WATERSHED ANALYSIS OF THE
MYSTIC RIVER AND NEPONSET RIVER WATERSHEDS

TASK 3A-B TECHNICAL MEMO
MYSTIC RIVER WATERSHED SPATIAL DATA AND MAPPING ANALYSES

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Prepared by:

Paradigm Environmental

Great Lakes Environmental Center

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1 INTRODUCTION

This technical memorandum describes the development of spatial datasets representing Hydrologic Response Units (HRUs) and broad Stormwater Control Measure (SCM) categories for the Mystic River Watershed, as well as the generation of flow and pollutant loading time series for the HRUs using long-term continuous simulation. First, available geospatial data are summarized and analyzed. The development process and outputs for HRU and SCM Siting layers are then described. HRUs are developed to be comparable to MassDEP Pollutant Loading Export Rates for MS4 permits and are used to analyze pollutant loading at several spatial scales (e.g., watershed, subwatershed, municipality). SCM categories are designed to allow planning-level siting and optimization of SCMs using the Opti-Tool and are based on numerous criteria (e.g., soil infiltration capacity, proximity to waterbodies, proximity to buildings, etc.). The HRU and SCM Siting layers, coupled with the flow and pollutant loading rates, are key building blocks that will be used in the property parcel analysis (Task 3C), environmental justice analysis (Task 3D), and the development of town-specific fact sheets (Task 3E).

2 HYDROLOGIC RESPONSE UNIT MAPPING ANALYSIS

This task includes collecting and reviewing the needed spatial data and conducting spatial analysis for developing the HRU footprints and SCM opportunity footprints within the Mystic River watershed. The resulting mapped areas will be summarized by the hydrologic boundaries (i.e., sub-watersheds) and jurisdictional boundaries (i.e., municipalities).

2.1 Data Inventory

Readily available data that could facilitate the development of HRU and SCM layers were collected, reviewed, and assessed. Data were obtained from online repositories as well as from employees at the United States Environmental Protection Agency (EPA). Table 2-1 provides an inventory of GIS data collection and indicates if that dataset is used as a primary layer in the HRU and SCM siting development or if it is used in post-processing for summary analysis.

Table 2-1. GIS data inventory

Name	Description	Source	Source Link	Source Date	HRU Analysis		Siting Analysis	
					Primary	Post-process	Primary	Post-process
LULC	Land use and land cover	MassGIS	https://www.mass.gov/info-details/massgis-data-2016-land-coverland-use	May, 2019	Yes		Yes	
Soils	Hydrologic soil group	MassGIS	https://www.mass.gov/info-details/massgis-data-soils-ssurgo-certified-nrcs	November, 2021	Yes		Yes	
Soils	Hydrologic soil group	USDA	https://websoilsurvey.sc.egov.usda.gov/DSD/Download/Cache/STATSGO2/wss_gsmsoil_MA_[2016-10-13].zip	October, 2016	Yes		Yes	
Structures	Building footprints	MassGIS	https://www.mass.gov/info-details/massgis-data-building-structures-2-d	September, 2022			Yes	
DEM (elevation)	For ground slope	MassGIS	https://www.mass.gov/info-details/massgis-data-digital-terrain-model-dtm-from-1990s-aerial-imagery	April, 2022			Yes	
Depth to water table	For siting analysis	MassGIS	https://www.mass.gov/info-details/massgis-data-soils-ssurgo-certified-nrcs	November, 2021			Yes	
Shallow bedrock	For siting analysis	MassGIS	https://www.mass.gov/info-details/massgis-data-usgs-124000-surficial-geology	July, 2022			Yes	
21E contaminated site locations	For siting analysis	MassGIS	https://www.mass.gov/info-details/massgis-data-massdep-tier-classified-oil-andor-hazardous-material-sites-mgl-c-21e	December, 2021			Yes	
AUL contaminated site locations	For siting analysis	MassGIS	https://www.mass.gov/info-details/massgis-data-massdep-oil-andor-hazardous-material-sites-with-activity-and-use-limitations-aul	December, 2021			Yes	
Waterbodies (streams, lakes, ponds)	For siting analysis	MassGIS	MassGIS 2016 LULC				Yes	
Wetlands	For siting analysis	MassGIS	MassGIS 2016 LULC				Yes	

Name	Description	Source	Source Link	Source Date	HRU Analysis		Siting Analysis	
					Primary	Post-process	Primary	Post-process
Parcel boundaries	For summary results	MassGIS	https://www.mass.gov/info-details/massgis-data-property-tax-parcels	February, 2023		Yes		Yes
Municipal boundaries	For summary results	MassGIS	https://www.mass.gov/info-details/massgis-data-municipalities	April, 2022		Yes		Yes
Environmental Justice Areas	For summary results	EPA	Provided by EPA Staff			Yes		Yes
Watershed Boundaries	For summary results	MassGIS	https://www.mass.gov/info-details/massgis-data-major-watersheds	June, 2000		Yes		Yes
Subwatershed boundaries	For summary results	MassGIS	https://www.mass.gov/info-details/massgis-data-drainage-sub-basins	December, 2007		Yes		Yes
Subwatershed boundaries (Mystic River Watershed)	For summary results	EPA	Provided by EPA Staff			Yes		Yes
MS4 boundaries	For summary results	EPA	Provided by EPA Staff			Yes		Yes
CSS Drainage (Mystic River Watershed)	For summary results	EPA	Provided by EPA Staff			Yes		Yes

2.2 HRU Development

A set of unique HRUs was developed based on the Mystic River Watershed's land use, land cover, and soil characteristics. Each HRU represents areas of similar physical characteristics attributable to core processes identified through GIS overlays. The HRUs represent the primary building blocks for developing the rainfall-runoff response timeseries and characterizing the unique landscape features in the watershed. The HRU development process used these primary data types that are typically closely associated with hydrology in the watershed:

- **Land Use – Land Cover (LULC):** *Land use describes the principal programmatic use and/or vegetation type. The programmatic, or zoning, element of this attribute is critical for water quality simulation. The land cover defines landscape as having either pervious or impervious cover.*
- **Hydrologic Soil Group (HSG):** *Represents one of four soil classes (i.e., A, B, C, and D) commonly associated with a spectrum of infiltration rates with HSG-A having the highest and HSG-D having the lowest.*

The HRU-based approach reflects the key physical features that influence runoff and pollutant loadings such as land use, soil, and impervious cover. It is based on the best available local datasets characterizing existing conditions. The LULC and HSG layers were converted to 1-meter rasters with the same extent and spatial alignment. Each raster was then reclassified to appropriate categories for the analysis in this watershed and is consistent with the categories used in the Opti-Tool (see Section 2.2.1 and Section 2.2.2). When overlaid, the unique combinations of these rasters determined the number of possible HRU categories.

2.2.1 *Land Use – Land Cover Reclassification*

Land use categories indicate activities taking place at the parcel scale (e.g., industrial use) and are important for characterizing the hydrologic and water quality responses from those areas (Huang et al., 2013; Tong and Chen, 2002; Tunsaker and Levine, 1995). Land cover designations supplement land use categories by providing additional texture to parcel descriptions, enabling their hydrologic and water quality response to be further characterized (Wilson, 2015). The MassGIS (Bureau of Geographic Information) 2016 land use – land cover layer contains both land use and land cover information as separate attributes that can be accessed independently or in a useful combination with one another. For example, measuring the portions of pervious and impervious surfaces for a commercial parcel is possible. The land cover information in this layer is consistent with Coastal Change Analysis Program (C-CAP)'s high-resolution land cover classification scheme. For more information on the data development process and data accuracy reporting, see the full detailed description (PDF) document. For HRU development, the MassGIS 2016 land use – land cover attributes were reclassified to 12 unique either pervious or impervious land segments as shown in Table 2-2; this corresponds to the reclassification cross-walk (Table 2) of the MassDEP MS4 permitting guidance (MassDEP, n.d.), which is adapted in Table 2-3. The spatial distribution of the reclassified LULC layer is shown in Figure 2-1.

Table 2-2. Reclassified LULC categories

LULC ID	Reclassified Model Group	Perviousness
1	Paved Agriculture	Impervious
2	Paved Commercial / Industrial	Impervious
3	Paved Forest	Impervious
4	Paved High Density Residential	Impervious
5	Paved Medium Density Residential	Impervious
6	Paved Open Land	Impervious
7	Paved Transportation	Impervious
8	Agriculture	Pervious
9	Developed Open Space	Pervious
10	Forest	Pervious
11	Open Space (Undeveloped)	Pervious
12	Water	N/A

Table 2-3. Land use – Land cover reclassification crosswalk (adapted from MassDEP, n.d.)

	Description		Land Cover																		
			Nodata	Impervious	Developed Open Space	Cultivated	Pasture/Hay	Grassland	Deciduous Forest	Evergreen Forest	Scrub/ Shrub	Palustrine Forested Wetland	Palustrine Scrub/Shrub Wetland	Palustrine Emergent Wetland	Estuarine Emergent Wetland	Unconsoli-dated Shore	Bare Land	Water	Palustrine Aquatic Bed	Estuarine Aquatic Bed
		ID	0	2	5	6	7	8	9	10	12	13	14	15	18	19	20	21	22	23
Land Use	Unknown	0	Dev. Open	Paved Open	Dev. Open	Ag.	Ag.	Open Space	Forest	Forest	Forest	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Water	Water	Water
	Open land	2	Dev. Open	Paved Open	Dev. Open	Ag.	Ag.	Open Space	Forest	Forest	Forest	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Water	Water	Water
	Commercial	3	Dev. Open	Paved Commercial	Dev. Open	Ag.	Ag.	Open Space	Forest	Forest	Forest	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Water	Water	Water
	Industrial	4	Dev. Open	Paved Commercial	Dev. Open	Ag.	Ag.	Open Space	Forest	Forest	Forest	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Water	Water	Water
	Forest	6	Dev. Open	Paved Forest	Forest	Forest	Ag.	Forest	Forest	Forest	Forest	Forest	Forest	Forest	Forest	Open Space	Open Space	Water	Water	Water
	Agriculture	7	Dev. Open	Paved Ag.	Ag.	Ag.	Ag.	Ag.	Forest	Forest	Forest	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Water	Water	Water
	Recreation	8	Dev. Open	Paved Open	Dev. Open	Ag.	Ag.	Open Space	Forest	Forest	Forest	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Water	Water	Water
	Tax exempt	9	Dev. Open	Paved Commercial	Dev. Open	Ag.	Ag.	Open Space	Forest	Forest	Forest	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Water	Water	Water
	Mixed use, primarily residential	10	Dev. Open	Paved High Density Residential	Dev. Open	Ag.	Ag.	Open Space	Forest	Forest	Forest	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Water	Water	Water
	Residential - single family	11	Dev. Open	Paved Medium Density Residential	Dev. Open	Ag.	Ag.	Open Space	Forest	Forest	Forest	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Water	Water	Water
	Residential - multi-family	12	Dev. Open	Paved High Density Residential	Dev. Open	Ag.	Ag.	Open Space	Forest	Forest	Forest	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Water	Water	Water
	Residential - other	13	Dev. Open	Paved Medium Density Residential	Dev. Open	Ag.	Ag.	Open Space	Forest	Forest	Forest	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Water	Water	Water
	Mixed use, other	20	Dev. Open	Paved Commercial	Dev. Open	Ag.	Ag.	Open Space	Forest	Forest	Forest	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Water	Water	Water
	Mixed use, primarily commercial	30	Dev. Open	Paved Commercial	Dev. Open	Ag.	Ag.	Open Space	Forest	Forest	Forest	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Water	Water	Water
	Right-of-way	55	Dev. Open	Paved Trans.	Dev. Open	Ag.	Ag.	Open Space	Forest	Forest	Forest	Open Space	Open Space	Open Space	Open Space	Open Space	Open Space	Water	Water	Water
	Water	88	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water

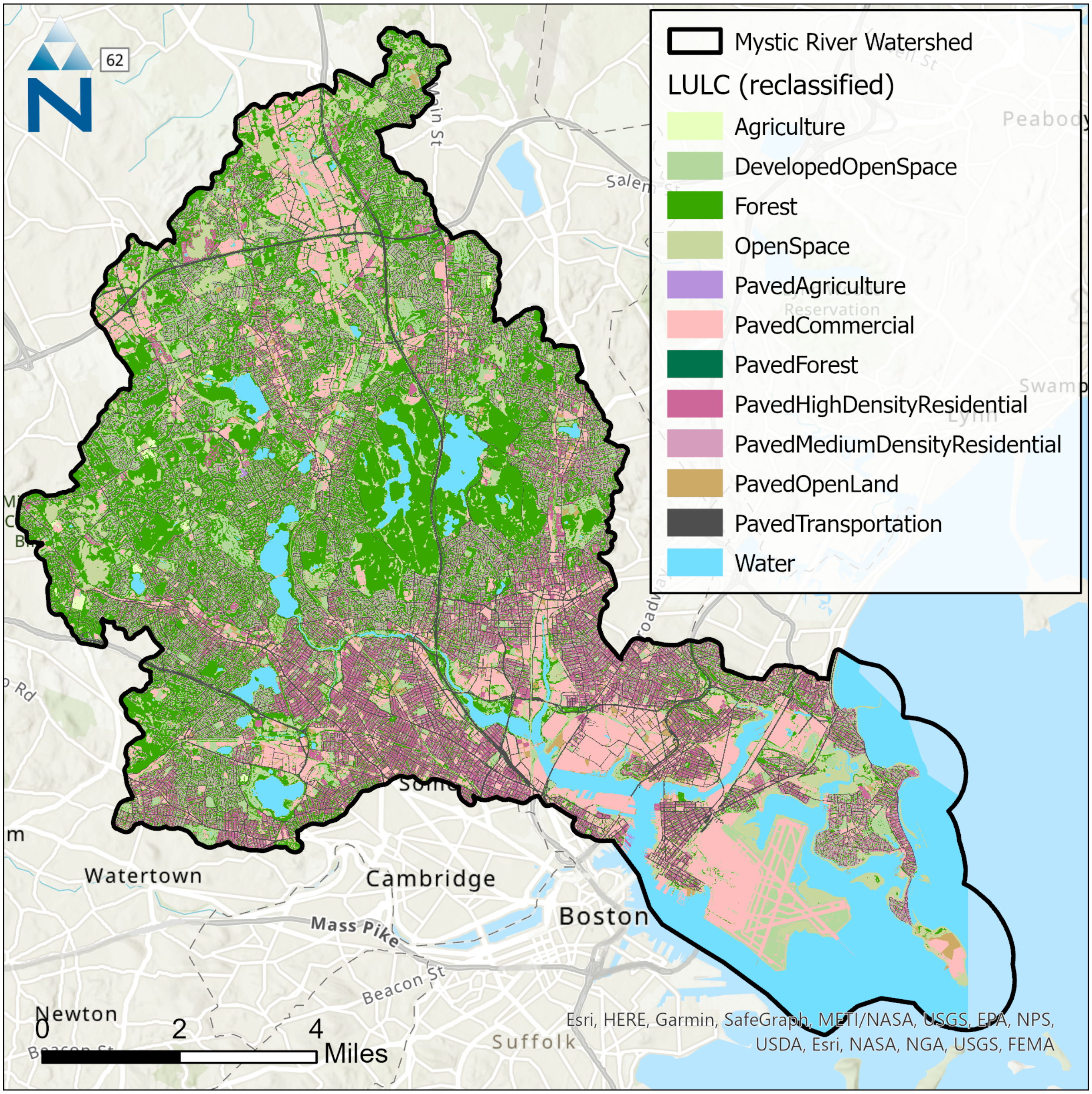

Figure 2-1. Reclassified land use -land cover categories for the Mystic River Watershed.

2.2.2 *Hydrologic Soil Group Reclassification*

HSGs characterize the propensity for precipitation to saturate and percolate through the subsurface or contribute to runoff. Soils with similar hydrologic and physical properties (e.g., texture, permeability) are grouped by HSGs (USDA, 2003). HSG-A generally has the highest infiltration and lowest runoff potential whereas HSG-D has the lowest infiltration and highest runoff potential. HSG classifications are used within the model as a basis for setting certain hydrologic parameters including infiltration rates.

HSG designations for the Mystic River Watershed were obtained from MassGIS and the State Soil Geographic (STATSGO2) Database (Soil Survey Staff, n.d.). The MassGIS soils dataset has been reviewed and approved by the Natural Resources Conservation Service (NRCS) as meeting the standards and requirements for inclusion in the national Soil Survey Geographic database (SSURGO). As shown in Table 2-4, some HSG designations were unspecified in the MassGIS dataset and were assigned a HSG from the STATSGO2 database. Dual HSGs were represented by their primary type, following MassDEP guidance (MassDEP, n.d.). When no HSG data was available, HSG C was assigned as a conservative choice given that most of the missing areas were highly urbanized (or corresponded with waterbodies where HSG is not relevant).

Table 2-4. Soil – HSG reclassification

HSG - SSURGO	HSG - STATSGO2	HSG Reclassification	Watershed Area (%)	Justification
A	N/A	A	35%	
A/D	N/A	A	1%	Dual HSGs were represented by their primary type (MassDEP, n.d.)
B	N/A	B	5%	-
B/D	N/A	B	5%	Dual HSGs were represented by their primary type (MassDEP, n.d.)
C	N/A	C	4%	-
C/D	N/A	C	2%	Dual HSGs were represented by their primary type (MassDEP, n.d.)
D	N/A	D	9%	-
No Data	A	A	4%	When SSURGO information was available, the STATSGO2 data layer was used to fill the gaps.
No Data	B	B	2%	
No Data	C	C	5%	
N/A	N/A	C	28%	When no data was available, HSG C was chosen as a conservative choice

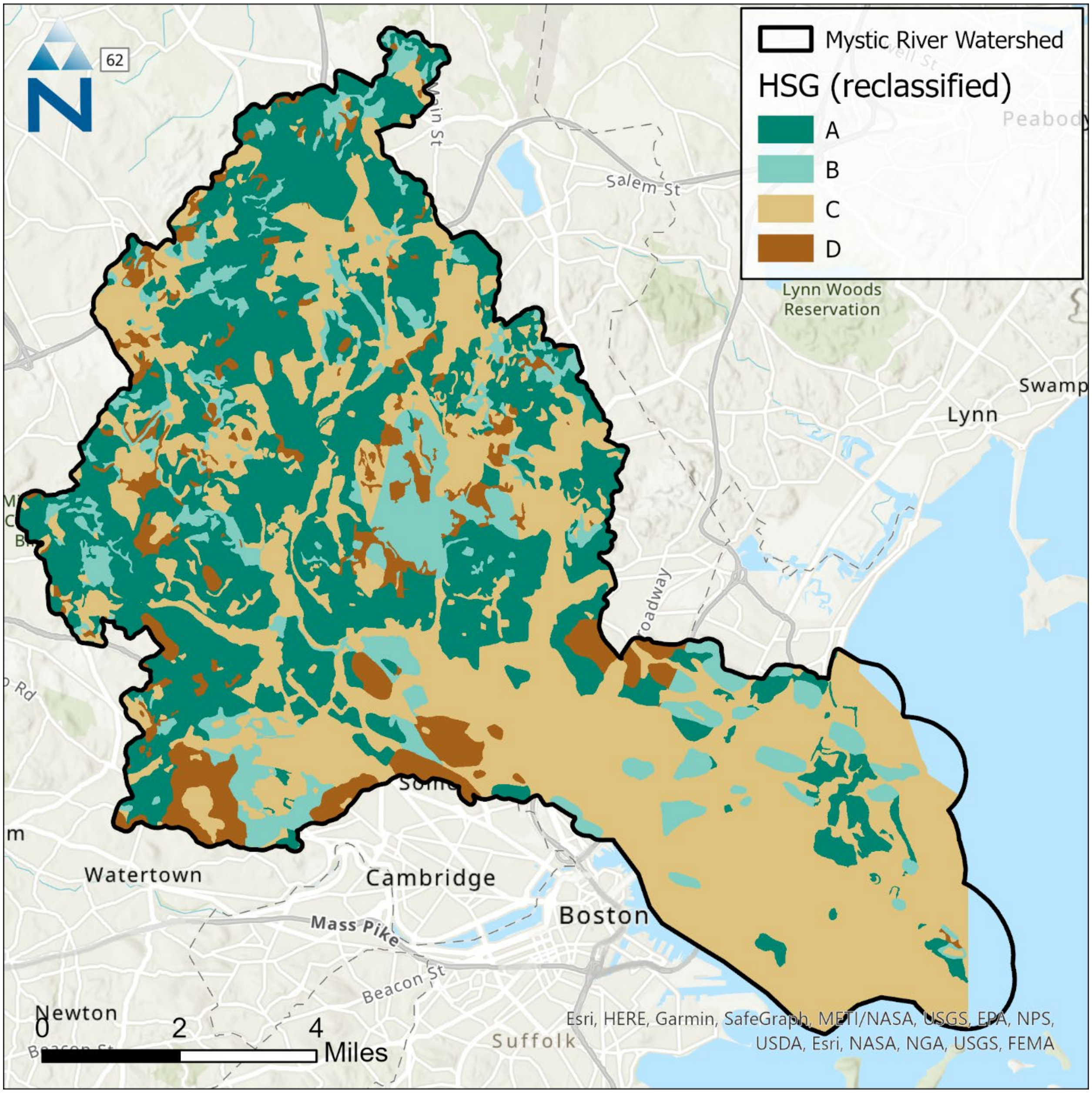

Figure 2-2. Reclassified hydrologic soil groups for the Mystic River Watershed.

2.2.3 *Mapped HRU Categories*

The land use - land cover and HSG layers described above were spatially overlaid in GIS to derive a composite raster (Figure 2-3). The resulting raster and attribute table were reclassified into 24 unique mapped HRUs (Table 2-5) suitable for use in the Opti-Tool and comparable to the Pollutant Loading Export Rates (PLERs) used in MS4 permitting (MassDEP, n.d.). The spatial distribution of mapped HRUs for the Mystic River Watershed is shown in Figure 2-4.

