Choosing Locations for Green Infrastructure in the Lower Raritan Watershed

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Contents:

Overview

The Lower Raritan Watershed (LRW), or Water Management Area 9 (WMA9) has diverse land uses, and much of it is heavily urbanized and suburbanized. The population is most dense in Somerset County, New Brunswick, Freehold, and near the Raritan bay. There is a lot of legacy pollution, but non-point source (NPS) pollution is a big problem in the watershed. The impervious surface created by buildings, roads, parking lots, and even suburban lawns, causes heavy stormwater runoff. When rain water flows along these impervious surfaces rather than infiltrating into the ground, it leads to a number of problems, including flashiness and contamination (Brabec 2002). Rain water concentrates quickly, and high volumes of water rush to streams, causing flooding and erosion of stream banks (Brabec 2002, Allan 2004). The water collects pollutants along the way, including excess nutrients (N and P), heavy metals, sediments, and bacteria (*Escherichia coli*). These pollutants end up in water bodies and impairs their functions and beauty.

Stormwater detention basins are designed to mitigate flooding from 5-year design storms and greater (NJ BMP Manual, 2016). Because these basins were originally designed for such as narrow purpose, there is scope for much greater functionality from them. There is a trend to "retrofit" stormwater detention basins with native vegetation to increase nutrient uptake, trap sediment, and decrease flows by infiltration and evapotranspiration (Milandri et al. 2012, Fassman 2012). Retrofitting can have added benefits of bringing biodiversity to an area, having great aesthetic value, and decreasing maintenance costs. Because there are so many of these basins, retrofitting could have a large collective impact. Green infrastructure and renovating detention basins is still unfamiliar to most municipalities, at which level most basins are managed, so it is an important job for the LRWP to work with municipalities to start the process.

Literature Review

Identifying Function of Green Infrastructure for Matching with Watershed Needs

Green infrastructure is thought to have positive effects on stormwater quality. In theory, sediment settles in the basin due to retention time and the interaction with plants (NJ Stormwater BMP Manual). Contaminants, such as heavy metals and hydrocarbons, can settle into the sediment via sorption (Weiss et al. 2006). Nutrients, nitrogen and phosphorus, can settle in stormwater basins by chemical and physical processes in the soil medium and by uptake by plants in vegetated systems (Reddy et al. 2013, Milandri et al. 2012). In addition to pollutant settling, green infrastructure can reduce peak flows via retention, infiltration, and evapotranspiration (Winston et al. 2016). There are a wide range of possibilities for the design of green infrastructure, which have a corresponding range of effectiveness for removal of contaminants and reduction of storm flows.

The most basic form of retrofitting includes removal of concrete low-flow channel, planting desired vegetation, updating outflow pipe to 3 inches, and adjusting mowing regime to approximately once per year. There are many other options, including installation of a forebay to capture sediment, excavating and replacing soil with an infiltration mix, and building a full artificial wetland system with a dam (NJ Stormwater BMP Manual, 2016). Each stormwater

N.J.A.C. 7:8 Stormwater Management Rules - Design and Performance Standards		
	Nonstructural Strategies	Assist with Strategies #2, 4, 7, and 8; See Page 4
	Water Quantity	Yes, when designed as an on-line system
	Groundwater Recharge	Yes, for systems designed to infiltrate into the subsoil
	Water Quality	80 - 90% TSS Removal, Depending on Vegetation Selection and Depth of Soil Bed

Figure 1. Example of performance notes for stormwater BMPs from the New Jersey Stormwater BMP Manual. This table is for Bioretention systems.

basin is unique due to landscape and design factors, and there is no clear consensus on the effect of best management practices on water quality (Bartone and Urchin 1999, Fassman 2012, Milandri et al. 2012, others). More research is needed to determine the best mix of vegetation and maintenance regimes that produce the best results over time; however, the NJ Stormwater BMP Manual does offer general removal ranges for sediment according to basin design (ex. Figure 1). Bioretention, shown in Figure 1, removes 80-90% of total suspended solids (TSS). Constructed wetlands maximize the removal of TSS, removing 90%. Infiltration basins are constructed to maximize groundwater recharge and remove pollutants, 80% TSS. Extended detention basins (those with sedimentation forebays) are estimated to remove 40-60% of TSS depending on the retention time of the water.

The selection of retrofit design will depend on the parameter that is to be remediated. The cost and effectiveness should be taken in to account when selecting basins for updating. Areas with highest pollutant loads offer the most potential improvement by installing green infrastructure. On the other hand, areas with low levels of pollutants may be treated with simple, low-cost vegetated detention basins. Using designs that are inexpensive and easy to install and maintain may be a good way to introduce green infrastructure to municipalities and residents.

General Frameworks for Environmental Decision Making

In determining where to place retrofits, there are some frameworks that inform the scope of factors that may be important. Pickett et al. (2001) proposes the Variable Source Area approach for using urban ecology as a planning tool (Figure 2). This approach combines nested hierarchies of land use and land cover, sociopolitical structures, and watershed abiotic factors. There are a range of first order variables to consider, including climate, geology, soils, and land use. These variables determine the types of retrofits that are possible and appropriate as well as infiltration potential. The LRW does cross the Piedmont and coastal plains physiographic regions (Figure 3), and there is a lot of variability among soil types and underlying geology. Examining the soil in various regions may give a general idea of what types of retrofits are possible given the soil. One caveat is that most urban soil is highly compacted,

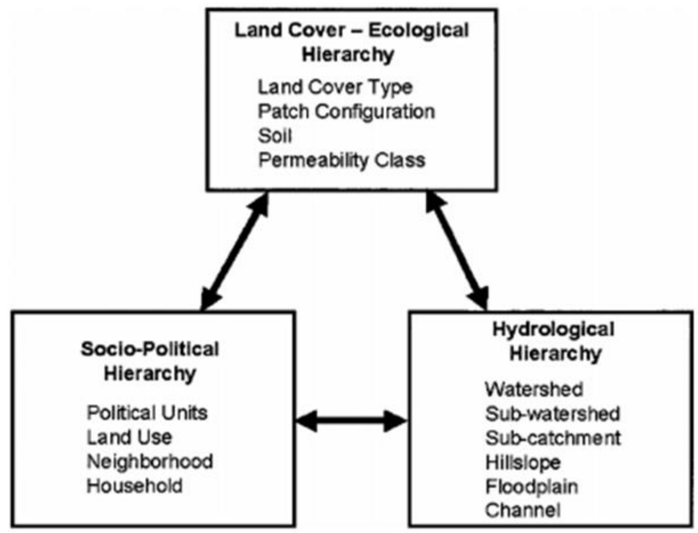


Figure 2 Three interacting nested hierarchies of spatial heterogeneity representing key disciplinary perspectives used in modeling watershed function in urban areas. Land cover represents nested ecological structures that control interception and runoff. The sociopolitical hierarchy contains nested units of environmental decision making and resource use. The hydrological hierarchy indicates the nesting of spatially differentiated units connected by runoff and runon dynamics.

Figure 2. Model of the use of urban ecology to inform planning (Pickett et al. 2001)

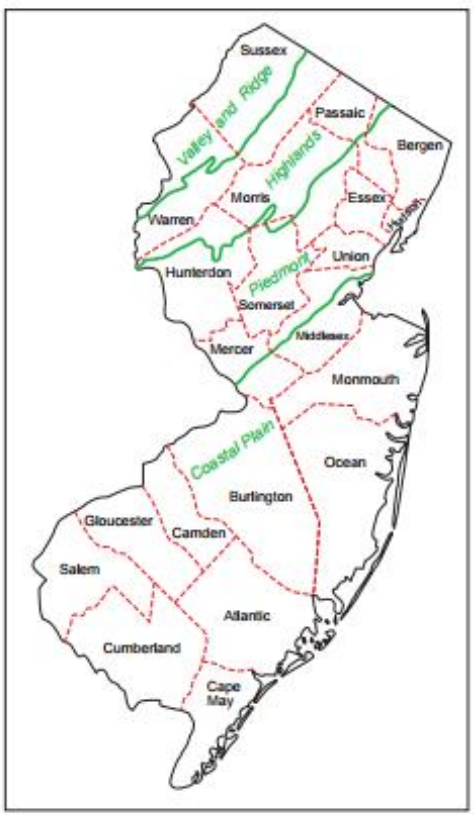


Figure 3. Physiographic regions of New Jersey, from Dalton (2003)

so it may not function according to its soil class (Gregory et al. 2006). Another factor that makes soil type a poor decision making tool on a broad scale is changes to soils due to excavation and construction. During construction of the basins, soils may have been exported or imported to the site that make them inconsistent with surrounding soils (Stephanie Murphy, Director of Rutgers Soil Testing Laboratory, pers. commun.).

