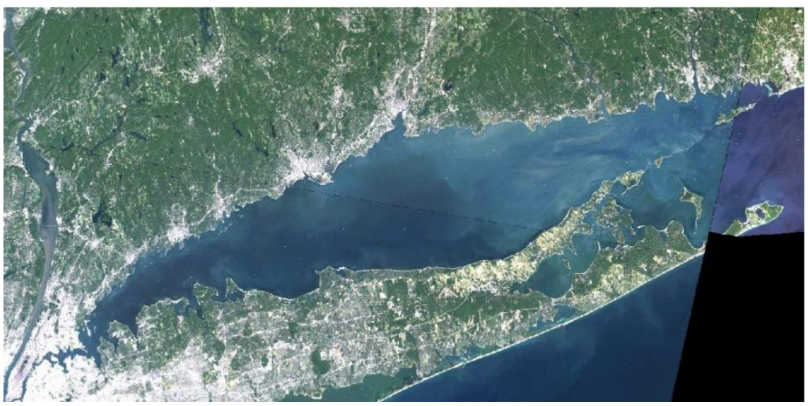

Long Island Sound Hydrodynamic and Water Quality Model Data Acquisition Plan

NYCDEP Bureau of Environmental Planning and Analysis

Contract: BEPA-LIS-HWQMS; PIN: 82619BEPALIS

February 2021

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Attachments

Tables

Acronyms

ADCPs	Acoustic Doppler Current Profilers
BOD	Biochemical Oxygen Demand
BSi	Biogenic Silica
CMAQ	Community Multiscale Air Quality Modeling System
CDOM	Colored Dissolved Organic Matter
CSO	Combined Sewer Overflow
CT	Connecticut
CTDEEP	Connecticut Department of Energy and Environmental Protection
DAP	Data Acquisition Plan
DEP	New York City Department of Environmental Protection
DHI	Danish Hydraulic Institute Water & Environment, Inc.
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DON	Dissolved Organic Nitrogen
DOP	Dissolved Organic Phosphorus
ENC	Electronic Nautical Charts
EPA	US Environmental Protection Agency
HDR	Henningson, Durham & Richardson Architecture & Engineering, PC
HWQMs	Hydrodynamic and Water Quality Models
IEC	Interstate Environmental Commission
LI	Long Island
LIS	Long Island Sound
LISICOS	Long Island Sound Integrated Coastal Observing System
MGD	Million Gallons per Day
MGDS	Marine Geoscience Data Systems
MEG	Model Evaluation Group
NADP	National Atmospheric Deposition Program
NARR	North American Regional Reanalysis
NH3	Ammonia
NH4	Ammonium
NJ	New Jersey

NJDEP	New Jersey Department of Environmental Protection
NJHDG	New Jersey Harbor Dischargers Group
NLM	Nitrogen Load Models
NO23	Nitrite plus Nitrate Nitrogen
NO3	Nitrate Nitrogen
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination
NWQMC	National Water Quality Monitoring Council
NY	New York
NYC	New York City
NYSDEC	New York State Department of Environmental Conservation
PAR	Photosynthetically Active Radiation
PO4	Orthophosphate
POC	Particulate Organic Carbon
PON	Particulate Organic Nitrogen
POP	Particulate Organic Phosphorus
PVSC	Passaic Valley Sewerage Commission
QAPP	Quality Assurance Project Plan
SAV	Submerged Aquatic Vegetation
SBU	Stoney Brook University
SCDHS	Suffolk County Department of Health Services
SFM	Sediment Nutrient Flux Model
SIA	Available Dissolved Silica
SOD	Sediment Oxygen Demand
SWEM	System-Wide Eutrophication Model
TDP	Total Dissolved Phosphorous
TDN	Total Dissolved Nitrogen
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TON	Total Organic Nitrogen
TOP	Total Organic Phosphorous
TP	Total Phosphorus
UConn	University of Connecticut
USACE	US Army Corps of Engineers
USGS	US Geological Survey
WQP	Water Quality Portal
WRRF	Wastewater Resource Recovery Facility

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1 Background

1.1 Project Purpose

The Long Island Sound-Hydrodynamic and Water Quality Modeling Support (LIS-HWQMS) project being completed for the New York City Department of Environmental Protection (DEP) includes the development of updated and refined hydrodynamic and water quality models (HWQMs) of Long Island Sound (LIS). The updated HWQMs will provide a framework to integrate water management planning and assessments in the future to support Clean Water Act compliance required under the 2000 Dissolved Oxygen (DO) TMDL (NYSDEC & CTDEP 2000) as well as future nutrient management activities and related evaluations. The models will need to accurately represent tidal transport/circulation and water quality over the entire inter-connected system (i.e., New York Bight, New York Harbor, offshore coastal waters) and other areas of the region (e.g., New Jersey tributaries, Newark Bay, Sandy Hook Bay), which is defined as the LIS study area.

Water quality in LIS and in NY/CT coastal embayments is a function of two main processes: physical controls due to tidal circulation and vertical density stratification (hydrodynamics); and biogeochemical controls driven by nutrient loading, algal nutrient cycling, sediment interactions and ecological processes (e.g., SAV and shellfish). In LIS, the physical/hydrodynamic tidal processes that drive circulation in three-dimensions are critical to reproducing water quality dynamics that affect nutrients, phytoplankton and DO levels in open waters, coastal embayments and the larger regional and coastal areas of NY, CT and NJ. The important biogeochemical processes controlling DO levels in LIS include: oxygen production processes (phytoplankton growth and atmospheric reaeration); and oxygen consumption processes (phytoplankton respiration/death, biochemical oxygen demand (BOD) or carbon oxidation, sediment oxygen demand and ammonia nitrification). In addition, other coupled and important eutrophication processes include: algal nutrient uptake and recycling; particulate organic matter settling and subsequent decay (diagenesis) in the sediment; light attenuation in the water column due to suspended solids and potentially colored dissolved organic matter (CDOM) and its effect on algal growth; organic to inorganic mineralization and hydrolysis processes; zooplankton grazing; and potential ecological interactions with SAV and filtering shellfish. Ecological modeling is not included as part of this project.

The selected hydrodynamic model must include the following features: time-variable and three-dimensional calculations; a curvilinear model grid with sufficient spatial resolution to represent shoreline features; vertical model grid segmentation to represent stratification processes; river, runoff and point source freshwater inflows; tidal and wind forcing; turbulent closure routines; density driven circulation; atmospheric coupling for surface mixing and heat exchange; and bottom roughness for bed induced mixing.

The selected water quality (eutrophication) model must include the following features: time-variable and three-dimensional calculations using the same model grid as the hydrodynamic model; particulate and dissolved organic nitrogen, phosphorus and carbon including at a minimum labile and refractory fractions; inorganic nitrogen (ammonia and nitrite plus nitrate); inorganic phosphorus (orthophosphate); biogenic and available silica; multiple algal groups; dissolved oxygen; light attenuation; particulate organic matter settling; and a coupled sediment flux model.

1.2 Data Acquisition Plan Purpose

In order to update the HWQMs of the LIS, hydrodynamic and water quality data will be acquired to develop model inputs and to calibrate and validate the models. This Data Acquisition Plan (DAP) outlines the data needs for model development as well as the process of obtaining and documenting the data. Since the specific model frameworks have not been chosen yet, the DAP will be updated if the chosen models require additional data beyond what is outlined in this document.

The LIS HWQMs will be calibrated with two modeling time periods. The first time period will use the historical 1994-1995 dataset used for the original calibration of the System-Wide Eutrophication Model (SWEM) of LIS and will involve refinement of the LIS model grid. The second time period will use more recent data from 2003-2010, which represents a time period before nitrogen controls were implemented at the East River WRRFs. After model calibration is complete, the LIS HWQMs will be validated with data from the 2011-2018 time period, which represents a time period after nitrogen controls were implemented at the East River WRRFs. In addition to the model calibration and validation time periods, a post-audit time period using data from 2019-2022 will be used for further validation of the LIS HWQMs. The data needed to perform calibration, validation and post-audit of the LIS HWQMs will need to be retrieved from a myriad of sources, which are outlined in this document.

The DAP was developed so that a systematic and thorough approach is used to acquire and document the necessary data to complete the project. The process outlined in the DAP will identify the data needed to be acquired and the quality standards to be used for the LIS modeling.

The DAP outlines the model data needs and the sources identified to fill these needs. The Project Team is familiar with the majority of data sources available to complete the model development but during the process of data acquisition, it is likely that more data will be identified. The goal of the DAP is to outline the necessary data to perform a successful model calibration and validation effort, and not necessarily to find and obtain all existing data for LIS. If data gaps are identified, those gaps will be specified in a Data Gap Report to be completed as part of the LIS-HWQMS project.

1.3 Roles and Responsibilities

Table 1-1 presents the roles and responsibilities of HDR staff that will complete the data acquisition process. Although HDR will have primary responsibility for acquiring data for the project, assistance will be provided by Nova Consulting and Engineering, LLC (Nova).

Table 1-1. HDR Roles and Responsibilities

Staff Member	Title	Responsibilities
Andrew Thuman	Project Manager	DAP oversight
Richard Isleib	Modeling Lead	Implementation and management of all data collection activities, QC of DAP implementation, subconsultant coordination
Nicholas Kim	Hydrodynamic Modeling Lead	Identification of hydrodynamic model needs and data sources
Cristhian Mancilla	Water Quality Modeling Lead	Identification of water quality model needs and data sources
Jaak Vandensype	Database Manager	Database development guidance
Modeling Staff	Hydrodynamic and Water Quality Modelers	Data retrieval, documentation, plotting/analysis
Nova Staff	HDR Staff Extension	Data acquisition and database support, data source QC protocol gathering and documentation
DHI Staff	GUI/DST Lead	Provide input on database development

1.4 Schedule

The modeling will be conducted in four phases: initial model refinements and calibration to the 1994-1995 dataset; model calibration to the 2003-2010 dataset; model validation to the 2011-2018 dataset; and post-audit modeling to the 2019-2022 dataset. Subsequently, the DAP will be completed in four phases. Data acquisition began near the end of 2020 as part of developing the DAP. The data acquisition for the 1994-1995 initial model calibration time period will be completed by February 28, 2021. Data acquisition for the longer calibration and validation time period (2003-2018) will be completed by December 31, 2021, although these efforts can be completed sooner based on project needs. The data acquisition for the 2019-2022 model post-audit time period will be completed when the QC'd data become available, which is expected to occur in mid-2023.

As the Contract Task 3 (1994-1995) and Task 4 (2003-2018 long-term and 2019-2022 post-audit) modeling progresses during the 2021-2023 time period, additional data gathering may be needed along with analysis of data to assist in developing model inputs and understanding water quality dynamics in LIS. These efforts will occur in the early stages of these tasks and is expected to occur during the first 3-6 months of each task.

1.5 Budget

The primary data acquisition process is included in Contract Task 2 (Quality Control and Quality Assurance) although additional data gathering may be required in Contract Task 3 (Selection, Calibration and Validation of Hydrodynamic and Water Quality Models) and Contract Task 4 (Setup and Execution of a Continuous Long-Term Simulation of the Hydrodynamic and Water Quality Models from 2003-2018). Any additional data needs and gathering required during execution of Contract Tasks 3 and 4 is not known at this time and will be addressed as additional data needs are identified during the modeling. The budget (including expenses) allocated for the Contract Task 2 data acquisition is presented in Table 1-2.

Table 1-2. Task 2 Data Acquisition Budget

Team Member	Hours	Budget
HDR	901	$131,992
Nova	664	$69,463
DHI	56	$9,857
Arcadis	80	$18,550
Total	1,701	$229,862

The hours/budget allocated in Contract Task 2 for DHI are to provide input on database development as it relates to GUI/DST development; and for Arcadis are to provide assistance in developing and maintaining the Quality Assurance Project Plan (QAPP).

2 Models

Although final selection of the LIS HWQMs has not occurred at this point in the project, the types of data needed to develop model inputs and for model calibration/validation and the associated data sources will be similar. The model data requirements are described further below.

2.1 Hydrodynamic Model

The selected hydrodynamic model will include the following features: time-variable and three-dimensional calculations; a curvilinear model grid with sufficient spatial resolution to represent shoreline features; vertical model grid segmentation to represent stratification processes; river, runoff and point source freshwater inflows; tidal and wind forcing; turbulent closure routines; density driven circulation; atmospheric coupling for surface mixing and heat exchange; and bottom roughness for bed induced mixing.

2.1.1 Input Data Needs

The hydrodynamic model requires information to define the physical constraints of the model domain. This information includes coastline data as well as bathymetric data, so the model can be described in three dimensions. Hydrodynamic models also require data to define open (tidal) boundary conditions of the model domain including water elevation to define the tides, temperature and salinity data. Freshwater inputs also need to be defined. These freshwater inputs include rivers, Water Resource Recovery Facility (WRRF) discharges, stormwater (e.g. combined sewer overflow (CSO), stormwater and direct runoff) and groundwater depending on the importance of each source. The model also requires meteorological data to describe atmospheric influences on the calculated hydrodynamic circulation. These data include wind speed and direction, air temperature, atmospheric pressure, relative humidity, and solar irradiance. Other information includes water clarity, which influences the penetration of solar irradiance into the water column.

For most of these data, it is important to have a continuous record although the required time scale may differ by model input type. Tidal water elevation and meteorological inputs are generally required on an hourly or shorter time interval basis. Other inputs such as river flows are adequate if daily information is available for model input. For some smaller (<1 MGD) WRRFs only monthly data may be available and is adequate for model input due to their smaller contribution to the overall water balance.

2.1.2 Calibration/Validation Data Needs

Calibration and validation data are used to help assess how well the model reproduces observed conditions, so these data help define water body conditions for the time periods being modeled. These data include tidal water elevation, temperature, salinity, and current speed and direction (where available). Continuous data (e.g., hourly) are more useful for model calibration and validation, especially for water elevation and currents. Salinity and temperature grab sampling data are helpful for these constituents when continuous data are not available. It is important that the model reproduces these constituents because they affect water column density, which affects vertical mixing. Vertical mixing is an important factor impacting bottom water DO levels. It is preferable to have data that covers the spatial extent of the modeling domain and spatial coverage is more important when spatial variability is known to occur.

2.2 Water Quality Model

The selected water quality (eutrophication) model will include the following features: time-variable and three-dimensional calculations using the same model grid as the hydrodynamic model; particulate and dissolved organic nitrogen, phosphorus and carbon including at a minimum labile and refractory fractions; inorganic nitrogen (ammonia and nitrite plus nitrate); inorganic phosphorus (orthophosphate); biogenic and available silica; multiple algal groups; dissolved oxygen; light attenuation; particulate organic matter settling; and a coupled sediment flux model.

2.2.1 Input Data Needs

Water quality models of eutrophication processes have more state-variables than hydrodynamic models, which means that more constituents need to be defined at the model boundaries and for model loads. This translates to a larger data gathering effort. The water quality model will include the following constituents.

- Particulate organic nitrogen (PON)
- Dissolved organic nitrogen (DON)
- Ammonia nitrogen (NH3)
- Nitrite plus nitrate nitrogen (NO23)
- Particulate organic phosphorus (POP)
- Dissolved organic phosphorus (DOP)
- Orthophosphate (PO4)
- Biogenic silica (BSi)
- Available dissolved silica (SIA)
- Particulate organic carbon (POC)
- Dissolved organic carbon (DOC)
- Multiple phytoplankton groups (as represented by chlorophyll-a)
    - At this time, it is anticipated that two algal groups (e.g., winter/spring and summer) will be used that represent winter/spring and summer algal groups.
- Dissolved oxygen (DO)

In addition, organic nitrogen, phosphorus and carbon will be divided by reactivity (i.e., reactive, labile, refractory) based on available information, prior studies and best professional judgement. Often the data are not available for all of the constituents, so other measured data are used to define boundary conditions or loads. For example, total Kjeldahl nitrogen (TKN) and NH3 data can be used to calculate total organic nitrogen (TON) and then organic nitrogen can be split into PON and DON based on best professional judgment, literature values or as part of the calibration and validation process.

