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FEASIBILITY OF POINT-NONPOINT NUTRIENT TRADING IN THE LONG ISLAND SOUND WATERSHED

Prepared for NEIWPCC by rbouvier consulting

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Part I: Introduction

1. Goal of this Report

The purpose of this report is to explore the economic opportunities and obstacles to creating a robust, interstate nutrient water quality trading program for the entire Long Island Sound (LIS) watershed, one that includes both point and non-point sources. This report is part of a larger project, which not only investigates the potential for the LIS watershed to support a traditional water quality trading program from an economic perspective, but also the potential of such a trading program to meet water quality goals and broader ecosystem health objectives. As such, it should be read in the context of the larger project, not as a stand-alone output. A list of companion documents is found in Appendix A.

1.1 Market Essentials

At its most basic, any effective market needs a robust source of supply as well as a strong demand. Going further, the underpinnings of a well-functioning market include a well-defined commodity, trust between market participants, and the institutions necessary to facilitate trading. Water quality trading is no exception. At the risk of seeming simplistic, this section explores all of these necessary components from a theoretical perspective. The sections that follow apply lessons learned from other trading programs, as well as specifics of the LIS watershed, to these components. The final section will explore the potential of the LIS watershed to support a water quality trading program, highlight the characteristics of the LIS watershed that would support such a program, and point out the obstacles that would need to be overcome in developing such a program. [1]

The first necessary component of any trading program is a **clearly delineated commodity**. In the case of water quality trading, that commodity is usually defined as a reduction in delivered nitrogen or phosphorus, measured at the edge-of-tide.[2]

[1] Additional lessons gleaned from other trading programs are compiled in "Lessons from Water Quality Trading Case Studies: A Literature Review", a link to which can be found in the Appendix.

[2] Edge-of-tide refers to the nutrient load that reaches the edge of the Long Island Sound. Attenuation of nutrients and sediment occurs between the nutrient load that reaches a stream in Vermont, for example, and the nutrient load that reaches the Long Island Sound. An edge-of-tide factor or ratio is usually applied to account for the fact that a one pound nutrient reduction in one part of the watershed does not necessarily result in a one pound reduction in nutrient pollution in the Long Island Sound.

Next, consider the **demand for that commodity**. Theoretically, the overall demand for nutrient reduction arises from the gap between the number of units of nitrogen or phosphorus that a waterbody can ecologically sustain and the number of units being delivered by all sources, point and non-point. Herein lies one of the main differences between a water quality market and a market for a more traditional commodity: the demand for nutrient reduction must be driven by a regulatory cap, usually the total maximum daily load (TMDL). Ideally, the TMDL would reflect the amount of nitrogen or phosphorus that could be emitted into the LIS without compromising its ecological integrity. Whether or not that is the case is one of the key components of a successful water quality trading program. That metric of success – ecological integrity, not just economic feasibility – will determine whether a water quality trading program will succeed or fail, and is a factor that a market with a more traditional commodity does not have to take into consideration. This factor will be considered in depth in the companion document by Paul Stacey of Footprints in the Water (see Appendix A).

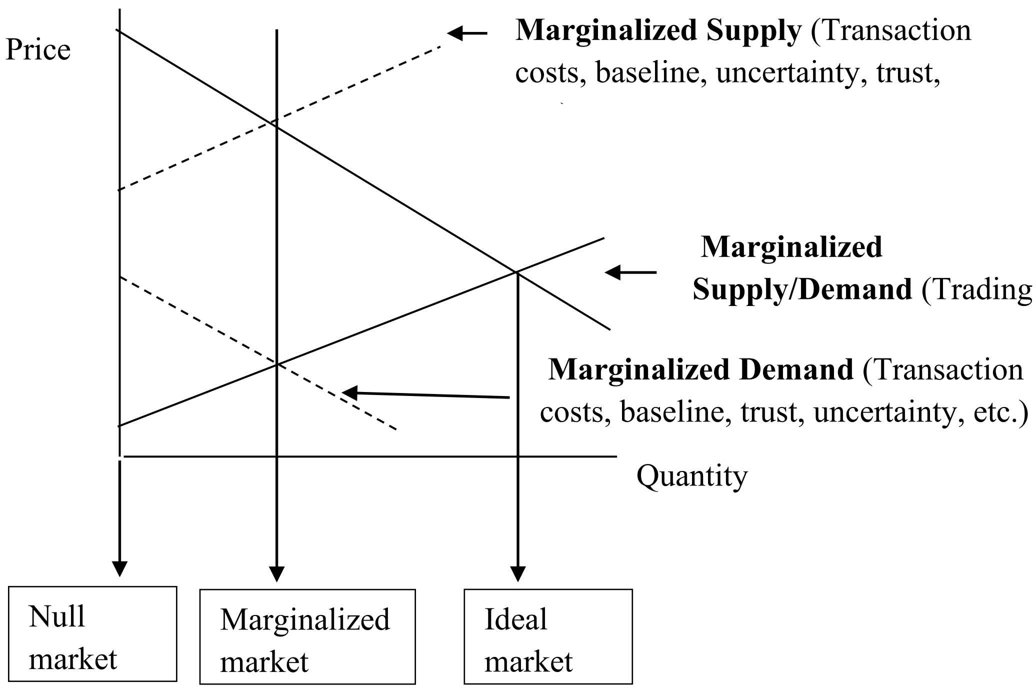
An individual discharger's demand for nutrient reduction is therefore determined in part by its allocated load. However, one added complication is that a point source can reduce the amount of nutrients it generates simply by investing in added pollution control technology. Therefore, an individual firm's discharger's **effective demand** for nutrient reduction credits is the gap between its allocated load and the amount of nutrients it currently emits, *minus* the amount of nutrients it can reduce without trading. This is a point we will return to later in section 3.5.

The **supply of any commodity** to be traded is determined by the marginal cost of producing that commodity. In the case of water quality trading, the supply is determined by the cost of "producing" a unit of nutrient reduction. Theoretically, an entity capable of reducing nutrients would enter into the market if the going price of a nutrient credit were greater than the cost of nutrient reduction, minus any transaction costs. From a theoretical perspective, "entities" capable of reducing nutrients include both point and non-point sources. Practically, the potential sources of nutrient reduction are constrained by institutional, political, and cultural factors. We will consider the supply of nutrient reduction credits in part 4.

Finally, the **institutional framework** underlying any market include clear property rights, social institutions of trust, and infrastructure for the smooth flow of goods and information (Goodwin, et al., 2020). These have been explored in more detail in *Water Quality Trading in the Long Island Sound Study Area: A Preliminary Look at Some Economic Issues*, also by this author.

Figure 1 shows a conceptual model of a nutrient trading market, as illustrated in Hoag et al. (Hoag et al., 2017). The ideal market price and quantity supplied are found where the downward-sloping solid demand curve intersects with the upward-sloping solid supply curve. Anything that increases a supplier's costs or reduces its willingness to supply credits will tend to shift the supply curve up and to the left (the dashed supply curve), while anything that increases the cost to the buyer or reduces its willingness to buy credits will shift the demand curve down and to the left (the dashed demand curve). If costs increase enough so that the demand and supply curves do not intersect, or if parties are unwilling to engage in trade, there will be no market.

Figure 1: Conceptual Supply and Demand Model for Nutrient Trading Credits, with Marginalizing Effects



Source: Adapted from Hoag et al., 2017.

Hoag et al. (Hoag et al., 2017) identified three environments required for a viable trading market: (1) an amenable *physical environment* with a commodity to trade, sufficient physical supplies, and sufficient physical demand; (2) an amenable *economic environment* with willing buyers and sellers, familiarity with the commodity and its controls, and a viable market infrastructure; and (3) a friendly *institutional environment* with willing policy makers/agencies with the necessary expertise, flexible regulations, and sufficient institutional commitment (Hoag et al., 2017).

A strong physical environment, Hoag et al. find, is most likely to be found where water quality is a concern and where both point and non-point sources can be found in abundance within the same watershed. They estimate the potential supply and demand by investigating the number of watersheds across the contiguous United States that do not meet their designated water quality standards, and by determining annual total nitrogen and total phosphorus loads from both point and nonpoint sources. Their results imply that only about 5 percent of impaired watersheds have feasible supply and demand conditions for nitrogen trading, and about 13 percent of watersheds are in the "Goldilocks zone" for phosphorus trading (Hoag et al., 2017).

Where the Long Island Sound Study Area falls on the spectrum between a "null market" and an "ideal market" rests in part on the characteristics of the study area, as well as the rules that policy makers establish.

2. Description of the LIS Watershed

This section is an inventory of the Long Island Sound Watershed. It focuses on nitrogen and phosphorus pollution, and potential trading partners for a nutrient pollution trading program. In this section we will provide a basic summary of watershed statistics, information about how much nitrogen and phosphorus is being discharged into the watershed, the sources of that pollution, a deeper look at discharges from regulated sources, and a review of potential trading partners.

The scope of this inventory is the Long Island Sound Watershed as a whole. This was done primarily for two reasons: 1. The ultimate goal is to improve the water quality of Long Island Sound, which is impacted by the entirety of the watershed, and 2. to include a wide enough area for there to be an adequate number of potential trading partners for a trading program.

One of the challenges of studying the entire watershed is finding data that are consistent across all six states located in the watershed. Data such as the current levels of nitrogen and phosphorus in waterbodies, the amount discharged by National Pollutant Discharge Elimination System (NPDES) permit holders, and TMDL levels are often tracked and compiled at the state level and may not be presented in a consistent format across all states. In addition, while the Environmental Protection Agency (EPA) sets guidelines and discharge limits for New Hampshire and Massachusetts, other states (Connecticut, New York, Rhode Island, and Vermont) establish and monitor their own discharge limits. Finally, certain states, such as Connecticut, have been previously studied in depth and have quite a bit of data available, while other states have more limited data availability.

In order to maintain consistency in data, uniform sources across all states were used where possible. Other information was compiled from each state by the team. Information in this inventory comes from a variety of sources including the Long Island Sound Study, the United States Geological Survey (USGS), the USGS Spatially Referenced Regression on Watershed Attributes (SPARROW), EPA discharge monitoring reports, the United States Department of Agriculture (USDA), the EPA Enforcement and Compliance History Online (ECHO), as well as other state and federal sources.

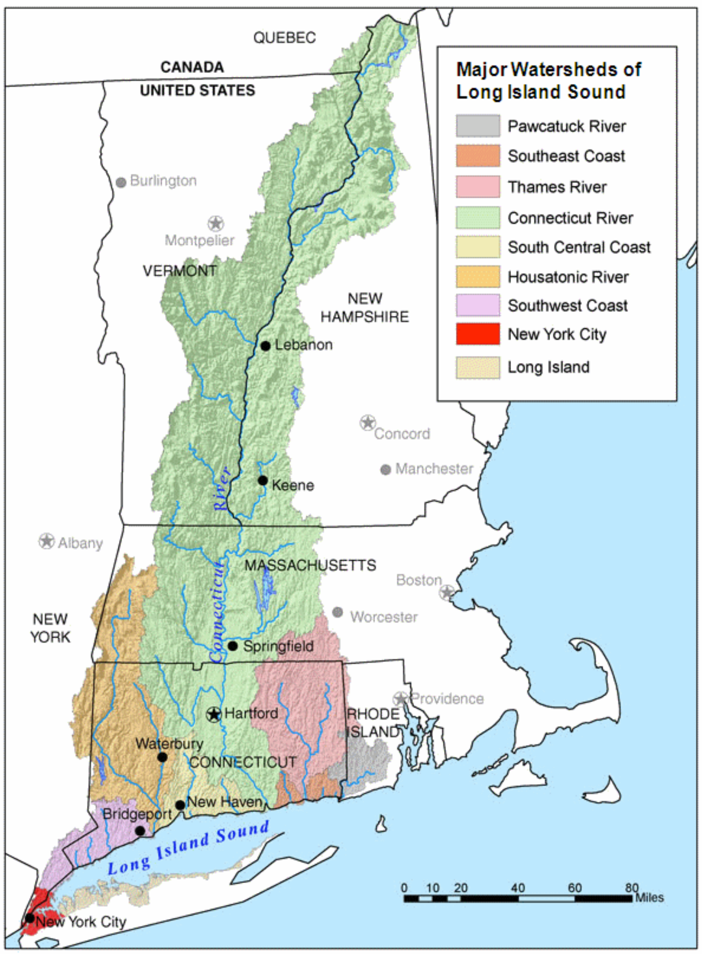
A note on terms

Throughout this report the term watershed is used in reference to the entire Long Island Sound (LIS) watershed not including the portion of the watershed that is in Canada. The Long Island Sound study (LISS) area refers to the areas of Connecticut and New York that are a part of the Long Island Sound Study (Long Island Sound Study, 2019).

2.1. Watershed Overview

The LIS watershed covers 16,820 square miles. It spans the states of Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, and New York. It is made up of the Upper Connecticut, Lower Connecticut, Connecticut Coastal, and portions of the Lower Hudson and Long Island watersheds (Long Island Sound Study, 2019).

Figure 2: Major Watersheds of Long Island Sound



Source: Green Cities Blue Waters, 2016.

Rivers from three states empty directly into the Sound: 11 in Connecticut, four in New York, and one in Rhode Island. The Connecticut River is the largest river to empty into the sound and carries 70% of the freshwater that enters Long Island Sound. The length of the river in the United States is 410 miles and flows through the states of Vermont, New Hampshire, Massachusetts, and Connecticut, draining over 11,000 square miles along its journey to the Sound (Connecticut River Conservancy, 2021).

2.2 Population in the LIS Watershed

The 2010 Census puts the watershed population at 8.93 million people. The population has grown 3.5% since the 2000 census (Long Island Sound Study, 2019). As of this report, watershed population data from the 2020 census has not yet been made available.

Table 1: Population of the LIS Watershed

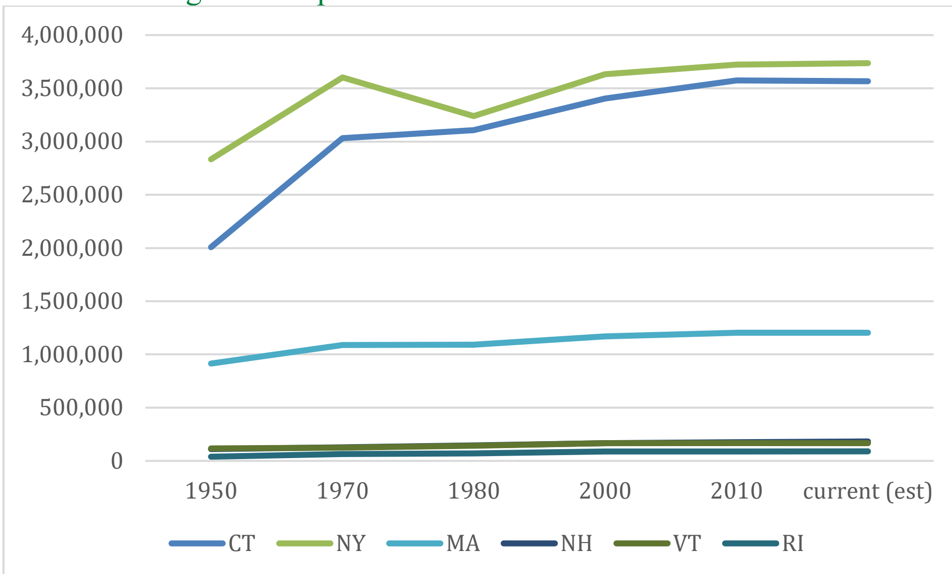
State	Population
Connecticut	3,574,097
New York	3,723,619
Massachusetts	1,203,754
New Hampshire	176,664
Rhode Island	88,939
Vermont	167,021

Note: Numbers represent the population in the areas within the Watershed, not necessarily in each State as a whole.

Source: US Census Bureau, 2010.

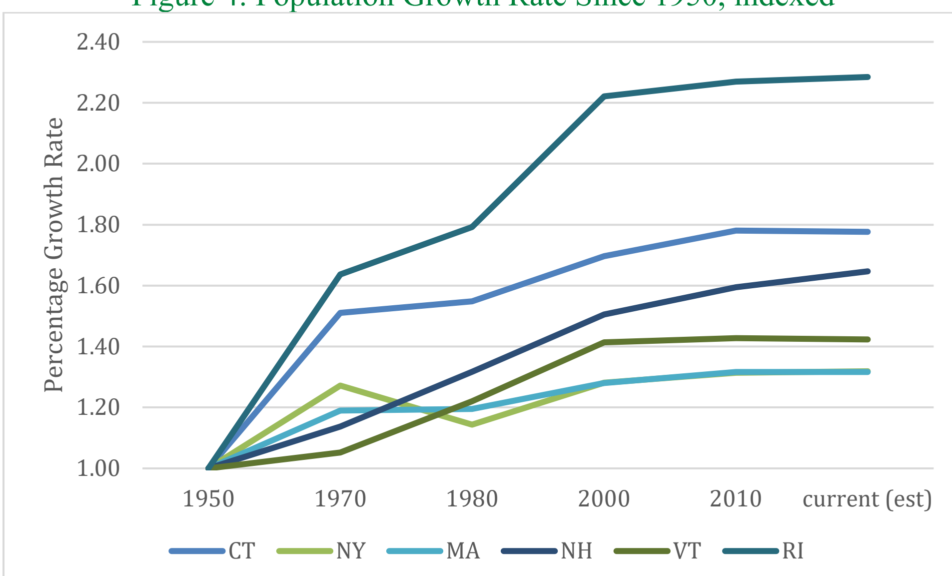
Figure 3 shows that the portions of New York State and Connecticut in the LIS watershed have the highest populations in absolute terms. However, Figure 4 indexes the population at 1950 levels to focus on growth rates. It shows that the population in the portion of Rhode Island that is in the LIS watershed has more than doubled since 1950.

Figure 3: Population in LIS Watershed Since 1950



Source: US Census Bureau, 2020.

Figure 4: Population Growth Rate Since 1950, indexed



Source: US Census Bureau, 2020.

Part II: Market Potential in the LIS Watershed

3. Sources of and Factors Affecting Potential Demand

The National Network on Water Quality Trading (NNWQT), in partnership with the US EPA EnviroAtlas team and the USDA Office of Environmental Markets, published a report in 2018 that mapped potential demand for both agricultural-generated water quality credits and stormwater-generated credits (National Network on Water Quality Trading et al., 2018). Their analysis indicates that potential demand rests on two main sources: biophysical demand, and policy or regulatory drivers of demand. Rather than reinvent the wheel, this report uses the mapping exercise as a starting point to evaluate the **sources of potential demand in the LIS watershed**.

According to NNWQT, the **biophysical indicators of demand** (indicators related to the degree and sources of pollution in a watershed) include: percentage of pollution contributed by nonpoint sources relative to that contributed by point sources, the presence of regulated point source facilities with permit limits discharging into impaired waters that have incurred a recent violation;[3] and the total annual load volume from NPDES sites; and the share of land cover in impervious surface.

