Establishing Nitrogen Target Concentrations for Three Long Island Sound Watershed Groupings:

Embayments, Large Riverine Systems, and Western Long Island Sound Open Water

Subtask A. Summary of Embayment and Western LIS N Loading

Submitted to:

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Submitted by:

Tetra Tech, Inc.

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This Tetra Tech technical study was commissioned by the United States Environmental Protection Agency (EPA) to synthesize and analyze water quality data to assess nitrogen-related water quality conditions in Long Island Sound and its embayments, based on the best scientific information reasonably available. This study is neither a proposed Total Maximum Daily Load (TMDL), nor proposed water quality criteria, nor recommended criteria. The study is not a regulation, is not guidance, and cannot impose legally binding requirements on EPA, States, Tribes, or the regulated community. The technical study might not apply to a particular situation or circumstance, but it is intended as a source of relevant information to be used by water quality managers, at their discretion, in developing nitrogen reduction strategies.

Subtask A. Summary of Embayment and Western LIS N Loading

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Introduction and Methods Overview

The purpose of Subtask A was to summarize nitrogen loading data for 24 embayments and Western LIS (made up of the Eastern Narrows and Western Narrows combined). Nitrogen loads were used to (1) relate to response indicator values in the waters selected by EPA to develop protective target concentrations and (2) calculate and allocate load reductions required to meet the protective nitrogen target concentrations.

Tetra Tech relied primarily on data from Dr. Jaime Vaudrey from the University of Connecticut, who developed a model using land use and population patterns to estimate nitrogen loads and yields for 116 embayments to LIS. Dr. Vaudrey's team used input data for the period 2010–2014 to run the model. These 116 embayments cover all the watersheds included in this analysis. Dr. Vaudrey's team normalized loads and yields by both area of the embayment and watershed.

Additionally, Dr. Vaudrey's team allocated nitrogen loads by source contributions that included atmospheric deposition (including municipal separate storm sewer systems [MS4s]), fertilizer, sewer (including wastewater), combined sewer overflows (CSOs), and septic and cesspools. Vaudrey load scenarios were primarily developed using Center for Land Use Education and Research (CLEAR) 2010 land use data; however, National Land Cover Database (NLCD) 2011 land use data were used for two embayments with incomplete CLEAR coverage (Pawcatuck River, Rhode Island and Connecticut, and East River, NY [part of the Western Narrows]) (Vaudrey et al. 2016). Vaudrey et al. (2016) estimated embayment nitrogen loading following the approach presented by Valiela et al. (1997). In the Valiela et al. (1997) model, inputs of nitrogen from various sources (e.g., atmospheric deposition, CSOs, fertilizer, wastewater treatment plants, septic systems) are estimated based on major land uses and population patterns. Nitrogen losses are then estimated based on the various watershed ecosystem land uses (natural vegetation, turf, agricultural land, residential areas, and impervious surfaces). For diffuse sources such as atmospheric deposition and fertilizer nitrogen, nitrogen losses occur via transport through the vegetation, soil, vadose zone, and aquifer. Losses from septic systems also include attenuation through aquifer transport. Attenuation is calculated separately for each major land use since processes and loss rates vary among land uses. The number of people located within sewered and CSO areas was determined by analyzing U.S. Census Bureau data within defined sewer or CSO areas. People not located in defined sewer areas were assumed to be on traditional septic systems. Model attenuation factors and loading rates were updated to reflect local conditions for LIS.

Estimates for atmospheric deposition do not always appear proportional to the embayment area because atmospheric deposition is a function of average rainfall, watershed and embayment surface area, and land use. Greater than average rainfalls result in greater deposition. Vaudrey et al. (2016) modeled attenuation of nitrogen deposition based on land use and the transport of nitrogen through the soil, vadose zone, and aquifer, with urbanized lands having lower attenuation. They also adjusted attenuation to reflect locally relevant information such as insufficient organic carbon to support denitrification in the Northport Bay area, as reported by Young et al. (2013).

Note that, in some cases, the data presented in this memo for each embayment for *total nitrogen loadings (sewer)* (Vaudrey et al. 2016) and *point sources* (USEPA 2015) differ. CSOs may no longer exist, data contained in EPA's Integrated Compliance Information System (ICIS) is more recent than the Vaudrey data, and/or methodology might result in different estimates. For total nitrogen loadings, Vaudrey et al. (2016) used a 4-year average (2011–2014) of the nitrogen loads from wastewater treatment facilities, except where upgrades to the facility were completed. In those cases, only data for the resulting lower contribution of nitrogen were included. Nitrogen load data were obtained from

Connecticut Department of Energy and Environmental Protection (CT DEEP) and Rhode Island Department of Environmental Management (RI DEM). For point sources, Tetra Tech estimated annual loads based on data provided by EPA and supplemented by ICIS through 2015, the most recent year available, not a 4-year average like Vaudrey used. More detail about how Tetra Tech calculated point source values from ICIS is available in the Subtask B section of this memo. Tetra Tech also extracted data from The Nature Conservancy (TNC), which applied the Nitrogen Loading Model (NLM) to 13 embayments along the north shore of Nassau County, NY, and northwestern Suffolk County, NY. TNC used input data from the period 2010–2015 to run its model. The model provided nitrogen load and yield estimates normalized by both area of open water embayment and watershed area. TNC broke down the loads by source contributions, including atmospheric deposition, fertilizer (lawns, recreation, and agriculture), and wastewater (sewage treatment plants, septic, and cesspools). TNC estimates were available for only the following New York embayments: Northport-Centerport Harbor Complex, Hempstead Harbor, Huntington Bay, Huntington Harbor, Lloyd Harbor, Oyster Bay/Cold Spring Harbor Complex, and Manhasset Bay (Lloyd et al. 2016).

Tetra Tech extracted nitrogen loads, yields, and source contributions from both University of Connecticut (Vaudrey et al. 2016) and TNC (Lloyd et al. 2016) data sets for each of the selected embayments. Additional source data were considered, but they were not on the same spatial or numeric scales to be included in the compiled data. All collected data are included in *Appendix A1: Embayment Loads.* The Vaudrey et al. (2016) load estimates provided comprehensive load estimates for all 24 selected embayments compared to only 7 of the 24 selected embayment load estimates included with the TNC data set. Therefore, due to the extensive data availability of the Vaudrey et al. (2016) estimates and the comparability of a consistent method across embayments, the following summary focuses on the Vaudrey et al. (2016) data.

Note that, in some cases, individual embayments selected by EPA corresponded to multiple embayments defined by Vaudrey et al. (2016). For example, the Northport-Centerport Harbor Complex, NY, embayment consists of three Vaudrey et al. (2016) embayments: Centerport Harbor, NY; Northport Bay, NY; and Northport Harbor, NY. In these cases, loads, yields, and land use characteristics calculated in Vaudrey et al. (2016) were aggregated to the embayments specified by EPA.

In addition to compiling nitrogen data, as described above, Tetra Tech also compiled and calculated summary information (e.g., drainage area, land use characteristics) for each of the embayments. Compiled data, which are summarized under the Results section following the table, include data extracted directly from Vaudrey et al. (2016) as well as information found in technical reports, peer-reviewed literature sources, and Tetra Tech-calculated information, as described in Table A-1.

Table A-1. Sources of Information for Summary Statistics

Summary Statistic	Calculated by Tetra Tech or Obtained Directly from a Source?	Notes
Total Drainage Area of Watershed	Literature source	Vaudrey et al. 2016.
Total Area of Embayment	Literature source	Vaudrey et al. 2016.
Main Tributaries	Literature source	Various literature and geographic information system (GIS) sources, including U.S. Geological Survey (USGS) (2017). See the Results section for specific citations.

Summary Statistic	Calculated by Tetra Tech or Obtained Directly from a Source?	Notes
Residence Time	Calculated by Tetra Tech	A rough estimate of freshwater residence time was calculated using a residence time empirical model for southern New England embayments (Abdelrhman 2005). The model relates flushing time to the readily available physical properties embayment length (km) and surface area (km^2). Open water embayment areas and flowpath lengths were estimated in GIS using the embayments delineated by Vaudrey et al. (2016).
Depth at Mean Lower Low Water (MLLW)	Calculated by Tetra Tech	The National Oceanic and Atmospheric Administration (NOAA) Coastal Relief Model bathymetry was used to approximate average and maximum MLLW depths (i.e., mean at low tide) for each embayment as a rough estimate (NOAA 2015). See *Appendix A2: Bathymetry Data* for a description of methods used for bathymetric estimates.
Land Use Characteristics (e.g., % Watershed in Developed, Forest, or Agriculture Lands)	Literature source	Vaudrey et al. 2016.
MS4s (Name, Number, and Percent of Watershed)	Calculated by Tetra Tech	See *Appendix B: Dischargers Compiled* and the Subtask B section of this memo for a description of methods.
Point Sources (Name, Number, and Loading)	Calculated by Tetra Tech	See *Appendix B: Dischargers Compiled* and the Subtask B section of this memo for a description of methods.
Total Nitrogen Loading (Entire Watershed and by Source)	Literature source	Vaudrey et al. 2016.

Results

Nitrogen loads, yields, open water area, and watershed area for the 24 selected embayments, the Eastern Narrows, Western Narrows, and Western LIS (Eastern and Western Narrows combined) are summarized in Table A-2. The loads reported are for total nitrogen load, including atmospheric loading to the watershed and embayment. A more detailed description and summary statistics for each of the selected embayments follow the table.

Nitrogen loads to selected embayments ranged from 7,156 kg N/year for Stonington Harbor, CT, to 1,222,734 kg N/year for Oyster Bay/Cold Spring Harbor Complex, NY. The Eastern Narrows includes 35 Vaudrey embayments with an estimated total load of 1,937,053 kg N/year. The Western Narrows includes seven Vaudrey embayments with an estimated total load of 16,541,950 kg N/year; 99 percent of the nitrogen loads to the Western Narrows is from the East River, NY, embayment (16,297,860 kg N/year).

Table A-2 also includes total nitrogen yields (loads normalized to the area of open water embayment and to watershed area). Coupled with considerations of degree of flushing (residence time), yield normalized to open water embayment area can be an indication of areas where one might expect localized effects of nitrogen entering LIS such as the Pequonnock River, Byram River, Pawcatuck River, Southport Harbor/Sasco Brook, Nissequogue River, Mamaroneck River, and the Western Narrows. Yield normalized to watershed area corrects total watershed load for differences in total area, thus indicating watersheds with relatively higher areal nitrogen generation such as in the Oyster Bay/Cold Spring Harbor, Western Narrows, Huntington Bay, Manhasset Bay, and Nissequogue River watersheds.

Table A-2. Summary of Nitrogen Loads and Yields by Watershed, including 24 Embayments, the Eastern Narrows, Western Narrows, and Western LIS (Eastern and Western Narrows Combined)

Watershed	Open Water Area [km^2]	Watershed Area [km^2]	Load [kg N/yr]	Yield, Normalized to Embayment Area [kg N/yr-km^2]	Yield, Normalized to Watershed Area [kg N/yr-km^2]
Pawcatuck River, CT and RI	2.6	674.6	243,928	92,451	356
Stonington Harbor, CT	1.8	6.2	7,156	3,980	753
Saugatuck Estuary, CT[a]	2.5	225.6	102,692	41,115	425
Norwalk Harbor, CT	6.9	155.5	189,593	27,675	1,152
Mystic River, CT	1.2	67.2	29,825	25,455	420
Niantic Bay, CT[a]	11.4	76.2	35,757	3,149	242
Farm River, CT	0.4	67.4	34,678	82,290	505
Southport Harbor/ Sasco Brook, CT[a]	0.3	111.6	48,632	152,762	432
Northport-Centerport Harbor Complex, NY[a]	12.0	21.2	73,375	6,101	2,597
Port Jefferson Harbor, NY	5.0	15.5	58,623	11,790	3,286
Nissequogue River, NY	2.0	97.4	335,698	171,940	3,414
Stony Brook Harbor, NY	3.7	19.9	34,756	9,433	1,466
Mt. Sinai Harbor, NY	1.6	13.3	39,043	23,736	2,749
Mamaroneck River, NY	0.5	66.5	61,036	126,764	918
Hempstead Harbor, NY	6.4	51.0	129,392	20,174	2,539
Huntington Bay, NY	4.4	3.7	15,251	3,450	4,083
Huntington Harbor, NY	1.5	23.9	59,591	39,414	2,488
Lloyd Harbor, NY	2.3	6.1	8,803	3,811	1,451
Oyster Bay/Cold Spring Harbor Complex, NY[a]	22.2	66.8	1,222,734	55,174	18,294
Manhasset Bay, NY	8.4	37.5	150,680	17,859	4,013
Pequonnock River, CT	0.2	86.8	104,214	516,340	1,200
Byram River, CT and NY	0.1	70.3	34,338	278,725	489
New Haven Harbor, CT	30.3	587.9	892,576	29,468	1,518
Little Narragansett Bay, CT	3.3	39.3	22,046	6,681	561
Eastern Narrows, CT and NY	347.0	711.1	1,937,053	28,961	2,626
Western Narrows, NY	56.1	408.4	16,541,950	325,607	40,324
Western LIS (Eastern and Western Narrows Combined), CT and NY	403.1	1,119.5	18,479,002	157,017	16,481

[a] Includes multiple Vaudrey et al. (2016) embayments.

