Outfall Catchment Mapping and Ranking

Last updated: December 27, 2017

Background

The federal Clean Water Act, passed in 1972, established regulation of pollutant discharges into "waters of the United States." [1] This law requires municipalities to qualify for a permit under the National Pollutant Discharge Elimination System (NPEDS) program in order to lawfully discharge stormwater into rivers, streams, and lakes. In Massachusetts, the 2003 Region 1 Final General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4 permit hereafter) is in effect, although it expired in 2008, and a new permit was signed in April of 2016.[2] The permit was set to go into effect on July 1, 2017, but the US Environmental Protection Agency postponed the effective date one year, until July 1, 2018. Under the terms of the new permit, MS4 municipalities will be required to adopt stronger measures for minimizing the impact of pollutants from their stormwater on the cleanliness of the receiving waters.[3]

In 2013, the Neponset River Watershed Association (NepRWA) and MAPC secured a Community Innovation Challenge (CIC) grant from the state of Massachusetts to assist the Neponset Valley Watershed municipalities in collaborating to adopt a new approach to meet the new MS4 requirements. The CIC grant program promoted municipal efficiency through regional collaboration. In this case, the goal was to provide policy templates, recommendations, and technical tools that Neponset Valley municipalities could use to meet the new requirements of the MS4 permit. Representatives from conservation commissions and departments of public works who are both involved in the permitting or in operation and management of stormwater came together to create the Neponset Valley Regional Stormwater Collaborative. The collaborative includes representatives from Canton, Dedham, Foxborough, Medfield, Milton, Norwood, Randolph, Sharon, Stoughton, Walpole, Westwood, and the Boston Water and Sewer Commission, with a representative from Boston participating as a technical advisor.

In order for Massachusetts MS4 municipalities to meet the terms of the new permit, they must meet more stringent illicit discharge detection and elimination (IDDE) requirements. "Illicit Discharges" are any substances that enter the stormwater system other than stormwater, including chemicals, oils, gasoline, or waste.[4] Such discharges are associated with auto or other industrial activities,

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[1] United States Environmental Protection Agency. "Summary of the Clean Water Act." http://www2.epa.gov/laws-regulations/summary-clean-water-act Last modified November 12, 2014

[2] Environmental Protection Agency. 2003. *National Pollutant Discharge Elimination System (NPEDS) General Permit for Stormwater Discharges from Small Separate Storm Sewer System.* http://www.epa.gov/region1/npdes/permits/permit_final_ms4.pdf

[3] United States Environmental Protection Agency. 2016. *National Pollutant Discharge Elimination System (NPEDS) General Permits for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems in Massachusetts*. https://www3.epa.gov/region1/npdes/stormwater/ma/2016fpd/final-2016-ma-sms4-gp.pdf

[4] With some exceptions. United States Environmental Protection Agency, 2016. pg 30.

older residences, and failing septic systems. According to the new MS4 permit, Massachusetts MS4 municipalities will be required to a) identify receiving waters associated with each outfall, b) delineate catchment areas draining to each outfall, and c) rate the potential for illicit discharge of the outfall catchment areas as High or Low. This rating can be used as a tool to focus outreach, infrastructure, and enforcement campaigns to property owners or neighborhoods. Meeting this standard requires technical analysis of hydrology, topography, land use, and stormwater infrastructure. This document describes the methods that MAPC has developed to meet the terms of each of these new requirements.

Several public agencies have previously tackled the task of automatically delineating catchments using topographic data in cities such as San Francisco, Portland, and Tampa.[5] By adopting these methods in Massachusetts, municipalities should be able to meet the requirements more cost-effectively. However, any attempt at standardization must contend with the highly varied quality and completeness of municipal stormwater infrastructure data and the often limited technical capacity available at the local level. To reduce redundancy of effort and account for the varied resources available in different cities and towns, MAPC built on previous examples by developing a regionally applicable method to conduct this analysis that requires a minimum of local stormwater infrastructure data in a standardized format. MAPC has published and maintains a set instructions and of ArcGIS tools that can be applied for any municipality in Massachusetts and potentially beyond. This document describes the method and provides instructions for implementing it using ArcGIS and CommunityViz, an ArcGIS add-in.

MAPC has applied this method in a number of municipalities, including the Towns of Milton, Westwood, Stoughton, and Medfield. Other consultants and GIS Analysts working throughout the state and beyond have also downloaded and applied this methodology.

Data and Software Requirements

Catchment delineation

- ArcGIS 10.2 or above
- Spatial Analyst extension

Catchment ranking

- ArcGIS 10.2 or above
- Microsoft Excel

Stormwater Infrastructure Data

- Complete inventory of catch basins within municipal boundaries, regardless of ownership

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[5] "Urban Catchment Delineation Tool." https://code.google.com/p/besasm-toys/wiki/urbanCatchmentDelineationTool Last modified June 13, 2012; Nick Birth and Greg Braswell. 2011. "The 'Urban Drainage' Model: SF DPW uses Lidar DEM and Custom Algorithm for Delineating Drainage Catchments and Hydrologic Modelling." *Bay Area Automated Mapping Association Journal* 5: 5-6.*http://www.baama.org/Resources/Documents/BAAMA_Journal_V5I1_LoRes.pdf*.

- Catch basins have an integer ID field that corresponds to outfall IDs (see “Creating Outfall Catchments” below
- Optional: “Owner” or other fields used to group catch basins into catchment areas.

Other Data Inputs

- Digital Elevation Model (DEM): for this analysis, we used the high resolution (1m) digital elevation models.[6] These models were created from point data captured by Lidar sensors in flights from 2002 to 2012, and processed by USGS.
- Vector feature classes to “etch” into the DEM, such as:
    - Water features: MassDEP Hydrography[7]
    - Road center lines: MassDOT Road Inventory[8]
    - Gutters or edges of rights of way: MAPC Massachusetts Land Parcel Database.[9]

Assigning Outfalls to Receiving Waters

The new permit requires for each municipal outfall to be associated with receiving waters both for the Notice of Intent, and for the outfall priority ranking requirement. The Notice of Intent that municipalities submit to the Department of Environmental Protection in the fall after the permit goes into effect requires municipalities to list each body of water receiving stormwater from the municipality, along with each impairment and the number of outfalls that contribute stormwater to each. Using GIS and various reference datasets such as topography and wetlands, outfalls can be assigned IDs from the MassDEP Impaired Waters dataset, or the 303(d) waters, named for section 303(d) of the Federal Clean Water Act. [10] Section 303(d) requires each state to monitor the quality of its bodies of water. This dataset includes both a line and polygon feature class representing the bodies of water that MassDEP monitors according to the requirements of section 303(d).[11] Each stream segment or lake has a unique identifier, or “AU ID.”

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[6] MassGIS. “LiDAR Terrain Data.” http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/lidar.html

[7] Massachusetts Department of Environmental Protection. “MassDEP Hydrography (1:25,000).” March 2010. MassGIS. http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/hd.html

[8] Massachusetts Department of Transportation. “”MassDOT Roads.” June 2014. MassGIS. http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/eotroads.html

[9] Metropolitan Area Planning Council. “MAPC Massachusetts Land Parcel Database.” 2017. MAPC. https://www.mapc.org/learn/data/#landparceldb

[10] Visit http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/wbs2012.html for details and metadata.