Policy or regulatory indicators of demand include the drivers that induce regulated entities to reduce pollution. These include, but are not limited to, the presence of impaired waterways (meaning that there are facilities that must comply with a TMDL, or are in "pre-TMDL" conditions[4]), and the existence of regulated Municipal Separate Storm Sewer Systems (MS4s), which may require NPDES permits and/or credits or offsets.

Finally, **economic indicators of demand** include the cost of pollution control technology relative to the cost of a pollution reduction credit.

3.1 Point versus Non-Point Source Contribution to Pollution

In order to know the potential impacts of any trading program it is necessary to establish the **current level of pollutants and the pollutant sources**. The pollutants that are being assessed

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[3] While the NNWQT also included the share of land cover in agriculture as a biophysical indicator of demand, we did not include that here as an indicator of demand, as agricultural sources are not regulated under the Clean Water Act. It will, however, be included as an indicator of supply.

[4] Waterbodies that are identified as impaired but not yet subject to TMDLs may be subject to interim limits.

for a possible trading program are nitrogen and phosphorus. The LISS area does not currently have a TMDL for phosphorus; however, several subwatersheds within the LIS watershed (described below) do have phosphorus impairments and as such are potential trading partners. This section covers the amount of nutrient pollution in Long Island Sound and its sources.

The information in the following section comes predominantly from the SPARROW modeling tool.[5] These data were compiled from multiple sources and include information from USGS monitoring stations, historic stream flow data, and other state and federal data sources. The tool uses this information to model the movement of contaminants from both point and non-point sources through a watershed. While SPARROW does not report live data, which would enable us to see the amount of nutrient pollution that is currently discharged into Long Island Sound, it does provide an overview of nutrient pollution and its sources.

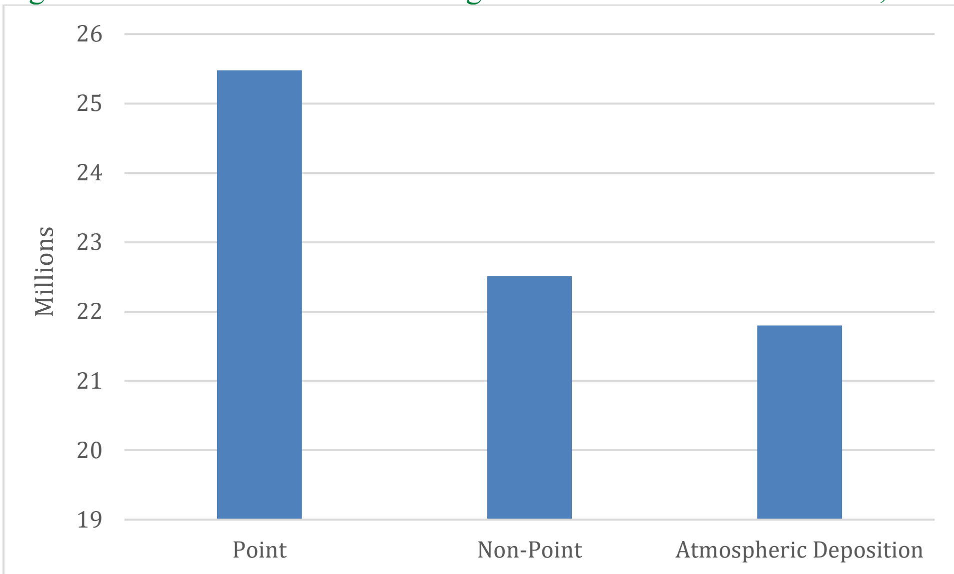
The following includes measurements of annual aggregated loads of nitrogen and phosphorus. Aggregating combines loads of different sources of nitrogen and phosphorus. Total Aggregated Load for Nitrogen includes organic nitrogen, ammonia, nitrate, and nitrite; or total Kjeldahl nitrogen (TKN), nitrate, and nitrite, while phosphorus measurements include phosphorus and phosphate (United States Geological Survey, 2020).

3.1.1 Nitrogen

An average of 69.8 million tons of nitrogen was discharged into the LIS watershed annually from 1999 to 2014. Of this amount, approximately 31.2% came from atmospheric deposition, 32.2% came from non-point sources other than atmospheric deposition, and the remaining 37% came from point sources (United States Geological Survey, 2020). The fact that at least a third of the nitrogen in the LIS watershed comes from non-point sources is a critical point. A watershed-wide nitrogen trading system must include non-point sources in order to achieve water quality goals. It is also evident that atmospheric deposition of nitrogen is an important source of nitrogen in the Sound.

[5] Additional information about the SPARROW Modeling Tool is available here: https://www.usgs.gov/mission-areas/water-resources/science/sparrow-modeling-estimating-nutrient-sediment-and-dissolved?qt-science_center_objects=0#qt-science_center_objects.

Figure 5: Point and Non-Point Nitrogen Load for the LIS Watershed, in lbs

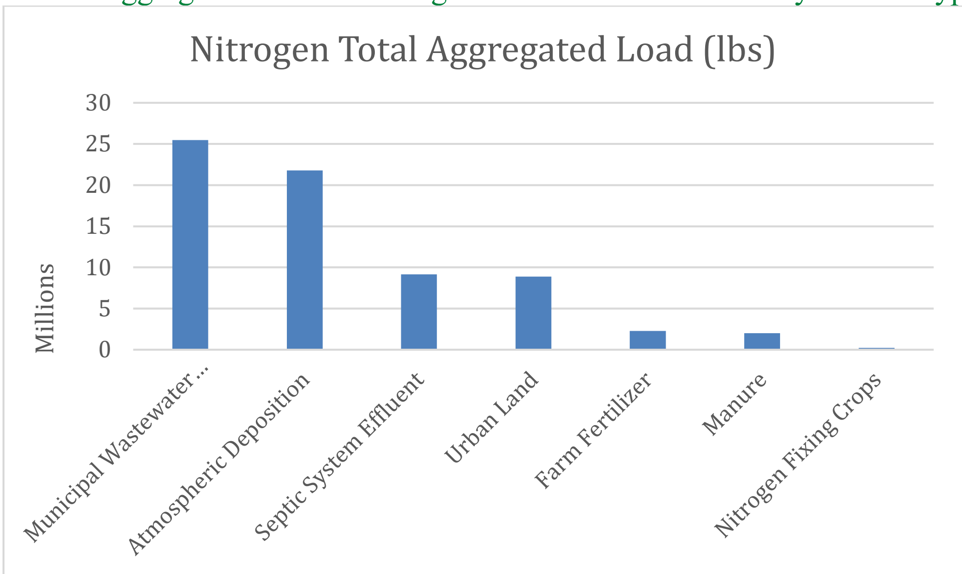


Source: US Geological Survey, 2020.

When broken out by source (Figure 6), it can be seen that the greatest contributor to non-point sources of nitrogen is atmospheric deposition. The primary source of atmospheric deposition is fossil fuel combustion from motor vehicles, industry, and power generation (EPA, 2020).

Atmospheric deposition is a source of nitrogen for many watersheds in the United States, but in the LIS watershed, atmospheric deposition is the primary non-point source of nitrogen, greater than runoff from urban land, septic system effluent, or farm fertilizer combined. By contrast, in most other watersheds in the United States, farm fertilizer is the primary source of non-point source nitrogen pollution. For instance, a study of the Mississippi River basin noted that 26% of nitrogen delivered to the Gulf of Mexico via the Mississippi River basin could be attributed to atmospheric deposition while farm fertilizer accounts for 41% (United States Geological Survey, 2016). In the LIS watershed, however, farm fertilizer accounts for only 3% of the nitrogen in the watershed. The diffuse nature of how atmospheric nitrogen makes its way into the watershed makes it a difficult source to regulate via a trading program. To our knowledge, there are no water quality trading programs that specifically address atmospheric deposition.

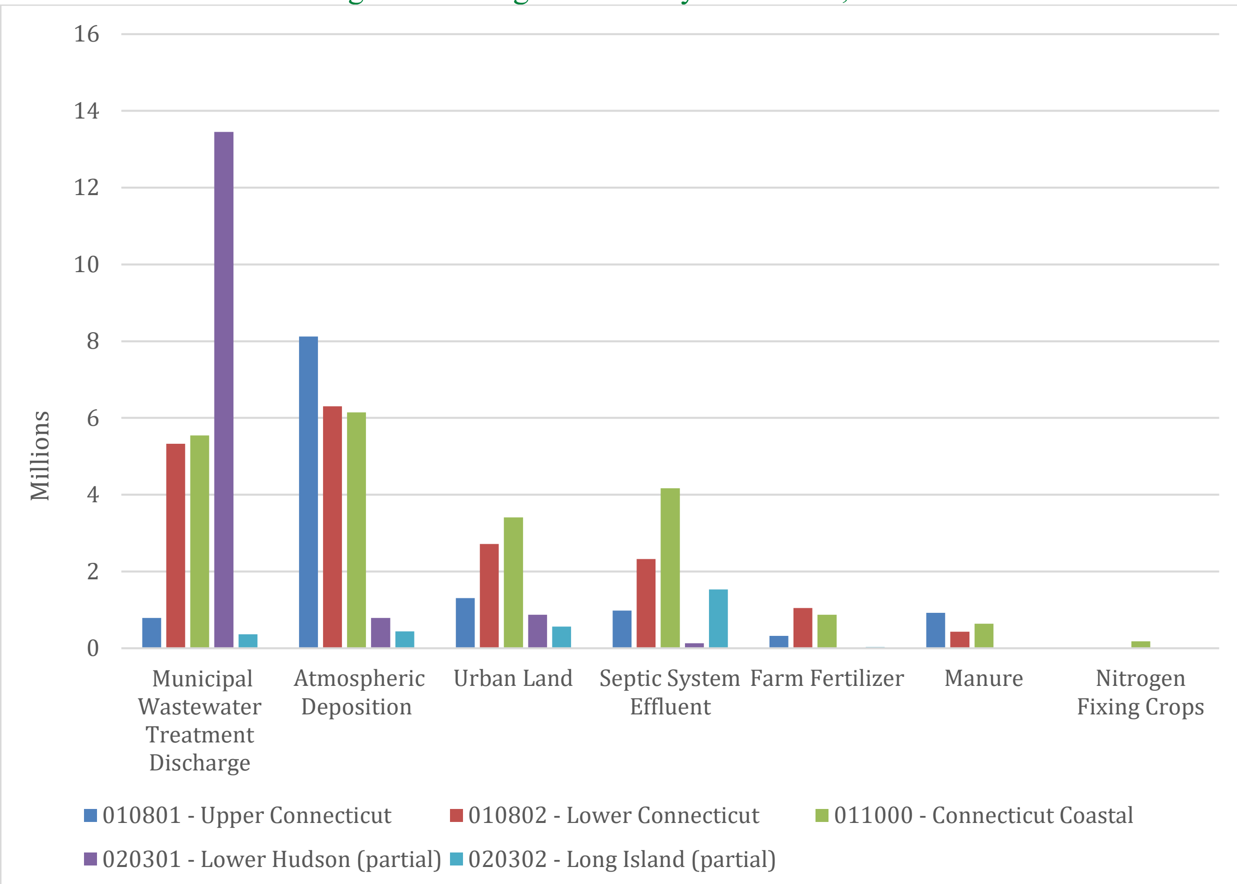
Figure 6: Total Aggregated Load of Nitrogen for the LIS Watershed by Source Type, in lbs



Source: US Geological Survey, 2020.

When the sources are broken out by watershed, the Lower Hudson, which includes parts of New York metropolitan area, contributes the greatest percentage of point source nitrogen in the form of wastewater treatment discharge.

Figure 7: Nitrogen Source by Watershed, in lbs

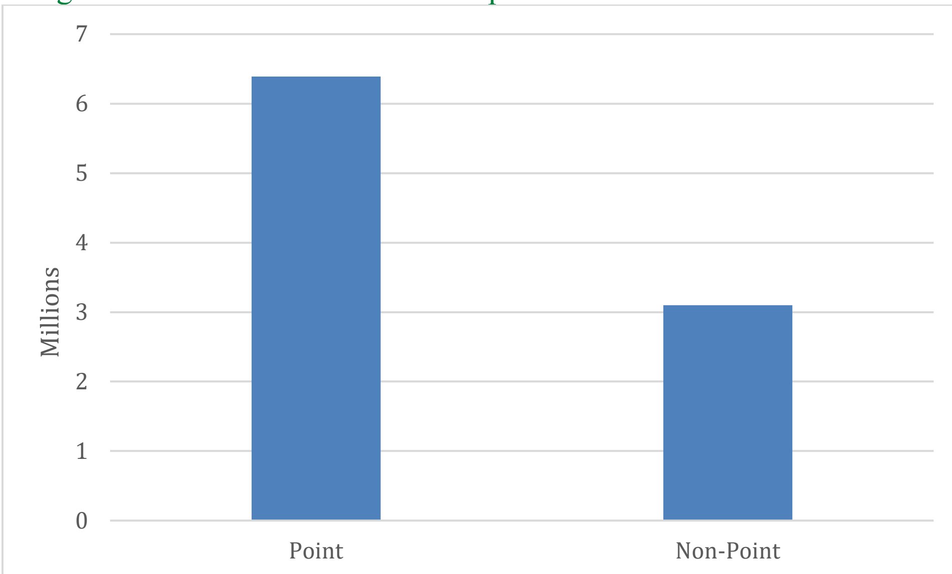


Source: US Geological Survey, 2020.

3.1.2 Phosphorus

Approximately 9.5 million pounds of phosphorus was discharged annually into the LIS watershed from 1999 to 2014. Of this, 32% was from non-point sources, and 68% was from point sources (United States Geological Survey, 2020).

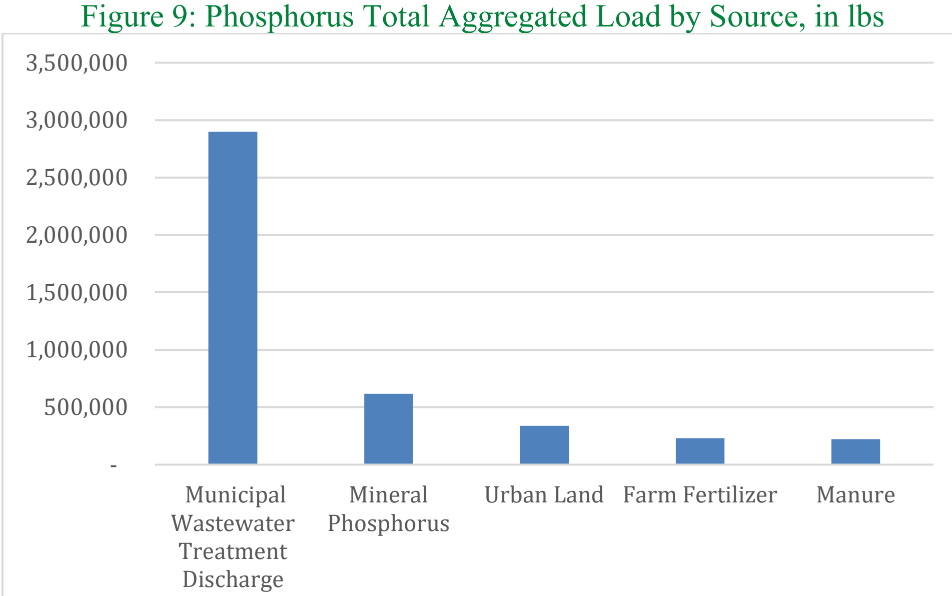
Figure 8: Point and Non-Point Phosphorus Load for the LIS watershed



Source: US Geological Survey, 2020.

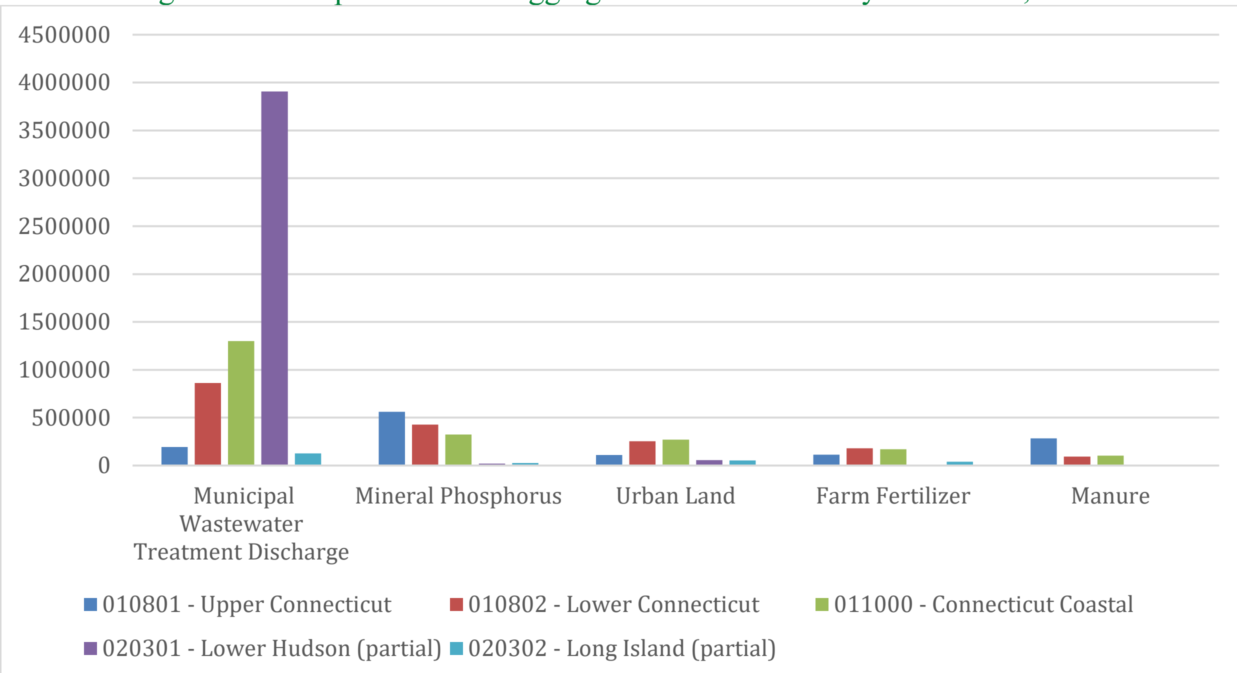
Figure 9 shows that the greatest contributor to point sources of phosphorus is municipal wastewater treatment discharge. At nearly 3 million pounds it accounts for 67% of phosphorus in the watershed. The primary source of this is run off, human excrete, and some soaps/detergents (EPA, 2019).

Figure 9: Phosphorus Total Aggregated Load by Source, in lbs



Source: US Geological Survey, 2020.

Figure 10: Phosphorus Total Aggregated Load Sources by Watershed, in lbs.



Source: US Geological Survey, 2020.

As with nitrogen, when the sources are broken out by watershed, the Lower Hudson, which includes parts of New York metropolitan area, contributes the greatest percentage of point source phosphorus in the form of wastewater treatment discharge.

The information presented in this section indicates that point sources represent only about a third of the overall nitrogen load in the LIS watershed. Moreover, it is likely that the portion of nitrogen represented by non-point sources has increased in recent years, as discharges from point sources have continued to decline, due in part to the success of the Connecticut Nitrogen Exchange. Point sources contribute the majority of phosphorus to the Long Island Sound. However, currently there is no TMDL for phosphorus within the LISS, although phosphorus regulations do exist elsewhere in the watershed.

