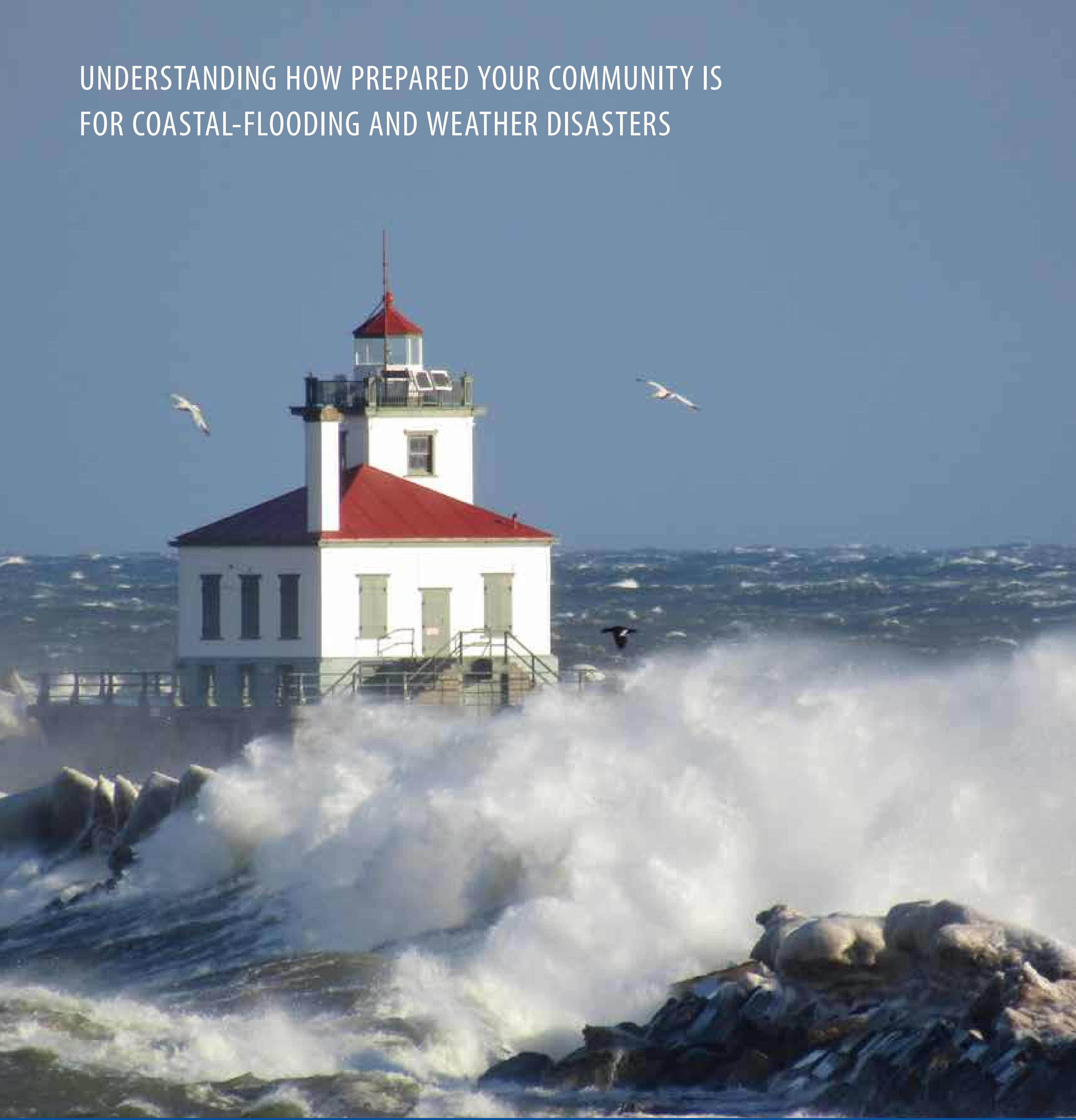
UNDERSTANDING HOW PREPARED YOUR COMMUNITY IS FOR COASTAL-FLOODING AND WEATHER DISASTERS



NEW YORK'S GREAT LAKES COASTAL RESILIENCE INDEX:

A Community Self-Assessment

NEW YORK SEA GRANT

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Cover Photo: Mary Ellen Barbeau, Oswego County Tourism

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RESILIENCE INDEX TEAM

Community Name ____

Date Completed ______________________________

Name	Title

Date proposed for next Index assessment ____________________________

INTRODUCTION

The purpose of this self-assessment is to provide community leaders with a simple and inexpensive method of predicting if their community will reach and maintain an acceptable level of functioning after coastal-flooding, or other disasters such as wind storm, ice storm, or flash flood. Experienced Local Planners, Engineers, Code Enforcement Officers, Floodplain Managers or Administrators can complete this self-assessment using maps generated from the New York Sea Grant (NYSG) Lake Ontario Inundation WebMap, NYSG Lake Ontario Inundation Map Package, and/or weather disaster (see appendices starting on page 19), and existing sources of information from their community. It might be helpful to use one booklet per event (coastal-flooding or weather disaster).

This assessment may identify problems your community should address before the next event and where resources should be allocated. Results of the assessment are presented as a *Resilience Index* that estimates the adaptability of your community to coastal-flooding and/or weather disasters. This self-assessment was created to identify areas in which your community may become more resilient. Your community's Resilience Index is an internal evaluation tool and should not be used to compare your community with others.

The Resilience Index and methodology do not replace a detailed study, just as self-diagnosing an ailment using a medical website is not a substitution for a checkup and tests by a physician.. But, the Resilience Index resulting from this Community Self-Assessment may encourage your community to seek further consultation.

NOTE: This Community Self-Assessment is date-specific and should be periodically applied as the community grows and/or the landscape changes, such as when shoreline erosion accelerates. Your community officials should conduct new assessments on a regular basis (annual, biannual, etc.) because of this growth and/or change.

For this exercise, please consider the following definitions:

DISASTER RESILIENCE is the ability of a community to withstand and recover and to protect critical assets from all-hazards disasters.

RESILIENCE is a community's ability to anticipate, prepare for, withstand and recover from extreme weather events such as storms, flooding and drought. Resilient communities are better able to sustain vital services, healthy ecosystems and economic vitality, making them less susceptible to future hazardous events and more attractive to businesses and residents alike.

Waves crashing through a gate in Monroe County, NY. Photo: Coastal Flooding Survey Project, Cornell University and New York Sea Grant.

RESULTS OVERVIEW

After completing this self-assessment, you should complete the summary that will help you determine your Resilience Index (see pages 15 and 16).

The Resilience Index used in this self-assessment will be defined as LOW, MEDIUM or HIGH.

The rating will give you an idea of how long it may take your community to provide basic services and reoccupy homes and businesses after a disaster.

For more details about interpreting Resilience Index results, go to page 17.

BUILD YOUR SCENARIOS

The primary goal of this self-assessment is to improve community resilience for two types of scenarios: coastal-flooding, and weather disasters. The risk of coastal-flooding along the Great Lakes and embayments typically begins in the spring and can last several months depending on various system-wide factors. The risk of weather disasters (i.e., ice storms, blizzards, flash floods) occurs throughout the Great Lakes region over shorter time periods (hours to days) during all seasons. Both can have devastating impacts.

This assessment will guide you through how to build scenarios for coastal-flooding and weather disasters for your community. You may decide to focus on either coastal-flooding or weather disasters, or consider the cumulative impacts of each occurring at the same time.

Coastal Flooding

A Benchmark high water level and two Credible Worst-Case Scenarios have been provided. In order to visualize inundation for the purposes of this assessment, you will use the NYSG Lake Ontario Inundation WebMap or the NYSG Lake Ontario Inundation Map Package to generate flood risk maps for different water levels. Some water levels provided in the mapping tools have occurred and others have not. Because wave run-up data are not readily available, the generated maps assume only flat water. In addition, they do not account for stormwater or groundwater. To see examples of generated maps go to pages 23, 24, 25, and 29.

For reference included is water level 247.3 feet (the upper limit of the four-foot range defined in the Lake Ontario-St. Lawrence River Management Plan 1958DD), the development line that was previously used by many communities. Theoretically, your community is able to function at this water level. You will use 249 feet as the Benchmark water level. This is near the peak water level Lake Ontario reached during 2017, and just under the new peak reached in 2019. As an example, you might consider two future scenarios: 249.5 feet and 250 feet. For this example, these would be Credible Worst-Case Scenario 1 and 2 respectively. It is important to note that to date these water levels have not been projected and are being provided as possible future scenarios.

Weather Disasters

Extreme weather events are occurring more frequently in our region. Example weather disasters are being provided to help you think about how they might impact the resilience of your community.

As a group, designate a location within your community as the "strike zone", meaning where the weather disaster will occur for your scenarios. Remember, this is a self-assessment, so try to designate a strike zone that will give you the most information about where the community vulnerabilities may be for the weather disaster/s of interest. Use the definitions of Benchmark and Credible Worst-Case Scenario to complete the table on page 7. These will then be referred as the Benchmark and Credible Worst-Case Scenario to complete the rest of the Resilience Index for the strike zone you have identified. You are encouraged to draw upon local knowledge and your from experience as well as the narratives and charts describing weather disasters that have been provided (Appendices pages 32-41).

Benchmark Section

Select a Benchmark storm from the ones provided on pages 32–41 of the Appendices. These events have actually occurred within the region. Please select and transfer the variables you are interested in from the Benchmark column of the chart provided in Appendices pages 32–41 to the table on page 7. You may also draw upon local knowledge and experience to include a different bad storm event as a Benchmark that is greater in intensity and/or specific to your geographic location than the ones provided.

Credible Worst-Case Scenario Section

The Credible Worst-Case Scenarios provided in the charts on Appendices pages 32–41 are at least 50% worse than their Benchmarks. Again, transfer the variables you are interested in from the Credible Worst-Case Scenario column of the chart provided in Appendices pages 32–41 to the table on page 7. If you added variables to your benchmark that are not from Appendices pages 32–41, please increase them by 50% for this section.

Coastal-Flooding Scenarios

	Reference	Benchmark Water Level	Credible Worst-Case Scenario 1	Credible Worst-Case Scenario 2
Water Level (ft)	247.3	249	249.5	250

Weather Disaster Scenarios

Weather Disaster Type:________________________________ Strike Zone:__________________________________

Variables of Interest*	Benchmark	Credible Worst-Case Scenario 1

**Variables found in pages 32–41 of the Appendices.*

CRITICAL INFRASTRUCTURE AND FACILITIES

The following lists are key indicators that will give a preliminary assessment of your community's resilience by considering how critical infrastructure and facilities are impacted and whether they will function after coastal-flooding and/or a weather disaster. A more detailed assessment process is available in the FEMA 386-2 publication (fema.gov).

