Flood Impacts and Adaptation Strategies: Filling Data Gaps in Upstate and Western New York

Final Report | Report Number 22-16 | February 2022

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Flood Impacts and Adaptation Strategies: Filling Data Gaps in Upstate and Western New York

Final Report

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NYSERDA Report 22-16 NYSERDA Contract 103918 February 2022

Notice

Preferred Citation

New York State Energy Research and Development Authority (NYSERDA). 2022. "Flood Impacts and Adaptation Strategies: Filling Data Gaps in Upstate and Western New York," NYSERDA Report Number 22-16 (added by NYSERDA). Prepared by Center for International Earth Science Information Network (CIESIN), Columbia University, Palisades, NY. nyserda.ny.gov/publications

Abstract

Successfully adapting to climate change requires access to detailed data on the potential impacts from coastal and riverine flooding under different storm and sea level rise scenarios. Increasing storm severity and frequency have highlighted the need for more comprehensive and detailed data to increase preparedness for future impacts. Center for International Earth Science Information Network (CIESIN) undertook this project to fill persistent data gaps and provide integrated critical infrastructure, building footprints, flood scenarios, and damage assessments to inform policy makers and empower citizens.

A new comprehensive collection of building footprints was developed for Upstate New York and Long Island. The building footprint data set combines data collected from local governments and Microsoft, manually digitized from New York State Orthoimagery, and extracted from light detection and ranging (LiDAR) data. Critical infrastructure data was collected from various national and local sources and attached (where applicable) to building footprints. Flood model data were assembled from the Federal Emergency Management Agency (FEMA) flood data collections. Information on economic valuations and modeled flooding were added to building footprints and used as inputs in a modified Hazards U.S. (HAZUS) flood assessment methodology to produce detailed estimates of possible flood impacts.

The flood scenarios, building footprints, and impact assessment statistics produced in this project are publicly available for use in regional and local planning and can be downloaded and incorporated into organizations own analysis. A web map application visually displays these data by county and municipality.

The thousands of hours CIESIN spent collecting, creating, and validating the data and the support NYSERDA provided will allow others to reproduce the financial impact assessment and use the data for their communities' needs. The following document contains details of the data collection and integration, analysis methods, and a summary of the data and information available to the public.

Keywords

Building footprints, building occupancy, flood impacts

Acknowledgments

The authors would like to acknowledge the support of NYSERDA for the support provided through the duration of this project, and for the flexibility granted to us to shift methodology and final data design to meet the challenges encountered throughout the project. The authors would also like to thank Columbia University for providing material support (matching funds) and administrative support for the project. Most importantly, we give thanks to the numerous staff who contributed to the data collection, editing, and methodology development of the project: over 20 staff contributed to the project, including:

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- Briar Mills
- Emilie Schnarr
- Kytt MacManus
- Lisa Lukang
- Xue Liu

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Acronyms and Abbreviations

ft	feet
m	meters
CIESIN	Center for International Earth Science Information Network
DTM	Digital Terrain Model
DSM	Digital Surface Model
FEMA	Federal Emergency Management Agency
LAS	Laser file
LASD	Laser file dataset (format)
LiDAR	Light Detection and Ranging
NYS	New York State
zLAS	Laser file (format)

Executive Summary

Building on previous work in methodology development and data development (Filling Data Gaps and Characterizing Storm Surge Impacts in the Hudson River Valley and Long Island, NYSERDA Agreement 60446), this project developed an integrated set of building footprints and infrastructure data for the 45 counties in New York State not covered by the previous project. New York City was excluded as public footprint data and detailed flood analysis became available from the New York City open data portal. In total, 3,265,985 building footprints were collected, reviewed, and integrated in the new data collection for upstate areas. The output of both projects has been published to the same web site (http://fidss.ciesin.columbia.edu/building_data_adaptation) and published as interactive maps linked from the same site.

1 Data Collection and Creation

Data were collated and editing using Geographic Information Systems (GIS) software (ArcGIS Desktop™ and ArcGIS Pro™) and the Python programming language. The editing of the collected footprints and creation of new footprints was completed manually with ArcGIS editing tools. Building extractions from Light Detection and Ranging (LiDAR) were completed in ArcGIS and Python. Analysis, integration, and data checks were all completed with Python processing scripts. Integration included assignment of attributes (occupancy class) from building parcels.