3.2 TMDLs in the LIS Watershed

The Clean Water Act (CWA) requires states to identify waters not meeting state water quality standards and develop TMDLs for those impaired water bodies. TMDLs set the maximum amount of a substance that a waterbody can receive without exceeding current water quality standards. The number of waterbodies subject to a TMDL – and the number of facilities that discharge into those waterbodies – is an indicator of potential demand.

3.2.1 TMDLs in the LISS Area

In 2000, the New York State Department of Environmental Conservation and the Connecticut Department of Environmental Protection, in partnership with the EPA, implemented a TMDL for the purposes of hypoxia management in the Long Island Sound that included nitrogen reduction targets. This TMDL includes twelve management zones within the LISS area; therefore, it encompasses significantly more square miles than any other TMDL included in the inventory. The LISS area is not subject to a phosphorus TMDL.

The LISS TMDL was approved in 2001 and is evaluated periodically. In 2012, the LISS Management Committee approved the Enhanced Implementation Plan for the Long Island Sound Total Maximum Daily Load[6] as a tool to assess the TMDL. It specifies the need for continued reduction of nitrogen from point sources, a comprehensive evaluation of current stormwater and nonpoint source control efforts, and development of a tracking system to assess the feasibility of nitrogen load reductions from non-point sources.

Currently, the wasteload allocation for nitrogen is slightly more than 14 million kilograms per year. In 2018, total facility discharges totaled approximately 5.2 million kilograms, 36% of the total allocation, and in 2019 facility discharges totaled approximately 4.6 million kilograms, or 34% of the total allocation (US Environmental Protection Agency, n.d.).

3.2.2 TMDLs in the LIS Watershed (Excluding LISS)

Using a list of the watershed subbasins in conjunction with location information from EnviroAtlas, the team determined which waterbodies in the LIS watershed (outside the LIS study area) were covered by a TMDL. Those watershed subbasins are listed in tables B 2 through B 7 in Appendix B. Outside the LIS study area, 22 HUC 12 level watersheds are subject to a phosphorus TMDL, while only one is subject to a nitrogen TMDL.

By using ECHO, the project team then determined the number of sub-basins where permitted facilities discharged more nitrogen or phosphorus than the allocated wasteload for that sub-basin. Results are shown in Table B 1 in Appendix B. Of those sub-basins subject to a phosphorus TMDL, six (in bold) experienced discharges in exceedance of their permitted load in 2018 and 2019. One watershed experienced discharges of approximately 12,000 kilograms of phosphorus in both 2018 and 2019 although the wasteload allocation is zero for that watershed. (Commonwealth of Massachusetts Executive Office of Environmental Affairs, Massachusetts Department of Environmental Protection. Bureau of Resource Protection, Division of Watershed

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[6] That document can be found here: http://neiwpcc.org/wp-content/uploads/2020/08/LIS-TMDL-Enhanced-Implementation-Plan.pdf

Management, 2001). This implies that there are relatively few point sources of phosphorus that exceeded their allocated load in those two years.

There is one TMDL for stormwater within the LIS watershed, for Eagleville Brook in Connecticut. The load allocation for stormwater is given as impervious cover (IC) as there is a complex array of pollutants transported by stormwater. Additionally, due to insufficient data and the variance in frequency and duration of stormwater it is not feasible to draw a distinction between discharges from point and nonpoint sources; therefore, the TMDL target is given as one figure, a goal of 12% or less of impervious cover in the watershed (State of Connecticut Department of Environmental Protection, 2007). It should be noted that, although this is the only TMDL for stormwater determined in the LIS watershed, many MS4 permits include requirements to control nutrient discharges to the watershed. See section 3.4.

Outside of the LISS area, there is only one TMDL for nitrogen, for the Piper Brook-Park River watershed in Massachusetts. In 2018, total facility discharges of nitrogen into that watershed were also below the total allocation: 1,049 kilograms in 2018 (56% of the total wasteload allocation), and 959 kilograms (51% of the total wasteload allocation) in 2019.

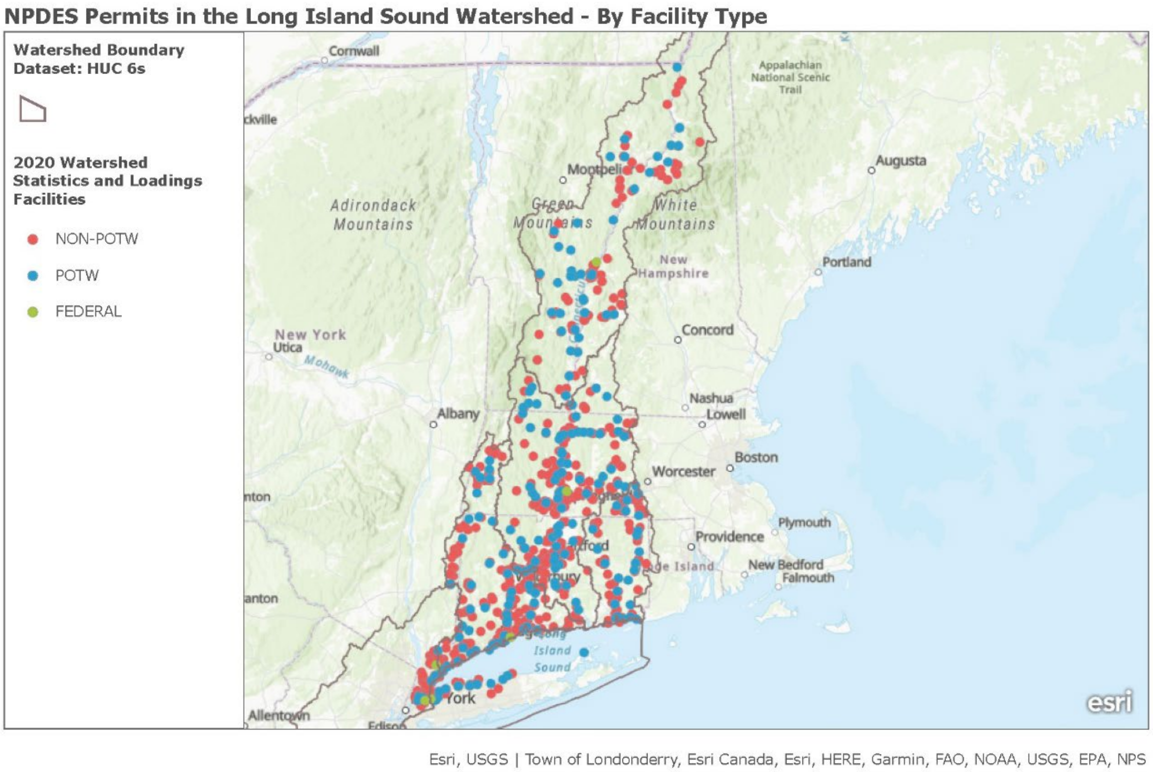
3.2.3 Summary of TMDLs in the LIS Watershed

The data and analysis in this section implies that the current TMDLs in the watershed are, for the most part, being met. For the purposes of establishing a trading market, therefore, the current TMDLs are insufficient to create a robust demand for nutrient reduction credits.

3.3 NPDES Regulated Discharges in the LIS Watershed

NPDES permits are issued by the states that have been given EPA approval to do so, or by EPA regions for states that have not sought or received such a designation. The permits fall primarily into two categories: Publicly Owned Treatment Works (POTW) and Non-Publicly Owned Treatment Works (Non-POTW). The rest are Federal permits at government run facilities (US Environmental Protection Agency, 2020). While facilities in watersheds subject to a TMDL are required to have a NPDES permit (see previous section), other facilities may be required to have a NPDES permit, even if they are not located within an impaired watershed. This section describes the NPDES permits within the LIS watershed.

Figure 11 NPDES Permits by Facility Type in the LIS Watershed



Source: EPA, 2020.

The team reviewed information from ECHO to investigate the number of discharge permits and the amount of nitrogen and phosphorus discharged by permit holders, by watershed, state, and by industry. This information will help determine potential sources of demand for nutrient credits. While a recent study conducted by the US Government Accountability Office (GAO) found that "summary data available from the ECHO State Water Dashboard are unreliable for the purpose of reporting changes in state or national NPDES compliance and enforcement activities since 2015" (US Government Accountability Office, 2021), we present these data as a snapshot of the percentage of systems over their permitted limit, not as a measure of how compliance and enforcement activity has changed over time.

Table 2: 2020 LIS Watershed NPDES Permits by Facility Type Indicator

State	Non-POTW	POTW	Federal
CT	255	83	1
MA	161	49	1
NH	54	15	1
NY	148	21	3
RI	0	0	0
VT	33	32	0
Total	**651**	**200**	**6**

Source: EPA, 2020.

Connecticut has the highest number of both non-POTW and POTW permits. There are no discharge permits in the small portion of the watershed that touches Rhode Island. As shown, the majority of these permits fall within the Connecticut Coastal Watershed.

Table 3 shows the total pounds of nitrogen and phosphorus discharged by NPDES permit holders into the LIS watershed in 2020.

Table 3: Nitrogen and Phosphorus Discharges by NPDES Permit Holders in the LIS Watershed (2020)

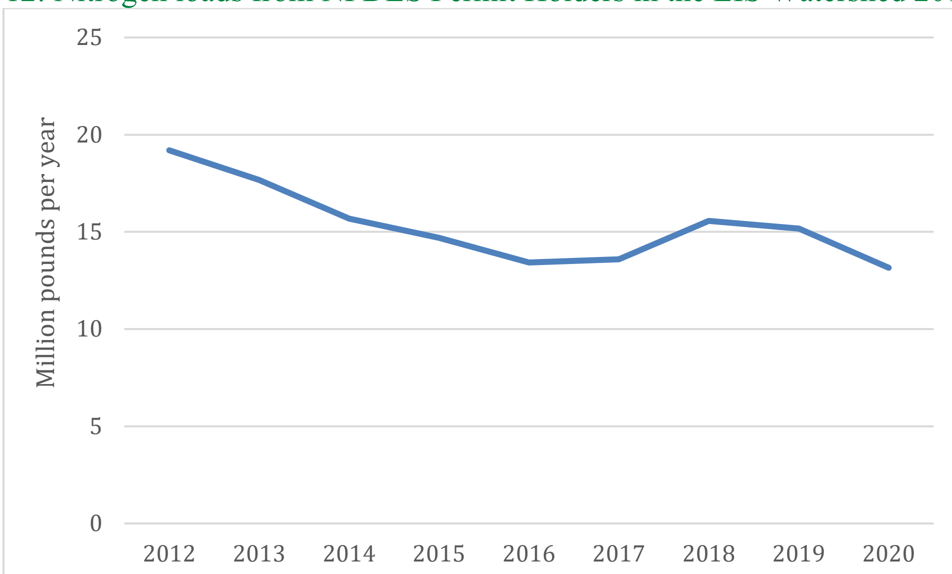
Watershed (Non-POTWs/POTWs/Federal)	Nitrogen Discharges (lb/year) Non-POTW	Nitrogen Discharges (lb/year) POTW	Phosphorus Discharges (lb/year) Non-POTW	Phosphorus Discharges (lb/year) POTW
Upper Connecticut (80/39/1)	178,634	581,160	4,588	2,993,134
Lower Connecticut (198/72/1)	254,083	2,993,134	17,814	863,655
Connecticut Coastal (246/70/1)	254,927	1,576,809	10,999	1,138,720
Lower Hudson (partial) (102/5/2)	2	7,795,284	34,627	2,033,200
Long Island (partial) (25/14/1)	4,033	20,7496	0	20,7496
Total	**691,679**[7]	**5,151,103**	**33,401**	**4,995,510**

Source: EPA, 2020.

[7] These figures do not include discharges from the Dominion Millstone Nuclear Power Plant into Fenger Brook (HUC 011000030305) in 2020 which were flagged as an outlier or possible error in the EPA data.

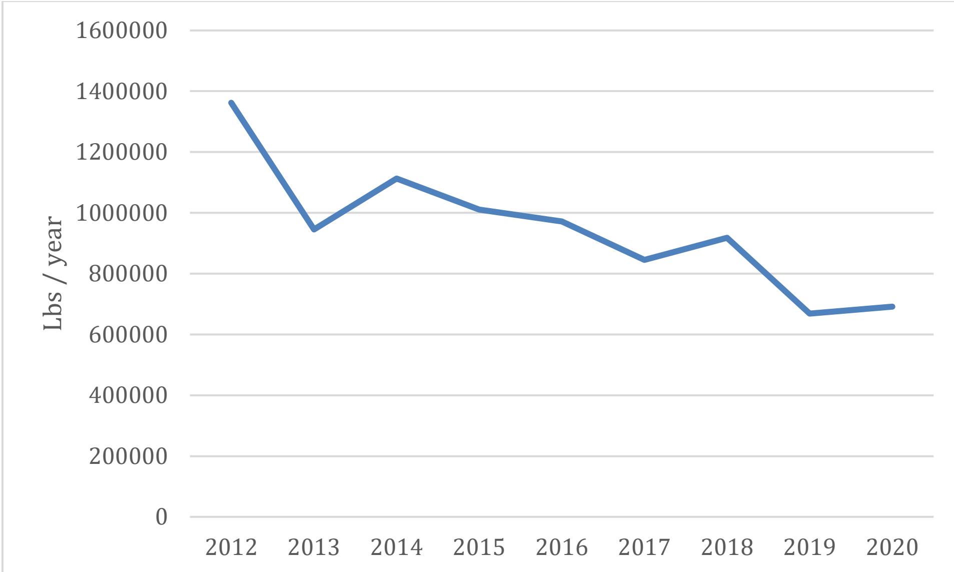
Overall, the amount of nitrogen released by NPDES permit holders in the watershed has been steadily decreasing since 2012. POTW sources of nitrogen have declined from approximately 19.2 million pounds per year to 13.2 million – a decrease of 31%. The Nitrogen Credit Exchange in Connecticut (a program established in 2002 that facilitates the exchange of credits between qualified sewage treatment plants in Connecticut) is a large part of this success – the program boasts that nitrogen loads from these plants has declined by 65 percent between 2002 and 2014 (State of Connecticut Department of Energy and Environmental Protection, 2020). Discharges from non-POTW sources have decreased by 49% from 1.4 thousand pounds in 2012.

Figure 12: Nitrogen loads from NPDES Permit Holders in the LIS Watershed 2012-2020



Source: EPA, 2020.

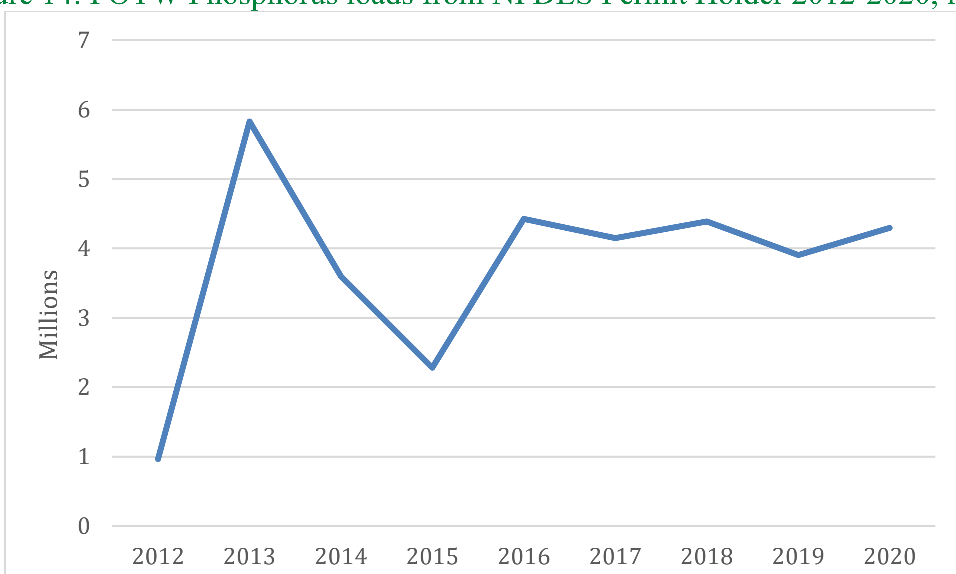
Figure 13: Non-POTW Nitrogen Loads from NPDES Permit Holder in the LIS Watershed 2012-2020



Source: EPA, 2020.

On the other hand, phosphorus discharges in the watershed have not shown a similar trend. After a short period of declining discharges from 2013 to 2015, POTW phosphorus discharges increased to 4.5 million pounds per year in 2016 and have stayed closed to that level over the next four years.

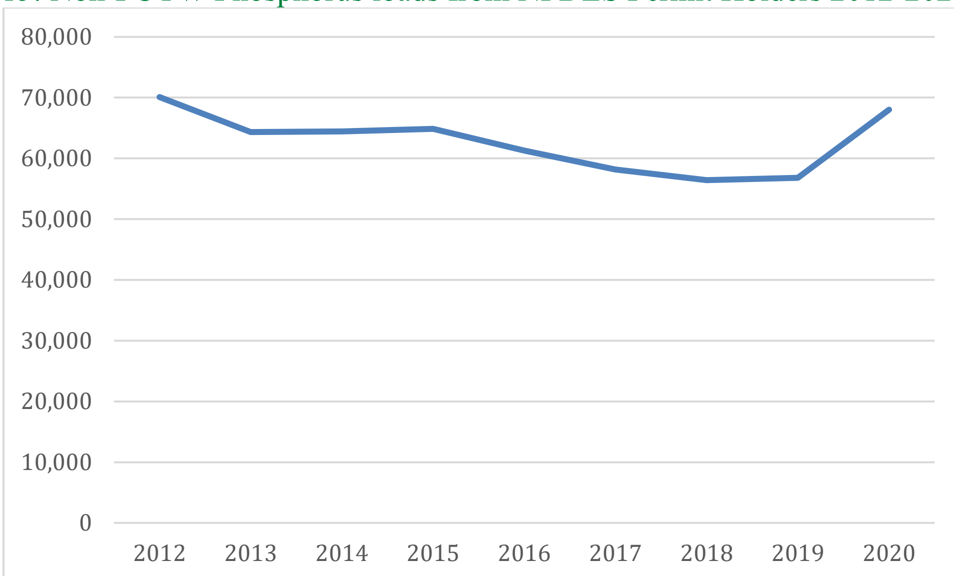
Figure 14: POTW Phosphorus loads from NPDES Permit Holder 2012-2020, lbs/yr



Source: EPA, 2020.

Non-POTW sources of phosphorus decreased from approximately 70,000 pounds in 2012 to a low of 56,800 pounds per year in 2019 before increasing again to 68,000 pounds per year in 2020.