[11] Massachusetts Department of Environmental Protection. “MassDEP 2014 Integrated List of Waters (305(b)/303(d)).” May 2016. MassGIS. http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers/wbs2014.html

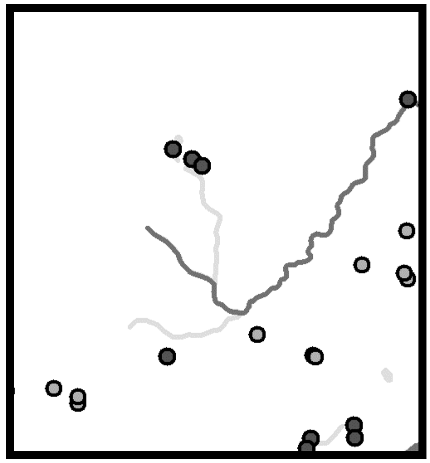

Figure 1. Using the USGS Hydrography dataset to associate the outfall to the Impaired Water.

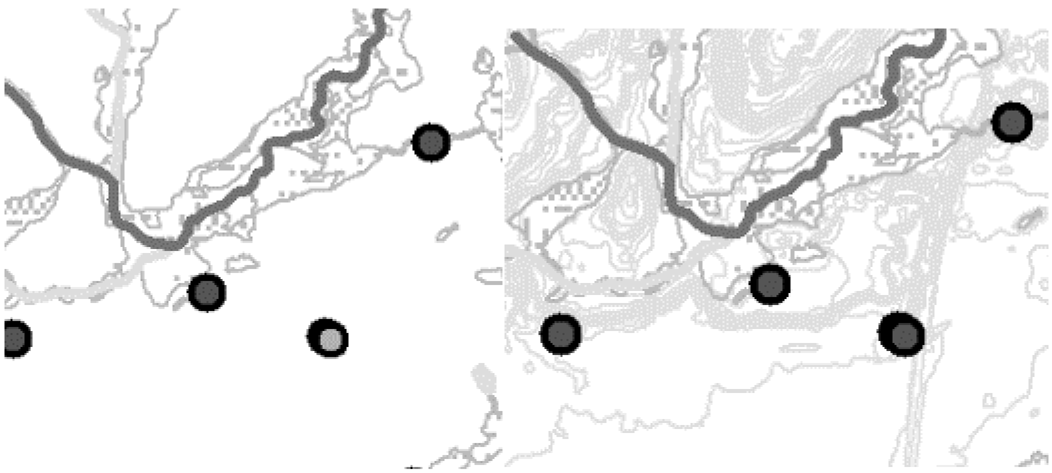

Figure 2. Using wetlands (left) and topographic contours (right) to associate outfalls with Impaired Waters

Delineating Outfall Catchments

The basic process for delineating the catchment areas for each outfall was to download, assemble, and enhance the Digital Elevation Model, then use it to define small catchments for each catch basin, and finally aggregate those smaller catchments into larger outfall catchment areas. In order to streamline the process for municipalities across Massachusetts, we created three custom ArcGIS tools: the Lidar Mosaic tool, the Create Burn Raster tool, and the Complete Watershed tool, packaged as the MAPC Catchment Delineation Toolbox. The tools are publicly available for download on Github.[12]

[12] Go to https://github.com/MAPC/stormwater-toolkit https://github.com/MAPC/stormwater-toolkit to download the toolbox.

Preprocessing the DEM

First, we downloaded the relevant Lidar images from MassGIS and mosaicked them into a single DEM. We built this process into an ArcGIS script tool called the Lidar Mosaic Tool. To use this tool, download the relevant Lidar images from MassGIS. Then, unzip all the files and save them in a single folder. Finally, run the tool inputting the folder in the "workspace" box and the desired name of the output raster (without an extension) in the "output raster" box.[13]

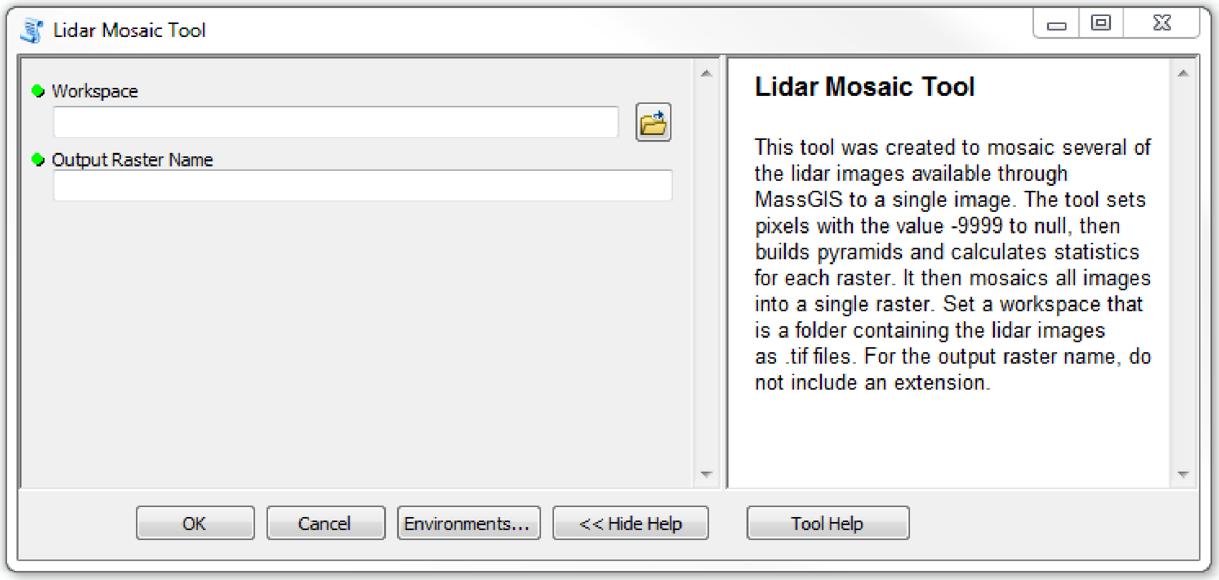

Figure 3. Lidar Mosaic script tool.