1. Check each box associated with the critical infrastructure and facilities that are impacted for each of the scenarios. Determine the impact for coastal-flooding scenarios by examining the maps generated using the NYSG Lake Ontario Inundation WebMap Appendix page 26, NYSG Lake Ontario Inundation Map Package (Appendix page 20). For weather disaster scenarios, determine the impact by considering the strike zone designated by your team. Then put a check mark in the last column if the infrastructure or facility is functional during or after your benchmark for coastal-flooding and/or weather disaster. Use the total check marks in the last column for Section A and Section B to complete page 15, "Determining Your Resilience Index."

Useful Definitions

A **critical facility** (also called critical action) typically provides crucial services/functions to a community, particularly during and after crisis, such as coastal-flooding and weather disasters. Critical facilities include, but are not limited to: emergency operations centers, designated public shelters, schools and day care centers, nursing homes, hospitals and medical facilities, police, fire and emergency response installations, vital data storage centers, power generating stations, drinking water and wastewater treatment plants, and places where hazardous wastes are located.

Critical Infrastructure and Facilities	Benchmark	Credible Worst-Case Scenario 1	Credible Worst-Case Scenario 2	Infrastructure/ facility functions after disaster*
Water Level (feet):	*249*	*249.5*	*250*	
Weather Disaster (list):				
Example: Power grid	✓			✓
Section A: Critical Infrastructure				
Wastewater treatment system				
Wastewater lift stations				
Storm drains				
Power grid: transformers				
Power grid: substations				
Alternate energy sources (i.e., solar, wind, etc.)				
Public water supply				
Transportation/evacuation routes				
Large-scale shoreline protection (i.e., breakwater, breakwall, etc.)				
Places of mass gathering (i.e., fairgrounds, shopping center, etc.)				
Others (list):				
Total check marks for Section A:				

**Identify all critical infrastructure that are functioning after the event, even if they were not impacted.*

Critical Infrastructure and Facilities	Benchmark	Credible Worst-Case Scenario 1	Credible Worst-Case Scenario 2	Infrastructure/ facility functions after disaster*
Water Level (feet):	*249*	*249.5*	*250*	
Weather Disaster (list):				
Example: Power grid	✓			✓
Section B: Critical Facilities**				
Municipal Hall				
Municipal Department of Public Works				
Critical record storage				
Other government building(s) (list):				
Fuel (i.e., diesel, gas) stations for disaster response operations				
Police station or other law enforcement building(s)				
Jail				
Fire station(s)/Emergency Medical Service				
Communications main office or substations				
Emergency operation center				
Access to areas suitable for disaster response staging				
Access to points of distribution (staging areas for necessities for residents)				
Evacuation shelter(s)				
Hospital(s)				
Vulnerable populations (i.e., mobility impaired, day care, group homes, people likely to refuse mandatory evacuation, etc.)				
Hazardous materials facilities (gas stations, marinas with fuel or other hazard materials, etc.)				
Private industries with hazardous materials				
Abandoned, deteriorated, or underused sites and buildings				
Total check marks for Section B:				

**Identify all critical facilities that are functioning after the event, even if they were not impacted.*

***Critical facilities may be defined a certain way in an ordinance. However, each community may identify other structures they consider critical.*

Additional Notes

TRANSPORTATION ISSUES

2. Assuming Credible Worst-Case Scenario 1 for coastal-flooding or Benchmark for weather disasters, if any of the following affect your transportation/evacuation route(s), will your community regain a pre-event level of service during or after a coastal-flooding event or after a weather disaster event? Check Yes or No.

Transportation Issue*	Yes	No
Will primary bridge(s) be out for less than one week?		
Will roads blocked by storm debris (trees, trash, etc.) be cleared in less than one week?		
Will washouts (roads) be passable in less than one week?		
Will flood-prone areas (roads, low-lying areas) be operational within one week?		
Is public transportation available to assist evacuation of residents unable to evacuate on their own?		
Is there more than one evacuation route?		
Is there a plan for post disaster traffic management?		
Are there ways to limit access in disaster areas for those other than critical personnel (emergency responders, disaster responders, etc.)?		
Is there sufficient parking for emergency/disaster response personnel and logistical response staging stations?		
Do road lights/stoplights have a reduced/no power setting, or alternate energy backup?		
Other (list):		
Total number of Yes answers and No answers:		

Additional Notes

DID YOU KNOW?

Communities with a channel debris removal plan can receive up to 200 points through the National Flood Insurance Program's Community Rating System.

**Some communities use waterways as transportation infrastructure and/or evacuation routes (canals, docks, streams, marinas, and ferries).*

COMMUNITY PLANS AND AGREEMENTS

3. Does your community have the following plans, personnel, or agreements in place? Check Yes or No.

Does your community:	Yes	No
Participate in the National Flood Insurance Program's Community Rating System?		
Use an early flood warning system?		
Have a floodplain manager/administrator certified by Association of Floodplain Managers (ASFPM)?		
Have Planning Board/Zoning Board of Appeals with formal training in planning?		
Have staff (Planning, Code Enforcement Officer (CEO), Building Inspector, Building Department) with credentials from the American Institute of Certified Planners (AICP) or degrees/professional experience in planning?		
Have FEMA-approved and NY State Department of Homeland Security and Environmental Services-approved All-Hazard Mitigation Plan (AHMP)?		
If you have an AHMP, has it been revised in the past two years?		
If you have an AHMP, does it include climate projections?		
Have a disaster mitigation equipment inventory (i.e., sand, sand bags, sand bagging machine, pumps, etc.)?		
Have Memorandums of Understanding or Memorandums of Agreement with neighboring communities to help each other during times of disaster?		
Participate in the Code Enforcement Disaster Assistance Response (CEDAR) Program?		
Have a comprehensive plan or strategic plan that addresses natural disasters?		
Have a floodplain manager or CEO/Building Inspector who participates in the following organizations:		
– Association of State Floodplain Managers or NYS Floodplain and Stormwater Managers Association?		
– American Planning Association (APA) or NY Upstate APA?		
– American Society of Civil Engineers (ASCE) or state or local section ASCE?		
– American Public Works Association?		
– NYS Building Officials Conference?		
Have a formal evacuation plan?		
Have an official debris management plan?		
Total number of Yes answers and No answers:		

Additional Notes

DID YOU KNOW?

Communities with an emergency warning dissemination plan for imminent flooding can earn up to 75 points through the National Flood Insurance Program's Community Rating System.

MITIGATION MEASURES

4. Has your community implemented the following ongoing mitigation measures or projects? Check Yes or No.

Mitigation Measures in Place	Yes	No
Locating or relocation of buildings and infrastructure out of flood-prone areas		
Flood-proofing of nonresidential structures		
Education programs about mitigation options for your community		
Acquisition of repetitive loss structures, infrastructure or property		
Incentives-based mitigation measures		
Adoption of the most recent International Buildings Codes		
– For NYS, this is the 2015 IBC/IRC		
Hiring certified Building Inspectors		
Staffing an adequate number of people to enforce building codes		
Have completed or planned shoreline restoration projects for critically eroding areas		
Require the protection and maintenance of sensitive coastal habitats, ecosystems, and natural features (dunes, barrier bars/beaches, wetlands)		
Require the protection and maintenance for areas of historical/cultural significance		
Have undeveloped public lands such as parks, forests or preserves in the coastal hazard areas (Coastal A Zones)		
Access to mitigation equipment (i.e., sand, sand bags, sand bag machine, pumps, etc.)		
Total number of Yes answers and No answers:		

Additional Notes

DID YOU KNOW?

Communities can receive up to 1,450 points through the National Flood Insurance Program's Community Rating System for keeping land vacant through ownership or regulations.

**Note that the Association of Floodplain Managers recommends communities consider higher elevations than the minimum National Flood Insurance Program standard.*

BUSINESS PLANS

5. What assets do the large retail stores (ex: The Home Depot, Wal-Mart, etc.), grocery stores and fuel distributors in your community have to:

i. stay open during/reopen after a coastal-flooding event; or
ii. reopen after a weather disaster?

If more than 50 percent of the large retail businesses in your community have the following equipment or plans, mark yes. If fewer than 50 percent have the equipment or plans, check no.

Business Equipment/Plans*	Yes	No
Generators		
Backup options for basic needs (water, sewer, food and communications)		
Plans to bring in staff to help reopen business		
Plans for restocking		
Plans for ice distribution		
Total number of Yes answers and No answers:		

Additional Notes

**Businesses may include functioning marinas or ports as important distribution points after a disaster. If so, consider these as businesses for this section.*

DID YOU KNOW?

Having a capital improvement program that corrects drainage problems can earn a community up to 70 points through the National Flood Insurance Program's Community Rating System.

SOCIAL SYSTEMS

6. Are there social systems that define your community or serve as the core of the community? Check Yes or No.

Social System Category	Yes	No	If yes, describe relationship
Ex: Strong faith-based networks	✓		*Church networks*
Strong faith-based networks (counted on during a disaster)			
Cultural identity (unified Hispanic, Asian or other ethnic communities)			
Neighborhood associations that support members in times of need			
Business cooperative of working relationships (industries that employ many residents, Chamber of Commerce, other business-related networks, etc.)			
Strong civil organizations (Kiwanis Club, Rotary Club, etc.)			
Active community center			
Established social network groups (ex: Facebook, Nextdoor) for communicating with residents.			
Total number of Yes answers and No answers:			

Additional Notes

DID YOU KNOW?

Developing a Program for Public Information (PPI) to disseminate relevant flood-related messages to the community on an annual basis can earn up to 200 points through the National Flood Insurance Program's Community Rating System.

DETERMINING YOUR RESILIENCE INDEX

To determine your Resilience Index for each section, use the following tables, which are based on the totals you entered for each section of the Index.

Section 1A: Critical Infrastructure

Total number of infrastructure functioning after a disaster: ______

Number of check marks	Percentage of infrastructure and facilities functioning during or after coastal flooding/after weather disaster	Resilience Index
0–3	0–27%	LOW
4–7	28–63%	MEDIUM
8–11	64–100%	HIGH

Your critical infrastructure **Resilience Index** is ____________.

Find out what your Resilience Index means on page 17.