Figure 15: Non-POTW Phosphorus loads from NPDES Permit Holders 2012-2020, lbs/yr

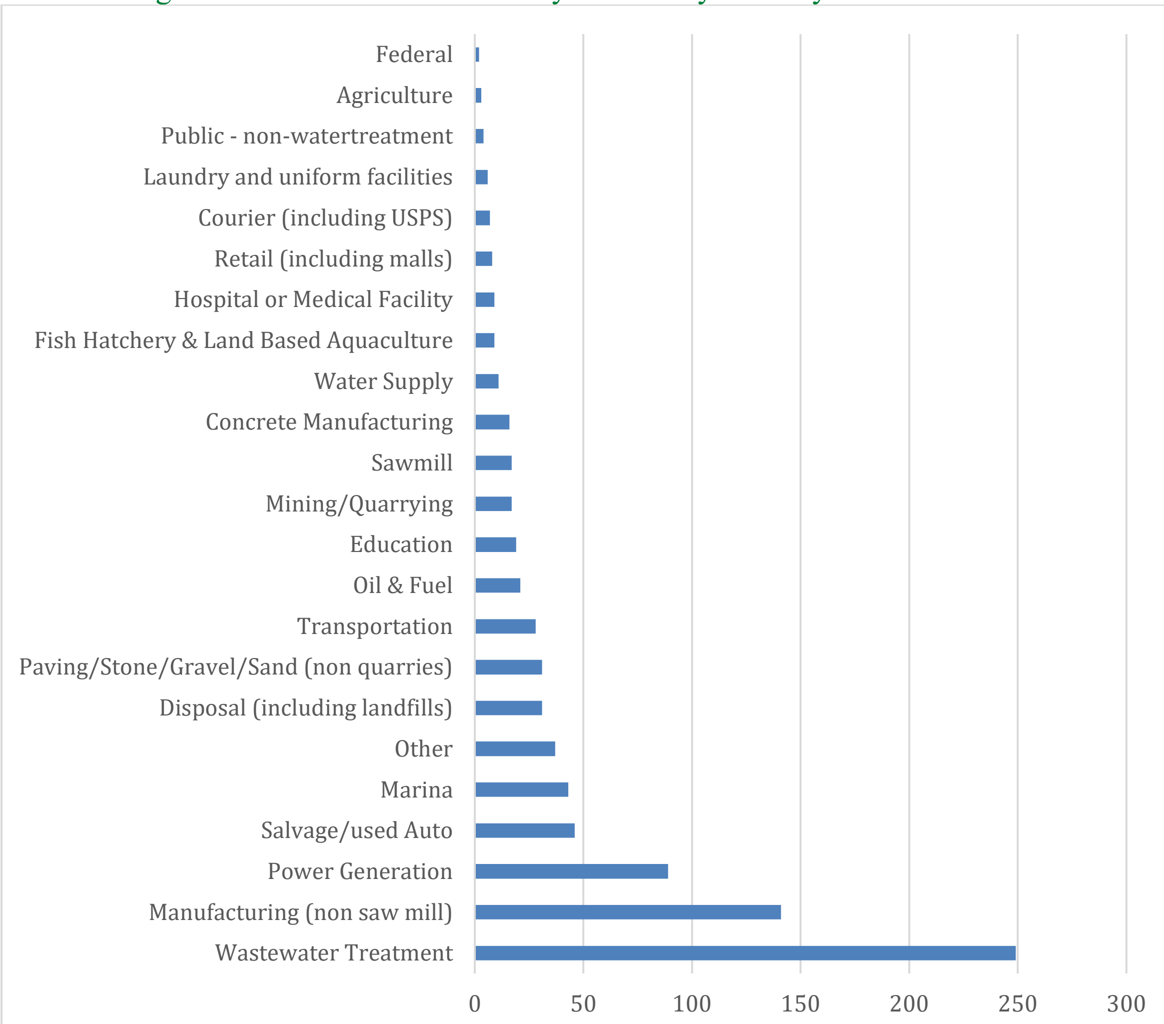


Source: EPA, 2020.

3.3.1 NPDES Permits by Industry

The following information shows what types of industries hold discharge permits in the LIS watershed. Most NPDES permits include Standard Industrial Classification (SIC) and/or North American Industry Classification System (NAICS) codes for the industry of the permit holder. The project team reviewed each permit to determine, to the best of our ability, the major industry for each facility. This included reviewing the permit information, searching the permit holder name online, and reviewing the address of the permit location in Google maps. It should be noted that while the team strove for as much accuracy as possible, there were times when the industry was not consistent or where the code was missing.

Figure 16: LIS Watershed Facility Permits by Industry - 2020 Permit Holders



Source: EPA, 2020.

The largest number of permits are issued are for wastewater treatment with 249 permits which accounts for 30% of the permits issued. Non-sawmill manufacturing and power generation represent 17% and 11% of permits.

3.3.2 NPDES Permit Holders in Exceedance in the LIS Watershed

The majority of NPDES permit holders stay at or below their discharge limits. Our team reviewed information from ECHO on permittees that exceeded their discharge limits for the years of 2016 – 2020 and found that, on average, 20 facilities per year exceeded their limits of nitrogen discharge limits, and an average of 13 per year exceeded their limits for phosphorus. In other words, only 2% of existing permit holders for nitrogen and 1% of permit holders for phosphorus exceed their permit limits on average, implying that there would be very few participants in a hypothetical market, at least under current regulations.

Table 4: NPDES Permit Holders in the LIS Watershed in Exceedance of Discharge Limits

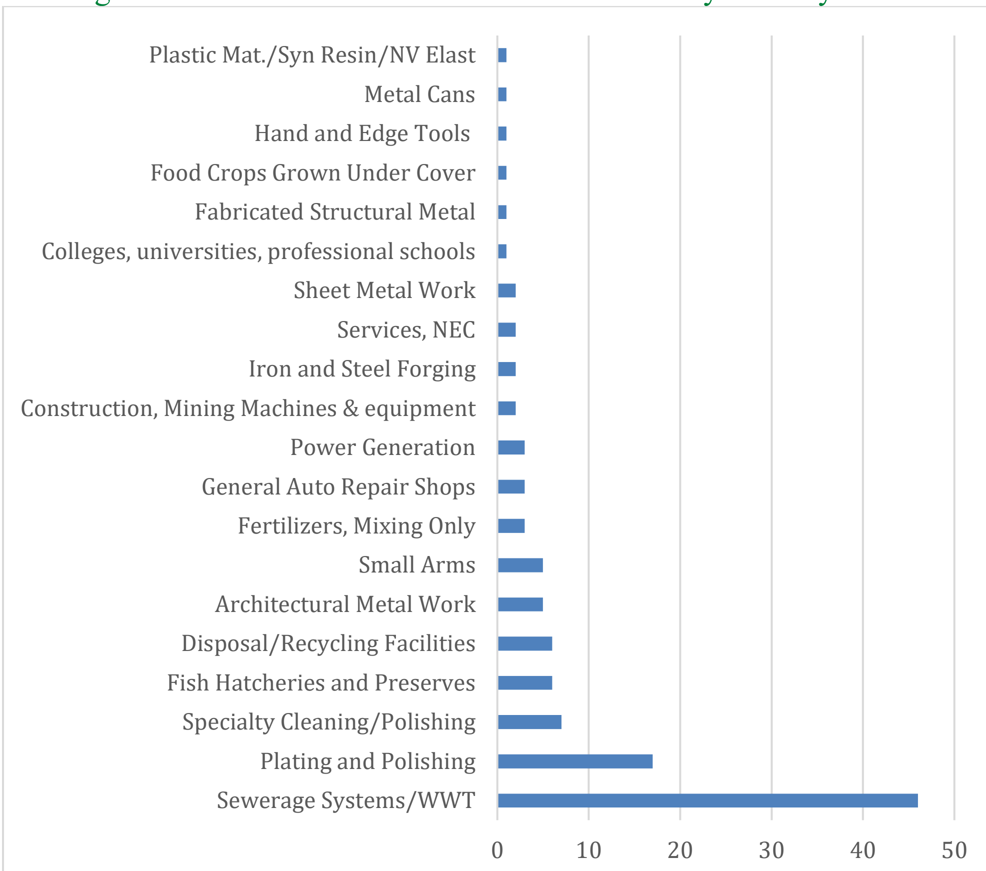
Year	Nitrogen		Phosphorus	
	Facilities over limit	N Over (lbs/year)	Facilities over limit	P Over (lbs/year)
2016	18	8,464	10	537
2017	26	16,312	7	1,002
2018	22	10688	13	551
2019	18	14,384	16	4,0953
2020	17	4,207.26	20	10,769
Average	20	10,811	13	10,761

Source: EPA, 2020.

The amount of nitrogen and phosphorus that is discharged in exceedance of permit limits is an average of 10,810 pounds of nitrogen annually, and an average of 10,761 pounds of phosphorus annually. Nitrogen exceedances account for an average of 0.05% of the total nitrogen discharged by permit holders. Phosphorus exceedances are responsible for 0.27% of total phosphorus discharged by permit holders. While the number of facilities in exceedance of nitrogen limits has decreased since 2017, the amount exceeding has fluctuated with a high of 14.4 thousand pounds in 2019 to 4.2 thousand pounds in 2020.[8] Phosphorus exceedance amounts have also fluctuated with a high of 40,952 pounds of phosphorus in 2019 and a low of 537 pounds in 2016.

[8] As reporting and/or monitoring may have been affected by the COVID-19 pandemic, this number may not be accurate.

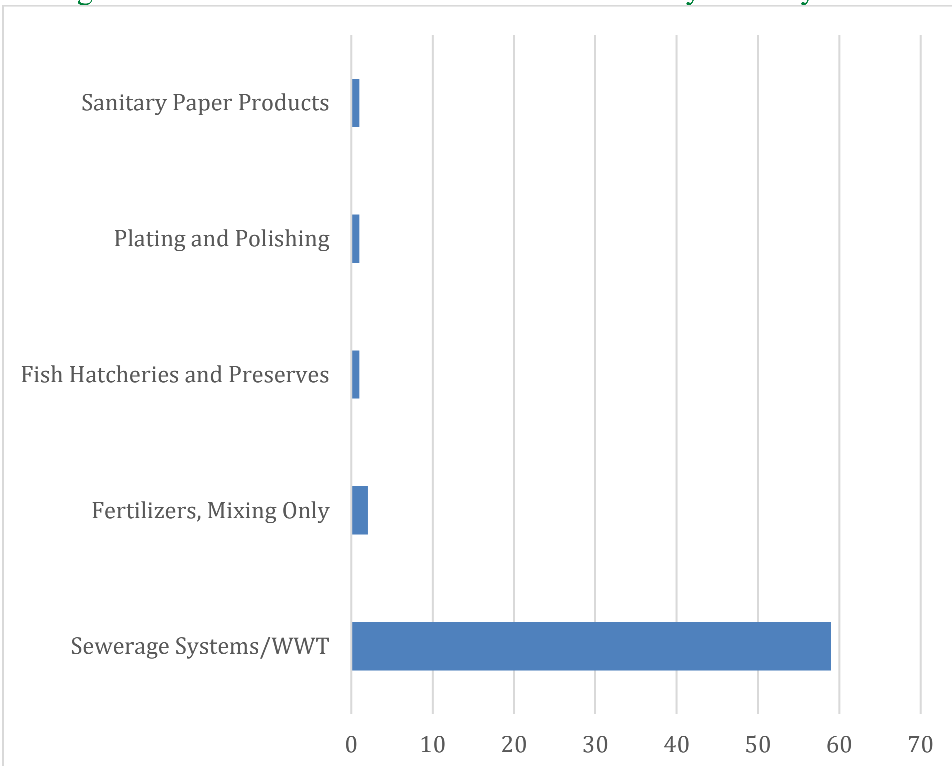
Figure 17: Nitrogen 2016 - 2020 NPDES Permit Exceedances by Industry in the LIS Watershed



Source: EPA, 2020.

Sewer and wastewater treatment facilities account for 40% of the permit holders who exceeded their permit limit for nitrogen from 2016 to 2020. Plating and polishing make up 15% of the overages. For those facilities that exceeded their limits for phosphorus, 92% are sewer and wastewater treatment facilities.

Figure 18: Nitrogen 2016 - 2020 NPDES Permit Exceedances by Industry in the LIS Watershed



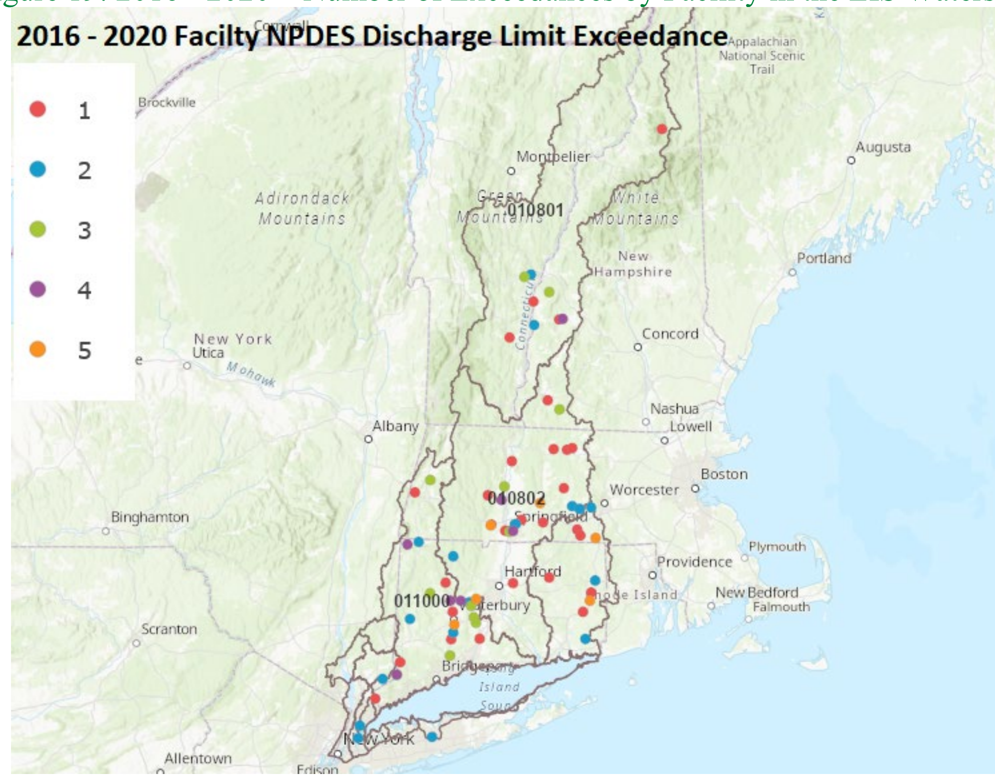
Source: EPA, 2020.

3.3.3. Multiple Discharge Limit Exceedance in the LIS Watershed

Several dischargers exceeded their permitted amounts in multiple years. Figure 19 illustrates the location of facilities that exceeded their discharge limits from 2016 – 2020.

While most facilities in violation exceeded their limits for either nitrogen or phosphorus, eight facilities exceeded limits for both nitrogen and phosphorus at least once during 2016 – 2020. Seven of these were wastewater treatment plants and one is listed as a turf care company. All eight also have multiple exceedances on at least one of these two pollutants, though not all in the same year.

Figure 19: 2016 - 2020 – Number of Exceedances by Facility in the LIS Watershed



Source: EPA, 2020.

Table 5 shows permit holders in the LIS Watershed that exceeded their discharge limits for a given year and also had discharge exceedances in a prior year. For example, of the 17 NPDES permit holders that exceeded the discharge limit for nitrogen in 2020, 14 had exceeded that limit in at least one other year.

Table 5: NPDES Permit Holders in the LIS Watershed with Exceedances in Multiple Years

	Total Exceeded	Exceedance in at least one prior year	Total Exceeded	Multiple Exceedance
2016	18	4[9]	10	5
2017	26	15	7	4
2018	22	17	13	6
2019	18	17	16	13
2020	17	14	20	13

Source: EPA, 2020.

[9] Included NPDES permit holders that also exceeded the permit limits in 2015

The analysis in this and the previous section implies that the current regulations are not sufficient to create a robust demand. The fact that the majority of facilities within the LIS watershed are well below their permitted load implies that most facilities would have limited need of credits to allow them to stay within compliance.

3.4 MS4 Programs

3.4.1 MS4s as a Potential Source of Demand

This section describes the potential for MS4s to participate in a trading system. MS4s are publicly owned and operated stormwater conveyance systems that discharge into US waters, are not part of a combined sewer system, and not part of a POTW. Beginning in 1990, operators of MS4s in cities and some counties with populations of 100,000 or more were required to obtain NPDES permits. The 1999 Phase II regulation required small MS4s in urbanized areas, as determined by the US Census, to obtain NPDES permits. (Phase II also included "non-traditional" MS4s, such as hospitals, public universities, and the like.) Phase II MS4s are automatically designated if any part of the MS4 is located in an urbanized area, according to the US Census. Therefore, the "universe" of small MS4s changes every ten years. However, the Census Bureau recently proposed changes to definition of an urbanized area for the 2020 Census. The impact of such a change for MS4 designation is still unclear.

MS4 permits are issued as a general permit to the impacted state. The state is then responsible for designating the permits to the operators, who are in turn required to develop stormwater management programs (US Department of Environmental Protection, 2021).

MS4s could potentially act as sources of demand for WQT credits. There are two different options when it comes to stormwater trading. In the first scenario, municipal waste and stormwater management facilities join a preexisting WQT program as one of the many credit generators and/or credit buyers. In this scenario the municipality takes on the role of trader, and all of the liability that comes with it (Jones, et al., 2017). In this situation, the municipality acts similar to a point source polluter. The assumption is that the municipality will be a purchaser of credits and rely on pollution mitigation enacted in rural areas.

3.4.2 MS4s in the LIS Watershed

The project team researched the lists of MS4s issued by each state in the watershed. We then reviewed each list to determine which of the MS4s on the list were located within the LIS watershed area. Connecticut had the highest number of MS4s with 96, while Massachusetts and New York had 42 and 43 respectively. New Hampshire, Rhode Island, and Vermont did not have any MS4s located within the watershed. These data are shown in figure 20 below.