Predictors of Impairments in a Watershed and Need for Green Infrastructure

Stream ecosystems are affected by human actions across spatial scales, and anthropogenic and abiotic gradients interact (Allan 2004). In a heavily developed watershed, such as the LRW, with a lot of agriculture, suburban, and urban activity, it is essential to examine the human effects on water quality and stream systems. Land use will have a strong impact on the amount and contamination of stormwater runoff, and other social, economic, and regulatory systems will leave their marks. Table 1 gives an overview of the effects of land use on streams, many of which are due to changes in runoff characteristics.

Land use/land cover change over time, especially draining of floodplains and loss of wetlands, is a good indicator of where there will be major changes in hydrology (Aghewi 2013). Aerial photography provides a basis to asses that change. High resolution, digital orthophotographs are available from the NJGIN Information Warehouse, and sets from 2002 and 2015 can be compared. Areas that have new development in riparian areas and changes to wetlands will also have changes to stormwater regimes and may need stormwater mitigation. Additionally, if areas of active development are targeted, perhaps green infrastructure can be incorporated at the outset rather than included as costly updates in 15 or 20 years when the impacts of the development are fully accounted for. “Extinction debt” is a time-delayed effect of habitat fragmentation on biodiversity, so impacts of new development may not be immediately apparent (Krauss et al. 2010).

TABLE 1 Principal mechanisms by which land use influences stream ecosystems

Environmental factor	Effects	References
Sedimentation	Increases turbidity, scouring and abrasion; impairs substrate suitability for periphyton and biofilm production; decreases primary production and food quality causing bottom-up effects through food webs; in-filling of interstitial habitat harms crevice-occupying invertebrates and gravel-spawning fishes; coats gills and respiratory surfaces; reduces stream depth heterogeneity, leading to decrease in pool species	Burkhead & Jelks 2001, Hancock 2002, Henley et al. 2000, Quinn 2000, Sutherland et al. 2002, Walser & Bart 1999, Wood & Armitage 1997
Nutrient enrichment	Increases autotrophic biomass and production, resulting in changes to assemblage composition, including proliferation of filamentous algae, particularly if light also increases; accelerates litter breakdown rates and may cause decrease in dissolved oxygen and shift from sensitive species to more tolerant, often non-native species	Carpenter et al. 1998, Delong & Brusven 1998, Lenat & Crawford 1994, Mainstone & Parr 2002, Niyogi et al. 2003
Contaminant pollution	Increases heavy metals, synthetics, and toxic organics in suspension associated with sediments and in tissues; increases deformities; increases mortality rates and impacts to abundance, drift, and emergence in invertebrates; depresses growth, reproduction, condition, and survival among fishes; disrupts endocrine system; physical avoidance	Clements et al. 2000, Cooper 1993, Kolpin et al. 2002, Liess & Schulz 1999, Rolland 2000, Schulz & Liess 1999, Woodward et al. 1997
Hydrologic alteration	Alters runoff-evapotranspiration balance, causing increases in flood magnitude and frequency, and often lowers base flow; contributes to altered channel dynamics, including increased erosion from channel and surroundings and less-frequent overbank flooding; runoff more efficiently transports nutrients, sediments, and contaminants, thus further degrading in-stream habitat. Strong effects from impervious surfaces and stormwater conveyance in urban catchments and from drainage systems and soil compaction in agricultural catchments	Allan et al. 1997, Paul & Meyer 2001, Poff & Allan 1995, Walsh et al. 2001, Wang et al. 2001
Riparian clearing/canopy opening	Reduces shading, causing increases in stream temperatures, light penetration, and plant growth; decreases bank stability, inputs of litter and wood, and retention of nutrients and contaminants; reduces sediment trapping and increases bank and channel erosion; alters quantity and character of dissolved organic carbon reaching streams; lowers retention of benthic organic matter owing to loss of direct input and retention structures; alters trophic structure	Bourque & Pomeroy 2001, Findlay et al. 2001, Gregory et al. 1991, Gurnell et al. 1995, Lowrance et al. 1984, Martin et al. 1999, Osborne & Kovacic 1993, Stauffer et al. 2000
Loss of large woody debris	Reduces substrate for feeding, attachment, and cover; causes loss of sediment and organic material storage; reduces energy dissipation; alters flow hydraulics and therefore distribution of habitats; reduces bank stability; influences invertebrate and fish diversity and community function	Ehrman & Lamberti 1992, Gurnell et al. 1995, Johnson et al. 2003, Maridet et al. 1995, Stauffer et al. 2000

Table 1.From Allan (2004).

The increase of imperious surface due to urban development is one of the mechanisms by which land use change affects watersheds. Table 2 provides an overview of the impacts and the thresholds as percent cover at which parameters are affected. Many biotic parameters are impaired at thresholds as low as 5-10% cover, but all parameters are degraded at 40-50% cover (Brabec et al. 2002) In examining impervious cover, we should consider *effective* impervious area (EIA), the area that is connected to the storm sewer system (Brabec et al. 2002), not just total impervious area, since EIA is the area that feeds stormwater infrastructure. In terms of impact on stream channels from flashiness, development within 150 meters of the stream channel has the strongest impact. Together these facts indicate that areas with 50% or greater impervious surface, within 150 meter of surface water, and connected to storm sewers will have serious stormwater runoff issues and should be targets for mitigation efforts.

Table 2. From Brabec et al. (2002)

TABLE 5. Summary of Degradation Measures and Their Associated Threshold Findings

	Impact Measurement	Percentage Impervious Threshold for Degradation	Study
Parameter type	Parameter		
Biotic	Benthic invertebrates	< 10 humans per hectare	Jones and Clark (1987)
		8	Horner et al. (1997)
		15	Klein (1979)
	Fish diversity	10 urbanized	Limberg and Schmidt (1990)
		12	Klein (1979)
		8	Miltner (1997)
		3.6	Booth and Jackson (1994)
		10	Wang et al. (forthcoming)
	IBI	8 urban land use	Yoder et al. (n.d.)
	Macroinvertebrate diversity	8 to 15	Shaver et al. (1994)
		8	Miltner (1997)
	Species diversity	10 to 15	Booth and Reinelt (1993)
Abiotic and biotic	IBI, habitat quality	10 to 20 urban land use	Wang et al. (1997)
	Mean event water-level fluctuation/ indicator species	10 TIA, 14 EIA	Taylor (1993)
	Variation of water depth and indicator species	15 to 21	Chin (1996)
Abiotic—physical	Temperature for cold-water biota	12	Galli (1990)
	Base flow	45	Klein (1979)
	Stream flow	> 21	Horner et al. (1997)
		Not defined	Krug and Goddard (1986)
	Peak flows	4.6	Booth and Jackson (1994)
	Channel enlargement and streambank erosion	Not given	Hammer (1972)
		34 urbanization	MacRae (1997)
		8 to 10	Booth and Reinelt (1993)
		30	May et al. (1997)
		10	Booth and Jackson (1994)
	Habitat assessment	4 to 9 impervious surface and 30 to 50 forest	Hicks and Larson (1997)
	Large woody debris	9	Horner et al. (1997)
	Sediment	20	Wydzga (1997)
		50	Horner et al. (1997)
		Not defined	Krug and Goddard (1986)
		43	Griffin et al. (1980)
		45	May et al. (1997)
Abiotic—chemical	Nutrients	42	Griffin et al. (1980)
	Phosphorous	45	May et al. (1997)
	Threshold of eutrophication based on TSS and TP	30	Todd et al. (1989)
	Chemical water quality	45	May et al. (1997)
	Oxygen	10	May et al. (1997)
		7.5 urbanized	Limburg and Schmidt (1990)
		43	Griffin (1980)
	Metals	50	Horner et al. (1997)
	Zinc	40	Horner et al. (1997)

NOTE: IBI = Index of Biotic Integrity; TIA = total impervious area; EIA = effective impervious area; TSS = total suspended solids; TP = total phosphorus.