Section 1B: Critical Facilities

Total number of critical facilities functioning after a disaster: ______

Number of check marks	Percentage of critical facilities functioning during or after coastal flooding/after weather disaster	Resilience Index
0–5	0–27.5%	LOW
6–11	27.6–60.5%	MEDIUM
12–18	60.6–100%	HIGH

Your critical facilities **Resilience Index** is ________________.

Find out what your Resilience Index means on page 17.

Additional Notes

TRANSPORTATION, COMMUNITY PLANS, MITIGATION MEASURES, BUSINESS PLANS, AND SOCIAL SYSTEMS

Use the box labeled "Total number of Yes answers" from Sections 2–6 to complete the following chart.

Sections 2–6	Number of Yes answers	Translate number of Yes answers to Resilience Index	Resilience Index	Comments
(Example) Section 2: Transportation Issues	*1*	3 or fewer (LOW) 4 to 7 (MEDIUM) 8 or more (HIGH)	*LOW*	*A road construction project will create an additional evaluation route within a year. Also, we are in talks with the local public transportation provider about a program to assist evaluation.*
Section 2: Transportation Issues		3 or fewer (LOW) 4 to 7 (MEDIUM) 8 or more (HIGH)		
Section 3: Community Plans and Agreements		6 or fewer (LOW) 7 to 13 (MEDIUM) 14 or more (HIGH)		
Section 4: Mitigation Measures		4 or fewer (LOW) 5 to 9 (MEDIUM) 10 or more (HIGH)		
Section 5: Business Plans		1 or fewer (LOW) 2 to 3 (MEDIUM) 4 or more (HIGH)		
Section 6: Social Systems		2 or fewer (LOW) 3 to 5 (MEDIUM) 6 or more (HIGH)		

Additional Notes

INTERPRETING RESILIENCE INDEX RESULTS

Resilience Index: A Resilience Index is an indicator of your community's ability to reach and maintain an acceptable level of functioning and structure after a disaster.

After completing this self-assessment, your Resilience Index was identified as LOW, MEDIUM, or HIGH in different categories (ex: critical infrastructure and facilities, transportation issues, community plans and agreements, etc.).

LOW Resilience Index. A low Resilience Index indicates that your community should pay specific attention to this category and make efforts to address the areas of low rating. If the critical infrastructure category received this rating, then reoccupation of your community may take more than 18 months before basic services are restored.

MEDIUM Resilience Index. A medium Resilience Index indicates that more work could be done to improve your resilience in this category. If the critical infrastructure category received this rating, reoccupation of your community may take less than 2 months before basic services are restored.

HIGH Resilience Index. A high Resilience Index indicates that your community is well prepared for coastal flooding and/or the weather disasters you considered during this exercise. If the critical infrastructure category received this rating, then your community probably will not suffer or will have minimal damage (can be functional in less than two weeks) to basic services.

NEXT STEPS

Regardless if your community has a **HIGH, MEDIUM, OR LOW** Resilience Index, you might consider learning about and investigating the weaknesses identified during this process. Refer to the references page for additional information on resources, training, and support.

For more information, contact Mary Austerman, NYSG Coastal Community Development Specialist at mp357@cornell.edu.

Acknowledgements

Appreciation is extended to the following people for their assistance in making this booklet applicable to New York, and communities for donating their time to strengthen New York's Great Lakes Coastal Resilience Index by piloting it or its components. In alphabetical order:

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Greece, NY
Sandy Creek, NY
Sodus Point, NY

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Sempier, T.T., D.L. Swann, R. Emmer, S.H. Sempier, and M. Schneider. 2010. *Coastal Community Resilience Index: A Community Self-Assessment.* MASGP-08-014.

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Advisory Team
Rochelle Bell, Monroe County Planning & Development
Rob Breen, Formerly of New York Department of State
Dale Currier, Oswego County Office of Emergency Management
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Dylan Maybee, Wayne County Emergency Management
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Jayme Thomann, Genesee/Finger Lakes Regional Planning Council

Mapping Team
Jessica Kuonen, New York Sea Grant
Kyla Semmendinger, Cornell University
Dr. Scott Steinschneider, Cornell University

REFERENCES & RESOURCES

Additional Resources

- Department for International Development
  - https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/186874/defining-disaster-resilience-approach-paper.pdf
- Federal Emergency Management Agency
  - National Flood Insurance Program Community Rating System: https://www.fema.gov/national-flood-insurance-program-community-rating-system
  - Understanding Your Risks: Identifying Hazards & Estimating Losses: https://www.fema.gov/media-library/assets/documents/4241
- National Oceanic & Atmospheric Administration
  - Digital Coast: https://coast.noaa.gov/digitalcoast/
  - Coastal Storms Program (Great Lakes Region): https://www.regions.noaa.gov/great-lakes/index.php/project/coastal-storms-program/
- New York Department of State, Office of Planning & Development
  - Geographic Information Gateway: https://opdgig.dos.ny.gov/#/home
  - Model Local Laws to Increase Resilience: https://www.dos.ny.gov/opd/programs/resilience/index.html
- New York Sea Grant
  - 2017 Flood: http://www.nyseagrant.org/waterlevel2017
  - Lake Ontario Inundation Map Package, Lake Ontario Inundation WebMap, and associated tutorials: https://seagrant.sunysb.edu/articles/t/coastal-community-development-program-resources-tools-coastal-resilience-index
- New York State Department of Environmental Conservation
  - Climate Smart Communities Program: https://www.dec.ny.gov/energy/50845.html
- New York State Floodplain and Stormwater Managers Association
  - https://www.nyfloods.org

Training

- Federal Emergency Management Agency
  - https://training.fema.gov/
- National Oceanic & Atmospheric Administration Digital Coast Training
  - https://coast.noaa.gov/digitalcoast/training/home.html
- New York Office of Emergency Management Training Programs
  - http://www.dhses.ny.gov/oem/training/

Networking

- Great Lakes Action Agenda Work Groups
  - https://www.dec.ny.gov/lands/91881.html
- New York's Great Lakes Resilience e-List:
  - To join the e-list, send an email message ***from*** the email address where you want to receive messages posted to the e-list.
  - Send the message to: NY-GL-Resilience-L-request@cornell.edu
  - In the subject line of your email, enter the single word: ***join***
  - Leave the body of the message blank

Contact

Mary Austerman
Coastal Community Development Specialist, New York Sea Grant
Phone: (315)331-8415
Email: mp357@cornell.edu

APPENDICES

*The coastal flooding and weather disaster narratives and charts are provided to help you think through community-specific impacts that are likely to occur during these events. These examples were developed with data and expertise of the National Weather Service and Northeast Regional Climate Center.

LAKE ONTARIO INUNDATION MAP PACKAGE TUTORIAL

Developed by Jessica Kuonen and Mary Austerman, New York Sea Grant

1. Introduction

This tutorial will guide you through how to make inundation maps for your community either as part of the New York Sea Grant's (NYSG) Coastal Resilience Index (CRI) or as a standalone exercise. The goal is to visualize inundation at different lake levels to bring awareness to infrastructure and services that may be at risk. Using this tutorial, you will be able to generate a series of maps for your community with the following predetermined lake levels scenarios:

- 247.3 ft: The upper limit of the 4-foot range for Plan 1958 DD
- 249 ft: Benchmark water level (approximate peak water level from 2017)
- 249.5 ft: Future water level scenario
- 250 ft: Future water level scenario

Note that the water levels are based on elevation data and do not account for wind-driven effects. These materials were developed by New York Sea Grant for Lake Ontario coastal communities.

Disclaimer: The data and maps in this tool illustrate the scale of potential flooding or land exposure at a given water level, not the exact location. They do not account for erosion, subsidence, or future construction. Water levels are shown as they would appear during calm conditions (excludes wind-driven changes in water levels). The data, maps, and information provided should be used only as a screening-level tool for management decisions. As with all remotely sensed data, all features should be verified with a site visit. The data and maps in this tool are provided "as is," without warranty to their performance, merchantable state, or fitness for any particular purpose. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference tool and not for navigation, permitting, or other legal purposes.

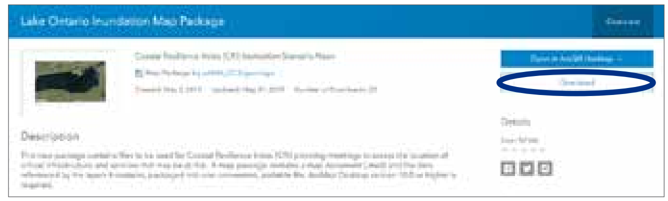
1a. What You Need

- A computer and internet connection
- A printer
- ArcMap Desktop (Version 10.0 or higher)
  - To find out which version of ArcMap Desktop you are working with, Open the program and go to **Help > About ArcMap**…

2. Access the Data

The map and data are provided in a map package (.mpk) format. A map package contains a map document (.mxd) and the data referenced by the layers it contains, packaged into one convenient, portable file.

1. **File management:** Create a folder on your computer from which you will work. Do not use spaces or special characters in the folder name or ArcMap will not be able to access the folder. Example folder name: LO_Inundation_Maps2019
2. Navigate to the New York Sea Grant Inundation Mapping Tools web page: https://seagrant.sunysb.edu/articles/r/12972
3. Select the **Lake Ontario Map Package** listed under "Lake Ontario Tools"
4. Select **Download > Save File** to save the map package (.mpk) to your local drive. (You may need to move it from the Downloads folder to the folder you created in Step 1).



5. Open Map Package

Option 1 (Recommended)

i. Open ArcMap

ii. ArcToolbox: **Data Management > Package > Extract Package (double-click)**

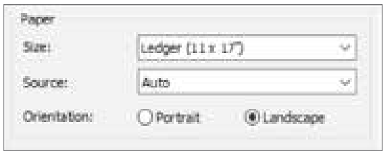
iii. Complete **Extract Package** tool form. For **Input Package**, browse and select the map package (.mpk) that you downloaded in step 3. For **Output Folder**, browse and select the folder that you created in step 1. Click **OK**.

iv. Once complete, in ArcMap go to **File > Open** > navigate to the folder that you created in Step 1, which is also now where you have extracted the map package to. There will be 2 folders: v10 and v107. If you are working with the latest version of ArcMap, v10.7, open the **v107** folder and select the .mxd file to open. If you are working with an earlier 10 version, open the **v10** folder version and select the LO_InundationMap (file type: ArcGIS ArcMap Document) to open.

Option 2

i. Double-click map package (.mpk) file in File Explorer. File should automatically open in ArcMap.

6. The default size of the map is 11x17 in Landscape orientation. Depending on your ArcMap settings, you may need to adjust the page size/orientation. **File > Page and Print Setup**. Select Paper Size: **Ledger (11x17")**, Paper Orientation: **Landscape**.