Figure 20: MS4s in the LIS Watershed

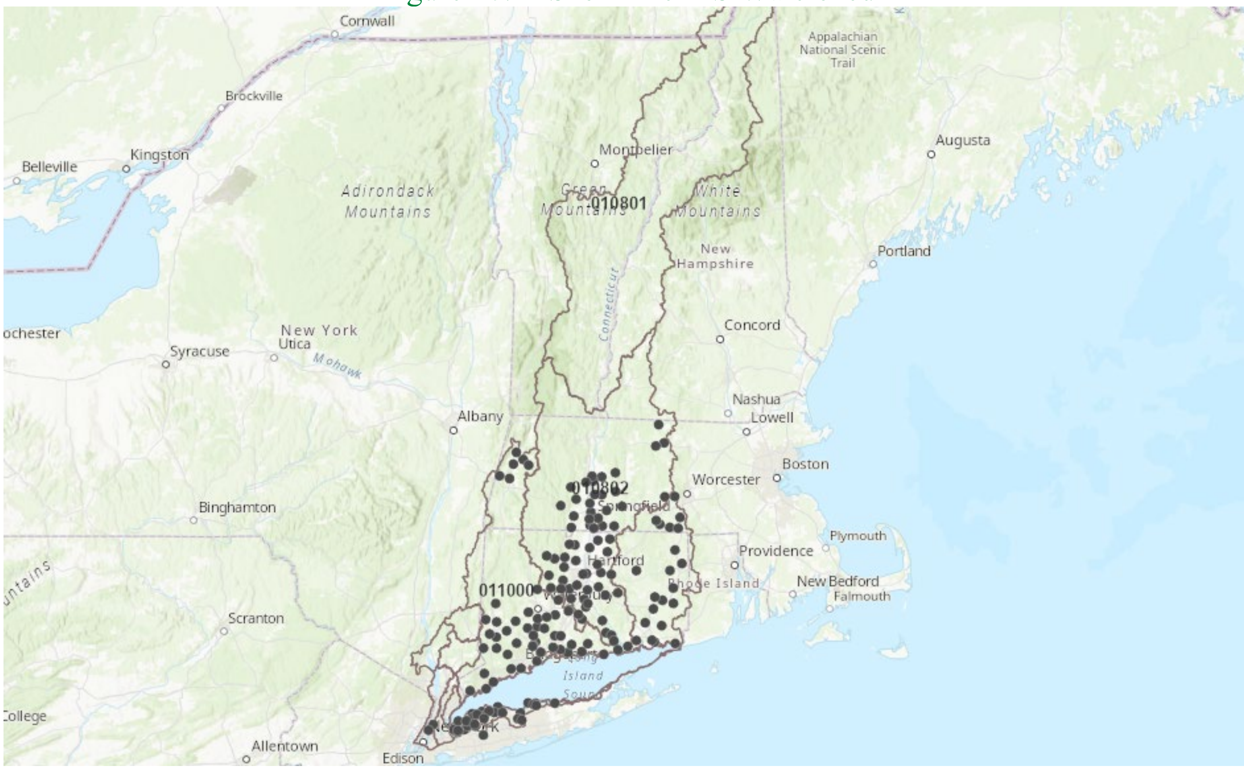


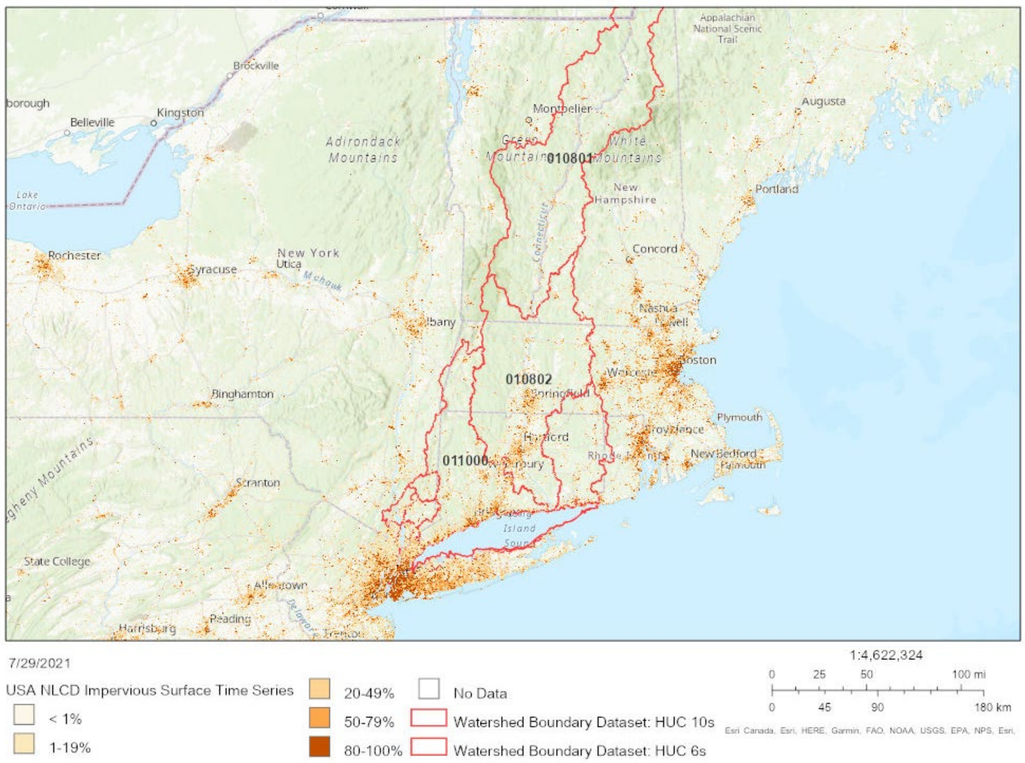
Table 6: MS4s in the LIS Watershed by State

State	MS4s
Connecticut	96
New Hampshire	0
Massachusetts	42
New York	43
Rhode Island	0
Vermont	0

Source: EPA (2020), EPA (2021a), State of Vermont (2020), Connecticut Department of Energy and Environmental Protection (2021), State of New York (2021)

While the amount and extent of impervious surface within the watershed is not a direct determinant of demand, it does affect the potential amount of untreated runoff from urban sources. As seen below, the majority of impervious surface in the watershed is concentrated in the southern area of the region. This may change as areas continue to develop and urbanize. To the extent that impervious surface increases outside of urbanized areas (and therefore outside of MS4 communities), it is not a current driver of demand for credits. However, as the number of small MS4s changes every ten years, and as the Census is currently proposing changes to the definition of an urbanized area, impervious surfaces - within MS4s - could become more of a driver of demand in the future.

Figure 21: Percent Impervious Surface in the LIS Watershed



Source: USA NLCD Impervious Surface Time Series (MRLC, 2019).

3.4.3 MS4s as a Potential Source of Demand: Conclusion

As seen above in figures 6 and 7, runoff from urban land has historically contributed about 12.7 percent of nitrogen and 7.8 percent of phosphorus to the Long Island Sound. If current trends towards urbanization and land use conversion continue, the amount of discharge from those sources could increase. To the extent that that increase occurs in already existing or newly created MS4s, such discharges could be subject to regulatory requirements, and therefore a potential source of demand for nutrient reduction credits. However, it is by no means a sure source of demand. Moreover, there are no current MS4 communities within the parts of New Hampshire, Vermont, or Rhode Island that touch the LIS watershed, further limiting the market.

3.5 Cost of Technological Upgrades

In order to determine effective demand for nutrient removal credits, the cost of obtaining those credits must be compared to the cost per pound for nutrient removal “in-house.” If the cost of technological upgrades to remove a certain number of nutrients is less than the cost of obtaining credits for the equivalent amount, a profit-maximizing firm will undertake the upgrade, rather than participating in a market. This section looks at the cost of nitrogen and phosphorus removal per pound. However, it is important to recognize that although these numbers are presented as cost per pound removal of *either* nitrogen or phosphorus, most systems are designed to remove *both* contaminants. In addition, presenting the marginal cost of abatement as a constant dollar figure may be misleading, as technological upgrades typically require large upfront costs.

3.5.1 Costs of Nitrogen and Phosphorus Removal

In 2015, JJ Environmental performed an evaluation of treatment plants in the Upper Long Island Sound Watershed. The purpose of this evaluation was to determine the cost and feasibility of nitrogen removal using low-cost retrofit technology. The authors found that the cost per pound of nitrogen removal ranged from $0.59 to $5.83 in the 10-year time frame and $0.41 to $4.41 for the 20-year time frame (all figures in 2021 dollars) (JJ Environmental, 2015).

A 2018 study of the effectiveness and costs of both established and emerging phosphorus removal technologies found that the per unit cost for phosphorus removal in wastewater ranged from $50.12 to $67.48 per pound of phosphorus removed (all figures in 2021 dollars) (Bashar et al., 2018).

3.5.2 Trends in Nutrient Removal

In 2010, Industrial WaterWorld, a journal for professionals in the wastewater industry, surveyed its subscribers regarding the costs of various treatment options for the removal of nutrients from wastewater, along with questions regarding the future of nutrient removal regulation and technology. Costs typically declined as facility size increased, indicating economies of scale in nutrient removal. In fact, responses indicated that facilities that had flows less than 100,000 gallons per day experienced per unit treatment costs nearly 15 times that of the largest facilities.

A more recent survey conducted by Black and Veatch, a management consulting firm, found that the number of wastewater utilities that were permitted for phosphorus, total nitrogen, or both, increased by six percent in 2020 over 2019 levels. Of those that did not have a current limit on nutrients in their wastewater permits, more of them are expecting to see such limits within the next five or ten years. Many are planning for such limits, even in the absence of such regulatory requirements now.

More wastewater utilities are also either actively planning for or considering technologies for phosphorus recovery, which allows for the resulting product to be used as a fertilizer or soil amendment. Phosphorus removal and recovery involves either chemical or bio-based precipitation. The precipitated phosphorus is then recovered from the resulting sludge using anaerobic digestion, dewatering and incineration. Currently, one of the most common technologies – struvite precipitation - is only economically viable for large wastewater treatment plants with high dissolved phosphorus loads. However, alternative measures are becoming more economical.

Our analysis indicates that, given the relatively low cost of pollution removal using in-house technology, point sources will not enter the market unless the price of a nitrogen reduction credit is lower than approximately $6.00 per pound, or unless the price of a phosphorus reduction credit is lower than approximately $70 per pound.

However, even this ignores transactions costs from the firm's point of view. As Walker and Selman point out, "because regulated point sources retain legal liability for meeting their permit, they may find it too risky to enter into an agreement in which there is uncertainty regarding the seller's actions and the credits actually generated" (Walker & Selman, 2014). Moreover, potential buyers are unlikely to engage in trades if they are uncertain about the price or availability of credits in the future. Large capital decisions, such as retrofits, are typically made considering a long time horizon, and the variability of the market is likely to serve as a barrier to trade.

3.5.3 Summary of Sources of and Factors Affecting Potential Demand

The information presented in the previous section indicates several issues that may contribute to an anemic demand for nutrient credits in the LIS watershed:

- **Lack of a regulatory driver.** While the LIS study area operates under a TMDL for nitrogen, the remaining areas in the LIS watershed do not (with the exception of Piper Brook). Even within the LIS study area, point sources are generally well within their regulatory limits. While an analysis of phosphorus TMDLs in the LIS watershed reveals that, overall, discharges of phosphorus from point sources are near their regulatory limit, one point source accounts for the majority of that discrepancy. The majority of point sources within the LIS watershed are well within their regulatory limits, providing no clear driver to participation in a trading market.
- **Technological advances in pollution control**. Our analysis finds that technological increases in waste control are likely to reduce the attractiveness of trading, as more point sources find it easier and less expensive to control wastes on their own.
- **Geographical boundaries**. The boundaries within which potential trades could take place in the LIS watershed may further limit demand. While expanding the size of the geographical area within which trades are acceptable may increase the number of potential trades, such trades need to be carefully vetted to ensure that they do not adversely affect water quality in one geographic area. Many programs limit the geographic area within which trades may take place.
- **Institutional factors**. Finally, institutional factors cannot be overlooked in establishing a trading program. While the price of a credit may indicate what a point source would have

to pay for a nutrient credit, it is not necessarily an indicator of what that point source would be willing to pay to engage in such a transaction. Willingness to engage in trade encompasses a whole host of complex factors, including legal obligations, trust, uncertainty, institutional culture, and others.

4 Sources of Potential Supply

4.1 Introduction

The counterpart to demand in any market transaction is, of course, supply. The supply of nutrient credits in a potential market includes point sources that are able to reduce nutrients beyond their allocated load and the number of non-point sources that would be willing to install best management practices to reduce nutrients at a certain price. Within the LIS watershed, shellfish and seaweed growers may also constitute an important component of supply.

This section explores the potential for the supply of nutrient reduction credits in the LIS watershed.

4.2 Potential Supply from Agriculture in the LIS Watershed

4.2.1 Number and Size of Farms in the LIS watershed

In general, agricultural land has been a major focus for trading program designers in other watersheds. In many cases, that focus is justified. For example, a 2015 report estimates that agriculture in the Chesapeake Bay Watershed (which makes up about 28 percent of the land use in the Bay) contributes the majority of both nitrogen and phosphorus to the Bay. However, land in farms (as defined by the USDA) makes up approximately 13 percent of the LIS Watershed. If only land under cultivation were counted, that figure would shrink to five percent (USDA, 2017). However, as seen in figure 6, farm sources (manure, farm runoff, and nitrogen fixing) only accounted for approximately six percent of the nitrogen in the Long Island Sound, and approximately nine percent of the phosphorus in the Sound. Reducing runoff from agricultural land, therefore, is certainly important to improving the health of Long Island Sound, but perhaps not to the same extent that it is in other trading programs.

In theory, agricultural producers can install best management practices on their properties, receive nutrient reduction credits, and sell those credits on the market. As such, the number and types of farms in the watershed is an indicator of potential supply. In the table 7 below, we report information from the 2017 Census of Agriculture, summarized by HUC 6 level watershed.

For the purposes of the census, the USDA counts any farm that produced and sold $1,000 of agricultural products in the prior year. These farms can vary in size from a few to hundreds of acres. The average size farm ranges from 52 acres in the Lower Hudson watershed to 157 acres in the Upper Connecticut watershed. While the Lower and Coastal Connecticut watersheds have a greater number of farms, the Upper watershed has a much higher number of acres of farmland.

Not all of the land designated as "farms" is actively farmed, with only about 33% of the land listed as farms actually devoted to crops. The remaining 67 percent includes land that is idle (land planted in cover crops is included as idle land), and woodland.

Table 7: Farms and Farmland by Watershed

		Upper CT	Lower CT	Coastal CT	Lower Hudson	Long Island
Farms	number	3,136	4,595	4,623	3,046	598
Land in farms	acres	492,800	363,420	380,747	182,011	31,002
Average size of farm	acres	157	80	82	60	52
Total cropland[10]	farms	2,158	3,312	3,397	2,273	437
	acres	145,405	121,867	136,639	107,205	23,330

Source: US Department of Agriculture, 2017.

Unfortunately, data are not available for the number of farms that include some sort of BMP on their property. Nor are we able to determine the number of pounds of runoff from each farm, which is information that is necessary to determine a baseline. Such a baseline in turn would be necessary in order to determine the potential supply of credits from a particular farm. While NEIWPCC and its partners have been working to develop a tool similar to the one used in the Chesapeake Bay, which can quantify the site-specific reductions in nitrogen, phosphorus, and sediment from conservation practices implemented on farm fields, such a tool has yet to be developed for the LIS watershed. Without these data, it is nearly impossible to estimate the potential supply of nutrient reduction credits from agricultural sources.

4.2.2 Land Use Changes in the LIS Watershed

Data from the University of Connecticut's Center for Land Use Education and Research (CLEAR) program demonstrate that farmland in the LISS area declined by nearly 50,000 acres (over 15 percent) during the period from 1985 to 2015 (UCONN Center for Land Use Education and Research, nd). (More recent data await the release of the latest version of the National Land Use Cover Database, due in mid- to late 2021.) A report from the Trust for Public Land notes that the Connecticut River Watershed (which is part of the LISS area) lost more than a quarter of

[10] The USDA defines cropland as having three components "cropland harvested, crop failure, and cultivated summer fallow—are collectively termed cropland used for crops, or the land used as an input to crop production."

its farmland between 1982 and 2002 (Trust for Public Land, 2006). This trend is likely to continue.

A further concern from a political economic standpoint is the possibility that agricultural producers may have the incentive to take land out of current production in order to "idle" it and thus be eligible for nutrient reduction credits. The Chesapeake Bay trading program, for example, states that "credits will not be generated under this policy from the purchase and idling of whole or substantial portions of farms to provide nutrient credits for use offsite" (Pennsylvania Department of Environmental Quality, 2006).

4.2.3 Attenuation and Baseline Considerations

Next, there is the issue of developing attenuation ratios.[11] As the majority of the acres in farmland are located in the upper areas of the LIS watershed, a pound of nitrogen or phosphorus reduced in the Upper Connecticut watershed would not generate the same number of credits as a pound of nitrogen or phosphorus reduced in the Lower Hudson watershed (should such a trade be even allowed under geographic restrictions). Therefore, attenuation rates throughout the watershed must be determined, and clear attenuation ratios would need to be established before potential supply could be estimated.

As discussed in the companion documents to this report, the baseline chosen by a nutrient trading program determines the supply of credits available. The choice of a baseline is crucially important to the effectiveness and success of a trading program: too low, and the program will potentially be ineffective in reducing pollution; too high, and nonpoint sources may not have enough of an incentive to enter the market.

4.3 Potential Supply from Aquaculture and Shellfish

Shellfish and seaweed aquaculture can provide a vital ecosystem service to the Long Island Sound and may be able to play a role in developing a trading program for the LIS watershed. High levels of nutrients may stimulate the excessive growth of phytoplankton in the water. This increases the turbidity of the water, which reduces the availability of light for aquatic vegetation. Without sufficient light, the growth of aquatic vegetation is inhibited, and the plants begin to decompose. The loss of oxygen-producing vegetation and further depleted oxygen levels due to the decomposition of said vegetation may cause hypoxic conditions (Flood, 2019). Shellfish and seaweed aquaculture can increase the water's capacity to assimilate nutrients.

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[11] Attenuation is the process by which nutrients are essentially reduced over time and distance from the point of discharge to the point of monitoring. Attenuation can occur through denitrification, uptake, assimilation, and other biogeochemical processes.

Oysters are the main type of farmed shellfish in the LIS watershed (Bricker, et al., 2017). They feed by filtering phytoplankton. The nutrients in the phytoplankton are assimilated into the shell and tissue of the oyster. In the case of nitrogen, the remaining nutrients are excreted through biodeposits in the form of dissolved nitrogen that does not stimulate the growth of phytoplankton. Additionally, the biodeposits enhance microbial activities that continue to transform nitrogen into its dissolved form (Flood, 2019) (Stephenson & Shabman, 2015). An individual oyster is estimated to be able to remove anywhere from 0.13 grams (when only including the shell and tissue of the oyster) to 2.02 grams (when accounting for biodeposits and the enhancement of sediments) (Flood, 2019). One study found that one million oysters in the Chesapeake Bay contained 92 to 657 pounds of nitrogen in their shell and tissue.

Types of seaweed, such as sugar kelp, also absorb nutrients as they grow, which are then removed when the plant material is harvested. A pilot program by the New York Attorney General's Office and the Long Island Sound Study for the use of red seaweed as a nutrient removal strategy reported removal rates over a 90-day growing period of 28 kilograms per hectare in the sound and 94 kilograms per hectare in the Bronx River Estuary (Stephenson & Shabman, 2015). The overall ecosystem value of oysters farmed in the sound is estimated to be between $8.5 million and $230 million (Bricker, et al., 2017).

Due to the ecosystem services they provide, shellfish and seaweed aquaculture may have a place in a trading program via nutrient assimilation credits. Nutrient assimilation credits can be awarded to farmers for the creation or enhancement of existing nutrient assimilation services. Aquaculture farmers would receive credits for the harvesting and cultivation of shellfish and seaweed and have the ability to sell credits to point sources in an existing trade market. Nutrient assimilation credits may provide growers with an economic incentive to expand their aquaculture production and encourage growth in an already existing industry while offering more opportunities to regulated point sources for compliance with their limits (Stephenson & Shabman, 2015).