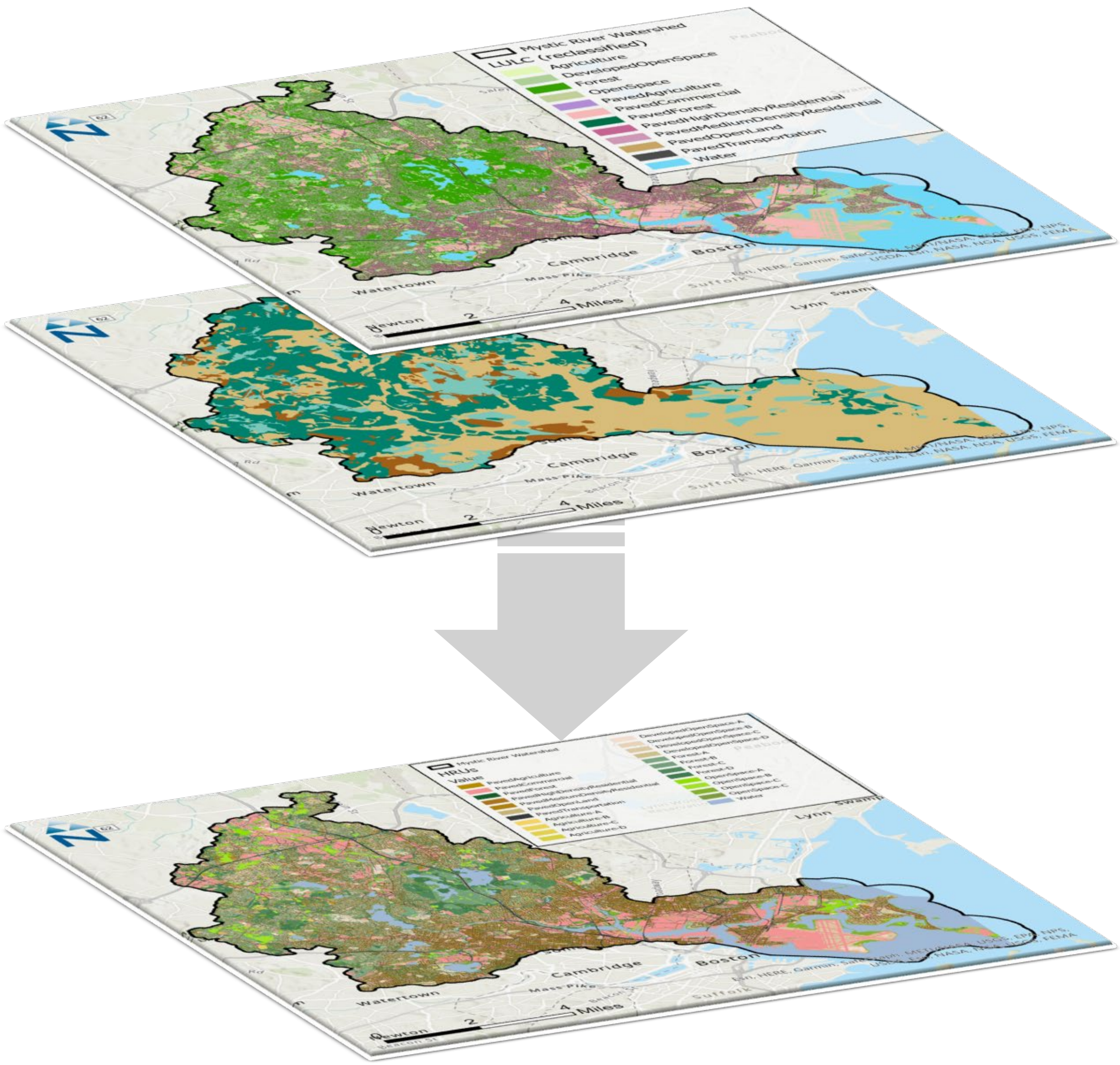

Figure 2-3. Mapped HRUs process (spatial overlay of land use – land cover and soil layers).

Table 2-5. Final HRU categories in the Mystic River watershed

HRU Code	HRU. Description	Land Use	Soil	Slope	Land Cover	Area (ac)	Area (%)
1000	PavedAgriculture	Agriculture	N/A	N/A	Impervious	10.6	0.02%
2000	PavedCommercial-Industrial	Commercial-Industrial	N/A	N/A	Impervious	7,133.7	12.95%
3000	PavedForest	Forest	N/A	N/A	Impervious	0.0	0.00%
4000	PavedHighDensityResidential	High Density Residential	N/A	N/A	Impervious	4,256.9	7.73%
5000	PavedMediumDensityResidential	Medium Density Residential	N/A	N/A	Impervious	4,235.8	7.69%
6000	PavedOpenLand	Open Land	N/A	N/A	Impervious	600.8	1.09%
7000	PavedTransportation	Transportation	N/A	N/A	Impervious	6,090.6	11.06%
					Sub-total (Impervious)	**22,328.43**	**40.53%**
8100	Agriculture-A	Agriculture	A	N/A	Pervious	27.0	0.05%
8200	Agriculture-B	Agriculture	B	N/A	Pervious	22.6	0.04%
8300	Agriculture-C	Agriculture	C	N/A	Pervious	28.5	0.05%
8400	Agriculture-D	Agriculture	D	N/A	Pervious	2.3	0.00%
9100	DevelopedOpenSpace-A	Developed Open Space	A	N/A	Pervious	3,607.8	6.55%
9200	DevelopedOpenSpace-B	Developed Open Space	B	N/A	Pervious	779.0	1.41%
9300	DevelopedOpenSpace-C	Developed Open Space	C	N/A	Pervious	2,956.0	5.37%
9400	DevelopedOpenSpace-D	Developed Open Space	D	N/A	Pervious	404.4	0.73%
10100	Forest-A	Forest	A	N/A	Pervious	6,187.0	11.23%
10200	Forest-B	Forest	B	N/A	Pervious	2,300.7	4.18%
10300	Forest-C	Forest	C	N/A	Pervious	4,012.3	7.28%
10400	Forest-D	Forest	D	N/A	Pervious	1,699.6	3.09%
11100	OpenSpace-A	OpenSpace	A	N/A	Pervious	833.8	1.51%
11200	OpenSpace-B	OpenSpace	B	N/A	Pervious	997.3	1.81%
11300	OpenSpace-C	OpenSpace	C	N/A	Pervious	1,254.8	2.28%
11400	OpenSpace-D	OpenSpace	D	N/A	Pervious	221.8	0.40%
12000	Water	N/A	N/A	N/A	Pervious	7,421.4	13.47%
					Total	**55,084.8**	**100%**

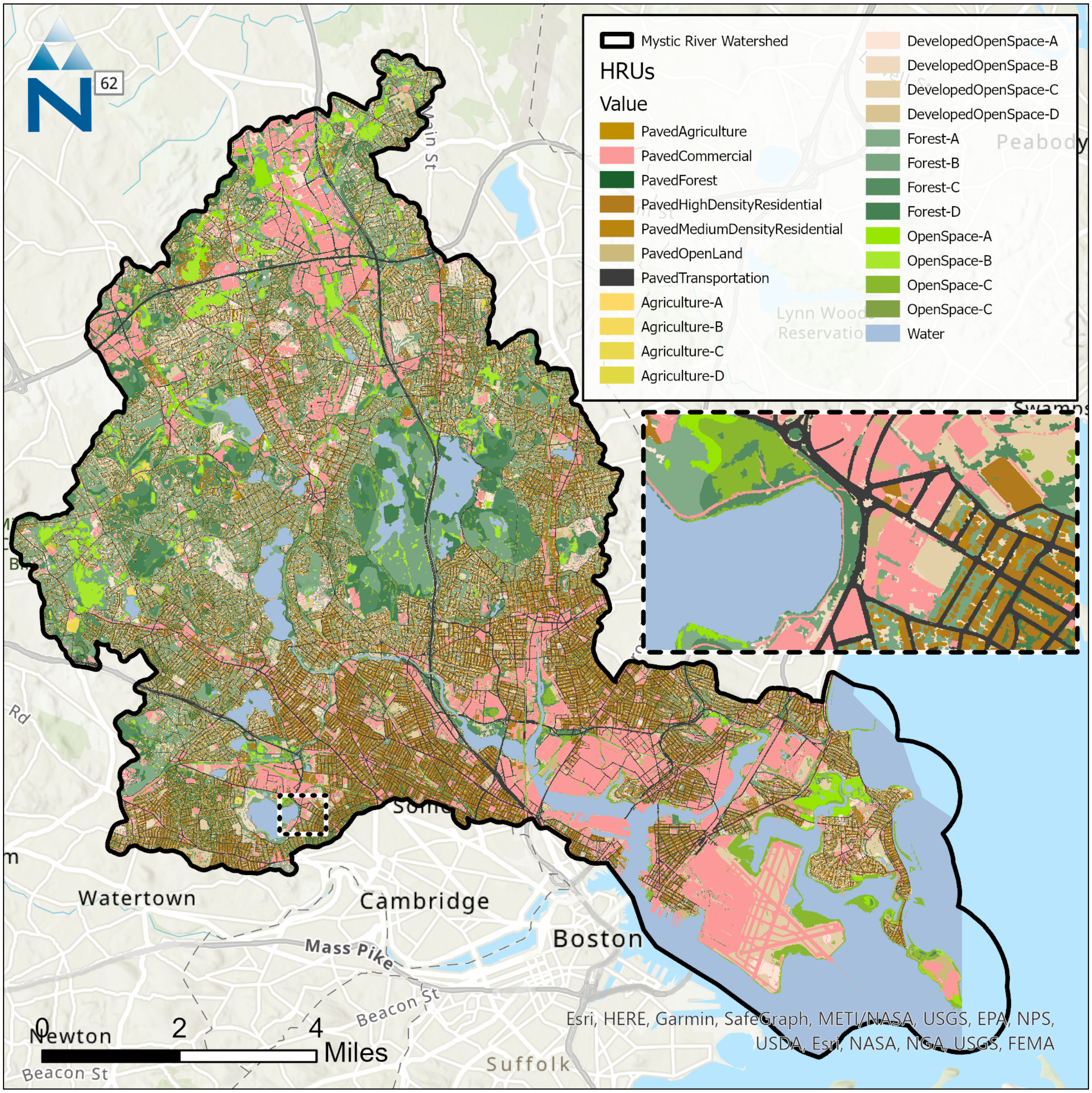

Figure 2-4. Mapped HRUs for the Mystic River Watershed with inset example showing level of detail.

2.3 SCM Siting Analysis

A GIS spatial data analysis was performed to identify potential stormwater control measure practices that would be technically feasible based on the available GIS data listed in the Data Inventory Section 2.1. Management categories include consideration of the dominant physical characteristics such as LULC, slope, and HSG. Other conditions may also be included, such as the proximity of impervious surfaces, water, and buildings; subsurface characteristics; public vs private areas; EJ populations; and sensitive locations (e.g., contaminated sites).

2.3.1 *SCM Siting Criteria*

Management categories are preferably considered for areas with pervious cover based on the suitability of site conditions for SCMs to treat stormwater runoff from impervious cover and reduce nutrient and bacteria loads. The suitability of site conditions was assessed using a combination of thresholds and attributes describing the physical characteristics represented in the GIS data. Figure 2-5 presents the proposed GIS decision tree for SCM site suitability and management categories for this study. In addition, rooftop disconnection was considered as an SCM for all building footprints.

Through the GIS screening process, the spatial distribution of SCM opportunity areas (representing the maximum available SCM footprint within the project area) was developed. For planning purposes, the total impervious areas by land use group can be proportionally distributed to the SCM drainage areas based on 1) the available percentage of opportunity area of the SCM type and 2) by land use type determined through the Management Category analysis. For example, if the opportunity area of a biofiltration SCM is 20% of the total available opportunity area in commercial land, then 20% of the impervious area in the commercial land could be treated by biofiltration practices located in that land use category.

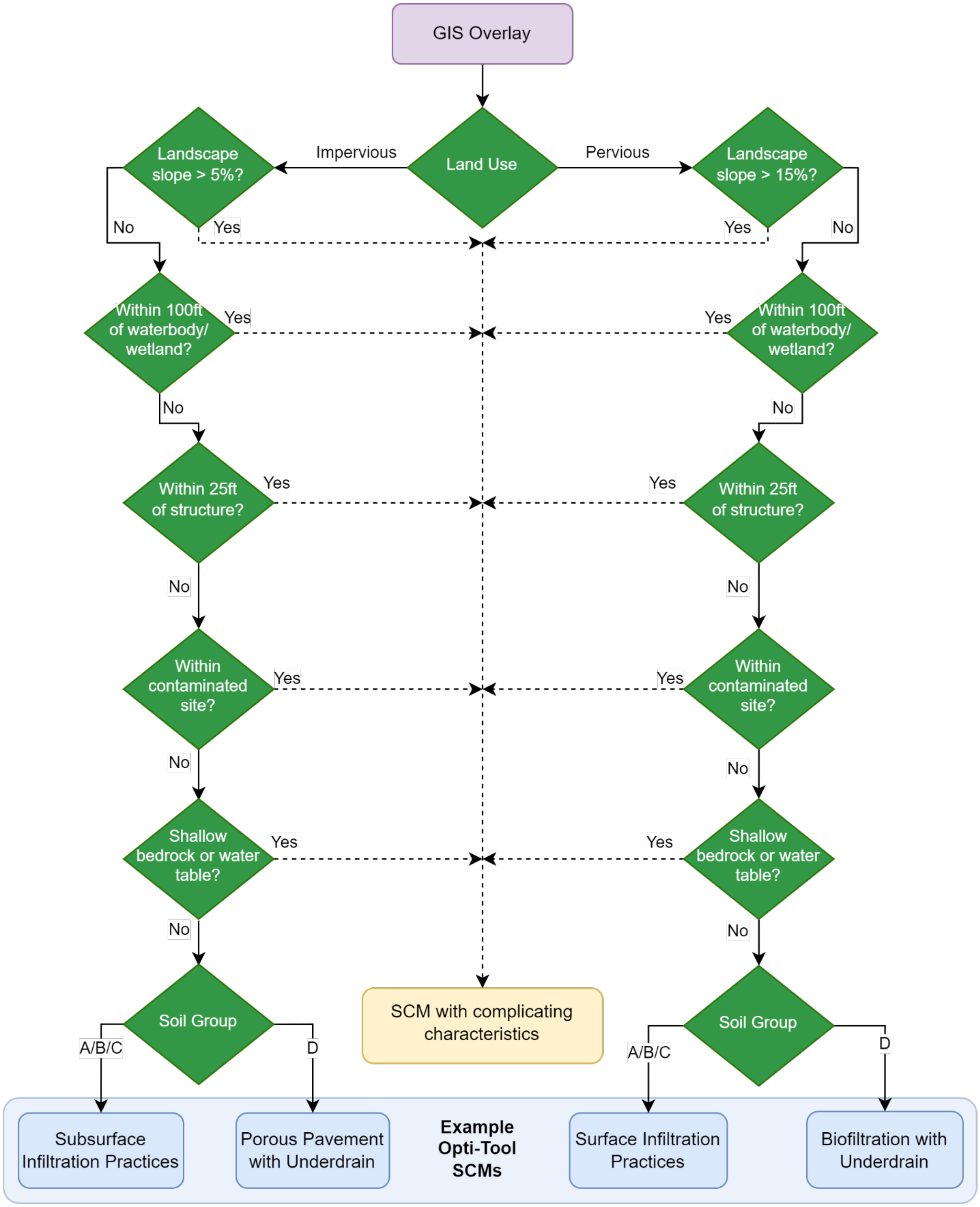

Figure 2-5. Example SCM siting decision tree and example SCM types.

2.3.2 *Mapped SCM Categories*

The distribution of mapped SCM categories within the Mystic River Watershed is shown in Table 2-6 and Figure 2-6. It should be noted that the shallow bedrock and water table criteria were excluded as they increased unsuitable areas from 45% to 52%. The SCM categories are useful for planning level analyses but should always be verified or superseded by field investigations prior to any SCM construction.

Table 2-6. Distribution of mapped SCM categories

Stormwater Management Category	Land Cover	HSG	Area (ac)	Area (%)
SCM with Complicating Characteristics	--	--	24,732.5	44.90%
Rooftop Disconnection (e.g., rain barrel, cistern)	Impervious	--	5,717.4	10.38%
Subsurface Infiltration Practice (e.g., infiltration trench)	Impervious	A	1,652.7	3.00%
	Impervious	B	250.2	0.45%
	Impervious	C	3,199.3	5.81%
Porous Pavement with Underdrain	Impervious	D	161.1	0.29%
		Impervious Subtotal	10,980.7	19.93%
Surface Infiltration Practice (e.g., rain garden, infiltration basin)	Pervious	A	4,222.4	7.67%
	Pervious	B	1,225.8	2.23%
	Pervious	C	3,580.2	6.50%
Biofiltration with Underdrain	Pervious	D	849.6	1.54%
		Pervious Subtotal	9,878.0	17.93%
Water/Wetland	--	--	9,493.6	17.23%
		Total	**55,084.8**	**100%**

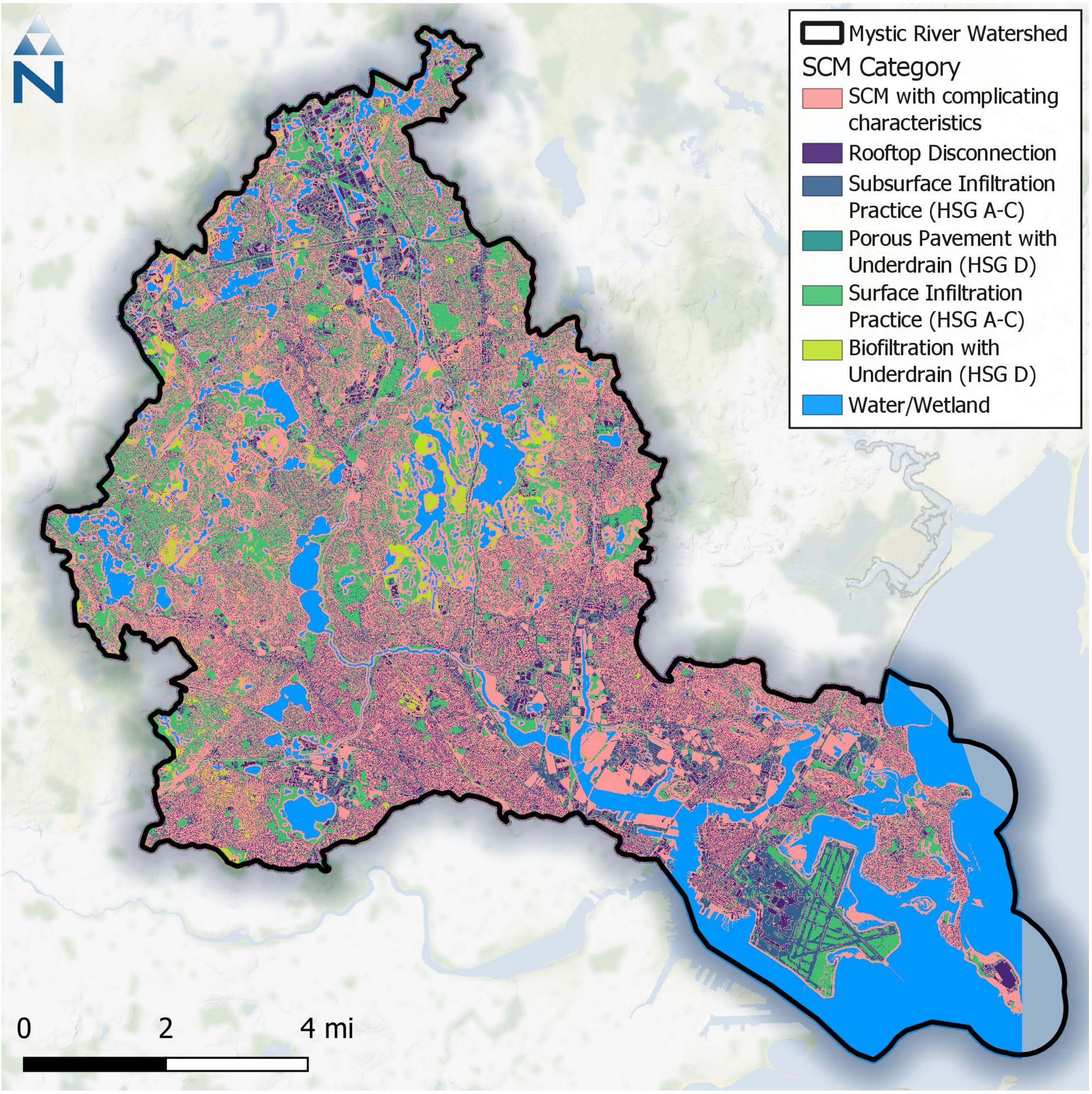

Figure 2-6. Spatial distribution of SCM categories within the Mystic River Watershed.

2.4 Summary Outputs

The Mystic River Watershed is approximately 41% impervious cover with mainly commercial, medium and high density residential, and transportation land uses. Forest and open space make up the majority of the remaining land area within the watershed with 26% and 20%, respectively. Higher infiltration HSGs A and B make up 40% and 13% of the watershed area, respectively; lower infiltration HSGs C and D constitute 39% and 9%, respectively. Rooftops represent 10% of the watershed indicating rooftop disconnection could be an important SCM opportunity for impervious areas. SCM opportunities on pervious areas are predominately surface infiltration-based practices.

On a finer scale, HRU and SCM categories were summarized over the municipality, subwatershed, and Combined Sewer System (CSS) area within the Mystic River Watershed. These layers are shown in Figure 2-7, Figure 2-8, and Figure 2-9, respectively. The entire Mystic River Watershed is within the Boston Urbanized MS4 area; therefore, summaries were not created for MS4 area. Note that total areas for the summaries presented is less than the watershed total presented in Table 2-5 and Table 2-6 because some bodies of water are not covered by the municipalities or subbasins (e.g., the tidal portions of the Mystic River, Boston Harbor).

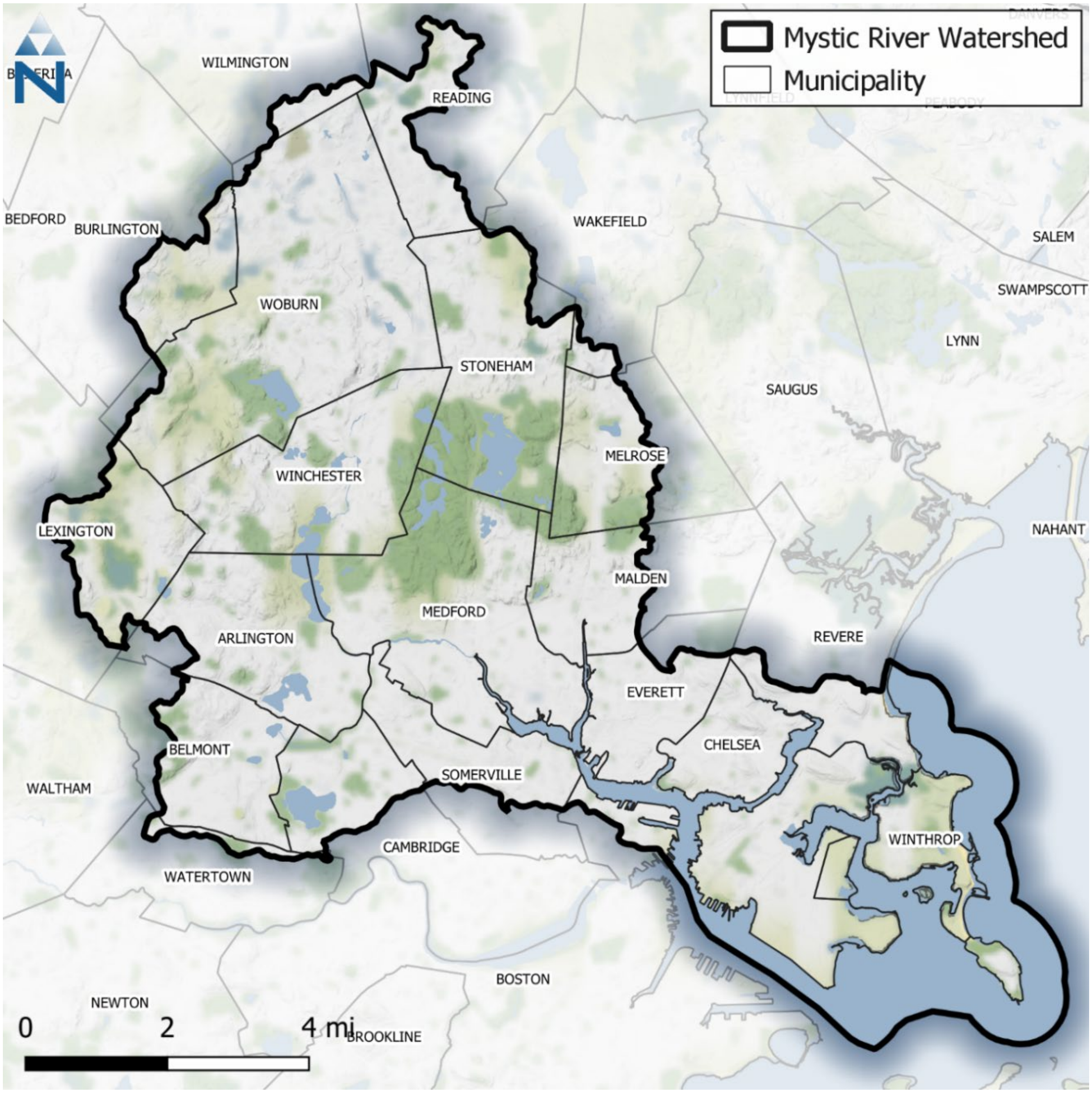

Figure 2-7. Municipalities within the Mystic River Watershed.