- If you want to make a map in a different size or orientation (ex: Letter (8.5x11"), change the settings under **File > Page and Print Setup** then adjust the data frame and text boxes in Layout View accordingly.

**Once open in ArcMap, you should see a view of Lake Ontario.*

3. Create Maps

Create maps for your community by zooming in to areas where critical infrastructure and facilities are located. Use Layout View or Data View. Customize the map. Display the different **Inundation Layers** individually and/or together, adjusting color and transparency as needed. Toggle layers on and off by selecting the box next to the layer. Other layers that may be useful to orienting yourself and locating critical infrastructure are **Roads, Municipal Boundaries**, and **Counties**.

3a. Considering Critical Infrastructure and Facilities and Different Lake Level Scenarios

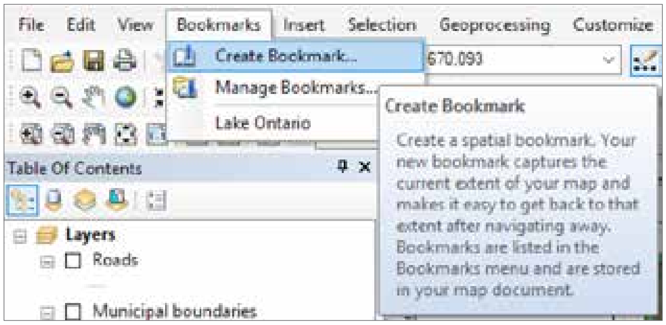
The sample list of critical infrastructure and facilities below is a sample taken from the NYSG CRI, and is provided as an example of an application for this map tool.

Critical Infrastructure
Wastewater treatment/lift system
Storm drains
Power grid (Transformers, substations) and alternate Energy Sources (i.e., solar, wind, etc)
Public water supply
Transportation/evacuation routes
Large-scale shoreline protection (i.e. breakwater, breakwall, etc.)
Places of mass gathering (i.e. fairgrounds, shopping center, etc.)
Critical Facilities
Municipal Hall and Government buildings
Municipal Department of Public Works
Critical Record Storage
Fuel stations
Police station or other law enforcement buildings
Jail, Fire Station(s)/Emergency Medical Service
Communications main office or substations
Emergency Operation Center
Access to Area suitable for disaster response staging & access to points of distribution
Evacuation shelters
Hospitals
Vulnerable populations
Hazardous materials facilities
Private industries with hazardous materials
Abandoned, deteriorated, or underused sites and buildings.

4. Export Maps

When you are happy with your map, return to **Layout View** to finalize the map.

1. In **Layout View**, consider setting a **Bookmark** so that you can return to the same extent at a later time.

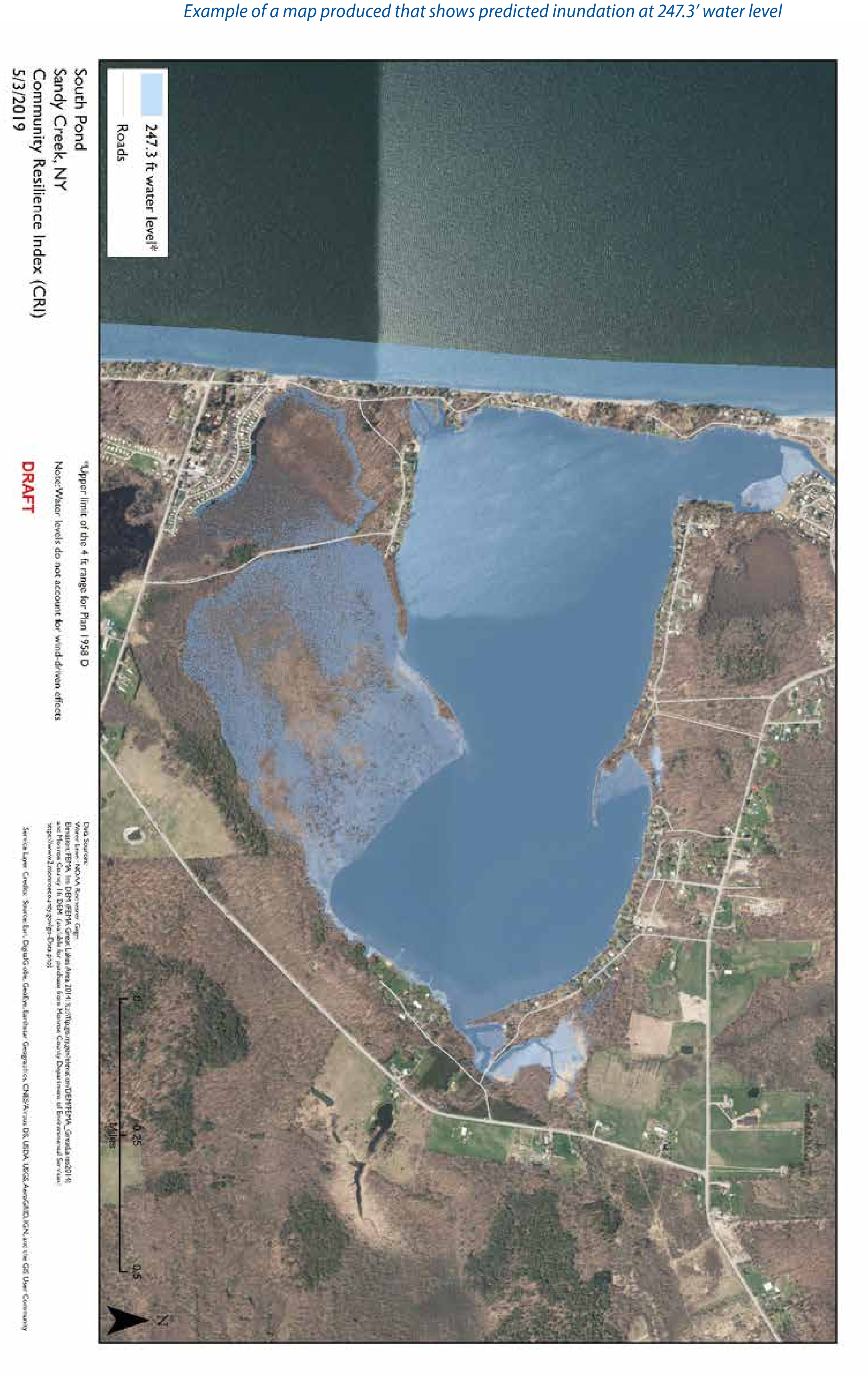


2. Decide which inundation layers you want to display.
3. To update the text at the lower left corner of the map (**<Location>, <Municipality>, <Date>**), double click on the text area in the layout view. See Appendix A for examples of finished maps.
4. Adjust scale bar as needed.
5. File > Export Map
    - Save in: (navigate to a folder where you would like to export the map as a PDF. You may want to create a folder called: Exported_Maps)
    - File name: (create a file name)
    - Save as type: PDF or JPEG
    - Resolution: allow for default identified with file type option
    - Output Image Quality: Best
    - Ratio: 1:1
    - Save

5. Print Maps

Print exported maps as needed.

Example of a map produced that shows predicted inundation at 247.3' water level



247.3 ft water level

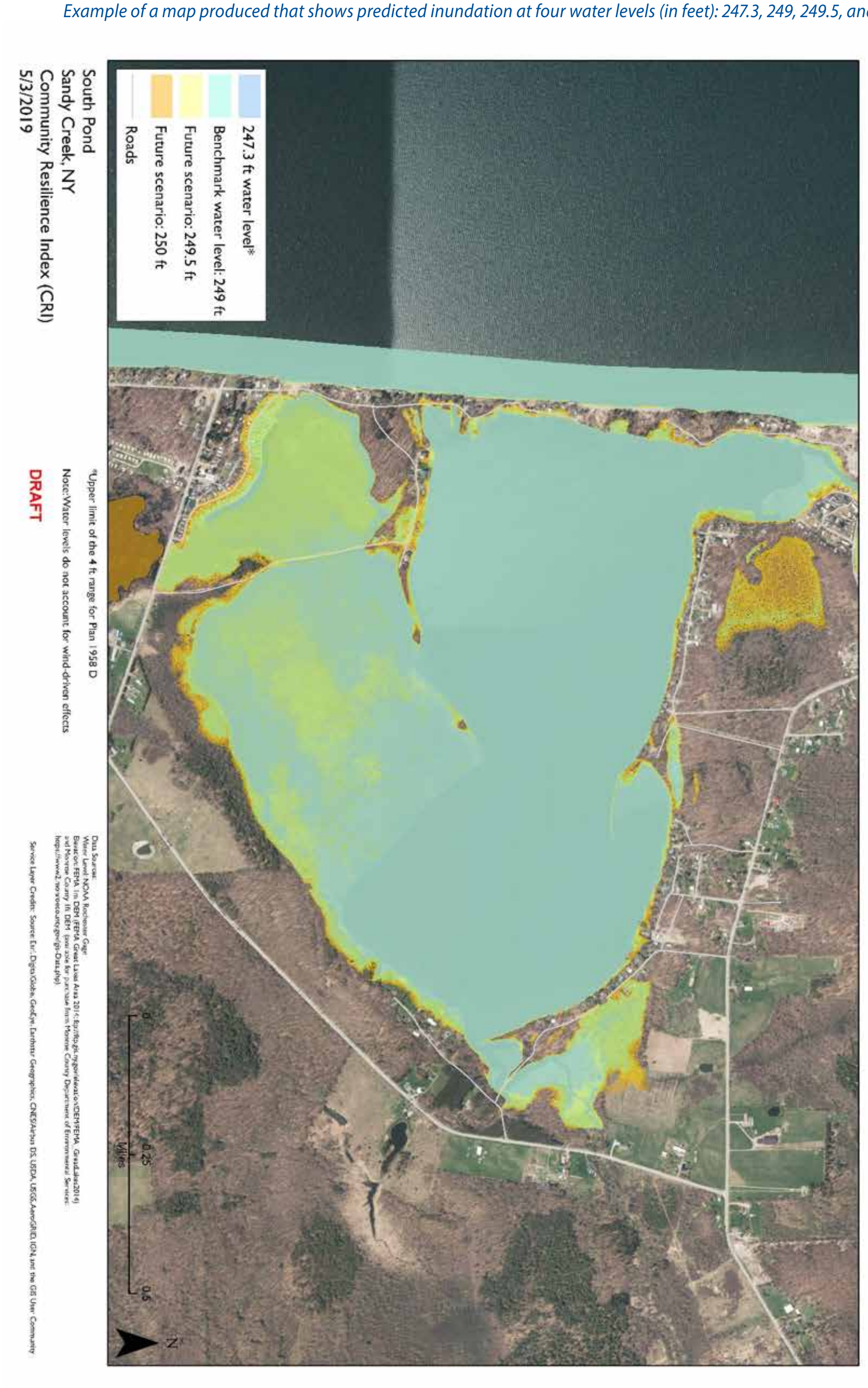
LAKE ONTARIO INUNDATION MAP PACKAGE TUTORIAL

Example of a map produced that shows predicted inundation at 249' water level

249 ft water level (benchmark)