Location in the watershed matters too: upstream impairments affect more miles of stream, but downstream impacts are more concentrated (Brabec et al. 2002). More specifically, Matteo et al. (2006) found that the location of urban forests matters for the reduction of stormwater runoff and associated contamination. An inverse to impervious cover, forest cover has an important impact watersheds. At least 15% forest land cover should be preserved in a catchment to prevent sediment and nutrient loading (Matteo et al 2006). They used a model to simulate different scenarios and found that a combination of road buffers and riparian buffers gives the highest reduction of runoff and contaminant loading. Though the importance of riparian buffers is well known, this indicates that the absence of street trees and road buffer is an indicator for watershed impairment. In their model they use a 10 foot roadside tree buffer as the BMP, which points to the importance of keeping or planting roadside trees whenever possible. This may mean targeting existing flood-control basins near roads, or working with environment and shad tree commissions on roadside trees as a non-structural approach to stormwater management.

In general, management of riparian areas is particularly attractive because it is well-documented and has immediate and direct influence on stream condition. Benefits of protecting riparian areas disproportionate to the land area required (Allan 2004).

Socio-Political Factors

While abiotic factors are the setting for stormwater management, environmental decision making takes place in the socio-political realm (Pickett et al. 2001). For this reason, socio-political factors may be the strongest factors that dictate retrofitting decisions. Decisions regarding watersheds are made within political boundaries, from state, to county, to municipality. There may be important differences between institutional ability and willingness to consider green infrastructure. Beyond this, there is a spatial dimension to wealth, power, knowledge, status, and territory that has a reciprocal relationship with biophysical patterns and processes (Pickett et al. 2001). Intervening in the biophysical system also requires an acknowledgement, and ideally and understanding of the sociocultural as well.

Successful implementation of green infrastructure will depend on willingness in political organizations such as county and municipal, and local grassroots champions. Because green infrastructure and detention basin retrofitting is not in wide use in New Jersey yet, starting with willing communities will smooth the path considerably. These types of issues have been examined by the Cooperative Extension Service. Tours. Voluntary acceptance of innovative farm practices has been studied extensively, and in NJ those lessons need to be aimed at suburban and urban populations. Adoption and voluntary participation studies.

The existence of Total Maximum Daily Load (TMDL) regulations provides a compelling reason to target a sub-watershed for green infrastructure improvements. The TMDL regulations stem from the Clean Water Act. Portion 130.7 of the Clean Water Act stipulates:

> …setting priorities for developing these loads; establishing these loads for segments identified, including water quality monitoring, modeling, data analysis, calculation methods, and list of pollutants to be regulated; submitting the State's list of segments identified, priority ranking, and loads established (WLAs/LAs/TMDLs) to EPA for approval; incorporating the approved loads into the State's WQM plans and NPDES permits; and involving the public, affected dischargers, designated area-wide agencies, and local governments in this process shall be clearly described in the State Continuing Planning Process (CPP) (TMDL and individual water quality-based effluent limitations 40 C.F.R. 130.7 [1992]).

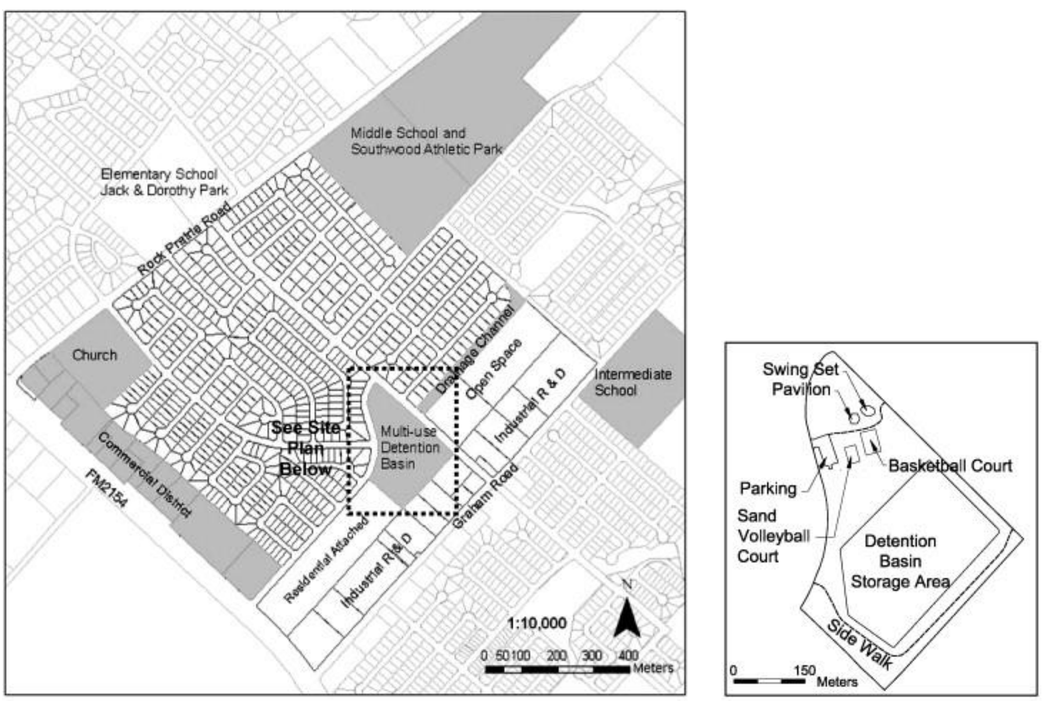
This regulation mandates a framework be put in place in a given catchment that will facilitate implementation of green infrastructure projects. Along with the TMDL come funding sources (ex. 319h grants), regulatory imperatives, and legal recourse if additional motivation is needed

(Clean Water Act, 33 U.S.C. §1251 et seq. [1972]). The framework of TMDLs makes the sub-watersheds where they are in force practical starting places for green infrastructure initiatives.

Another statutory issue that may be of interest is the compliance of detention basins with state standards for attenuating peak flow, improving water quality, and recharging groundwater. Salisbury and Obropta (2016) examined detention basins of different ages, from 10- to 32-years old and modeled their abilities in regards to design standards. Older basins do not meet any of the peak flow reduction targets because detention times are too shorts, and likewise infiltrate only 1% of target volume. This indicate that the oldest detention basins may be priorities for retrofitting, and that existing statutes support that imperative.

When stormwater basins are located in residential neighborhoods, social factors may be important in neighborhood willingness to implement green infrastructure (Baptiste et al. 2015). In a case study in Syracuse, NY, Baptiste et al. surveyed residents in different neighborhoods about their attitudes implementing runoff-reduction measures at their homes. Aesthetics, cost, gender (females more willing), and levels of environmental knowledge were the most important factors affecting a resident's attitude about implementing green infrastructure. There was a high general knowledge of environmental issues in this study, and no difference in knowledge based on neighborhood or education level of respondents. There was a countywide public campaign with extensive outreach in the area about stormwater-related issues, called "Save the Rain," and that campaign seems to have prepared people to be more receptive to green infrastructure than they might otherwise have been. In this case study, knowledge of issues was a strong determinant of willingness.