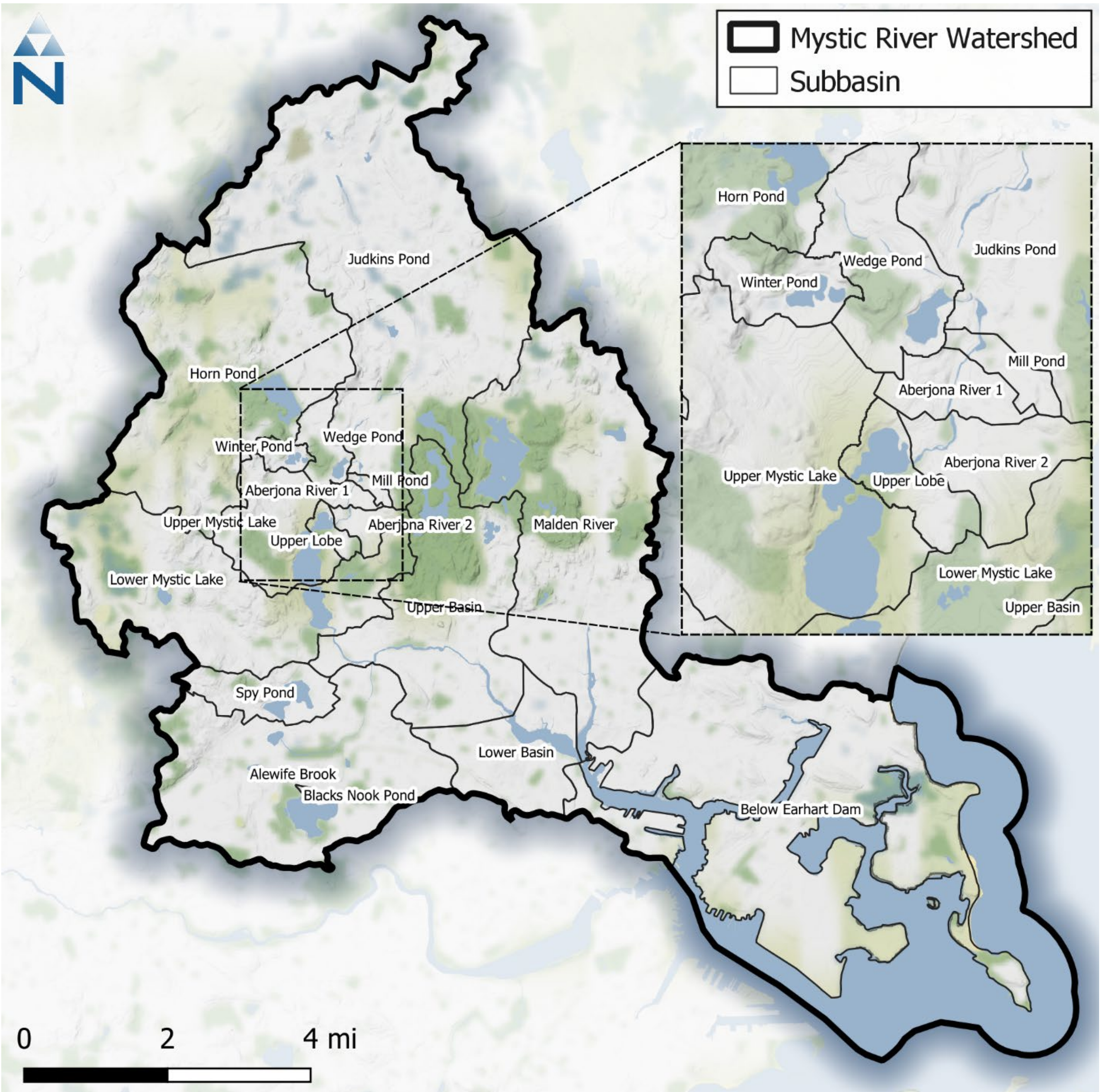

Figure 2-8. Subbasins within the Mystic River Watershed.

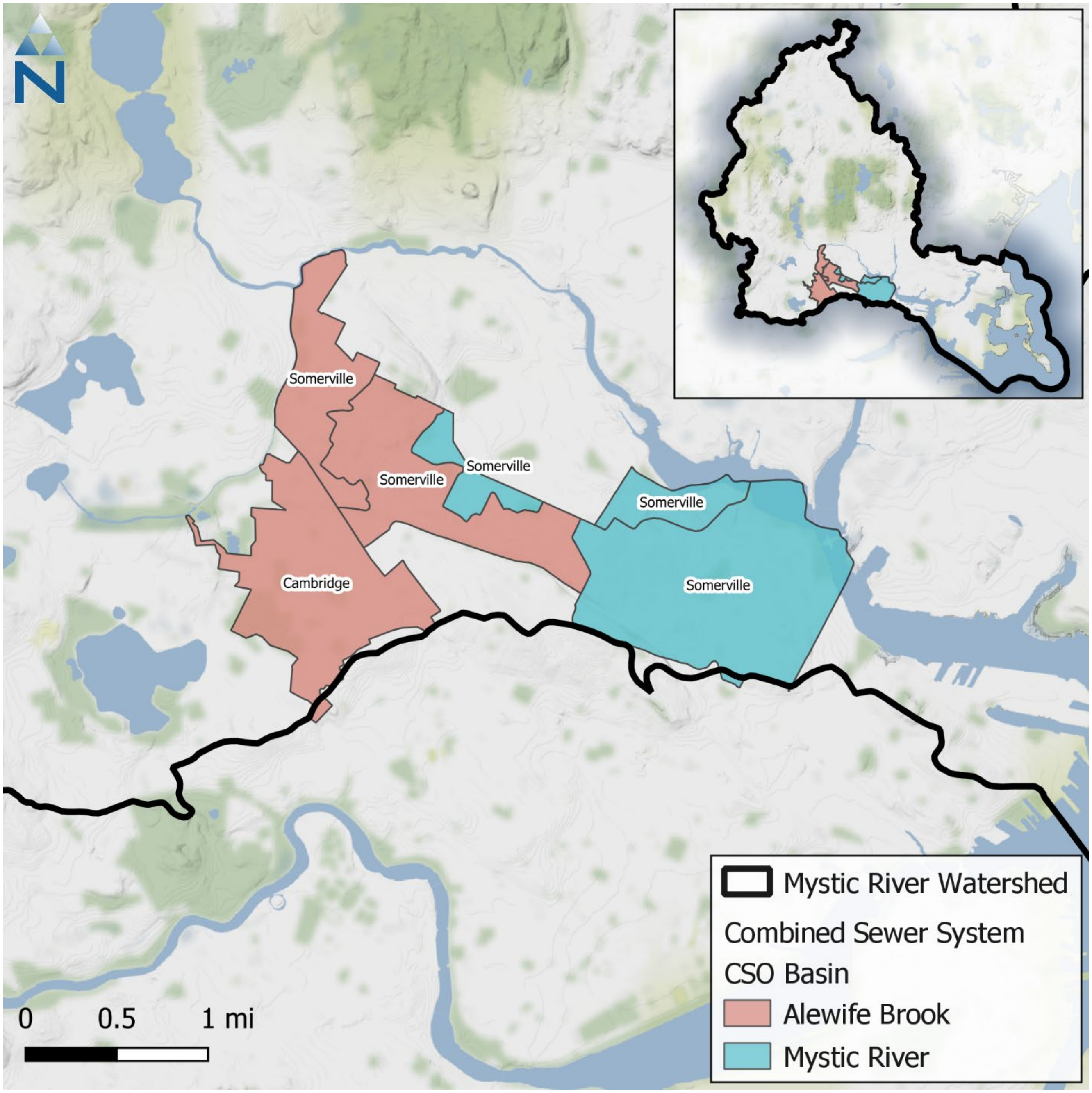

Figure 2-9. Combined sewer system areas within the Mystic River Watershed by CSO basin.

2.4.1 *HRU Summaries*

Summaries of HRU area by municipality, subwatershed, and CSS area within the Mystic River Watershed are shown in Table 2-7, Table 2-8, and Table 2-9, respectively. Along with HRU area, each table presents the area over which HRUs were aggregated and the total area of impervious HRUs. Note that Agriculture and Forest HRUs are grouped by HSG in the tables.

2.4.2 *SCM Summaries*

Summaries of SCM area by municipality, subwatershed, and CSS area within the Mystic River Watershed are shown in Table 2-10, Table 2-11, and Table 2-12, respectively. Along with area for each SCM category, each table presents the area over which SCMs were aggregated.

Table 2-7. Summary table of HRU area within each municipality. Agriculture and Forest HRUs are grouped by HSG

Municipality	Area in Watershed		Paved Agriculture (ac)	Paved Commercial (ac)	Paved Forest (ac)	Paved High Density Residential (ac)	Paved Medium Density Residential (ac)	Paved Open Land (ac)	Paved Transportation (ac)	Agriculture (A-D) (ac)	Developed Open Space-A (ac)	Developed Open Space-B (ac)	Developed Open Space-C (ac)	Developed Open Space-D (ac)	Forest (A-D) (ac)	Open Space-A (ac)	Open Space-B (ac)	Open Space-C (ac)	Open Space-D (ac)	Water (ac)	Impervious Area (1000-7000)	
	Acre	%	1000	2000	3000	4000	5000	6000	7000	8000	9100	9200	9300	9400	10000	11100	11200	11300	11400	12000	Acre	%
ARLINGTON	3,246.6	92.5%	-	163.2	-	378.8	419.5	31.1	518.3	-	348.5	39.6	109.2	25.2	954.8	6.5	4.6	17.1	0.0	230.3	1,510.9	46.5%
BELMONT	2,185.6	72.4%	0.3	140.8	-	201.5	290.7	14.0	319.2	5.7	111.3	74.0	100.8	102.8	749.6	6.0	9.2	21.1	8.0	30.7	966.5	44.2%
BOSTON	3,852.6	12.0%	0.9	1,720.5	-	272.1	55.9	77.3	306.4	0.0	66.8	56.4	611.9	-	192.9	130.1	11.7	305.9	1.5	41.9	2,433.1	63.2%
BURLINGTON	1,287.8	17.0%	-	206.7	-	52.4	74.8	4.3	131.7	-	82.7	14.1	110.0	29.0	401.2	21.8	102.7	21.6	33.3	1.4	469.9	36.5%
CAMBRIDGE	1,615.1	35.5%	-	308.6	-	244.3	78.1	36.4	207.1	-	6.1	66.5	105.2	7.7	313.8	4.2	22.0	43.2	0.0	171.8	874.6	54.1%
CHELSEA	1,418.7	100.0%	0.2	451.4	-	243.5	45.5	55.2	280.8	-	10.3	45.4	81.4	-	162.3	3.8	0.7	35.3	-	3.0	1,076.4	75.9%
EVERETT	1,709.8	77.8%	-	641.1	-	308.9	107.4	42.7	269.1	-	29.8	0.1	82.3	32.6	125.0	0.1	-	66.0	0.4	4.2	1,369.2	80.1%
LEXINGTON	2,082.7	19.6%	-	58.3	-	29.8	193.2	6.6	154.7	35.4	195.1	7.6	53.0	8.8	1,054.3	58.9	179.5	20.0	10.1	17.5	442.6	21.3%
MALDEN	1,755.4	54.1%	-	275.3	-	345.0	184.2	6.8	319.5	-	111.0	28.9	65.4	11.5	364.7	5.3	13.6	16.3	0.1	7.9	1,130.7	64.4%
MEDFORD	5,409.1	100.0%	-	497.2	-	487.2	514.5	87.1	756.2	-	364.7	60.3	256.0	25.6	1,924.6	12.4	80.7	76.7	45.7	220.2	2,342.2	43.3%
MELROSE	1,756.6	57.6%	-	101.5	-	153.8	250.1	27.3	221.0	-	136.6	4.9	134.5	0.4	656.5	4.5	6.6	25.9	7.9	25.0	753.8	42.9%
READING	1,599.7	25.0%	-	27.0	-	37.6	170.1	17.6	180.3	-	192.2	28.8	94.5	8.4	655.7	55.5	112.8	10.6	8.6	0.0	432.6	27.0%
REVERE	1,139.1	28.9%	-	211.6	-	169.2	91.6	11.4	209.4	-	27.7	54.0	75.1	-	144.1	31.4	0.7	40.0	-	72.8	693.2	60.9%
SOMERVILLE	1,714.2	64.9%	-	275.6	-	559.4	94.7	21.6	402.7	-	15.1	13.0	87.5	36.7	179.8	0.2	2.5	16.0	2.6	6.8	1,354.1	79.0%
STONEHAM	4,051.8	95.3%	-	220.8	-	144.7	371.9	21.3	400.8	5.8	347.1	84.1	226.9	10.6	1,629.4	25.2	95.6	35.5	36.4	395.7	1,159.6	28.6%
WAKEFIELD	221.0	4.3%	-	0.9	-	3.8	34.6	0.9	21.5	-	17.2	10.9	0.4	3.2	113.3	1.3	10.7	-	2.6	0.1	61.6	27.9%
WATERTOWN	219.4	8.3%	-	12.9	-	58.1	12.7	0.2	30.3	-	10.4	7.8	14.9	34.7	37.1	-	-	-	0.0	0.3	114.1	52.0%
WILMINGTON	291.9	2.7%	-	125.6	-	-	0.9	2.8	17.4	-	29.4	1.5	1.5	1.5	82.3	14.5	12.8	0.4	1.4	0.0	146.6	50.2%
WINCHESTER	4,062.2	100.0%	6.4	181.1	-	113.2	497.9	9.5	394.0	9.5	431.2	66.3	123.3	15.5	1,870.6	42.6	32.1	58.3	28.3	182.5	1,202.1	29.6%
WINTHROP	1,457.3	100.0%	-	189.5	-	172.5	156.0	8.9	156.3	-	114.1	39.1	206.7	-	117.0	62.5	2.6	54.8	-	177.3	683.2	46.9%
WOBURN	7,989.9	96.5%	0.0	1,306.0	-	280.7	591.6	87.1	784.2	24.0	960.5	75.9	413.7	50.5	2,462.1	340.9	292.2	116.9	34.9	168.8	3,049.6	38.2%
Total	49,066.4	89.1%	7.8	7,115.5	-	4,256.4	4,235.8	570.1	6,081.0	80.4	3,607.7	779.0	2,954.3	404.4	14,191.2	827.9	993.5	981.4	221.8	1,758.1	22,266.6	45.4%

Table 2-8. Summary table of HRU area within each subbasin. Agriculture and Forest HRUs are grouped by HSG

Subbasin		Percentage of Mystic Watershed	Paved Agriculture (ac)	Paved Commercial (ac)	Paved Forest (ac)	Paved High Density Residential (ac)	Paved Medium Density Residential (ac)	Paved Open Land (ac)	Paved Transportation (ac)	Agriculture (A-D) (ac)	Developed Open Space-A (ac)	Developed Open Space-B (ac)	Developed Open Space-C (ac)	Developed Open Space-D (ac)	Forest (A-D) (ac)	Open Space-A (ac)	Open Space-B (ac)	Open Space-C (ac)	Open Space-D (ac)	Water (ac)	Impervious Area (1000-7000)	
Name	Area (ac)	%	1000	2000	3000	4000	5000	6000	7000	8000	9100	9200	9300	9400	10000	11100	11200	11300	11400	12000	Acre	%
Below Earhart Dam	8,664.5	15.7%	0.6	3,061.3	-	1,042.0	422.4	200.9	1,126.8	0.0	235.1	194.5	1,015.0	23.4	675.2	215.3	14.2	290.1	1.7	146.1	5,853.9	67.6%
Aberjona River 1	141.2	0.3%	-	12.0	-	3.6	23.0	0.0	19.8	-	11.9	-	10.0	-	57.5	0.0	-	3.5	-	0.1	58.3	41.3%
Aberjona River 2	266.8	0.5%	-	3.4	-	1.7	46.9	0.1	36.9	-	20.5	0.2	15.3	-	134.9	0.4	-	6.2	-	0.4	89.0	33.3%
Alewife Brook	4,838.7	8.8%	0.3	538.2	-	843.7	416.6	58.2	725.9	5.7	171.0	150.0	259.7	148.3	1,190.9	10.9	34.8	70.3	8.0	206.0	2,583.0	53.4%
Blacks Nook Pond	8.8	0.0%	-	0.0	-	0.1	-	-	0.1	-	0.1	0.4	-	-	5.6	0.0	0.4	0.1	-	2.0	0.1	1.6%
Horn Pond	5,638.0	10.2%	0.0	481.7	-	192.2	515.8	42.7	526.7	27.2	636.3	66.5	303.7	57.5	2,174.7	107.5	221.6	71.0	77.8	135.1	1,759.2	31.2%
Judkins Pond	9,449.2	17.2%	-	1,459.8	-	361.4	767.0	83.4	1,012.8	5.8	1,061.5	125.6	522.0	42.6	3,043.9	358.9	338.5	124.3	38.3	103.4	3,684.4	39.0%
Lower Mystic Lake	4,357.1	7.9%	-	181.7	-	197.7	522.0	37.8	479.6	35.4	455.7	23.6	139.0	29.6	1,817.8	65.2	190.3	36.8	12.6	132.4	1,418.7	32.6%
Malden River	7,019.8	12.7%	-	671.7	-	755.6	716.3	69.0	922.8	-	450.5	68.0	360.3	27.1	2,250.0	33.8	115.3	126.7	31.1	421.6	3,135.3	44.7%
Mill Pond	75.9	0.1%	-	10.0	-	1.6	8.9	0.0	13.8	-	3.1	0.8	5.3	-	31.3	0.1	-	0.9	-	0.1	34.3	45.2%
Upper Basin	3,891.8	7.1%	-	275.1	-	355.2	339.9	54.1	530.7	-	225.2	61.8	141.0	21.5	1,510.1	5.8	67.8	36.4	47.9	219.2	1,555.0	40.0%
Spy Pond	827.3	1.5%	-	23.1	-	66.8	111.3	3.2	150.8	-	85.7	-	22.4	8.0	248.2	1.5	-	0.9	0.0	105.3	355.2	42.9%
Upper Lobe	171.1	0.3%	-	1.1	-	1.8	22.2	0.0	12.9	-	14.6	0.1	6.6	-	74.4	0.6	0.1	1.4	-	35.5	38.0	22.2%
Upper Mystic Lake	1,362.1	2.5%	6.4	18.7	-	8.9	192.3	1.6	120.6	6.2	180.5	76.7	24.9	3.4	561.6	7.1	4.3	5.2	-	143.7	348.5	25.6%
Wedge Pond	397.2	0.7%	-	37.1	-	23.5	41.3	2.4	41.5	-	43.2	-	9.2	8.9	157.4	7.6	-	0.4	0.5	24.0	145.9	36.7%
Winter Pond	178.0	0.3%	0.0	10.8	-	6.7	14.7	0.2	12.9	0.0	6.5	1.0	8.2	0.2	88.9	0.4	2.4	1.3	1.5	22.2	45.3	25.5%
Lower Basin	1,633.2	3.0%	-	301.3	-	390.4	74.3	25.4	344.7	-	5.8	9.1	101.2	34.0	175.3	-	2.2	43.6	2.3	123.4	1,136.2	69.6%
Total	48,920.8	88.8%	7.3	7,087.0	-	4,253.0	4,234.7	579.4	6,079.1	80.4	3,607.2	778.4	2,943.6	404.3	14,197.7	815.2	991.9	819.2	221.8	1,820.5	22,240.5	45.5%

Table 2-9. Summary table of HRU area within each CSS area. Agriculture and Forest HRUs are grouped by HSG

City	CSO Basin	CSS Area (ac)	Paved Agriculture (ac)	Paved Commercial (ac)	Paved Forest (ac)	Paved High Density Residential (ac)	Paved Medium Density Residential (ac)	Paved Open Land (ac)	Paved Transportation (ac)	Agriculture (A-D) (ac)	Developed Open Space-A (ac)	Developed Open Space-B (ac)	Developed Open Space-C (ac)	Developed Open Space-D (ac)	Forest (A-D) (ac)	Open Space-A (ac)	Open Space-B (ac)	Open Space-C (ac)	Open Space-D (ac)	Water (ac)	Impervious Area (1000-7000)	
			1000	2000	3000	4000	5000	6000	7000	8000	9100	9200	9300	9400	10000	11100	11200	11300	11400	12000	Acre	%
Cambridge	Alewife Brook	497.5	-	78.4	-	136.9	38.6	7.1	86.7	-	2.2	0.1	56.6	3.8	78.8	-	-	8.2	-	0.0	347.7	69.9%
Somerville	Alewife Brook	625.1	-	75.3	-	229.3	38.2	3.1	131.0	-	10.7	9.2	25.0	11.8	81.9	0.2	1.2	2.1	1.5	4.8	476.9	76.3%
Somerville	Mystic River	914.6	-	172.2	-	236.0	39.3	17.6	216.9	-	3.3	0.9	62.2	16.8	64.7	-	0.1	15.3	1.1	68.4	681.9	74.6%
	Total	2,037.2	-	325.9	-	602.3	116.0	27.7	434.5	-	16.2	10.2	143.7	32.5	225.3	0.2	1.3	25.5	2.6	73.2	1,506.5	73.9%