The following summaries provide nitrogen loads for each embayment for comparison, as well as summary information that might be useful in future analysis and allocation efforts.

A.1 Pawcatuck River, CT and RI

Figure A-1 shows a map of the Pawcatuck River watershed. Summary statistics are included in Table A-3.

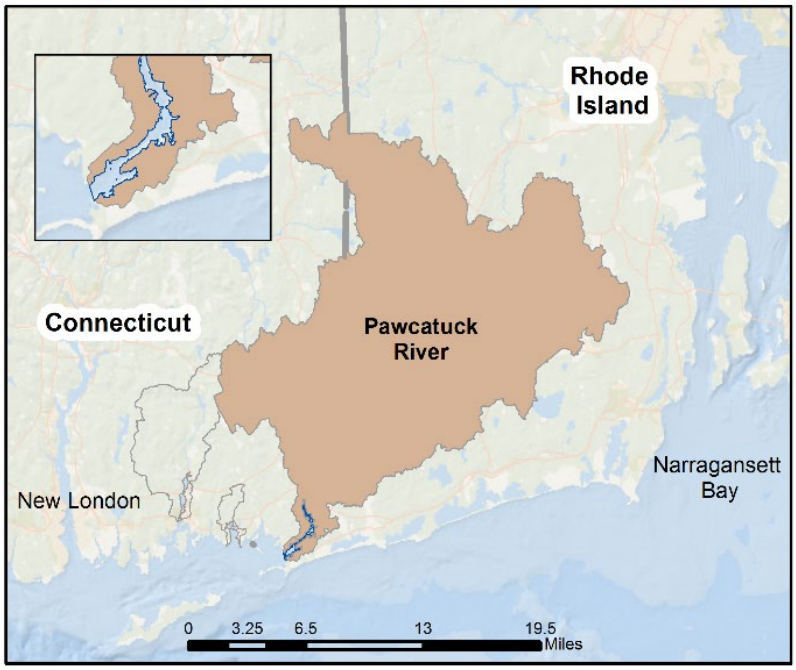

Figure A-1. Pawcatuck River Watershed, CT and RI. The inset highlights Pawcatuck River Embayment.

Table A-3. Summary Information for the Pawcatuck River Embayment and Watershed, CT and RI

Total Drainage Area of Watershed (Vaudrey et al. 2016)	674.6 km^2
Total Area of Embayment (Vaudrey et al. 2016)	2.6 km^2
Main Tributaries (FBEA 2011)	Ashaway River Beaver River Chipuxet River Meadow Brook Queen/Usquepaug River Shunock River Tomaquag Brook Wood River
Residence Time (Abdelrhman 2005 derived)	4.3 days
Depth at MLLW (NOAA 2015)	Average: 1.4 m Maximum: 4 m
Land Use Characteristics (Vaudrey et al. 2016; NLCD 2011 land use data)	Developed: 12% Forested: 75% Agricultural: 8% Water: 2% Grass: 2% Barren: 1%

MS4s: Ashaway New London Pawcatuck Washington Westerly	Percent of watershed with MS4: 8%		
Point Sources (USEPA 2015)		**kg N/year**	**lbs N/day**
	Stonington/Pawcatuck Water Pollution Control Facility (WPCF)	1,822	11
	Kenyon Industries, Inc.	26,627	161
	Westerly Wastewater Treatment Facility (WWTF)	48,282	292
	Sum of point sources	**76,731**	**464**
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/day**
	Atmospheric deposition	39,715	240
	Fertilizer	85,602	517
	Sewer	69,849	422
	CSOs	N/A	N/A
	Septic and cesspools	48,763	294
	Entire embayment	**243,929**	**1,473**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

A.2 Stonington Harbor, CT

Figure A-2 shows a map of the Stonington Harbor watershed. Summary statistics are included in Table A-4.

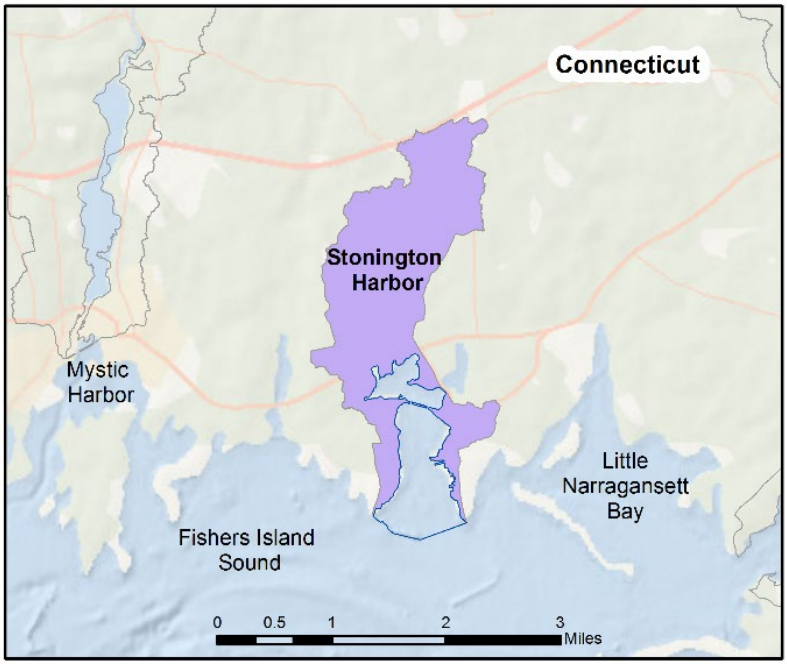

Figure A-2. Stonington Harbor Watershed, CT

Table A-4. Summary Information for Stonington Harbor Embayment and Watershed, CT

Total Drainage Area of Watershed (Vaudrey et al. 2016)	6.2 km^2		
Total Area of Embayment (Vaudrey et al. 2016)	1.8 km^2		
Main Tributaries (ESRI 2017)	Stony Brook		
Residence Time (Abdelrhman 2005 derived)	2.5 days		
Depth at MLLW (NOAA 2015)	Average: Maximum:	2.4 m 6 m	
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	24% 53% 2% 7% 13% 1%	
MS4s: New London Stonington	Percent of watershed with MS4:	35%	
Point Sources (USEPA 2015)	Stonington Borough WPCF	**kg N/year** 663	**lbs N/day** 4

		kg N/year	**lbs N/year**
Total Nitrogen Loading (Vaudrey et al. 2016)[a]	Atmospheric deposition	3,061	18
	Fertilizer	1,131	7
	Sewer	2,070	13
	CSOs	N/A	N/A
	Septic and cesspools	894	5
	Entire embayment	**7,156**	**43**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

A.3 Saugatuck Estuary, CT[1]

Figure A-3 shows a map of the Saugatuck Estuary watershed. Summary statistics are included in Table A-5.

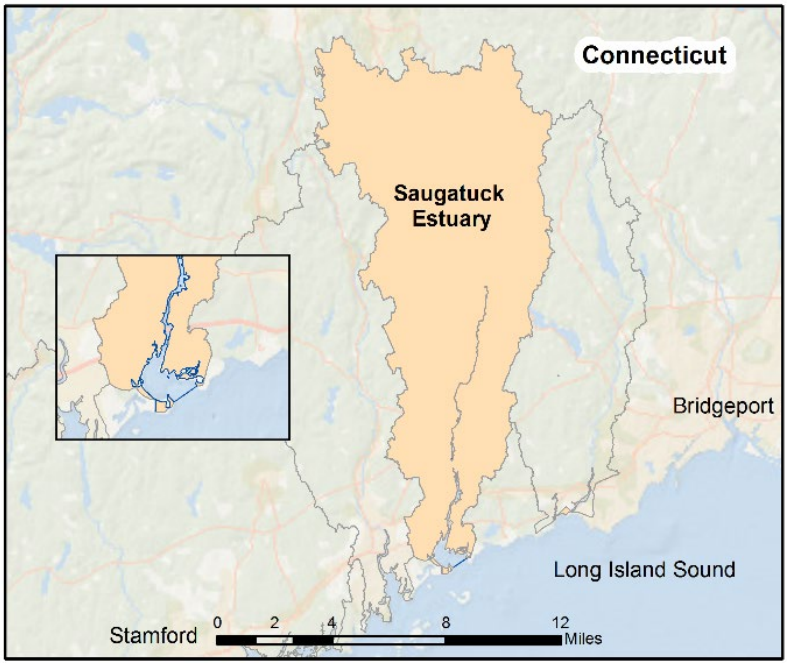

Figure A-3. Saugatuck Estuary Watershed, CT. The inset highlights Saugatuck Estuary Embayment.

Table A-5. Summary Information for Saugatuck Estuary Embayment and Watershed, CT

Total Drainage Area of Watershed (Vaudrey et al. 2016)	225.6 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	2.5 km^2	
Main Tributaries (AKRF, Inc. 2012)	Aspetuck River Beaver Brook Jennings Brook Little River Stony Brook West Branch	
Residence Time (Abdelrhman 2005 derived)	4.3 days	
Depth at MLLW (NOAA 2015)	Average: Maximum:	1.0 m 8 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	20% 64% 2% 3% 11% 0%

[1] Includes two Vaudrey et al. (2016) embayments: Saugatuck River, CT and Saugatuck River, North, CT (freshwater).

MS4s: Bethel Danbury Easton Fairfield Georgetown Newtown Norwalk Redding Ridgefield Weston Westport Wilton	Percent of watershed with MS4 • Saugatuck River, CT embayment: 100% • Saugatuck River, North, CT (freshwater) embayment: 36%		
Point Sources (USEPA 2015)	 Westport WPCF	**kg N/year** 3,313	**lbs N/day** 20
Total Nitrogen Loading (Vaudrey et al. 2016)[a]	 Atmospheric deposition Fertilizer Sewer CSOs[b] Septic and cesspools **Entire embayment**	**kg N/year** 24,685 30,214 4,760 238 42,795 **102,692**	**lbs N/year** 149 183 29 1 258 **620**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

[b] Vaudrey estimates are from data that represent the 2010–2014 period. More recent data from CT DEEP (http://www.ct.gov/deep/cwp/view.asp?a=2719&q=525758&deepNav_GID=1654) show that there are presently no CSOs in the Saugatuck Estuary watershed.

A.4 Norwalk Harbor, CT

Figure A-4 shows a map of the Norwalk Harbor watershed. Summary statistics are included in Table A-6.

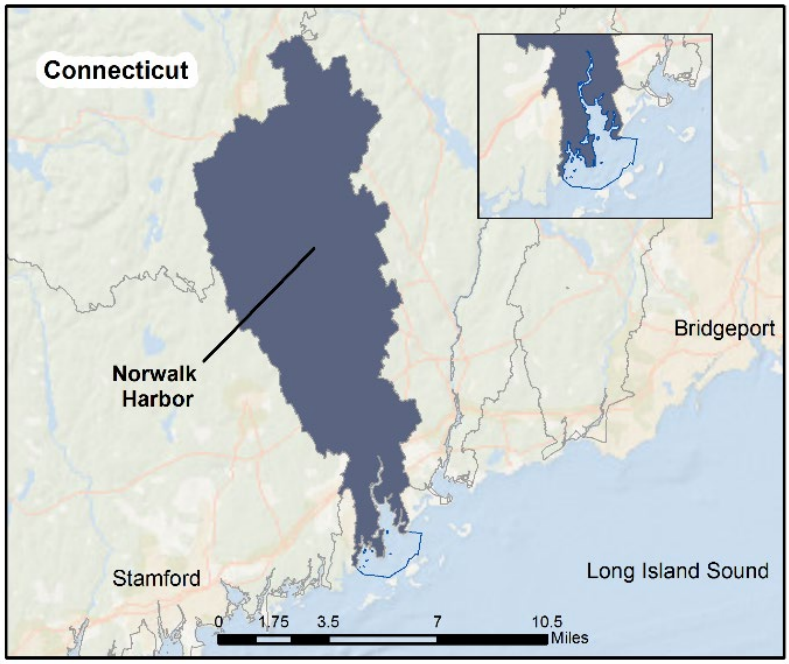

Figure A-4. Norwalk Harbor Watershed, CT. The inset highlights Norwalk Harbor Embayment.