The Lidar Mosaic tool performs the following steps:

1. Sets Null value to <-400
2. Builds Pyramids and Calculates Statistics
3. Mosaics to New Raster

Enhancing the DEM

Although the digital elevation model has a very high spatial resolution, it is still not precise enough to capture the relief and drainage patterns created by gutters, curbs, road crowns, or other features that are small but greatly impact stormwater runoff patterns. In order to take these important stormwater control features into account, we enhance the DEM to simulate these features by "burning" or etching them into the DEM. This process ensures that within an urban area, water is modeled as flowing off of properties and into roadways, where it cannot leave a gutter once it enters one, and does not cross the crown of the road. In addition to modeling

[13] The tool is set to mosaic using the value of the first listed raster in the case of overlapping rasters. It is also set to pull the pixel type from the first raster listed, so please use caution when mosaicking rasters from different lidar flyovers. This may require additional processing.

features of the urban landscape more faithfully, we burned in the streambeds and other bodies of water because the DEM did not accurately capture the known streambed for smaller streams that lay in flat floodplains. The image on the lower left shows a hillshade of the Lidar DEM before features were burned into it. The flat area in the southeast actually contains a streambed with a flat floodplain, which does not appear on the DEM, which means that the watershed tool will not accurately map the flow accumulation in this area. The roads also appear completely flat, as the slight curve of the road crown is not represented in the DEM. The lower right image shows the area after gutters, road crowns, and water bodies have been burned into it, which corrects these flat areas by etching known features into the elevation model, making it more representative of the hydrologic conditions in the area.

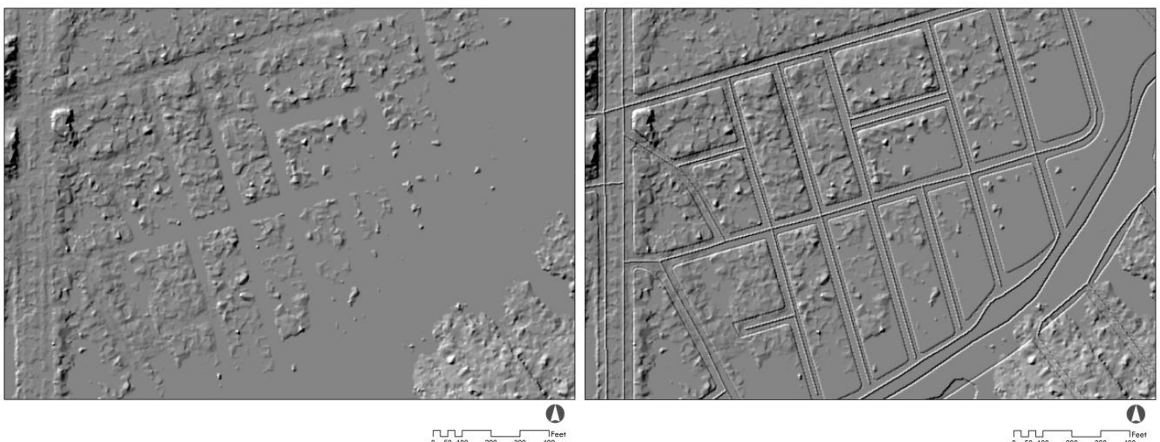

Figure 4. Hillshades before and after enhancement.

To enhance the DEM, we created several “burn” rasters, which are raster representations of features such as streams or gutters. The cells representing the feature are set to the “burn value,” or the value, in map units, that will be added to the original DEM, and all other cells are set to zero. We created an ArcGIS script tool to create these rasters more easily (Figure 3).

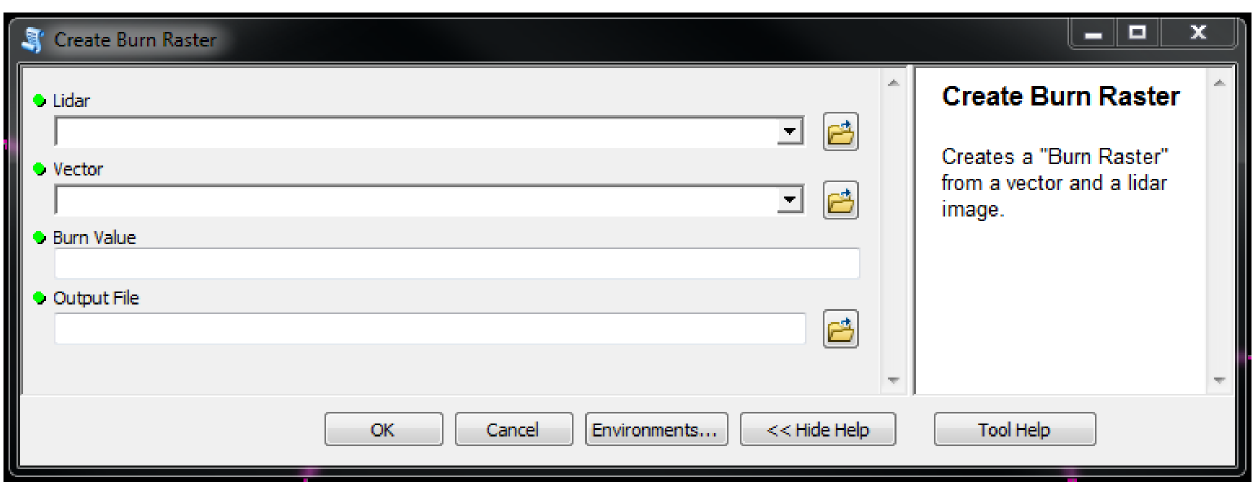

Figure 5. Create Burn Raster script tool.

This tool performs the following steps

1. Sets environments
    A. Processing Extent > Snap Raster: select lidar mosaic
    B. Processing Extent > Extent: same as lidar mosaic
    C. Raster Analysis > Cell size: same as lidar mosaic
    D. Raster Analysis > Mask: same as lidar mosaic
2. Creates an editable copy of the vector feature class
3. Adds a field to the vector's attribute table called "Burn_Val."
4. Populates the new field with the burn value.
5. Converts the vector to a raster
6. Converts nulls to zeros
7. Saves results

For example, to create a burn raster for the road crown, a user inputs the DEM that will be enhanced with the burn raster, the road center line shapefile or feature class as the "Input Vector", then enters .5 into the "Enter Burn Value" field, and finally names the output file. The user should repeat this process with any other variable. For gutters, stream channels, or other features that will be subtracted from the DEM rather than added, users can enter a negative number. This tool can be run in batch mode (right click > batch) to create several burn rasters at once. See table 1 for an example of values used for the Town of Milton.

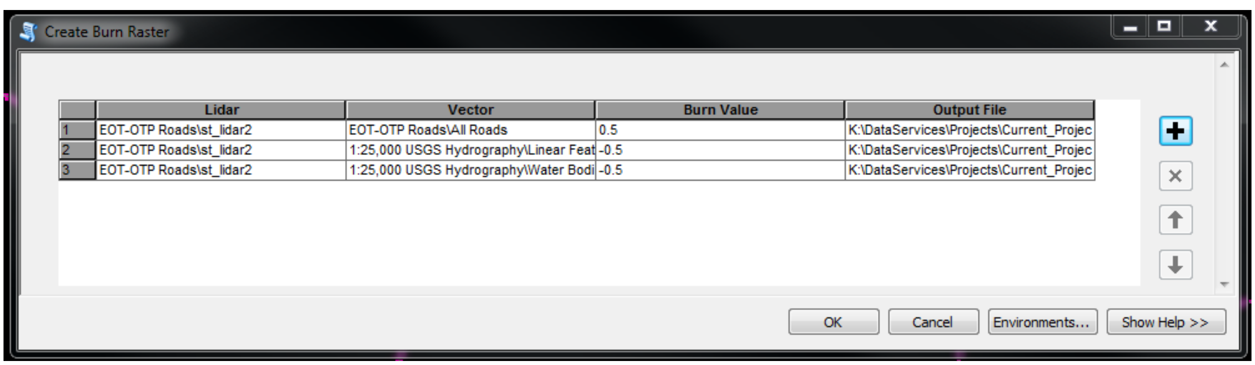

Figure 6. Create Burn Raster script tool in batch mode.