Table 2-10. Summary table of SCM area within each municipality

Municipality	Area in Watershed		SCM with Complicating Characteristics (ac)	Impervious Land Cover (ac)					Pervious Land Cover (ac)				Water/Wetland (ac)
				Rooftop Disconnection	Subsurface Infiltration Practice	Subsurface Infiltration Practice	Subsurface Infiltration Practice	Porous Pavement with Underdrain	Surface Infiltration Practice	Surface Infiltration Practice	Surface Infiltration Practice	Biofiltration with Underdrain	
	Acre	%	0	1	2	3	4	5	6	7	8	9	10
ARLINGTON	3,246.6	92.5%	1,808.8	443.2	155.3	5.1	77.2	10.4	307.7	43.6	117.2	26.9	251.1
BELMONT	2,185.6	72.4%	1,118.6	297.2	58.8	38.2	58.0	44.5	209.5	74.8	132.1	98.7	55.1
BOSTON	3,852.6	12.0%	1,492.3	478.0	28.2	20.4	958.7	1.6	67.1	28.9	547.4	0.1	229.7
BURLINGTON	1,287.8	17.0%	563.3	102.4	25.1	2.9	109.9	4.6	85.8	17.7	150.1	66.7	159.3
CAMBRIDGE	1,615.1	35.5%	739.8	245.5	6.7	33.9	136.2	12.6	9.9	82.1	125.1	13.8	209.5
CHELSEA	1,418.7	100.0%	829.9	247.9	14.1	16.6	190.2	-	6.6	31.8	70.0	-	11.6
EVERETT	1,709.8	77.8%	1,081.7	272.5	20.3	0.1	199.0	13.5	13.2	0.0	75.6	13.0	20.8
LEXINGTON	2,082.7	19.6%	893.7	133.9	78.6	1.2	17.7	1.1	405.2	42.2	173.3	62.4	273.4
MALDEN	1,755.4	54.1%	1,012.3	307.5	73.4	4.4	120.4	6.7	75.9	53.5	71.1	5.0	25.1
MEDFORD	5,409.1	100.0%	2,815.8	621.6	185.1	44.9	271.9	13.1	300.9	298.5	333.9	149.4	374.0
MELROSE	1,756.6	57.6%	1,007.1	214.3	48.7	1.7	99.0	0.0	118.2	19.5	192.4	1.4	54.2
READING	1,599.7	25.0%	719.9	120.2	64.7	4.3	50.5	0.9	263.6	43.1	144.4	11.7	176.4
REVERE	1,139.1	28.9%	664.2	143.1	19.4	11.5	99.0	-	16.2	23.7	45.7	-	116.2
SOMERVILLE	1,714.2	64.9%	988.7	394.0	19.1	9.1	144.4	32.4	6.5	15.2	70.4	25.9	8.5
STONEHAM	4,051.8	95.3%	1,839.1	286.0	116.2	17.4	162.0	0.9	367.6	200.1	362.8	136.0	563.8
WAKEFIELD	221.0	4.3%	135.0	17.0	4.0	3.7	0.0	0.3	16.9	24.6	1.9	5.6	12.0
WATERTOWN	219.4	8.3%	106.7	36.7	4.9	2.8	2.3	6.7	12.0	6.0	14.1	26.9	0.3
WILMINGTON	291.9	2.7%	111.2	49.0	43.4	0.4	0.5	1.1	54.6	5.9	2.9	4.7	18.4
WINCHESTER	4,062.2	100.0%	2,034.9	339.3	166.1	8.8	62.7	3.3	699.8	95.6	258.9	90.7	302.0
WINTHROP	1,457.3	100.0%	666.4	177.3	29.0	9.8	120.1	-	45.5	14.9	149.2	-	245.1
WOBURN	7,989.9	96.5%	3,765.8	789.6	491.7	13.1	319.4	7.1	1,139.9	103.9	541.3	110.3	707.7
Total	49,066.4	89.1%	24,395.2	5,716.2	1,652.7	250.2	3,199.3	161.1	4,222.4	1,225.8	3,579.9	849.6	3,813.8

Table 2-11. Summary table of SCM area within each subbasin

Subbasin		Percentage of Mystic Watershed	SCM with Complicating Characteristics (ac)	Impervious Land Cover (ac)					Pervious Land Cover (ac)				Water/Wetland (ac)
				Rooftop Disconnection	Subsurface Infiltration Practice	Subsurface Infiltration Practice	Subsurface Infiltration Practice	Porous Pavement with Underdrain	Surface Infiltration Practice	Surface Infiltration Practice	Surface Infiltration Practice	Biofiltration with Underdrain	
Name	Acre	%	0	1	2	3	4	5	6	7	8	9	10
Below Earhart Dam	8,664.5	15.7%	4,245.4	1,240.5	102.4	58.4	1,527.8	9.5	141.9	99.4	850.4	8.9	379.9
Aberjona River 1	141.2	0.3%	84.6	15.1	8.6	-	1.4	-	23.3	-	6.5	-	1.6
Aberjona River 2	266.8	0.5%	149.3	27.6	10.3	0.1	8.8	-	35.4	0.9	29.6	-	4.7
Alewife Brook	4,838.7	8.8%	2,440.5	782.5	104.9	76.7	238.2	66.7	235.5	163.3	317.3	136.4	276.9
Blacks Nook Pond	8.8	0.0%	3.4	-	0.1	0.0	-	-	0.8	2.1	-	-	2.5
Horn Pond	5,638.0	10.2%	2,731.1	440.7	241.7	9.8	177.2	6.0	817.6	105.3	473.2	144.6	490.9
Judkins Pond	9,449.2	17.2%	4,329.4	973.3	528.9	14.3	463.6	8.6	1,296.8	197.1	732.5	138.0	766.8
Lower Mystic Lake	4,357.1	7.9%	2,185.1	410.1	169.7	4.3	72.4	9.6	650.5	77.9	256.4	106.1	414.9
Malden River	7,019.8	12.7%	3,782.2	820.6	218.1	27.8	341.4	13.4	365.1	195.2	509.7	116.8	629.3
Mill Pond	75.9	0.1%	39.8	10.1	2.1	0.1	4.2	-	9.3	3.3	6.9	-	0.1
Upper Basin	3,891.8	7.1%	2,067.2	419.6	117.5	43.9	150.4	9.6	157.3	271.4	173.4	134.4	347.2
Spy Pond	827.3	1.5%	416.3	99.9	53.3	-	15.0	5.6	98.5	-	18.5	13.5	106.6
Upper Lobe	171.1	0.3%	66.9	12.3	7.0	-	2.2	-	33.9	1.3	11.6	-	36.0
Upper Mystic Lake	1,362.1	2.5%	603.2	107.5	50.8	7.6	7.1	0.6	278.7	96.9	50.8	6.3	152.6
Wedge Pond	397.2	0.7%	191.7	38.3	27.1	-	4.3	1.8	67.4	-	15.7	20.6	30.4
Winter Pond	178.0	0.3%	101.4	11.5	3.5	0.6	7.5	0.4	8.9	0.6	12.4	5.3	25.9
Lower Basin	1,633.2	3.0%	832.8	304.0	6.9	6.7	172.0	29.5	2.5	10.4	108.8	18.4	141.3
Total	48,920.8	88.8%	24,270.4	5,713.6	1,652.9	250.3	3,193.3	161.3	4,223.4	1,225.2	3,573.6	849.2	3,807.6

Table 2-12. Summary table of SCM area within each CSS area

City	CSO Basin	CSS Area (ac)	SCM with Complicating Characteristics (ac)	Impervious Land Cover (ac)					Pervious Land Cover (ac)				Water/Wetland (ac)
				Rooftop Disconnection	Subsurface Infiltration Practice	Subsurface Infiltration Practice	Subsurface Infiltration Practice	Porous Pavement with Underdrain	Surface Infiltration Practice	Surface Infiltration Practice	Surface Infiltration Practice	Biofiltration with Underdrain	
Cambridge	Alewife Brook	347.7	-	78.4	-	136.9	38.6	7.1	86.7	-	-	-	-
Somerville	Alewife Brook	625.1	361.0	152.8	10.5	5.8	31.7	7.9	3.8	12.2	22.0	11.2	6.2
Somerville	Mystic River	914.6	485.3	173.6	5.1	1.8	106.4	15.4	1.7	0.2	46.4	9.9	68.8
	Total	1,887.5	846.3	404.7	15.6	144.6	176.7	30.4	92.2	12.4	68.4	21.1	75.1

3 STORMWATER POLLUTANT LOADING ANALYSIS

In order to characterize unattenuated stormwater quality from the Mystic River Watershed HRUs, pollutant load export rates were generated for: i) Total Phosphorus (TP), ii) Total Nitrogen (TN), iii) Total Suspended Solids (TSS), iv) Zinc (Zn) and v) *E. coli* (most probable number [mpn]). These pollutant loading rates are generated for the full Opti-Tool time period (1992-2022). TP was also adjusted based the Mystic River Watershed Alternative TMDL analysis (for the period 2007-2016) to represent attenuated load, as described in Section 3.3.

3.1 Opti-Tool SWMM Model

Unattenuated stormwater flow and pollutant loading time series were developed for each HRU using the regionally calibrated SWMM model available as part of EPA's Opti-Tool software package (https://www.epa.gov/tmdl/opti-tool-epa-region-1s-stormwater-management-optimization-tool). Two updates were performed on the Opti-Tool SWMM model for this study: i) the meteorological input time series were updated with two additional years of data (2021 and 2022) and ii) additional time series were generated to better represent the HRUs within the Mystic River Watershed.

Meteorological input data for the Opti-Tool SWMM model comes from the NOAA station located at Boston Logan International Airport (WBAN station 14739). Hourly precipitation and daily minimum and maximum temperature time series for 2021-2022 were downloaded, evaluated for accuracy and completeness, and appended to the existing 1992-2020 input files. The additional time series were complete and did not introduce any extremes. The yearly precipitation totals are shown in Figure 3-1 with additional analysis of daily precipitation given in Table 3-1. Minimum, average, and maximum monthly total precipitation are shown in Figure 3-2. Average minimum and maximum monthly temperatures are shown in Figure 3-3.

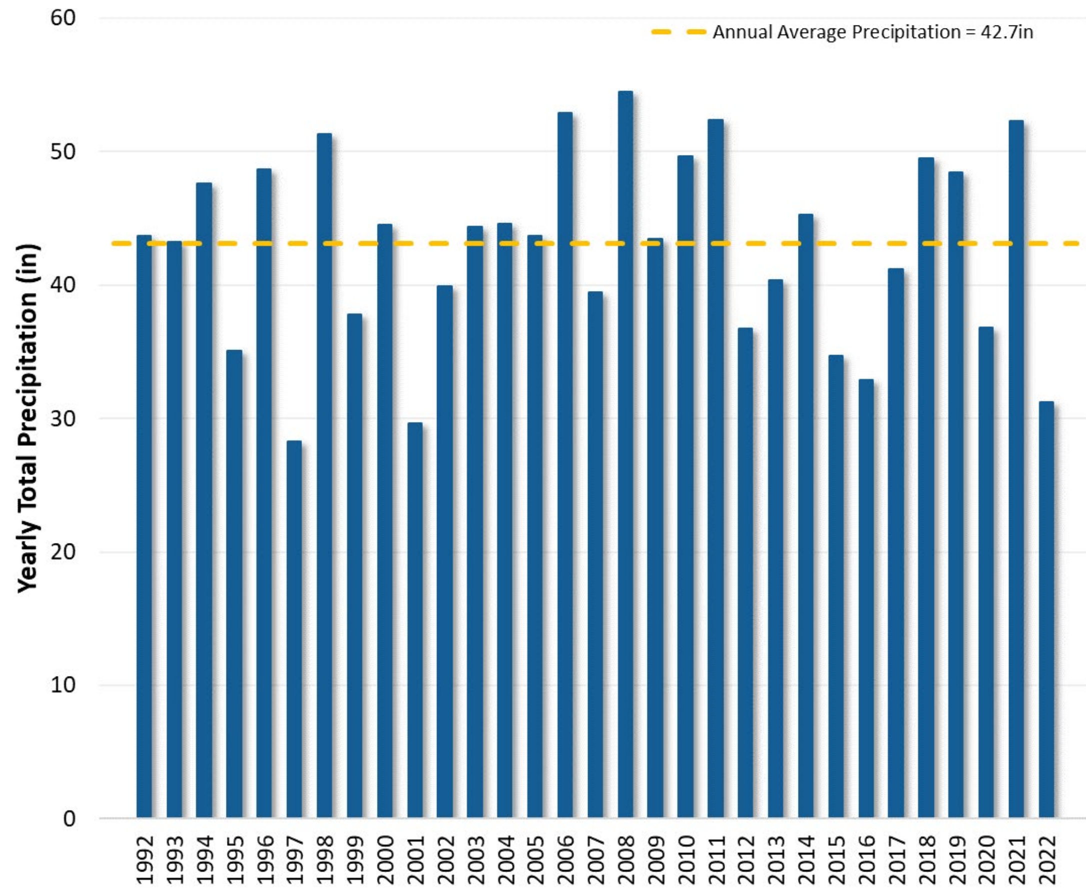

Figure 3-1. Annual total precipitation at Boston Logan International Airport.

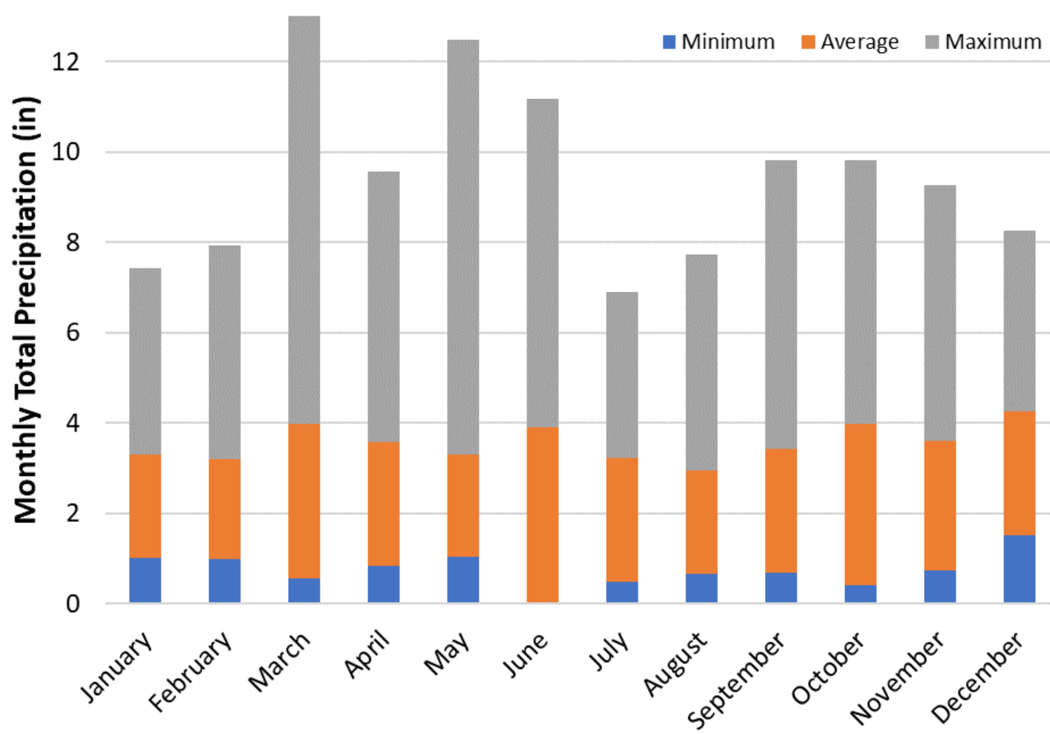

Figure 3-2. Monthly minimum, average, and maximum precipitation totals for 1992-2022.

Table 3-1. Analysis of daily rainfall at Boston Logan International Airport by year for the Opti-Tool SWMM model

Boston Logan Int. Airport - Boston, MA							
Year	Rainfall (in)	Percentile (10th % / Average / 90th %)	Difference From Average (in)	Number of Rain Days per Year: >= 0.1"	>= 0.5"	>= 1.0"	>=1.5"
1992	43.72	53%	1.00	79	24	8	3
1993	43.21	44%	0.49	74	32	11	3
1994	47.62	69%	4.90	81	33	14	3
1995	35.10	19%	-7.62	67	23	8	3
1996	48.70	75%	5.98	83	30	11	7
1997	28.26	3%	-14.46	59	21	3	0
1998	51.28	84%	8.56	73	31	16	10
1999	37.77	28%	-4.95	69	21	7	4
2000	44.52	59%	1.80	81	30	9	3
2001	29.64	6%	-13.08	56	17	5	4
2002	39.92	34%	-2.80	80	29	7	3
2003	44.37	56%	1.65	80	30	12	3
2004	44.57	63%	1.85	75	28	9	5
2005	43.67	50%	0.95	87	31	7	3
2006	52.89	94%	10.17	92	30	10	6
2007	39.47	31%	-3.24	66	24	11	4
2008	54.46	97%	11.75	92	34	13	7
2009	43.49	47%	0.77	79	31	11	3
2010	49.66	81%	6.94	67	31	14	7
2011	52.39	91%	9.67	86	42	15	3
2012	36.73	22%	-5.99	63	29	8	2
2013	40.36	38%	-2.36	67	26	11	4
2014	45.25	66%	2.53	79	30	11	5
2015	34.69	16%	-8.03	66	25	7	3
2016	32.89	13%	-9.83	67	22	7	1
2017	41.23	41%	-1.49	79	29	10	3
2018	49.52	78%	6.81	89	38	16	5
2019	48.41	72%	5.70	100	28	12	3
2020	36.83	25%	-5.89	70	28	7	4
2021	52.33	88%	9.61	87	38	17	7
2022	31.24	9%	-11.48	72	18	4	1
Average	42.72	--	--	**76**	**28**	**10**	**4**

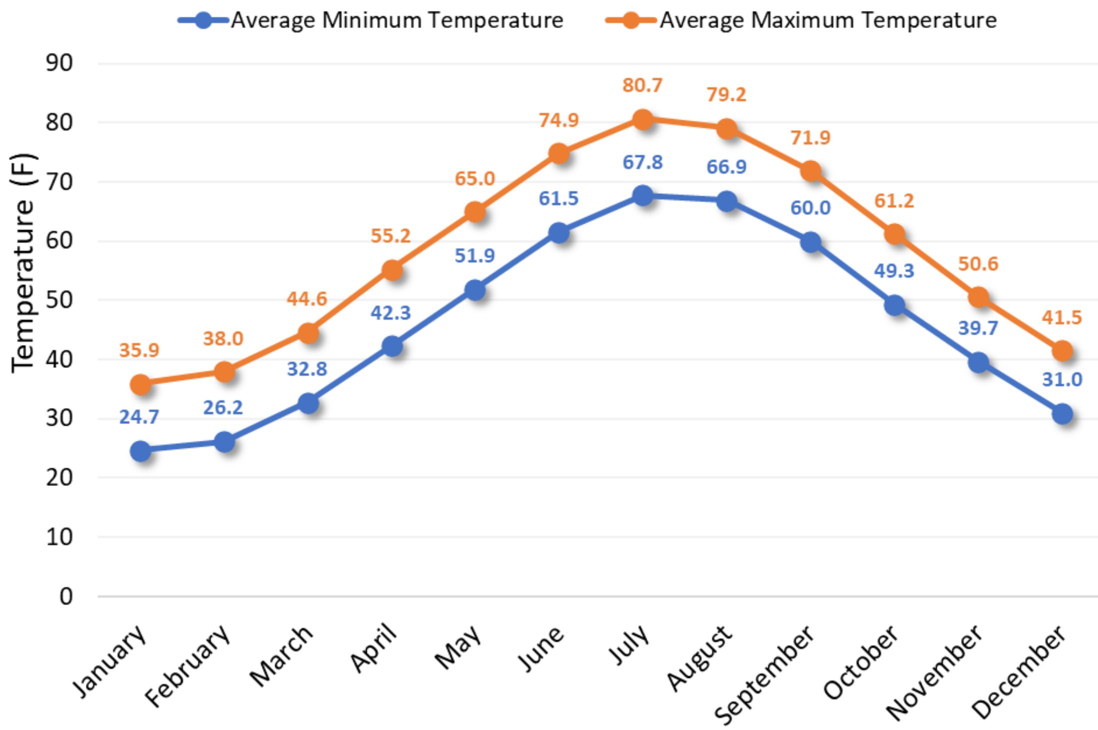

Figure 3-3. Average daily minimum and maximum temperature by month for 1992-2022.

There are currently 15 HRU time series of runoff and pollutant loads available for use in the Opti-Tool (Table 3-2). While these HRU time series cover a range of typical conditions found in urban watersheds, the pervious land use categories are more limited. For example, Forest and Agriculture are limited to type B soils. Because the Mystic River Watershed include a broader distribution of soil types for these HRU categories, the Opti-Tool was updated with new additional time series for Forest and Agriculture HRUs on A, C, and D soils to better represent the hydrology and water quality within the watershed. These additional time series were created by adding land use categories with the appropriate hydrologic and water quality parameters (e.g., infiltration rates, buildup, and washoff rates) to the Opti-Tool's calibrated SWMM model. Specifically, buildup and washoff values for *E. coli* from pervious LULC categories were needed; the updated annual average loading rates used are shown in Table 3-3.

Table 3-2. Existing Opti-Tool HRU time series

Opti-Tool Category	Land Use	Soil
Agriculture_I	Agriculture	IMP
Agriculture_B	Agriculture	B
Commercial_I	Commercial	IMP
Forest_I	Forest	IMP
Forest_B	Forest	B
HighDensityRes_I	High Density Residential	IMP
Highway_I	Highway	IMP
LowDensityRes_I	Low Density Residential	IMP
MedDensityRes_I	Medium Density Residential	IMP
OpenSpace_I	Open Space	IMP
Pervious_A	Pervious	A
Pervious_B	Pervious	B
Pervious_C	Pervious	C
Pervious_CD	Pervious	C/D
Pervious_D	Pervious	D

Table 3-3. Existing and updated annual average *E. coli* loading rates for Opti-Tool LULC categories

Opti-Tool Category	Existing Rate (mpn/ac/yr)	Updated Rate (mpn/ac/yr)	Reference
Pervious_A	N/A	6.37E+10	(CDM Smith, 2012)
Pervious_B	N/A	3.17E+11	(CDM Smith, 2012)
Pervious_C	N/A	6.76E+11	(CDM Smith, 2012)
Pervious_D	N/A	1.22E+12	(CDM Smith, 2012)
Forest_A	N/A	6.37E+09	(CDM Smith, 2012)
Forest_B	N/A	3.17E+10	(CDM Smith, 2012)
Forest_C	N/A	6.76E+10	(CDM Smith, 2012)
Forest_D	N/A	1.22E+11	(CDM Smith, 2012)
Agriculture_A	N/A	2.53E+09	(Vidon et al., 2009)
Agriculture_B	N/A	1.26E+10	(Vidon et al., 2009)
Agriculture_C	N/A	2.68E+10	(Vidon et al., 2009)
Agriculture_D	N/A	4.86E+10	(Vidon et al., 2009)
Commercial_I	1.00E+10	9.92E+09	(CDM Smith, 2012)
HigDensityRes_I	2.04E+12	2.02E+12	(CDM Smith, 2012)
MedDensityRes_I	2.04E+12	2.02E+12	(CDM Smith, 2012)
LowDensityRes_I	2.04E+12	2.02E+12	(CDM Smith, 2012)
Highway_I	2.38E+07	2.36E+07	(CDM Smith, 2012)
Forest_I	3.00E+11	2.98E+11	(CDM Smith, 2012)
OpenSpace_I	3.00E+12	2.98E+12	(CDM Smith, 2012)
Agriculture_I	N/A	1.18E+11	(CDM Smith, 2012)

Note: N/A values do not exist in previous Opti-Tool versions.

3.2 Pollutant Loading Results and Summaries

3.2.1 *Unit–Area Loading*

The results of the SWMM model simulation, which include 31-years of hourly surface runoff and pollutant loading timeseries. These time series are summarized as annual average rates in Table 3-4. It should be noted that Developed Open Space and Open Space HRUs use the same Pervious categories from the SWMM model. Because the focus of the Opti-Tool is management of runoff from the land surface, no loading rates were created for the Water HRU. Heat maps for unit-area flow and pollutant loading are shown in Figure 3-4 to Figure 3-9.