LAKE ONTARIO INUNDATION MAP PACKAGE TUTORIAL

Example of a map produced that shows predicted inundation at four water levels (in feet): 247.3, 249, 249.5, and 250



All water levels

LAKE ONTARIO INUNDATION WEBMAP TUTORIAL

Developed by Jessica Kuonen and Mary Austerman, New York Sea Grant

1. Introduction

This tutorial will guide you through how to make inundation maps for your community either as part of the New York Sea Grant's (NYSG) Coastal Resilience Index (CRI) or as a standalone exercise. The goal is to visualize inundation at different lake levels to bring awareness to infrastructure and services that may be at risk. Using this tutorial, you will be able to generate a series of maps for your community with the following predetermined lake levels scenarios:

- 247.3 ft: The upper limit of the 4-foot range for Plan 1958 DD
- 249 ft: Benchmark water level (approximate peak water level from 2017
- 249.5 ft: Future water level scenario
- 250 ft: Future water level scenario

Note that the water levels are based on elevation data and do not account for wind-driven effects. These materials were developed by New York Sea Grant for Lake Ontario coastal communities.

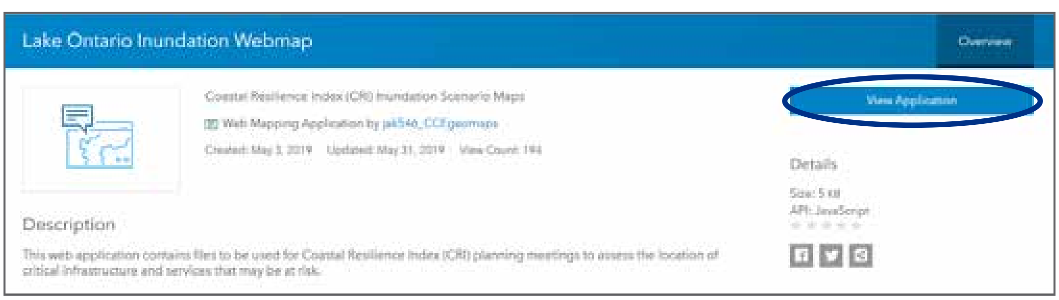
Disclaimer: The data and maps in this tool illustrate the scale of potential flooding or land exposure at a given water level, not the exact location. They do not account for erosion, subsidence, or future construction. Water levels are shown as they would appear during calm conditions (excludes wind-driven changes in water levels). The data, maps, and information provided should be used only as a screening-level tool for management decisions. As with all remotely sensed data, all features should be verified with a site visit. The data and maps in this tool are provided "as is," without warranty to their performance, merchantable state, or fitness for any particular purpose. The entire risk associated with the results and performance of these data is assumed by the user. This tool should be used strictly as a planning reference tool and not for navigation, permitting, or other legal purposes.

1a. What You Need

- A computer
- Internet connection
- A printer (optional)

2. Access the WebMap

1. Navigate to the New York Sea Grant New York Sea Grant Inundation Mapping Tools web page: https://seagrant.sunysb.edu/articles/r/12972
2. Select the **Lake Ontario Web Mapping Application** listed under "Lake Ontario Tools"
3. Select "View Application" in the top right of your screen.



3. Explore WebMap

After opening the application, you will see a view of Lake Ontario. Similar to other online mapping services (Google Maps, etc.). Zoom to your community and/or areas of interest. The different water levels are displayed as different "layers" in the map legend to the left of the screen. You will need to zoom into to nearly county-level in order for the layers to become active (clickable) and the layers will likely take some time to load completely.

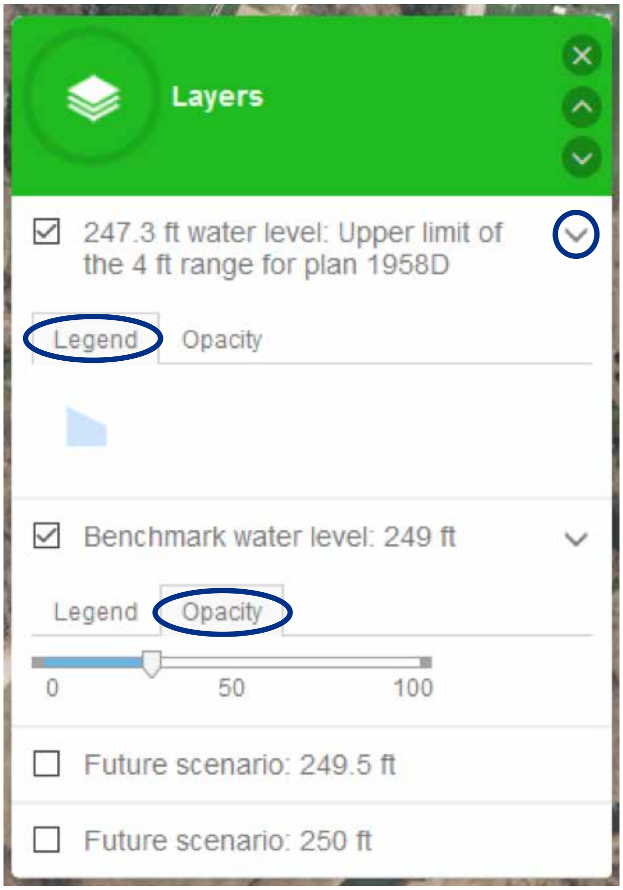
3a. Add/Remove Layers

Select the **Layers** button on the Toolbar (circled below).

The Layers menu will appear to the right of the screen, replacing the legend. There, you can toggle inundation layers on and off by selecting the checkbox next to the layer.

View Legend in "Layers View" & Change Opacity:

Select the arrow (>) to the right of the layer name to reveal the **Legend** and **Opacity** tabs. Adjust the opacity as needed using the slider bar.



3b. Considering Critical Infrastructure and Facilities and Different Lake Level Scenarios

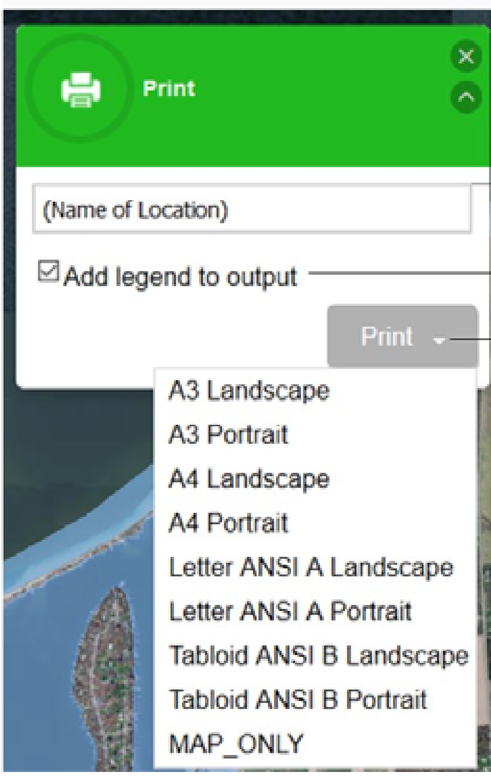
Create maps for your community by zooming in to areas where critical infrastructure and facilities are located. Display the different Inundation Layers individually and/or together. The sample list of critical infrastructure and facilities below is a sample taken from the NYSG CRI, and is provided as an example of an application for this map tool.

Critical Infrastructure
Wastewater treatment/lift system
Storm drains
Power grid (Transformers, substations) and alternate Energy Sources (i.e., solar, wind, etc)
Public water supply
Transportation/evacuation routes
Large-scale shoreline protection (i.e. breakwater, breakwall, etc.)
Places of mass gathering (i.e. fairgrounds, shopping center, etc.)
Critical Facilities
Municipal Hall and Government buildings
Municipal Department of Public Works
Critical Record Storage
Fuel stations
Policy station or other law enforcement buildings
Jail, Fire Station(s)/Emergency Medical Service
Communications main office or substations
Emergency Operation Center
Access to Area suitable for disaster response staging & access to points of distribution
Evacuation shelters
Hospitals
Vulnerable populations
Hazardous materials facilities
Private industries with hazardous materials
Abandoned, deteriorated, or underused sites and buildings.

4. Export/Print Maps

Select the **Print** button on the Toolbar, circled below.

Follow steps 1-4, below to add custom title (below as "Name of Location"), legend, and save/print your maps.



1. Type the name of the location Example: "Sodus Bay, near pier"

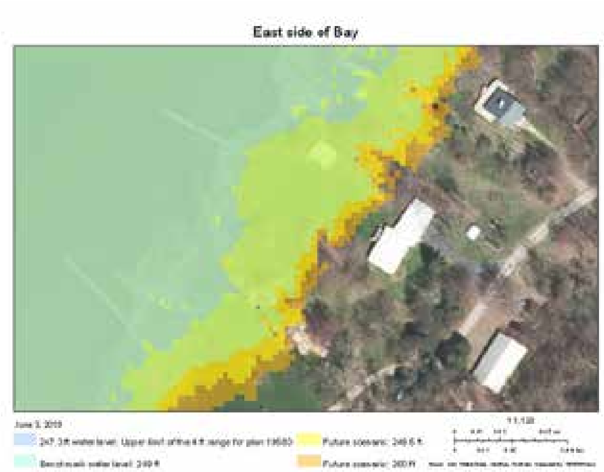
2. **Check** the box for **Add legend to output**

3. Select the dropdown arrow next to "Print" to select the size of the PDF output.

- For an **11x17** sized map, select **Tabloid ANSI B Landscape** (or Portrait)
- For an **8.5x11** sized map, select **Letter ANSI A Landscape** (or Portrait)

4. Once the map is created, a link will appear that says **Printout**. Select the link. Map will open in a new tab in browser. **Download** and **Save** map to local drive before printing.