In regards to residential neighborhoods, stormwater infrastructure can have an impact on property values, demonstrating the importance of public perception. A 1996 survey study of residents living near wet or dry detention basins found that residents responded much more positively to wet basins than dry basins (Emmerling-Dinovo 1996). Many respondents believed that the dry basins even had a negative impact on the image of the subdivision, and on average would not be willing to pay more for a lot adjacent to a dry basin. Lee and Li (2009) examined property value differences between homes in a residential neighborhood depending on their proximity to dry detention basins, and the context of the dry detention basin. They found lower property values for properties near flood control only basins (i.e., stormwater detention basins). On the other hand, they found higher property values near basins integrated with recreation opportunities. Examples of recreation opportunities include picnic tables or swings (Figure 4). These findings indicate that the public do not currently have a very good perception of dry



(a) Subdivision Plan (b) Site Plan of MDB, i.e., the Edelweiss Park

Figure 4. Detention basin in residential neighborhood integrated with recreation opportunities. From Lee and Li (2009).

detention basins, thus change may be acceptable. Perhaps the perception of the basin can be altered if it is incorporated into a recognizable function that benefits residents as in the Lee and Li study (2009). This idea of incorporating stormwater basins with other contexts may be an important concept for gaining positive public perception, and further study of other contexts or public participation in designs will do much to advance acceptance of neighborhood green infrastructure.

There are many such partnerships that could be imagined with organizations from the international to the local. For example, a program through The Nature Conservancy (TNC) called BirdReturns hired farmers to flood their fields in the off season to offer pop-up wetland habitat for migrating shore birds (McColl et al. 2016). The NJDEP Division of Fish and Wildlife is developing a habitat corridor plan called Connecting Habitat Across New Jersey (CHANJ). Their analysis is not yet available, but is projected to included "1) A statewide analysis depicting areas crucial for habitat connectivity… and 2) A menu of implementation actions for securing, restoring, and/or reconnecting habitats within those key areas" (Division of F&W 2017). These are examples of the types of initiatives in which detention basins could play a role beyond flood control and water quality improvements. The NJ Audubon Society, TNC, and NJF&W could become partners that add value to green infrastructure and involve a wider community of stakeholders in the process.

GIS models for Locating Priority Areas

Geographic information science and systems (GIS) provide some of the most useful tools for this spatial analysis. There are a number of models that address different elements of watershed management and may inform green infrastructure decisions. Matteo et al. used a

GWLF model of urban forestry. The schematic of the model is similar to Pickett et al.'s Variable Source Approach, and the model is used to assess the impacts of adding trees at various locations in the watershed (i.e., near the street, near the stream). Because the goals of green infrastructure are similar to the goals of this urban forestry model, it might be adapted for understanding the general impacts of implementing green infrastructure in the watershed.

Another model that is specific to watershed planning is the Critical Source Area model (Giri and Qiu 2016). This tool is designed with the Raritan watershed as its cast study. The Critical Source Area model is an integrated approach for targeting nonpoint source pollution in a watershed and hydrologically sensitive areas, which together indicate priority areas for green infrastructure. This model builds on the Soil and Water Assessment Tool (SWAT), which is a general model for assessing hydrology and transport of materials throughout the watershed. Martin-Mikle et al. (2015) incorporate some of the same factors with urban information such as zoning to create a tool for siting various types of stormwater mitigation tools in an urban landscape (Table 3). One of the advantages of their model is that they distinguish spatial scales, and suggest locations for interventions ranging from rain barrels to detention ponds, from a local to a catchment scale. This methodology may be a useful starting place for a rigorous, watershed-wide assessment of siting various types of stormwater interventions.

Table 1.
Data layers used to prioritize locations for low impact development (LID) at a watershed scale.

GIS layer	Resolution/format	Source	Citation
Land cover	30-m/raster	National Land Cover Database (NLCD) 2006	Fry et al. (2011)
Impervious Surface	10-m/raster	National Land Cover Database (NLCD) 2006	Fry et al. (2011)
DEM	10-m/raster	National Elevation Dataset (NED)	Gesch (2007)
Soil conductivity	6 ha/polygon	Soil Survey Geographic Database (SSURGO)	NRCS (2012)
Soil depth to Restrictive layer	6 ha/polygon	Soil Survey Geographic Database (SSURGO)	NRCS (2012)
Roads	1:100,000/Vector	Topologically Integrated Geographic Encoding and Referencing (TIGER) 2012, US Census Bureau	USCB (2013)
Zoning	Vector	City GIS Departments	
Building Footprint	Vector	City GIS Departments	
Floodplain	Vector	City GIS Departments	
Water bodies	1:24,000/Vector	National Hydrography Dataset (NHD), Version 2.0	USGS (2012)

Table options

Table 3. From Martin-Mikle et al. (2015)

Another approach to selecting areas for green infrastructure could incorporate conservation goals. Marxan is software used to optimize vegetation placement for conservation in landscape-level decision making (Jellinek 2017). This could be a valuable modeling tool to use in order to couple stormwater management activities with broader conservation goals. Detention basin retrofitting may overlap with the goals of groups beyond watershed managers and those interested in water quality.

Issue as it applies to the Lower Raritan

According to the New Jersey Hydrologic Modeling Database (2017), there are over 1500 stormwater basins of various designs in the LRW (Figure 7). This database is not comprehensive, so there are even more that exist in the watershed. These already-built structures constitute the low-hanging fruit for watershed improvement: they already collect water, but have very little functionality. Renovating existing basins may be a logical first step to green infrastructure in the LRW. There are known problems from NPS pollution that include sediment, nutrients, and *E. coli*, and fish are inedible due to mercury concentration (TMDLs 2016). The LRW doesn't comply with the vision or reality of the Clean Water Act, and retrofitting detention basins would be a step toward restoring biotic and aesthetic quality to the region.

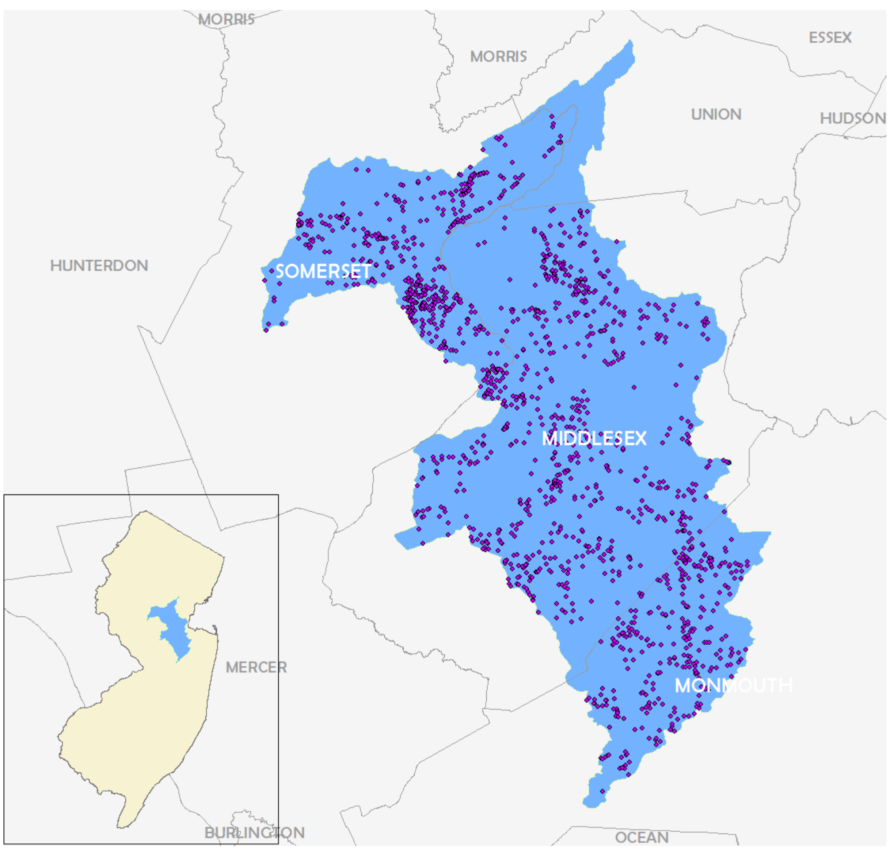
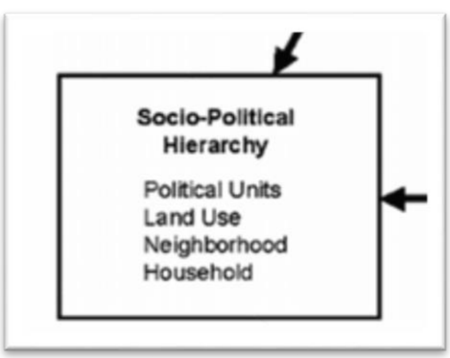


Figure 5. Stormwater basin locations in the LRW. There are 1535 identified in the database. Source: NJDEP and Hyrologic Modeling Database.