Table 3-4. Annual average (1992-2022) unit area stormwater loading rates

Mapped HRU	HRU Description	SWMM HRU	FLOW (MG/ac/yr)	TP (lb/ac/year)	TN (lb/ac/year)	Zn (lb/ac/year)	TSS (lb/ac/year)	*E. coli* (mpn/ac/year)
1000	PavedAgriculture	Agriculture_I	1.09	1.50	11.44	0.71	646.58	1.14E+11
2000	PavedCommercial	Commercial_I	1.09	1.80	15.25	1.37	376.05	9.59E+09
3000	PavedForest	Forest_I	1.09	1.50	11.44	0.71	646.58	2.88E+11
4000	PavedHigh DensityResidential	HigDensityRes_I	1.09	2.38	14.26	0.71	437.39	1.95E+12
5000	PavedMedium DensityResidential	MedDensityRes_I	1.09	1.97	14.26	0.71	437.39	1.95E+12
6000	PavedOpenLand	OpenSpace_I	1.09	1.50	11.44	0.99	646.58	2.88E+12
7000	PavedTransportation	Highway_I	1.09	1.39	10.26	1.76	1,474.83	2.28E+07
8100	Agriculture-A	Agriculture_A	0.01	0.10	0.59	0.01	6.81	3.08E+09
8200	Agriculture-B	Agriculture_B	0.07	0.43	2.49	0.02	28.59	1.18E+10
8300	Agriculture-C	Agriculture_C	0.15	0.79	5.20	0.05	58.85	2.52E+10
8400	Agriculture-D	Agriculture_D	0.28	1.38	7.97	0.07	92.73	4.43E+10
9100	DevelopedOpenSpace-A	Pervious_A	0.01	0.03	0.26	0.01	6.81	7.76E+10
9200	DevelopedOpenSpace-B	Pervious_B	0.07	0.11	1.11	0.02	28.59	2.97E+11
9300	DevelopedOpenSpace-C	Pervious_C	0.15	0.21	2.33	0.05	58.85	6.35E+11
9400	DevelopedOpenSpace-D	Pervious_D	0.28	0.37	3.64	0.07	92.73	1.12E+12
10100	Forest-A	Forest_A	0.01	0.03	0.12	0.01	6.81	7.76E+09
10200	Forest-B	Forest_B	0.07	0.11	0.54	0.04	28.59	2.97E+10
10300	Forest-C	Forest_C	0.15	0.21	1.16	0.09	58.85	6.35E+10
10400	Forest-D	Forest_D	0.28	0.37	1.88	0.14	92.73	1.12E+11
11100	OpenSpace-A	Pervious_A	0.01	0.03	0.26	0.01	6.81	7.76E+10
11200	OpenSpace-B	Pervious_B	0.07	0.11	1.11	0.02	28.59	2.97E+11
11300	OpenSpace-C	Pervious_C	0.15	0.21	2.33	0.05	58.85	6.35E+11
11400	OpenSpace-D	Pervious_D	0.28	0.37	3.64	0.07	92.73	1.12E+12
12000	Water	NA	-	-	-	-	-	-

Table 3-5. Annual average (1992-2022) total flow and pollutant loading for the Mystic River Watershed

HRU Code	HRU Description	FLOW (MG/year)	TP (lb/year)	TN (lb/year)	Zn (lb/year)	TSS (lb/year)	*E. coli* (mpn/year)
1000	PavedAgriculture	11.6	16.0	121.6	7.5	6,873.4	1.21E+12
2000	PavedCommercial	7,762.5	12,852.9	108,815.2	9,796.1	2,682,606.9	6.84E+13
3000	PavedForest	--	--	--	--	--	--
4000	PavedHighDensityResidential	4,632.1	10,137.0	60,695.4	3,007.3	1,861,900.8	8.32E+15
5000	PavedMediumDensityResidential	4,609.1	8,334.5	60,394.1	2,992.4	1,852,656.8	8.28E+15
6000	PavedOpenLand	653.8	901.9	6,874.5	594.8	388,478.7	1.73E+15
7000	PavedTransportation	6,627.4	8,483.3	62,495.4	10,691.9	8,982,633.2	1.39E+11
8100	Agriculture-A	0.3	2.7	15.9	0.1	183.9	8.32E+10
8200	Agriculture-B	1.5	9.8	56.3	0.5	646.1	2.67E+11
8300	Agriculture-C	4.3	22.6	148.2	1.3	1,677.4	7.18E+11
8400	Agriculture-D	0.6	3.2	18.3	0.2	212.9	1.02E+11
9100	DevelopedOpenSpace-A	43.5	92.4	921.6	18.6	24,566.6	2.80E+14
9200	DevelopedOpenSpace-B	51.7	87.4	861.3	17.1	22,268.4	2.31E+14
9300	DevelopedOpenSpace-C	449.6	618.3	6,883.4	137.1	173,967.1	1.88E+15
9400	DevelopedOpenSpace-D	113.8	148.2	1,474.0	28.3	37,503.2	4.52E+14
10100	Forest-A	74.7	158.5	742.2	64.0	42,129.3	4.80E+13
10200	Forest-B	152.7	258.0	1,245.4	100.8	65,767.3	6.84E+13
10300	Forest-C	610.3	839.3	4,651.7	372.1	236,131.8	2.55E+14
10400	Forest-D	478.4	622.9	3,199.5	238.1	157,609.7	1.90E+14
11100	OpenSpace-A	10.1	21.4	213.0	4.3	5,677.8	6.47E+13
11200	OpenSpace-B	66.2	111.8	1,102.7	21.9	28,509.2	2.96E+14
11300	OpenSpace-C	190.9	262.5	2,922.1	58.2	73,850.6	7.97E+14
11400	OpenSpace-D	62.4	81.3	808.5	15.5	20,571.0	2.48E+14
12000	Water	--	--	--	--	--	--
	Total	**26,607.7**	**44,065.6**	**324,660.3**	**28,168.2**	**16,666,422.1**	**2.32E+16**

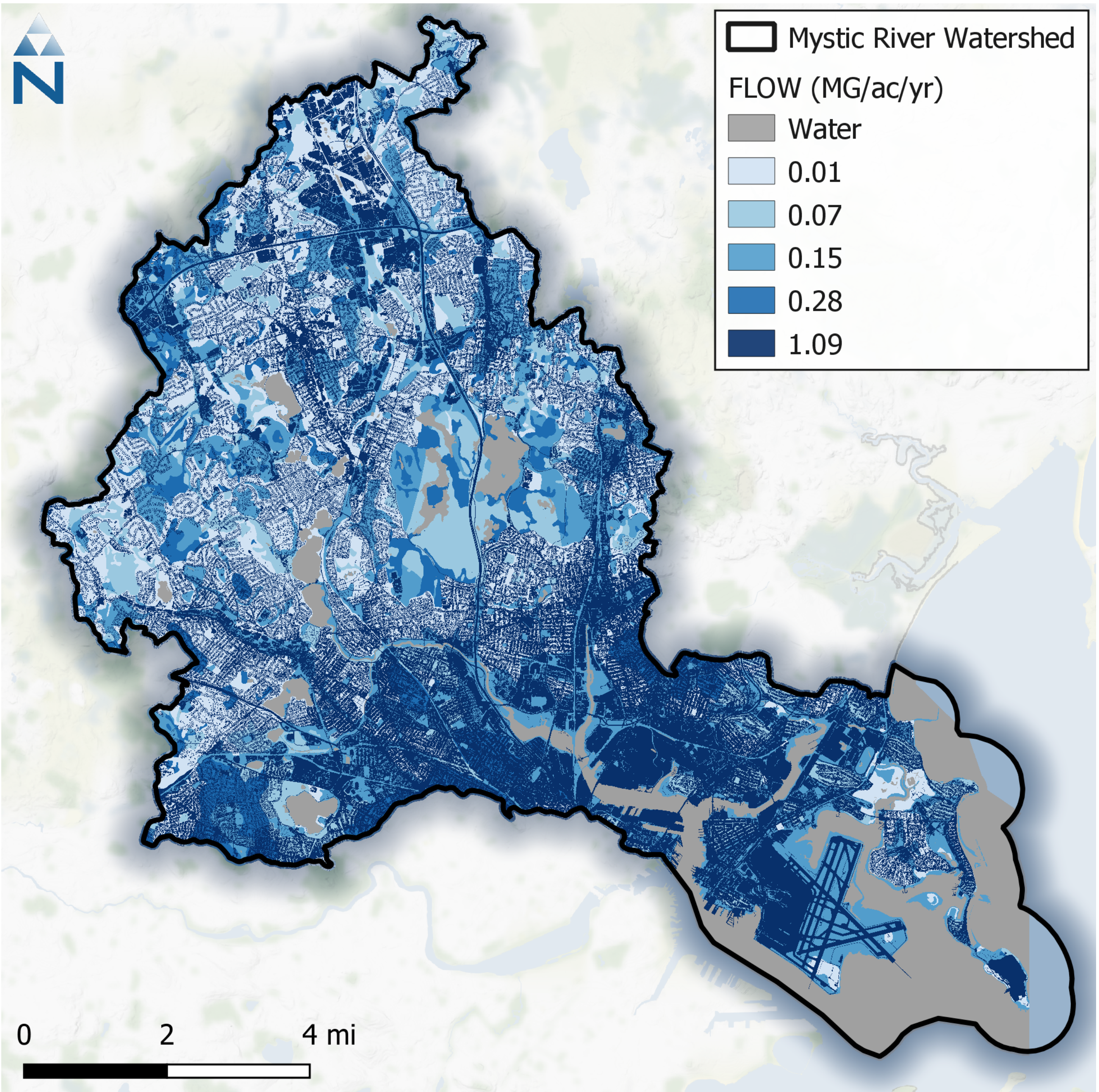

Figure 3-4. Heat map of annual average (1992-2022) unit-area surface runoff.

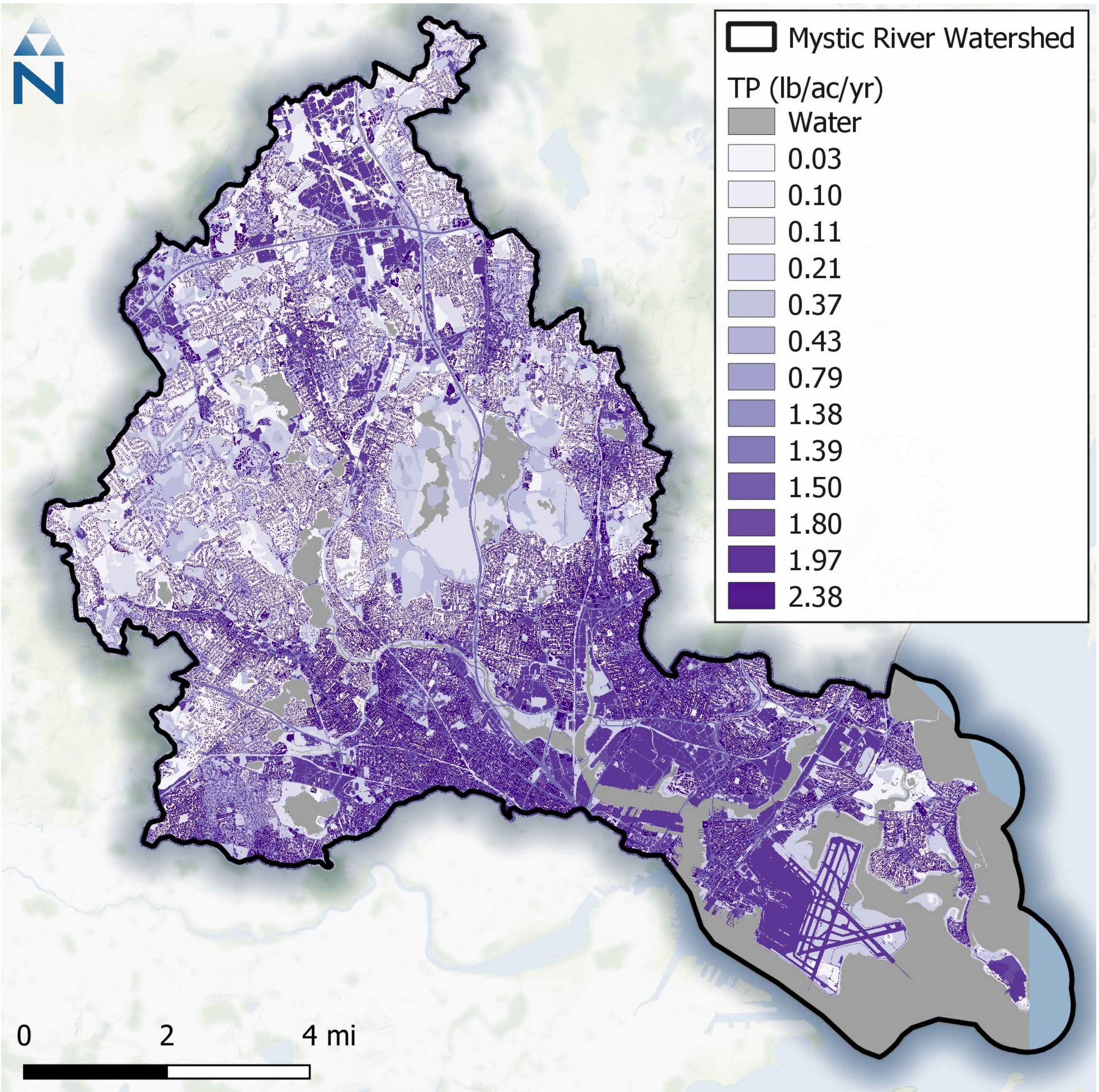

Figure 3-5. Heat map of annual average (1992-2022) unit-area TP load.

Figure 3-6. Heat map of annual average (1992-2022) unit-area TN load.

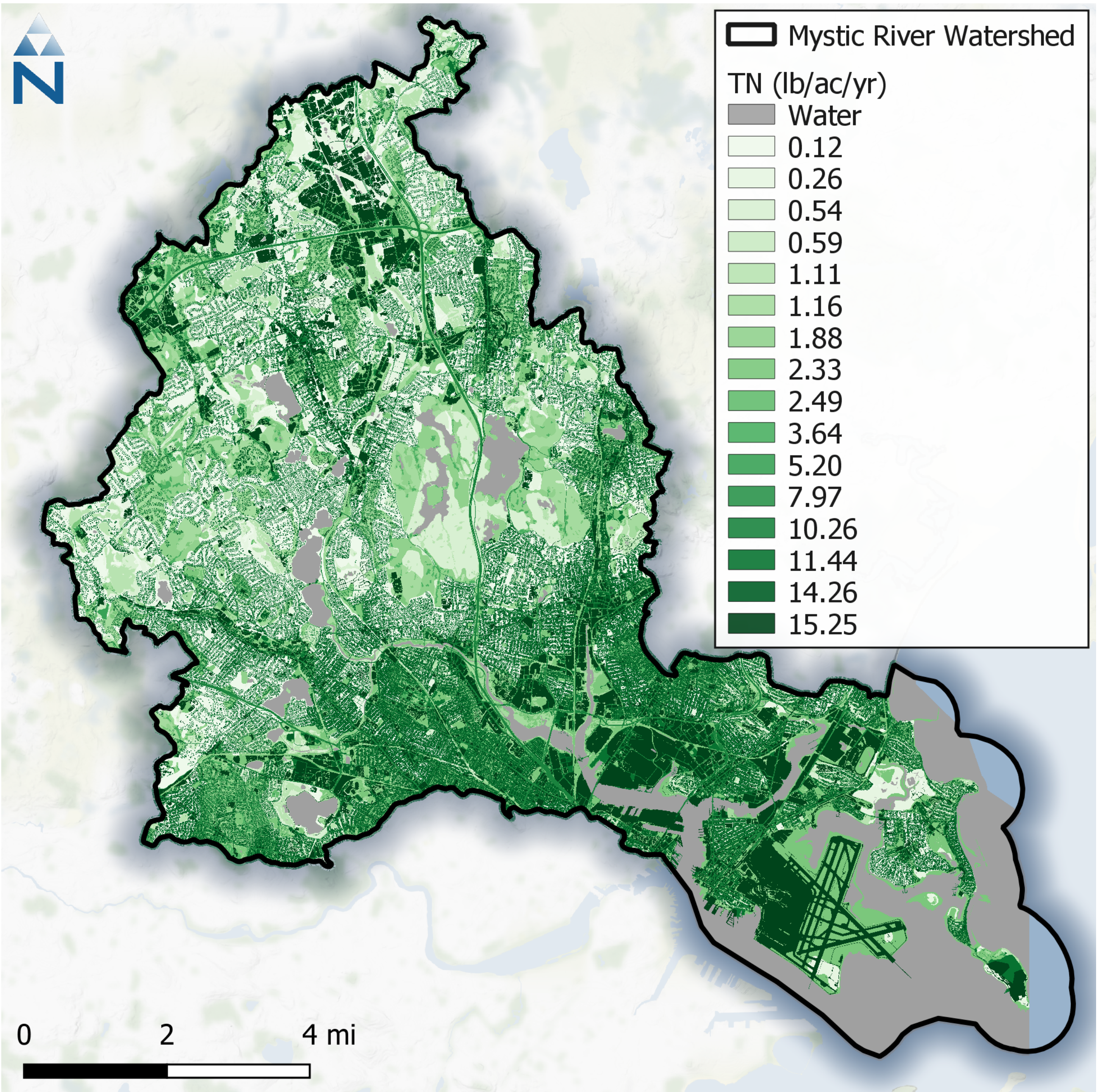

Figure 3-7. Heat map of annual average (1992-2022) unit-area TN load.

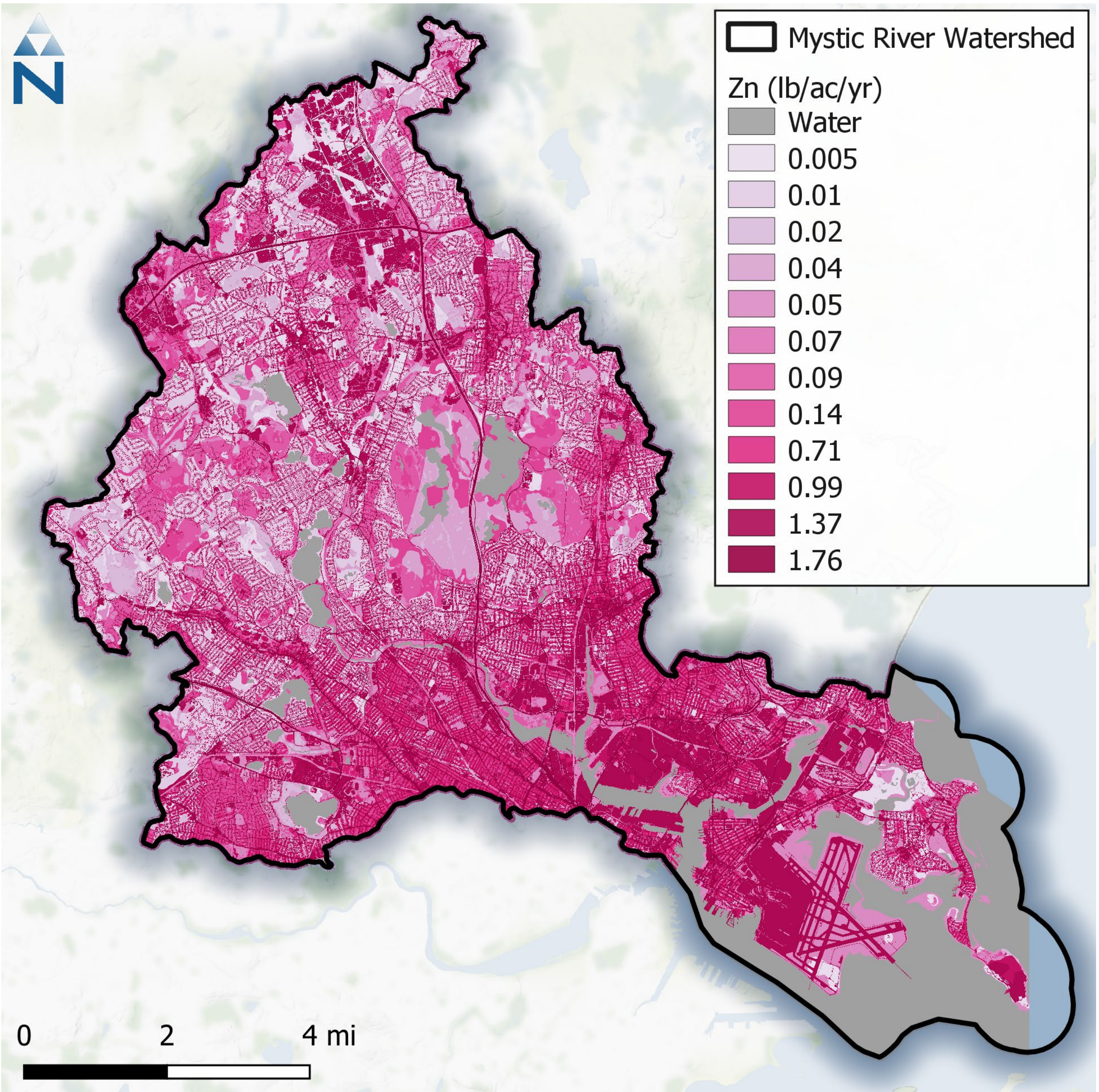

Figure 3-8. Heat map of annual average (1992-2022) unit-area Zn load.

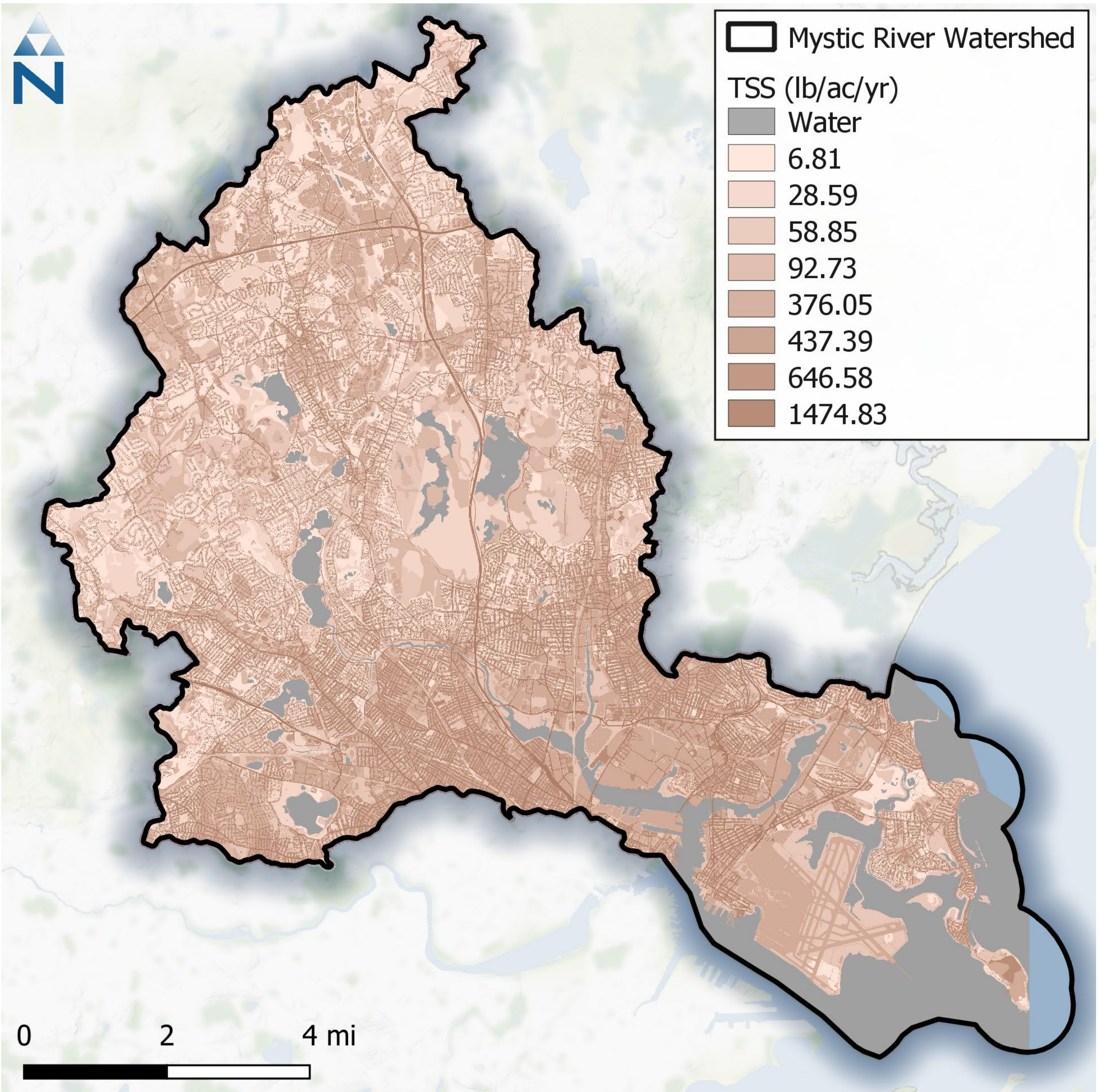

Figure 3-9. Heat map of annual average (1992-2022) unit-area TSS load.