Boundary conditions inputs are generally based on grab sampling data (where available), a calibrated model with a larger domain that encompasses the LIS model domain, or estimated in part from calibration and validation to observed data within the model domain.

External model loads (point and nonpoint source) will be based on WRRF discharge records, conveyance models (DEP InfoWorks models for CSO and stormwater discharges) and monitoring data (e.g., rivers and tributaries). These loads can be specified on a time frequency ranging from hourly (CSOs) to daily (WRRFs or rivers) to monthly (small WRRFs or tributaries).

Major river loads will be based on measured daily average river flow and available water quality data. Since river water quality data will most likely not be available on a daily basis, either concentration versus flow relationships will be developed to interpolate the concentrations to a daily value, or a load estimation program (e.g., USGS LOADEST) will be used. Coastal watershed loads will be developed based on available Nitrogen Load Models (NLMs) for CT, NY and the north shore Long Island (LI). These NLMs will be available from the University of Connecticut (UConn, Dr. Jamie Vaudrey) or as developed by CDM Smith as part of LI nitrogen management planning efforts. It is anticipated that these coastal watershed loads will be setup on either an annual or seasonal basis. USGS, NYSDEC, and the Rhode Island Department of Environmental Management (RIDEM) will be contacted to fill in gaps not included in existing models.

2.2.2 Calibration/Validation Data Needs

It is expected that much of the calibration and validation data will consist of grab sampling data for routinely monitored parameters (e.g., total nitrogen (TN) and total phosphorus (TP), TKN, NH3, NO23, PO4, chlorophyll-a). This will require the various model constituents to be processed before comparison to the observed data (e.g., sum of PON, DON, NH3 and NO23 for TN). Chlorophyll-a will be used to assign concentrations for the various phytoplankton groups; and if algal species data are available these data can be used to specify how chlorophyll-a data can be split into different algal groups (e.g., winter, spring and summer groups). Generally, weekly or monthly data are available for model calibration and validation with certain locations having continuous DO data available.

If available, additional special study data may be utilized to help define model coefficients. These types of data may include: algal productivity and/or respiration data to estimate algal growth and respiration rates; long-term BOD studies to estimate carbon oxidation; and Secchi depth or vertical profiles of photosynthetically active radiation (PAR) to estimate light extinction.

The water quality model will also include a sediment nutrient flux model (SFM) for the calculation of sediment oxygen demand (SOD) and sediment nutrient fluxes as a function of settled organic matter and subsequent sediment diagenesis. The types of sediment data needed to calibrate the SFM include: porewater and solid phase data; and SOD, ammonia, nitrate, orthophosphate sediment flux data. Generally, seasonal measurements of these types of data are ideal along with good spatial coverage in open water areas and in embayments.

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3 Identifying Data Sources

3.1 In-house Data

HDR has been involved with numerous modeling projects in and around LIS and will search its data archives to retrieve data for this modeling effort. In-house data include the original Battelle 1994-1995 dataset used to develop SWEM, DEP's Harbor Survey dataset, the New Jersey Harbor Dischargers Group (NJHDG) dataset, and the Connecticut Department of Energy and Environmental Protection (CTDEEP) dataset.

3.2 Publicly Available Data

Many public entities have data relevant to the LIS modeling on their websites or provide contact information for people who have access to historical data. HDR will retrieve readily available data and reach out to entities that have relevant data where data gaps exist. The primary agencies with relevant data include the following sources:

- National Oceanic and Atmospheric Administration (NOAA);
- New York City Department of Environmental Protection (NYCDEP)
- US Army Corps of Engineers (USACE);
- Connecticut Department of Energy and Environmental Protection (CTDEEP);
- New York State Department of Environmental Conservation (NYSDEC);
- Interstate Environmental Commission (IEC);
- US Environmental Protection Agency (EPA);
- US Geological Survey (USGS);
- National Atmospheric Deposition Program (NADP);
- New Jersey Department of Environmental Protection (NJDEP); and
- Long Island Sound Integrated Coastal Observing System (LISICOS).

The Water Quality Portal (WQP) (Read *et al.*, 2017) is also a resource that can be used to acquire available data. The WQP (http://www.waterqualitydata.us/) was developed as a national (and international) database by the National Water Quality Monitoring Council (NWQMC), EPA, and the USGS to provide a single point of access to water quality data collected over the past century. The WQP provides access to EPA STORET, USGS NWIS, and USDA STEWARDS hydrographic and water quality data.

3.2.1 Embayment Data

Two stand-alone embayment models will also be developed as part of this project. The embayments will include one in Connecticut and one on the north shore of LI. These embayments have not yet been identified and the effort to identify the data for each embayment has not been completed yet. However, HDR was able to obtain the embayment database compiled by TetraTech (2018) used to suggest nutrient endpoints for embayments in LIS. Figures of the sampling locations (embayments and other locations) of the studies that were compiled by TetraTech are included in Attachment 2. This resource will be revisited once the embayments are chosen. The endpoint document also identifies sources for the individual datasets and these sources will be contacted if additional data are needed.

An additional source of data for the embayments is the Universal Water Study (UWS) for Long Island Sound (Water Monitoring: Ecological Health - Save the Sound). The UWS consists of approximately two-dozen participants that follow the same sampling protocols for numerous embayments on LIS. The UWS began in 2017 and can potentially provide data for the LI embayment that is selected for model development.

3.3 Literature Searches

Based on the data sources identified, HDR believes that sufficient water quality data will be available for model calibration, validation and post-auditing in the open waters of LIS. HDR will conduct Google Scholar searches to identify and potentially acquire special study data that are not available from publicly available sources to fill in data gaps for model input or model calibration and validation. HDR will also work within the Project Team (Section 3.5) and the Long Island Sound Science and Technical Advisory Team (LIS STAC) (Section 3.6) to identify and acquire additional "grey" literature if available.

3.4 Existing Model Output

HDR will assess whether any publicly available, existing models can be used to specify loads or boundary conditions.

3.5 Team Networking

The Project Team includes members from Stony Brook University (SBU), Camp, Dresser, McKee & Smith (CDM Smith), Arcadis of New York, Inc. (Arcadis), Nova Consulting and Engineering, LLC (Nova) and DHI Water & Environment, Inc. (DHI) that may be aware of unpublished datasets that could be useful for modeling. The Project Team will reach out to colleagues to identify other sources of data.

In addition, the Model Evaluation Group (MEG) may also be aware of LIS data sources and relevant references to support development of the LIS HWQMs. As the project progresses, the MEG members will be contacted to determine whether they are aware of additional data sources that could benefit the project.

3.6 LIS STAC

HDR will work with members of the LIS STAC to identify literature and datasets not readily available online.

4 Data Sources

This section identifies known data sources that satisfy the requirements for developing model inputs and for calibrating/validating typical sophisticated HWQMs. The primary data sources to be used for model calibration and validation include: Battelle 1994-1995 data; CTDEEP LIS data; DEP Harbor Survey data; NJHDG data; and IEC LIS data. The monitoring locations where data are available from these data sources are presented in Attachment 1.

Much of the existing data is available on-line from the various data sources (e.g., DEP, NOAA, USGS) and will be downloaded as needed. If the needed data are not available on-line or more condensed/entire datasets are available from the data sources, outreach to the data source point of contact will be completed to obtain the data.

In addition, data needs for the HWQMs may come from the same data source (e.g., USGS flow and water quality data). In these cases, data needed for the hydrodynamic model and for the water quality model will be obtained at the same time.

4.1 Hydrodynamic Model

4.1.1 Inputs

4.1.1.1 Model Grid/Coastline

Coastline data defines the physical boundary of the model and helps define the shape of the model grid. The following data source will be queried.

NOAA

Coastline data are available from NOAA at the following site https://encdirect.noaa.gov/. This website provides electronic nautical charts (ENC) for contiguous US waters. Coastline, sounding data and navigation channel layout can be downloaded from this site.

4.1.1.2 Bathymetry

Bathymetric data define the vertical dimensions of the model. The following data sources will be queried.

NOAA

Bathymetry data are available from the Marine Geoscience Data System (MGDS: Long Island Sound Data Portal (marine-geo.org), and NOAA (https://encdirect.noaa.gov/), (Mapping the Long Island Sound Seafloor - NCCOS Coastal Science Website (noaa.gov).

The NOAA datasets are available for Phase 1 (central basin), Phase 2 (eastern basin) and Phase 3 (western basin) and are available for download at the following links.

Bathymetry and acoustic backscatter collected in Long Island Sound for the Phase I Long Island Sound Seafloor Mapping Project 2014 (NCEI Accession 0167946) - NCCOS Coastal Science Website (noaa.gov)

Bathymetry, acoustic backscatter, and LiDAR data collected in Long Island Sound for the Phase II Long Island Sound Seafloor Mapping Project 2015 (NCEI Accession 0167531) - NCCOS Coastal Science Website (noaa.gov)

Bathymetry and acoustic backscatter data collected in Long Island Sound for the Phase III Long Island Sound Seafloor Mapping Project 2015 (NCEI Accession 0167532) - NCCOS Coastal Science Website (noaa.gov)

USACE

HDR has historical dredging records for New York Harbor and the Passaic River. Due to the length of the model calibration and validation time periods, it may be necessary to adjust model depths for different years due to dredging, which will be discussed further during model development. Prior to developing the model grid, HDR will contact the USACE to determine whether more recent dredging information is available.

NYSDEC, CTDEEP and UConn

These entities (NYSDEC, CTDEEP and UConn) may have local information on dredging plans or other projects and will be contacted

Long Island Sound Research Center

The Long Island Sound Research Center has links to multiple bathymetric surveys of LIS: Long Island Sound Resource Center - Data Catalogue (uconn.edu).

4.1.1.3 Boundary Conditions

Boundary conditions define conditions at the tidal (open) ends of the hydrodynamic model domain. These conditions include water elevation, salinity and temperature. The following data sources will be queried.

Water Elevation

NOAA does not have tide gages near the probable edge of the model offshore boundaries, but existing gages on the NOAA website (CO-OPS Products - NOAA Tides & Currents) can be used to help define the model boundary water elevations. HDR will assess whether any existing publicly available models can also be used to assign water elevation at the model boundary conditions.

In previous applications of models with similar model domains to the LIS model, data were not used to assign water elevations at the open ocean boundaries. A process was developed that applied long-term circulation, tidal fluctuations and sub-tidal meteorological forcing components. The process is described in the Passaic Valley Sewerage Commission (PVSC) modeling report (2020) in Appendix O at the link below.

https://www.nj.gov/dep/dwq/pdf/CSO_SIAR_AppendixO_PVSC_20201001.pdf

Salinity and Temperature

Salinity and temperature boundary conditions will be obtained from climatological data contained in the NOAA World Ocean Atlas 2013 (WOA2013). As climatological data do not represent true monthly variations of salinity and temperature for the periods of model calibration and validation, it will be necessary to adjust the boundary conditions defined from WOA2013 so that computed salinity and temperature match the monthly mean salinity and temperature at the open ocean boundary.

HDR will search for other salinity and temperature data sources that may be used to supplement the World Ocean Atlas data.

4.1.1.4 Freshwater Sources

Freshwater inputs define the sources, volumes, and timing of freshwater discharges to LIS. These sources include rivers, WRRFs, CSOs, direct runoff, stormwater, and groundwater.

Rivers

River flows are available from the USGS. Table 4-1 below lists the rivers used in a previous analysis of the same region as the LIS model. In some cases, the gages do not include the entire drainage area, so the flows will be adjusted by a ratio of gaged to ungaged area. It is anticipated that these river gages will be used to develop model inputs but an updated USGS gage query will be completed and significant ungaged tributaries will be identified and included in the modeling.

Table 4-1. List of Rivers

River	Gauging Station #
1. Hudson River at Green Island	01358000[(1)]
2. Hackensack River	01378500
3. Passaic River	01389500
4. Saddle River	01391500
5. Raritan River	01403060
6. Normans Kill (Wappinger)	01372500[(2)]
7. Moordener Kill (Wappinger)	01372500[(2)]
8. Esopus Creek	01364500
9. Roundout Creek+Wallkill River	01367500/01371500
10. Wappinger Creek+Fishkill	01372500
11. Croton River	01375000
12. Saw Mill River	01376500[(2)]
13. Bronx River	01302000
14. Navesink +Shrewsbury	01407500
15. Catskill River (Wappinger)	01372500
16. Norwalk River	01209700
17. Housatonic River + Naugatuck River	01205500/01208500
18. Quinnipiac River	01196500
19. Connecticut River	01184000

River	Gauging Station #
20. Thames River (Shetucket + Quinebaug)	01122500/01127000
21. Manasquan + Shark Rivers	01408000/01407705
22. Metedeconk + Toms Rivers	01408120/01408500
23. Mulica River + Westconk River (Oswego, Batso, Bass)	01409400/01410000/ 01409500/01410150
24. Great Egg Harbor + Tuckahoe River	01411000/01411300

Notes:
(1) If no Gauge for 01358000 then add Mohawk and Hudson R. above Lock #1 (01357500+01335754)
(2) Use Wappinger data 01372500 to estimate the flow for this tributary

Coastal Watersheds

Coastal watersheds represent ungaged areas with direct runoff directly into LIS (e.g., north shore of LI). Freshwater flows can be estimated using a ratio of watershed area to a similar gaged watershed or from existing NLMs. Additionally, simple rainfall-runoff models (e.g., RAINMAN) can be used to estimate coastal watershed surface runoff flows. The RAINMAN model is similar to the rational runoff method (Q=CIA) with updates including time-variable analysis and the ability to represent sewer collection systems (HydroQual, 2005). USGS flow data will also be used as a resource to estimate these coastal watershed flows.

WRRFs

DEP will supply WRRF plant flow and temperature records for the 14 WRRFs for the period of 2003-2018 that will be used for model calibration and validation. Equivalent data will be required for the 2019-2022 post-audit time period.

NYSDEC, CTDEEP, RIDEM and NJDEP will be contacted to obtain WRRF information for NY, CT, RI and NJ discharges that affect water quality within the model domain outside of NYC (e.g., municipal and industrial discharges greater than one million gallons per day (MGD)).

HDR will review data from EPA's Permit Compliance System and Integrated Compliance Information System to view Discharge Monitoring Reports of facilities that discharge into the LIS (PCS-ICIS Search | Envirofacts | US EPA) or (Enforcement and Compliance History Online | US EPA) if additional information on point source discharges are required.

HDR has contacts within the membership of the NJHDG, including the PVSC that can be contacted for information related to discharges by northern New Jersey WRRFs.

CSOs, Stormwater and Direct Runoff

DEP has committed to providing output from its InfoWorks models for NYC's WRRFs sewershed areas. These conveyance models provide flow volumes for CSOs, stormwater and direct runoff.

NYSDEC, CTDEEP, RIDEM, and NJDEP will also be contacted to obtain available data on CSO, stormwater and direct runoff discharges to LIS and the Hudson River.

In previous NYC area modeling analyses, HDR has used the simple RAINMAN rainfall-runoff model to estimate runoff flows for areas without data. This approach can still be used if data are not found for watershed areas that discharge to the model domain that do not have sufficient data to develop model inputs.

