy Harbor Beach is located in the northwest corner of Monroe County, on the south shore of Lake Ontario. Hamlin Beach State Park is located a few kilometres to the west. The creek mouth is protected with two shore perpendicular jetties that also provide access to the lake for two shallow draft marinas. Refer to the plan view of the site in Figure 2.11. The western jetty has trapped sand in a fillet beach and is the focus of this flooding investigation.

![Site 2: Sandy Harbor Beach, Monroe County (Reach 1063)](image)

**Figure 2.11 Study Site #2, Sandy Harbor Beach**

A row of cottages and permanent homes is located at the back of the fillet beach and susceptible to flooding due to the low land elevations. Refer to Figure 2.12 for a view of the homes looking west from the west jetty. In some locations, the home foundations are actually located below the beach crest, making them more susceptible. Wave runup predictions will be completed with the FEPS to investigate the flood susceptibility of this community to the range of lake levels in the legacy plans.
Figure 2.12   Homes Located at the Edge of the Fillet Beach, Study Site #2

The site was surveyed by the USACE in August 2002 to collect elevations for the beach and building foundations. A portion of the survey is reproduced in Figure 2.13.

Figure 2.13   Portion of USACE Site Survey from August 2002
The survey confirms the visual observations from the site visit. For the profile closest to the western jetty, the beach crests at an elevation of 2.8 m, while the elevation is lower for the second line, 2.05 m in Figure 2.13. The foundation elevations for the homes in Figure 2.13 range from a low of 1.57 m to a high of 1.98 m. On average, the foundations are approximately 1.7 m above CD.

The bathymetric data for the area was combined with the topographic survey to generate a typical profile for Sandy Harbor Beach in Figure 2.14. The nearshore features a gentle slope of approximately 1:300 (V:H). A home is located landward of the beach crest for reference. In addition to low topography around the homes, the land is also low adjacent to the river and the marine basin constructed along the creek banks.

![Bathymetry Data](image)

**Figure 2.14  Typical Nearshore and Beach Profile at Sandy Harbor Beach**

The FEPS flooding module was applied at Sandy Harbor Beach to investigate wave runup elevations for the legacy plans. The input wave conditions were representative of the historical conditions from 1981 to 1995. The results from Van der Meer and Janssen (1995) are reviewed.

For the current regulation plan, 1958D with deviations, wave runup was predicted to exceed the 2.0 m contour on the beach a total of 5 times between 1981 and 1995. The predicted elevations range from 2.10 to 2.18 m above CD. Refer to Figure 2.15.

A five year window of the actual time series output from COSMOS is presented in Figure 2.16, from 1986 to 1990. From the spring of 1986 to the fall of 1987 lake levels were extremely high and fluctuated between 1.0 and 1.35 m above Chart Datum. On three occasions, the wave runup elevation reached or exceeded the 2.0 m depth contour. These findings highlight the seasonality of Lake Ontario storms and the increased risk of flood hazards when storms strike during higher water periods in the fall, winter and spring.
The results for Plan 1998 are very similar to 1958DD and thus are not presented.

The lake levels for Plan 1958D without Deviations produced a total of 201 runup events with elevations exceeding 2.0 m. This is a dramatic increase and highlights the benefits of the historical deviations for avoiding flooding on Lake Ontario. The first ten runup events listed in chronological order are presented in Figure 2.17a. The runup events are
listed in order of peak runup elevation in Figure 2.17b for the top ten events. The runup elevations ranged from 2.48 to 3.43 m. All of these events would have resulted in flooding at Sandy Harbor Beach.

Figure 2.17a  Wave Runup Storm Listing in Chronological Order for 1958D without Deviations (only first 10 storms)

A similar trend was observed in the runup results for Pre-project. A total of 230 events featured runup levels greater than the beach crest elevation of 2.0 m. The top ten storms are listed in Figure 2.18 and range in elevation from 2.47 to 2.86 m. Rushing water from these hypothetical events would have crested the beach and reached the building.
foundations in most cases. The impacts of waves directly impacting the structure would result in significant structural damage.