1.1 Building Footprints

Online searches were conducted to find existing building footprint data. If building footprint data was not available online, it was requested from every county GIS office or planning department in the upstate counties and large municipalities. For counties and municipalities without building footprints, three different sources were used to create the footprints: Microsoft building outlines extracted from imagery, building footprints extracted from LiDAR, and footprints manually created by digitizing over New York State orthoimagery.

1.1.1 Downloaded Footprints

Data downloaded or received via email from county and municipal sources were reviewed for fitness of use and completeness. In many places, the data only included partial coverage. Where this was the case, the provided footprints were integrated with the Microsoft and LiDAR extracted footprints, and then reviewed and updated.

1.1.2 LiDAR Extracted Footprints

The methodology to extract the building footprints from LiDAR data was compiled from various sources. The foundation of the methodology came from Esri's 2017 workshop, "3D Mapping with Lidar Point Clouds Hands-On Workshop Using ArcGIS® Pro 2.0," first unveiled at the 2017 ESRI User Conference in San Diego, California. The team at the Center for International Earth Science Information Network (CIESIN) at Columbia University heavily modified the tools and scripts provided by the ESRI tutorial to work specifically for the purposes of this project. The LiDAR data was downloaded by project from the NYS Information Technology Services FTP. Due to their enormous size, the files were compressed to zLAS format, producing significantly smaller files that are optimized for Esri software. The zLAS files were combined into a LAS data set (LASD).

Initial draft building outlines were produced by county from each LASD using the following processes:

- A Digital Surface Model (DSM) and a Digital Terrain Model (DTM) raster were created for each zLAS file contained in the LASD.
  - Statistics were calculated for each zLAS file to obtain the point spacing and classification codes.
  - Using the cell sizes, classification codes, and tile extents, the DSM and DTM rasters were created by interpolating the elevation values of the LiDAR points in the LASD.
- A mosaic data set was created for each pair of corresponding DSM and DTM rasters.
- The Esri MultiDirectional Hillshade template provided with the workshop materials was applied to the mosaic data set to detect possible buildings over 2.5 meters in height. Cells representing possible buildings were reclassified to one and all others were reclassified to zero.
- If a cell with a value of one did not have any direct neighbors with a value of one it was set to zero using the SciPy convolve function. SciPy is a collection of algorithms and functions for Python.
- Finally, all cells with a value of one in the mosaic data set were converted to a vector feature class representing the initial "draft polygons."

Draft polygons then went through additional processing to fill in gaps and reduce noise to create a final building footprint data set:

- Draft polygon feature classes were merged together at the county level. Polygons smaller than 1.5 square meters were discarded.
- County-wide feature classes were dissolved to produce single-part polygons.
- Holes smaller than 10 square meters in polygons were filled in to create solid features.
- Polygons more than 2 meters from an address point were discarded.
- Esri's Regularize Building Footprint tool was used with the following parameters:
  - Allow for right angles and diagonals
  - Tolerance = 1.5 meters
  - Densification = 1.5 meters
  - Precision = 0.15 meters
  - Diagonal Penalty = 2 meters
- The feature classes were converted from multipart to single-part polygons; features smaller than 10 square meters were discarded.
- The Polbsy-Popper score, which measures compactness, was calculated for each polygon. Features with a score less than 0.4 were discarded.
- The number of vertices of each polygon was calculated. Features with 16 or more vertices were discarded.

The LiDAR-extracted footprints were not perfect in all cases (false positives, poorly constructed outlines) so they were reviewed manually during the process described below.