In locating specific areas or even basins for retrofitting, the models proposed by Martin-Mikle et al. (2015) and Giri and Qui (2016). Subsasis Giri, who is working on modeling priority areas for green infrastructure, is a post-doctoral researcher at Rutgers, working with Dr. Rick Lathrop of the Sustainable Raritan River Initiative. This local expert can probably provide examples of hydrologically sensitive areas with high NPS pollution. In addition to GIS-based models, the conceptual model of Pickett et al. for use of urban ecology in planning is a valuable starting place. It is a good reminder of the many factors that affect environmental decision-making as well as the types of stakeholders that should be involved for a successful planning process.

Proposal of approach for addressing issue in the Lower Raritan

Because of the size of the LRW, I took a watershed-wide approach to do an initial triage of areas, and then a case-study approach to candidate areas. This analysis provides an example of how to begin to select an area of focus, then identifies a few different types of landscape contexts that may each require different planning processes and designs. Inspired by Rutgers Cooperative Extention Agent Pat Rector's porch book sales pitch to promote rain gardens in a neighborhood, these "types" could be approached with a "porch book" of a different scale to address stormwater basins located in residential, municipal, school, or corporate settings. I will focus on the socio-political factors for the most part, due to their importance in environmental decision-making.



Watershed wide Considerations

The LRW crosses 51 municipal boundaries. That creates a lot of separate negotiations and planning processes. In order to streamline planning, it may be practical to work with one or a few townships at a time.

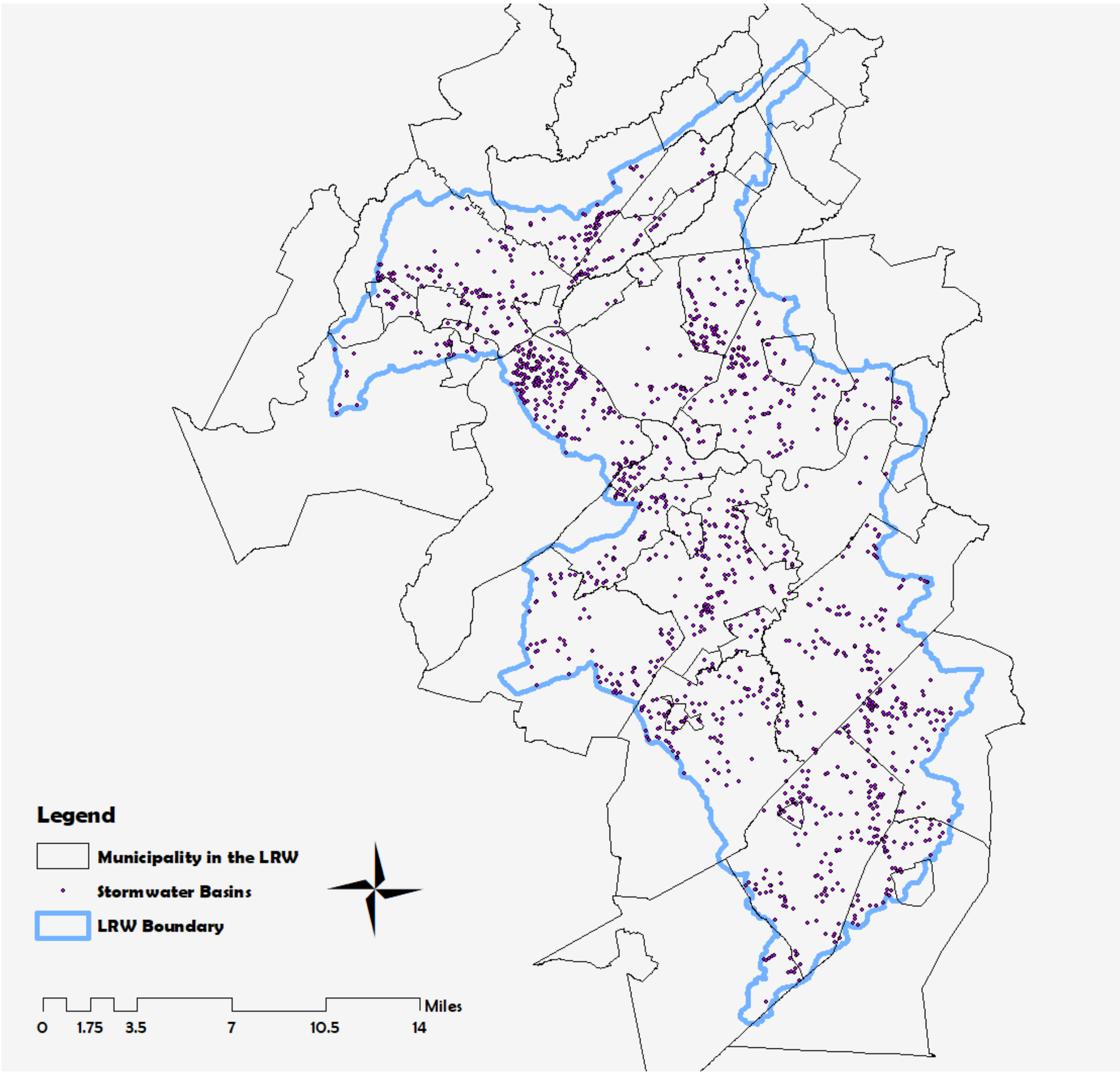


Figure 6. The LWR and the municipalities that it crosses with locations of stormwater basins. Source: NJDEP and the NJ Hydrologic Modeling Database.