**Site #2 Sandy Harbor Beach**

**Summary of Runup Events (1981 to 1995) for Pre-project**

Source Data File: E:\Study Sites\Site02 - Sandy Harbor Beach\Results for Legacy Plans\pre project\Profile 3

Selected Data Range: 14 Jan 1981 12AM to 31 Dec 1995 11PM

Minimum Runup Elevation (m): 2.00
Minimum Event Duration (hrs): 3
Number of Events: 230

<table>
<thead>
<tr>
<th>Start</th>
<th>End</th>
<th>Duration</th>
<th>Peak Elev.</th>
<th>Volume for Event (m3/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>02 Dec 1985 03PM</td>
<td>03 Dec 1985 10AM</td>
<td>20</td>
<td>2.86</td>
<td>60.28</td>
</tr>
<tr>
<td>13 Mar 1983 08AM</td>
<td>15 Mar 1983 01AM</td>
<td>30</td>
<td>2.83</td>
<td>13.37</td>
</tr>
<tr>
<td>25 Jan 1987 12PM</td>
<td>25 Jan 1987 07PM</td>
<td>56</td>
<td>2.80</td>
<td>3680.94</td>
</tr>
<tr>
<td>28 Jan 1986 04PM</td>
<td>29 Jan 1986 07AM</td>
<td>16</td>
<td>2.39</td>
<td>41.78</td>
</tr>
<tr>
<td>06 Apr 1982 11AM</td>
<td>06 Apr 1982 11PM</td>
<td>13</td>
<td>2.58</td>
<td>0.39</td>
</tr>
<tr>
<td>04 Apr 1982 01PM</td>
<td>05 Apr 1982 02AM</td>
<td>14</td>
<td>2.55</td>
<td>10.22</td>
</tr>
<tr>
<td>05 Mar 1993 02PM</td>
<td>05 Mar 1993 10PM</td>
<td>33</td>
<td>2.50</td>
<td>58.96</td>
</tr>
<tr>
<td>10 Dec 1986 03AM</td>
<td>11 Dec 1986 04PM</td>
<td>38</td>
<td>2.48</td>
<td>2.95</td>
</tr>
<tr>
<td>04 Apr 1987 07AM</td>
<td>07 Apr 1987 08AM</td>
<td>74</td>
<td>2.47</td>
<td>2254.41</td>
</tr>
<tr>
<td>18 Dec 1985 05AM</td>
<td>18 Dec 1985 01PM</td>
<td>9</td>
<td>2.47</td>
<td>28.80</td>
</tr>
</tbody>
</table>

**Figure 2.18 Wave Runup Storm Listing for Top Ten Storms for Pre-project**
2.4 Site #4 – Edgemere Drive

The Edgemere Drive community was constructed on the former barrier beach that separated Cranberry and Long Pond from Lake Ontario. Refer to Figure 2.19. Braddock Bay is located immediately to the west, while the mouth of the Genesee River is located several kilometers to the east. Edgemere Drive is part of the Town of Greece, Monroe County, New York.

Site 4: Edgemere Drive, Greece (Reach 1023-1025)

Figure 2.19 Plan View Map of Edgemere Drive (Reaches 1024 and 1025)

The development along Edgemere Drive has a long history of flooding problems. A photograph of extreme wave overtopping at a low crested seawall during the winter of 1973 is provided in Figure 2.20. The spray from the incoming waves is several stories high and capable of causing extreme structural damage to the homes.

During calm weather, the waters edge is either at the base of the seawalls or a small sand beach is present. The homes are located very close to the crest of the shore protection, as seen in Figure 2.21.
Figure 2.20  Wave Overtopping for a 1973 Storm, Edgemere Drive (image courtesy Dr. Martin)

Figure 2.21  Waterfront Lots Along Edgemere Drive During Fair Weather

Additional information on the long settlement history along Edgemere Drive and the lakeshore further to the west is discussed in Section 6.1. When waves overtop the
seawalls, the homes are susceptible to damage from wave spray, as seen in Figure 2.20. During the 1973 high water period, waves directly attacked the homes, leading to structural failures. Refer to Figure 2.22.

Since many of the lakefront homes were constructed on top of the former barrier beach, Edgemere Drive has a lower elevation than the home foundations. For example, refer to Figure 2.23. Water that is transported over the seawalls often flows inland and leads to street flood, such as the conditions documented in Figure 2.24.

Since the sewer system is located under the road, this type of street flooding can then lead to sewer backups. Information provided by the Town of Greece indicated street flooding and sewer backups or plugged main lines was a problem 16 times between 1969 and 1986.
Figure 2.23  Road Grade Below Home Foundation Elevations Along Edgemere Drive

Figure 2.24  Street Flooding Along Edgemere Drive (image courtesy Dr. Martin)