

Nutrient Source Identification Report Addendum: Methods

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This report is being submitted as a final grant deliverable for the MS4 Municipal Assistance Grant Program. This specific submission is not intended for regulatory compliance purposes.

Acknowledgements

This is one among twenty Nutrient Source Identification Reports prepared by the Neponset River Watershed Association (NepRWA) and the Pioneer Valley Planning Commission (PVPC). These reports are meant to provide MS4 permitted municipalities with documents they can finalize and submit to U.S. EPA as part of their Year 4 reporting requirements.

This work is made possible through a grant from the MassDEP Municipal Assistance Program. Project staff from NepRWA and PVPC appreciate the conversation and feedback provided by MassDEP and U.S. EPA staff in working through methodology to prepare these reports. Aside from producing nutrient source identification reports for 20 communities, this project also resulted in the following: lake-pond phosphorous control plan Year 4 submission requirements for two communities; documentation of approach and methods for use by other MS4 permittees across MA in meeting these Year 4 requirements; and setting of the stage for upgrading existing stormwater infrastructure in key high pollutant loading catchments.

NepRWA and PVPC staff are grateful also to the partner communities who joined them in this pilot project. Following is a list of cities and towns who participated in this project:

<i>Agawam</i>	<i>Medfield</i>	<i>Southampton</i>
<i>Canton</i>	<i>Milton</i>	<i>Southwick</i>
<i>Dedham</i>	<i>Northampton</i>	<i>Stoughton</i>
<i>Foxborough</i>	<i>Quincy</i>	<i>Westfield</i>
<i>Granby</i>	<i>Randolph</i>	<i>Westwood</i>
<i>Longmeadow</i>	<i>Sharon</i>	<i>Wilbraham</i>
<i>Ludlow</i>	<i>South Hadley</i>	

Introduction

This is an addendum to the Town’s Nutrient Source Identification Report. This document explains the methods followed to produce the information in the report. All actions described were performed using ArcMap 10.6.1.

The analysis requires 3 existing shapefiles. Information on each of these required shapefiles is provided in Table 1 below.

Table 1. Shapefiles Used in Analysis

Existing Data Set	Origin	Date Published/Updated	Link
2016 Land Cover/Land Use	MassGIS	May 2019	https://docs.digital.mass.gov/dataset/massgis-data-2016-land-coverland-use
Soil Survey Geographic (SSURGO) Database for Norfolk and Suffolk Counties, Massachusetts	USDA	June 2020	Downloaded through Web Soil Survey (https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm). Hydrologic soil groups extracted using Soil Data Viewer Version 6.1 (https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/geo/?cid=nr142p2053619)
Town Catchments	Town GIS Files	Current as of 6/10/21	N/A
Massachusetts Land Parcel Database (Metro Boston Region)	MAPC	May 2019	Used to locate SCM opportunities, this shapefile contains the “Parloc_ID” field used to identify parcels. https://datacommon.mapc.org/browser/datasets/360

Creation of Base Shapefile

To support the analysis, a base shapefile containing pertinent information for land cover, land use, and soil types in the area of interest was created. This was completed by performing a “union” operation with two input shapefiles shown in Table 1 above: the 2016 Land Cover/Land Use shapefile and a shapefile containing the SSURGO soil hydrologic groups. Each record in the resulting shapefile represents areas with specific land cover, land use, and soil types.

Several fields were then added to the resulting shapefile to support later steps of this analysis. Table 2 below lists the added fields and provides a brief description of the data that was added. The complete shapefile is entitled “NSIRBaseShapefile” and is available in the files the Town received upon completion of this project.

Table 2. Summary of Fields Added to “NSIRBaseShapefile”