Table 1. Features and burn values.

Feature	Data Source	Burn value
Gutters	MAPC Statewide Parcel dataset, ROWs converted to polylines	-0.25m
Road Crowns	MassDOT Road centerlines	0.50m
Water Features	MassDEP	-0.25m

There is an ArcHydro tool called "DEM Reconditioning" that performs a similar function to burning streams or rivers into a DEM. This tool creates a stepped groove of a specified width along a linear feature. This tool cannot be used on polygons such as wide rivers, lakes, or ponds, however.

After creating the set of burn rasters, the user should add the burn rasters to the DEM using the Raster Calculator.

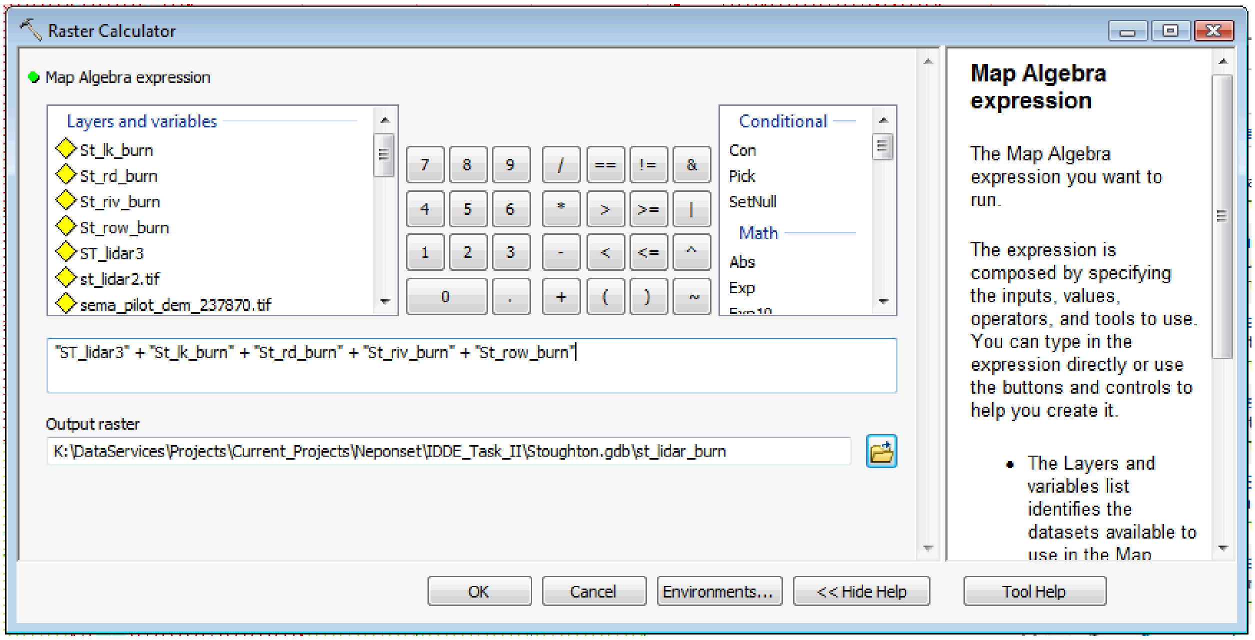

Figure 7. Using the Raster Calculator tool to enhance the DEM using the burn rasters.

Creating Catch Basin Catchments

To simplify the steps necessary to create catch basin watersheds, we created a "Complete Watershed" script tool. Tool inputs are the enhanced DEM, the pour point (catch basin) vector layer, the field to be used for catch basin IDs, the maximum snap distance, and finally a name for the output file. The inputs have the following requirements: 1) the workspace must be a geodatabase, 2) both the Lidar DEM and the catch basin file should be stored within the workspace geodatabase, 3) neither input file should be nested in a group layer in the map document, and 4) the "snap point field" should be an integer.

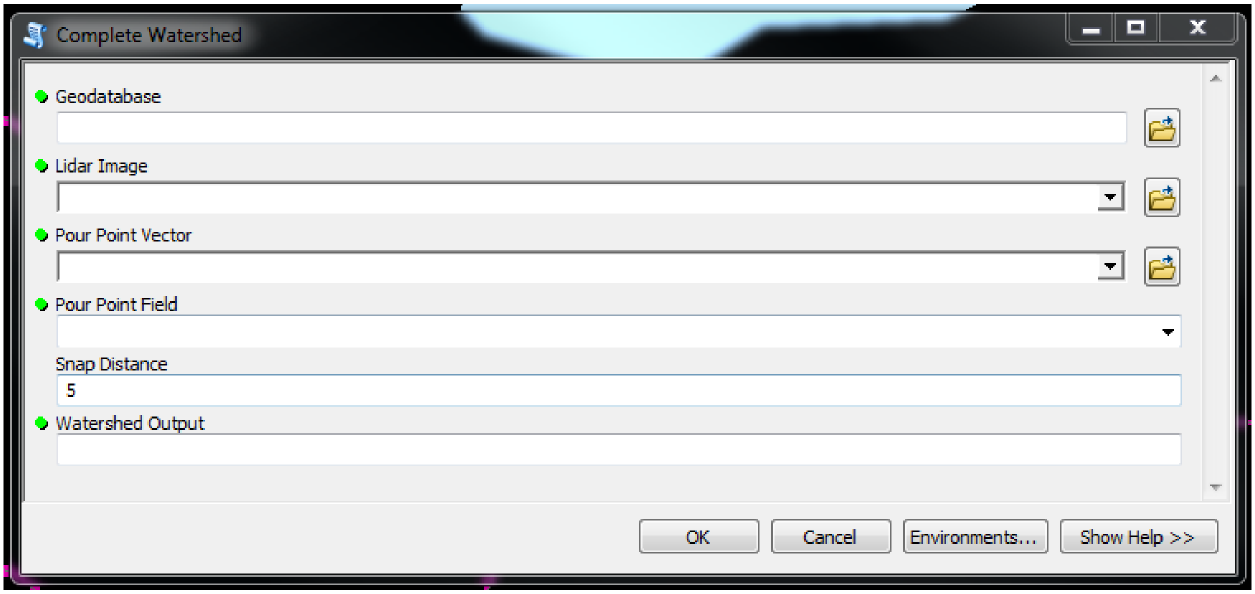

Figure 8. The Complete Watershed script tool.