Groundwater

USGS is currently working on a groundwater model for the State of Connecticut. If output from this model is available for the model calibration and validation periods, it will be obtained for assigning model groundwater flow inputs in model areas where groundwater sources are significant. HDR will contact USGS to discuss how their models can be used for input to the LIS and embayment models.

CDM Smith and USGS have groundwater models for much of LI. If output from this model is available for the model calibration and validation periods, it will be obtained for assigning model groundwater flow inputs in model areas where groundwater sources are significant.

These groundwater models will be reviewed closely especially when developing the two embayment models.

4.1.1.5 Meteorology

Meteorological data provides information on the atmospheric forcings on a waterbody that affect circulation and density stratification. These model forcing inputs include wind speed and direction, atmospheric pressure, relative humidity, air temperature, and solar radiation as impacted by cloud cover. Water clarity can also impact the penetration of solar radiation into the water column, which affects temperature and density stratification.

The North American Regional Reanalysis (NARR) (https://psl.noaa.gov/data/gridded/data.narr.html) database provides smoothed data on a 0.25 deg resolution (~30km). These meteorological data have been applied for the LTCP2 and PVSC regional hydrodynamic models. These data can be complimented with readily available local meteorological data from Newark Liberty International Airport (EWR), John F. Kennedy International Airport (JFK), Central Park (CPK) and other stations.

Solar radiation inputs can be estimated from cloud cover and can be used with NOAA cloud cover data or NARR estimates to calculate solar radiation for model input.

The LISICOS program (UConn's Long Island Sound Observatory) has monitoring buoys that collect real time meteorological data. More research will need to be done by HDR to determine if these data are archived and available for model input use.

Brookhaven National Laboratory measures solar radiation (Meteorology Services - Data Downloads (bnl.gov)) and these data can also be used to supplement other available information.

4.1.2 Calibration and Validation

Calibration and validation data help assess how well the model reproduces the hydrodynamic conditions in the LIS. These data include water elevation, salinity, temperature and current measurements (where available).

4.1.2.1 Water Elevation

Tide gages and acoustic Doppler current profilers (ADCPs) can provide water elevation measurements that can be used to assess if the model is reproducing the effects of the astronomical tides and meteorological forcings on water elevation.

NOAA has multiple tide gages (real-time and predictions) within the proposed modeling domain that can be used for model calibration and validation (CO-OPS Products - NOAA Tides & Currents).

USGS also has tide gages that can be used for model calibration and validation (Southeastern New York Coastal Monitoring (usgs.gov)).

4.1.2.2 Salinity and Temperature

Salinity and temperature data are used to assess how well the model reproduces these constituents. It is important that the model reproduces these constituents because they affect water column density, which affects vertical mixing. Vertical mixing is an important factor impacting bottom water dissolved oxygen levels.

DEP Harbor Survey data includes salinity and temperature data that can be used for model calibration and validation in western LIS, East River, Hudson River and Jamaica Bay.

CTDEEP has salinity and temperature data that can be used for model calibration and validation (Water Monitoring Data Availability (ct.gov)) and has monitoring locations throughout LIS.

The NJHDG dataset includes salinity and temperature data in the Hudson River and northern NJ waters that can be used for model calibration and validation. NJHDG data are typically available upon request from the NJHDG and HDR has working relationships with NJHDG.

LISICOS

The LISICOS program website (UConn's Long Island Sound Observatory) allows for downloading of CTDEEP salinity and temperature conductivity, temperature and DO (CTD) data at multiple sites. The LISICOS program has monitoring buoys that collect continuous salinity and temperature measurements that can be used for model calibration and validation.

HDR has the original Battelle 1994-1995 dataset used for the original model calibration of SWEM and the salinity and temperature data from this dataset will be used for the initial model calibration.

SCDHS

The Suffolk County Department of Health Services (SCDHS) monitors water quality along the north and south shores of LI. The salinity and temperature data will be obtained for the north shore embayments for model calibration and validation of the open waters LIS hydrodynamic model and one NY embayment hydrodynamic model. HDR will contact SCDHS to obtain the relevant salinity and temperature data.

EPA

EPA's WQX/STORET site (Water Quality Data Download | Water Data and Tools | US EPA) has water quality data that can be used to supplement the DEP, CTDEEP and SCDHS salinity and temperature data for model calibration and validation.

Stony Brook University

HDR will contact SBU team members to assess whether additional data are available.

4.1.2.3 Current Speed and Direction

Current measurements allow for comparison between measured and modeled currents for evaluating circulation in the specific areas where monitoring data is available. The following data sources will be queried.

LISICOS

The Long Island Sound Observatory has current data (UConn's Long Island Sound Observatory) at various stations around LIS. These data can potentially be used for model calibration and validation. The LISICOS website indicates that ADCP measurements are collected at the Western Sound Station (NOAA ID 44040). LISICOS will be contacted to find out if the data are archived and if other site data is available.

4.2 Water Quality Model

As the selected water quality model will have a number of parameters that may not be routinely monitored (e.g., particulate and DON and phosphorus), the available data will need to be processed to generate values needed for model inputs. Examples of a few data processing steps that may be required are outlined below.

- TON = TKN – NH3
  - PON and DON estimated from other datasets, literature or best professional judgment (e.g., DON = 0.8 x TON, PON = 0.2 x TON)
- DON = Total dissolved nitrogen (TDN) – NH3 – NO23
- Total organic phosphorus (TOP) = TP – PO4
  - POP and DOP estimated from other datasets, literature or best professional judgement (e.g., DOP = 0.8 x TOP, POP = 0.2 x TOP)

- DOP = Total dissolved phosphorus (TDP) – PO4

These data processing steps will be dependent on the available data from a specific data source and will be discussed and documented during the modeling process.

4.2.1 Inputs

4.2.1.1 Boundary Conditions

Water quality boundary conditions define the water quality concentrations at the tidal (open) ends of the model domain. These boundary conditions need to be specified for all of the modeled constituents as noted in Section 2.2.1. The following data sources will be queried.

EPA's WQX/STORET site (Water Quality Data Download | Water Data and Tools | US EPA) has water quality data that can potentially be used to specify the offshore tidal (open) boundary conditions.

NOAA's World Ocean Database (National Centers for Environmental Information (noaa.gov)) potentially has DO, nutrient and chlorophyll data that could be used for boundary conditions and will be reviewed.

4.2.1.2 Loads

Rivers

Water quality concentrations from available USGS sites can be used together with USGS gage flow to create loads for each gaged river watershed. This could be accomplished by: interpolating between concentration measurements to calculate daily loads from daily flow data; developing concentration versus flow relationships to fill in daily concentrations using the resulting relationships; developing monthly or seasonal loading concentrations by pooling concentrations from multiple years for each period and calculating daily loads with flow varying daily and concentrations varying seasonally or monthly; or by using a load estimation program such as the USGS LOADEST program.

Coastal Watershed Loads

Coastal watershed loads to LIS will be required for the smaller watersheds that drain directly to LIS along portions of Westchester County, the Connecticut coastline, the Rhode Island coastline and the north shore of LI coastline that are not represented by a major river load model input. It is anticipated that the NLMs developed by UConn for the Connecticut coastal watersheds and NLMs developed by CDM Smith (LIS Project Team Member) for the north shore of LI, will be used to determine annual or seasonal loads. Currently these NLMs are developed for TN and an approach will be developed and discussed on how to calculate loads for other important model inputs (e.g., TP, DOC).

WRRFs

DEP will supply WRRF water quality records for its 14 WRRFs for the period of 2003-2018 that will be used for model calibration and validation. The same data will be required for the 2019-2022 post-audit time period.

NYSDEC, CTDEEP and NJDEP will be contacted to obtain WRRF information for NY, CT and NJ discharges that affect water quality within the model domain outside of NYC (e.g., municipal and industrial discharges greater than 1 MGD). If the embayments chosen for stand-alone embayment modeling include discharges from facilities smaller than 1 MGD, those facilities will be considered for inclusion depending on the relative contribution of loads to the embayment.

It is anticipated that not all modeled constituents will be included in available point source records. Additional contact with these State agencies will be conducted to determine if any non-reported data is available to help estimate inputs for the needed model parameters. If no additional data is available, an approach will be developed and discussed to estimate the missing model inputs.

HDR will review data from EPA's Permit Compliance System and Integrated Compliance Information System to view Discharge Monitoring Reports of facilities that discharge into the LIS (PCS-ICIS Search | Envirofacts | US EPA) to aid in developing point source model inputs.

HDR will contact the NJHDG, including the PVSC to determine what information related to discharges by northern New Jersey WRRFs are available.

IEC's staff conducts inspections with sampling at industrial facilities and municipal WRRFs year-round that include effluent sampling. Samples collected at these facilities are analyzed in the IEC's certified laboratory to determine compliance with the IEC's Water Quality Regulations and with each facility's specific National Pollutant Discharge Elimination Program (NPDES) permit. The Commission reports results of inspections to the facility, the appropriate State agency and EPA and enters the data into the EPA developed database, ICIS. HDR will determine if it can gain access to these data and if so, will use the data as needed to assist in developing point source model inputs.

Vaudrey et al. (2016) developed a Long Island Sound Loading Model for Connecticut and New York sources to the LIS that can be used for guidance in assigning loads from WRRFs and other sources on an annual basis. The report indicates that WRRF information was obtained from CTDEEP.

CSOs, Stormwater and Direct Runoff

DEP has committed to providing output from its InfoWorks models for NYC's WRRFs that will include flow volumes; and HDR will obtain readily available flow volume information from other municipalities with discharges to the LIS study area. HDR will use available CSO and stormwater monitoring data to apply discharge concentrations (e.g., event mean concentration) to the flows supplied by the InfoWorks models or flow volume estimates. In this manner the CSO and stormwater loads will be developed.

Groundwater

Groundwater loads were not included in the original SWEM modeling. Some literature indicates that it could be important, especially for embayments. If included, loads will be calculated based on flows applied in the hydrodynamic model and groundwater data available from USGS or groundwater modeling by USGS and/or CDM Smith.

Atmospheric Deposition

The NADP (NTN Data (wisc.edu)) has monitoring data for ammonium (NH4), nitrate (NO3) and TN that will be used to estimate dry and wet atmospheric deposition loads along with rainfall data.

EPA's Community Multiscale Air Quality Modeling System (CMAQ) (CMAQ: The Community Multiscale Air Quality Modeling System | US EPA) output could be used to supply ammonium and nitrate deposition rates for developing atmospheric deposition loads and will be compared to the loads developed using the NADP data.

4.2.1.3 Parameters and Constants

Parameters and constants define the rates for various model parameter transformation pathways (e.g., algal growth and respiration, ammonia nitrification), among other things. Parameters and constants are often based on literature values, prior modeling efforts and best professional judgment. Previous SWEM modeling will provide a starting point for many parameters and constants as SWEM was calibrated to the 1994-1995 dataset. In addition, UConn and SBU will be contacted to determine if any special studies have been completed that may also provide guidance in setting up model parameters and constants (e.g., algal respiration studies).

DEP Harbor Survey and CTDEEP datasets have Secchi depth and vertical PAR data that can be used to estimate light extinction coefficients. Initial literature reviews indicate that UConn has primary productivity and respiration data that can be used to guide assigning algal growth and respiration rates. CTDEEP measures zooplankton at a few stations that can be used to estimate zooplankton grazing rates.

4.2.1.4 Time Variable Functions

Time-variable functions are model inputs that vary over time. These functions can include the daily amount of solar radiation, the length of daylight, or wind speed affecting atmospheric reaeration. The following datasets will be queried.

Solar (Shortwave) Radiation

The LISICOS website indicates that solar radiation measurements are collected at the Western Sound Station (NOAA ID 44040). LISICOS will be contacted to find out if the data are available for use in setting up model inputs.

Brookhaven National Laboratory measures solar radiation (Meteorology Services - Data Downloads (bnl.gov)). These data will be obtained and can also be used to supplement other available information.

The NARR database also includes shortwave solar radiation.

If solar radiation data are not available, or only available for certain time periods, solar radiation can be calculated from cloud cover data, which is typically more readily available.

Fraction of Daylight

Fraction of daylight input tells the model how long the sun shines on a given day and will be estimated given the latitude of the model study area.

Wind Speed

Wind speed can be used to calculate atmospheric reaeration rate (per time units) in addition to using surface current speeds calculated by the hydrodynamic model. If wind speed is used, it will be transferred from the hydrodynamic model to the water quality model for use in calculating atmospheric reaeration. In some instances, an oxygen transfer coefficient (length per time units) may be used that can be assigned as spatially varying.

The LISICOS program (UConn's Long Island Sound Observatory) has monitoring buoys that collect real-time meteorological data. Research will need to be done to determine if these data are archived and are useful for setting up model inputs.

4.2.2 Calibration and Validation

4.2.2.1 Water Column

Grab Samples

HDR has the DEP Harbor Survey dataset to use for model calibration and validation, and it is also available online (Harbor Water Quality - DEP (nyc.gov)).

HDR has portions of the CTDEEP dataset and will acquire any missing data needed for model calibration and validation (Long Island Sound Water Quality and Hypoxia Monitoring Program Overview (ct.gov)).

HDR has downloaded the IEC Access database (Western Long Island Sound Monitoring Program | Interstate Environmental Commission (iec-nynjct.org)). These data will be used to supplement the DEP and CTDEEP datasets for model calibration and validation.

The NJHDG has been sampling in NJ waters since 2003 (Passaic Valley Sewerage Commission | What We Do (nj.gov)). HDR has the NJHDG database and can request additional years for the validation period when the data become available.

HDR will access NJDEP's data mining tool to find additional data for model calibration (NJDEP New Jersey Department of Environmental Protection (DataMiner) (state.nj.us)) in NJ water bodies.

EPA's WQX/STORET site (Water Quality Data Download | Water Data and Tools | US EPA) has water quality data that can be used to supplement the DEP, CTDEEP and other data for water quality model calibration and validation.

In 2008 and 2009, EPA Region 2 sampled nutrients and DO in the NY Bight under an approved QAPP. One of the years may also have had phytoplankton/zooplankton data available. In 2010, EPA conducted synoptic DO monitoring in the NY Bight under an approved QAPP. Further outreach to EPA on this 2008, 2009 and 2010 data will be completed to obtain the data. Although this data is not in LIS, use of this data for model calibration in other areas of the model study area will be important.

Additional data may be available from the National Aquatic Resource Surveys (Data from the National Aquatic Resource Surveys | National Aquatic Resource Surveys | US EPA) and will be reviewed for use in the model calibration and validation.

HDR will contact SBU to assess whether additional data are available for north shore LI embayments. The SCDHS monitors water quality along the north and south shores of LI. HDR will contact SCDHS to obtain relevant water quality data in north shore embayments for model calibration and validation.

Other data sources may be identified during the data acquisition process and will be queried as needed.

Continuous Data Sondes

The LISICOS program (UConn's Long Island Sound Observatory) has monitoring buoys that collect continuous DO measurements. These data can be downloaded from their website and will be used for model calibration and validation.

From 2011 through 2017, NJDEP completed glider surveys using an autonomous underwater vehicle along paths near the NJ coastline. These surveys included continuous recordings of temperature, salinity, CDOM, chlorophyll and depth (https://www.nj.gov/dep/bmw/glider.html#/). Further outreach to NJDEP on the 2011-2017 data will be completed to obtain the data. Although this data is not in LIS, use of this data for model calibration in other areas of the model study area will be important.