Table A-6. Summary Information for Norwalk Harbor Embayment and Watershed, CT

Total Drainage Area of Watershed (Vaudrey et al. 2016)	155.5 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	6.9 km^2	
Main Tributaries (NRWIC 1998)	Silvermine River Comstock Brook Cooper Pond Brook	
Residence Time (Abdelrhman 2005 derived)	4.8 days	
Depth at MLLW (NOAA 2015)	Average: Maximum:	1.5 m 10 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	33% 50% 1% 2% 14% 0%
MS4s: Fairfield Georgetown Lewisboro New Canaan Norwalk Redding Ridgefield Weston Wilton	Percent of watershed with MS4:	94%

Point Sources (USEPA 2015)	Norwalk WPCF	**kg N/year** 96,588	**lbs N/day** 583
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/day**
	Atmospheric deposition	23,356	141
	Fertilizer	19,450	117
	Sewer	121,472	734
	CSOs[b]	6,074	37
	Septic and cesspools	19,241	116
	Entire embayment	**189,593**	**1,145**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

[b] Vaudrey estimates are from data that represent the 2010–2014 period. More recent data from CT DEEP (http://www.ct.gov/deep/cwp/view.asp?a=2719&q=525758&deepNav_GID=1654) show that there is presently one CSO in the Norwalk Harbor watershed.

A.5 Mystic Harbor, CT

Figure A-5 shows a map of the Mystic Harbor watershed. Summary statistics are included in Table A-7.

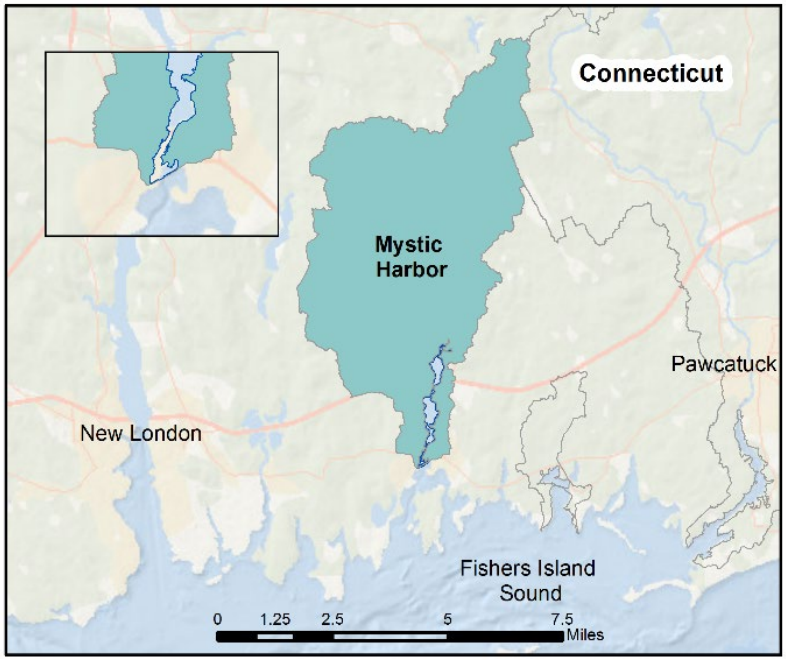

Figure A-5. Mystic Harbor Watershed, CT. The inset highlights Mystic Harbor Embayment.

Table A-7. Summary Information for Mystic Harbor Embayment and Watershed, CT

Total Drainage Area of Watershed (Vaudrey et al. 2016)	67.2 km^2		
Total Area of Embayment (Vaudrey et al. 2016)	1.2 km^2		
Main Tributaries (ESRI 2017)	Whitford Brook Haleys Brook		
Residence Time (Abdelrhman 2005 derived)	3.5 days		
Depth at MLLW (NOAA 2015)	Average: Maximum:	0.5 m 4 m	
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	15% 67% 6% 2% 9% 1%	
MS4s: Groton Ledyard Mystic New London Old Mystic Stonington	Percent of watershed with MS4:	34%	
Point Sources (USEPA 2015)		**kg N/year**	**lbs N/day**
	Ledyard WPCF	663	4
	Stonington Mystic WPCF	2,485	15
	Sum of point sources	**3,148**	**19**

		kg N/year	**lbs N/day**
Total Nitrogen Loading (Vaudrey et al. 2016)[a]	Atmospheric deposition	5,855	35
	Fertilizer	8,258	50
	Sewer	8,030	49
	CSOs	N/A	N/A
	Septic and cesspools	7,682	46
	Entire embayment	**29,825**	**180**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

A.6 Niantic Bay, CT[2]

Figure A-6 shows a map of the Niantic Bay watershed. Summary statistics are included in Table A-8.

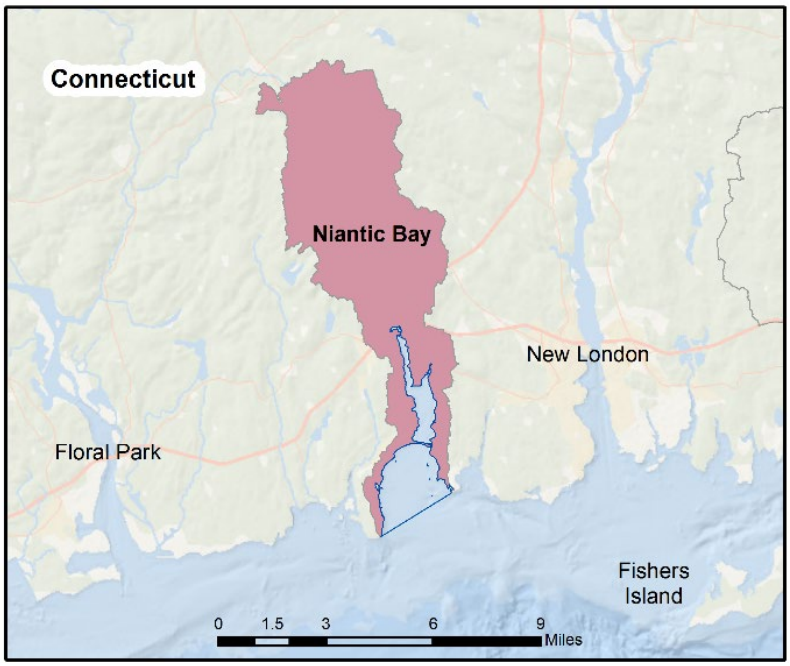

Figure A-6. Niantic Bay Watershed, CT

Table A-8. Summary Information for Niantic Bay Embayment and Watershed, CT

Total Drainage Area of Watershed (Vaudrey et al. 2016)	76.2 km^2
Total Area of Embayment (Vaudrey et al. 2016)	11.4 km^2
Main Tributaries (ECCD 2009)	Latimer Brook Oil Mill Brook Stony Brook
Residence Time (Abdelrhman 2005 derived)	3.92 days
Depth at MLLW (NOAA 2015)	Average: 4.5 m Maximum: 14 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: 16% Forested: 67% Agricultural: 3% Water: 4% Grass: 7% Barren: 3%
MS4s: East Lyme Montville New London Niantic Waterford	Percent of watershed with MS4 • Niantic River, CT embayment: 24% • Niantic Bay, CT embayment: 100%
Point Sources	No identified point sources within the watershed

[2] Includes two Vaudrey et al. (2016) embayments: Niantic River, CT and Niantic Bay, CT.

		kg N/year	lbs N/year
Total Nitrogen Loading (Vaudrey et al. 2016)[a]	Atmospheric deposition	24,292	147
	Fertilizer	6,508	39
	Sewer	N/A	N/A
	CSOs	N/A	N/A
	Septic and cesspools	4,957	30
	Entire embayment	**35,757**	**216**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

A.7 Farm River, CT

Figure A-7 shows a map of the Farm River watershed. Summary statistics are included in Table A-9.

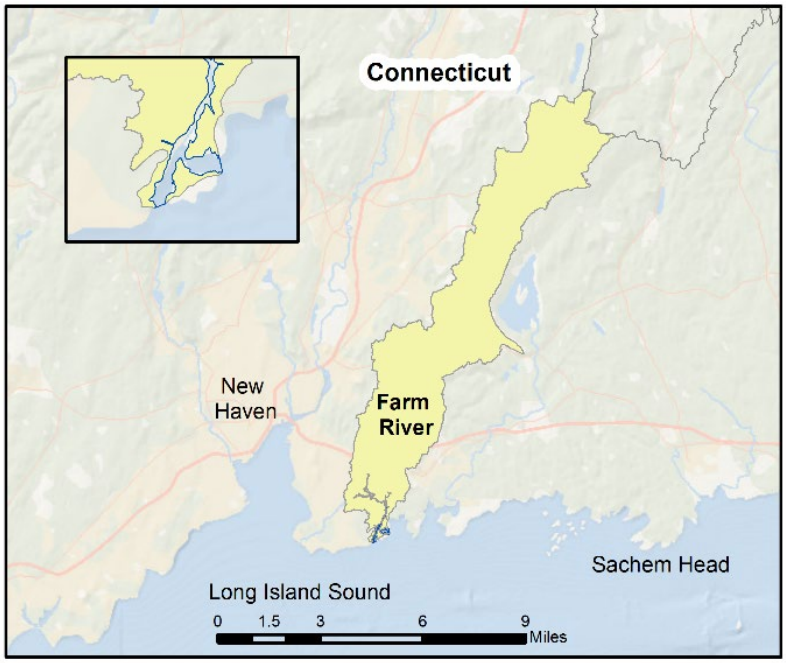

Figure A-7. Farm River Watershed, CT. The inset highlights Farm River Embayment.

Table A-9. Summary Information for Farm River Embayment and Watershed, CT

Total Drainage Area of Watershed (Vaudrey et al. 2016)	67.4 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	0.4 km^2	
Main Tributaries (ESRI 2017)	Maloney Brook Burrs Brook Gulf Brook	
Residence Time (Abdelrhman 2005 derived)	3.2 days	
Depth at MLLW	Not available	
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	25% 44% 9% 6% 12% 4%
MS4s: Branford East Haven Guilford New Haven North Branford North Haven Wallingford	Percent of watershed with MS4:	71%
Point Sources	No identified point sources within the watershed	

		kg N/year	**lbs N/year**
Total Nitrogen Loading (Vaudrey et al. 2016)[a]	Atmospheric deposition	7,482	45
	Fertilizer	12,460	75
	Sewer	N/A	N/A
	CSOs	N/A	N/A
	Septic and cesspools	14,737	89
	Entire embayment	**34,679**	**209**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

A.8 Southport Harbor/Sasco Brook, CT[3]

Figure A-8 shows a map of the Southport Harbor/Sasco Brook watershed. Summary statistics are included in Table A-10.

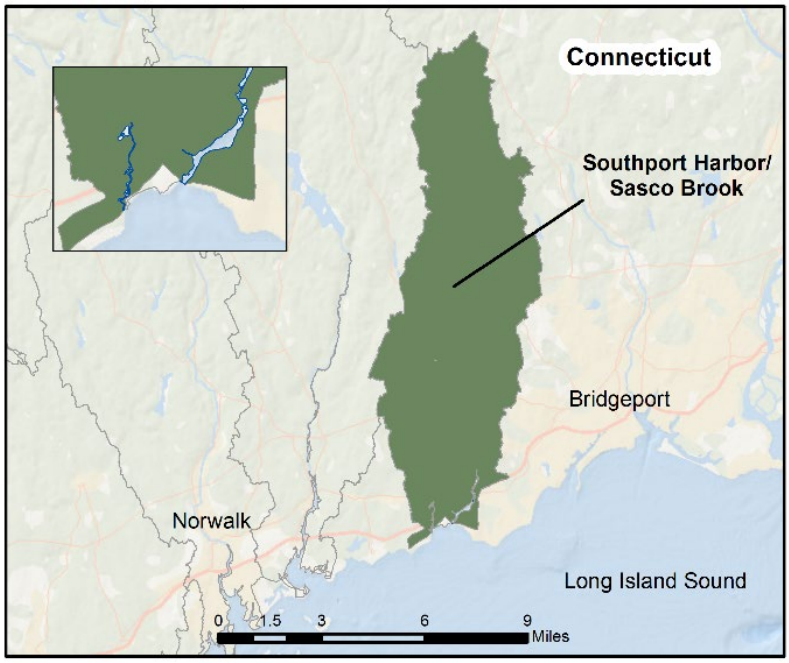

Figure A-8. Southport Harbor/Sasco Brook Watershed, CT. The inset highlights Southport Harbor/Sasco Brook Embayment.

Table A-10. Summary Information for Southport Harbor/Sasco Brook Embayment and Watershed, CT

Total Drainage Area of Watershed (Vaudrey et al. 2016)	111.6 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	0.3 km^2	
Main Tributaries (ESRI 2017)	To Mill River: • Browns Brook • Cricker Brook • Morehouse Brook • Canoe Brook • Chub Brook • Tatetuck Brook To Sasco Brook: • Great Brook	
Residence Time (Abdelrhman 2005 derived)	Mill River: Sasco Brook:	2.4 days 1.5 days
Depth at MLLW (NOAA 2015)	*Southport Harbor* Average Maximum:	 0.5 m 6 m

[3] Includes two Vaudrey et al. (2016) embayments: Mill River, CT and Sasco Brook, CT.

Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	26% 47% 3% 5% 19% 0%	
MS4s: Bridgeport Easton Fairfield Monroe Trumbull Westport	Percent of watershed with MS4 • Mill River, CT embayment: • Sasco Brook, CT embayment:	 50% 99%	
Point Sources	No identified point sources within the watershed		
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/year**
	Atmospheric deposition	9,211	56
	Fertilizer	22,187	134
	Sewer	N/A	N/A
	CSOs	N/A	N/A
	Septic and cesspools	17,234	104
	Entire embayment	**48,632**	**294**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

A.9 Northport-Centerport Harbor Complex, NY[4]

Figure A-9 shows a map of the Northport-Centerport Harbor Complex watershed. Summary statistics are included in Table A-11.

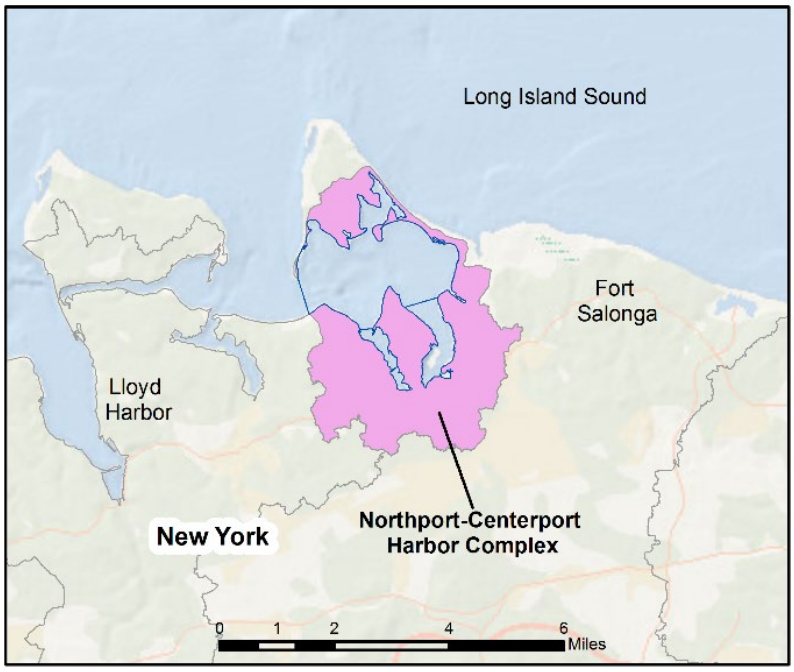

Figure A-9. Northport-Centerport Harbor Complex Watershed, NY

Table A-11. Summary Information for Northport-Centerport Harbor Complex Embayment and Watershed, NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	21.2 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	12.0 km^2	
Main Tributaries (ESRI 2017)	No major tributaries identified	
Residence Time (Abdelrhman 2005 derived)	Centerport Harbor: Northport Bay: Northport Harbor:	1.9 days 4.3 days 2.4 days
Depth at MLLW (NOAA 2015)	Average: Maximum:	3.7 m 21 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	47% 37% 0% 2% 12% 2%
MS4s: Asharokan Huntington Huntington Bay Northport	Percent of watershed with MS4 • Centerport Harbor, NY embayment: • Northport Bay, NY embayment: • Northport Harbor, NY embayment:	 100% 98% 99%

[4] Includes three Vaudrey et al. (2016) embayments: Centerport Harbor, NY; Northport Bay, NY; and Northport Harbor, NY.

Point Sources (USEPA 2015)	Northport (Village)	**kg N/year** 1,491	**lbs N/day** 9
Total Nitrogen Loading (Vaudrey et al. 2016)[a]	Atmospheric deposition Fertilizer Sewer CSOs Septic and cesspools **Entire embayment**	**kg N/year** 21,243 3,662 2,925 N/A 45,545 **73,375**	**lbs N/day** 128 22 18 N/A 275 **443**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

A.10 Port Jefferson Harbor, NY

Figure A-10 shows a map of the Port Jefferson Harbor watershed. Summary statistics are included in Table A-12.

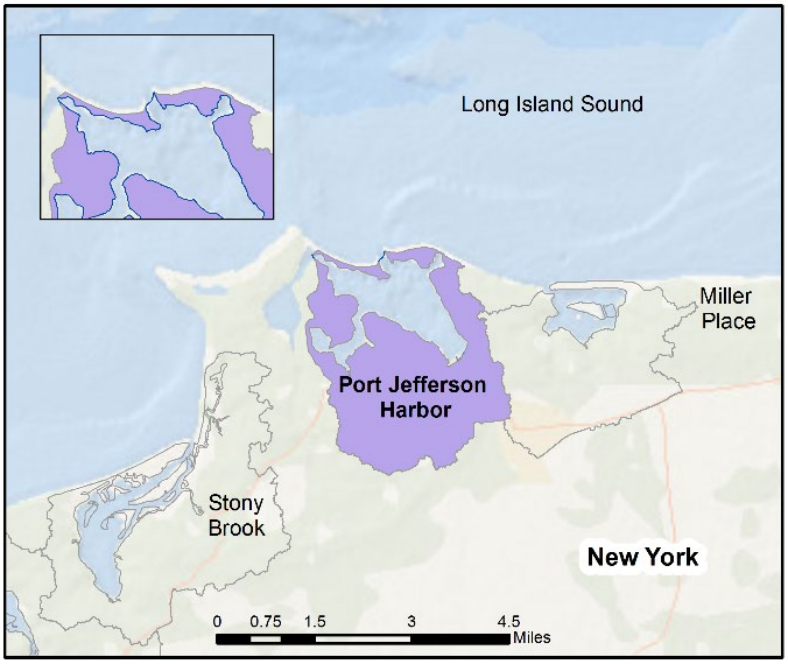

Figure A-10. Port Jefferson Harbor Watershed, NY. The inset highlights Port Jefferson Harbor Embayment.

Table A-12. Summary Information for Port Jefferson Harbor Embayment and Watershed, NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	15.5 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	5.0 km^2	
Main Tributaries (Cashin Associates 2009; ESRI 2017)	Conscience Bay Setauket Harbor	
Residence Time (Abdelrhman 2005 derived)	3.1 days	
Depth at MLLW (NOAA 2015)	Average: Maximum:	3.8 m 13 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	40% 41% 0% 2% 12% 5%
MS4s: Belle Terre Brookhaven Old Field Poquott Port Jefferson	Percent of watershed with MS4:	98%

Point Sources (USEPA 2015)	Port Jefferson, Suffolk County Sewer District [SCSD] #1	**kg N/year** 3,645	**lbs N/day** 22
	SUNY SCSD #21	6,627	40
	Sum of point sources	**10,272**	**62**
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/year**
	Atmospheric deposition	10,077	61
	Fertilizer	2,109	13
	Sewer	16,404	99
	CSOs[b]	757	4
	Septic and cesspools	29,276	177
	Entire embayment	**58,623**	**354**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

[b] Vaudrey estimates are from data that represent the 2010–2014 period. More recent data from New York State (https://data.ny.gov/Energy-Environment/Combined-Sewer-Overflows-CSOs-Map/i8hd-rmbi/data) show that there are presently no CSOs in the Port Jefferson Harbor watershed.

A.11 Nissequogue River, NY

Figure A-11 shows a map of the Nissequogue River watershed. Summary statistics are included in Table A-13.

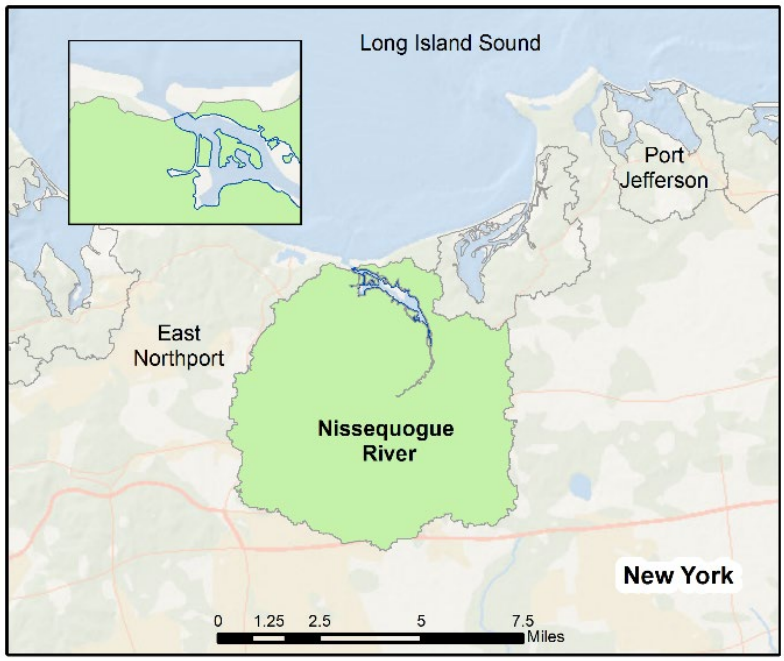

Figure A-11. Nissequogue River Watershed, NY. The inset highlights Nissequogue River Embayment.

Table A-13. Summary Information for Nissequogue River Embayment and Watershed, NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	97.4 km^2		
Total Area of Embayment (Vaudrey et al. 2016)	2.0 km^2		
Main Tributaries (ESRI 2017)	Sunken Meadow Creek Northeast Branch		
Residence Time (Abdelrhman 2005 derived)	4.5 days		
Depth at MLLW (NOAA 2015)	Average: Maximum:	0.1 m 3 m	
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	48% 34% 0% 2% 15% 1%	
MS4s: Head of Harbor Islip Nissequogue Smithtown The Branch	Percent of watershed with MS4:	99%	
Point Sources (USEPA 2015)	Kings Park SCSD #6	**kg N/year** 1,491	**lbs N/day** 9

		kg N/year	**lbs N/day**
Total Nitrogen Loading (Vaudrey et al. 2016)[a]	Atmospheric deposition	11,917	72
	Fertilizer	16,789	101
	Sewer	N/A	N/A
	CSOs[b]	127,442	770
	Septic and cesspools	179,549	1,085
	Entire embayment	**335,697**	**2,028**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

[b] Vaudrey estimates are from data that represent the 2010–2014 period. More recent data from New York State (https://data.ny.gov/Energy-Environment/Combined-Sewer-Overflows-CSOs-Map/i8hd-rmbi/data) show that there are presently no CSOs in the Nissequogue River watershed.

A.12 Stony Brook Harbor, NY

Figure A-12 shows a map of the Stony Brook Harbor watershed. Summary statistics are included in Table A-14.

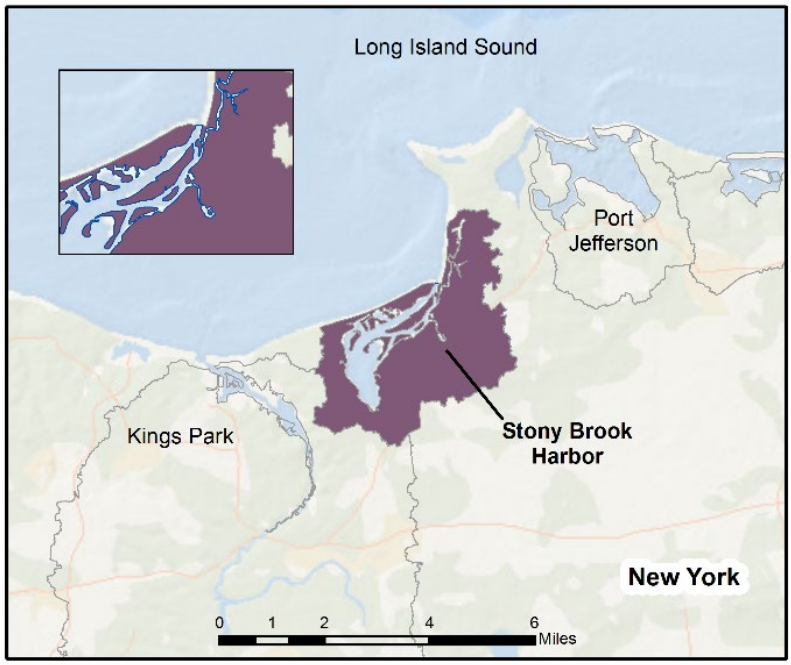

Figure A-12. Stony Brook Harbor Watershed, NY. The inset highlights Stony Brook Harbor Embayment.