Example of exported webmap:



2017 LAKE ONTARIO FLOOD

Lake Ontario

Length: 193 miles **Width:** 53 miles **Average depth:** 283 feet

Maximum depth: 802 feet **Volume:** 393 $miles^3$

Water surface area: 7,340 $miles^2$

Total shoreline length: 712 miles (326 miles in NY)

Elevation: 243 feet **Retention/Replacement time:** 6 years

Watershed includes ≥16K miles of streams and 260 lakes.

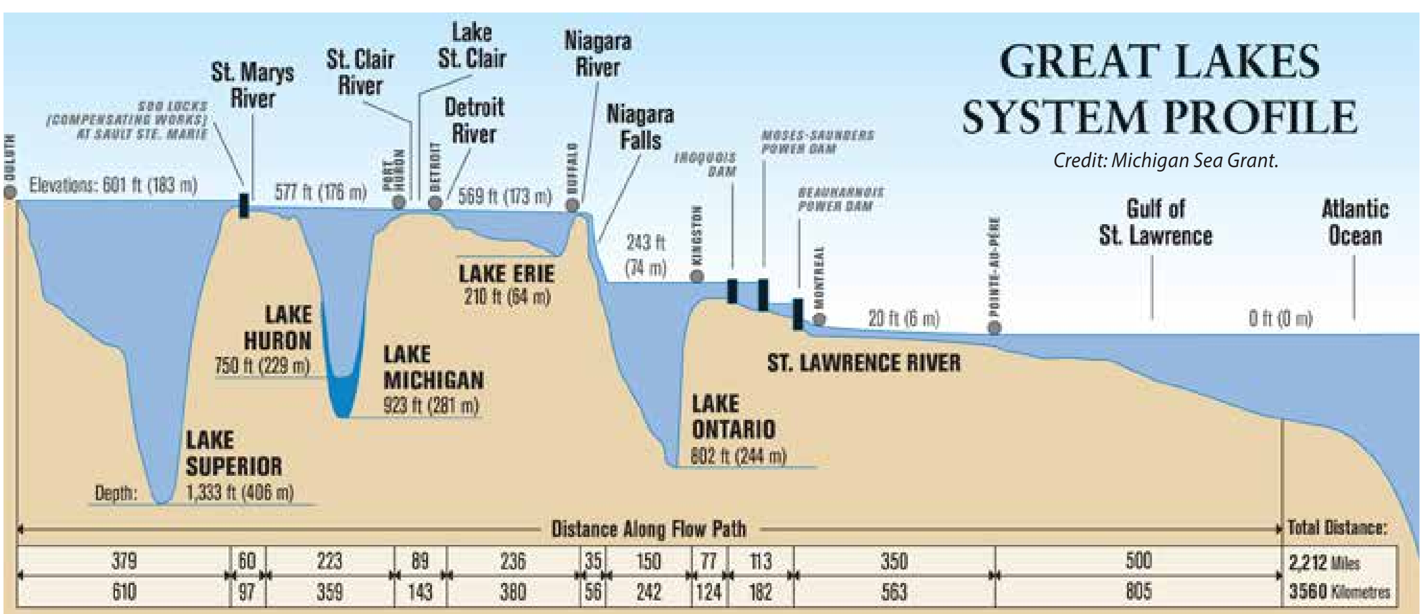
As the last lake in the hydrologic series of Great Lakes, Lake Ontario has the lowest mean surface elevation of the lakes at 243 feet above sea level. The lake's primary source of inflowing water is the Niagara River, draining Lake Erie, with the St. Lawrence River serving as the outlet. The drainage basin covers 24,720 square miles. The primary drivers of lake levels are precipitation and over-lake evapotranspiration. Flooding along the Lake Ontario shoreline can be induced by high static water levels, storm-related activity, such as storm surge and wave runup, or a combination of the two.

Although flooding occurred in 1951, 1952, 1973, 1974, 1976, and 1993, Lake Ontario reached record high lake levels in 2017, which were surpassed in 2019. Warmer and wetter winter conditions across the Great Lakes basin followed by unprecedented rainfall over the entire basin throughout the spring of 2017, resulted in increased inflows into Lake Ontario from its tributaries and the upper Great Lakes. This caused major flooding on the shoreline of Lake Ontario and the St. Lawrence River that peaked at 248.72 feet in May 2017. Impacts from this event included property damage, public infrastructure damage, road and park closures, shoreline erosion, and untreated sewage dispersal.

Credit: New York Sea Grant; Michigan Sea Grant.

Wave action during the 2017 Lake Ontario flood severely undercut the shoreline. Photo: Coastal Flooding Survey Project, Cornell University and New York Sea Grant.

Contributor: Kyla Semmendinger, Department of Biological & Environmental Engineering, Cornell University



Credit: Michigan Sea Grant.

2017 LAKE ONTARIO FLOOD

The Village of Sodus Point (Wayne County, NY)

Village size: 960 acres

Lake Ontario shoreline: 1.86 miles

Sodus Bay Shoreline: 4.5 miles

Population: 900 people

Total number of housing units: 886

Number of waterfront housing units: 224

Lowest elevation: 247.5 feet

With a minimum elevation of 247.5 feet, the Village of Sodus Point (Wayne County, NY) is among the communities first impacted by high water levels. The village is 960 acres with 1.86 miles of Lake Ontario shoreline and 4.5 miles of shoreline on Sodus Bay, which is the largest embayment on the south shore of Lake Ontario. Recent census data indicates that there are 886 housing units, 224 being waterfront. Tourism plays a significant role in the Village's economy. Below is a snapshot of some impacts from the Village's perspective.

- April 10, 2017: sand bagging began; nearly 300,000 sand bags were deployed with help from neighboring municipalities, Wayne County, high school teams, National Guard, and others.
- April 20 – November 18, 2017: State of Emergency.
- Pumping efforts: To keep the Village dry a number of pumps (9 pumps ≥ 3-inches, and 30, 2-inch pumps) ran 24-hours per day, 7 days per week, for at least 14 weeks.
- Homes and businesses sustained crawl space and first floor inundation.
- Suspended solids discharge violated; DEC authorized direct discharge; temporary force main required to meet demand.
- One property lost 15–25 feet of shoreline.
- One house taken down to avoid collapse.
- Several houses being elevated to avoid future flooding (as of 2019, 10 were completed and more being planned).
- Shoreline protection: 28 seawalls toppers constructed, 9 new seawalls installed; 12 new riprap projects.

Contributors: Dave McDowell, Mayor, Village of Sodus Point, NY and Jayme Thomann, Senior Planner, Genesee/Finger Lakes Regional Planning Council

The location of Sodus Point, NY. Credit: Jessica Kuonen, New York Sea Grant.

Flood waters damaged docks, decks and even inundated the inside of some homes. Photo: Coastal Flooding Survey Project, Cornell University and New York Sea Grant.

Flooded streets in Sodus Point, NY. Photo: Coastal Flooding Survey Project, Cornell University and New York Sea Grant.

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- Gabriel, A.O., Kreutzwiser, R.D., Stewart, C.J., 1997. Great Lakes flood thresholds and impacts. J. Great Lakes Res. https://doi.org/10.1016/S0380-1330(97)70912-2 http://glisa.umich.edu/media/files/2017-Climate-trends-and-impacts-summary.pdf

BLIZZARD

Benchmark: March 4, 1999

Location: Monroe and Wayne counties

Benchmark Conditions: Heavy rain turned to snow that fell at a rate of 2–3 inches per hour over a 6-hour period that resulted in 7–28 inches of total snowfall.

Credible Worst-Case Scenario Conditions: As you think through a blizzard Credible Worst-Case Scenario, consider a snowfall rate of 3–4 inches per/hour, with totals of 26–48 inches over a 12-hour period.

Blizzard snowfall nearly completely buried vehicles in a parking lot. Photo: NOAA's National Weather Service (NWS) Collection, Image ID: wea04198, Kevin Shaw, NOAA/NOS/OCS.

The following impacts from the National Oceanic and Atmospheric Administration/ National Weather Service's Storm Event Database describe an historic blizzard that hit the region in 1999.

On March 4, 1999, heavy rain changed to heavy snow as cold air circulated into the region. Snow fell at the rate of two to three inches per hour. Snowfall amounts were greatest across Monroe and Wayne counties, with over two feet falling. The strong winds off Lake Ontario resulted in **blizzard** conditions for nearly six hours. Drifts reached four to five feet in places. The New York State Thruway (I-90) was closed from Depew to Syracuse. Several hundred cars were stranded in the closed section. Then Governor George E. Pataki declared Cayuga, Livingston, Monroe, Orleans, Oswego, Wayne, and Wyoming counties State Disaster Areas. Livingston, Monroe, Ontario, Orleans, Wayne, and Wyoming counties were also declared Federal Disaster Areas. The National Guard was called on to help remove cars, rescue stranded motorists, transport medical staff, and deliver food and medical supplies. Schools and businesses were closed throughout the area. Nearly 10,000 customers lost power during the storm for up to three days.

Blizzard conditions often result in snowfall rates that are nearly impossible for road crews to keep roads clear of snow. In the aftermath of a blizzard, sloppy roads, vehicles trapped by snow mounds, and piles of plowed snow litter the landscape making travel a challenge. Photo: NOAA's National Weather Service (NWS) Collection, Image ID: wea04839, Courtesy of Joe Flood.

A ***blizzard*** is a storm that contains large amounts of snow OR blowing snow with winds in excess of 35 mph and visibilities of less than 1/4 mile for an extended period of time (at least 3 hours).