4.2.2.2 Sediment

Sediment flux, solid phase and pore water data are available in LIS from the Battelle 1994-1995 sampling used for SWEM calibration and will be used for the LIS HWQM calibration as noted below. Research into any additional datasets will be completed.

The DEP City-Wide Ecological and Water Quality Studies monitoring program conducted in Jamaica Bay in 2017 and 2019 included measurement of sediment flux, solid phase and pore water data. This dataset will be used in the LIS HWQM long-term model calibration and validation efforts.

Other sources of sediment data have been identified from the Long Island Sound Study website (LISS Research Grant Program - Long Island Sound Study) and will be obtained for use in the modeling if applicable.

Fluxes

Recent benthic flux studies in the LIS region have been performed by Balcom et al. (2007), the Fulweiler laboratory at Boston University (https://www.fulweilerlab.com/longislandsound-benthic-fluxes.html), the Tobias laboratory at the University of Connecticut (https://tobias.lab.uconn.edu/current-projects/), and the Altabet laboratory at the University of Massachusetts (http://webserver.smast.umassd.edu/lab_altabet/). HDR will contact these sources to obtain all available data and assess what measurements were collected. In addition, the Battelle 1994-1995 dataset used to calibrate SWEM had SOD and nutrient flux data available in LIS. The types of sediment flux data needed for model calibration and validation are SOD, ammonia flux, nitrate flux and orthophosphate flux.

Solid Phase

Sediment solid phase data in LIS are available from the Battelle 1994-1995 dataset used to calibrate SWEM. An initial review of literature sources indicated there may be some total organic carbon mapping from the mid-1990s that could provide guidance to the model calibration and validation. The literature review will be continued.

Porewater

Porewater data in LIS are available from the Battelle 1994-1995 dataset used to calibrate SWEM. No additional sources have been identified at this time but further literature review will be completed.

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5 Data Management

5.1 Documentation

All of the datasets that are acquired will be documented in a spreadsheet or series of spreadsheets. The spreadsheets will document the following information.

- Data source
- Original data format (e.g., spreadsheet, Access database, text file)
- File location on HDR's system
- Constituents
- Sampling station locations and depths
- Temporal coverage including any time gaps

HDR will also attempt to obtain any metadata files associated with the datasets as well as available QAPPs for monitoring or database development. HDR plans to develop centralized databases that include similar data types (e.g., grab samples, continuous data sondes, ADCPs). Metadata for the databases will include any data transformations from the original format. A Metadata file will be created for the final formats of the data.

5.2 Data Archiving and Storage

The centralized databases will be maintained on HDR's ProjectWise file storage system and on the LIS Wiki SharePoint site along with any associated Metadata and QC protocols during the 5-year life of the project. Original raw databases downloaded from a data source and any intermediate modified compiled databases will be archived on HDR's file storage system.

After project completion, project data files will be retained in accordance with HDR's records retention policy. In general, all project data and model information are maintained for three years in active storage and after three years are moved to permanent storage for 17 years (20 years in total).

5.3 Data Access

Retrieved data and acquired literature in electronic form will be made available on the LIS Wiki SharePoint site for stakeholders during the five-year life of the project plus one additional year. The Wiki SharePoint site is currently under construction and the final details of the site and its structure have not been completed yet. As the Wiki SharePoint site is developed, further information regarding data access will be provided.

5.4 Data Acceptance

Large databases from public agencies with documented QAPPs have data that has gone through an acceptable level of quality review for uses such as model inputs and model calibration and validation. The LIS HWQM QAPP will also provide guidance on the usage of secondary (existing) data. All data that will be used for the development and calibration/validation of the models will be plotted to further assess if questionable data made it through the source specific quality control process. Visual outliers will be tested statistically using methods such as Chauvenet's criterion. If statistical outliers are found, HDR will reach out to the originators of the dataset to help resolve whether the data are acceptable. Any data deemed as outliers or questionable will be noted in the data documentation and, if deemed appropriate, will be excluded from the analysis.

5.5 Data Gaps

Any data gaps identified in acquired datasets will be noted in the data documentation spreadsheets.

HDR will identify any unfulfilled data needs for model input or calibration/validation and include the identified data gaps in the Data Gap Report to be completed as part of the project. The Data Gap Report will categorize the impact of the data gaps on model results and outline approaches to fill or work around the data gaps.

It is fairly common to have data gaps for modeling projects where a monitoring project was not specifically designed for a modeling effort. HDR has the experience to work around the data gaps that may be found and properly document data gaps and proposed solutions.

6 References

Balcom, P., Godfrey, J., Bennett, D., Grenier, G., Cooper, C., Cohen, Arbige, D., & Fitzgerald, W. (2007). Deploying Benthic Chambers to Measure Sediment Oxygen Demand in Long Island Sound. “Diving for Science 2007”, Proceedings of the American Academy of Underwater Sciences.

HydroQual, 2005. Application of RAINMAN to New York/New Jersey Harbor. Interim Submittal to the New York/New Jersey Harbor Estuary Program Pathogen Work Group. September 2005.

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Read, E. K., Carr, L., De Cicco, L., Dugan, H. A., Hanson, P. C., Hart, J. A., Kreft, J., Read, J. S., and Winslow, L. A. (2017), Water quality data for national-scale aquatic research: The Water Quality Portal, *Water Resour. Res.*, 53, 1735– 1745, doi:10.1002/2016WR019993. TetraTech, Inc., 2018. Establishing Nitrogen Endpoints for Three Long Island Sound Watershed Groupings: Embayments, Large Riverine Systems, and Western Long Island Sound Open Water. Submitted to EPA Region 1 and Long Island Sound Office. 4/13/2018.

Vaudrey, J.M.P., C. Yarish, J.K. Kim, C.H. Pickerell, L. Brousseau, J. Eddings, M. Sautkulis (2016), Long Island Sound Nitrogen Loading Model. University of Connecticut, Groton, CT.

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ATTACHMENT 1

Primary Calibration Data Source Monitoring Station Locations

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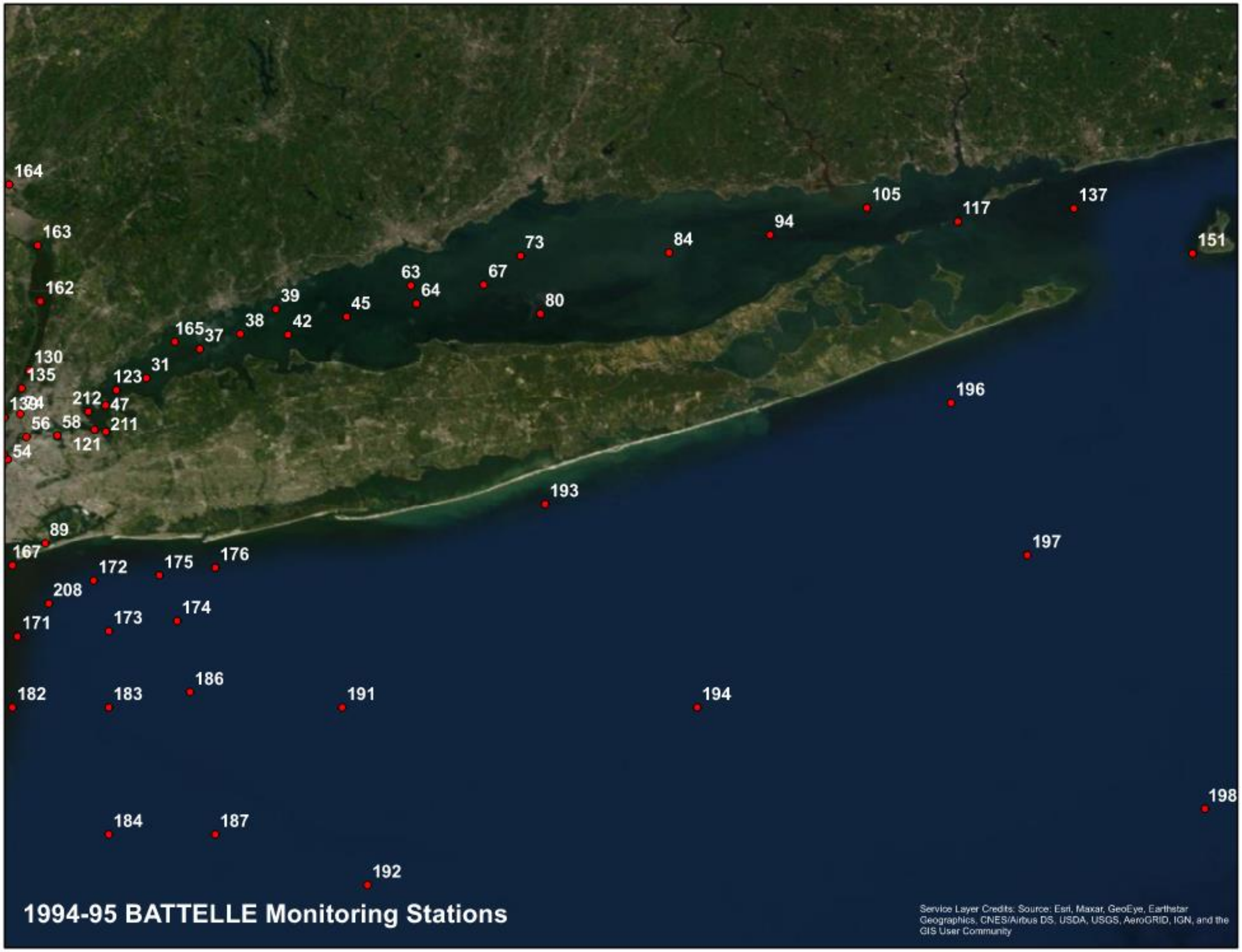
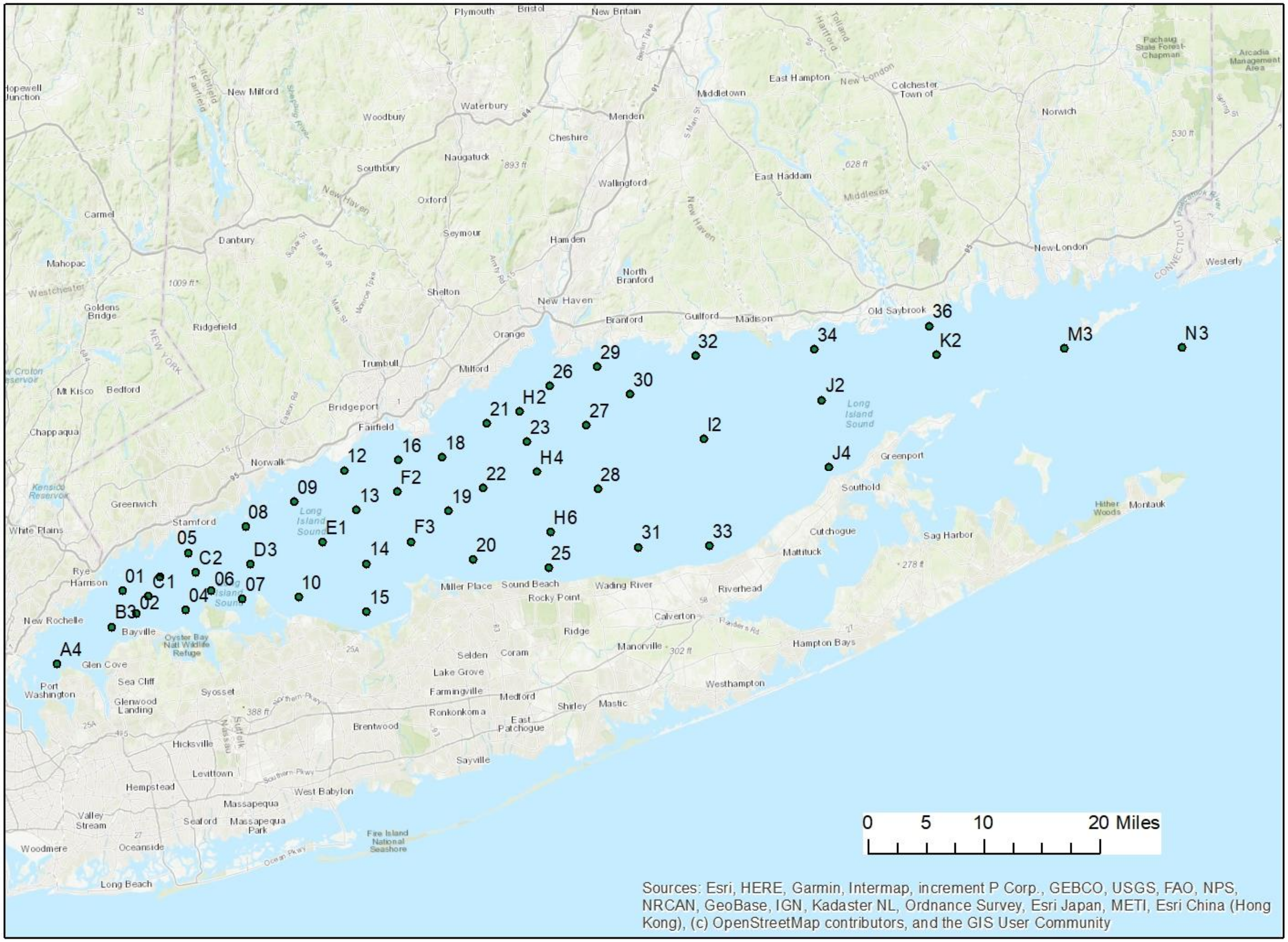
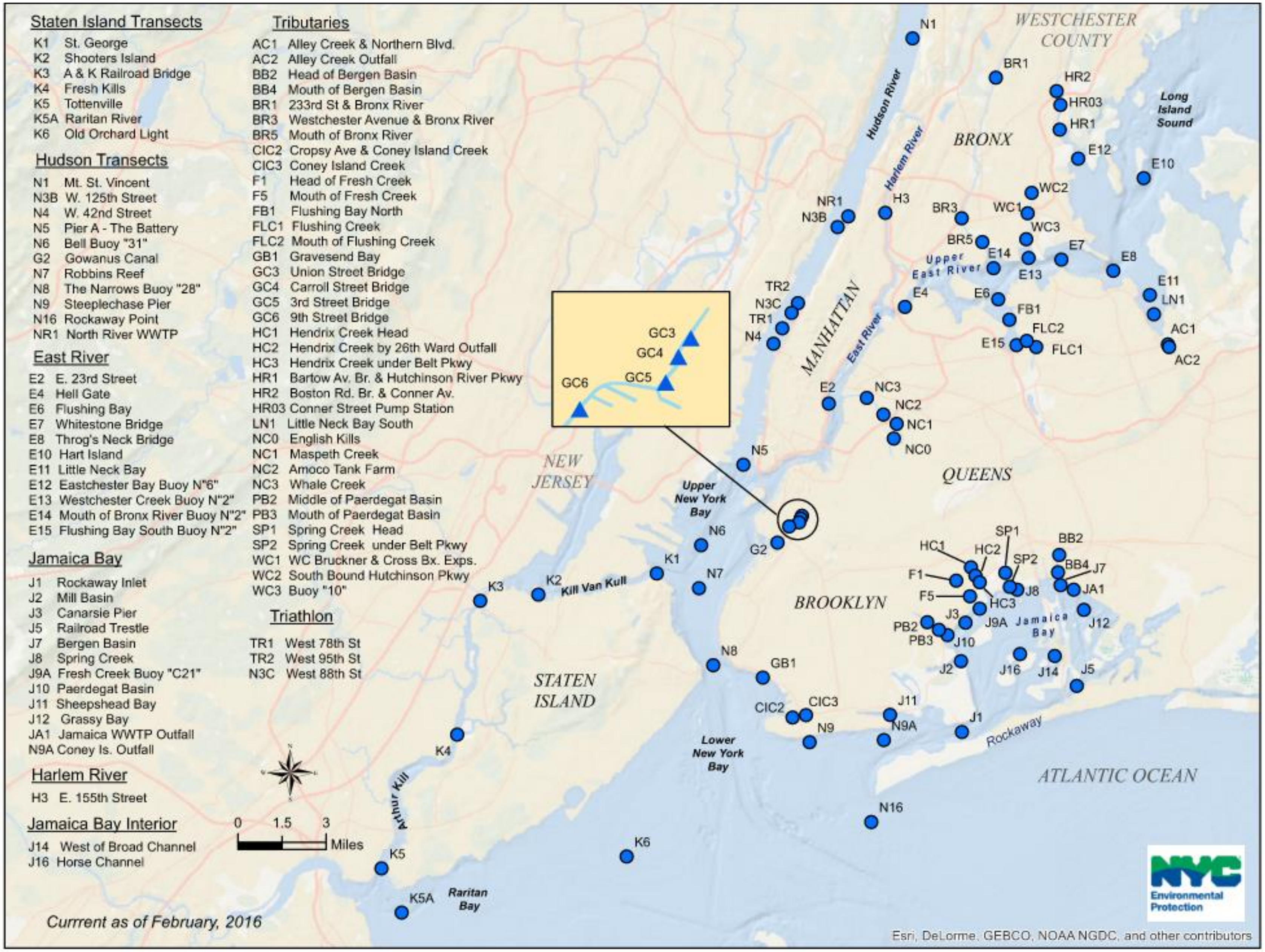
Batelle 1994-1995 LIS Study Area Monitoring Stations