1.1.3 Microsoft Footprints

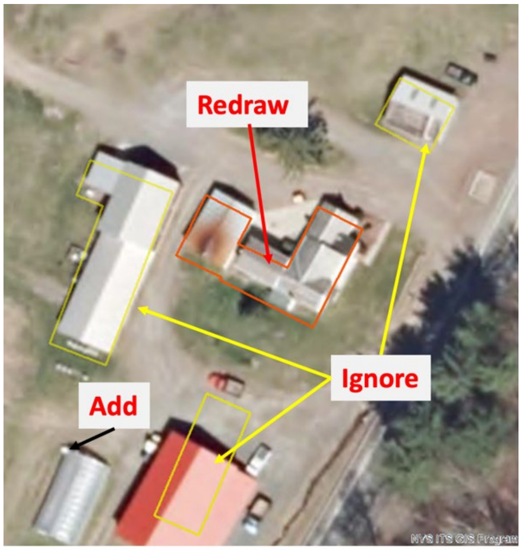
After the start of the project, Microsoft released automatically extracted footprints from satellite imagery for the United States (https://github.com/microsoft/USBuildingFootprints). These data were obtained for New York State and integrated with the building footprints collected from downloads and LiDAR extracted data. The Microsoft footprints contain omissions (no features where buildings are present in the imagery), false positives (buildings extracted from non-building features, such as trees and shrubs), and poorly formed features (too large, small, or not shaped like the building outline). A quick-review methodology was developed so that the buildings could be reviewed by analysts in combination with the New York State orthoimagery using just a web browser (similar to mechanical turking, a type of outsourcing to a distributed workforce)). The LiDAR extracted footprints were included in the review process alongside the Microsoft footprints. Analysts classified the Microsoft and LiDAR footprints into three types: useable as-is, redrawing needed, or no building present in the imagery. GIS software was then used to delete the footprints that were false positives.

1.1.4 Digitized Footprints

In areas without LiDAR data (and those created before the release of the Microsoft footprints), building footprints were digitized manually using the most recent NYS Orthoimagery web service available. A template ArcGIS map document for each municipality was used to define a standardized working session. The map document, coupled with strict standards and procedures, ensured consistent and reliable building footprints. Guidelines included the use of right angles, digitizing all buildings larger than a car, and excluding house decks and patios. In areas with LiDAR and Microsoft data, the footprints tagged as poorly formed (needing redrawing) were included with the map document template to indicate areas with footprints where the buildings needed to be drawn. To speed up the labor-intensive process, tiles of images with the poorly formed footprints were generated and mechanical turking processes allowed analysts to re-draw the footprints with only a web browser. Figure 1 shows an example tile image used to redraw and infill footprints with the instructions presented to an analyst.

Figure 1. Sample Mechanical Turk Image

Annotated image with footprint to redraw (red), footprints that are acceptable, or to be redrawn later (yellow), and the NYS Orthoimagery service.



1.1.5 Footprint Validation

The building footprints were validated to ensure the accuracy and quality of the final data product. If the footprints were separated by municipality, they were first merged to the county level and then all footprints were validated accordingly:

1.1.5.1 Points to Validate

For each municipality a separate data layer was created to collect "points to validate." During the digitizing workflow, if the imagery resembled a building but it was difficult to distinguish, a point feature was created to flag the area. Each point was checked by a person other than the one who created the point, and buildings were added where appropriate.

1.1.5.2 Topology and Multipart Polygons

Topology rules were set up to catch overlapping features. If an overlap occurred, it was eliminated by merging it with one feature or merging both features together. Multipart polygons were separated using the ArcGIS Multipart to Singlepart tool and individually examined. Polygons were either deleted, merged together, or left separated.

1.1.5.3 Building Counts

To determine possible building omissions and commissions, building footprint data sets were checked against the Housing Count in the 2010 U.S. Census. Census blocks were flagged as "errors of omission," if the census contained a housing count greater than zero but no building footprint features existed in the block. These were checked against the NYS Orthoimagery web service. If the imagery contained a building, then the missing polygon was digitized. "Errors of commission" were flagged if the census block contained a housing count of zero but there were building footprint polygons in the block. Each building was checked against the NYS Orthoimagery web service and features were deleted if no building was detected. Errors of omission were not checked for downloaded buildings.

1.1.6 Additional Attributes

After the building footprints were validated, attributes were added to capture the geographic location and source information of each polygon. The buildings were spatially joined to administrative boundaries to attach the county and municipality that they fell into, and the source information was joined from the orthoimagery, LiDAR index files, Microsoft footprint source, or manually filled in with information collected at the time of download. All of the attributes included with the footprints are shown in Table 1.

Table 1. Building Attributes

Attributes included in the building footprints data, including analysis outputs described in later sections.