County	Town/City	Total Snowfall Reported (inches)
Monroe	Hamlin	28
Monroe	Perinton and Fairport	26
Monroe	Rochester Airport	24
Wayne	Ontario	24
Wayne	Walworth	23
Monroe	Greece and Webster	20
Wyoming	Portageville	17
Ontario, Livingston and Cattaraugus	Canandaigua, Avon and Franklinville	16
Livingston	Mt. Morris	15
Livingston	Dansville	14
Oswego, Ontario and Allegany	Oswego, Honeoye, and Angelica	13
Genesee, Allegany and Orleans	Batavia, Friendship and Albion	12
Cattaraugus, Allegany and Wyoming	Olean, Alfred, Whitesville, and Strykersville	11
Wayne and Cattaraugus	Sodus and Salamanca	10
Wyoming	Bennington	9
Erie	Wales	8
Genesee and Chautauqua	Darien and Arkwright	7

Blizzard

Variables	Benchmark: March 4, 1999	Worst-Case Scenario
Wind Gust (mph)	44 (sustained winds 35 - the definition of blizzard)	55–60 (sustained winds 40-45)
Snow (inch)	2–3"/hour	3–4"/hour; totals of 36-48 inches
Event Duration	6 hours on March 4th	12 hours
Impact Area of the Disaster	Erie, Niagara, Monroe, Wayne, Oswego, Livingston, Ontario counties	
Power Outage Duration	2–3 days	3-4 days (more power outages because higher sustained winds)
Number of People Without Power	10,000	Dependent on the population density of the impacted area; you could use the benchmark figure as the minimum
Number of People Evacuated	No evacuations but shelters opened along the thruway because of its closure	
Damage	None reported for this particular disaster	Potential structural damage because of snowload
Other Impacts*	I-90 closed with several hundred cars stranded; schools and businesses closed; had to dump snow into the Genesee River	Similar to benchmark impacts; road closures; people without heat; generator illness/deaths; drifting snow; high snow drifts; clearing of snow will take longer
Federal Disaster Area	Livingston, Monroe, Ontario, Orleans, Wayne, and Wyoming counties	
State Disaster Area	Cayuga, Livingston, Monroe, Orleans,Oswego, Wayne, and Wyoming counties	

**Economic loss can be considered; agricultural damages can be for multiple years following the disaster; could impact tourism.*

Damage (figures based on value of the dollar from the year of the event)

County	Property Damage ($)
Orleans County	350K
Monroe County	1.75M
Wayne County	1.25M
Oswego County	250K

Note: If a benchmark has state of emergency, assume that will happen for Credible Worst-Case Scenario.

FLASH FLOOD FROM HEAVY PRECIPITATION

Benchmark: May 13–14, 2014

Location: Seneca and Yates counties

Benchmark Conditions: Several weather factors came together that resulted in 4–5 inches of rain in less than 2 hours, devastating parts of Penn Yan, New York, and nearby areas. This rainfall total has a one percent probability of occurring in a given year, making this a 100-year rainfall event.

Credible Worst-Case Scenario Conditions: A 500-year event would result in 10 inches of rain over 3-6 hours. Islip, NY experienced 9 inches of rain over 2 hours in 2014.

East Valley Road, north of Branchport, NY. Floodwaters were beyond the capacity of existing ditches and culverts. Many area roads were damaged from the velocity and volume of the floodwater. Photo: Courtesy of Dave Enty (NWS Binghamton).

Several clusters of thunderstorms moved across the Finger Lakes region from May 13–14, 2014. A narrow band of 4 to 5 inches of rain occurred in less than 2-hours over the central portion of Yates and Seneca counties. Rainfall resulted in devastating **flash flooding** in Penn Yan, NY that destroyed roads and buildings. Total public damages are estimated between 10 and 12 million dollars. The following impacts are from the National Oceanic and Atmospheric Administration/National Weather Service's Storm Event Database:

Throughout Yates County, creeks overtopped their banks, homes flooded, and roads were washed out or impassable. Water rescues took place around Italy, NY and Keuka Park, including one motorist that was trapped in their vehicle. In Penn Yan, catastrophic flash flooding occurred in the downtown area of the Village. The hardest hit areas were in the vicinity of Elm Street and Champlin Avenue where roads buckled, parking lots caved in, and the Owl's Nest Community Center collapsed. Tractor-trailer container boxes were seen floating down the streets, where they collided into the Wagner Restaurant causing significant structural damage. The foundations of several homes were washed away during the flood.

As floodwater travels across the land, it picks up debris. This house was nearly surrounded by debris that was left from receding floodwater. Photo: Mary Austerman, New York Sea Grant.

A ***flash flood*** is a rapid and extreme flow of high water into a normally dry area, or a rapid water level rise in a stream or creek above a predetermined flood level, beginning within six hours of the causative event (e.g., intense rainfall, dam failure, ice jam).

Floodwaters carry sediments as well. After the floodwaters receded, dirt, silt, and rocks covered much of this lawn. Photo: Mary Austerman, New York Sea Grant.

Benchmark: July 12, 2006

Location: Wayne County

Benchmark Conditions: Over 5 inches of rain fell over a 3–6 hour period. This rainfall total has a one percent probability of occurring in a given year, making this a 100-year rainfall event.

Credible Worst-Case Scenario Conditions: A 500-year event would result in 10 inches of rain over 3-6 hours. Islip, NY experienced 9 inches of rain over 2 hours in 2014.

Flash Flood from Heavy Precipitation

Variables	Benchmark: July 12, 2006	Worst-Case Scenario
Rain (inch)	5+ inches over 3-6 hours	10 inches over 3–6 hours (9" occurred in 2 hours in Islip, NY in 2014)
X Year Event	100 year rain event; 25 year rain event at Macedon (Wayne County)	500 year rain events
Event Duration	One Day	
River Crest Height	Crest heights are not representative because the flood waters weren't on gaged streams	
Injuries	None reported	There is no way to estimate, but more likely to occur with a 500 year event.
Death Toll	None reported	There is no way to estimate, but more likely to occur with a 500 year event.
Number of People Evacuated	6 homes in Wayne County	Dependent on the population density of the impacted area; you could use the benchmark figure as the minimum
Damage	6 homes destroyed; roads washed away; thousands of cars damaged; crops (squash, potatoes, corn, etc.) ruined	Dependent on impacted area; similar to damages that occurred during the benchmark; likely more intense and widespread damages
Other Impacts*		Water supply and quality issues; community isolation; human health (mold, insects, etc).
State of Emergency	Wolcott (Wayne County)	

**Economic loss can be considered; agricultural damages can be for multiple years following the disaster; could impact tourism.*

Damage (figures based on value of the dollar from the year of the event)

County	Property Damage ($)	Crop Damage ($)
Orleans County	200K	500K
Monroe County	500K	0
Wayne County	1.5M	200K
Cayuga County	300K	150K

Note: If a benchmark has state of emergency, assume that will happen for Credible Worst-Case Scenario.

FLASH FLOOD FROM ICE JAM

Benchmark: January 22–26, 1999

Location: Western NY

Benchmark Conditions: Over the course of a few days, flash flooding occurred from rapid snowmelt and ice jamming.

Credible Worst-Case Scenario Conditions: As you think through a Credible Worst-Case Scenario for flash flooding that results from ice jamming, consider deeper snowpack, and slightly higher air temperatures for longer period of time, causing the snow to melt quicker.

Flash flooding from rapid snowmelt and ice jamming occurred over a course of days (January 22–26) in 1999. The following impacts are from the National Oceanic and Atmospheric Administration/ National Weather Service's Storm Event Database.

Warm temperatures melted nearly two feet of ripe snowpack from record snowfall in late December and early January. Wind blown ice collected in drainage areas such as inlets, outlets and culverts, creating an **ice jam**. The runoff and ice jamming caused flooding in poor drainage and low-lying regions across the area with roads closed in some locations for a couple of days. Some of the hardest hit areas included Lancaster and Williamsville in Erie County, Royalton in Niagara County, Batavia and Corfu in Genesee County and Chili in Monroe County. Evacuations occurred in Angola, Chili and Lancaster.

Ice jam flooding occurred in Buffalo area creeks on January 23rd and 24th with Cayuga Creek the most serious. Some evacuations were necessary and roads were closed in the vicinity of south Cheektowaga. Conditions improved on the 25th as the jams loosened and moved downstream, causing flooding. Ellicott, Tonawanda, and Cazenovia Creeks were above flood stage for one to two days; often cresting at night, and led to flooding in Bowmansville and Batavia.

East of Lake Ontario, flooding was reported in Lewis County along the Moose River due to another massive ice jam.

Rapid snowmelt and wind can result in the formation of a temporary ice jam, which acts similar to a dam, preventing the natural movement of water. Photo: Courtesy of J.I. Garver, Union College.

Ice jams can cause flooding. The formation of a nearby ice jam has caused road and homes to flood. Photo: Courtesy of J.I. Garver, Union College.

An ***ice jam*** describes pieces of floating ice carried with a stream's current that can accumulate and obstruct stream flow. Ice jams often develop upstream of bridges, downstream of dams, and at river bends, and can cause flooding or flash flooding.

Flash Flood from Ice Jam

Variables	Benchmark: January 22-26, 1999	Worst-Case Scenario
Air Temperature (F)	56 degrees max temperature over the event's duration; above freezing (20–25 degrees above normal) for 3 consecutive days	Low 60s; (25-30 degrees above normal) for 3 consecutive days
Snowmelt	2 feet of snow	3-4 feet of snow (Higher snow depths are common in Lake Effect snow regions)
Rain (inch)	0.28 inch on January 22; 0.5 inch 22nd–26th	.5-1 inch over the 3 day period
Snow (feet)	2 feet of snowpack on the ground that melted	3-4 feet of snowpack on the ground that melted
Event Duration	2–5 days (January 23 and 24; conditions improved on the January 25); flooding conditions were variable	3 days, flooding will likely be variable
River Crest Height	Crest heights are not representative because during ice jamming levels could be affected by ice in the creek/stream/river.	
Number of People Evacuated	200 homes in Angola, Chili and Lancaster	Dependent on the population density of the impacted area; you could use the benchmark figure as the minimum
Damage	$1.2M across Erie, Genesee, Monroe, Niagara and Orleans counties	Similar damages likely to occur
Other Impacts*	Road closures; some basement/ urban flooding	Similar impacts are likely however more intense; potential winter recreation evacuations, deaths, loss in revenue (a lot of water quick; flash flood); potential structural damage from snowload

**Economic loss can be considered; agricultural damages can be for multiple years following the disaster; could impact tourism.*

Damage (figures based on value of the dollar from the year of the event)

County	Property Damage ($)
Niagara County	65K
Orleans County	25K
Monroe County	105K
Erie County	430K
Genesee County	270K
Livingston County	35K
Chautauqua County	50K
Cattaraugus County	35K

Note: If a benchmark has state of emergency, assume that will happen for Credible Worst-Case Scenario. The event duration was variable based on stream capacity, runoff rates, etc.

ICE STORM

Benchmark: March 3–4, 1991

Location: Western and Northern NY

Benchmark Conditions: Over a period of 12–18 hours, heavy snow turned to ice, causing downed trees and utility poles. Many were without power for up to 14 days.

Credible Worst-Case Scenario Conditions: As you think through a Credible Worst-Case Scenario for an ice storm, consider more snow before switching to ice, greater ice totals, and the event lasting for longer than 18 hours.