Batelle 1994-1995 LIS Study Area Monitoring Stations

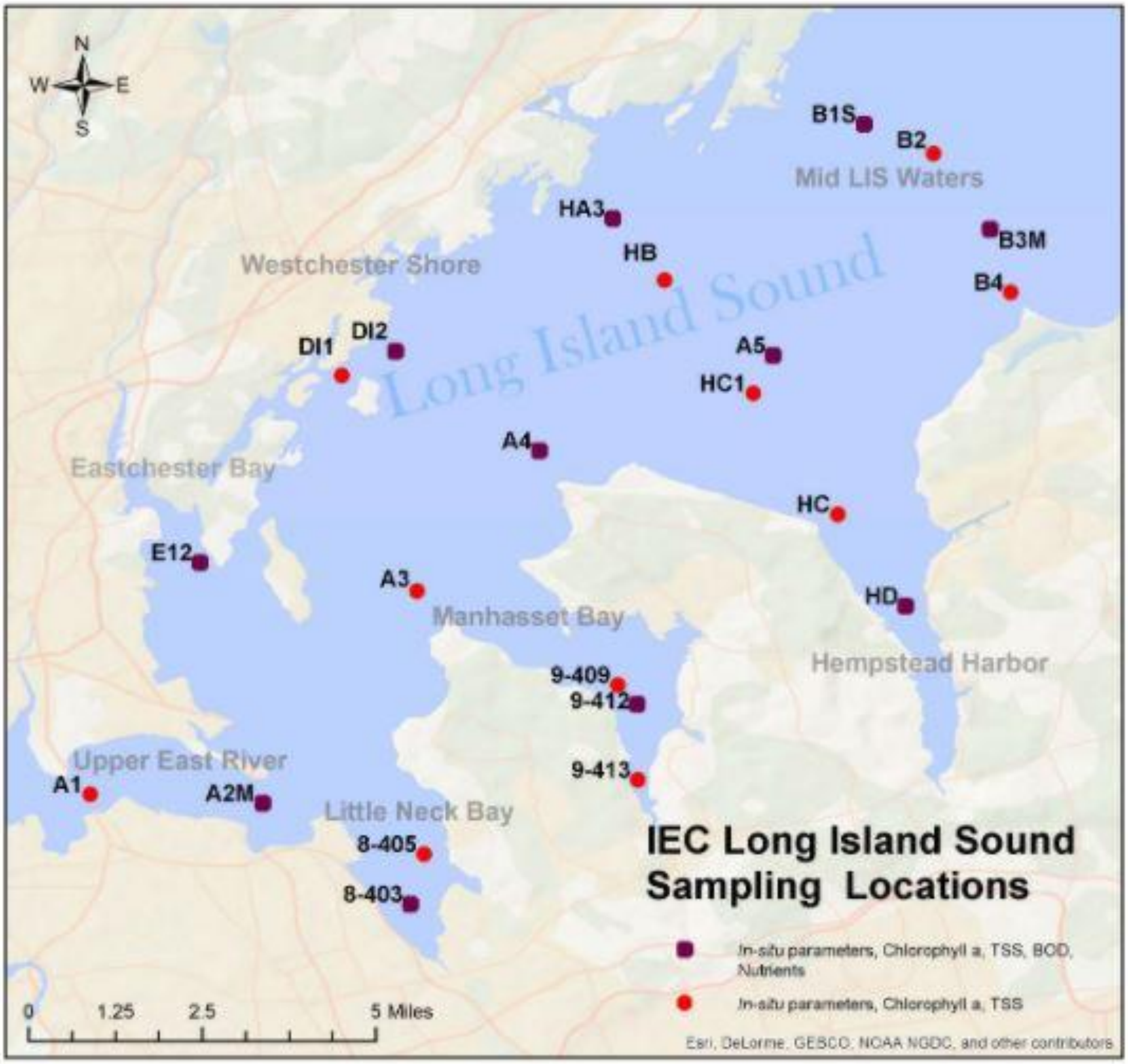


CTDEEP LIS Monitoring Stations



DEP Harbor Survey Monitoring Stations

NJHDG Monitoring Stations



IEC LIS Monitoring Stations

ATTACHMENT 2

Nutrient Endpoint Data Source Monitoring Station Locations

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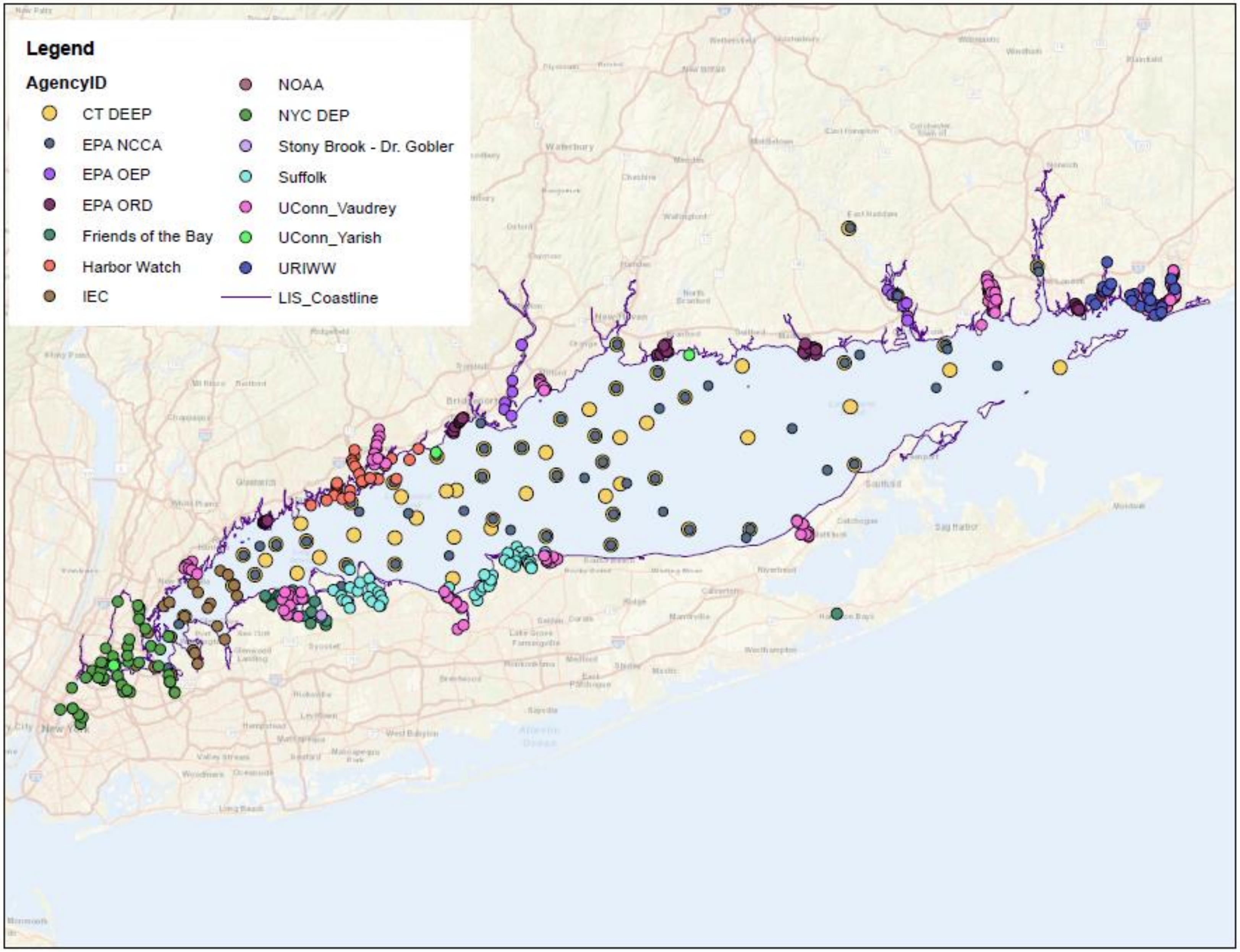
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Stony Brook - Dr. Gobler