Field Name	Description
BuildingID	The unique building identifier. The first three digits represent the county fips code and the digits to the right of the underscore are sequential unique integers (i.e., BuildingID '001_1' represents Albany county building number 1).
CountyName	The name of the county.
MuniName	The name of the municipality.
Source	The data source of the feature: • NYS Digital Orthoimagery • NYS ITS LiDAR: <Name of LiDAR Project> • Organization that provided the building footprints or Microsoft Building Footprints Release <V1.0 or V1.1>
SourceID	The specific source of each feature • The orthoimagery tile ID • The LiDAR tile ID • Any ID included with a downloaded data source
SourceDate	The date of the data used to create the feature • The date of the orthoimagery • The date of the LiDAR • The date the downloaded data was created
RoofType	The roof type of each feature • Peaked • Flat • Unknown • NULL
InfrType	The type(s) of critical infrastructure.
OccClass	FEMA Hazus-MH occupancy class.
FFE	First-Floor Elevation (feet).
LossCat100	Category of loss from FEMA 100-year flood (None, Slight, Moderate, Substantial).
LossCat500	Category of loss from FEMA 500-year flood (None, Slight, Moderate, Substantial).
Adaptation	Flood adaptation option(s) for building of specific occupancy class.
AdptSource	Sources of adaptation options.

1.2 Critical Infrastructure

Critical infrastructure data are important for assessing flood impacts. The critical infrastructure data was acquired from a variety of sources ranging from the Department of Homeland Security's Homeland Infrastructure Foundation-Level Data (HIFLD) to the New York State GIS Program Office via the Clearinghouse for the complete study area (not just areas within modeled flood areas) The raw data was either downloaded at the national or State level and with a temporal range from 2005 to 2017. Although most of the data was downloaded as vector point shapefiles, text files, and vector polygons. See appendix 1 for a full list of critical infrastructure and sources.

Critical infrastructure layers were projected to NAD 1983 UTM Zone 18N and clipped to NYS administrative boundaries. The attribute tables were standardized to contain only ID, name, type (if applicable), and administrative boundary name fields. The critical infrastructure data were joined to the building feature classes using the following steps:

- Joined point feature classes to the nearest tax parcel polygon with a corresponding property class.
- If the selected parcel is greater than 500 m from the point, join the point instead to the nearest parcel of any type.
- Selected building footprints that lie in the joined tax parcel or polygon infrastructure feature classes and added an attribute listing the type(s) of critical infrastructure.
- Any polygons that did not contain buildings were manually checked to ensure no buildings were overlooked in the digitizing process.

1.3 Flood Grids

The flood grids were created using FEMA floodplain data. The best available FEMA flood designations were stitched together using the Special Flood Hazard Areas (SFHA) and Q3 Flood Data created by FEMA from the FEMA 1999 Flood Insurance Rate Maps (FIRM).[1] Although the SFHA data is more up-to-date, it is not geographically complete and was supplemented with the Q3 data. The following steps were taken to transform the flood polygons into flood-depth rasters:

- Dissolved the polygons by floodplain classification to create 100- and 500-year flood outlines.
- Converted the outlines to points.
- Deleted points less than 300 meters from an adjacent point.
- Extracted elevation values from the NYS Digital Elevation Model (DEM).
- Interpolated, using ESRI's Inverse Distance Weighting tool, created a raster surface of water elevation values with the same cell size as the DEM.
- Subtracted the DEM from the interpolated surface to obtain a flood-depth raster.
- Clipped the resulting flood-depth raster to the floodplain polygon outline.
- Set negative or zero flood-depth values to 0.1 feet.

The resulting flood-depth grids were used in the impact assessment.