For oysters, the cost per pound of nitrogen removed ranges significantly but could compare favorably to the costs of installing other BMPs. Bricker et al. find that bioextraction can be used as a complement to existing measures. However, she cautions that ramping up the scale of current operations may result in conflicts with other users of the Long Island Sound (Bricker, et al., 2017).

Flood, a researcher at the University of Delaware, looked at the cost per pound of nitrogen removed via oyster aquaculture to the cost per pound of specific BMPs available to a certain WWTP in the Delaware Inland Bays. He estimates the marginal cost per pound of nitrogen removed via oyster production ranged from $35 to $204 per pound (Flood, 2019). Credit prices would need to be sufficiently high compared to the costs of production to encourage growth in the aquaculture industry.

4.3.1 Existing Shellfish and Seaweed Operations

As of 2018, the Connecticut Department of Agriculture lists the Connecticut shellfish industry as consisting of 45 harvester and aquaculture operations in Long Island Sound. Of these 45 operations, 10 are classified as aquaculture cage operations, 11 as consisting of both cage and bottom culture operations, and 24 traditional bottom culture operations. There are 44 licensed shellfish harvesters, 110 shellfish harvest vessels, 21 licensed seed oysterman, 70 licensed seed helpers, 30 licensed seed boats, and 32 firms' licenses for wholesale shellfish sales and distribution in the state.[12] The Connecticut Department of Agriculture is responsible for leasing shellfish grounds for the purposes of planting, cultivating, and harvesting shellfish crops. There are currently 313 shellfish leases, totaling to 25,354 acres, although not all of these acres are actively farmed (Connecticut Department of Agriculture, 2017). The US Army Corps of Engineers (USACE) is responsible for permitting aquaculture operations. The USACE lists eight permits for shellfish operations in the state of Connecticut, and six permits for seaweed operations (US Army Corps of Engineers, 2021).

For New York, the USACE lists seven permits for shellfish operations (US Army Corps of Engineers, 2021). Under the Suffolk County Shellfish Aquaculture Lease Program, there are currently 56 sites leased for commercial shellfish aquaculture. As it stands, there are currently no seaweed operations in the state of New York (Suffolk County Economic Developement and Planning Department, 2021). The Cornell Cooperative Extension of Suffolk County is in the process of running a feasibility study to determine the viability of commercial seaweed farming in the area (Cornell Cooperative Extension, Suffolk County, 2019).

A list of existing shellfish and seaweed operations in the LIS watershed can be found in Appendix C.

4.3.2 Summary of Potential Supply from Seaweed and Shellfish Aquaculture

Seaweed and shellfish aquaculture is an exciting possibility for nutrient reduction in the LIS watershed. As shown in this section, the marginal cost per pound of nitrogen removed varies significantly but is comparable to the marginal cost per pound of nitrogen removed by some agricultural and stormwater BMPs. As the current price of a nitrogen credit in Connecticut is $1.36 per pound for sellers (personal communication), however, it is unlikely that the revenue from selling credits could induce more aquaculture suppliers to enter the market. Rather,

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[12] A seed oyster is a small oyster, below approximately 2 cm long, that can be sold to oyster growers.

providing credits on the market is more likely to be seen as a complement to more conventional revenue sources. Moreover, issues of scalability of the industry may be an issue in the future, as an expanding aquaculture industry could increase conflicts with other ocean-based uses.

4.4 Cost of Installing and Maintaining Agricultural and Stormwater BMPs

This section discusses the cost of installing and maintaining BMPs to reduce nutrient runoff from non-point sources, including agriculture and stormwater. The cost of such BMP installation and maintenance is an important component of the supply of nutrient reduction credits. As non-point sources are currently not directly regulated under the Clean Water Act, the installation of BMPs is entirely voluntary. The cost of such installation and maintenance could thus be considered a barrier to entry to the market. In order for BMPs to be profitable or worthwhile, the price that a potential supplier could receive from the sale of a credit has to at least meet the cost of the BMP – unless the BMP is revenue enhancing in some other way. This section looks at the cost of BMP installation and maintenance and compares it to the cost of a nutrient reduction credit.

There are multiple types of BMPs that could be implemented in order to reduce nitrogen and phosphorus entering the Sound. The more conventional options are listed here. These strategies are presented in two categories: agriculture BMPs and stormwater BMPs, as LISS is investigating using both agricultural and stormwater-related non-point sources in any proposed trading program.

While there are voluminous amounts of information on the types, efficacy and costs of different BMPs, for this report, we rely on a report issued by the University of Maryland's Center for Environmental Science (UMCES) (Price, Holladay, & Wainger, 2019). We use this report for three main reasons: one, the data that they use are robust (353 BMPs) and consistent (Maryland only)[13]; two, the methodology they use is comprehensive, described in further detail below; and three, they use data from the Chesapeake Bay Partnership's Chesapeake Assessment Scenario Tool (CAST), which was recommended for use in a 2014 report prepared for NEIWPCC on NPS control tracking systems, which are critical for the development of trading programs which include NPS. Such a tool is currently in development for nitrogen.

UMCES reviewed efficiency and cost data for both agricultural and stormwater BMPs. Stormwater BMPs from the Maryland counties regulated by Maryland's MS4 program and agricultural BMPs from projects funded by Maryland Agricultural Cost Share (MACS) program. The MACS program provides farmers with grants to cover up to 87.5 percent of the cost to install certain BMPs (p. 4). The UMCES report updates the cost estimates for BMPs originally

[13] As climactic and geographic differences between the LIS watershed and the Chesapeake Bay differ, the costs per pound of nutrient removed are not directly applicable to the LIS watershed. Numbers are presented for illustrative purposes only.

set out by CAST. Table D1 in the Appendix shows the different types of BMPs analyzed in the UMCES report.

UMCES calculated the annualized costs of each BMP. The BMP lifespan was defined as time from construction to major overhaul or complete replacement. Costs included by UMCES were operations and maintenance (O&M), land acquisition and opportunity cost, and annualized costs. O&M costs were estimated by creating an annual multiplier based on maintenance intensity and frequency. This produced a range of 8.2% of installation costs (stream restoration) to 13.4% (infiltration practices). The multiplier was applied to the median per unit implementation costs.

Land costs represent the lost opportunity to develop the land. To estimate the costs of installing stormwater practices, 50% of land was estimated to be developable and 50% as not developable (due to proximity to streams, for example.). The authors used a land value of a developable acre in Maryland. For forest planting, opportunity costs per acre were divided by a multiplier. Finally, when looking at agricultural land, opportunity costs were estimated using cropland rental rates. Edge-of-tide nitrogen and phosphorus removal for each BMP was calculated using the watershed model in CAST.

Tables D2 and D3 show the average cost per pound of pollutant removed at EofT for nitrogen and phosphorus, respectively. They are ranked from lowest to highest. The average cost per pound of nitrogen removed for each BMP at the edge of tide ranged from less than a dollar per pound (for grass buffers) to over $13,000 per pound (for many stormwater practices). The average cost per pound of phosphorus removal again ranged from less than a dollar per pound (grass buffers) to over $70,000 per pound, again for most stormwater practices. In general, the cost per pound of phosphorus removed is substantially higher than that for nitrogen.

Currently, the price of a credit for a pound nitrogen reduction in Connecticut is $1.36 for sellers (Raffa, 2021). In other words, this is the revenue that credit generators could expect for each pound of nitrogen reduction. Standard economic theory suggests that a supplier would choose to enter the market only if the marginal cost of producing a product were exceeded by the marginal revenue received from selling that product. Using that logic, only the BMPs that are the most inexpensive to install and maintain would be feasible from a profit maximizing perspective, even within a wide margin.

Although there is no existing phosphorus trading program in LISS, the current price of a phosphorus reduction credit in North Carolina ranges between $139 and $690 per pound, depending on the watershed. Following the same logic, only a handful of BMPs would be financially feasible at the current price. The preceding analysis does not include any transactions costs, or institutional constraints, between supply and demand. Once these considerations are taken into account, the situation for trading looks rather more bleak.

4.5 Other Pollution Reduction Programs

Government-sponsored programs designed to incentivize farmers to reduce pollution may further reduce a supplier's willingness to participate in the market. If agricultural producers are receiving a payment from an already existing program, they may not be eligible to receive a nutrient reduction credit for the same BMP (see the discussion about additionality and credit stacking in the first two companion documents listed in Appendix A).

Incentive programs for nutrient pollution abatement and maintaining water quality standards at the state and watershed levels are listed in Appendix E. Most of these programs offer economic incentives such as grants or tax credits to both public and private facilities for the installation of pollution-reducing technologies and capital equipment. Payments or reimbursements from these programs may cover the entire cost of the project or offer to cost-share a certain percentage or dollar amount, while others give sales tax exemptions. Some programs offer payments to landowners for planting vegetative buffers that prevent bank erosion. Two of these programs are trading programs that were mentioned previously in section 3.3, the Nutrient Management Credit (NMCredit) and the Nitrogen Credit Exchange Program. Programs such as the Precision Feed Management (PFM) Program offer services from trained professionals that help farmers reduce their nutrient loads. There are a number of federal programs, such as the Section 319 Nonpoint Source Competitive Grant Program from the Clean Water Act that is used either to fund some of the programs listed below or offer other opportunities to interested parties. Other federal programs include but are not limited to: the Environmental Quality Incentive Program (EQIP), the Conservation Reserve Program (CRP), and Regional Conservation Partnership Program (RCPP), the National Water Quality Initiative (NWQI), and the Clean Water State Revolving Fund (CWSRF).

It appears New Hampshire has one pollution reduction incentive program for individuals and businesses aimed at reducing water pollution, the Agricultural Nutrient Grant Program, which provides financial assistance for implementing measures to mitigate water pollution to agricultural and livestock operations (New Hampshire Department of Agriculture, Markets & Food, 2017).

Vermont has a wide-ranging number of incentive programs (State of Vermont Agency of Agriculture, Food and Markets, n.d.). Programs like the Watersheds United Vermont's Woody Buffer Grant, provide payments for the planting and management of vegetative buffers between agricultural lands and waterways to prevent bank erosion and nutrient and sediment pollution (Watersheds United Vermont, n.d.). Vermont's River Corridor Easement Program provides funds for the purchase of river channel management rights, in which landowners are paid not to interfere with flow of rivers and to establish a vegetative buffer (State of Vermont, 2020).

Connecticut has incentive programs in the form of tax credits by providing tax exemptions for the purchases of certain water pollution control equipment, and the development and implementation of pollution reduction technologies (State of Connecticut Department of Revenue Services, 2014).

In New York, it appears there are two incentive programs. The Agricultural Non-Point Source Abatement and Control provides cost sharing for the implementation of Best Management Practices through soil and water conservation districts that may form partnerships with farms (New York Department of Agriculture and Markets, n.d.). The Water Quality Improvements Program (WQIP) provides grant funding for a wide range of projects that improve water quality and reduce harmful algal blooms (New York Department of Environmental Conservation, n.d.).

4.6 Summary of Potential Supply

The information presented in this section indicates several issues that may affect the supply of nutrient credits in the LIS watershed:

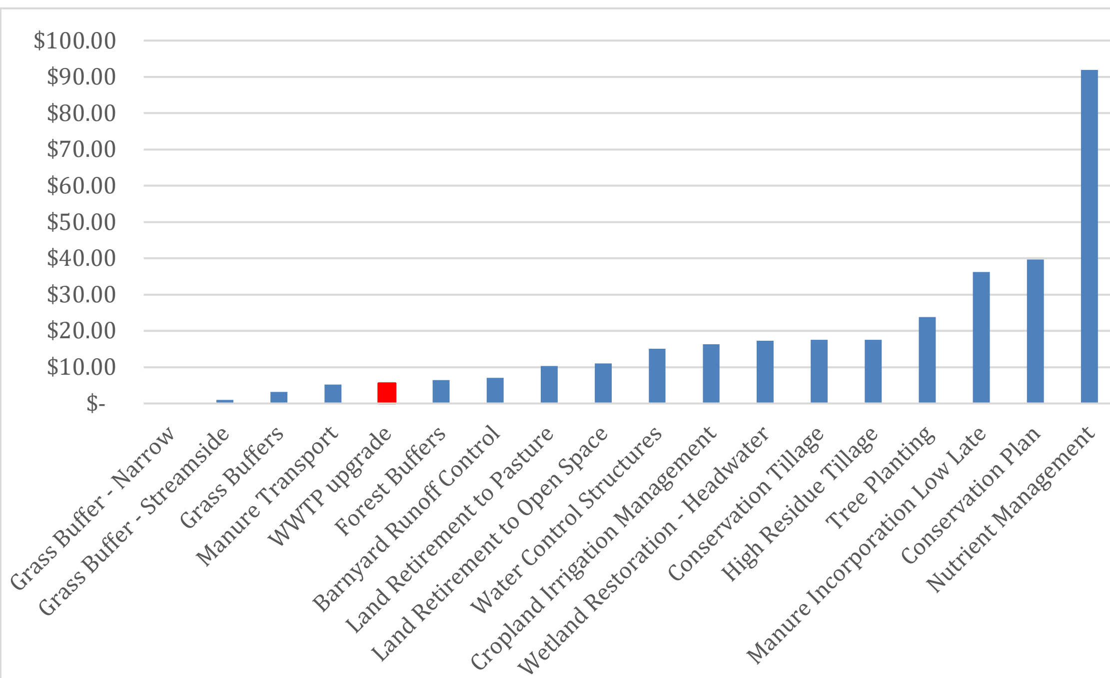
- **Number and acres of farmland in cultivation.** Data indicate that both in the LISS area and in the LIS watershed overall, the number and acres of farms have been declining, and there is no reason to think that that trend will reverse itself.
- **Shellfish and seaweed cultivation**. There is a potential for owners and operators and shellfish and seaweed operations to provide nutrient reduction credits. However, the price of a credit must be high enough (and transactions costs low enough) for owners/operators to participate in the market.
- **Cost of installing and maintaining BMPs**. In order for agricultural operators to have a strong enough incentive to participate in the market, the price of a permit must be high enough to cover the annualized costs of BMP installation and maintenance (including any opportunity cost of foregone production), as well as any transactions costs.
- **Baseline determination**. The potential supply of permits will be limited by the determination of the baseline – which may, in turn, influence the ecological viability of any trading program.
- **Other pollution reduction programs**. The number and extent of other government sponsored pollution reduction programs may have the unintended consequence of limiting participation in a nutrient credit market, as agricultural producers may be prevented from receiving payment for a service paid for or partially reimbursed by another program.

Part III: Putting Supply and Demand Together

5 Marginal Abatement Cost Curves for Nitrogen and Phosphorus

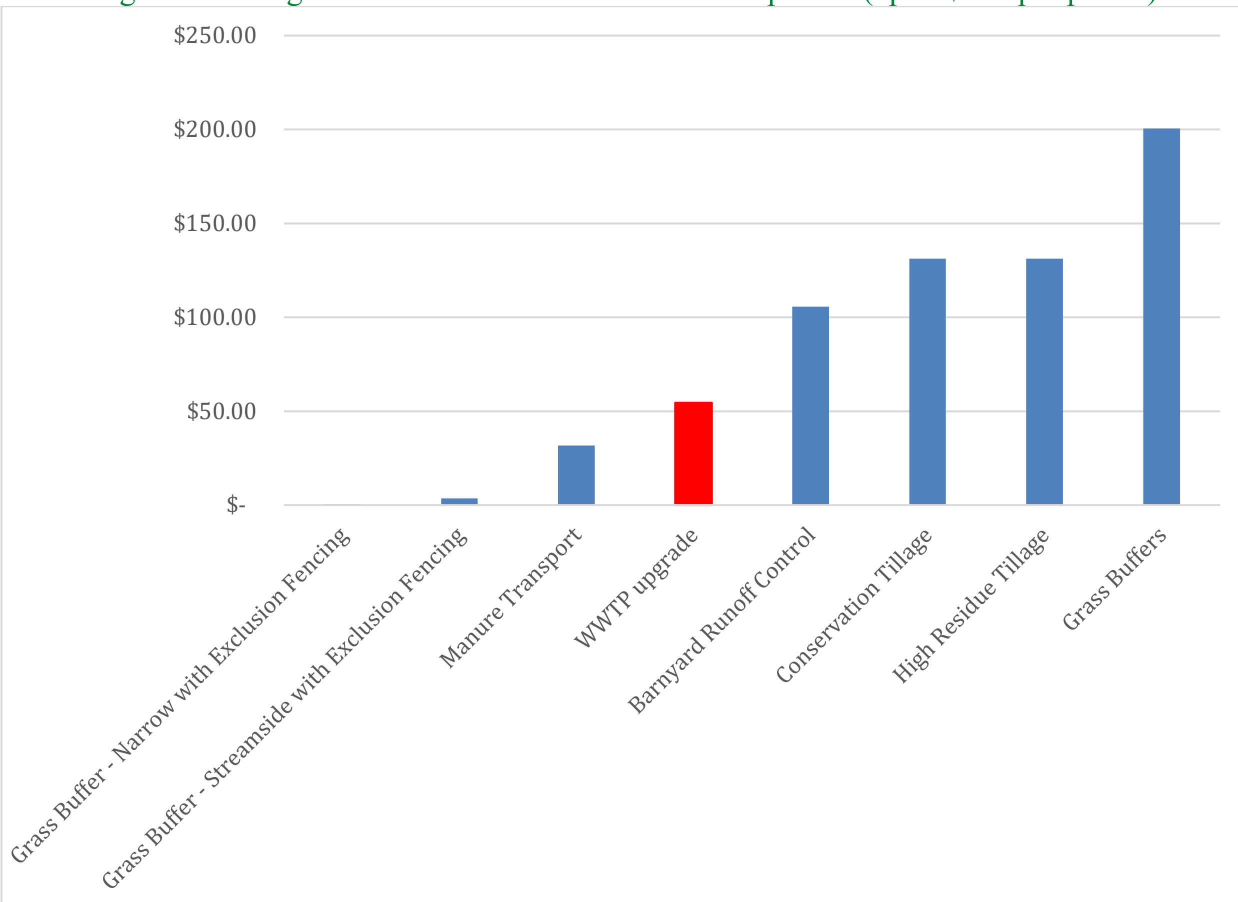
By graphing the costs per pound of nitrogen and phosphorus control from Appendix D, we are able to develop a rudimentary marginal abatement cost curve for nitrogen and phosphorus. Each bar represents a specific BMP. We only include the BMPs for which the control costs are below $100 per pound for nitrogen and below $250 per pound for phosphorus for easier visuals. The complete list of BMPS and their associated costs are found in Appendix D. Note that the costs for removal of both nutrients can rise quite high. For comparison purposes, we also include the cost per pound of upgrading treatment control technology at wastewater treatment plants, in red.

Figure 22: Marginal Abatement Cost Curve for Nitrogen (up to $100 per pound)



Source: Price, Holladay, and Waigner, 2019; and authors' calculations. All figures in 2021 dollars.