Added Field	Description
FIRST_PLCR	The phosphorus loading category to which a record was assigned. See Table 1-2 in Attachment 1 of Appendix F of the 2016 Massachusetts Small MS4 General Permit for a full listing of loading categories and rates.
FIRST_NLCR	The nitrogen loading category to which a record was assigned. See Table 1 in Attachment 1 of Appendix H of the 2016 Massachusetts Small MS4 General Permit for a full listing of loading categories and rates
MAX_PLER	The numerical phosphorus loading rate assigned to a record. The value originates from Table 1-2 in Attachment 1 of Appendix F of the 2016 Massachusetts Small MS4 General Permit
MAX_NLER	The numerical nitrogen loading rate assigned to a record. The value originates from Table 1 in Attachment 1 of Appendix H of the 2016 Massachusetts Small MS4 General Permit
MAX_DCIA_M	The multiplier from the applicable Sutherland equation to estimate directly connected impervious area for a record. Note that entry is <Null> for all non-impervious records. For more detailed information about how these values were assigned, see the “DCIA Calculation” section below.
MAX_DCIA_E	The exponent from the applicable Sutherland equation to estimate directly connected impervious area for a record. Note that entry is <Null> for all non-impervious records. For more detailed information about how these values were assigned, see the “DCIA Calculation” section below.

In addition to these fields, other new fields were added as placeholders for later analysis. These fields are entitled “AreaAcre,” “ImpAreaAcr,” “ImpPercent,” “PercentOfC,” “DCIAPercen,” “DCIAAcre,” “PLoadLbYr,” and “NLoadLbYr.” Values for these fields are all “0” in the “NSIRBaseShapefile” and actual values were calculated later in the process as described in the “Summarized Analysis” section.

Preparation of Catchment Shapefile and Intersect with Base Shapefile

To prepare the Town’s catchment shapefile for later analysis, a field entitled either “CatchAreaAcr” or “CatchAreaA” (depending on inherent limitations on field name size in the Town’s shapefile) was added to the attribute table. The “calculate geometry” function was used to populate this field for each record, measuring the total area of each catchment in acres.

Once the additional field was added, the “Intersect” tool was run with two input datasets: “NSIRBaseShapefile” (described in the last section) and the Town’s Catchment shapefile. The resulting shapefile was entitled “[TownName]Intersect” and is available in the files the Town received upon completion of this project.

This resulting shapefile limits the information contained in the broader “NSIRBaseShapefile” to what specifically occurs in each of the Town’s catchments, allowing further catchment-level analysis of several criteria.

Summarized Analysis

Operations were then performed on the extra fields that were carried through from “NSIRBaseShapefile” for later analysis. Table 3 below lists the fields, the description of the data they contain, and shows the operations involved in calculating the applicable data. Further details about each calculation can be found in the individual sections below.

Table 3. New Fields Added to "[TownName]Intersect" Shapefile

New Field	Description	Units	Function Used to Calculate	Calculation Method
AreaAcre	The area of a record.	Acres	Calculate Geometry	Calculate the area in acres.
ImpAreaAcr	The area of impervious surfaces occupied by a record.	Acres	Calculate Geometry	Query only records with “Impervious” entry for CoverName, then calculate the area in acres. After removing the query, all non-impervious records will have a “0” listed for this field.
ImpPercent	The amount of impervious area in a record as a percentage of the overall	Percentage of the total catchment area	Field Calculator	$([ImpAreaAcr]/[CatchAreaAcr])*100$

	catchment area.			
PercentOfC*	The percentage of the catchment represented by a record.	Percentage of the total catchment area	Field Calculator	$([AreaAcre]/[CatchAreaAcr])*100$
DCIAPercen	An estimate of directly connected impervious area represented by a record	Percentage of the total catchment area.	Field Calculator	$([ImpPercent]^{[MAX_DCIA_E]})*[MAX_DCIA_M]$
DCIAAcre	An estimate the amount of directly connected impervious area associated with a record.	Acres	Field Calculator	$([DCIAPercen]/100)*[CatchAreaAcr]$
PLoadLbYr	The estimated phosphorus load from a record	Lbs/Year	Field Calculator	$[AreaAcre]*[MAX_PLER]$
NLoadLbYr	The estimated nitrogen load from a record	Lbs/Year	Field Calculator	$[AreaAcre]*[MAX_NLER]$

*PercentOfC was only used as a “check” field and is not described further in this document.

Impervious Calculation

The “[TownName]Intersect” shapefile contains polygons of areas within each catchment with like land cover, land use, and soil type. To begin the analysis for impervious area, the “[TownName]Intersect” attribute table was queried so that only polygons with an entry of “Impervious” for the “CoverName” field were shown. Then, the Calculate Geometry tool was used in the “ImpAreaAcr” field on those queried records to display the area of each impervious polygon in acres. These results were eventually summed for overall catchment totals of impervious area as described in the “Final Preparation of Deliverable Shapefile” section below.