Table A-14. Summary Information for Stony Brook Harbor Embayment and Watershed, NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	19.9 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	3.7 km^2	
Main Tributaries (Robbins 1977)	West Meadow Creek	
Residence Time (Abdelrhman 2005 derived)	4.0 days	
Depth at MLLW (NOAA 2015)	Average: Maximum:	0.7 m 4 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	30% 48% 3% 7% 10% 2%
MS4s: Brookhaven Head of Harbor Nissequogue Old Field Smithtown	Percent of watershed with MS4:	96%
Point Sources	No identified point sources within the watershed	

		kg N/year	**lbs N/day**
Total Nitrogen Loading (Vaudrey et al. 2016)[a]	Atmospheric deposition	8,376	51
	Fertilizer	4,348	26
	Sewer	N/A	N/A
	CSOs	N/A	N/A
	Septic and cesspools	22,032	133
	Entire embayment	**34,756**	**210**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

A.13 Mt. Sinai Harbor, NY

Figure A-13 shows a map of the Mt. Sinai Harbor watershed. Summary statistics are included in Table A-15.

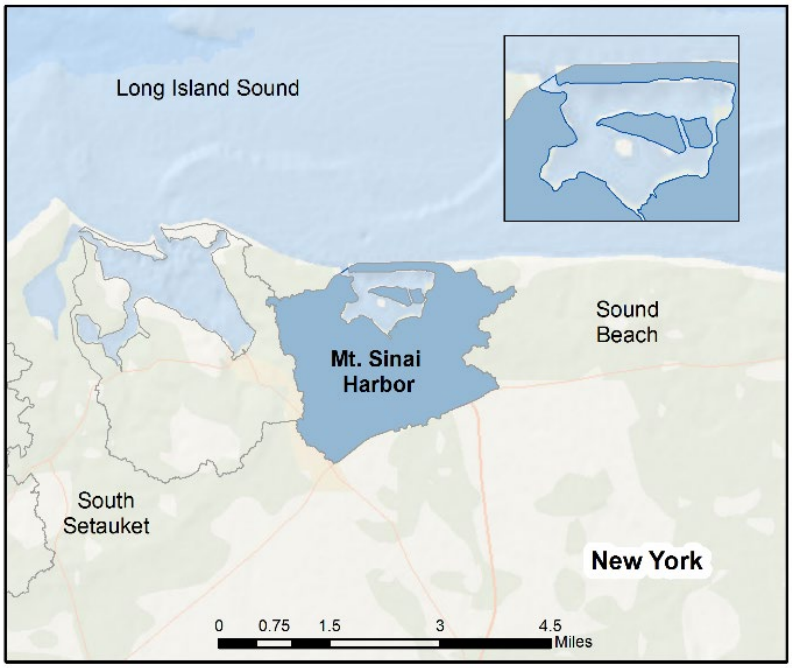

Figure A-13. Mt. Sinai Harbor Watershed, NY. The inset highlights Mt. Sinai Harbor Embayment.

Table A-15. Summary Information for Mt. Sinai Harbor Embayment and Watershed, NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	13.3 km^2		
Total Area of Embayment (Vaudrey et al. 2016)	1.6 km^2		
Main Tributaries (ESRI 2017)	No major tributaries identified		
Residence Time (Abdelrhman 2005 derived)	2.0 days		
Depth at MLLW (NOAA 2015)	Average Maximum:	2.1 m 11 m	
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	41% 43% 0% 3% 12% 1%	
MS4s: Belle Terre Brookhaven Port Jefferson	Percent of watershed with MS4:	98%	
Point Sources	No identified point sources within the watershed		
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/day**
	Atmospheric deposition	4,345	26
	Fertilizer	2,604	16
	Sewer	N/A	N/A
	CSOs	N/A	N/A
	Septic and cesspools	32,094	194
	Entire embayment	**39,043**	**236**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

A.14 Mamaroneck River, NY

Figure A-14 shows a map of the Mamaroneck River watershed. Summary statistics are included in Table A-16.

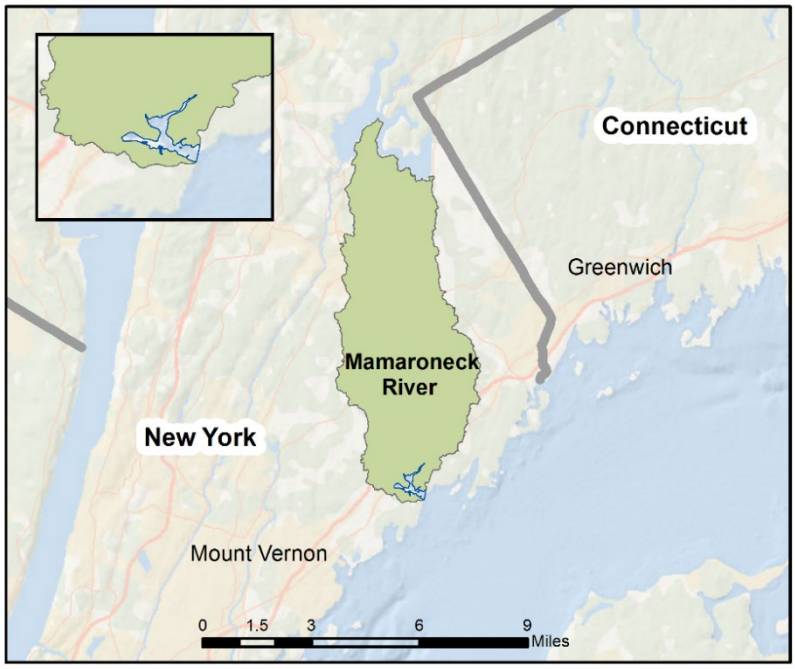

Figure A-14. Mamaroneck River Watershed, NY. The inset highlights Mamaroneck River Embayment.

Table A-16. Summary Information for the Mamaroneck River Embayment and Watershed, NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	66.5 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	0.5 km^2	
Main Tributaries (USGS 2017)	Beaver Swamp Brook Otter Creek Sheldrake River West Branch Mamaroneck River	
Residence Time (Abdelrhman 2005 derived)	1.8 days	
Depth at MLLW (NOAA 2015)	Average: Maximum:	1.3 m 5 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	42% 35% 0% 1% 22% 0%
MS4s: Harrison Mamaroneck North Castle Rye Scarsdale White Plains	Percent of watershed with MS4:	100%

Point Sources (USEPA 2015)	Mamaroneck WPCF	**kg N/year** 51,359	**lbs N/day** 310
Total Nitrogen Loading (Vaudrey et al. 2016)[a]	 Atmospheric deposition Fertilizer Sewer CSOs[b] Septic and cesspools **Entire embayment**	**kg N/year** 9,367 36,123 N/A 15,394 152 **61,036**	**lbs N/day** 57 218 N/A 93 1 **369**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

[b] Vaudrey estimates are from data that represent the 2010–2014 period. More recent data from New York State (https://data.ny.gov/Energy-Environment/Combined-Sewer-Overflows-CSOs-Map/i8hd-rmbi/data) show that there are presently no CSOs in the Mamaroneck River watershed.

A.15 Hempstead Harbor, NY

Figure A-15 shows a map of the Hempstead Harbor watershed. Summary statistics are included in Table A-17.

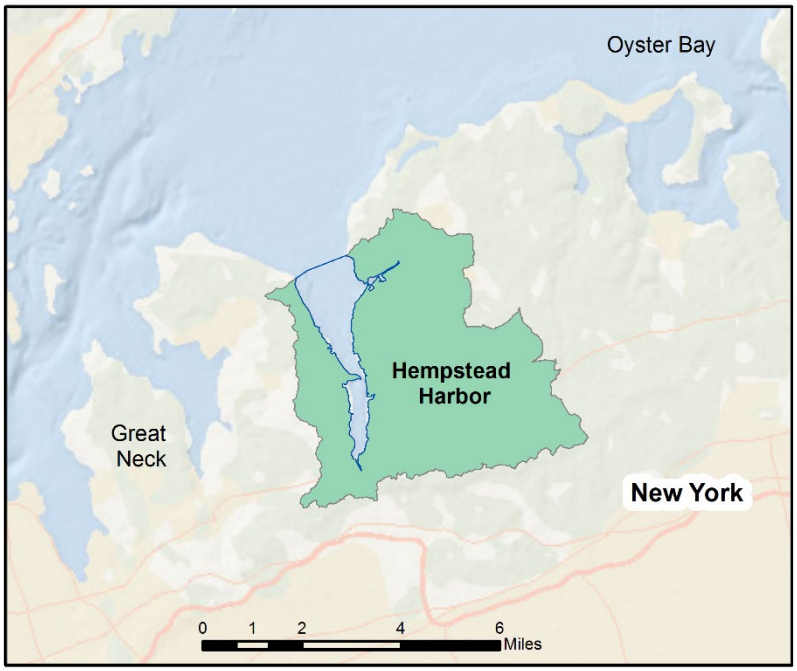

Figure A-15. Hempstead Harbor Watershed, NY

Table A-17. Summary Information for Hempstead Harbor Embayment and Watershed, NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	51.0 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	6.4 km^2	
Main Tributaries (USGS 2017)	No major tributaries identified	
Residence Time (Abdelrhman 2005 derived)	4.9 days	
Depth at MLLW (NOAA 2015)	Average: Maximum:	3.6 m 29 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	47% 21% 1% 1% 29% 1%

MS4s: Brookville East Hills Flower Hill Glen Cove North Hempstead North Hills Old Brookville Old Westbury Oyster Bay Roslyn Roslyn Estates Roslyn Harbor Sands Point Sea Cliff Upper Brookville	Percent of watershed with MS4: 99%		
Point Sources (USEPA 2015)	Glen Cove	**kg N/year** 25,514	**lbs N/day** 154
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/day**
	Atmospheric deposition	14,114	85
	Fertilizer	33,174	200
	Sewer	30,529	184
	CSOs[b]	379	2
	Septic and cesspools	51,196	309
	Entire embayment	**129,392**	**780**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

[b] Vaudrey estimates are from data that represent the 2010–2014 period. More recent data from New York State (https://data.ny.gov/Energy-Environment/Combined-Sewer-Overflows-CSOs-Map/i8hd-rmbi/data) show that there are presently no CSOs in the Hempstead Harbor watershed.

A.16 Areas Adjacent to the Northport/Centerport Harbor Complex, NY[5]

Figure A-16 shows a map of the Huntington Bay, Huntington Harbor, and Lloyd Harbor watersheds. Summary statistics are included in Table A-18, Table A-19, and Table A-20.

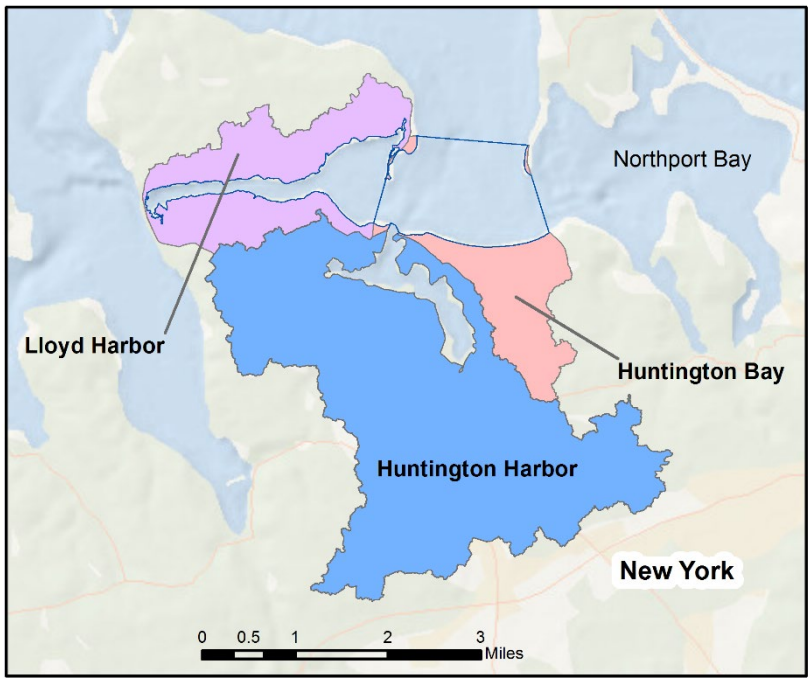

Figure A-16. Huntington Bay, Huntington Harbor, and Lloyd Harbor Watersheds, NY

Huntington Bay, NY

Table A-18. Summary Information for Huntington Bay Embayment and Watershed, NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	3.7 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	4.4 km^2	
Main Tributaries (USGS 2017)	No major tributaries identified	
Residence Time (Abdelrhman 2005 derived)	2.3 days	
Depth at MLLW (NOAA 2015)	Average: Maximum:	5.6 m 15 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	55% 22% 0% 1% 19% 3%

[5] Includes three Vaudrey et al. (2016) embayments: Huntington Bay, NY; Huntington Harbor, NY; and Lloyd Harbor, NY.