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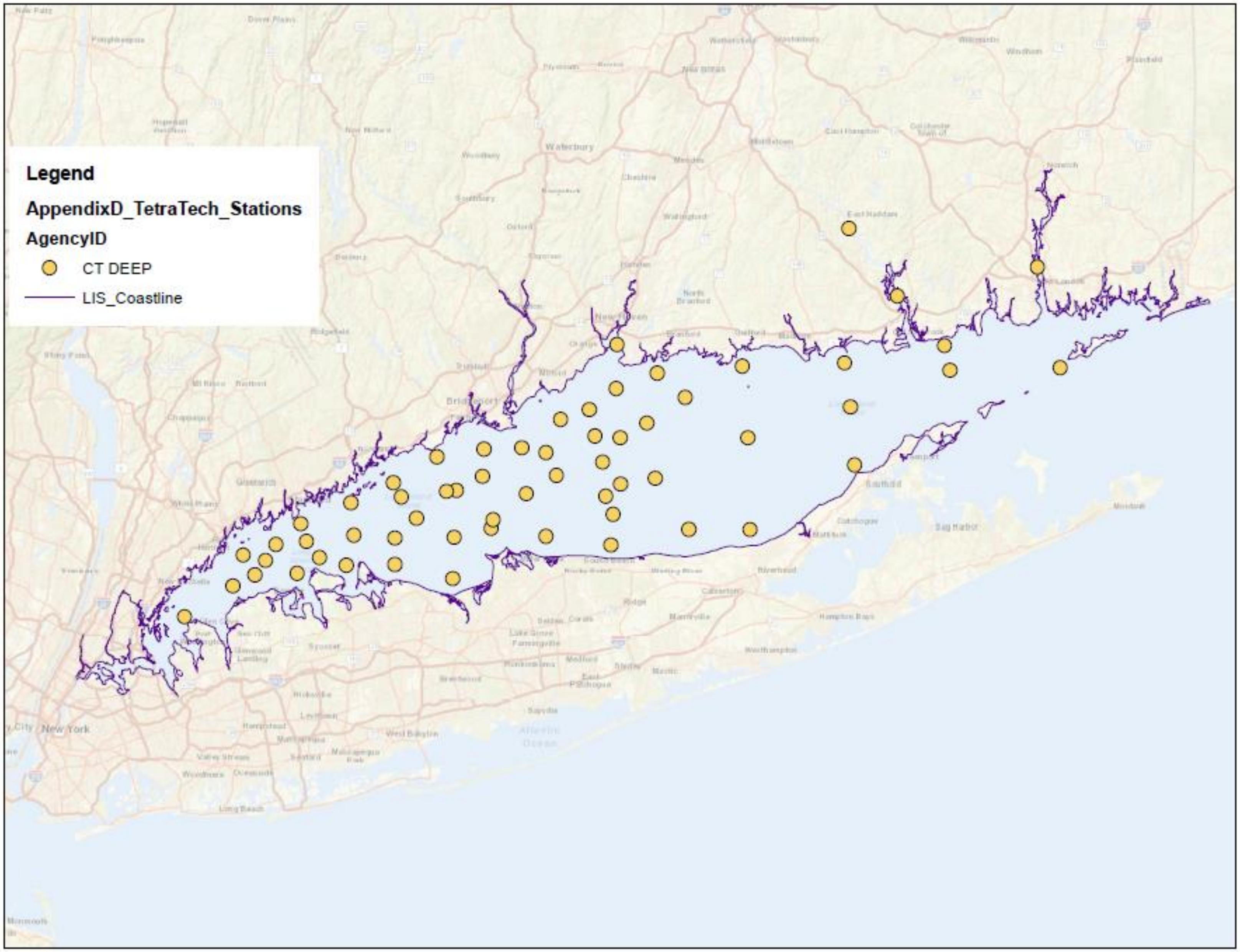
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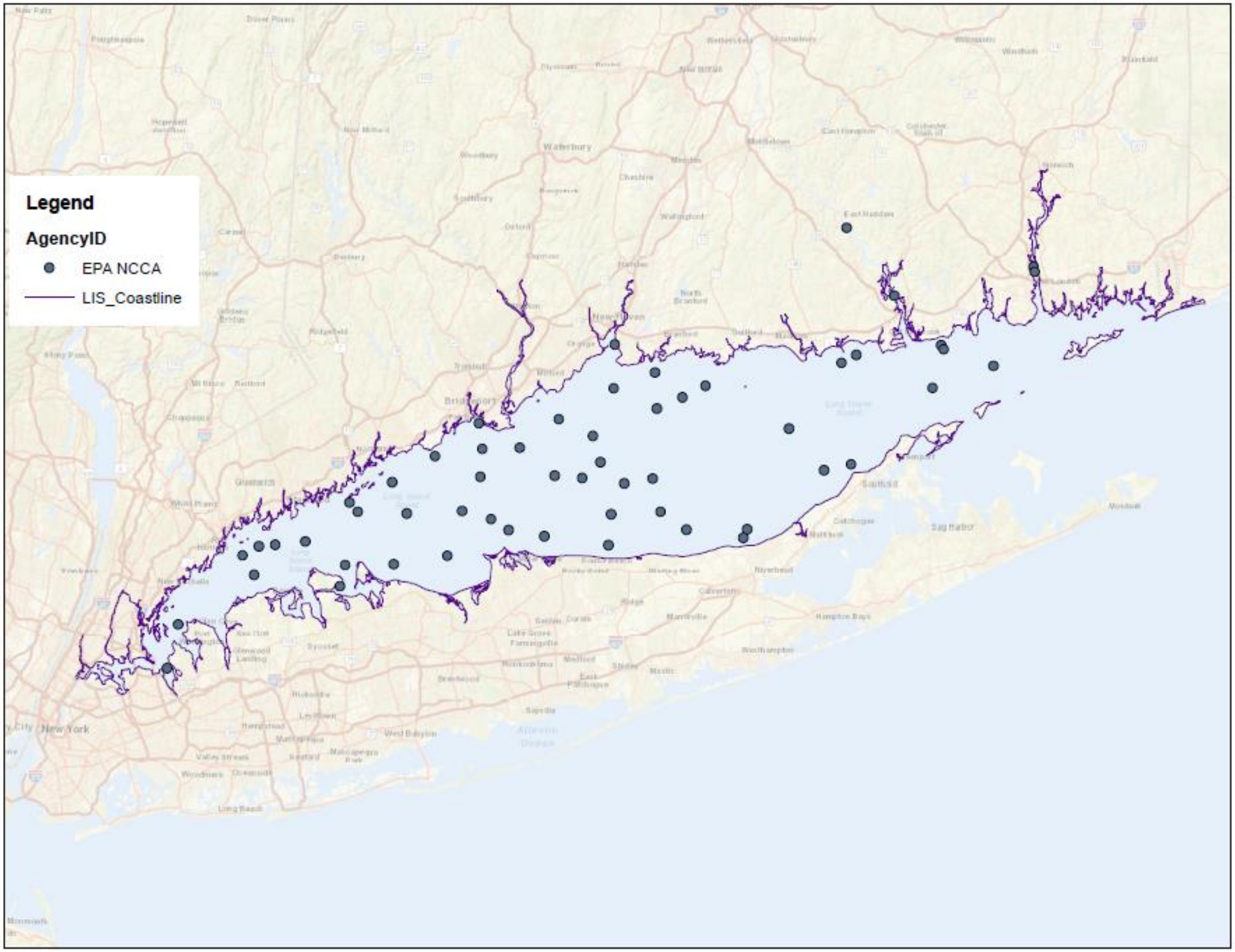
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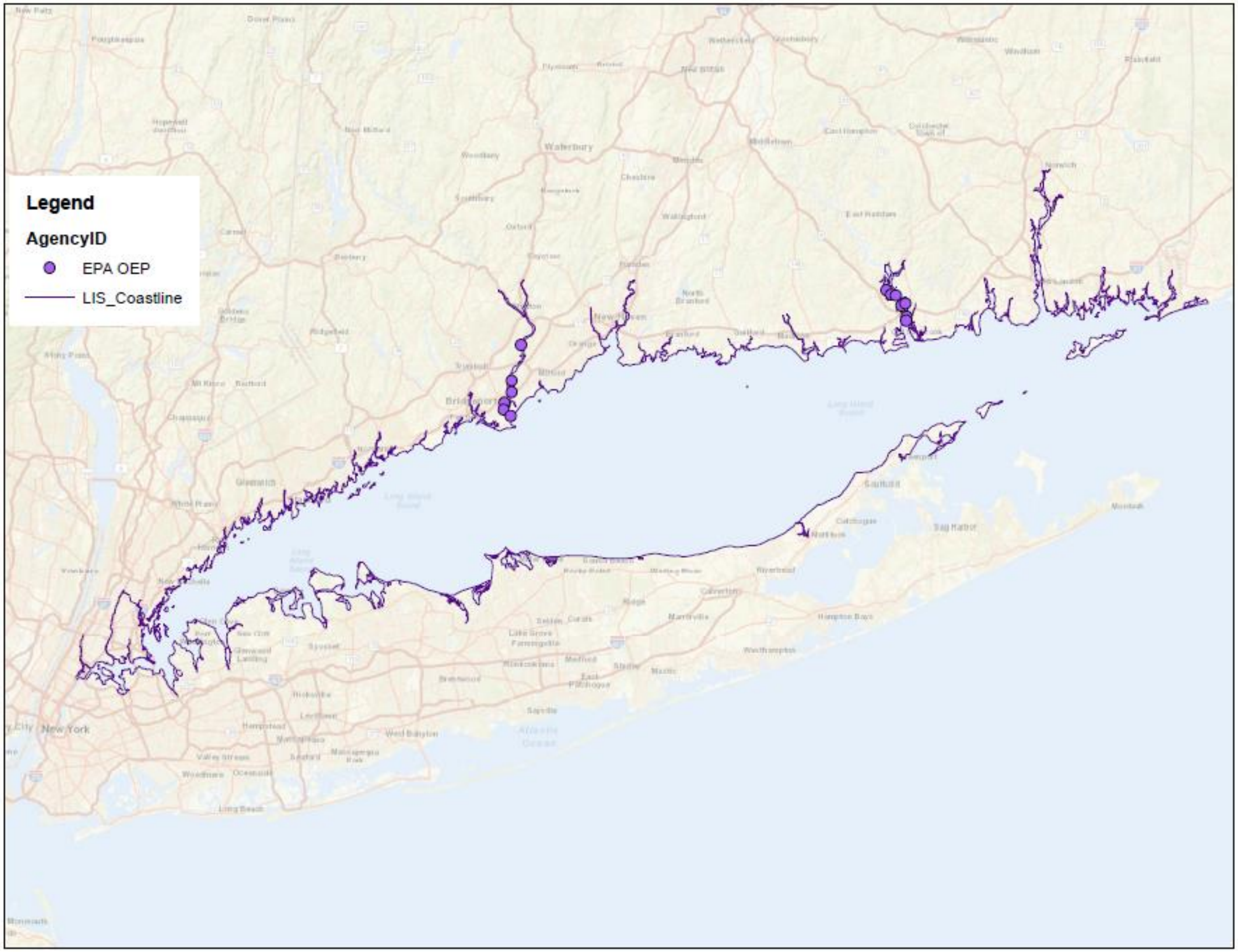
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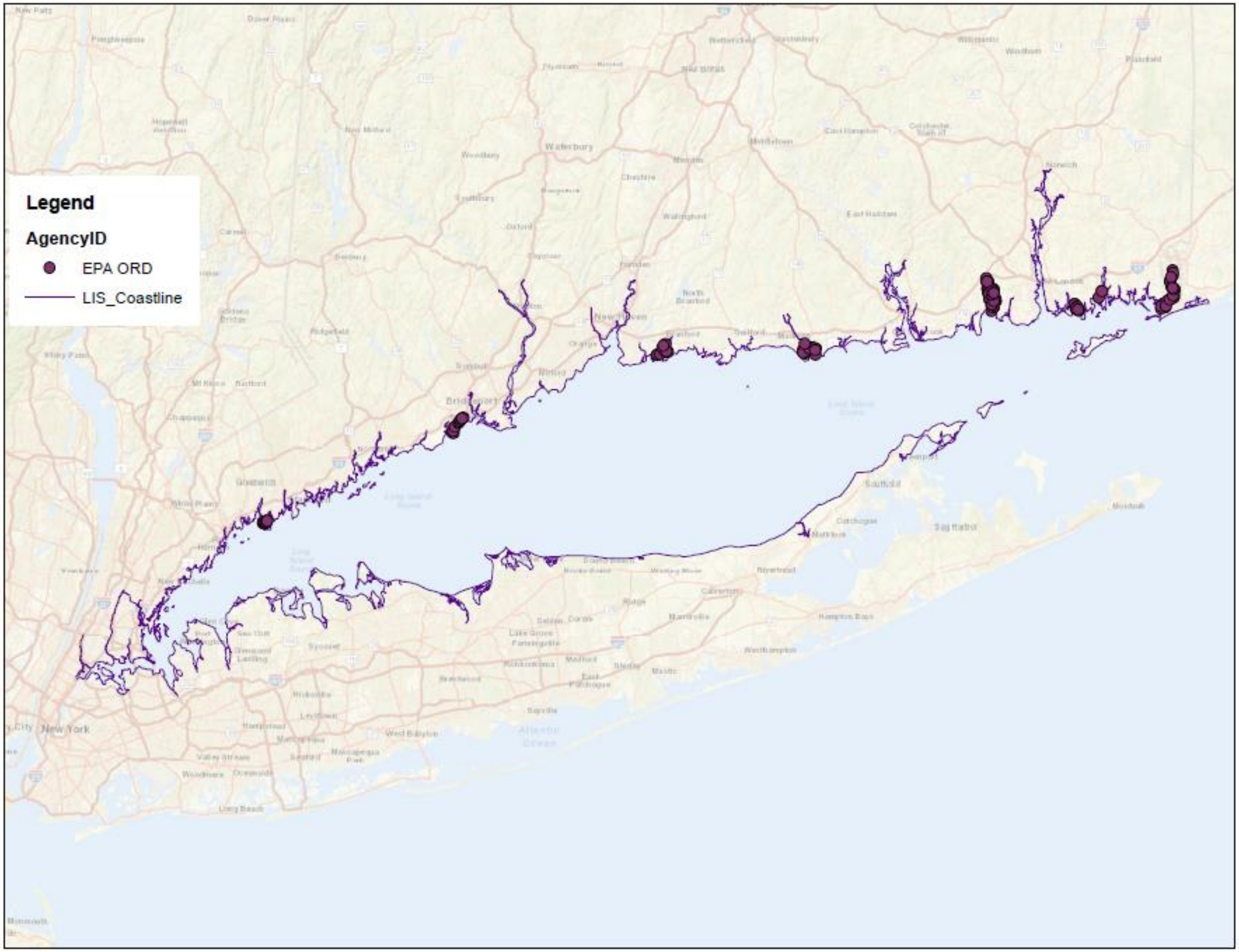
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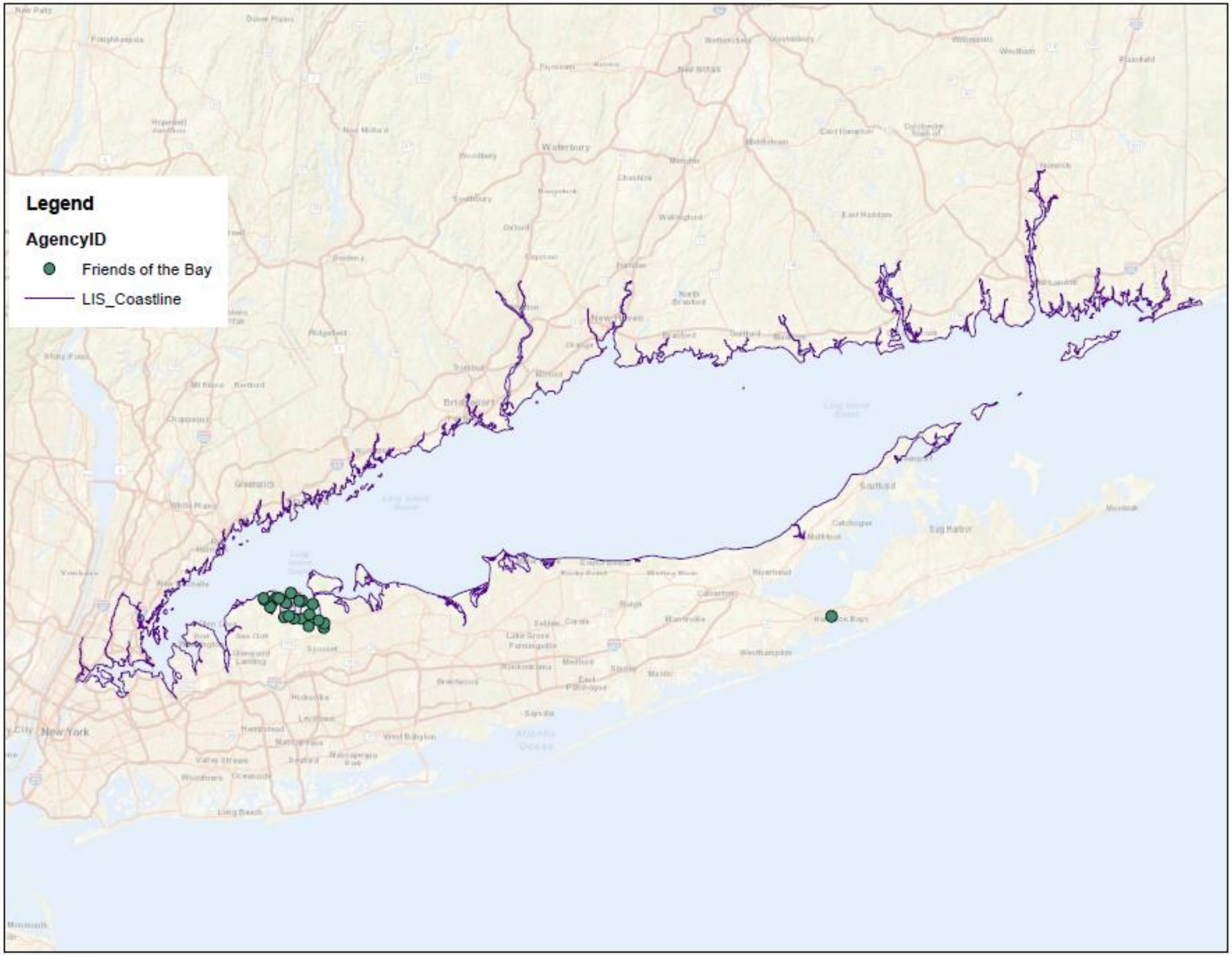