To further illustrate impervious cover statistics and for use in DCIA calculation, the impervious cover in each polygon was also calculated as a percentage of each catchment. For this measurement, the Field Calculator tool was used on the “ImpPercent” field to divide the impervious area of each polygon (“ImpAreaAcr”) by the total catchment size (“CatchAreaAcr” or “CatchAreaA”, created when preparing the catchment shapefile). This figure was then multiplied by 100 to obtain a percent.

DCIA Calculation

DCIA estimates were based on the Sutherland equations and an EPA guidance document entitled “Estimating Change in Impervious Area (IA) and Directly Connected Impervious Areas (DCIA) for Massachusetts Small MS4 Permit” (Revised April 2014). Table 4 below shows the relation between various land uses in the watershed, the chosen “connectedness” category, and the associated Sutherland equation used in the DCIA estimate.

Table 4. "Connectedness" Category and Sutherland DCIA Equation Assignments for All Land Uses. NOTE: DCIA and IA are both percentages.

USEGENNAME	"Connectedness" Category	Sutherland Equation
Agriculture	Mostly Disconnected	$DCIA = 0.01(IA)^2$
Commercial	Average	$DCIA = 0.1(IA)^{1.5}$
Forest	Mostly Disconnected	$DCIA = 0.01(IA)^2$
Industrial	Average	$DCIA = 0.1(IA)^{1.5}$
Mixed use, other	Average	$DCIA = 0.1(IA)^{1.5}$
Mixed use, primarily commercial	Average	$DCIA = 0.1(IA)^{1.5}$
Mixed use, primarily residential	Average	$DCIA = 0.1(IA)^{1.5}$
Open land	Average	$DCIA = 0.1(IA)^{1.5}$
Recreation	Average	$DCIA = 0.1(IA)^{1.5}$
Residential - multi-family	Highly Connected	$DCIA = 0.4(IA)^{1.2}$
Residential - other	Average	$DCIA = 0.1(IA)^{1.5}$
Residential - single family	Average	$DCIA = 0.1(IA)^{1.5}$
Right-of-way	Average	$DCIA = 0.1(IA)^{1.5}$
Tax exempt	Average	$DCIA = 0.1(IA)^{1.5}$
Unknown	Average	$DCIA = 0.1(IA)^{1.5}$
Water	Average	$DCIA = 0.1(IA)^{1.5}$

In these equations, the percentage of impervious cover for a given area is used to determine the percentage of DCIA in the same area. Thus, DCIA percent was calculated in the “DCIAPercen” field using Field Calculator. In this calculation, the impervious percentage of the catchment represented by the polygon (“ImpPercent”) was raised to the power shown in the appropriate equation (already entered in the “MAX_DCIA_E” field when preparing the base shapefile) and multiplied by the factor shown (already entered in the “MAX_DCIA_M” field when preparing the base shapefile). Essentially, the Field Calculator equation was “DCIAPercen” = (“ImpPercent” ^ “MAX_DCIA_E”) * “MAX_DCIA_M”. These results were eventually summed for overall catchment totals of impervious area as described in the “Final Preparation of Deliverable Shapefile” section below.

Finally, the estimated acreage of DCIA for each polygon was calculated in the “DCIAAcre” field using Field Calculator. In this calculation, “DCIAPercen” was divided by 100 and multiplied by the overall catchment size (“CatchAreaAcr” or “CatchAreaA”).

Note that, by default, any records with a “0” in the “ImpPercent” field (such as records with non-impervious land cover) also resulted in an entry of “0” for “DCIAPercen” and “DCIAAcre”, as DCIA only exists where impervious area exists.

Also, please note that, for catchments located in the Charles River Watershed, DCIA calculations, were not calculated using the exact same method as what was used in the Charles River Phosphorus TMDL. The TMDL used a similar method but adjusted the model in some instances. Thus, the results in the DCIA and phosphorus loading estimates in the TMDL and the results from this report may differ somewhat.