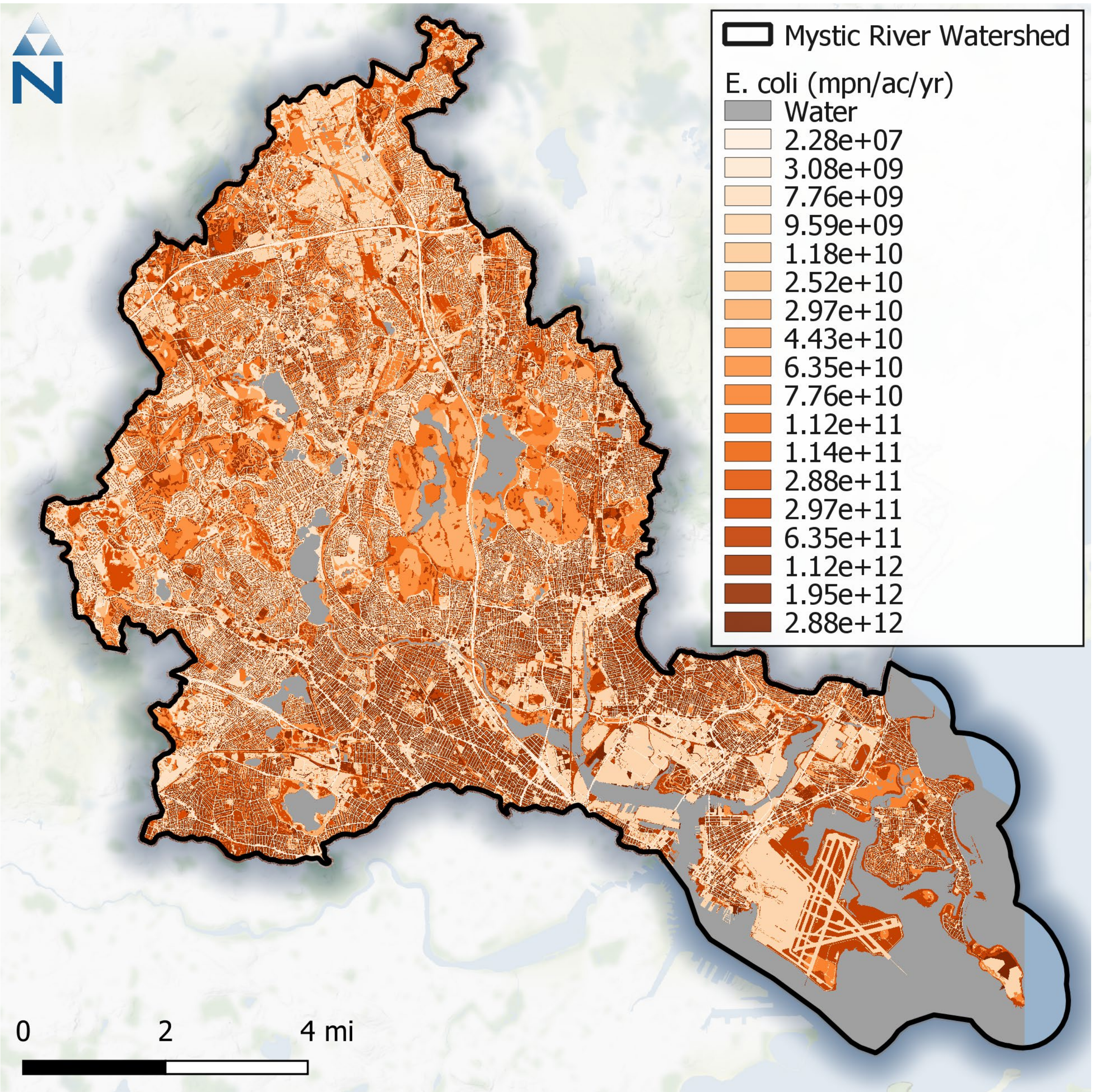

Figure 3-10. Heat map of annual average (1992-2022) unit-area *E. coli* load.

3.2.2 *Municipality Loading*

Total annual average flow and pollutant loading was calculated for each municipality within the Mystic River Watershed (Table 3-6). Area normalized heat maps for total annual average flow and pollutant loading by municipality are shown in Figure 3-10 to Figure 3-15.

Table 3-6. Annual average (1992-2022) total flow and pollutant loading by municipality

Municipality	Area in Watershed		FLOW (MG/yr)	TP (lb/yr)	TN (lb/yr)	Zn (lb/yr)	TSS (lb/yr)	*E. coli* (mpn/yr)
	Acre	%						
ARLINGTON	3,246.6	92.5%	1,731.4	2,919.6	20,486.4	1,772.3	1,229,929.2	1.82E+15
BELMONT	2,185.6	72.4%	1,189.1	1,964.4	14,005.3	1,176.0	798,193.1	1.27E+15
BOSTON	3,852.6	12.0%	2,816.1	4,638.5	37,395.7	3,268.0	1,358,935.3	1.51E+15
BURLINGTON	1,287.8	17.0%	614.8	978.3	7,468.0	654.7	368,656.1	4.82E+14
CAMBRIDGE	1,615.1	35.5%	1,021.3	1,734.1	12,611.7	1,083.6	612,966.3	8.84E+14
CHELSEA	1,418.7	100.0%	1,207.6	2,009.5	14,965.5	1,387.7	760,449.3	8.23E+14
EVERETT	1,709.8	77.8%	1,541.2	2,610.7	19,576.5	1,709.3	866,634.0	1.08E+15
LEXINGTON	2,082.7	19.6%	599.5	967.2	6,969.7	575.7	397,984.3	6.34E+14
MALDEN	1,755.4	54.1%	1,274.8	2,200.6	15,599.8	1,340.8	828,273.6	1.15E+15
MEDFORD	5,409.1	100.0%	2,837.2	4,666.3	33,418.6	2,947.8	1,906,392.7	2.66E+15
MELROSE	1,756.6	57.6%	912.6	1,521.5	10,827.7	887.8	594,820.4	1.02E+15
READING	1,599.7	25.0%	545.7	863.4	6,278.2	554.4	408,707.8	6.22E+14
REVERE	1,139.1	28.9%	788.4	1,323.3	9,665.0	868.3	523,602.4	6.44E+14
SOMERVILLE	1,714.2	64.9%	1,530.3	2,685.8	18,520.8	1,592.8	1,018,251.0	1.47E+15
STONEHAM	4,051.8	95.3%	1,525.6	2,441.8	17,618.1	1,525.6	1,013,761.1	1.46E+15
WAKEFIELD	221.0	4.3%	80.5	130.0	916.3	73.8	54,532.9	9.63E+13
WATERTOWN	219.4	8.3%	142.8	254.0	1,732.4	127.5	87,020.1	1.93E+14
WILMINGTON	291.9	2.7%	167.4	268.4	2,219.4	210.2	78,167.6	2.52E+13
WINCHESTER	4,062.2	100.0%	1,505.9	2,436.5	17,627.1	1,488.9	1,003,725.7	1.52E+15
WINTHROP	1,457.3	100.0%	795.5	1,365.4	10,039.2	794.2	472,104.7	8.65E+14
WOBURN	7,989.9	96.5%	3,669.3	5,928.7	45,295.4	4,040.4	2,223,546.5	2.7E+15
Total	**49,066.4**	**89.1%**	**26,496.9**	**43,908.0**	**323,236.7**	**28,079.9**	**16,606,654.3**	**2.29E+16**

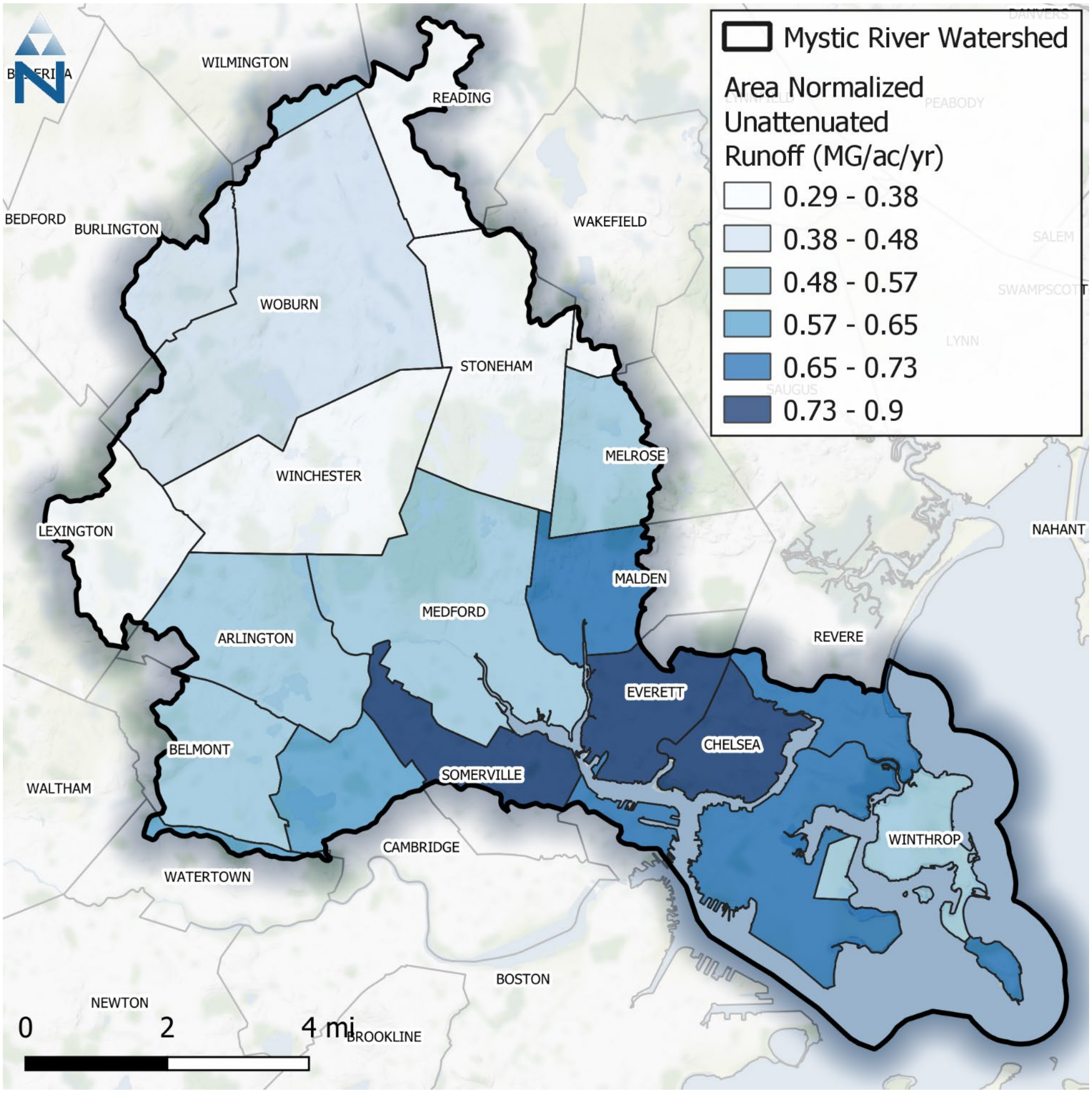

Figure 3-11. Area normalized annual average (1992-2022) total surface runoff by municipality.

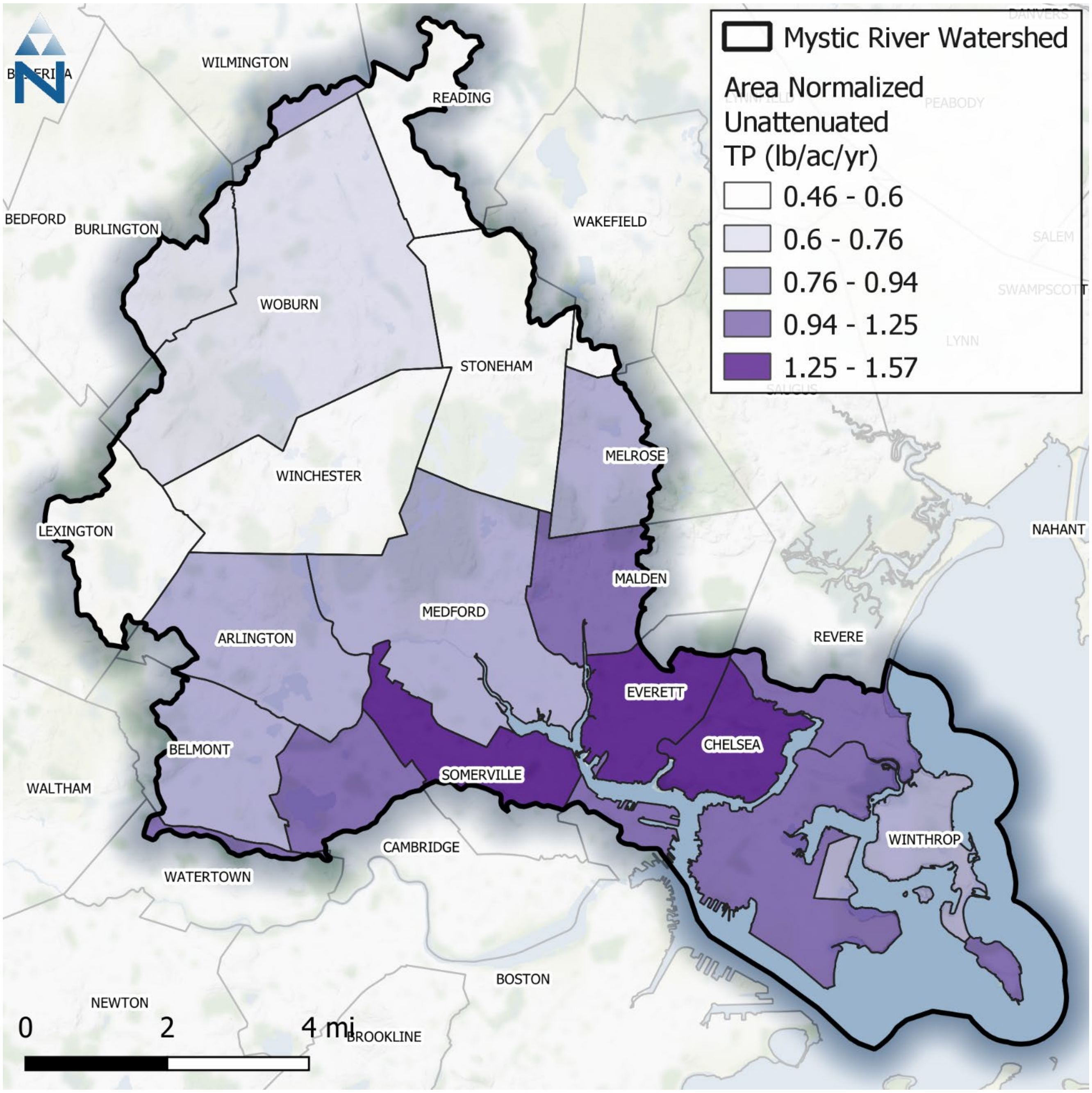

Figure 3-12. Area normalized annual average (1992-2022) TP load by municipality.

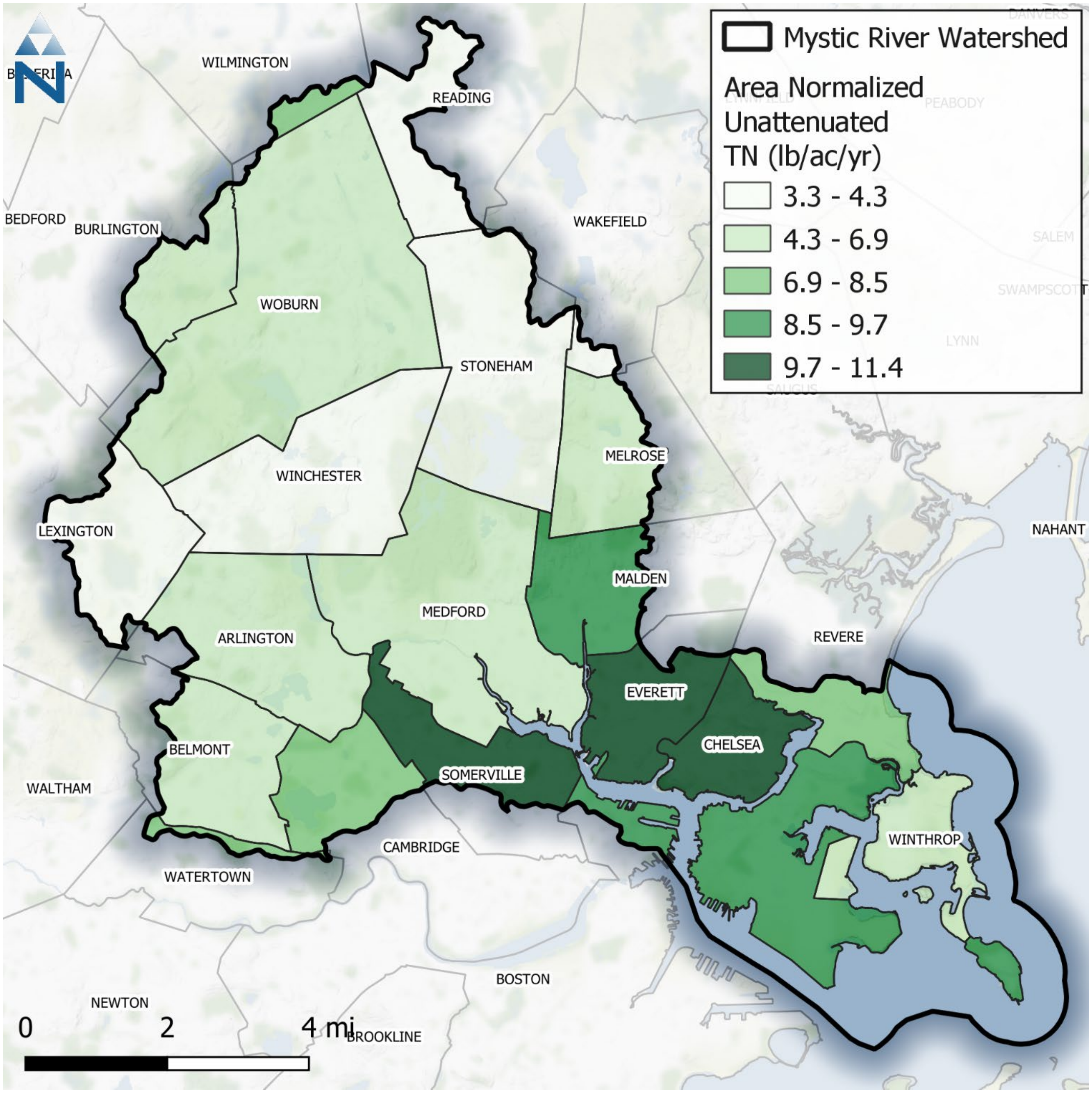

Figure 3-13. Area normalized annual average (1992-2022) TN load by municipality.

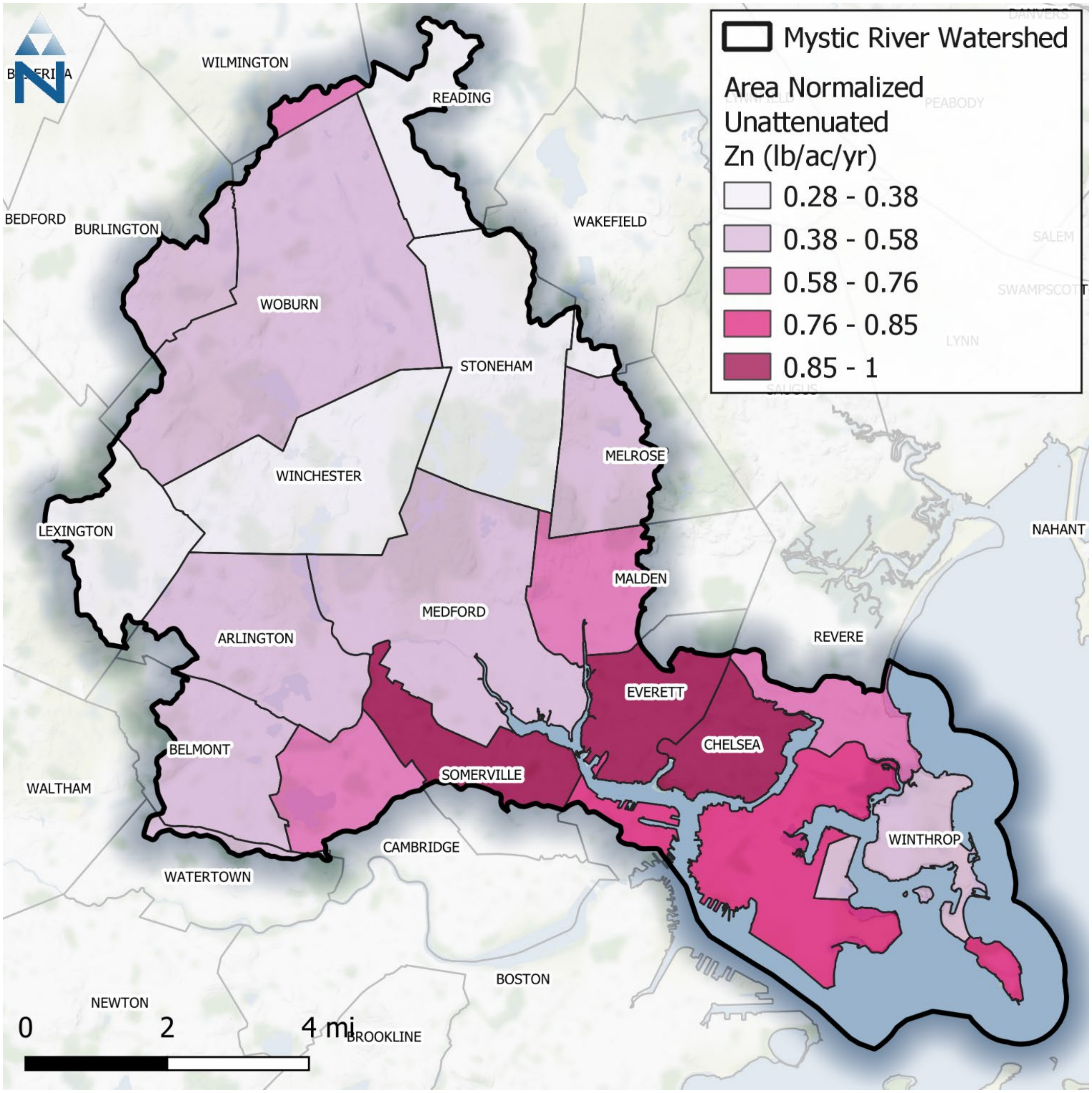

Figure 3-14. Area normalized annual average (1992-2022) Zn load by municipality.