MS4s: Huntington Huntington Bay Lloyd Harbor	Percent of watershed with MS4: 98%		
Point Sources (USEPA 2015)	No identified point sources within the watershed		
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/day**
	Atmospheric deposition	7,195	43
	Fertilizer	952	6
	Sewer	N/A	N/A
	CSOs	N/A	N/A
	Septic and cesspools	7,105	43
	Entire embayment	**15,252**	**92**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

Huntington Harbor, NY

Table A-19. Summary Information for Huntington Harbor Embayment and Watershed, NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	23.9 km^2		
Total Area of Embayment (Vaudrey et al. 2016)	1.5 km^2		
Main Tributaries (USGS 2017)	No major tributaries identified		
Residence Time (Abdelrhman 2005 derived)	2.7 days		
Depth at MLLW (NOAA 2015)	Average: 2.0 m Maximum: 8 m		
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: 54% Forested: 24% Agricultural: 0% Water: 1% Grass: 21% Barren: 0%		
MS4s: Huntington Huntington Bay Lloyd Harbor	Percent of watershed with MS4: 100%		
Point Sources (USEPA 2015)	Huntington	**kg N/year** 9,122	**lbs N/day** 55
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/day**
	Atmospheric deposition	4,317	26
	Fertilizer	6,186	37
	Sewer	6,674	40
	CSOs	N/A	N/A
	Septic and cesspools	42,413	256
	Entire embayment	**59,590**	**359**

[1] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

Lloyd Harbor, NY

Table A-20. Summary Information for Lloyd Harbor Embayment and Watershed, NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	6.1 km^2		
Total Area of Embayment (Vaudrey et al. 2016)	2.3 km^2		
Main Tributaries (USGS 2017)	No major tributaries identified		
Residence Time (Abdelrhman 2005 derived)	3.5 days		
Depth at MLLW (NOAA 2015)	Average: Maximum:	1.4 m 6 m	
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	20% 52% 2% 6% 18% 2%	
MS4s: Lloyd Harbor	Percent of watershed with MS4:	99%	
Point Sources (USEPA 2015)	No identified point sources within the watershed		
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/day**
	Atmospheric deposition	4,326	26
	Fertilizer	1,791	11
	Sewer	N/A	N/A
	CSOs	N/A	N/A
	Septic and cesspools	2,686	16
	Entire embayment	**8,803**	**53**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

A.17 Oyster Bay/Cold Spring Harbor Complex, NY[6]

Figure A-17 shows a map of the Oyster Bay/Cold Spring Harbor Complex watershed. Summary statistics are included in Table A-21.

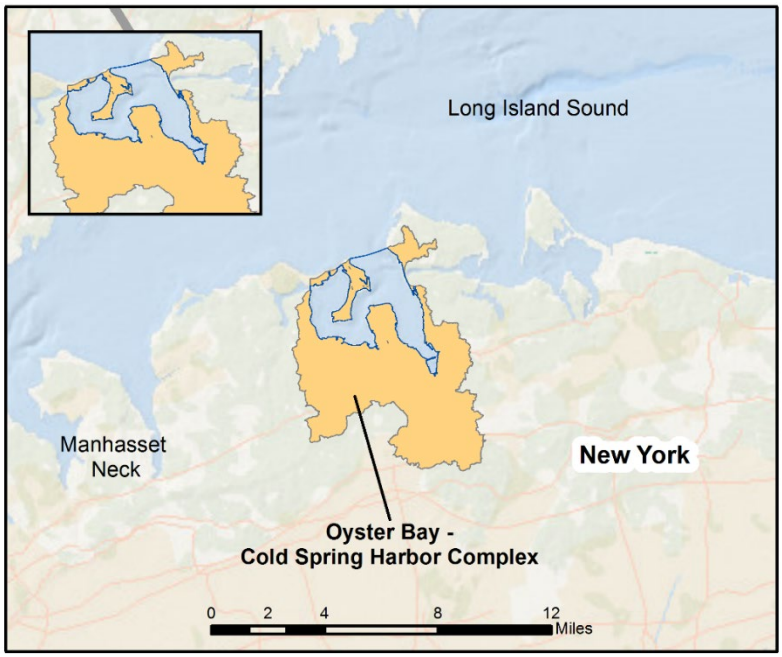

Figure A-17. Oyster Bay/Cold Spring Harbor Complex Watershed, NY. The inset highlights Oyster Bay/Cold Spring Harbor Complex Embayment.

Table A-21. Summary Information for Oyster Bay/Cold Spring Harbor Complex Embayment and Watershed, NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	66.8 km^2
Total Area of Embayment (Vaudrey et al. 2016)	22.2 km^2
Main Tributaries (USGS 2017)	To Oyster Bay: • Tiffany Creek To Cold Spring Harbor: • No major tributaries identified
Residence Time (Abdelrhman 2005 derived)	Oyster Bay: 5.3 days Cold Spring Harbor: 5.7 days
Depth at MLLW (NOAA 2015)	Average: 4.7 m Maximum: 24 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: 31% Forested: 48% Agricultural: 1% Water: 2% Grass: 18% Barren: 1%

[6] Includes two Vaudrey et al. (2016) embayments: Oyster Bay, NY and Cold Spring Harbor, NY.

MS4s: Bayville Centre Island Cove Neck Huntington Laurel Hollow Lloyd Harbor Matinecock Mill Neck Muttontown Oyster Bay Oyster Bay Cove Upper Brookville	Percent of watershed with MS4: • Oyster Bay 100% • Cold Spring Harbor 100%		
Point Sources (USEPA 2015)	Oyster Bay	**kg N/year** 8,284	**lbs N/day** 50
Total Nitrogen Loading (Vaudrey et al. 2016)[a]	 Atmospheric deposition Fertilizer Sewer CSOs[b] Septic and cesspools **Entire embayment**	**kg N/year** 32,763 15,286 8,707 1,135,623 30,355 **1,222,734**	**lbs N/day** 198 92 53 6,859 183 **7,385**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

[b] Vaudrey estimates are from data that represent the 2010–2014 period. More recent data from New York State (https://data.ny.gov/Energy-Environment/Combined-Sewer-Overflows-CSOs-Map/i8hd-rmbi/data) show that there are presently no CSOs in the Oyster Bay/Cold Spring Harbor Complex watershed.

A.18 Manhasset Bay, NY

Figure A-18 shows a map of the Manhasset Bay watershed. Summary statistics are included in Table A-22.

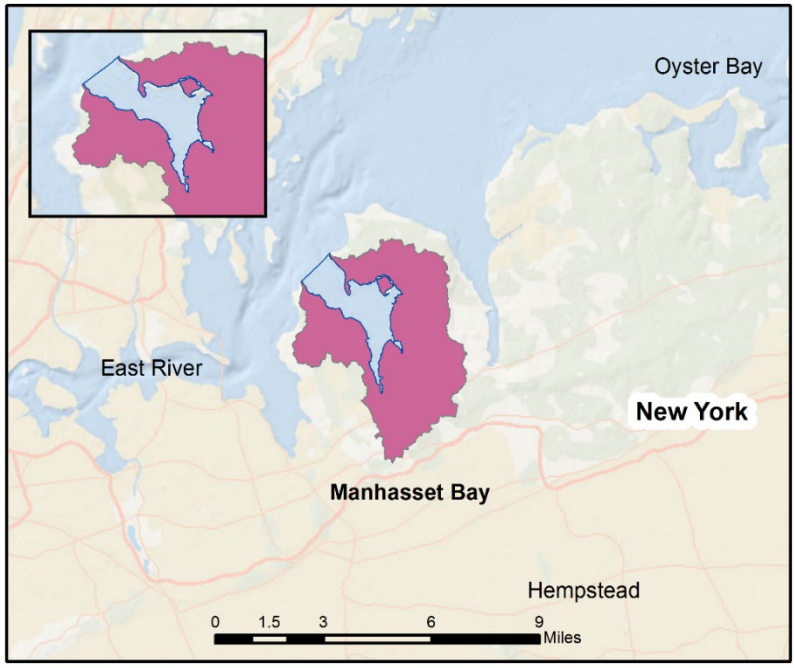

Figure A-18. Manhasset Bay Watershed, NY. The inset highlights Manhasset Bay Embayment.

Table A-22. Summary Information for Manhasset Bay Embayment and Watershed, NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	37.5 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	8.4 km^2	
Main Tributaries (USGS 2017)	Mitchells Creek	
Residence Time (Abdelrhman 2005 derived)	5.1 days	
Depth at MLLW (NOAA 2015)	Average: Maximum:	3.2 m 14 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	54% 15% 0% 2% 28% 1%

MS4s: Baxter Estates Flower Hill Great Neck Great Neck Plaza Kensington Kings Point Lake Success Manor Haven Munsey Park North Hempstead North Hills Plandome Plandome Heights Plandome Manor Port Wash North Roslyn Estates Sands Point Thomaston	Percent of watershed with MS4: 99%		
Point Sources (USEPA 2015)		**kg N/year**	**lbs N/day**
	Great Neck Water Pollution Control District (WPCD)	36,614	221
	Port Washington	28,827	174
	Sum of point sources	**65,441**	**395**
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/day**
	Atmospheric deposition	14,381	87
	Fertilizer	19,987	121
	Sewer	61,381	371
	CSOs[b]	2,271	14
	Septic and cesspools	52,660	318
	Entire embayment	**150,680**	**911**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

[b] Vaudrey estimates are from data that represent the 2010–2014 period. More recent data from New York State (https://data.ny.gov/Energy-Environment/Combined-Sewer-Overflows-CSOs-Map/i8hd-rmbi/data) show that there are presently no CSOs in the Manhasset Bay watershed.

A.19 Pequonnock River, CT

Figure A-19 shows a map of the Pequonnock River watershed. Summary statistics are included in Table A-23.

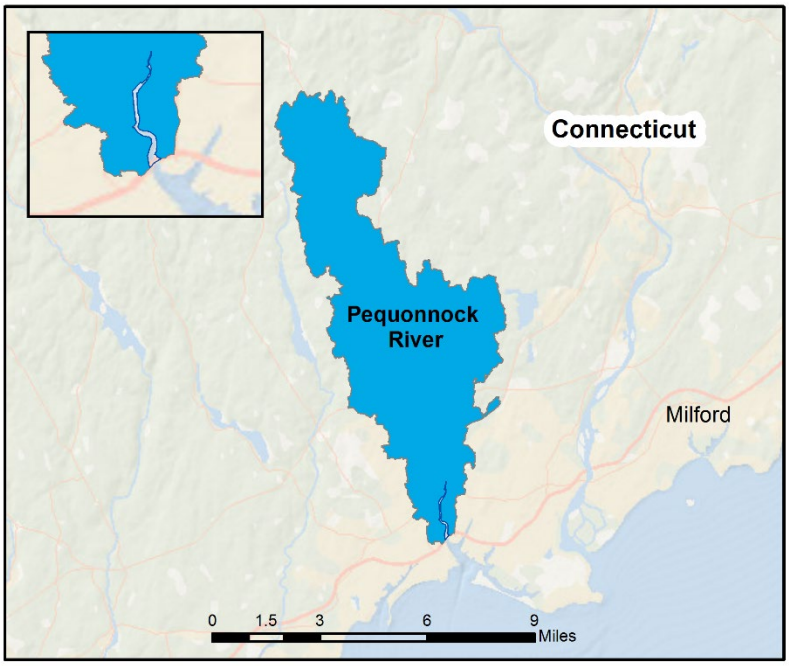

Figure A-19. Pequonnock River Watershed, CT. The inset highlights Pequonnock River Embayment.

Table A-23. Summary Information for Pequonnock River Embayment and Watershed, CT

Total Drainage Area of Watershed (Vaudrey et al. 2016)	86.8 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	0.2 km^2	
Main Tributaries (USGS 2017)	Belden Brook Booth Hill Brook Canoe Brook Horse Tavern Brook Island Brook North Farrars Brook West Branch Pequonnock River	
Residence Time (Abdelrhman 2005 derived)	2.2 days	
Depth at MLLW (NOAA 2015)	Average: Maximum:	2.1 m 6 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	45% 36% 1% 1% 16% 1%

MS4s: Bridgeport Easton Fairfield Monroe Newtown Shelton Trumbull	Percent of watershed with MS4: 94%		
Point Sources (USEPA 2015)	No identified point sources within the watershed		
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/day**
	Atmospheric deposition	8,219	50
	Fertilizer	11,596	70
	Sewer	63,989	386
	CSOs	3,199	19
	Septic and cesspools	17,210	104
	Entire embayment	**104,213**	**629**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

A.20 Byram River, CT and NY

Figure A-20 shows a map of the Byram River watershed. Summary statistics are included in Table A-24.