Phosphorus Load Calculation

Phosphorus loads were calculated for each record in the “[TownName]Intersect” shapefile by multiplying the area of each polygon (“AreaAcre”) by the phosphorus loading rate assigned to the record’s specific land cover/land use/soil type combination (the “MAX_PLER” field, which was entered during the creation of the base shapefile). The Field Calculator tool was used to complete this calculation in the “PLoadLbYr” field. As the name suggests, the units for the loading estimates are pounds/year. These results are eventually summed for overall catchment totals of impervious area as described in the “Final Preparation of Deliverable Shapefile” section below.

For reference, the phosphorus loading category into which each record is assigned is recorded in the “FIRST_PLCR” field, which stands for Phosphorus Load Crosswalk. The entries in this field correspond to the land uses and phosphorus load export rates shown in Table 1-2 of Attachment 1 to Appendix F of the 2016 Massachusetts Small MS4 General Permit. An abbreviated crosswalk is shown in Table 5 below.

Note that the “CoverName” field was also consulted when assigning phosphorus loading rates. If the polygon was identified as “Impervious,” it was given the loading rates for Directly Connected Impervious for a given land use shown in Table 1-2 of Attachment 1 to Appendix F of the 2016 Massachusetts Small MS4 General Permit. If the polygon was identified as non-impervious, it was given the loading rates for Pervious cover for a given land use shown in the same table. The pervious loading rates often rely on the records’ soil type, so the “HSG_P” field was consulted as necessary when assigning phosphorus loading rates to pervious records.

Also note that in most cases, land use categories were descriptive enough to assign the polygon to a particular phosphorus loading category. However, in the case of some more general land uses (such as “Unknown”), the “CoverName” field was consulted to assign the polygon to an appropriate category.

Table 5. Crosswalk Linking Land Use and Land Cover to the Phosphorus Source Categories Shown in Table 1-2 of Attachment 1 to Appendix F of the 2016 Massachusetts Small MS4 General Permit

USEGENNAME	Phosphorus Source Category
Agriculture	Agriculture (Ag)
Commercial	Commercial/Industrial (Com-Ind)
Forest	Forest (For)
Industrial	Commercial/Industrial (Com-Ind)
Mixed use, other	Varied based on land cover
Mixed use, primarily commercial	Commercial/Industrial (Com-Ind)
Mixed use, primarily residential	Medium-Density Residential (MDR)
Open land	Varied based on land cover
Recreation	Varied based on land cover
Residential - multi-family	Multi-Family and High-Density Residential (MFR-HDR)
Residential - other	Medium-Density Residential (MDR)
Residential - single family	Medium-Density Residential (MDR)
Right-of-way	Varied based on land cover
Tax exempt	Varied based on land cover
Unknown	Varied based on land cover
Water	Varied based on land cover

N Load Calculation

Nitrogen loads were calculated for each record in the “[TownName]Intersect” shapefile by multiplying the area of each polygon (“AreaAcre”) by the nitrogen loading rate assigned to the record’s specific land cover/land use/soil type combination (the “MAX_NLER” field, which was entered during the creation of the base shapefile). The Field Calculator tool was used to complete this calculation in the “NLoadLbYr” field. As the name suggests, the units for the loading rates are pounds/year. These results are eventually summed for overall catchment totals of impervious area as described in the “Final Preparation of Deliverable Shapefile” section below.

For reference, the nitrogen loading category into which each record is assigned is recorded in the “FIRST_NLCR” field, which stands for Nitrogen Load Crosswalk. The entries in this field correspond to the Nitrogen Source Categories and nitrogen load export rates shown in Table 1 of Attachment 1 to Appendix H of the 2016 Massachusetts Small MS4 General Permit. An abbreviated crosswalk is shown in Table 6 below. Note that this crosswalk only considers the land cover of the record (the “CoverName” field) and, where necessary, the soil type of the record (the “HSG_N” field).