[1] https://gis.ny.gov/gisdata/inventories/details.cfm?DSID=246

2 Impact Assessment

2.1 Flood Loss

The FEMA Hazus-MH flood loss estimation methodology was modified for this project and scripted to run outside of the Hazus application. Data and methods were extracted from the user and technical manuals. The loss estimation was only completed for counties that have FEMA flood data (either SFHA or Q3 data). The first and most complicated steps were adding all of the attributes required for the depth-damage functions used in the Hazus process:

- Tax parcel data was separated by county and cleaned to resolve duplicate or overlapping geometry.
- 300 tax parcel property classes were matched to the 28 Hazus occupancy classes using their Standard Industrial Classification (SIC) codes.
    - In cases with no clear match, general occupancy classes were created such as RESX or X (residential or mix, respectively).
- The tax parcels were joined to the building footprints.
    - Footprints containing multiple parcels were given the sum value of those parcels.
    - If more than one building was present in a parcel, they were given an area-weighted proportion of the parcel value.
    - If a building did not fall into a parcel or the parcel did not have any information, it was joined to Hazus block-level data.
- Attributes from provided Hazus block-level data were joined to the building footprints.
- Flood zone (A, V, or Riverine) was determined by location relative to the SFHA vector data.
- Tables from the Hazus user manuals were used to determine the most likely First-Floor Elevation for every building based on the block type, FIRM entry date, year built, flood zone, and occupancy class.
- Table 14.6 (Default Hazus Contents Value Percent of Structure Value) was edited to include the general occupancy classes added in step 2 and applied to the building footprints.

Table 2. Building Attributes

Attributes and sources attached to the buildings for use in flood analysis. The occupancy classes were added to all footprints, not just those used in the flood loss estimation.

Attribute	Source
Occupancy Class	Tax parcels
Year Built	
Building Value	
FIRM Entry Date	Hazus block level data
Block type	
Flood zone	SFHA designation
First-Floor Elevation	Hazus manual tables
Contents Value	

Using the flood data and buildings with attributes, the flood analysis was performed. The steps for the analysis are as follows:

- The Hazus depth-damage functions for both buildings and contents were modified to eliminate attributes that were not available (number of stories, presence of a basement) and to add average functions for the additional general occupancy classes.
- The depth of flooding was extracted from the flood grids using the zonal statistics tool.
- The depth-damage functions were applied to each building to get an estimate of impact due to 100- and 500-year floods.
- The damage percentages were converted to the FEMA damage classifications (none, slight, moderate, and substantial) at the building level.
- Damages were aggregated to the block group, municipality, and county levels.

2.2 Adaptation Options

Adaptation options specific to each building occupancy class for all building footprints were determined through internet research and attached to building footprints. See Table 3 for the full list of adaptation options.

Table 3. Adaptation Options

Adaptation strategies appropriate for each occupancy class.

Occupancy Class	Adaptation
AGR1	(1) Integrate grass buffers, hedgerows, bunds, riparian buffer strips, temporary ponds, and ditching into agricultural land. (2) Plant seasonal cover crops. (3) Extensification and restricted grazing season. (4) Maintain and/or realign channels.
COM1	(1) Dry floodproof mechanical systems below BFE or elevate critical systems above BFE. (2) Wet floodproof space below BFE and fill basement to lowest adjacent grade. (3) Make a plan for protecting or moving inventory.
COM2	(1) Dry floodproof mechanical systems below BFE or elevate critical systems above BFE. (2) Wet floodproof space below BFE. (3) Plan for protecting or moving inventory. (4) Run elevators to upper landing, turn off disconnects, and shut and cover all openings.
COM3	(1) Elevate structures such that the lowest floor is above BFE. (2) Dry floodproof mechanical systems below BFE or elevate systems above BFE.
COM4	(1) Offices and workspaces should be kept out of floodplain as much as possible. (2) Dry floodproof critical systems below BFE or elevate systems above BFE. (3) Make a plan for protecting or moving inventory.
COM5	(1) Offices should be kept out of floodplain as much as possible. (2) Develop a plan to keep employees and communication channels safe.
COM6	(1) Floodproof, ensure there is backup power, and keep generators as safe as possible from floods (for example, on the roof). (2) Develop a flood emergency operations plan, as well as continual maintenance. (3) Maintain sensitive functions above BFE.
COM7	(1) Floodproof, ensure there is backup power, and keep generators as safe as possible from floods (for example, on the roof). (2) Develop a flood emergency operations plan, as well as continual maintenance. (3) Maintain sensitive functions above BFE.
COM8	(1) Store food and perishables in waterproof containers above BFE. (2) Build a mezzanine for storage or temporary relocation of valuable equipment.
COM9	(1) Store food and perishables in waterproof containers above BFE. (2) Install the HVAC system on the roof to reduce exposure to floodwaters.
COM10	(1) Reduce excessive paved surface, use pervious surfaces where possible.
COMX	(1) Elevate the site, utilities. and mechanical equipment above the BFE. (2) Wet or dry floodproof, reinforcing walls against floodwater. (3) Install drainage collection, sump pumps, and backflow prevention measures for sewage systems.
EDU1	(1) Elevate the site and all utilities above the BFE; anchor and protect all plumbing, water supply, gas lines, or electric cables below the BFE; prewire portable generator connections and install surge protection and uninterruptible power supplies.
EDU2	(1) Elevate the site and all utilities above the BFE; anchor and protect all plumbing, water supply, gas lines, or electric cables below the BFE; prewire portable generator connections and install surge protection and uninterruptible power supplies
EDUX	(1) Elevate the site and all utilities above the BFE; anchor and protect all plumbing, water supply, gas lines, or electric cables below the BFE; prewire portable generator connections and install surge protection and uninterruptible power supplies.
GOV1	(1) Establish local emergency response systems that can coordinate with municipality and county. (2) Ensure that emergency response facilities are floodproofed or out of floodplain, if possible (3) encourage development in less vulnerable areas.
GOV2	(1) Establish local emergency response systems that can coordinate with municipality and county. (2) Ensure that emergency response facilities are floodproofed or out of floodplain, if possible (3) encourage development in less vulnerable areas.