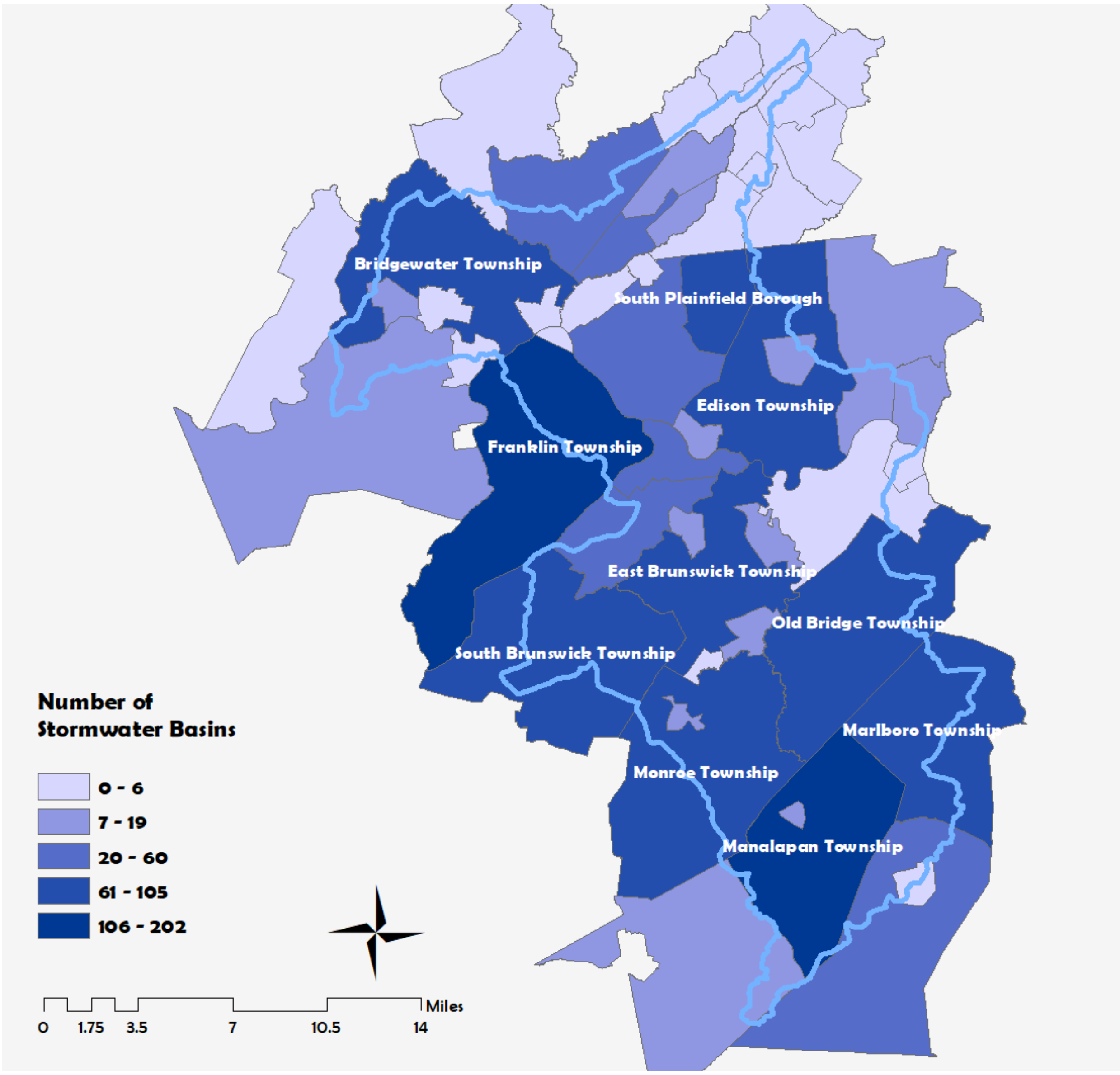


Figure 7. The LWR and the number of stormwater basins per municipality. Source: NJDEP and the NJ Hydrologic Modeling Database.

Figure 7 shows a map of the count of basins in each municipality. This only includes basins that fall within the LRW, so if a municipality does not fall completely within its borders, basins outside of the LRW are not included in the count. Franklin Township, Somerset County, has the most, with 202. This is striking since only about one third of the area of Franklin is within the LRW, so that township has many more that are not included here. Manalapan is second, with 141, and East Brunswick, Bridgewater, and Edison each have about 100 (Table 4).

Township	Number of Stormwater Basins
Franklin Township	202
Manalapan Township	141
East Brunswick Township	105
Bridgewater Township	105
Edison Township	101
Monroe Township	99
Marlboro Township	95
Old Bridge Township	92
South Plainfield Borough	76
South Brunswick Township	74

Table 4. Top ten number of basins per municipality in the LRW. Source: NJ Hydrologic Modeling Database.

After examining which municipalities have a lot of stormwater basins, I checked for the overlap of TMDLs. There are regulations for Total Maximum Daily Loads (TMDL) in some subwatersheds of the LRW, mostly in the north. TMDLs are for mercury in fish, P, sediment, and *E. coli* (TMDL 2016). The overlap reveals TMDLs in all of the municipalities with the top ten number of detention basins except Marlboro Township. Bridgewater, Monroe, Edison, and South Plainfield all appear to have a high number of

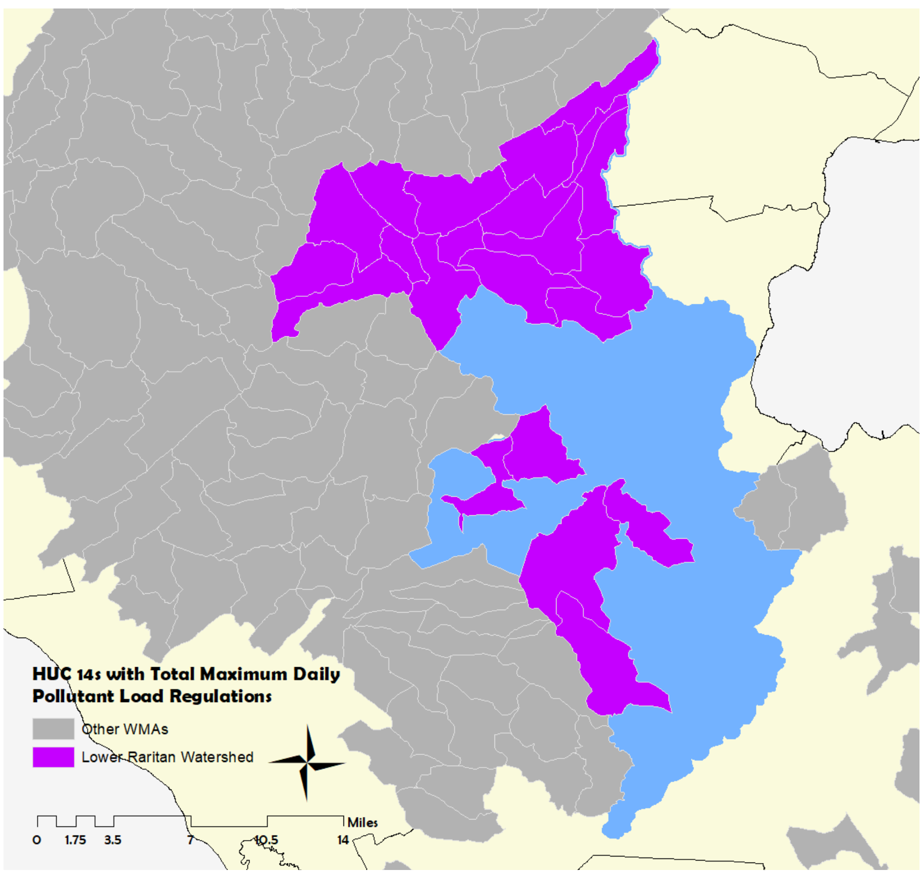


Figure 8. Locations of subwatersheds with TMDLs. Source: NJDEP.

stormwater basins in subwatersheds with TMDLS, but Franklin has a very high density in the Piscataway-Millstone area.