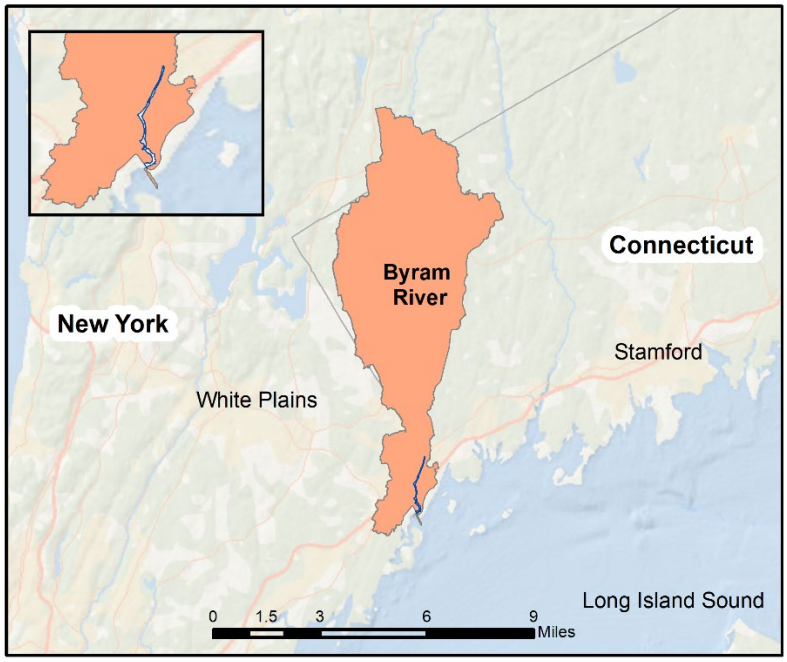

Figure A-20. Byram River Watershed, CT and NY. The inset highlights Byram River Embayment.

Table A-24. Summary Information for Byram River Embayment and Watershed, CT and NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	70.3 km^2		
Total Area of Embayment (Vaudrey et al. 2016)	0.1 km^2		
Main Tributaries (USGS 2017)	Converse Pond Brook East Branch Byram River Wilshire Pond Brook		
Residence Time (Abdelrhman 2005 derived)	2.2 days		
Depth at MLLW (NOAA 2015)	Average: Maximum:	0.8 m 4 m	
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	27% 44% 1% 4% 24% 0%	
MS4s: Fairfield Greenwich North Castle Port Chester Rye Rye Brook	Percent of watershed with MS4:	44%	
Point Sources (USEPA 2015)	Port Chester WPCF	**kg N/year** 128,066	**lbs N/day** 774

		kg N/year	**lbs N/day**
Total Nitrogen Loading (Vaudrey et al. 2016)[a]	Atmospheric deposition	6,372	38
	Fertilizer	17,227	104
	Sewer	4,967	30
	CSOs	N/A	N/A
	Septic and cesspools	5,772	35
	Entire embayment	**34,338**	**207**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

A.21 New Haven Harbor, CT

Figure A-21 shows a map of the New Haven Harbor watershed. Summary statistics are included in Table A-25.

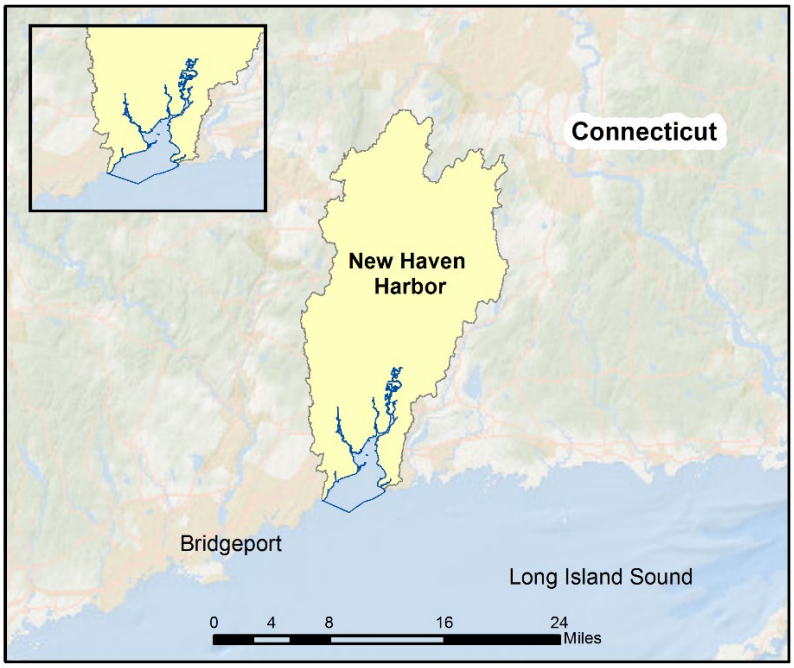

Figure A-21. New Haven Harbor Watershed, CT. The inset highlights New Haven Harbor Embayment.

Table A-25. Summary Information for New Haven Harbor Embayment and Watershed, CT

Total Drainage Area of Watershed (Vaudrey et al. 2016)	587.9 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	30.3 km^2	
Main Tributaries (USGS 2017)	Quinnipiac River West River Mill River Muddy River Tenmile River	
Residence Time (Abdelrhman 2005 derived)	3.5 days	
Depth at MLLW (NOAA 2015)	Average: Maximum:	1.5 m 7 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	37% 38% 5% 3% 16% 1%

MS4s: Berlin Bethany Cheshire Cheshire Village East Haven Hamden Hartford Meriden Middlefield Middlesex Middletown New Haven North Branford North Haven Orange Prospect Southington Wallingford Wallingford Center Waterbury West Haven Wolcott Woodbridge	Percent of watershed with MS4: 82%		
Point Sources (USEPA 2015)		**kg N/year**	**lbs N/day**
	Cheshire WPCF	9,940	60
	Cytec	34,460	208
	Meriden WPCF	19,218	116
	New Haven East WPCF	527,342	3,185
	North Haven WPCF	22,863	138
	Pharmacia & Upjohn Company, LLC	1,070	6
	Southington WPCF	13,751	83
	Wallingford WPCF	76,707	463
	West Haven WPCF	34,957	211
	Sum of point sources	**740,311**	**4,472**
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/day**
	Atmospheric deposition	100,748	609
	Fertilizer	100,480	607
	Sewer	582,444	3,518
	CSOs	29,122	176
	Septic and cesspools	79,782	482
	Entire embayment	**892,576**	**5,392**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

A.22 Little Narragansett Bay, CT[7]

Figure A-21 shows a map of the Little Narragansett Bay watershed. Summary statistics are included in Table A-25.

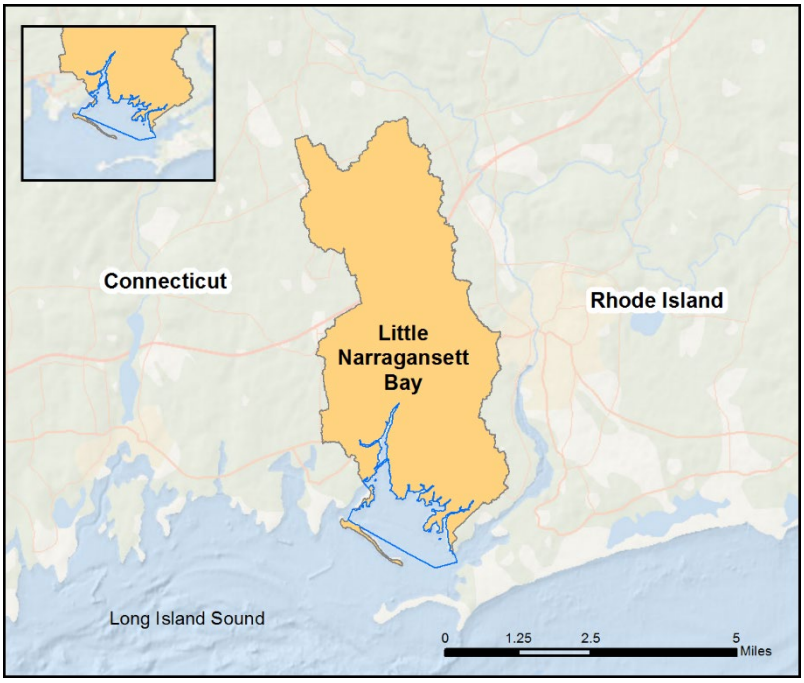

Figure A-22. Little Narragansett Bay Watershed, CT. The inset highlights Little Narragansett Bay Embayment.

Table A-26. Summary Information for Little Narragansett Bay Embayment and Watershed, CT

Total Drainage Area of Watershed (Vaudrey et al. 2016)	39.3 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	3.3 km^2	
Main Tributaries (USGS 2017)	Anguilla Brook Wheeler Brook Donahue Brook	
Residence Time (Abdelrhman 2005 derived)	3.9 days	
Depth at MLLW (NOAA 2015)	Average: Maximum:	1.1 m 4 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	12% 55% 13% 7% 12% 1%
MS4s: New London Pawcatuck Stonington	Percent of watershed with MS4:	21%
Point Sources (USEPA 2015)	No identified point sources within the watershed	

[7] Includes two Vaudrey et al. (2016) embayments: Little Narragansett Bay, CT and Wequetequock Cove, CT.

		kg N/year	**lbs N/day**
Total Nitrogen Loading (Vaudrey et al. 2016)[a]	Atmospheric deposition	8,256	50
	Fertilizer	9516	57
	Sewer	NA	NA
	CSOs	NA	NA
	Septic and cesspools	4,275	26
	Entire embayment	**22,046**	**133**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

A.23 Eastern Narrows, CT and NY

Figure A-23 shows a map of the Eastern Narrows watershed. Summary statistics are included in Table A-27.

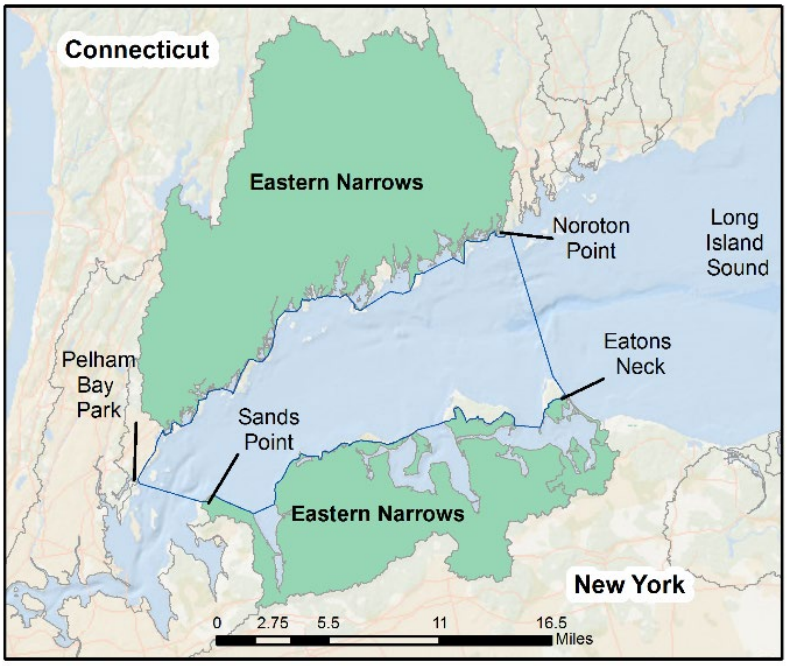

Figure A-23. Eastern Narrows Watershed, CT and NY

Table A-27. Summary Information for Eastern Narrows Embayment and Watershed, CT and NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	711.1 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	347.0 km^2	
Main Tributaries (ESRI 2017)	Mamaroneck River Fivemile River Gorhams Pond Noroton River Rippowam River Mianus River Premium River Beaver Swamp Brook Blind Brook Byram River Greenwich Creek	
Residence Time (Abdelrhman 2005 derived)	17.5 days	
Depth at MLLW (NOAA 2015)	Average: Maximum:	14.1 m 55 m
Land Use Characteristics (Vaudrey et al. 2016, CLEAR 2010 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	37% 37% 0% 2% 23% 1%

MS4s: See *Appendix B: Dischargers Compiled* for the 48 MS4s in this watershed	Percent of watershed with MS4:	93%	
Point Sources (USEPA 2015)		**kg N/year**	**lbs N/day**
	Blind Brook WPCF	33,963	205
	Glen Cove	25,514	154
	Greenwich WPCF	73,063	441
	Huntington	9,112	55
	Mamaroneck WPCF	51,359	310
	New Canaan WPCF	2,816	17
	New Rochelle WPCF	48,046	290
	North Castle WPCF	1,325	8
	Northport Village	1,491	9
	Oyster Bay	8,284	50
	Port Chester WPCF	128,066	774
	Stamford WPCF	46,058	278
	Sum of point sources	**429,097**	**2,591**
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/day**
	Atmospheric deposition	161,908	978
	Fertilizer	220,465	1,332
	Sewer	138,942	839
	CSOs[b]	1,152,887	6,963
	Septic and cesspools	262,851	1,588
	Entire embayment	**1,937,053**	**11,700**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

[b] Vaudrey estimates are from data that represent the 2010–2014 period. More recent data from CT DEEP (http://www.ct.gov/deep/cwp/view.asp?a=2719&q=525758&deepNav_GID=1654) and New York State (https://data.ny.gov/Energy-Environment/Combined-Sewer-Overflows-CSOs-Map/i8hd-rmbi/data) show that there are presently no CSOs in the Eastern Narrows watershed.