Figure 23: Marginal Abatement Cost Curve for Phosphorus (up to $250 per pound)



Source: Price, Holladay, and Waigner, 2019; and authors' calculations. All figures in 2021 dollars.

Both figures 22 and 23 clearly show that although some BMPs are less expensive per pound of pollutant reduced than a WWTP upgrade, the majority are not. Even ignoring any "uncertainty premium", WWTP upgrades likely would be financially more prudent for the owners of WWTPs (which are generally municipalities) than engaging in trading. Furthermore, the price of a credit would have to rise substantially in order for many farmers to be incentivized to implement BMPs on their property – which would then make it less likely for point sources to purchase credits.

If we then superimpose the price per credit onto the charts, the situation becomes even more stark for trading. For example, the value of an equalized nitrogen credit in CT was $10.95 for sellers in 2018.[14] In 2021 dollars, that is equivalent to $11.64. A price of $11.64 per credit may be enough to induce some farmers to implement BMPs, assuming that those BMPs are above baseline. However, if WWTP operators can update their facility at a relatively low cost, they are not likely to demand credits on the market.

In a market system, there are only two ways for the price to rise: an increase in demand or a decrease in supply. Decreasing supply is not an option. Increasing demand for credits can only be done by increasing regulatory pressure on the regulated community, expanding the existing regulatory community, or by increasing the cost of WWTP upgrades (essentially decreasing the opportunity cost of purchasing a credit on the market).

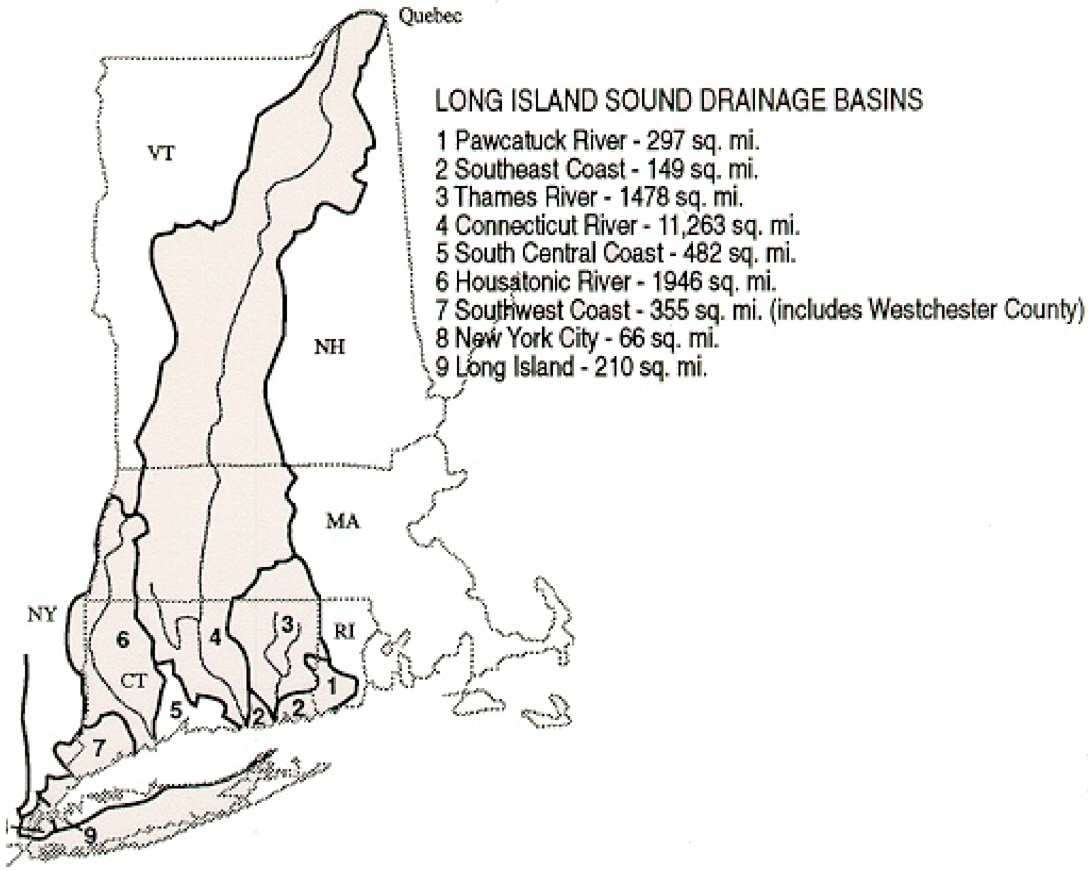
Moreover, this is assuming that trading is possible for the entire watershed, including interstate trading. This possibility is discussed in the next section.

6. A Note on Interstate Trading

There are nine major drainage basins within the LIS watershed (see figure 24). The Thames River watershed and the Housatonic River spans Connecticut and a portion of Massachusetts; the Southwest Coast includes parts of Connecticut and New York; and the Connecticut River watershed basin spans all six states in the LIS watershed. If a trading system were to expand to include the areas outside the LISS area (in other words, to include Massachusetts, Rhode Island, Vermont, and New Hampshire), any inconsistencies or ambiguities between the states' programs would need to be resolved.

[14] We use the 2018 price for illustrative purposes only. Credit prices vary widely, depending on a variety of factors. The price of an equalized nitrogen credit in CT at the time of this writing (2021) was only $1.36 for sellers. Cold and wet weather in 2018 impacted the ability of plants to remove nitrogen.

Figure 24: Major Drainage Basins within the LIS Watershed



Source: Long Island Sound Study

In 2017, US EPA Region 3 (Region 3) issued a discussion paper on the multiple considerations involved in exploring or establishing a program for the use of trading across state boundaries in the Chesapeake Bay watershed. Among their findings are the following conclusions, which may be relevant for the LIS watershed:

- **Varying definitions of credits and offsets**. Region 3 found that the definitions of credits and offsets differed between the states in the Chesapeake Bay region. They state that "public uncertainty over basic definitions, no matter how seemingly subtle the uncertainty may be, could... act as a deterrent to interstate trades." One possible advantage of establishing a multi-state trading system in the LIS watershed is that the definition of credits and/or offsets could be made consistent from the program's inception, rather than attempting to make those definitions consistent after the fact.
- **Intra-basin versus inter-basin trading**. Region 3 points out that interstate trading could potentially take place intra-basin (for example, within the Potomac basin between West Virginia and Virginia), and inter-basin (for example, between the Susquehanna River basin in Pennsylvania and the Potomac basin in Maryland). They find that "inter-basin

trading may be possible in the Chesapeake Bay watershed for basins where there is room for load exchanges between basins - as long as there is a demonstration that the water quality standards would still be met. Applicability would be influenced by the locations of buyers and sellers as they effect [sic] attenuation, the need to account for the fact each basin impacts Bay water quality differently, local water quality impacts, retirement ratios and so forth" (CB discussion paper, 3).

- **Multilateral versus unilateral approaches** One of the key considerations in expanding the existing trading program is how the different states will coordinate their programs. The Chesapeake Bay discussion paper distinguishes between two different approaches: a unilateral approach and a multilateral approach. The unilateral approach is the simplest, whereby one state agrees to accept credits from another state, without any reciprocal agreement. A multilateral (or bilateral, if there are only two parties) involves more formal coordination between the jurisdictions, usually involving more explicit legal agreements regarding the types of trades allowed. While multilateral agreements may provide for more certainty and stability, they are more cumbersome to administer, and may require more scrutiny to ensure that they do not violate ecological integrity. The document then describes various scenarios where States' individual programs could be harmonized with each other, thus facilitating interstate trading and minimizing transactions costs.

The Region 3 discussion paper outlined some potential advantages and disadvantages to interstate trading:

Potential advantages of interstate trade:

- To balance supply and demand
- To increase the competitiveness of the market
- To increase economic efficiency (increase cost savings)
- Reduce overall administration costs (in the case of a harmonized inter-state system)

Potential disadvantages of interstate trade:

- Increased staff time for coordination among state agencies
- Local water quality concerns, including equity concerns (see the section on "hot spots" in the companion document *Water Quality Trading in the Long Island Sound Study Area: A Preliminary Look at Some Economic Issues*)
- Reluctance to spending local ratepayer funds on credits generated in a different jurisdiction

It is worth noting that, as of the date of this writing, no interstate trades have taken place in the Chesapeake Bay watershed, despite such preparation. One such trade almost took place, but fell through as the buyer determined that it did not need the extra credits after all. However, the groundwork that was put in place remains in the event that an interstate trade may arise in the future.

Part IV: "Wedges" between Supply and Demand

This report has outlined potential demand and supply factors within the LIS watershed. However, as shown in Figure 1, even if a market has strong potential demand and supply, a robust market may not emerge if there are enough obstacles between buyers and sellers. Those obstacles may include geographical considerations, institutional considerations, administrative costs, and other issues. This section briefly describes those barriers, although a full treatment of these issues is beyond the scope of this report. Fuller discussion of these factors can be found in the companion report *Water Quality Trading in the Long Island Sound Study Area: A Preliminary Look at Some Economic Issues*.

- **Geographical considerations**. While expanding the size of the trading area may be beneficial for the sake of a "thick" market, it may come at the expense of local water quality. A white paper issued by the EPA in 2020 advised trading program managers to consider water quality goals, connectivity and pollutant processing when evaluating the appropriate scale for a trading area.
- **Institutional considerations**. Institutional considerations include trust, risk aversion, perceptions of fairness and equity, and cultural factors.
- **Administrative costs**. These costs include costs incurred during credit creation, implementation, monitoring, and enforcement costs. Likewise, there may be an "adoption premium" for suppliers of credits – the price they would have to be paid above and beyond the credit price in order to participate in the market. See the companion documents *Water Quality Trading in the Long Island Sound Study Area: A Preliminary Look at Some Economic Issues* and *Water Quality Trading Literature Review: Report for Long Island Sound Trading Project.*
- **Other issues**. Other issues may form "wedges" in between supply and demand, such as trading ratios, attenuation, and additionality. See the documents listed in the bullet above.

Part V: Conclusions and Recommendations

LISS and its partners, including WWTPs, have made significant progress in reducing nitrogen discharges to the Sound. Nitrogen credit trading has been a significant contributing tool in achieving these reductions. However, work remains to be done in order to continue to improve the ecological health of LIS as currently expressed through water quality goals.

Based upon the economic analysis presented here, expanding WQ trading beyond the existing point to point exchange in Connecticut will be of limited utility in achieving WQ goals in an efficient and cost-effective manner without the creation or identification of drivers to generate demand. In our opinion, the effort and cost necessary to expand trading in the LIS watershed would be more appropriately channeled into reducing pollutants at the source, rather than at the "end of pipe."

Our analysis suggests that the existing barriers to expanded use of trading include:

- Limited demand
- Uncertain supply
- Geographical boundaries (both political and hydrologic)
- Administrative and other costs
- Institutional factors.

Of these challenges, limited demand is the most crucial, as is the case in many other putative trading programs. Under the current TMDL scheme, there is simply very little regulatory pressure for nutrient sources to reduce their discharges. Without that demand driver, any market is likely to collapse. Expanding supply (both through agriculture and aquaculture operations) will simply exacerbate the problem from a market perspective.

However, under certain circumstances, LISS and its partners may find the expansion of WQT helpful as one possible tool in achieving specific water quality/ecological goals. Should that be the case, we make the following recommendations:

- Rethink the current TMDL as a regulatory driver, both in quantity (current pollution limits may not be stringent enough to stimulate demand) and in scope (including other nutrients such as phosphorous, as well as other sources of pollution, such as stormwater runoff). After considering both regulatory and non-regulatory drivers of demand, a regulatory driver such as a refined TMDL would be most likely to increase the demand for nutrient reduction credits. However, others will need to determine if such a regulatory update is appropriate.

- Continue existing efforts to develop a nitrogen tracking tool, and consider expanding those efforts to include phosphorus as well, to identify sources of potential demand under appropriate regulatory schemes.

- Create a common framework for trading across state boundaries.

- Consider ways in which existing and potential MS4 communities could participate in a trading program.

- Streamline existing pollution reduction programs to allow agricultural producers to take advantage of multiple opportunities.

- Consider a targeted funding source, such as the "Flush Tax" in Maryland, that would incentivize agricultural and shellfish/seaweed producers to provide nutrient reduction credits in the absence of a robust demand.

- Consider innovative ways in which sources of atmospheric nitrogen could be integrated into a pollution reduction program, potentially including air quality trading linked to existing climate pollutant markets.

The experience of other programs and much scientific and economic research has shown that a successful WQT program needs specific conditions in order to achieve water quality goals: robust demand, strong supply, a clearly delineated commodity, and a supportive institutional framework. It is our conclusion that, while expanding the current WQT program seems to offer an intriguing alternative or supplement to "command and control" regulations, the geographic, political, institutional, and regulatory context of the LIS watershed does not support such an expansion.

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Part VI: Appendices

Appendix A: List of Companion Documents

- Mascia, Raphaella. August, 2020. *Water Quality Trading Literature Review: Report for Long Island Sound Trading Project.*
- rbouvier consulting. December, 2020. *Water Quality Trading in the Long Island Sound Study Area: A Preliminary Look at Some Economic Issues.*
- rbouvier consulting. April, 2021. *Summary of Interviews with Selected Trading Programs and Individuals*.
- Stacey, Paul. October, 2021. *An Alternative, Ecosystem-Based Analytical Platform to Test and Facilitate Water Quality Trading.*

Appendix B: Watershed Information

Table B 1: Reported Phosphorus Facility Discharges by HUC 12 Level Watersheds in the LIS Watershed

Watershed	State	Total Wasteload Allocation (kg/year)	Total Reported Facility Discharges (2018)	Total Reported Facility Discharges (2019)
Batchelor Brook-Connecticut River	MA	398	62.14	111.58
Beaver Brook-Millers River	**MA**	**4**	**519.37**	**604.64**
Black River	VT	1,158	0	0
Branford River	CT	56	0	0
Cady Brook-Quinebaug River	**MA**	**0**	**443.41**	**332.05**
Doolittle Brook-Mill River	**MA**	**0**	**11,972.57**	**12,095.95**
Little River	MA	172	0	0
Lower West Branch Westfield River	MA	206	0	0
Middle French River	**MA**	**160.3**	**807.39**	**995.18**
Mill Brook	MA	0	0	0
Mill Brook-Millers River	**MA**	**29**	**1,267.79**	**632.31**
Mill River	MA	0	0	0

Watershed	State	Total Wasteload Allocation (kg/year)	Total Reported Facility Discharges (2018)	Total Reported Facility Discharges (2019)
Otter River	**MA**	**255**	**644.10**	**586.95**
Outlet Chicopee River	MA	0	0	0
Piper Brook-Park River	CT	94	35.42	23.6
Sawmill River	MA	0	0	0
Sevenmile River	**MA**	**0**	**131.54**	**72.57**
Torbell Brook-Millers River	NH	339.6	70.31	77.11
Upper French River	MA	1,067	98.43	113.40
Upper Quaboag River	MA	397	0	0
Wells River	VT	0	0	0
Whitney Pond-Millers River	MA	108	0	0
Total		**4,444**	**16,052.47**	**15,645.34**

Source: Various TMDLs, EPA (2020).

Tables B2 through B7 show the total allocated load and the total wasteload allocation for each waterbody covered by a TMDL in the LIS watershed.

Table B 2: Waterbodies by HUC12 Level Watershed for TMDLs for Phosphorus in Connecticut

Water Body	HUC12 Level Watershed	Total Allocated Load (kg/yr)	Total WLA (kg/yr)
Cedar Pond	Branford River	49	30
Linsley Pond	Branford River	54	26
Batterson Park Pond	Piper Brook-Park River	222	94
Total		**325**	150

Table B 3: Waterbodies by HUC12 Level Watershed for TMDLs for Nitrogen in Connecticut (excluding TMDLs for the Long Island Sound Study Area)

Connecticut (Nitrogen)			
Water Body	**HUC12 Level Watershed**	**Total Allocated Load (kg/yr)**	Total WLA (kg/yr)
Batterson Park Pond	Piper Brook-Park River	4,943	1,885
Total		**4,943**	1,885

Table B 4: Waterbodies by HUC12 Level Watershed for TMDLs for Phosphorus in Massachusetts

Water Body	HUC12 Level Watershed	Total Allocated Load (kg/yr)	Total WLA (kg/yr)
Quaboag Pond	Upper Quaboag River	2,588	375
Quacumquasit Pond	Upper Quaboag River	146	22
Millers Basin Lakes			
Reservoir No. 1	Beaver Brook-Millers River	50	4
Ward Pond	Beaver Brook-Millers River	19	0
Riceville Pond	Mill Brook-Millers River	204	8
South Athol Pond	Mill Brook-Millers River	330	21
Bents Pond	Otter River	227	49
Bourn-Hadley Pond	Otter River	81	22
Brazell Pond	Otter River	41	13
Cowee Pond	Otter River	39	0
Davenport Pond	Otter River	59	0
Greenwood Pond 1	Otter River	25	13
Greenwood Pond 2	Otter River	58	8
Hilchey Pond	Otter River	122	21
Minott Pond South	Otter River	32	0
Minott Pond	Otter River	40	0
Ramsdall Pond	Otter River	269	57
Stoddard Pond	Otter River	127	20
Wrights Reservoir	Otter River	157	52
Lake Denison	Torbell Brook-Millers River	157	42
Lake Monomonac	Torbell Brook-Millers River	887	143
Whites Mill Pond	Torbell Brook-Millers River	589	58
Lower Naukeag	Whitney Pond-Millers River	507	108
Wallace Pond	Whitney Pond-Millers River	129	0
Selected French Basin Lakes			
Dresser Hill Pond	Cady Brook-Quinebaug River	14	0

Buffumville Lake	Little River	862	90
Granite Reservoir	Little River	369	52
Jones Pond	Little River	64	5
Pikes Pond	Little River	217	18
Shepherd Pond	Little River	70	7
Hudson Pond	Middle French River	24	10
Larner Pond	Middle French River	108	27
Lowes Pond	Middle French River	212	51
McKinstry Pond	Middle French River	15	10
Peter Pond	Middle French River	27	14.3
Pierpoint Meadow Pond	Middle French River	93	31
Robinson Pond	Middle French River	56	17
Cedar Meadow Pond	Upper French River	193	68
Dutton Pond	Upper French River	248	129
Greenville Pond	Upper French River	737	235
Rochdale Pond	Upper French River	993	282
Texas Pond	Upper French River	1,050	353
Selected Connecticut Basin Lakes			
Aldrich Lake East	Batchelor Brook	1,342	202
Aldrich Lake West	Batchelor Brook	1,393	196
Lake Warner	Doolittle Brook-Mill River	1,790	0
Loon Pond	Mill River	41	0
Lake Wyola	Sawmill River	282	0
Selected Chicopee Basin Lakes			
Wickaboag Pond	Mill Brook	729	0
Minechoag Pond	Outlet Chicopee River	53	0
Mona Lake	Outlet Chicopee River	19	0
Browning Pond	Sevenmile River	200	0
Sugden Reservoir	Sevenmile River	230	0
Indian Lake	Lower West Branch Westfield River	298	206
Total		**18,612**	**3,039**