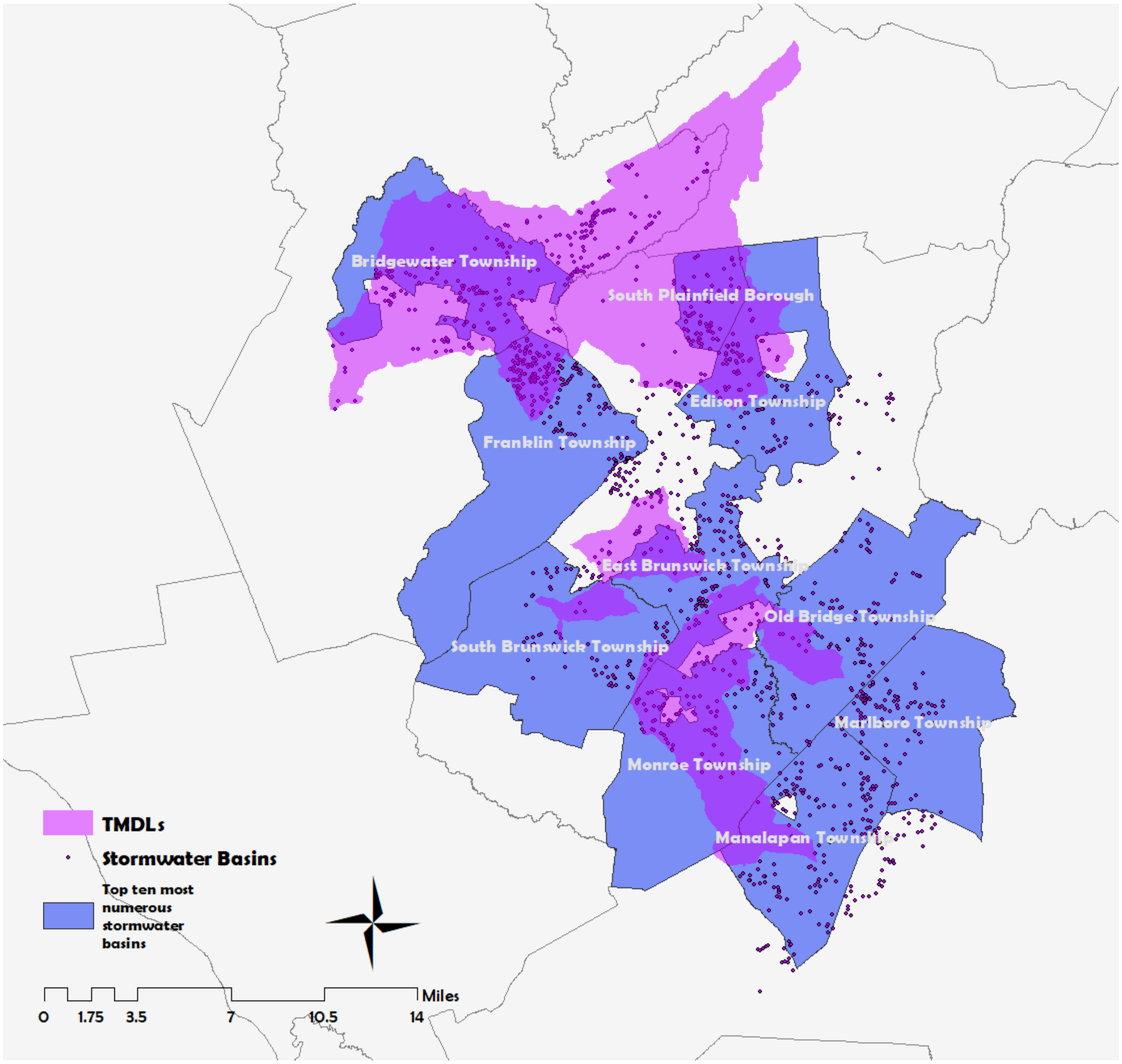


Figure 9. TMDLs, municipalities, and basin locations in the LRW. Source: NJDEP and NJ Hydrologic Modeling Database.

Franklin Township Case-Study

Because Franklin has such a high number and density of stormwater basins in this area, I examined the Pistcataway-Millstone I-287 area more closely. There is a mix of land use, including agriculture and wetlands, but the area is primarily developed.

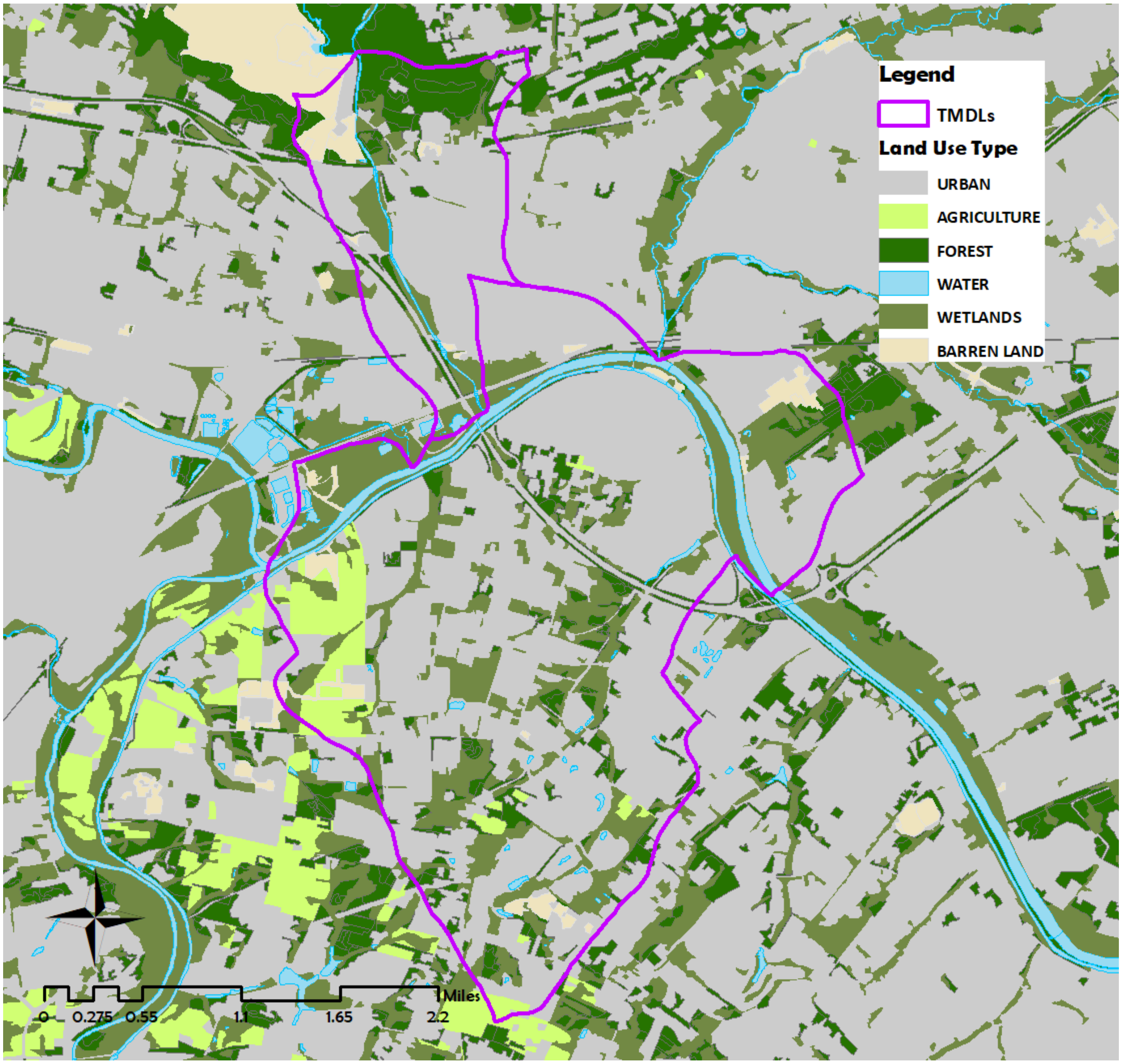


Figure 10. Land use in Piscataway-Millstone I-287 subwatershed of Franklin Township, Somerset County. Source: NJDEP.