The tool combines the following steps:

1. Fills any sinks in the enhanced DEM
2. Creates a flow direction raster from the filled DEM
3. Creates a flow accumulation raster using the flow direction raster
4. Snaps the pour points (catch basins) to pixels with high accumulated flow within the specified snap distance (in map units)
5. Creates watersheds using the flow direction raster and snapped pour points as inputs
6. Converts the watershed raster to a vector

Snapping the pour points (step 4 above) is particularly important, since catch basins points may not coincide with the pixels where the gutters have been burned into the DEM. For this step, the inputs are the point feature class representing the catch basins, and a maximum snap distance in map units. The tool will shift the location of the catch basins to coincide with pixels of highest flow accumulation in the flow accumulation raster within the radius specified as the "snap distance." If this step is skipped, water will be modeled as flowing past the catch basins. The default value in this field is 5 map units. For the Town of Milton, we evaluated a range of radii and arrived at a maximum snap distance of 10 meters—the width of an average roadway—by visually assessing the distance between the catch basin points and the areas of high flow accumulation. If catch basin catchments look "stringy" or extremely small, try adjusting the snap distance.

The output of this tool is a set of very small watersheds—one for each catch basin. The tool will also output a set of intermediate rasters that can be used for troubleshooting or for other analyses.

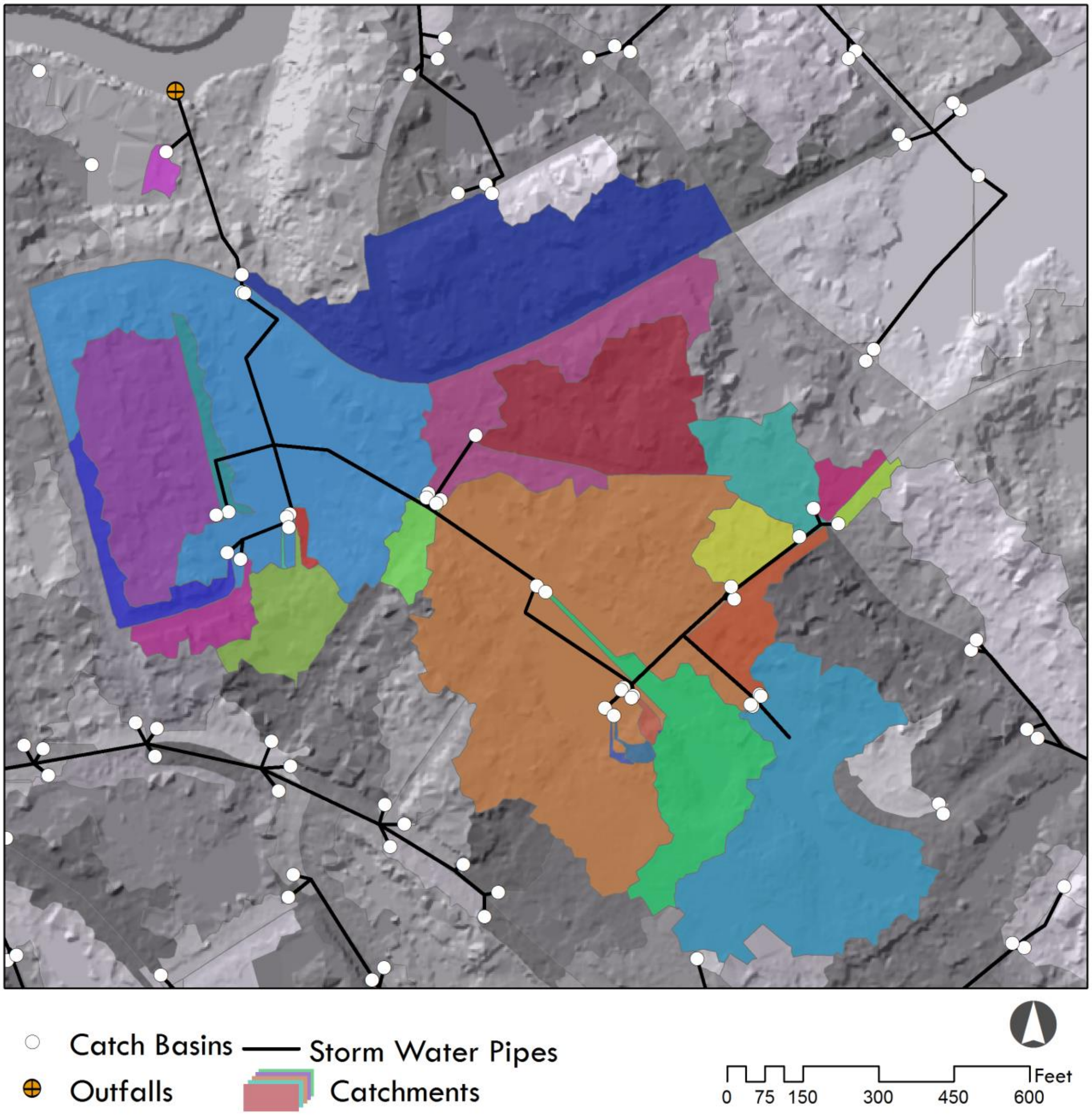

Figure 7. Catchments for each catch basin. The "streaky" catchments are in very flat areas with very low flow accumulation. Aggregating the catchments by outfall corrects for most of these issues.

The "cbid_int" field in the output raster matches the catch basin integer field, and can be used to join the original attribute table to the watershed layer.

Creating Outfall Catchments – An example from Milton, Massachusetts

The MS4 permit draft requires municipalities to delineate land areas that contribute rain water runoff to particular outfalls, so the small catch basin catchment areas must be "dissolved" into larger units based on which outfall they feed into. In order to achieve this, the catch basin feature class should contain a field that assigns each feature to an outfall. This way, catch basins catchment areas that drain to the same outfall can be grouped.

This grouping can be done based on local knowledge of the stormwater system. MAPC has also developed a methodology for linking catch basins and their outfalls using a common ID. Inputs are point feature classes for catch basins and outfalls and a line feature class representing stormwater pipes. This method will not produce a perfect result, but will likely save municipal staff time by providing a preliminary result that can be modified manually. Using the methods outlined here, municipalities will not need perfectly clean, accurate, and precise datasets in order to begin tracing evidence of illicit discharge discovered at an outfall back to the land area that contributed rain water to that outfall. The following sections describes how we conducted this analysis for the Town of Milton.

Creating "pipe system" IDs

To connect catch basins to their outfalls, we:

1. Buffered the pipe line features out according to the pipe diameter, then dissolve into a large multipart polygon.
2. Exploded the multipart polygon into many single part pipe polygons.
3. Created a "Pipesys_ID" field in the attribute table of the new pipe polygon feature class.
4. Populated the "Pipesys_ID" field with the OID number using the field calculator.
5. Performed a spatial join to link the original pipe line network to the pipe polygon feature class.
6. Performed additional spatial joins to link the pipe polygon feature class to both the catch basins and the outfalls.