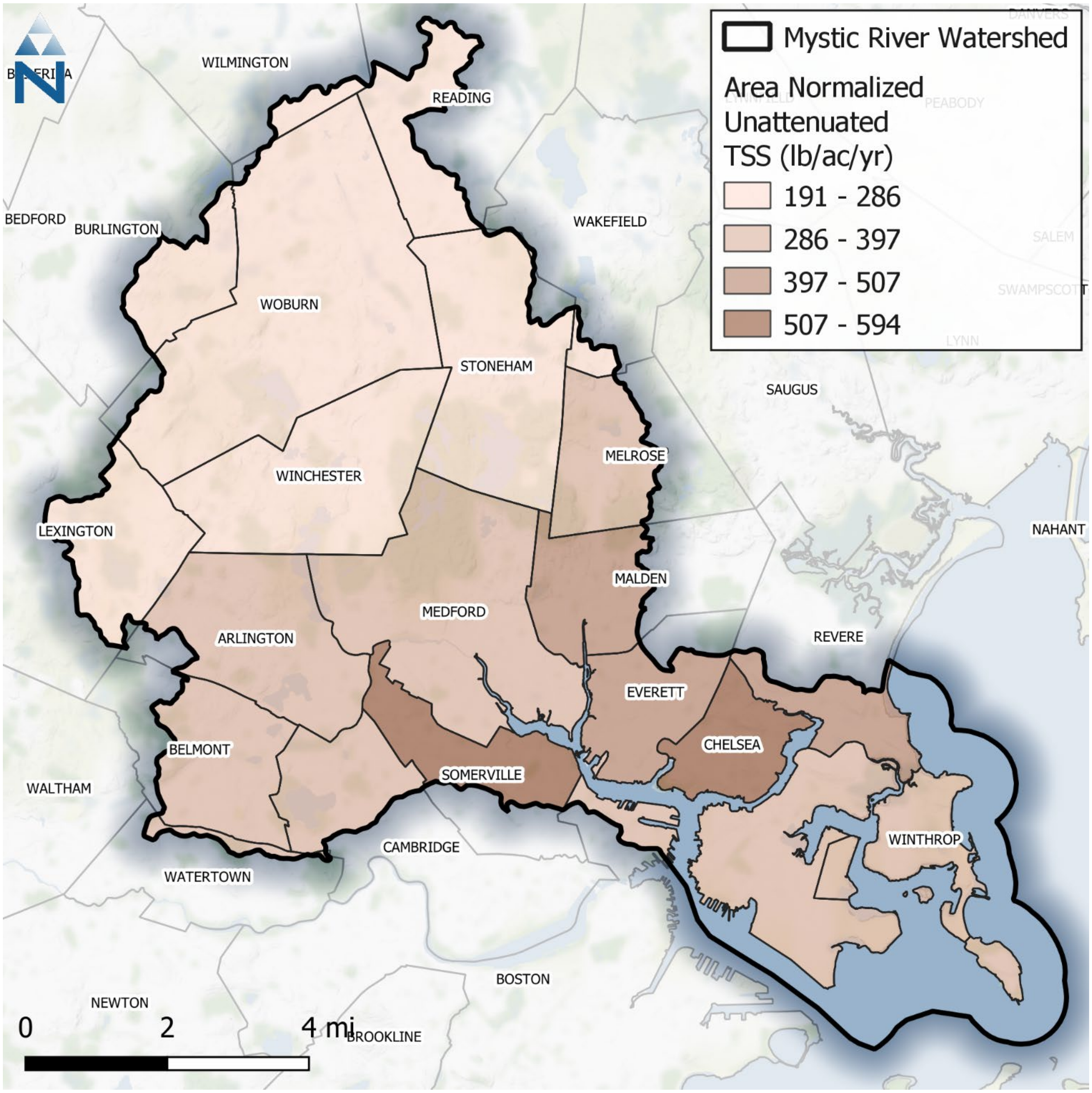

Figure 3-15. Area normalized annual average (1992-2022) TSS load by municipality.

Figure 3-16. Area normalized annual average (1992-2022) *E. coli* load by municipality.

Figure 3-17. Area normalized annual average (1992-2022) *E. coli* load by municipality.

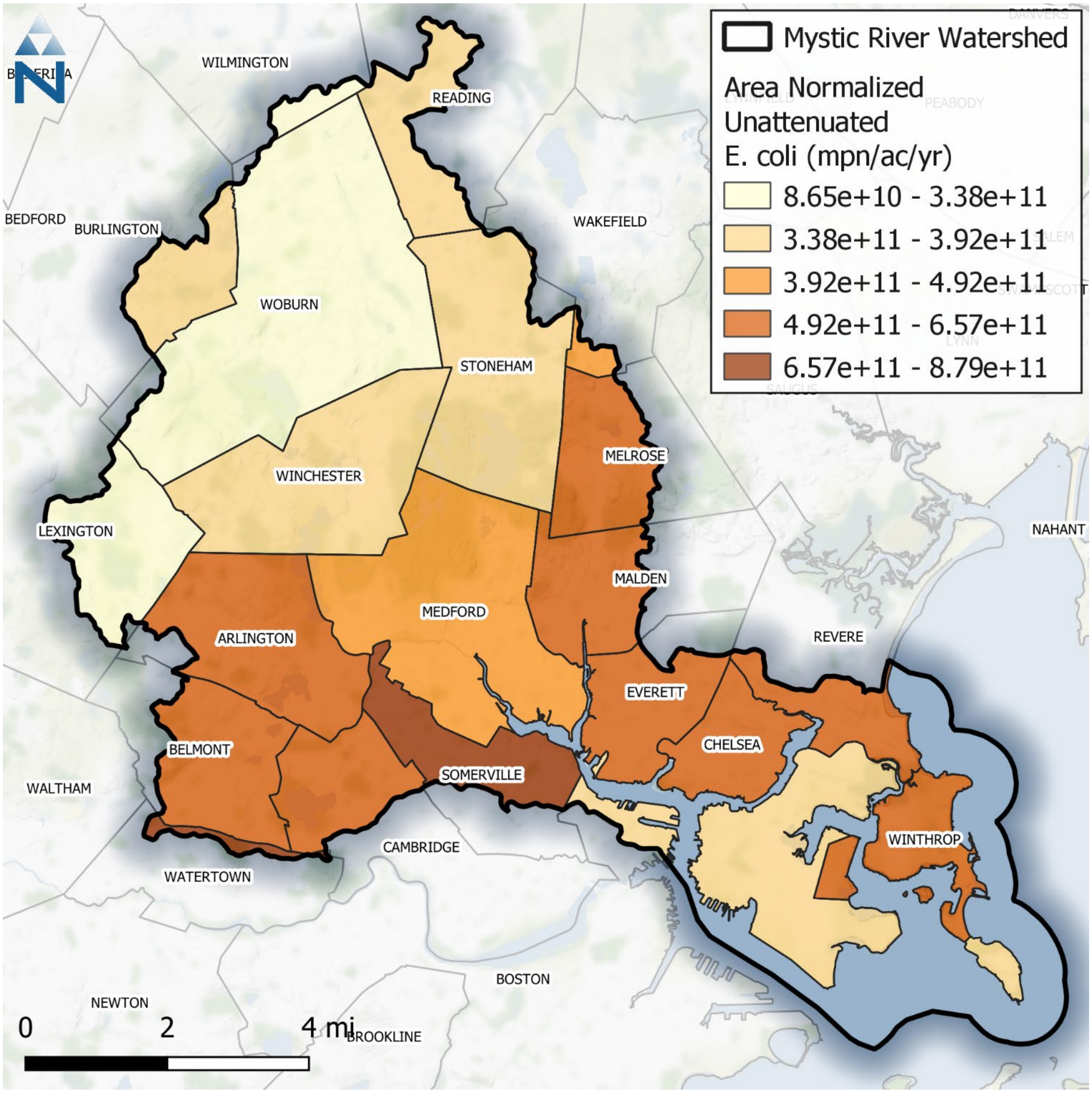

Figure 3-18. Area normalized annual average (1992-2022) *E. coli* load by municipality.

3.2.3 *Subwatershed Loading*

Total annual average flow and pollutant loading was calculated for each subbasin within the Mystic River Watershed (Table 3-7). Heat maps for total annual average flow and pollutant loading by subbasin are shown in Figure 3-16 to Figure 3-21.

3.2.4 *CSS Area Loading*

Total annual average flow and pollutant loading was calculated for each CSS area within the Mystic River Watershed (Table 3-8).

Table 3-7. Annual average (1992-2022) total flow and pollutant loading by subwatershed

Subbasin		Percentage of Mystic Watershed	FLOW (MG/yr)	TP (lb/yr)	TN (lb/yr)	Zn (lb/yr)	TSS (lb/yr)	*E. coli* (mpn/yr)
Name	Area (ac)							
Below Earhart Dam	8,664.5	15.73%	6,661.3	11,114.2	85,431.4	7,525.8	3,698,226.2	4.45E+15
Aberjona River 1	141.2	0.26%	68.6	110.4	822.3	72.5	47,395.8	6.28E+13
Aberjona River 2	266.8	0.48%	110.9	174.2	1,262.2	111.6	82,645.5	1.15E+14
Alewife Brook	4,838.7	8.78%	3,055.9	5,242.4	36,894.1	3,070.2	1,952,909.6	3.15E+15
Blacks Nook Pond	8.8	0.02%	0.6	1.0	5.9	0.4	298.3	5.87E+11
Horn Pond	5,638.0	10.24%	2,245.3	3,620.0	26,811.0	2,286.2	1,421,660.8	2.13E+15
Judkins Pond	9,449.2	17.15%	4,431.7	7,156.8	54,320.4	4,867.2	2,756,748.4	3.32E+15
Lower Mystic Lake	4,357.1	7.91%	1,739.5	2,849.0	20,427.3	1,735.6	1,191,210.9	1.84E+15
Malden River	7,019.8	12.74%	3,757.3	6,300.0	44,939.1	3,823.9	2,435,015.1	3.65E+15
Mill Pond	75.9	0.14%	40.5	63.2	476.6	47.1	30,029.6	2.6E+13
Upper Basin	3,891.8	7.07%	1,920.2	3,157.7	22,290.8	1,968.6	1,310,844.5	1.83E+15
Spy Pond	827.3	1.50%	407.6	665.3	4,687.6	435.9	319,225.1	3.94E+14
Upper Lobe	171.1	0.31%	45.4	74.2	535.6	43.3	31,634.3	5.45E+13
Upper Mystic Lake	1,362.1	2.47%	420.6	679.8	4,940.2	408.2	295,530.9	4.73E+14
Wedge Pond	397.2	0.72%	174.6	288.3	2,096.1	179.8	111,081.0	1.59E+14
Winter Pond	178.0	0.32%	62.6	101.2	720.9	59.9	37,596.5	5.68E+13
Lower Basin	1,633.2	2.96%	1,300.3	2,223.9	15,756.6	1,399.2	864,845.3	1.13E+15
Total	**48,920.8**	**88.81%**	**26,442.9**	**43,821.6**	**322,418.1**	**28,035.5**	**16,586,897.6**	**2.28E+16**

Table 3-8. Annual average (1992-2022) total flow and pollutant loading by CSO area

City	CSO Basin	CSS Area (ac)	FLOW (MG/yr)	TP (lb/yr)	TN (lb/yr)	Zn (lb/yr)	TSS (lb/yr)	*E. coli* (mpn/yr)
Cambridge	Alewife Brook	497.5	402.2	707.1	4,929.4	401.6	247,639.5	4.15E+14
Somerville	Alewife Brook	625.1	537.0	969.2	6,537.4	533.3	347,212.2	5.72E+14
Somerville	Mystic River	914.6	771.7	1,318.0	9,315.6	840.8	527,110.8	6.65E+14
	Total	**2,037.2**	**1,711.0**	**2,994.4**	**20,782.4**	**1,775.7**	**1,121,962.5**	**1.65E+15**

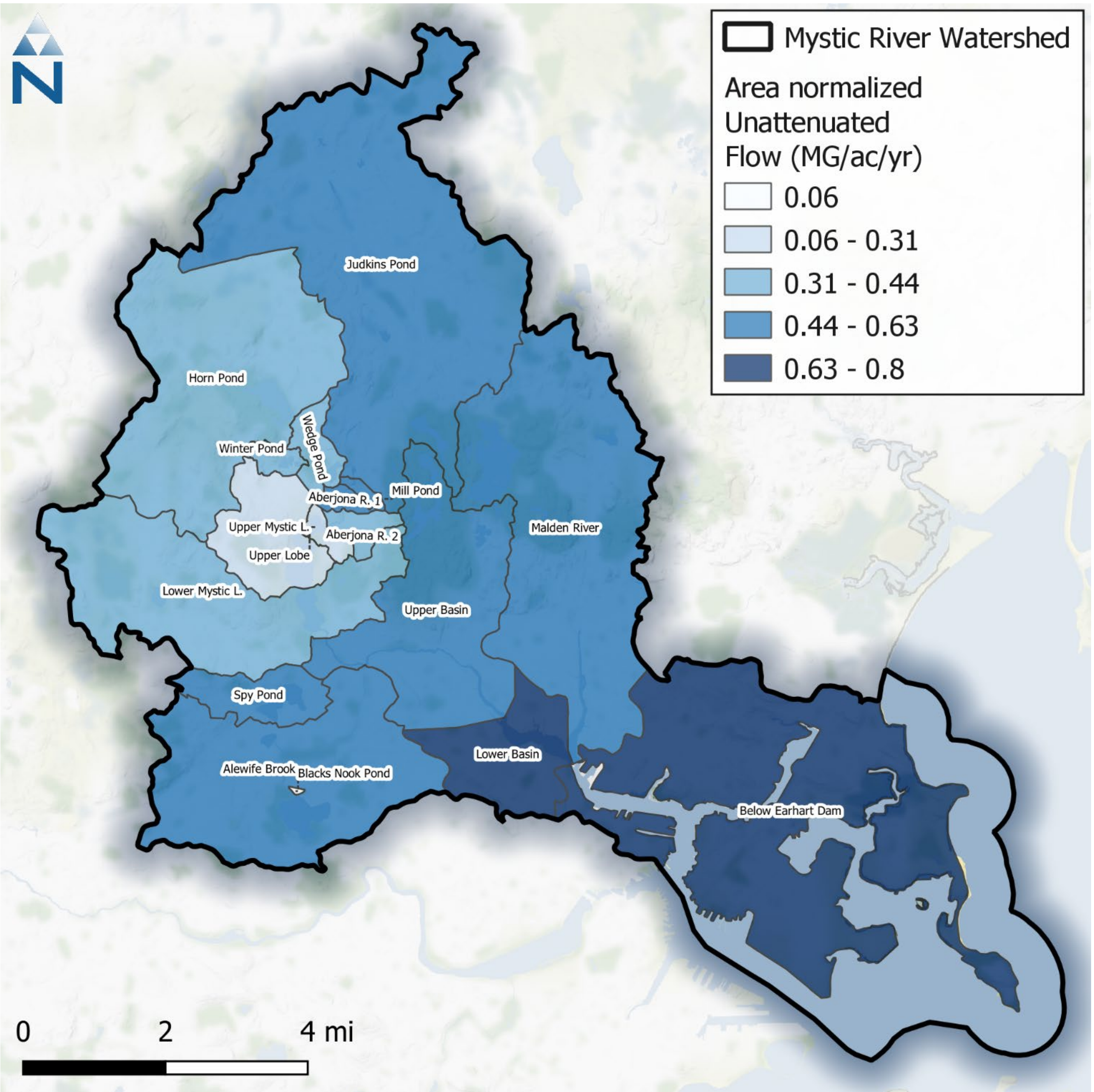

Figure 3-19. Area normalized annual average (1992-2022) total surface runoff by subbasin.

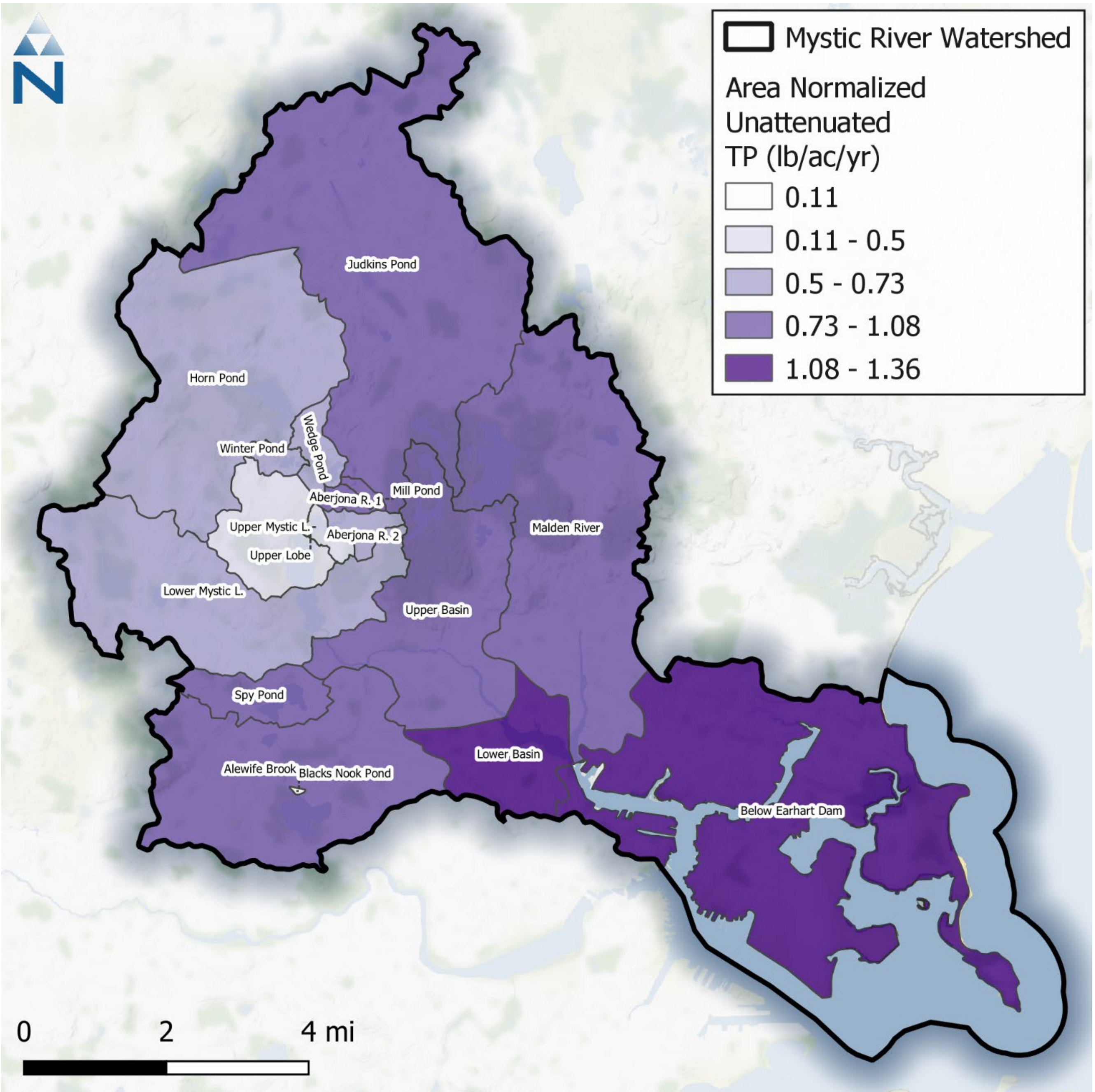

Figure 3-20. Area normalized annual average (1992-2022) total TP load by subbasin.

Figure 3-21. Area normalized annual average (1992-2022) total TN load by subbasin.

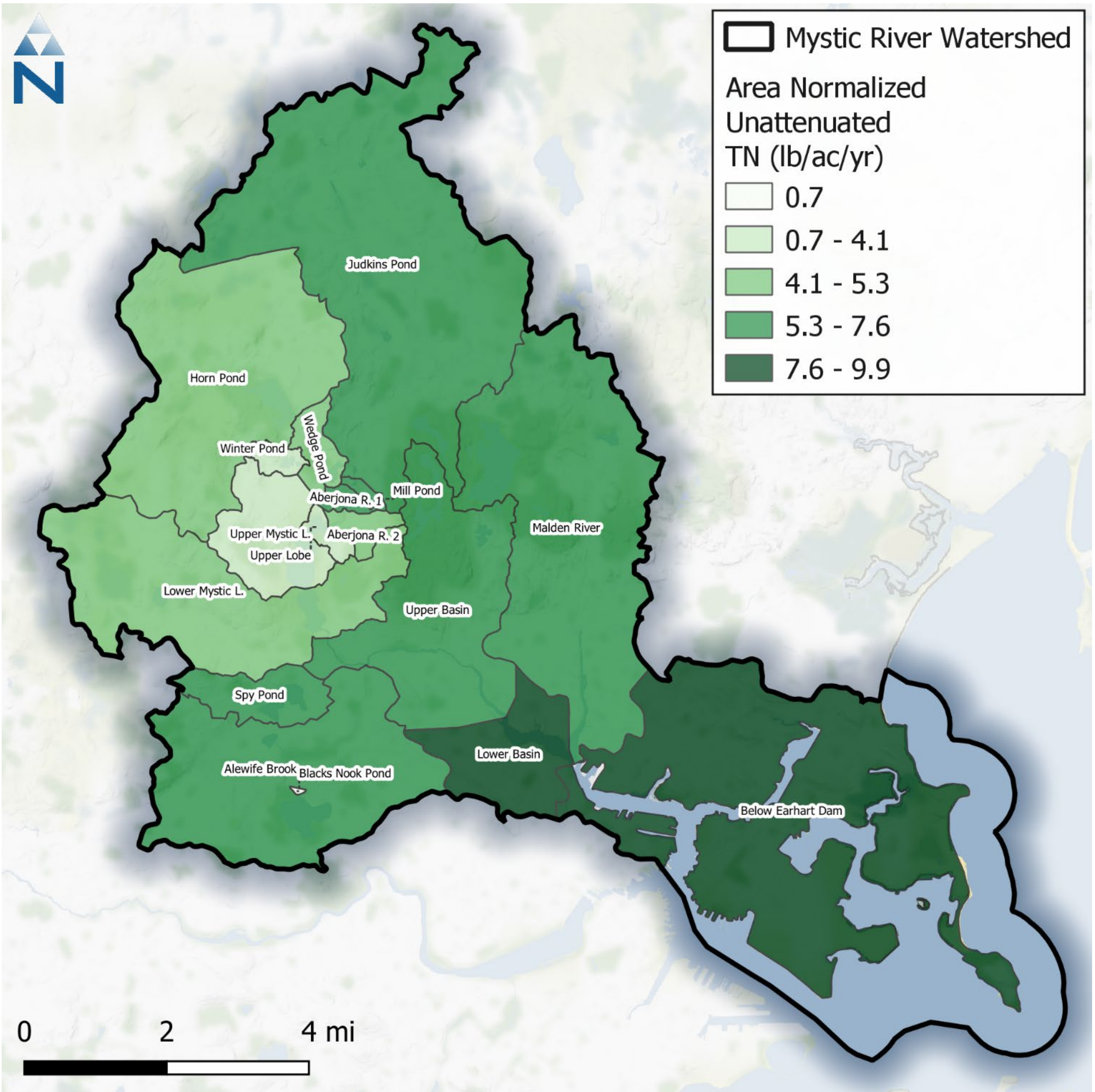

Figure 3-22. Area normalized annual average (1992-2022) total TN load by subbasin.