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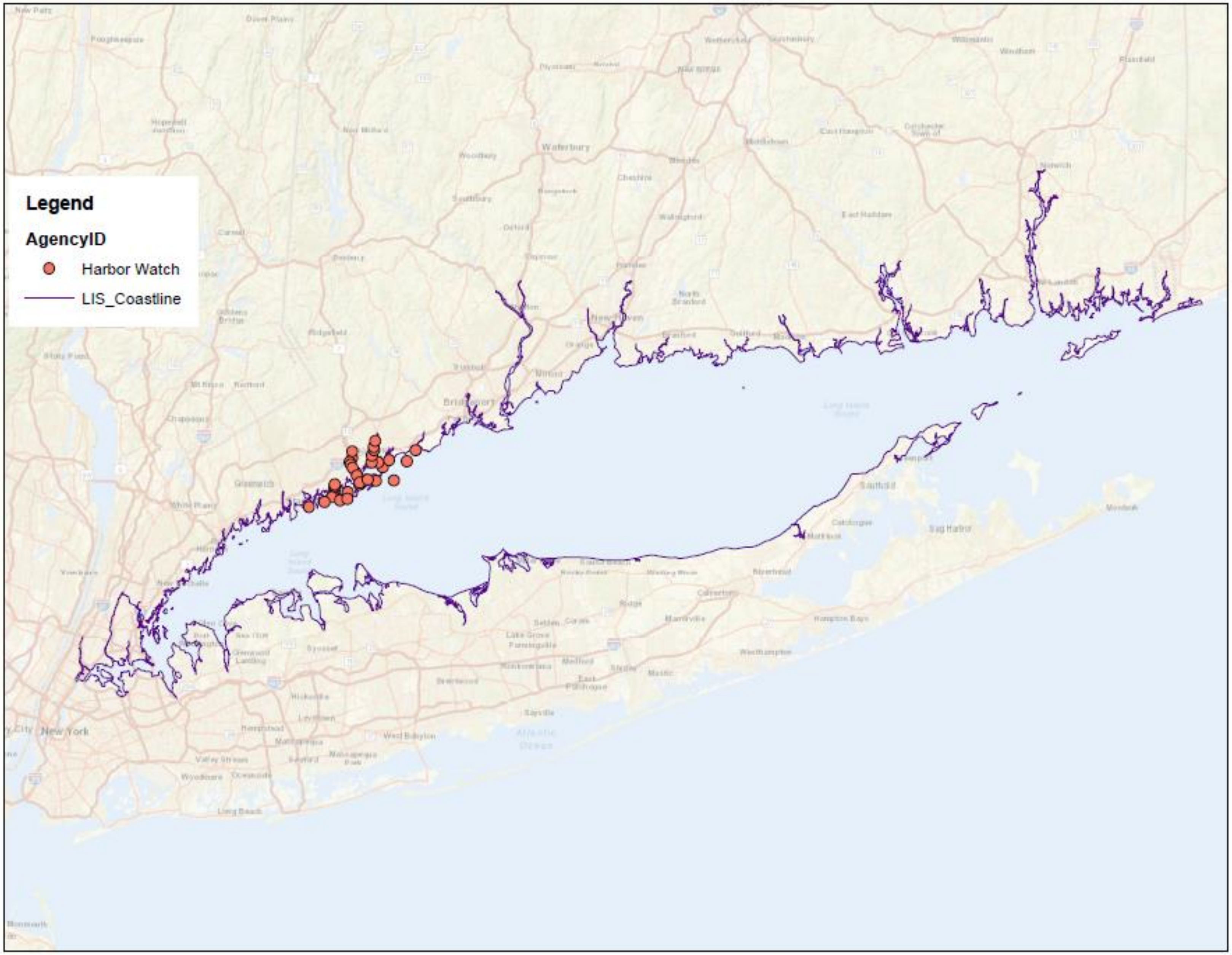
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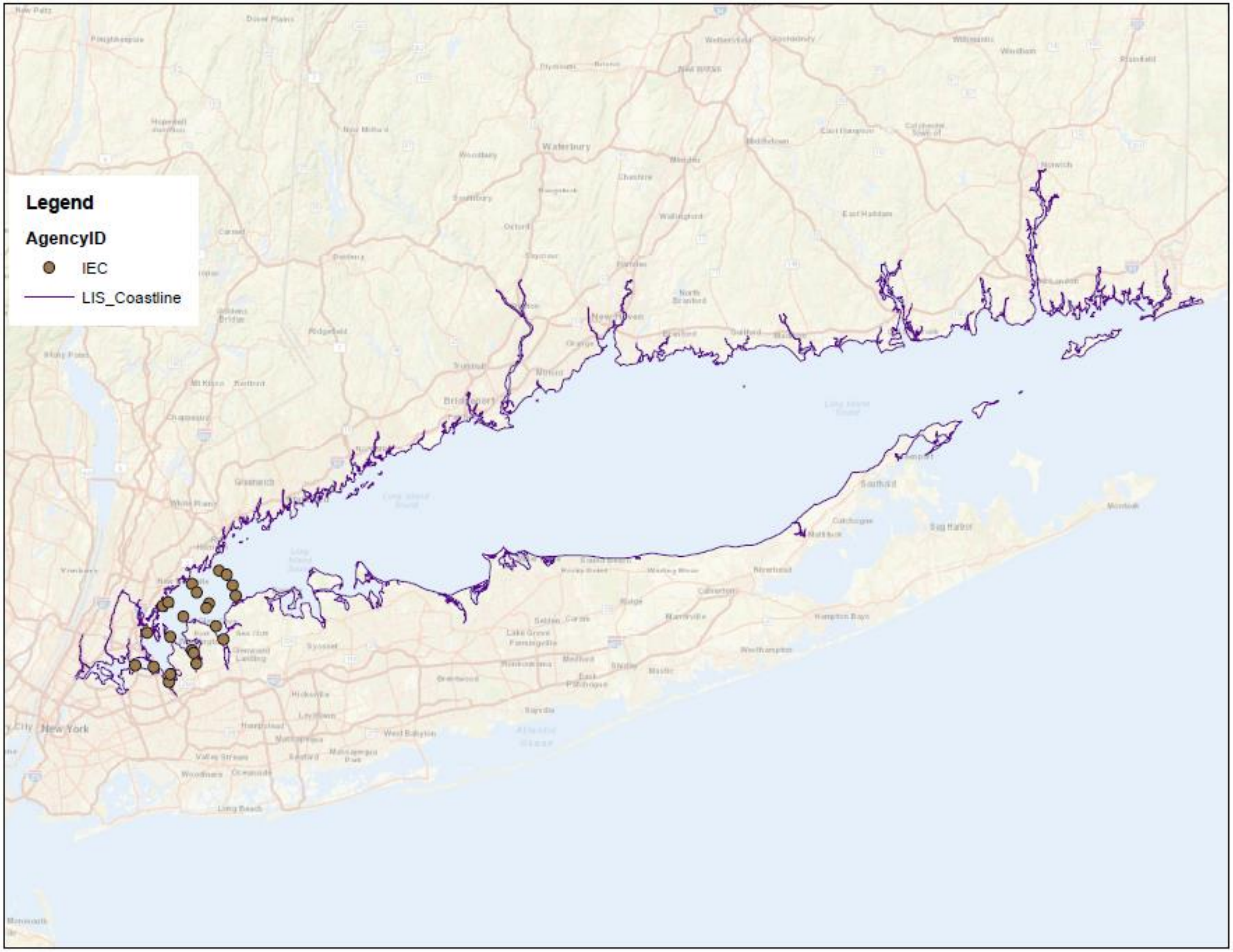
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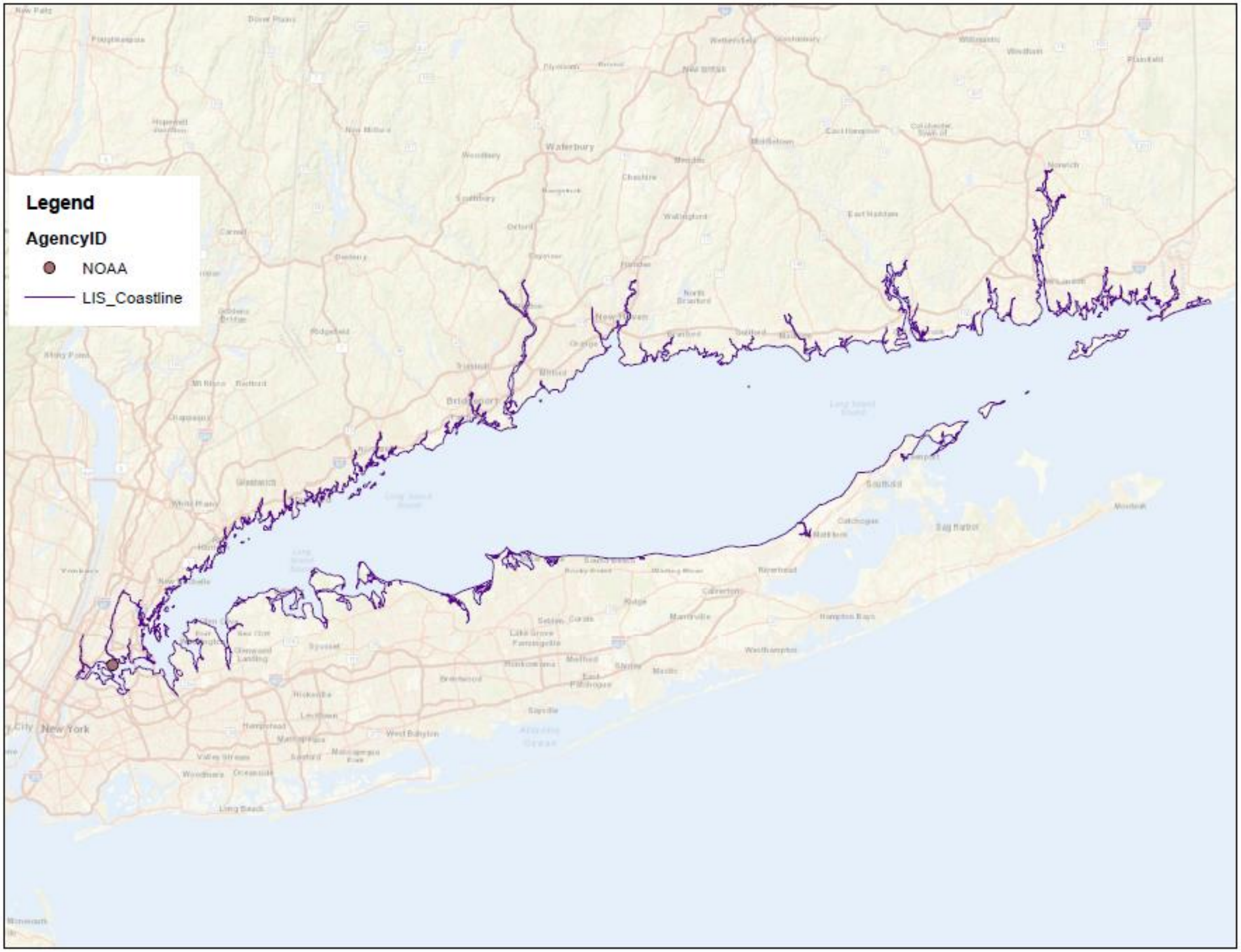
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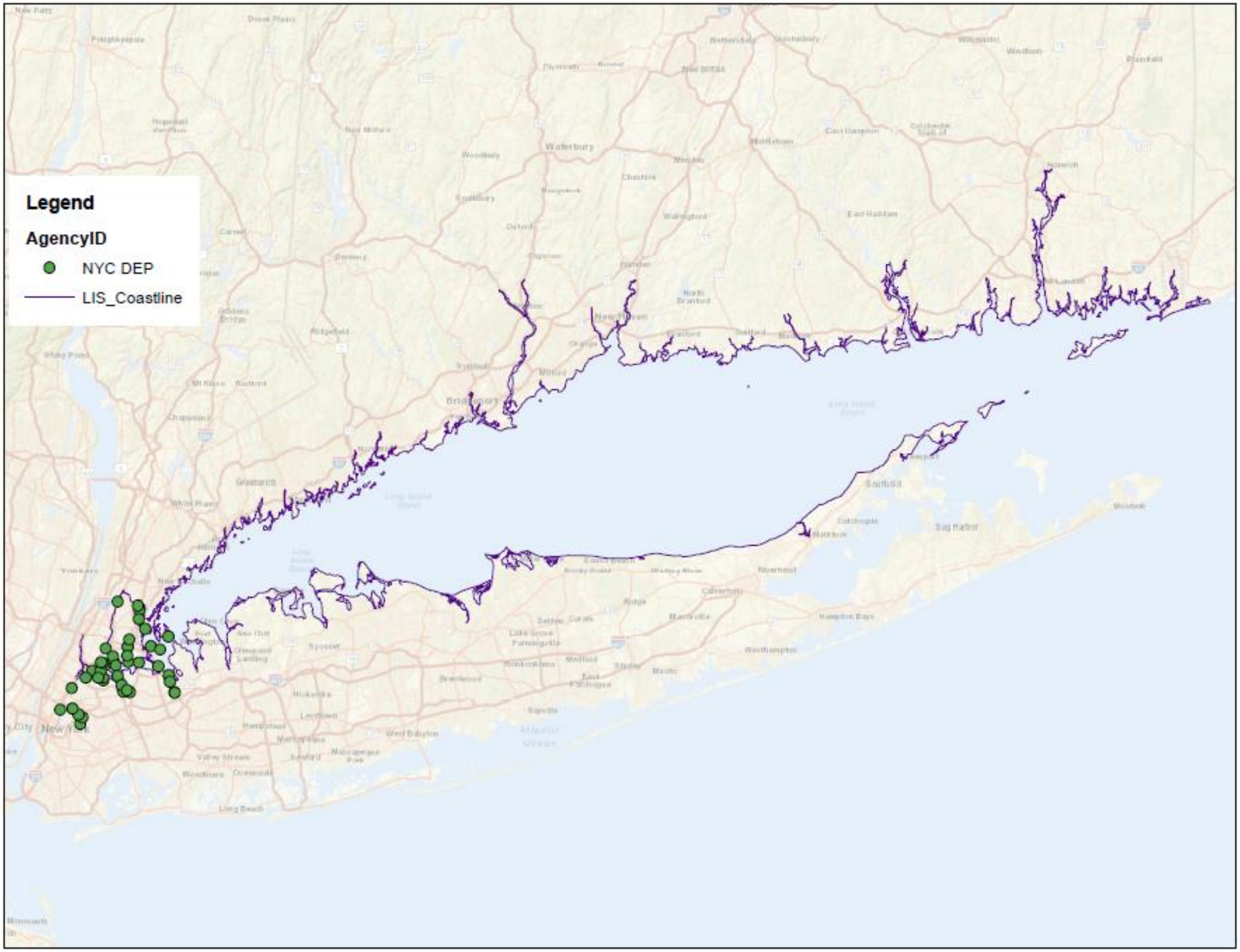
New York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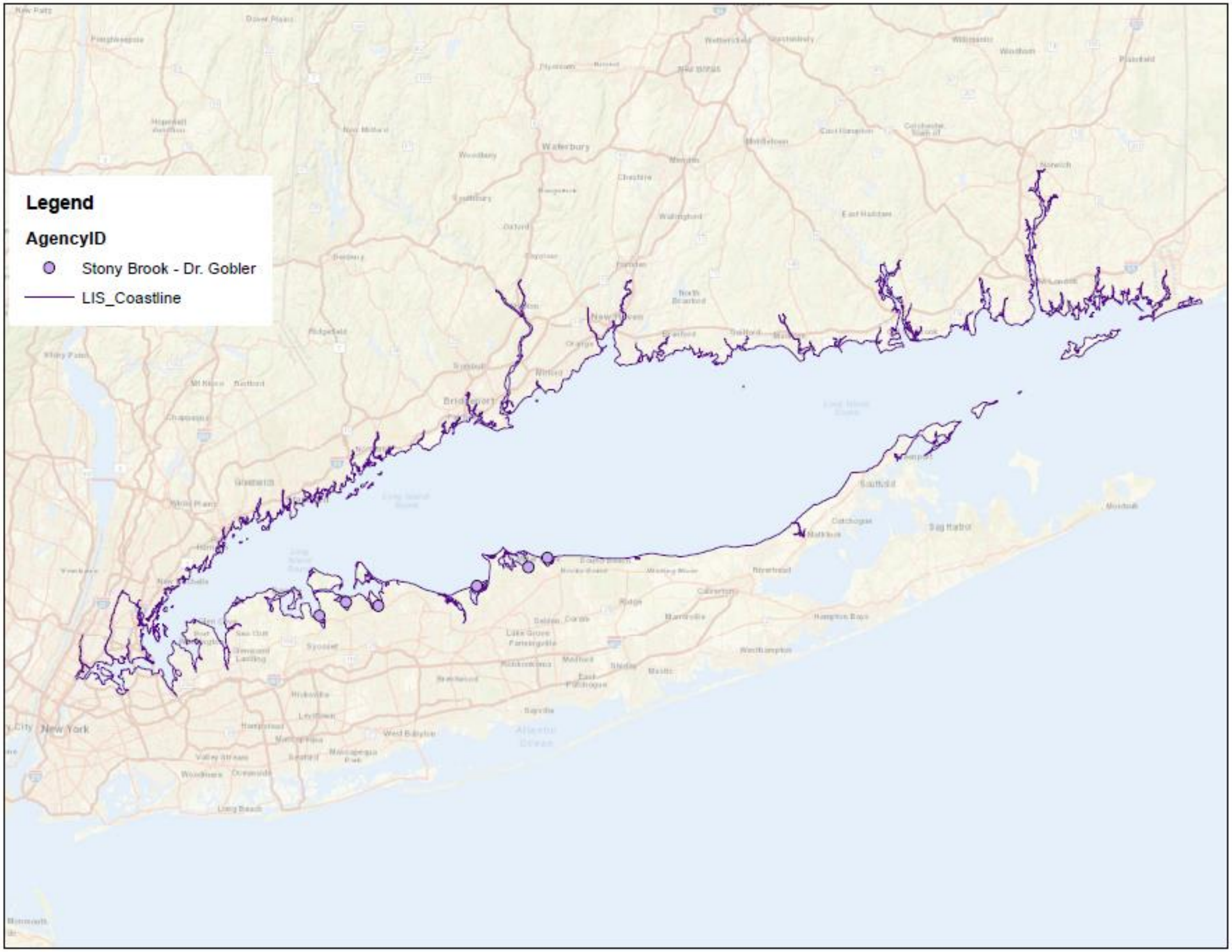