A.24 Western Narrows, NY

Figure A-24 shows a map of the Western Narrows watershed. Summary statistics are included in Table A-28.

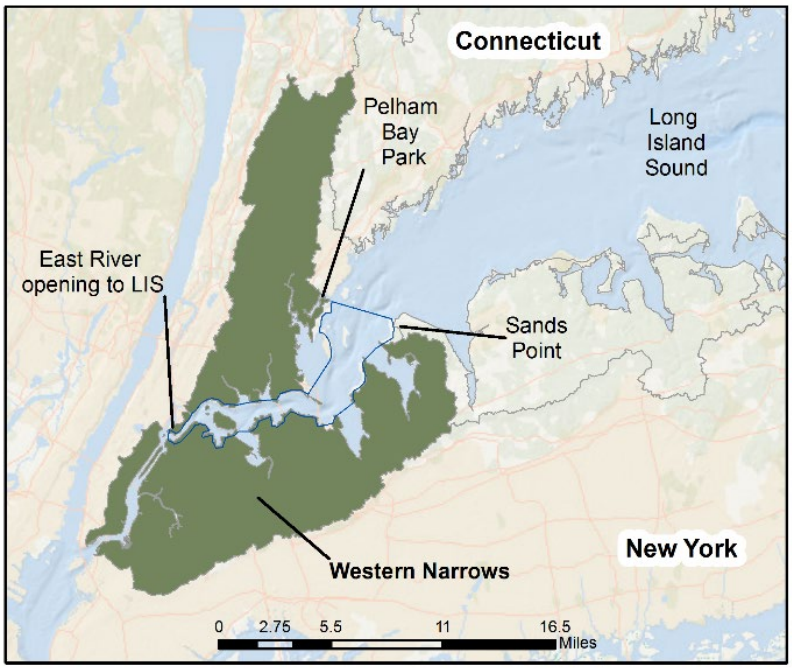

Figure A-24. Western Narrows Watershed, NY

Table A-28. Summary Information for Western Narrows Embayment and Watershed, NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	408.4 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	56.1 km^2	
Main Tributaries (ESRI 2017)	East River Bronx River Westchester Creek Hutchinson River Flushing Creek	
Residence Time (Abdelrhman 2005 derived)	4.4 days	
Depth at MLLW (NOAA 2015)	Average: Maximum:	8.6 m 35 m
Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data; NLCD 2011 land use data)	Developed: Forested: Agricultural: Water: Grass: Barren:	86% 6% 0% 2% 6% 0%
MS4s: See *Appendix B: Dischargers Compiled* for the 34 MS4s in this watershed	Percent of watershed with MS4:	99%

Point Sources (USEPA 2015)		**kg N/year**	**lbs N/day**
	Belgrave	14,082	85
	Bowery Bay	1,888,691	11,408
	Great Neck WPCD	36,614	221
	Hunts Point	1,358,532	8,206
	Newtown Creek	5,483,830	33,123
	Port Washington	28,827	174
	Red Hook	646,131	3,903
	Tallman Island	778,671	4,703
	Wards Island	2,468,552	14,910
	Sum of point sources	**12,703,930**	**76,733**
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/day**
	Atmospheric deposition	189,684	1,146
	Fertilizer	182,142	1,100
	Sewer	14,677,204	88,651
	CSOs[b]	1,432,874	8,654
	Septic and cesspools	60,046	363
	Entire embayment	**16,541,950**	**99,914**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

[b] Vaudrey estimates are from data that represent the 2010–2014 period. Recent data from New York State (https://data.ny.gov/Energy-Environment/Combined-Sewer-Overflows-CSOs-Map/i8hd-rmbi/data) show that there are approximately 50 CSOs in the Western Narrows watershed.

A.25 Eastern and Western Narrows (Combined), CT and NY

Figure A-25 shows a map of the Eastern and Western Narrows combined watersheds. Summary statistics are included in Table A-29.

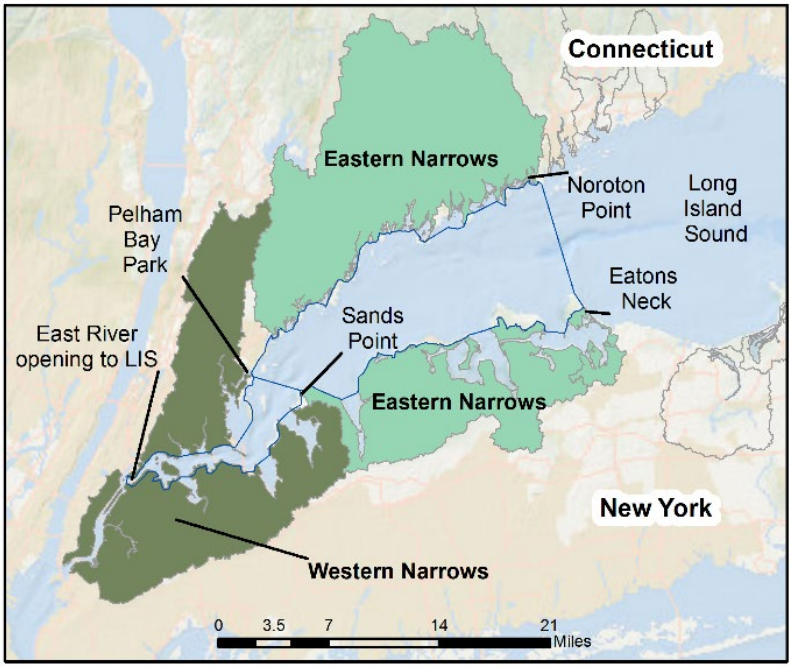

Figure A-25. Eastern and Western Narrows (Combined) Watersheds, CT and NY

Table A-29. Summary Information for Eastern and Western Narrows (Combined) Embayments and Watersheds, CT and NY

Total Drainage Area of Watershed (Vaudrey et al. 2016)	1,119.5 km^2	
Total Area of Embayment (Vaudrey et al. 2016)	403.1 km^2	
Main Tributaries (ESRI 2017)	East River Bronx River Westchester Creek Hutchinson River Flushing Creek Mamaroneck River Fivemile River Gorhams Pond Noroton River Rippowam River Mianus River Premium River Beaver Swamp Brook Blind Brook Byram River Greenwich Creek	
Residence Time (Abdelrhman 2005 derived)	22 days	
Depth at MLLW (NOAA 2015)	Average: Maximum:	13.3 m 55 m

Land Use Characteristics (Vaudrey et al. 2016; CLEAR 2010 land use data; NLCD 2011 land use data)	Developed: 56% Forested: 25% Agricultural: 0% Water: 2% Grass: 17% Barren: 0%		
MS4s: See *Appendix B: Dischargers Compiled* for the 74 MS4s in this watershed	Percent of watershed with MS4: 95%		
Point Sources (USEPA 2015)		**kg N/year**	**lbs N/year**
	Blind Brook WPCF	33,963	205
	Glen Cove	25,514	154
	Greenwich WPCF	73,063	441
	Huntington	9,112	55
	Mamaroneck WPCF	51,359	310
	New Canaan WPCF	2,816	17
	New Rochelle WPCF	48,046	290
	North Castle WPCF	1,325	8
	Northport Village	1,491	9
	Oyster Bay	8,284	50
	Port Chester WPCF	128,066	774
	Stamford WPCF	46,058	278
	Belgrave	14,082	85
	Bowery Bay	1,888,691	11,408
	Great Neck WPCD	36,614	221
	Hunts Point	1,358,532	8,206
	Newtown Creek	5,483,830	33,123
	Port Washington	28,827	174
	Red Hook	646,131	3,903
	Tallman Island	778,671	4,703
	Wards Island	2,468,552	14,910
	Sum of point sources	**13,133,027**	**79,324**
Total Nitrogen Loading (Vaudrey et al. 2016)[a]		**kg N/year**	**lbs N/year**
	Atmospheric deposition	351,592	2,124
	Fertilizer	402,607	2,432
	Sewer	14,816,145	89,490
	CSOs[b]	2,585,761	15,618
	Septic and cesspools	322,897	1,950
	Entire embayment	**18,479,002**	**111,614**

[a] Total nitrogen loadings were calculated based on Vaudrey's work, using data from 2010–2014, as described on page A-1.

[b] Vaudrey estimates are from data that represent the 2010–2014 period. More recent data from CT DEEP (http://www.ct.gov/deep/cwp/view.asp?a=2719&q=525758&deepNav_GID=1654) and New York State (https://data.ny.gov/Energy-Environment/Combined-Sewer-Overflows-CSOs-Map/i8hd-rmbi/data) show that there are approximately 50 CSOs in the Eastern and Western Narrows (combined) watersheds.

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Appendix A1: Embayment Loads

See Excel file.

Appendix A2: Bathymetry Data

Summary

Tetra Tech used the NOAA Coastal Relief Model (CRM) to provide estimated embayment average and maximum depths.

Background

Tetra Tech considered a number of potential data sources to compute estimated average and maximum depths for LIS selected embayments. Tetra Tech considered CT DEEP contour data;[1] however, those data do not fully cover near-shore embayments and do not provide coverage of eastern LIS (east of Mystic River). Tetra Tech also considered more site-specific NOAA bathymetry data available through NOAA's Bathymetric Data Viewer.[2] Those data are available for a reasonable number of the selected embayments; however, the LIS data are spread across multiple files and the data are inconsistent among embayments. Because of the purpose of these estimates (quick overview for Subtask A) and level-of-effort concerns, Tetra Tech did not pursue use of that site-specific information. Ultimately Tetra Tech used the NOAA CRM[3] to provide an estimate of depth for most embayments. The CRM is an integrated effort to cover the elevation of land and water boundaries of the U.S. coastal zone. While the resolution is slightly coarse (90 m^2 pixels, with 1-meter increments), the coverage is most complete and the resolution is sufficient to compute average and maximum depth estimates for most embayments.

Coastal Relief Model Description[4]

NOAA's CRM provides a comprehensive view of the U.S. coastal zone, integrating offshore bathymetry with land topography to create a seamless representation of the coast. The CRM spans the east and west coasts of the United States, the northern coast of the Gulf of Mexico, Puerto Rico, and Hawaii, and reaches out to—and in places even beyond—the continental slope.

Bathymetric data sources for the NOAA CRM include the U.S. National Ocean Service Hydrographic Database, USGS, the Monterey Bay Aquarium Research Institute, the U.S. Army Corps of Engineers, and various other academic institutions. Topographic data are from USGS and the Shuttle Radar Topography Mission. The CRM database contains grids, or digital elevation models, of the entire coastal zone of the conterminous United States, as well as Hawaii and Puerto Rico.

The vertical datum of the CRM is "sea level." Source elevation data were not converted to a common vertical datum because of the large cell size of the CRM (3 arc-second; ~90 meters). This means that the vertical uncertainty of CRM elevations (greater than 1 meter) exceeds the differences between vertical datums (usually less than 1 meter). The vertical datum for the source bathymetric data was generally MLLW. Source topographic data were in North America Vertical Datum of 1988. MLLW is defined as:

> The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a

[1] http://www.ct.gov/deep/cwp/view.asp?a=2698&q=322898&deepNav_GID=1707%20.
[2] https://maps.ngdc.noaa.gov/viewers/bathymetry/.
[3] https://maps.ngdc.noaa.gov/viewers/wcs-client/.
[4] Overview: https://www.ngdc.noaa.gov/mgg/coastal/crm.html; and Volume I metadata: https://www.ngdc.noaa.gov/metaview/page?xml=NOAA/NESDIS/NGDC/MGG/DEM/iso/xml/713.xml&view=xml2text/xml-to-text-ISO.

control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.[5]

The depths can be considered as during low tide, but are accurate only to within about 1 meter.

Methods

1. Extracted coastal relief data for a bounded area containing the LIS.
2. Reprojected to NAD_1983_StatePlane_Connecticut_FIPS_0600_Feet.
3. Resampled from 266 feet x 266 feet (~90 meter pixels) to 33 feet x 33 feet (~10 meter pixels) using a bilinear interpolation. This should better capture and differentiate small polygons such as the smaller embayments.
4. Selected only values less than 1 to remove nonwater areas that happen to be within the open water boundaries as a result of mapping inconsistencies.
5. Computed zonal statistics by open water embayment.
6. Computed zonal statistics by Western and Eastern Narrows.

[5] https://tidesandcurrents.noaa.gov/datum_options.html.