At this point, all interconnected pipes shared a Pipesys_ID, and all associated outfalls and catch basins shared that ID. When selecting the buffer distance, we visually inspected the spatial relationship between a sample of the catch basins and outfalls and the pipe lines. Although in some cases the point features were not snapped to the line network precisely, in most cases they still intersected with the buffered pipe systems, so the imprecision did not affect the results. Another way to address snapping errors in the data would be to set a search distance when performing the spatial join.

Checking the data

After applying the automated method above to Milton's data, we noticed several inconsistencies in the infrastructure data. Common errors include pipe systems without associated outfalls, catch basins with no associated pipe networks, interconnected pipe networks, and outfalls with no associated pipe network or "uphill" outfalls. We met with officials from Milton's Department of Public Works to correct some of these areas based on their local knowledge. The local DPW staff informed us of some of the most common sources for these errors. The Milton

DPW has a very complete dataset recording the location of every catch basin in the municipality. Because those features are easily visible from the surface, and their locations are relatively predictable, they were able to perform a survey recording each catch basin location in the town with a GPS. The underground components of the infrastructure were much more difficult for them to survey, because the pipe networks may be very old in some parts of town, or are not owned or operated by the municipality, and they do not have access to the plans for those segments of pipes and their associated outfalls.

Table 2. Common problems with municipal stormwater data.

Data Problem	Common Causes	Solution
Pipe Systems with no associated outfall	The outfall may belong to DCR, MassDOT, or a private system, or the system may be so old that no plans exist	Outfall imputed based on local knowledge, owner recorded in a separate "owner" field
Catch basins with no associated pipe networks	Most catch basins were recorded in a survey of the entire town, so even though the catch basin was visible to the surveyor, the town may not own the catch basin, or the catch basin may be in a development that has not submitted their stormwater infrastructure plans to the town.	Catch basins are assigned a new pipe system ID, and an outfall is imputed based on local knowledge. If the catch basins are not owned by the town, the owner is recorded in the "owner" field.
Interconnected Pipe networks	Pipe networks may be interconnected, but for this method, each catch basin may be assigned to only one outfall, so the Town DPW stormwater experts were able to assess which outfall was most likely associated with each catch basin.	Pipe networks split by assigning certain segments distinct pipe system IDs based on local knowledge. Catch basin and outfall IDs changed to match associated pipes.
Outfalls with no associated pipe network or outfalls that appear in unlikely positions, such as on hilltops	Could be a pipe end erroneously recorded as an outfall	Do not assign catch basins to these outfalls. No additional solution needed. Could flag for field investigation.

In order to resolve these issues enough to aggregate the catchments by outfall, we made manual adjustments to the network based on the DPW staff's extensive experience and personal knowledge of the stormwater system. In instances where a pipe network may be interconnected and could outfall to more than one place, for example, we adjusted the data based on information from the DPW staff.

We initially identified instances where more than one outfall was associated with an interconnected pipe network by using the “find identical” tool, then joining the output table back to the outfall table. In the image below, for example, the automated method assigned a single ID to outfalls 1, 2, and 3, because they are associated with a single interconnected pipe network. In order to assign only one outfall to each catch basin, we assigned new unique IDs to each outfall and manually assigned them to appropriate pipes and catch basins.

Catch basin 4 in the image below is an example of a catch basin that was missed by the automated method of ID assignment, since the small joining pipe segment is missing from the dataset. Such catch basins were assigned manually whenever possible.

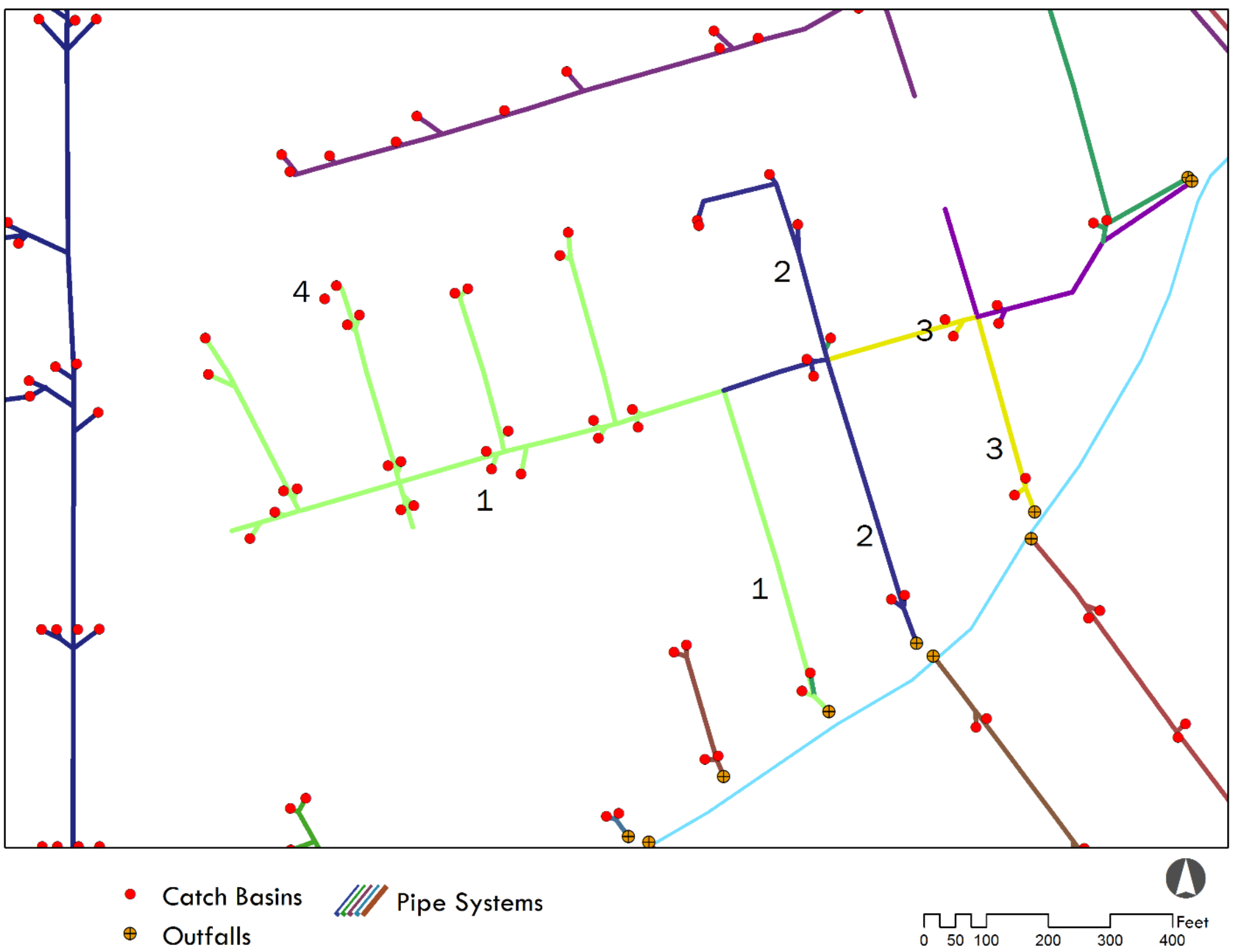

Figure 9. Splitting pipe systems by outfall.