Table 3 continued

Occupancy Class	Adaptation
GOVX	(1) Establish local emergency response systems that can coordinate with municipality and county. (2) Ensure that emergency response facilities are floodproofed or out of floodplain, if possible (3) encourage development in less vulnerable areas.
IND1	(1) Elevate lowest floor above BFE or dry floodproof the entire building. (2) Install green infrastructure where possible. (3) Store electrical and mechanical equipment above BFE.
IND2	(1) Elevate lowest floor above BFE or dry floodproof the entire building. (2) Install elevated mezzanines to relocate equipment and inventory. (3) Store electrical and mechanical equipment above BFE.
IND3	(1) Floodproof critical storage spaces and wet floodproof offices. (2) Store food and perishables in waterproof containers above BFE. (3) Prepare a plan to protect brewing equipment and relocate vehicles. (4) Bolt tanks to platforms and elevate above BFE.
IND4	(1) Equipment should be located away from floodwaters, for example on the roof, on the landward side of a building, behind a structural element. (2) Install elevated mezzanines to relocate equipment. (3) Store electrical and mechanical equipment above BFE.
IND5	(1) Equipment should be located away from floodwaters, for example on the roof, on the landward side of a building, behind a structural element. (2) Install elevated mezzanines to relocate equipment. (3) Store electrical and mechanical equipment above BFE.
IND6	(1) Elevate equipment above BFE. (2) Use anchors and tie-down straps to keep shelves and materials in place.
INDX	(1) Equipment should be located away from floodwaters, for example on the roof, on the landward side of a building, behind a structural element. (2) Install elevated mezzanines to relocate equipment. (3) Store electrical and mechanical equipment above BFE.
REL1	(1) Obtain flood insurance. (2) Elevate furnace, water heater, and electric panel. (3) Incorporate flood openings below BFE, and ensure waterproof building materials (4) Develop a plan to keep community members safe.
RES1	(1) Obtain flood insurance. (2) Elevate furnace, water heater, and electric panel. (3) Install "check valves." (4) Incorporate flood openings below BFE and ensure waterproof building materials.
RES2	(1) Keep out of floodplain or elevate and anchor home. (2) Keep utilities, water heaters, and mechanical devices above BFE.
RES3	(1) Obtain flood insurance. (2) Elevate furnace, water heater, and electric panel. (3) Install "check valves." (4) Incorporate flood openings below BFE and ensure waterproof building materials.
RES4	(1) Store food and perishables in waterproof containers above BFE.
RES5	(1) Obtain flood insurance. (2) Elevate furnace, water heater, and electric panel. (3) Install "check valves." (4) Incorporate flood openings below BFE and ensure waterproof building materials.
RES6	(1) Keep an alternate power source. (2) Ensure that generators are as safe as possible from floods by keeping them on the roof.
RESX	(1) Obtain flood insurance. (2) Elevate furnace, water heater, and electric panel. (3) Install "check valves." (4) Incorporate flood openings below BFE, and ensure waterproof building materials.
X	(1) Elevate lowest floor above BFE. (2) Elevate mechanical equipment. (3) Wet floodproof with water resistant materials. (4) Dry floodproof to seal with removable barriers. (5) Limit use below BFE to allow movement of water.