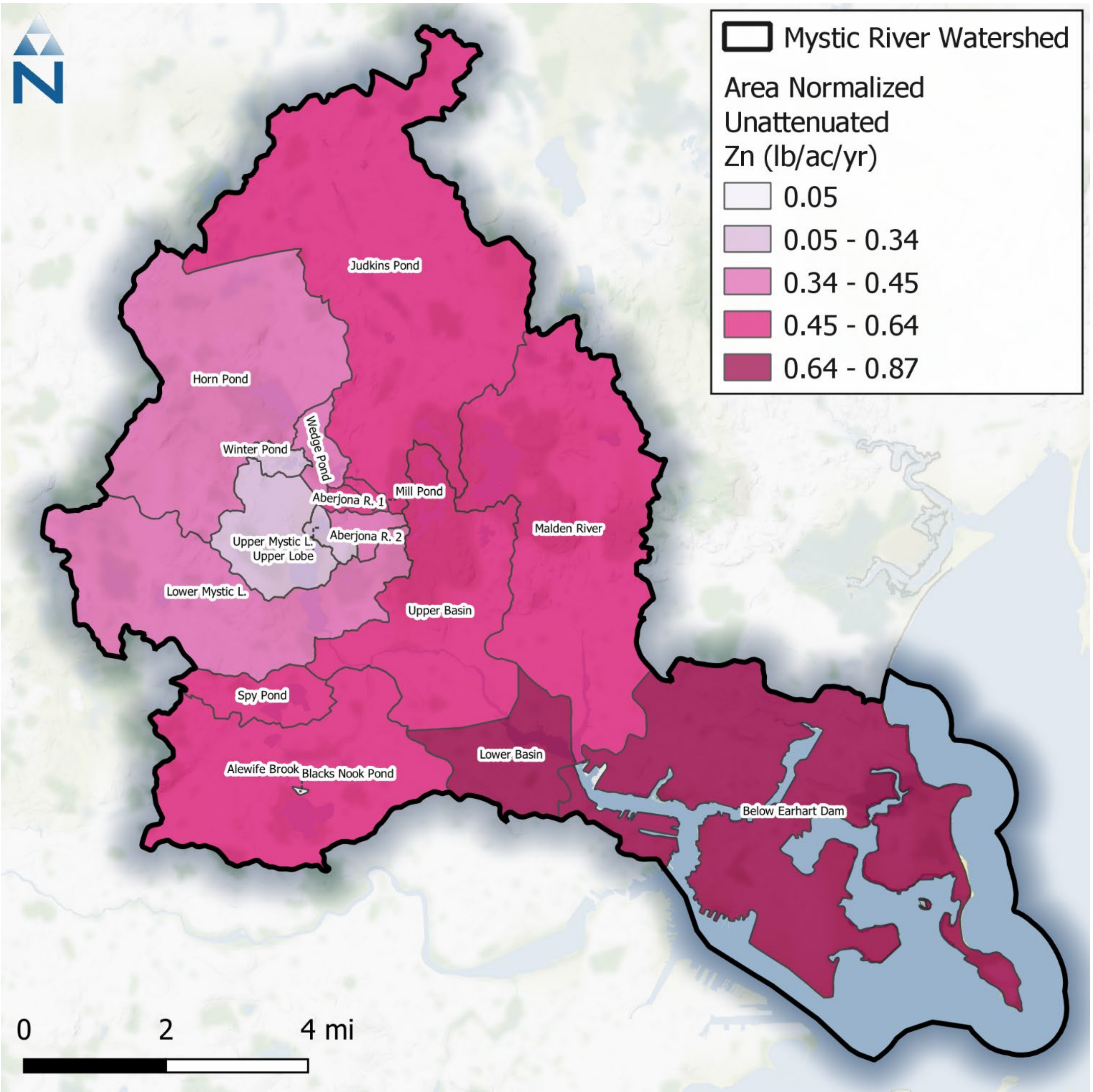

Figure 3-23. Area normalized annual average (1992-2022) total Zn load by subbasin.

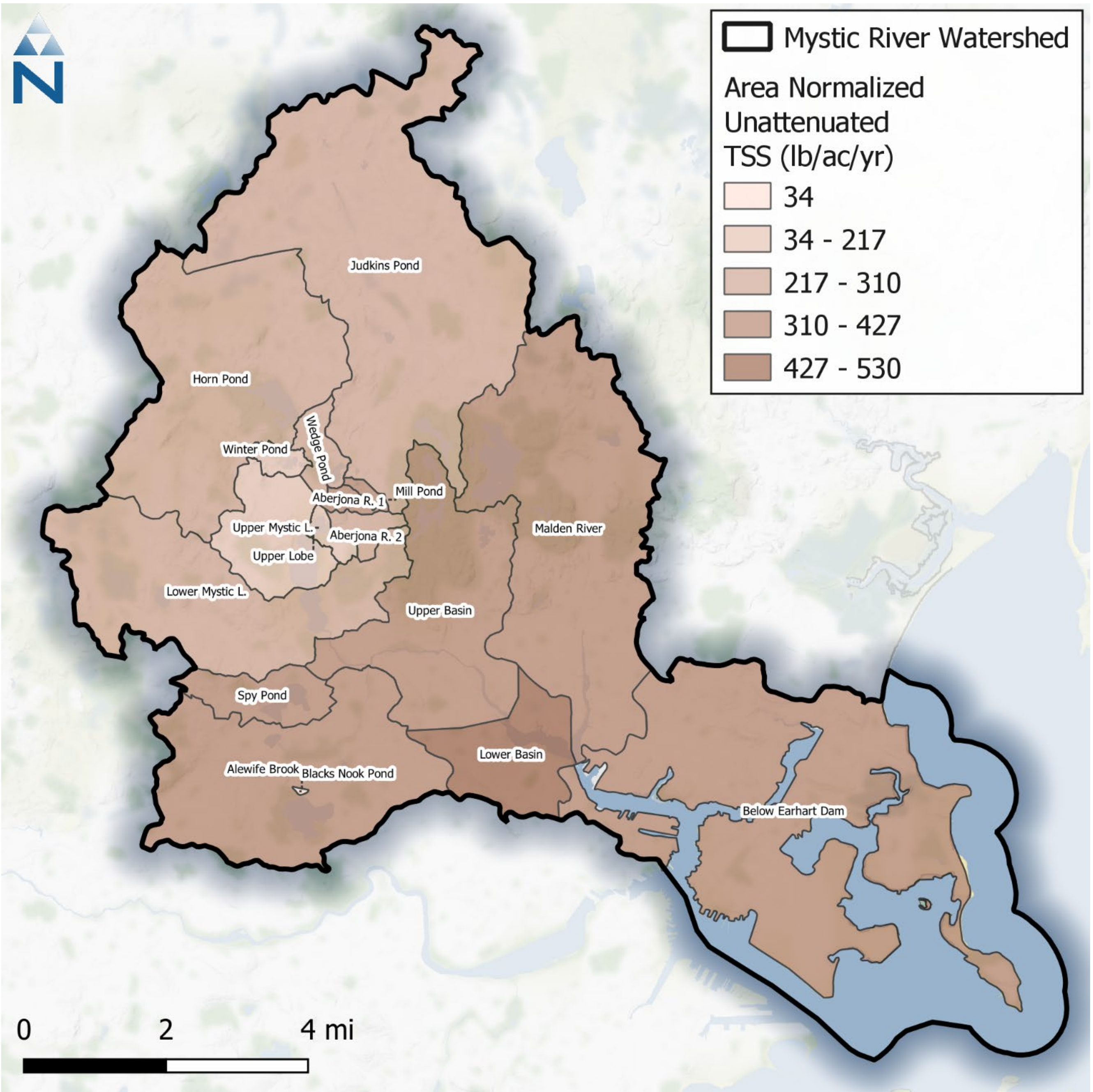

Figure 3-24. Area normalized annual average (1992-2022) total TSS load by subbasin.

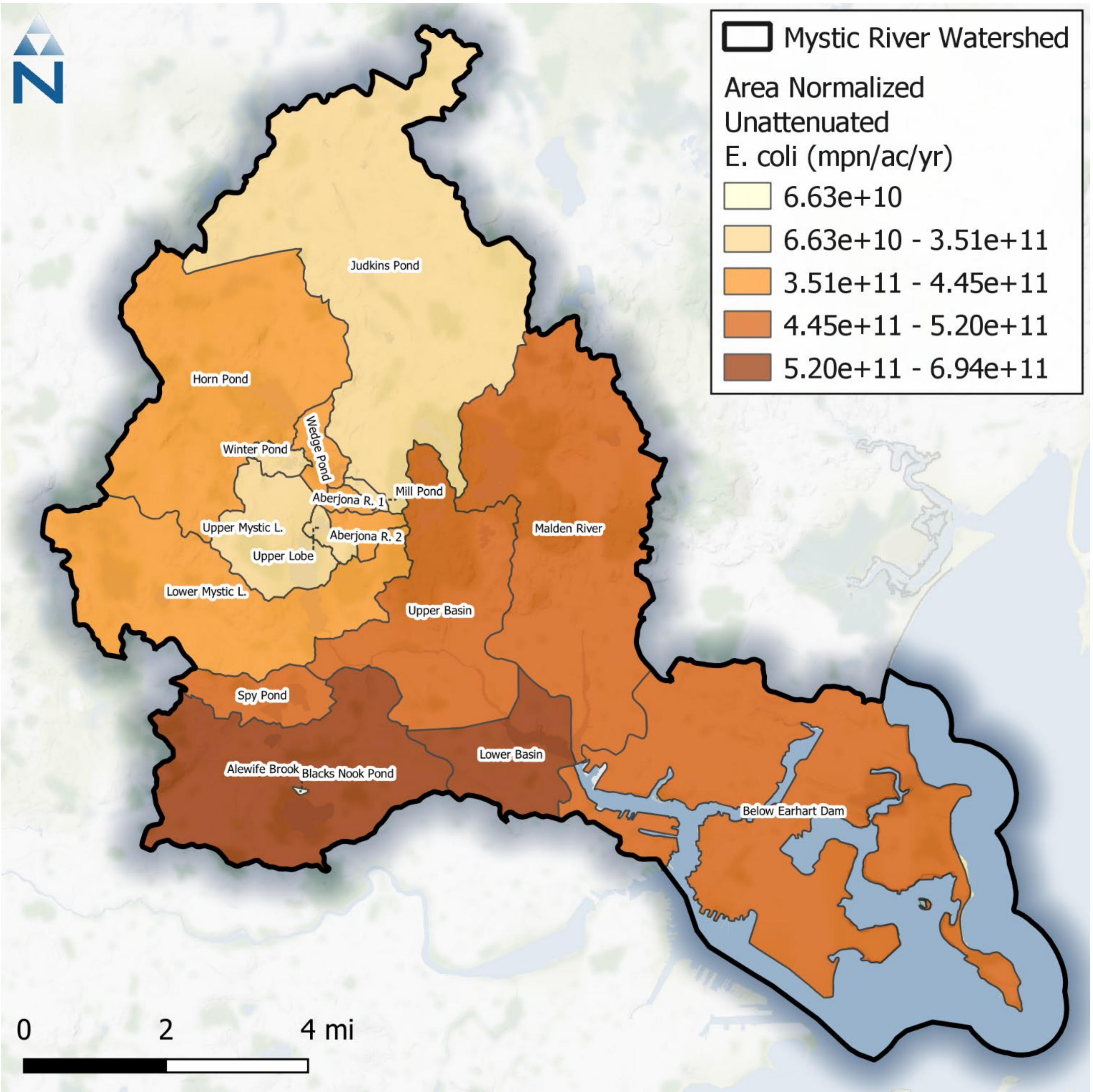

Figure 3-25. Area normalized annual average (1992-2022) total *E. coli* load by subbasin.

3.3 Alternative TMDL TP Adjustment

Development of the Mystic River Alternative TMDL included calibrating attenuation factors so that total routed TP loads from stormwater, groundwater, and CSOs matched observed delivered loads during the 2007-2016 period (USEPA, 2020). The attenuation factors were updated using the most recent HRU distribution and loading (Sections 2 and 3) such that the TP load for each subbasin above the Earhart Dam is equal to the load in the Alternative TMDL.

While the Alternative TMDL considered all sources of TP, the current focus is on stormwater management only. Table 3-9 and Figure 3-22 present the annual average stormwater TP load from the land surface based on the updated HRU distribution and loading rates for each subbasin ("Unattenuated") and the stormwater portion of delivered TP load considering the updated instream attenuation factors ("Attenuated"). The unattenuated and attenuated stormwater loads for each municipality were calculated based on the HRU distribution of unique combinations of municipalities and subbasins. Using these values and the 62% reduction per municipality from the Alternative TMDL, the required load reductions and the delivered, attenuated loads were calculated for each municipality (Table 3-10 and Figure 3-23).

Table 3-9. Stormwater annual average TP load (2007-2016) for subbasins upstream of the Earhart Dam

Subbasin	Subbasin ID	Attenuation Factor	Annual Average TP Load (lb/yr)	
			Unattenuated	Attenuated
Aberjona River 1	2	0.06	109.67	102.92
Aberjona River 2	3	0.07	172.58	160.50
Alewife Brook	4	0.74	5,222.37	1,351.73
Blacks Nook Pond	5	1.00	0.90	0.00
Horn Pond	6	0.92	3,590.22	272.19
Judkins Pond	7	0.44	7,107.07	3,982.95
Lower Mystic Lake	8	0.37	2,826.07	1,772.80
Malden River	9	0.52	6,260.50	2,999.29
Mill Pond	10	0.06	62.78	59.24
Upper Basin	11	0.22	3,137.18	2,451.29
Spy Pond	12	0.91	662.26	62.46
Upper Lobe	13	0.06	73.41	68.87
Upper Mystic Lake	14	0.30	672.44	470.90
Wedge Pond	15	0.41	286.63	169.56
Winter Pond	16	0.87	100.27	13.40
Lower Basin	17	0.18	2,212.59	1,825.25
		Total	**32,496.94**	**15,763.35**

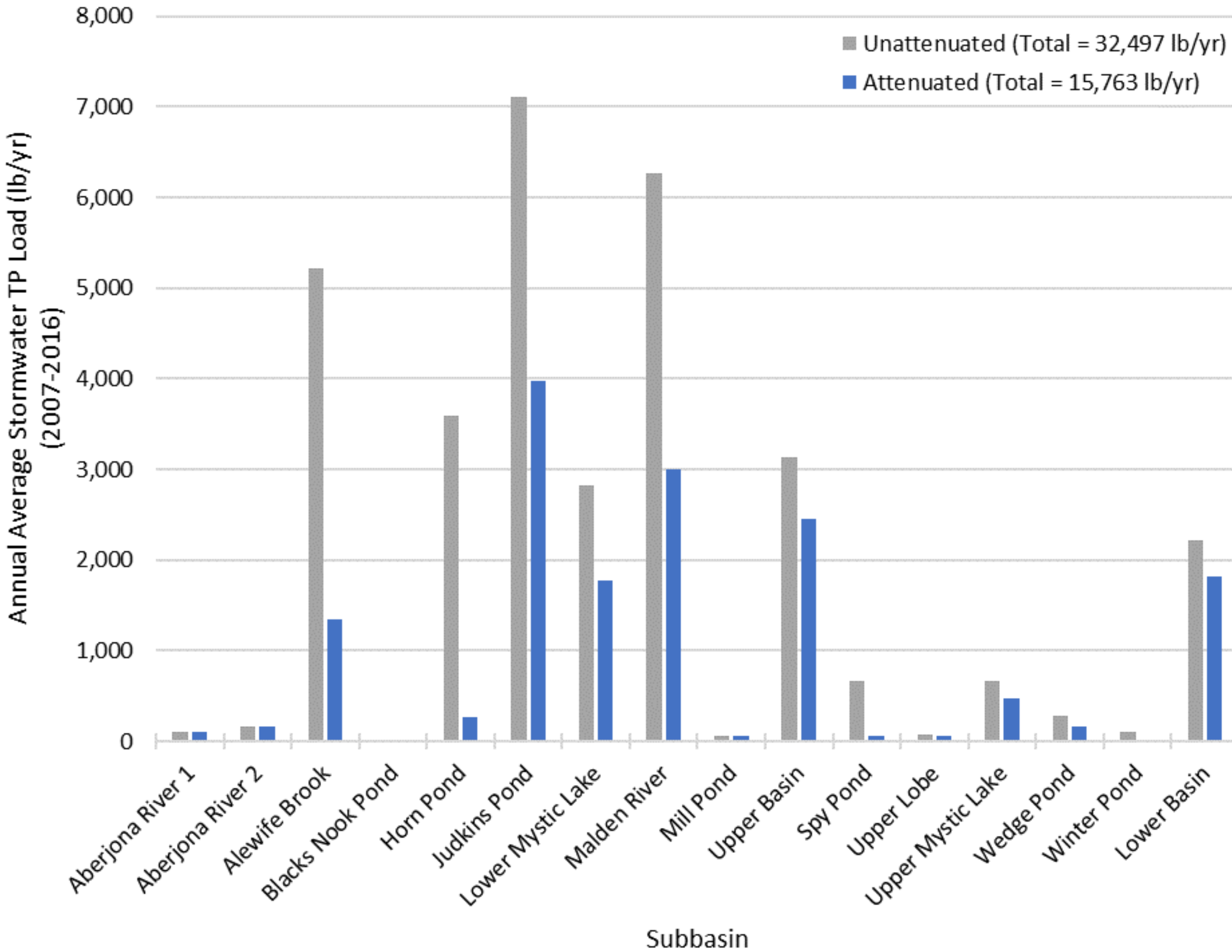

Figure 3-26. Stormwater annual average TP load by subbasin, with and without instream attenuation.

Table 3-10. Stormwater annual average TP load (2007-2016) for municipalities upstream of the Earhart Dam

Municipality	Municipality ID	Annual Average TP Load (lb/yr)			
		Unattenuated	Attenuated	Required Reduction	Attenuated After Reduction
ARLINGTON	10	2,905.63	1,376.08	1,801.49	522.91
BELMONT	26	1,956.96	489.78	1,213.31	186.11
BOSTON	35	0.00	0.00	0.00	0.00
BURLINGTON	48	970.12	170.62	601.48	64.84
CAMBRIDGE	49	1,726.31	446.59	1,070.31	169.71
CHELSEA	57	0.00	0.00	0.00	0.00
EVERETT	93	825.87	395.66	512.04	150.35
LEXINGTON	155	955.60	531.43	592.47	201.94
MALDEN	165	2,191.93	1,050.11	1,358.99	399.04
MEDFORD	176	4,640.49	3,323.72	2,877.10	1,263.01
MELROSE	178	1,510.34	723.57	936.41	274.96
READING	246	852.87	477.97	528.78	181.63
REVERE	248	0.00	0.00	0.00	0.00
SOMERVILLE	274	2,586.62	1,644.68	1,603.70	624.98
STONEHAM	284	2,421.70	1,301.00	1,501.46	494.38
WAKEFIELD	305	127.67	61.77	79.15	23.47
WATERTOWN	314	254.97	65.99	158.08	25.08
WILMINGTON	342	267.03	149.65	165.56	56.87
WINCHESTER	344	2,415.35	1,444.08	1,497.52	548.75
WINTHROP	346	0.00	0.00	0.00	0.00
WOBURN	347	5,887.49	2,110.65	3,650.24	802.05
	Total	**32,496.94**	**15,763.35**	**20,148.10**	**5,990.07**

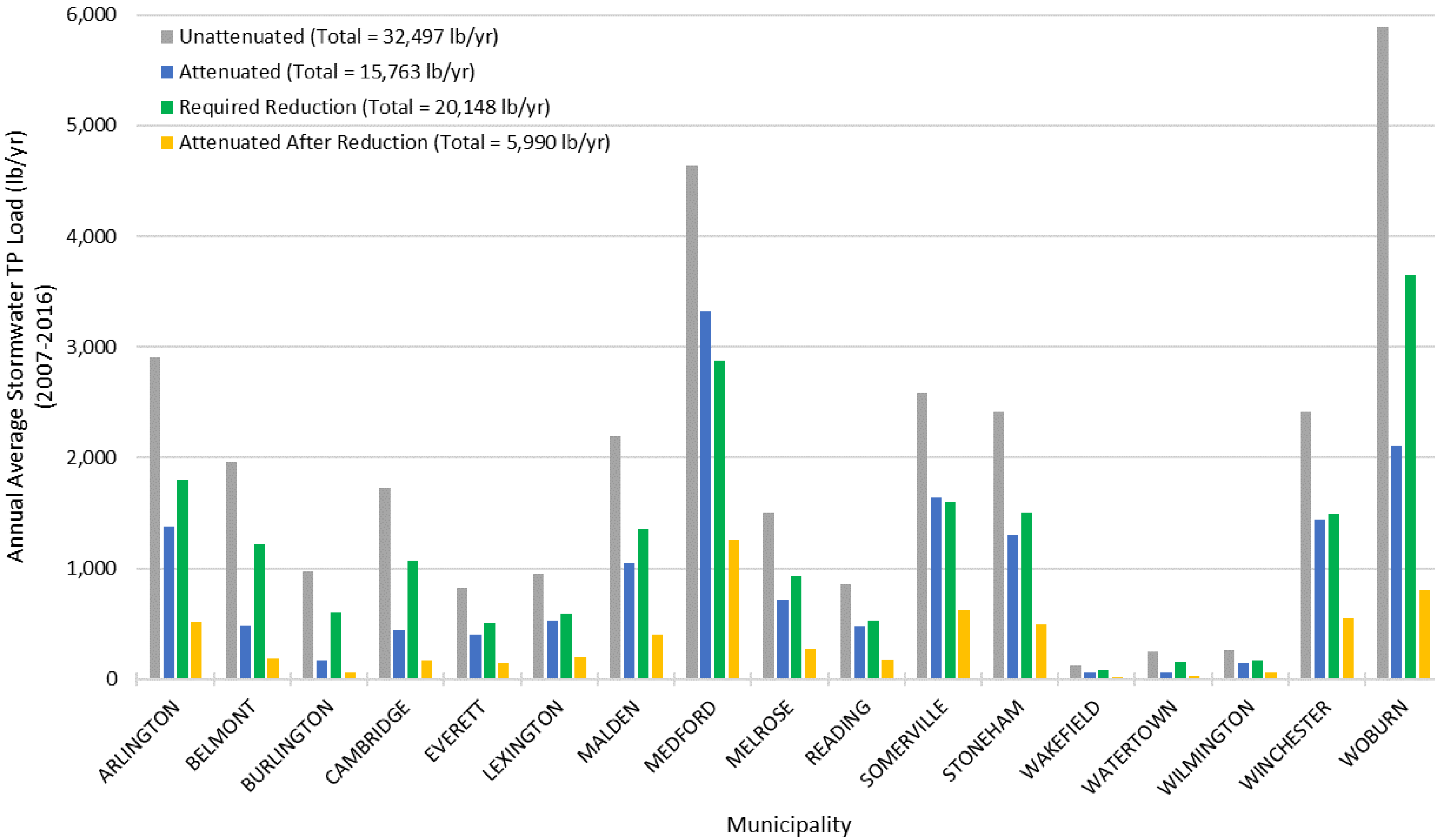

Figure 3-27. Stormwater annual average TP load by municipality, with and without instream attenuation and required reduction to meet targets in the Alternative TMDL.

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