We also added an “owner” field to account for interconnections in the infrastructure. According to the permit, municipalities must monitor not only their own outfalls, but also interconnections with other systems. For the purposes of the new MS4 permit, an interconnection is “the point where the permittee’s MS4 discharges to another MS4 or other storm sewer system, through which the discharge is conveyed to waters of the United States."[14] Additionally, some areas that do not have much potential for illicit discharge, such as "roadway drainage in undeveloped areas with no dwellings and no sanitary sewers, drainage for athletic fields, parks, and associated parking without services, cross country drainage alignments," may be excluded from regulation by the permit. [15] There is a cemetery in Milton, for example, that is on a private stormwater pipe system, and may also be excluded since it would be considered an undeveloped area with no dwellings under the terms of the permit. Drainage along roadways in the Blue Hills would also be excluded for the same reason.

After each catch basin was assigned to a pipe system, which was in turn associated with a single outfall, we merged the smaller catch basin catchments into larger catchments based on outfall and owner. Merging on owner as well as outfall allows municipalities to distinguish between MS4 regulated areas and areas that would be exempt because of a private system or another exemption. See the image below for the resulting output:

[14] United States Environmental Protection Agency. 2016: 34
[15] United States Environmental Protection Agency. 2016: 35

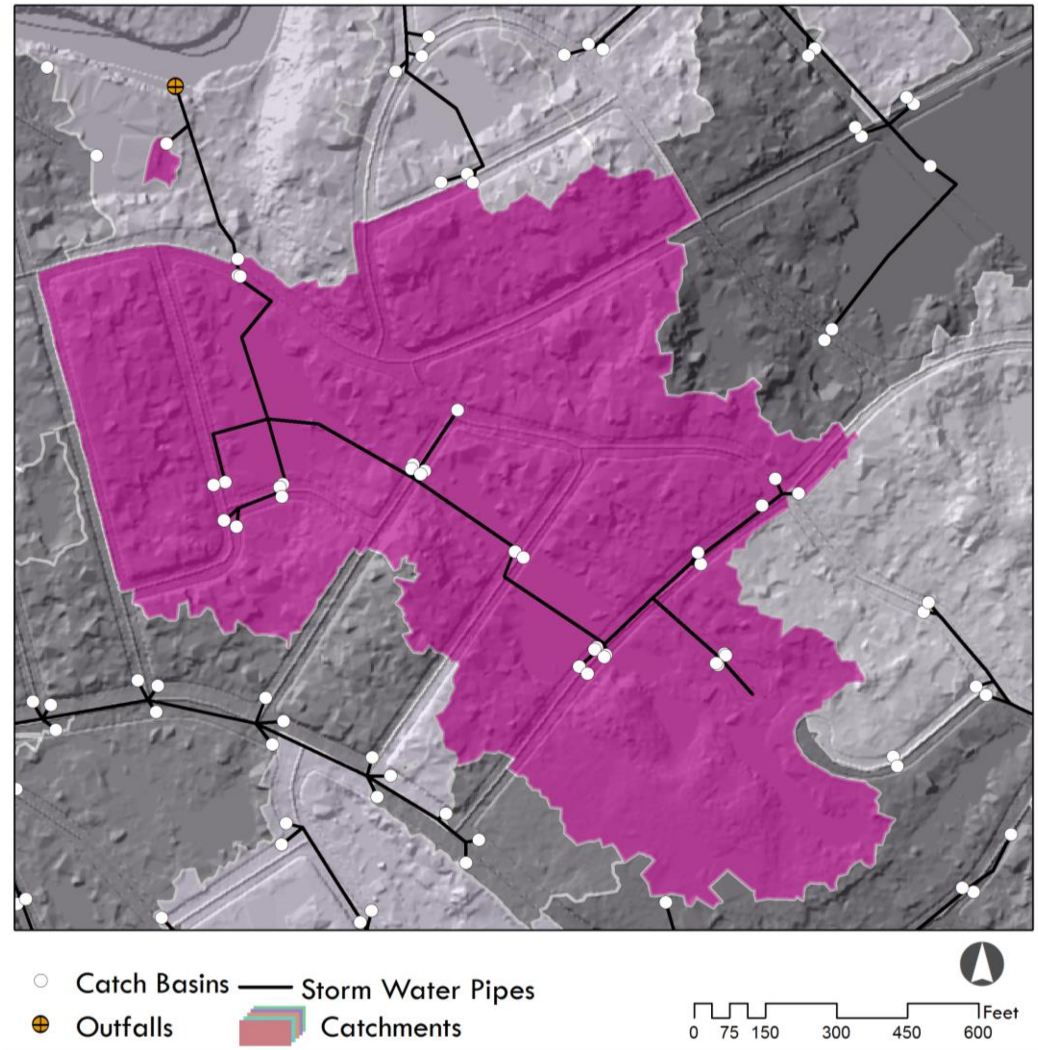

Figure 10. Outfall Catchments.

Ranking Catchments

Once we delineated outfall catchments for Milton and linked outfalls with Impaired Waters in Milton, we ranked Milton's outfall catchments according to how likely they were to contribute pollution to the receiving waters. NepRWA developed a spreadsheet-based method to prioritize outfalls and catchments based on criteria pulled directly from the language of the new permit. Some fields in the spreadsheet can be completed using GIS, and other should be completed using local knowledge of the stormwater system and municipality.

This spreadsheet analysis evaluates sites based on a set of specified quantitative criteria pulled directly from the language of the permit.

In this case, the presence of older homes, industrial uses, septic systems, and other physical features were summarized into a composite score from 0 to 100. Catchments with a median score or below were considered low priority, catchments within the third quartile were considered medium, and those within the top quartile were considered high priority, or most likely to contribute illicit discharges to impaired waters.

Land use codes were designated as medium or high potential for illicit discharges using information found in the 2004 manual from Center for Watershed Protection, titled "Illicit Discharge Detection and Elimination: a guidance manual for program development and technical assessments".[16] The guidance manual provided illicit discharge pollution potential for a variety of land uses and included their SIC codes in Attachment A, which were compared to and converted to NAICS codes during this process.

We used the following criteria for the analysis:

Generating sites, Businesses

We used two data sources to capture information on businesses that are at high or medium risk for illicit discharge into the stormwater system, and used these two datasets to create lists of high and medium risk businesses, which we then combined to create an index of generating businesses. One dataset is the Massachusetts Land Parcel Database, which summarizes the assessor's records associated with each parcel. This dataset contains a land use code assigned by the assessor. These codes can be very specific—gas stations are distinguished from automobile repair shops, for example. The other dataset is establishment listings published by InfoGroup. Each business in this dataset has an associated classification code as well. These codes, called North American Industry Classification System (NAICS) codes are the standardized codes used by the US Census Bureau and other federal agencies for collecting economic data. These codes are even more specific than those from the parcel dataset. See the tables below for descriptions of the business types that we classified into high and medium risk businesses.