Table 6. Crosswalk Linking Land Cover and Soil Type to the Nitrogen Loading Categories Shown in Table 1 of Attachment 1 to Appendix H of the 2016 Massachusetts Small MS4 General Permit

Land Cover	Soil Type	Nitrogen Source Category
Impervious	All	All Impervious Cover
Non-Impervious	A	Developed Land Pervious (DevPERV)-HSG A
Non-Impervious	B	Developed Land Pervious (DevPERV)-HSG B
Non-Impervious	C	Developed Land Pervious (DevPERV)-HSG C
Non-Impervious	D	Developed Land Pervious (DevPERV)-HSG D
Non-Impervious	A/D	Developed Land Pervious (DevPERV)-HSG A
Non-Impervious	B/D	Developed Land Pervious (DevPERV)-HSG B
Non-Impervious	C/D	Developed Land Pervious (DevPERV)-HSG C/D

Final Preparation of Deliverable Shapefile

Once all calculations were made as described above, the “[TownName]Intersect” shapefile was condensed using the Dissolve tool. The “Dissolve_Field” was defined as the field containing catchment identifiers and the following fields were defined as “Statistics Fields” with a “Statistic Type” of “Sum”: “AreaAcre,” “ImpAreaAcr,” “ImpPercent,” “DCIAAcre,” “DCIAPercen,” “PLoadLbYr,” and “NLoadLbYr.”

The resulting layer was named “[TownName]Final” and was provided with all other deliverables from this project. This shapefile displays the Town’s catchment and contains totals of each catchment’s area, impervious area, estimated DCIA, impervious percentage, estimated DCIA percentage, estimated phosphorus load, and estimated nitrogen load.

Selection of SCM/BMP Sites

To select sites for future evaluation for SCM/BMP retrofits, the NSP BMP Tool was used. Town-owned sites were identified as the most desirable parcels to inspect first, since they typically do not require use agreements or other considerations. A .csv file was exported from the tool that contained records for all Town-owned properties and the Tool’s priority score for each property relative to both phosphorus and nitrogen. To obtain this score, the tool considers multiple factors such as pollutant loading rate, soil type, location of stormwater infrastructure, and various confounding factors. The closer the score is to 1, the better it is expected to be for a retrofit targeting the selected pollutant.

This .csv file was imported into ArcGIS and joined with an existing parcel layer from the Metropolitan Area Planning Council (MAPC), which also contained a “parloc_id” field to allow the records from the .csv to be spatially referenced.

The display of the catchments was changed to make the highest-loading catchments stand out. The display of the BMP Tool results was changed to make the parcels with the highest priority score stand out. The map was then examined and any high-score parcels in high-loading catchments were noted. In cases where there weren’t enough, lower-scoring parcels in mid-loading catchments or mid-scoring parcels in high-loading catchments were chosen.

The top-5 of these chosen parcels were included in the body of the report, while the longer list of all Town-owned properties was included in an Appendix. As all of these properties are evaluated in the future, the Town may re-run the above analysis focusing on non-Town-owned properties.

If a municipality does not have access to a resource like the NSP BMP Tool, this analysis could be completed in ArcGIS by using the “Intersect” tool with the input datasets of “NSIRBaseShapefile” (the base shapefile) and any parcel layer the municipality has access to. Then, the series of nutrient loading calculations described in the above sections could be reproduced and the completed layer could be dissolved using the parcel identifiers as a “Dissolve_Field.” The resulting shapefile would display the highest-loading parcels throughout the municipality. This could be used along with the catchment loading shapefile as a prioritization tool in determining which parcels to assess first. It would also be recommended that a field identifying an owner of each parcel be preserved during this process, as Town-owned parcels are often more desirable opportunities.

Final Deliverables

Along with the final report and this methods addendum, the Town was provided with copies of three ArcGIS shapefiles that were used in or products of the analysis. Table 7 below gives a brief description of each shapefile.

Table 7. Descriptions of Shapefiles Provided as Deliverables of this Project

Shapefile Name	Description
NSIRBaseShapefile	A shapefile containing polygons with like land cover, land use, soil type, and pertinent loading rates, multipliers, etc. for Neponset towns.
[TownName] Intersect	The product of an intersect operation between the base shapefile above and the Town’s stormwater catchment shapefile. This shapefile specifically shows only the information from the base shapefile that is pertinent to the Town’s catchments. Calculations for impervious area, directly connected impervious area, and pollutant loads were made within this shapefile’s attribute table.
[TownName] Final	This shapefile is the final product of the analysis. It contains the following for each catchment within the Town: total area (acres), total impervious area (acres), percent of catchment that is impervious, total estimated directly connected impervious area (acres), estimated percent of catchment that is directly connected impervious area, estimated phosphorus load from catchment (lb/year), estimated nitrogen load from catchment (lb/year)