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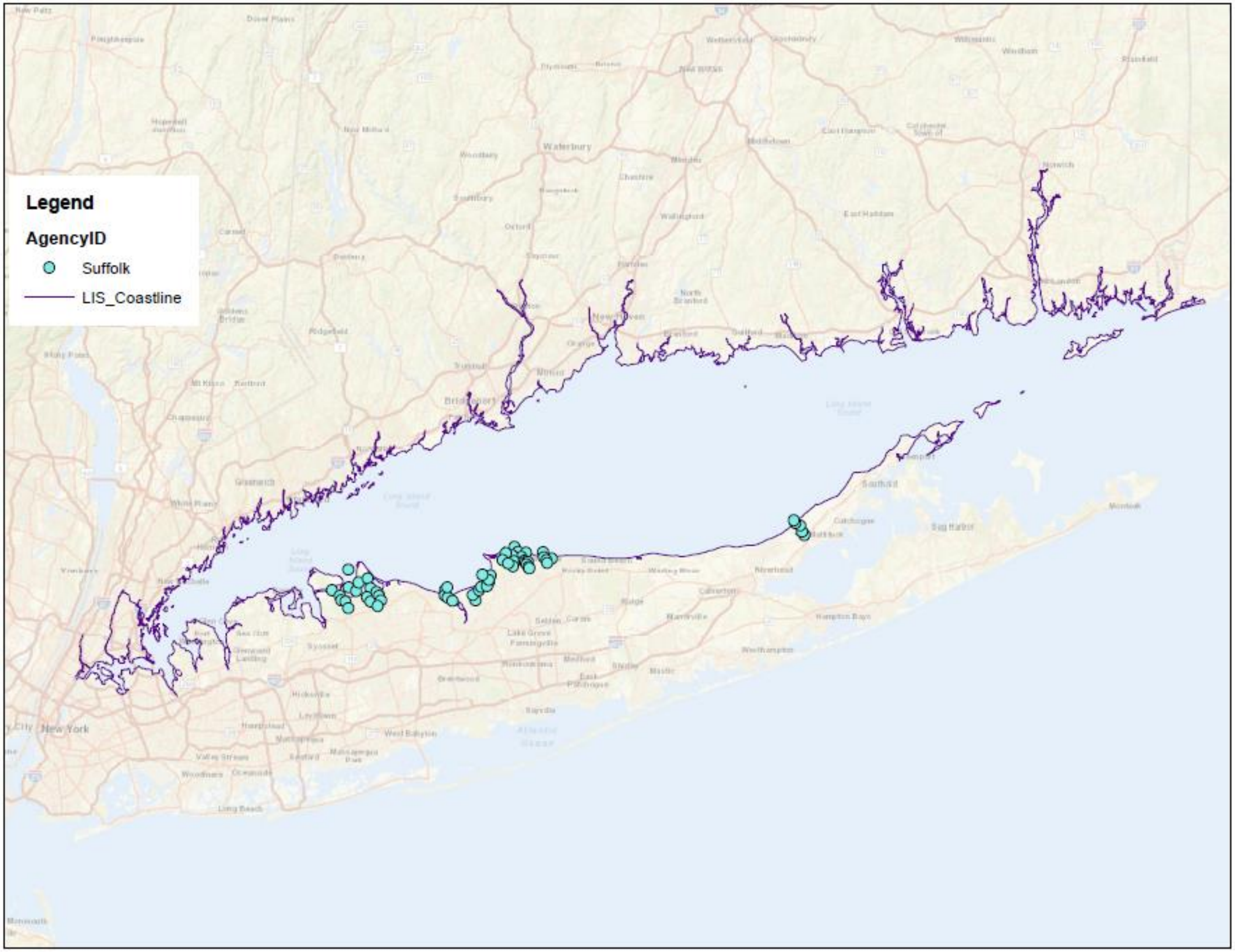
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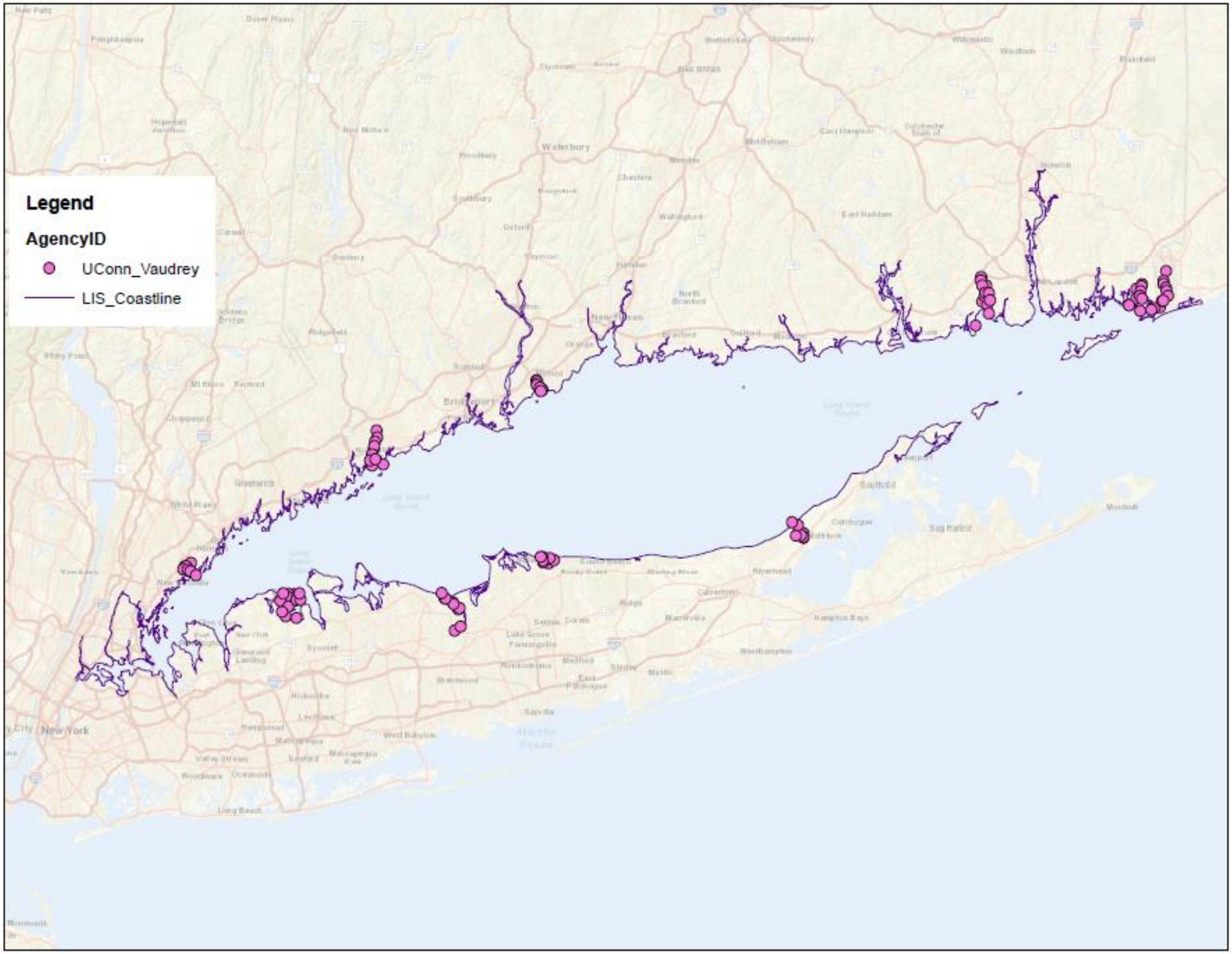
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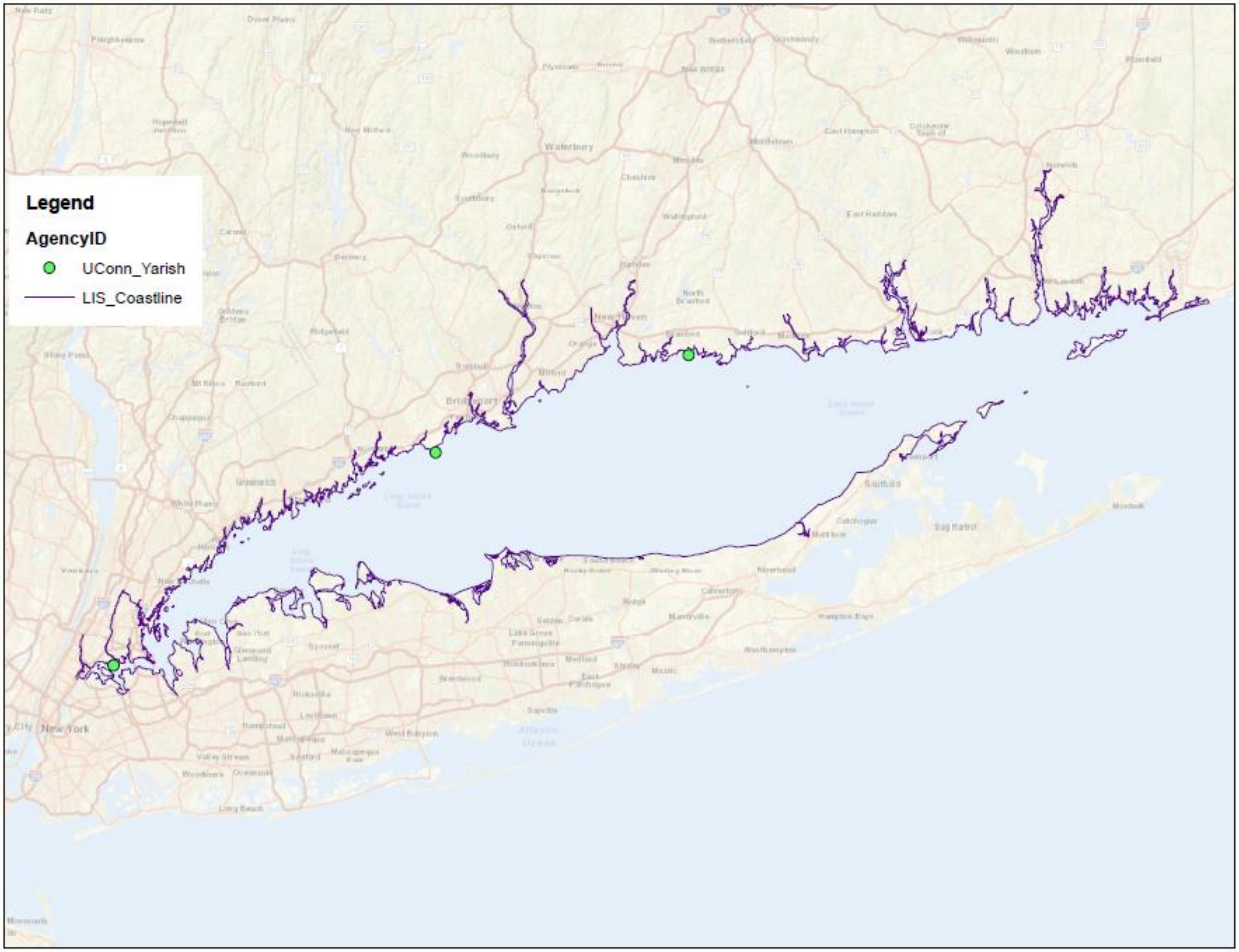
LIS_Coastline
Waterbury
New Haven
Bridgeport
New York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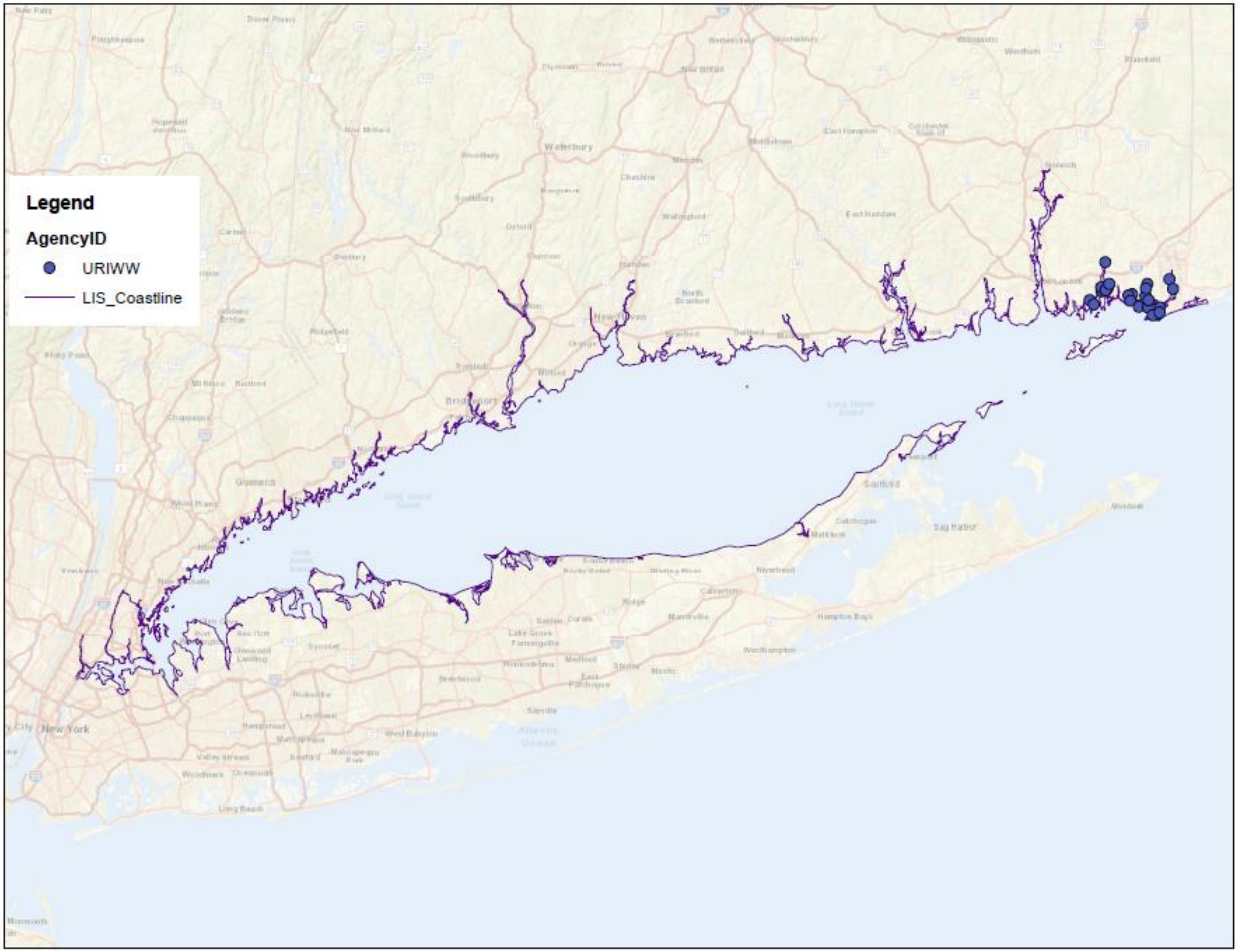
LIS_Coastline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