High Potential businesses:	
• Heavy Construction equipment rental and leasing • Building and heavy construction (for land disturbing activities) • Buildings for manufacturing operations • Apparel and other fabrics • Auto recyclers and scrap yards • Boat building and repair • Chemical products • Food processing • Garbage truck washout activities • Leather tanners	• Paper and wood products • Petroleum storage and refining/ gas production plants • Tanks holding fuel and oil for retail distribution • Natural or manufactured gas storage • Textile mills • Transportation equipment • Landfills and hazardous waste material disposal • Maintenance depots • Streets and highways construction

[16] Environmental Protection Agency. "Illicit Discharge Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments." https://www3.epa.gov/npdes/pubs/idde_manualwithappendices.pdf Last Updated on October, 2004.

High Potential businesses:	
• Metal production, plating, and engraving operations • Facilities providing building materials, hardware, and farm equipment, heating, hardware, plumbing, lumber supplies and equipment	• Ports • Railroads • Petroleum bulk stations or terminals • Research and development facilities

Medium Potential businesses:	
• Auto repair facilities/ automotive vehicles or supplies sales and service • Automobile parking lots or garages • Bus transportation facilities and related properties • Campgrounds/RV parks • Car dealers • Car washes • Food stores and wholesale beverage/ supermarkets • Small retail and services stores • Eating and drinking establishments	• Gasoline stations/ fuel service areas • Marinas • Nurseries and garden centers • Oil change shops • Restaurants • Chemical products • Food processing • Rubber and plastics • Colleges and universities • Airports • Rental car lots • US postal service • Trucking companies and distribution centers

Figure 11. Lists of commercial potential illicit discharge generating sites.

To create the Business Generator Index, we multiplied the count of medium risk businesses from both datasets within each catchment by five, and added the result to the count of high risk businesses multiplied by ten (medium risk businesses * 5 + high risk businesses * 10). Next, we divided this index by the acreage of the catchment to produce a density index. We used the generating site index density value as a criterion for the suitability analysis.

Generating sites, Residential

For residential properties, the age of the house contributes to its risk for contributing illicit discharge to the stormwater system. The draft Massachusetts MS4 permit states that one of the ranking factors that MS4 municipalities are to consider is "Age of development and infrastructure – Industrial areas greater than 40 years old and areas where the sanitary sewer system is more than 40 years old will probably have a high illicit discharge potential. Developments 20 years or younger will probably have a low illicit discharge potential."[17] We created a residential index similar to that of the business index. In this case, we used the same parcel database, this time using the "last built date." We used this category based on the assumption that new construction

[17] United States Environmental Protection Agency. 2016: 35.

or drastic rebuilding would be required to follow the building codes in effect at the date of construction.

Again, we created two categories of residential risk: high, for the count of houses in a catchment built more than 40 years ago, and medium, for the count of houses in the catchment built 20 to 40 years ago. We created an index using the same formula as that for the business index (count of medium risk *5 + count of high risk *10), and divided the result by the acreage of the catchment. We used this housing index per acre value as a criterion for the suitability model.

Sewer and Septic

We also created criteria reflecting the density of sewer lines and the concentration of septic systems within each catchment. Based on the line shapefiles we got from the GIS Analyst at Milton's DPW sent us, we calculated the length of sewer pipe within each catchment divided by the total area of that catchment. Milton also provided us with a shapefile representing each parcel that has a septic system. For the "septic" criterion, we simply divided the number of septic systems in each catchment by the acreage of that catchment.

Quality of Receiving Waters

As described above, each catchment was associated with a single receiving water in the Integrated List of Waters created and maintained by MassDEP and published by MassGIS. We used the category of the associated receiving waters as a criterion within the suitability analysis. Categories of Impaired waters range from 1 to 5, with 5 being the most impaired, and 1 being unimpaired. Category 2 and 3 waters may be unimpaired for some uses and not assessed for others, or there may not be enough information available to make an assessment. Within Milton, all waters were rated a category 5, but elsewhere in the Neponset Watershed, some of the waters rank in a lower category, so we included the receiving water criterion even though it makes no difference in the rankings of the catchments for Milton.

Table 3. Ranking criteria and weights

Criterion	**Description**	**Dataset**
Business Generating Site Index Density	Count of businesses of specified types divided by catchment area (in acres)	MAPC Massachusetts Land Parcel Database, InfoGroup
Density of older houses	Summary index, weighted count of houses older than 40 and 20 years.	MAPC Massachusetts Land Parcel Database
Density of sewer pipes	Length of sewer pipes per acre	municipal infrastructure data
Density of septic systems	Number of septic systems per acre	municipal data

Quality of receiving waters	Category of water, 3, 4, or 5	303(d) Integrated List of Waters dataset from MassDEP, available through MassGIS

Discussion

The increasingly stringent requirements of federal stormwater permits combined with the lack of dedicated funding streams for stormwater infrastructure maintenance present substantial challenges to local jurisdictions. Given these circumstances, municipalities will greatly benefit from tools that allow them to cost-effectively satisfy analytical permit requirements so that resources and attention can be focused on infrastructure, outreach, and enforcement. This document describes one such tool recently prepared by MAPC and now available to any city or town in Massachusetts.

The methodology and data resources described here will help many municipalities meet the "catchment delineation" requirement in the system mapping section of the new MS4 permit, provided the Outfall/ Interconnection Inventory is relatively complete, and gaps in knowledge can be filled by DPW staff.[18] Cities and towns do not need to collect or developed detailed stormwater infrastructure information, and MAPC has also provided highly detailed information on land uses and establishments that pose a higher risk for water pollution, eliminating the need for cities and towns to acquire or compile such data. Furthermore, the tool is structured to provide the specific types of data and designations required by the NPDES permit. For example, the permit requires municipalities to classify catchments into four groups—excluded, high priority, low priority, and problem. These products should help municipalities with the first three categories. If municipalities assign an "owner" to each catch basin, they will be able to distinguish between excluded and included catchments. The step-by-step instructions provided in this document, combined with the published data catalog and ArcGIS tool published online, will enable jurisdictions or consultants with relatively modest technical capabilities to use this method.

The delineation methodology and ranking process has some limitations that could be addressed through additional data collection. For example, it would have been useful to include the age of the sewer pipes as a ranking criterion. Most municipalities in the Neponset Watershed do not have this data available, however. The catchment ranking described here does not distinguish between problem catchments and other catchments. For the purposes of the MS4 permit, a "problem outfall" is one that has had an outfall that tested as contaminated, or that direct observation indicates that there is some kind of illicit discharge connected to that outfall.[19] Such a catchment would be considered a problem catchment regardless of its ranking in this suitability analysis, and must be investigated. In the future, the ranking could include historical data on whether a catchment has ever been designated a problem catchment, so that former problem

[18] United States Environmental Protection Agency. 2016: 32.
[19] United States Environmental Protection Agency. 2016: 34.

catchments will rank higher than those that have had no observed contamination. If data are available, such analysis could be easily incorporated into a future version of the tool.