Table B 5: Waterbodies by HUC12 Level Watershed for TMDLs for Phosphorus in Massachusetts

New Hampshire (Phosphorus)			
Water Body	**HUC12 Level Watershed**	**Total Allocated Load (kg/yr)**	96.6
Pearly Lake	Torbell Brook-Millers River	132	
Total		**132**	96.6

Table B 6: Waterbodies by HUC12 Level Watershed for TMDLs for Phosphorus in Vermont

Vermont (Phosphorus)			
Water Body	**HUC12 Level Watershed**	**Total Allocated Load (kg/yr)**	
Ticklenaked Pond	Wells River	104	0
Black River	Black River	1,291	132
Total		**1,395**	132

Table B 7: Waterbodies by HUC 12 Level Watershed for TMDLs for Stormwater in Connecticut

Connecticut (Stormwater)		
Waterbody	**HUC 12 Level Watershed**	**Total Allocated Load (kg/yr)**
Eagleville Brook	Nelson Brook-Willimantic River	12% IC

Table B 8: Load Allocation and Wasteload Allocation for the LISS Area

Long Island Sound Study Area	
Total Load Allocation (kg/yr)	**Total Wasteload Allocation (WLA)**
21,741,589	14,113,073

Table B 9: HUC 8 Level Watersheds within the LISS Area TMDL for Nitrogen

Long Island Sound Study Area
Saugatuck Subbasin/Southwest Coast
Quinnipiac Subbasin/South Central Coast
Housatonic Subbasin
Farmington Subbasin
Lower Connecticut Subbasin
Shetucket Subbasin
Thames Subbasin/Southeast Coast
Quinebaug Subbasin
Bronx Subbasin
Northern Long Island Subbasin

Appendix C: Existing Shellfish and Seaweed Permits

Table C 1: Existing Shellfish Operations in Connecticut and New York

Shellfish Operations		
Project Name	Permit Type	Date Issued
Connecticut		
Stonington Aqua Farms/Shellfish Aquaculture-cages	Standard Permit	11/07/2019
William MacKay Shellfish Aquaculture	Letter of Permission	02/03/2017
City of Bridgeport/Bloom Shellfish	Standard Permit	03/24/2010
Old Harbor Marina 14-3	Letter of Permission	10/21/2016
The Strand/BRC Group, Inc. - Stellarma Oyster	Standard Permit	10/24/2013
Charles Island Oyster Farm/Milford Lease 12M	Standard Permit	10/11/2013
Briarpatch Enterprises Aquaculture/Nancy Follini L-390	Letter of Permission	10/20/2016
The Strand/BRC Group, Inc. - Stellarma Oyster	Standard Permit	07/13/2018
New York		
Hassel, Alfred Aquaculture	Letter of Permission	07/08/2009
New York Harbor Foundation, Inc. - Soundview Oyster Habitat Restoration Project	Standard Permit	06/25/2020
Winter, Douglas	Letter of Permission	03/22/2011
Harbor Lights Oyster Company LLC	Letter of Permission	03/16/2011
Peconic Bay Oyster Company, LLC	Letter of Permission	03/16/2011
North Sea Shellfish Farm c/o Kevin Greene	Letter of Permission	10/01/2009
Cornell Cooperative Extension - Cedar Beach County Park Shellfish Hatchery Seawater Intake System	Letter of Permission	12/03/2018

Table C 2: Existing Seaweed Operations in Connecticut and New York

Seaweed Operations		
Project Name	Permit Type	Date Issued
Connecticut		
New England Sea Farms, LLC Kelp Aquaculture at Lease SW# 21	Standard Permit	01/16/2020
Cos Cob Kelp and Shell/Steve Timchak Seaweed Aquaculture L-678	Standard Permit	11/21/2019
Jean Paul Vellotti dba East Coast Kelp	Standard Permit	11/20/2017
Pryor Kelp Farm (William Pryor)	Standard Permit	02/05/2019
LionMind Ventures, LLC - Seaweed Aquaculture	Standard Permit	11/19/2018
JP (Jean Paul) Vellotti dba East Coast Kelp	Standard Permit	02/15/2018

Appendix D: BMPS and Costs from the MACS Program

D 1: BMPs Included in the MACS Program

Name	Description*
Barnyard Runoff Control	Includes the installation of practices to control runoff from barnyard areas.
Forest Buffers	Forest buffers are linear wooded areas that help filter nutrients, sediments and other pollutants from runoff as well as remove nutrients from groundwater.
Grass Buffers	Grass buffers are linear strips of grass or other non-woody vegetation maintained to help filter nutrients, sediment and other pollutants from runoff.
Grass Buffer - Narrow with Exclusion Fencing	Converts streamside pasture to open space and prevents livestock from entering the stream.
Grass Buffer - Streamside with Exclusion Fencing	Converts streamside pasture to open space and prevents livestock from entering the stream.
Land Retirement to Open Space	Agricultural land retirement takes marginal and highly erosive cropland out of production by planting permanent vegetative cover such as shrubs, grasses, and/or trees.
Loafing Lot Management	The stabilization of areas frequently and intensively used by people, animals or vehicles by establishing vegetative cover, surfacing with suitable materials, and/or installing needed structures.
Off Stream Watering Without Fencing - Troughs	This BMP requires the use of alternative drinking water sources such as permanent or portable livestock water troughs placed away from the stream corridor.
Wetland Restoration - Headwater	Establish or create wetlands in a headwater area by manipulation of the physical, chemical, or biological characteristics to develop a wetland where one did not previously exist.
Water Control Structures	Installing and managing boarded gate systems in agricultural land that contains surface drainage ditches.
Animal Waste Management System - Livestock	Any structure designed for collection, transfer and storage of manures and associated wastes generated from the confined portion of animal operations.
Manure Transport	Manure is composted using various methods.
Conservation Plan	Farm conservation plans are a combination of agronomic, management and engineered practices that protect and improve soil productivity and water quality, and to prevent deterioration of natural resources on all or part of a farm.
Conservation Tillage	Management eliminates soil disturbance by plows and implements intended to invert residue.
High Residue Tillage	A minimum of 60% crop residue cover must remain on the soil surface as measured after planting.
Cropland Irrigation Management	Cropland under irrigation management is used to decrease climatic variability and maximize crop yields.
Pasture Management	Defined as maintaining a 50% pasture cover with managed species (desirable, inherent) and managing high traffic areas.
Manure Incorporation Low Late	Manure is incorporated into the soil between 1 and 3 days of application with less than 40% soil disturbance.
Land Retirement to Pasture	Converts land area to pasture.
Nutrient Management	Various practices for reducing nitrogen. May include injection of inorganic N, incorporation, setbacks, split applications, variable rate N application, or reduced rate, among others.
Non Urban Stream Restoration	Stream restoration is a change to the stream corridor that improves the

Name	Description*
	stream ecosystem by restoring the natural hydrology and landscape of a stream, and helps improve habitat and water quality conditions in degraded streams.
Precision Intensive Rotational/Prescribed Grazing	This practice utilizes a range of pasture management and grazing techniques to improve the quality and quantity of the forages grown on pastures and reduce the impact of animal travel lanes, animal concentration areas or other degraded areas.
Tree Planting	Tree planting includes any tree planting, except those used to establish riparian forest buffers, targeting lands that are highly erodible or identified as critical resource areas.
Stormwater BMPs	
Wet Ponds and Wetlands	A water impoundment structure that intercepts stormwater runoff then releases it to an open water system at a specified flow rate.
Urban Stream Restoration	Stream restoration is a change to the stream corridor that improves the stream ecosystem by restoring the natural hydrology and landscape of a stream, and helps improve habitat and water quality conditions in degraded streams.
Urban Forest Planting	Urban forest planting includes trees planted in a contiguous area to establish forest-like conditions, with minimal mowing as needed to aid tree and understory establishment.
Filtering Practices	Practices that capture and temporarily store runoff and pass it through a filter bed of either sand or an organic media.
Bioretention/raingardens - C/D soils, underdrain	An excavated pit backfilled with engineered media, topsoil, mulch, and vegetation. These are planting areas installed in shallow basins in which the storm water runoff is temporarily ponded and then treated by filtering through the bed components, and through biological and biochemical reactions within the soil matrix and around the root zones of the plants. This BMP has an underdrain and is in C or D soil.
Infiltration Practices w/ Sand, Veg. - A/B soils, no underdrain	A depression to form an infiltration basin where sediment is trapped and water infiltrates the soil. Design specifications require infiltration basins and trenches to be built in A or B soil types.
Bioretention/raingardens - A/B soils, underdrain	An excavated pit backfilled with engineered media, topsoil, mulch, and vegetation. These are planting areas installed in shallow basins in which the storm water runoff is temporarily ponded and then treated by filtering through the bed components, and through biological and biochemical reactions within the soil matrix and around the root zones of the plants. This BMP has an underdrain and is in A or B soil.
Storm Drain Cleaning	Removal of sediment and organic matter from catch basins in a targeted manner that focuses on water quality improvements.
Vegetated Open Channels - A/B soils, no underdrain	Open channels are practices that convey stormwater runoff and provide treatment as the water is conveyed.
Mechanical Broom Technology - 1 pass/2 weeks	Sweeper is equipped with water tanks, sprayers, brooms, and a vacuum system pump that gathers street debris.

*Definitions from Chesapeake Assessment Management Tool

Source: Price, Holladay, and Waigner, 2019.

D 2:Average Cost per Pound of Nitrogen Removal in MD (EofT), Ranked

Name	Type	Average Cost per pound (EoT)
Grass Buffer - Narrow with Exclusion Fencing	Ag	$ 0.13
Grass Buffer - Streamside with Exclusion Fencing	Ag	$ 0.96
Grass Buffers	Ag	$ 3.19
Manure Transport	Ag	$ 5.19
Forest Buffers	Ag	$ 6.42
Barnyard Runoff Control	Ag	$ 7.05
Land Retirement to Pasture	Ag	$ 10.30
Land Retirement to Open Space	Ag	$ 11.01
Water Control Structures	Ag	$ 15.08
Cropland Irrigation Management	Ag	$ 16.29
Wetland Restoration - Headwater	Ag	$ 17.32
Conservation Tillage	Ag	$ 17.54
High Residue Tillage	Ag	$ 17.54
Tree Planting	Ag	$ 23.84
Manure Incorporation Low Late	Ag	$ 36.20
Conservation Plan	Ag	$ 39.67
Nutrient Management	Ag	$ 91.88
Animal Waste Management System - Livestock	Ag	$ 143.20
Loafing Lot Management	Ag	$ 286.07
Precision Intensive Rotational/Prescribed Grazing	Ag	$ 323.97
Non Urban Stream Restoration	Ag	$ 336.48
Filtering Practices	SW	$ 418.37
Forest Planting	SW	$ 659.15
Infiltration Practices w/ Sand, Veg. - A/B soils, no underdrain	SW	$ 660.24
Bioretention/raingardens - A/B soils, underdrain	SW	$ 1,697.44
Urban Stream Restoration	SW	$ 1,698.53
Wet Ponds and Wetlands	SW	$ 2,010.13
Off Stream Watering Without Fencing - Troughs	Ag	$ 2,030.32
Vegetated Open Channels - A/B soils, no underdrain	SW	$ 4,454.97
Bioretention/raingardens - C/D soils, underdrain	SW	$ 6,783.23
Storm Drain Cleaning	SW	$ 13,563.19

D 3: Average Cost per Pound of Phosphorus Removal in MD (EofT), Ranked

Name	Type	Average Cost per pound (E of T)
Grass Buffer - Narrow with Exclusion Fencing	Ag	$ 0.51
Grass Buffer - Streamside with Exclusion Fencing	Ag	$ 3.60
Manure Transport	Ag	$ 31.69
Barnyard Runoff Control	Ag	$ 105.70
Conservation Tillage	Ag	$ 131.24
High Residue Tillage	Ag	$ 131.24
Grass Buffers	Ag	$ 200.48
Forest Buffers	Ag	$ 241.77
Non Urban Stream Restoration	Ag	$ 431.90
Wetland Restoration - Headwater	Ag	$ 526.04
Manure Incorporation Low Late	Ag	$ 533.10
Conservation Plan	Ag	$ 631.43
Tree Planting	Ag	$ 697.20
Pasture Management	Ag	$ 720.01
Land Retirement to Pasture	Ag	$ 855.07
Land Retirement to Open Space	Ag	$ 1,417.59
Precision Intensive Rotational/Prescribed Grazing	Ag	$ 1,525.74
Nutrient Management	Ag	$ 1,601.61
Animal Waste Management System - Livestock	Ag	$ 2,173.40
Urban Stream Restoration	SW	$ 2,180.09
Filtering Practices	SW	$ 3,279.40
Loafing Lot Management	Ag	$ 4,286.91
Forest Planting	SW	$ 5,235.05
Infiltration Practices w/ Sand, Veg. - A/B soils, no underdrain	SW	$ 7,768.14
Wet Ponds and Wetlands	SW	$ 10,501.69
Off Stream Watering Without Fencing - Troughs	Ag	$ 14,320.98
Bioretention/raingardens - A/B soils, underdrain	SW	$ 18,626.09
Bioretention/raingardens - C/D soils, underdrain	SW	$ 44,304.52
Vegetated Open Channels - A/B soils, no underdrain	SW	$ 52,375.53
Storm Drain Cleaning	SW	$ 70,462.32

Appendix E: Other Pollution Reduction Incentive Programs in the LIS Watershed

Table E 1: Pollutant Reduction Incentive Programs

Program	State	Public/Private	What Program Mitigates	Fund Distribution	Applicant Actions Needed
Agricultural Nutrient Grant Program	NH	Public	-Agricultural nutrient pollution from commercial fertilizers -Animal manures and agricultural composts.	Reimbursement up to $5,000 upon project completion	-Implementation of BMP -Provide project description, itemized budget, and objectives
Natural Resources Conservation Council (NRCC) Clean Water Design and Implementation Block Grant	VT	Public	Nutrient and Sediment pollution	Direct payment of 50% or more of total costs for projects $50,000 or less	-Project listed in DEC Watershed Projects Database-Preliminary design, final design, or implementation of pollution reducing tech
Watersheds United Vermont - Woody Buffer Block Grant	VT	Public	-Nutrient and sediment pollution -Bank erosion	Direct payment	-Plant woody riparian buffers on at least 8.8 acres plants -Must be landowner, municipality, and other partners

Program	State	Public/Private	What Program Mitigates	Fund Distribution	Applicant Actions Needed
Vermont Watershed Grants	VT	Public	Reduce phosphorus loading and/or sedimentation	Direct payment up to $10,000	Municipalities, local or regional governmental agencies, nonprofit organizations, and citizen groups are eligible to receive Watershed Grants for work on public or private lands, Individuals may be partners
Ecosystem Restoration Grants	VT	Public	Nutrient and sediment pollution	Direct payment	-Natural resource restoration projects -Minimum grant size $20,000
River Corridor Easement Program	VT	Public	Nutrient and sediment pollution	Purchasing of river channel management rights	Landowner in restricted from intervening with erosion and channel adjustments within corridor
Vermont Housing and Conservation Board (VHCB) Water Quality Grants	VT	Private	Agricultural pollution	Direct payment up to $40,000	Farmers can apply for water quality grants for on-farm capital improvements. Eligible projects include production area

Program	State	Public/Private	What Program Mitigates	Fund Distribution	Applicant Actions Needed
					improvements, manure management projects, farm equipment, and infrastructure for pasture management. Grants typically help farmers pay for project components that state or federal grant programs cannot cover.
Capital Equipment Assistance Program (CEAP)	VT	Public	-Surface runoff of agricultural waste -Phosphorous from manure	Cost shares up to 90%, cap varies depending on project	-Project questionnaire -Obtain quotes for cost of equipment -Letters of support
Farmstead Best Management Practices	VT	Public	-Surface runoff of agricultural waste	-Engineering services for design of BMP -Reimbursement up to $100,000 upon project completion	-BMP project meets designs standards of USDA or designed by certified engineer -project costs documented and itemized

Program	State	Public/Private	What Program Mitigates	Fund Distribution	Applicant Actions Needed
Farm Agronomic Practice (FAP) Program	VT	Public	-Agricultural waste -Erosion	-Grants up to $8,000 per farm operation -Direct payment per acre	Required Agricultural Practices
Vermont's Conservation Reserve Enhancement Program (CREP)	VT	Public	-Sediment runoff	-Direct one-time payments from $375 to $1,950 an acre -Rental and maintenance payments for 15-years, $80 to $298 per acre	-Plant woody riparian buffer -Owned or operated the land for 12 months prior to enrollment. -Land must be adjacent to a perennial stream or river that lack vegetative buffers and have agricultural related water quality impacts
Tax Exemptions for Certain Water Pollution Control Equipment	CT	Public	-Phosphorus, etc.	Exemption from municipal property taxes	Purchase tangible personal property certified by DEEP to be used by facilities for the treatment of industrial waste

Program	State	Public/Private	What Program Mitigates	Fund Distribution	Applicant Actions Needed
Purchases of Tangible Personal Property Incorporated Into or Consumed in Water Pollution Control Facilities	CT	Public	Industrial waste pollution	Exemption from sales and use tax	Purchases of tangible personal property to be used in treatment of industrial waste
Conservation Innovation Grants Connecticut State Program (CIG)	CT	Public	Nutrient pollution, specifically phosphorus	Reimbursement of up to 50% of project costs	Grantees must self-certify and maintain records showing that participating producers receiving payments using CIG funding meet the EQIP eligibility and AGI requirements, no duplicate payments

Program	State	Public/Private	What Program Mitigates	Fund Distribution	Applicant Actions Needed
Agricultural Non-point Source Abatement and Control	NY	Public	Agricultural pollution	Cost-share up to 75% of project costs	-Implementation of BMP -Soil and water conservation districts, can work with farms -Projects include conservation measures, such as nutrient management through manure storage, vegetative buffers along streams, and conservation cover crops.
Water Quality Improvement Project (WQIP) Program	NY	Public	-Potentially harmful algal blooms -$1 million specifically to reduce nitrogen loading in the Long Island Sound.	Reimbursement	-Municipality, Soil and Water Conservation District, or Nonprofit -Contract with DEC -Draft workplan and budget with DEC -Submit Quarterly reports Soil and Water

Program	State	Public/Private	What Program Mitigates	Fund Distribution	Applicant Actions Needed
Nutrient Management Credit (NMCredit)	NY	Public	Nutrient from manure	Credits that can be used for reimbursement of nutrient management related expenses, up to $10 per acre and $12 per animal unit	-Must have at least 25 animal units and manage at least 50 tons of manure -Keep records of manute movement
Precision Feed Management (PFM) Program	NY	Public	Phosphorus and nitrogen from manure	-Improved animal productivity and profitability	-Implemented formulated diets -Improve production of higher digestible homegrown feeds -Monitor animal performance and diet
Nitrogen Credit Exchange Program	Long Island Sound	Public	Nitrogen pollution from point sources	-$7.07 per credit received	-to receive credits, must discharge less than permitted amount of nitrogen pollution