The historic **ice storm** that began on March 3, 1991, crippled parts of western and northern New York. The event started with 4–6 inches of heavy, wet snow that was then coated with ice, and lasted for 12-18 hours over the course of two days. Downed trees were one of the largest impacts of the event. During the overnight hours many were woken by the sound of falling branches and trees, many of which landed on power lines, houses and vehicles. Recovery often happened with the help of neighbors. The Rochester *Democrat and Chronicle* reported makeshift bed and breakfasts providing support for neighborhoods, and electrical cords traversing the streets to share much needed power. Homes were evacuated because of the lack of heat from power outages. In agricultural areas, fruit crop trees were damaged. The following occurred as result of downed trees and dangerous/ impassible roads:

- Over 300,000 customers were without power for up to 14 days (after 7 days 37,500 customers were still without power)
- Then Governor Mario Cuomo declared a state of emergency for 19 counties
- Churches and closed schools served as emergency shelters
- Many businesses were closed

Jim Mahoney, formerly of Rochester, recalls being woken to the sound of crashing tree limbs. "It was totally dark and nothing could really be seen. However, the crashing sounds of tree branches falling could be heard from every direction. It was very eerie, like being in a war zone with random explosions detonating all around. What we were hearing were limbs dropping to the ground as the weight of the ice caused them to break off. For the next couple of hours we listened to the sounds, getting up every so often to peer out the window into the darkness."

During ice storms, the weight of the snow and ice often causes trees and utility poles to break, leaving roads impassable and people without power for days, and in some cases even weeks. Photo: New York Sea Grant.

An ***ice storm*** is used to describe occasions when damaging accumulations of ice are expected during freezing rain situations. Significant accumulations of ice pull down trees and utility lines resulting in loss of power and communication. These accumulations of ice make walking and driving extremely dangerous. Significant ice accumulations are usually ¼ inch or greater.

Trees, tree limbs and utility poles buckle under the weight of heavy, wet snow that turned to ice during an ice storm. In some neighborhoods, many large, long-lived trees are lost during single events. Photo: New York Sea Grant.

He goes on to describe the scene as the sun rose. "Tree branches were down all around, those remaining had tons of ice burdening them...and the ice kept coming from the sky. The storm finally tapered off Monday March 4, after more than 16 hours. For miles, everything standing was coated by more than an inch of ice. The falling trees and power lines and subsequent loss of power brought the area to a virtual standstill…for days."

Ice Storm

Variables	Benchmark: March 3–4, 1991	Worst-Case Scenario
Snow (inch)	4–6" inches of heavy wet snow coated with ice across the western fringes of the storm	6–10"; ice changes over to wet snow at the end of the event
Ice (inch)	1–2"	4–5"; 1998 ice storm had 5" ice in Jefferson and St. Lawrence counties and Canada
Event Duration	12–18 hours of ice over two days; freezing rain fell in Rochester for 17 consecutive hours. Virtually everything shut down through March 5th. Rochester schools were closed all week.	18–24 hours of ice
Power Outage Duration	Full restoration March 16th (14 days)	2–3 weeks; dependant on power company restoration crews and coverage area
Number of People Without Power	325,000 customers (more than 750,000 people)	Dependent on population density; but majority of people in the coverage area would likely be without power; you could use benchmark as the minimum
Injuries	Minor. Mainly from falling ice or limbs. These numbers are probably low due to timing of the storm (late at night/before sunrise).	Injuries are possible; carbon monoxide from generators, falling trees, car accidents, slipping on ice, power outage
Death Toll	None	Deaths possible see injuries above
Number of People Evacuated	1,000 homes	Dependent on population density, temperatures, power outage duration
Damage	Property, infrastructure, and crop damage	Possible property damage (downed trees and utility poles, fruit trees, lumber forest, trees on structures, snowload issues if snow present, etc.)
Other Impacts*	"High water flooded basements when sump pumps were unable to work due to power failures"	Similar to benchmark other impacts; river and lowland flooding; possible road closures; debris management; possible need to open shelters; economic impact from businesses being closed; supply shortages; dairy farms can't milk without generator
Federal Disaster Area	Allegany, Genesee, Jefferson, Lewis, Livingston, Monroe, Ontario, Orleans, St. Lawrence, Steuben, Wayne, Wyoming and Yates counties	
State Disaster Area	Allegany, Cattaraugus, Cayuga, Chemung, Genesee, Jefferson, Lewis, Livingston, Monroe, Ontario, Orleans, Oswego, St. Lawrence, Schuyler, Seneca, Steuben, Wayne, Wyoming and Yates counties	

Damage (figures based on value of the dollar from the year of the event)

County	Property Damage ($)	Crop Damage ($)
Niagara County	20M	1M
Orleans County	25M	1M
Monroe County	35M	1M
Wayne County	25M	1M
Cagyuga County	10M	500K
Oswego County	15M	1M
Jefferson County	15M	1M
Erie County	45M	500K

County	Property Damage ($)	Crop Damage ($)
Genesee County	25M	500K
Livingston County	15M	1M
Ontario County	25M	1M
Wyoming County	20M	1M
Chautauqua County	5M	500K
Cattaraugus County	10M	1M
Allegany County	10M	1M

Note: If a benchmark has state of emergency, assume that will happen for Credible Worst-Case Scenario.

References

Jim Mahoney, formerly of Rochester: http://www.progrocher.com/pix/IceStorm/ice1.htm

The Rochester Democrat & Chronicle: https://www.democratandchronicle.com/story/news/2019/03/03/ice-storm-1991-rochester/3048857002/, https://www.democratandchronicle.com/story/news/2019/03/03/ice-storm-1991-rochester/3048857002/

The Post: https://www.monroecopost.com/news/20160211/column-remembering-great-ice-storm-of-1991

WINDSTORM

Benchmark Date: September 6–7, 1998

Location: Central and Western New York

Benchmark Conditions: Two derecho events brought wind gusts of 90–95 mph.

Credible Worst-Case Scenario Conditions: As you think through a high wind event Credible Worst-Case Scenario, consider wind gusts of 120-130 mph, which are the strongest winds measured for a derecho.

A long-lived severe wind event, or **derecho**, moved across areas of New York on September 6–7, 1998, causing widespread damage, injuries and death. Some of the most severely impacted counties in central and western New York were, Allegany, Cayuga, Monroe, Niagara, Onondaga, Oneida, Oswego, Orleans, Seneca and Wayne. National Weather Service surveys of Onondaga County alone revealed a damage swath 10 to 12 miles long and nearly 30 miles wide. Estimated peak wind gusts were near 115 mph, but averaged 90-95 mph for the event. Hundreds of thousands of people were without power for much of Labor Day, and some customers did not have their power restored for the better part of a week. The following impacts are from the National Oceanic and Atmospheric Administration/National Weather Service's Storm Event Database:

Downed trees, utility poles, and power lines resulting from strong, damaging winds and large hail caused the bulk of the damages. Many roads were closed and tens of thousands of trees were lost in Onondaga County alone. In Syracuse, 150 and 125 year old churches were nearly destroyed from powerful wind and portions of the steeple and bell tower from one were blown hundreds of yards, damaging nearby structures. A large tree crashed through the roof of a home and struck an elderly woman who was sleeping. She later died from extensive head injuries. University housing was damaged and a textile company and strip malls lost most of their roofs. Many houses lost shingles and siding, and windows were blown out of homes and buildings, including University Hospital. Several people sustained minor injuries due to flying debris.

The last day of the New York State Fair was canceled after two fatalities and seven injuries. Most temporary structures and tents were destroyed, and the National Guard was called in to assist with clean up. Onondaga County qualified for Federal Disaster funds.

A large tree falls onto a house during a windstorm, causing damage to the structure and its contents. Photo: New York Sea Grant.

A ***derecho*** is a widespread and usually fast-moving windstorm associated with severe thunderstorms and can produce damaging straight-line winds over areas hundreds of miles long and more than 100 miles across.

During these types of events, downed utility poles can result in impassable roads, and leave people without power for days, and in some cases even weeks. Photo: New York Sea Grant.

Windstorm

Variables	Benchmark: September 6–7, 1998 (Labor Day Derecho)	Worst-Case Scenario
Wind Gust (mph)	90–95	120–130 (strongest winds measured in a derecho)
Hail (inch)	0.75"	1.5–2" (this is the typical maximum for hail storms in our region)
Event Duration	10–15 minutes at any one location; it took 2 hours for the storm to travel the damage path on September 6, 1998 (Labor Day)	No change for a single location; if looking at the whole state the total duration would be increased to 6–8 hours
Event Impact Area	The wind storm traveled Niagara County along Erie Canal past Syracuse. See "Damage Path" below.	
Power Outage Duration	1 week	1–2 weeks (based on the fact that the Credible Worst-Case Scenario would be more widespread and service crews will be needed in more locations; more outside crews will need to be called to our area)
Number of People Without Power	Hundreds of thousands	Dependent on the population density of the impacted area; you could use the benchmark figure as the minimum
Injuries	11 injuries (flying debris and a man struck by lightning)	Dependent on the population density of the impacted area; you could use the benchmark figure as the minimum
Death Toll	3 in Onondaga County	Dependent on the population density of the impacted area; you could use the benchmark figure as the minimum
Damage Path	250 miles long, 20–30 miles wide	400 miles long; up to 50 miles wide
Damage	Downed trees and limbs, downed utility poles and lines; vehicles; structural damage to homes, churches, barns, businesses, hospitals, etc.; aircraft at Rochester Airport; fruit orchards	Same types of damage as benchmark just more intense and widespread
Other Impacts*		Secondary impacts likely from longer power outages such as food storage/gas storage; public health; safe drinking water (wells)
State of Emergency	Cayuga, Monroe, Onondaga, Wayne, and sections of Orleans counties	Potentially widespread
Federal Disaster Area	Cayuga, Monroe, Onondaga, and Wayne counties	Potentially widespread
State Disaster Area	Cayuga, Monroe, Onondaga, and Wayne counties	Potentially widespread

**Economic loss can be considered; agricultural damages can be for multiple years following the disaster; could impact tourism.*

Damage (figures based on value of the dollar from the year of the event)

County	Property Damage ($)	Crop Damage ($)
Niagara County	250K	2M
Orleans County	5M +100K hail	5M
Monroe County	21.2M + 350K	2M
Wayne County	10M	500K
Cayuga County	5M	1M
Oswego County	500K	1M
Allegany County	15K	0

Note: If a Benchmark has state of emergency, assume that will happen for Credible Worst-Case Scenario.

Additional Notes

Additional Notes

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New York Sea Grant is part of a nationwide network of 33 university-based programs working with coastal communities through the National Oceanic Atmospheric Administration (NOAA). Sea Grant research and outreach programs promote better understanding, conservation, and use of America's coastal resources. Sea Grant is funded in New York through SUNY and Cornell University and federally through NOAA.

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