3 Data and Services

3.1 Data Availability

The building footprints, 100-year flood depths, 500-year flood depths, and damage assessments have been assembled and are available on the CIESIN web site.[2] The footprints include the data source, date, a unique identifier, the occupancy class, and both the 100- and 500-year damage category. The Flood rasters include the estimated flood depth (feet), while the flood vector files show the outlines of the flood extents. The impact assessment include dollar estimates of damages for census units (block groups), municipalities, and counties. Dollar estimates for individual buildings are not available as these data are only considered accurate in aggregate, not at the individual structure level.

3.2 Services

Map services that allow the data to be visualized and queried have been developed and are available publicly on the CIESIN web site. These services include the building footprints and flood rasters. The services can be accessed via a web client published by CIESIN, or reached via an Application Programming Interface (API) and used directly in GIS software or other web applications. CIESIN user services can be queried about the data (via email or phone during CIESIN's regular business hours).

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2 http://fidss.ciesin.columbia.edu/building_data_adaptation

Appendix A. Data Sources

A variety of data sets were used to produce not only the building footprint data, but the critical infrastructure and flood scenarios as well. Below is a summary of the organizations and government agencies where data was collected.

A.1 Building Footprints

Source	Coverage
<Broome County GIS and Mapping Services (GIS Portal)>	Broome
Cortland County Planning Department	Cortland
Town of Tonawanda Technical Support Department	Tonawanda (town), Erie
City of Rochester Department of Information Technology	Rochester, Monroe
Oneida County Department of Planning	Oneida
Ontario County GIS Data Resource Center	Ontario
Oswego County Real Property Tax Service	Oswego
Saratoga County Planning Department	Saratoga
Schenectady County Planning Department	Schenectady
Steuben County Planning Department	Steuben
Sullivan County Real Property Tax Services	Sullivan
Tompkins County ITS GIS Division	Tompkins

A.2 Microsoft Footprints

U.S. Building Footprints. June 2018. Microsoft. https://github.com/Microsoft/USBuildingFootprints Accessed 06/29/2018.

A.3 LiDAR

New York Office of Information Technology Services. 2017–2018. New York Lidar Point Cloud. New York State.

A.4 Critical Infrastructure

Name	Source	Coverage	Date of Data
State Emergency Operations Centers	Department of Homeland Security's HIFLD	National	2015
Local Emergency Operations Centers (EOC)	Department of Homeland Security's HIFLD	National	2009
Emergency Medical Service (EMS) Stations	Department of Homeland Security's HIFLD	National	2010
Fire Stations	Department of Homeland Security's HIFLD	National	2010
Health Facilities	NYS Department of Health	State	2017
Nursing Homes	Department of Homeland Security's HIFLD	National	2017
Places of Worship	Department of Homeland Security's HIFLD	National	2016
Police Departments	Department of Homeland Security's HIFLD	National	2017
Power Plants	U.S Energy Information Administration	National	2017
Prisons	Department of Homeland Security's HIFLD	National	2017
Public Libraries	Amy Heebner, Division of Library Development, New York State Library	State	2017
Public Schools (K-12)	NYS Department of Education and NYS GIS Program Office	State	2017
Private Schools	Department of Homeland Security's HIFLD	National	2015
Colleges and Universities	Department of Homeland Security's HIFLD	National	2015
Wastewater Facilities	New York State Department of Environmental Conservation	State	2011

A.5 Flood Grids

Orton, P., MacManus, K., Fico, A., Mills, J., F. Conticello, F. Cioffi, T. Hall, N. Georgas, U. Lall, A. Blumberg. 2018. Hudson River and Western Long Island Sound Flood Elevations from Tides, Storm Surge and Rainfall. New York State.

Federal Emergency Management Agency (FEMA). 2019. National Flood Hazard Layer (NFHL) and Q3 Flood Data.

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