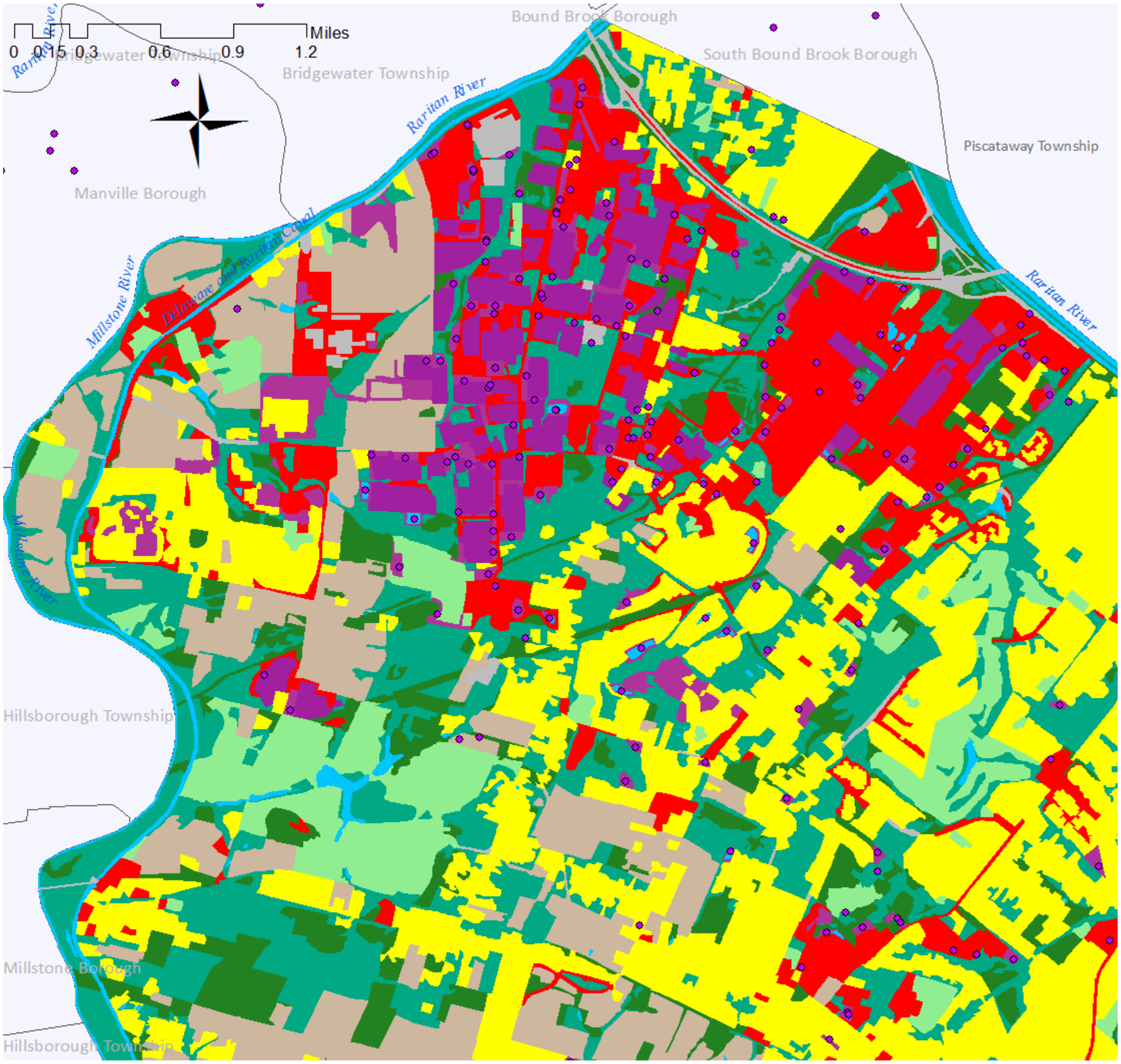
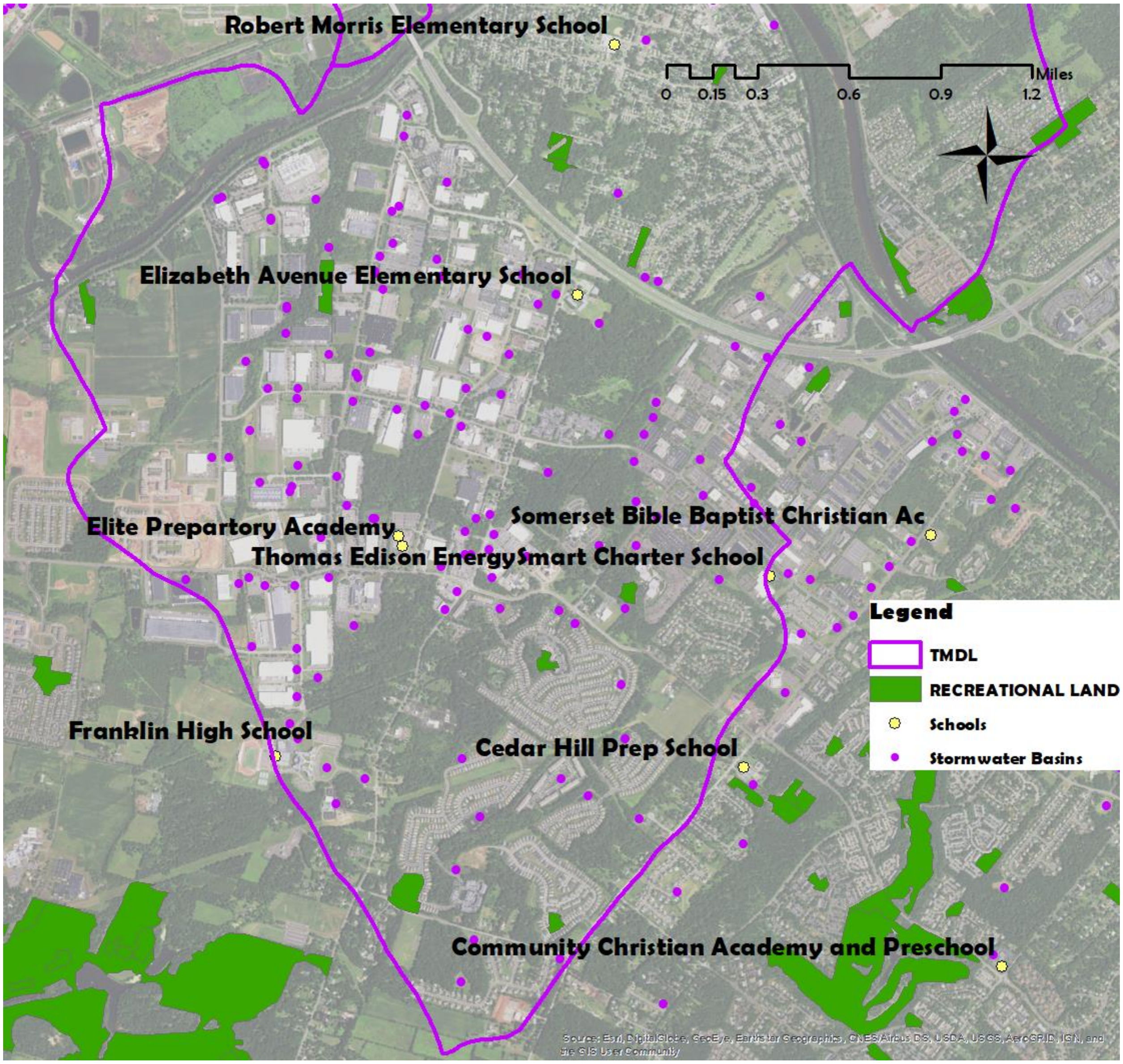
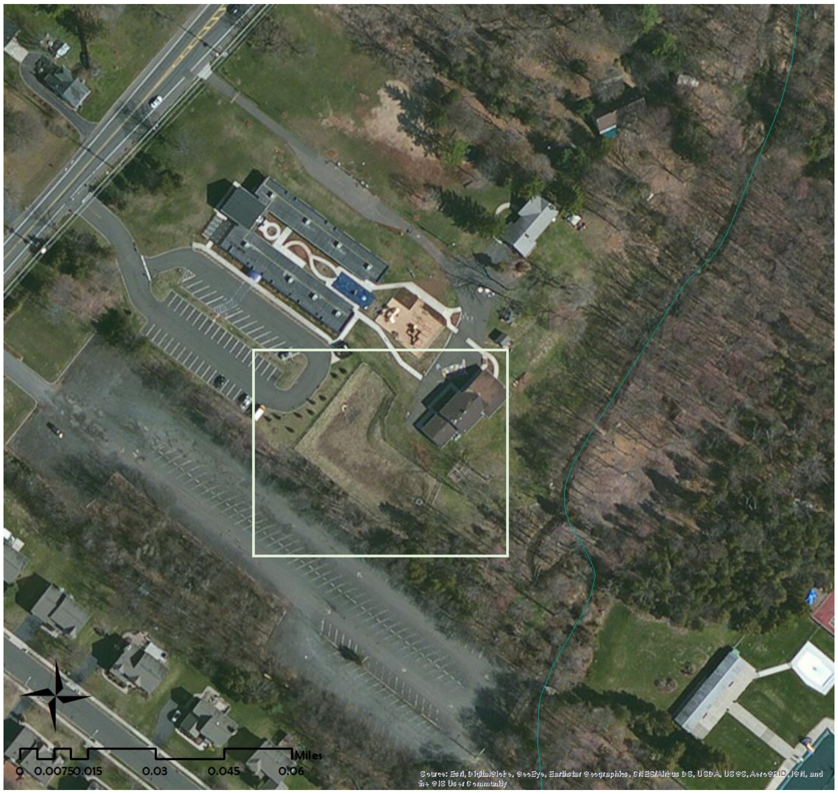


Figure 11. Detailed land use of Piscataway-Millstone I-287 area. Source: NJDEP.

A more detailed breakdown of the area reveals that a large portion is residential. Most of the stormwater basins in the residential area are wet basins. While there may be scope for changing vegetation around the edges, wet basins are not such good candidates for retrofitting. Most of the basins, however, fall within commercial and industrial parcels. These basins are precominately dry detention basins, which are good candidates for simple retrofits.



One strategy that I considered is to target schools. Retrofitting detention basins at schools would add a strong outreach element to each project in addition to water quality improvement. The potential for informing the public about issues affecting the watershed by exposing them to such as project could be quite valuable.

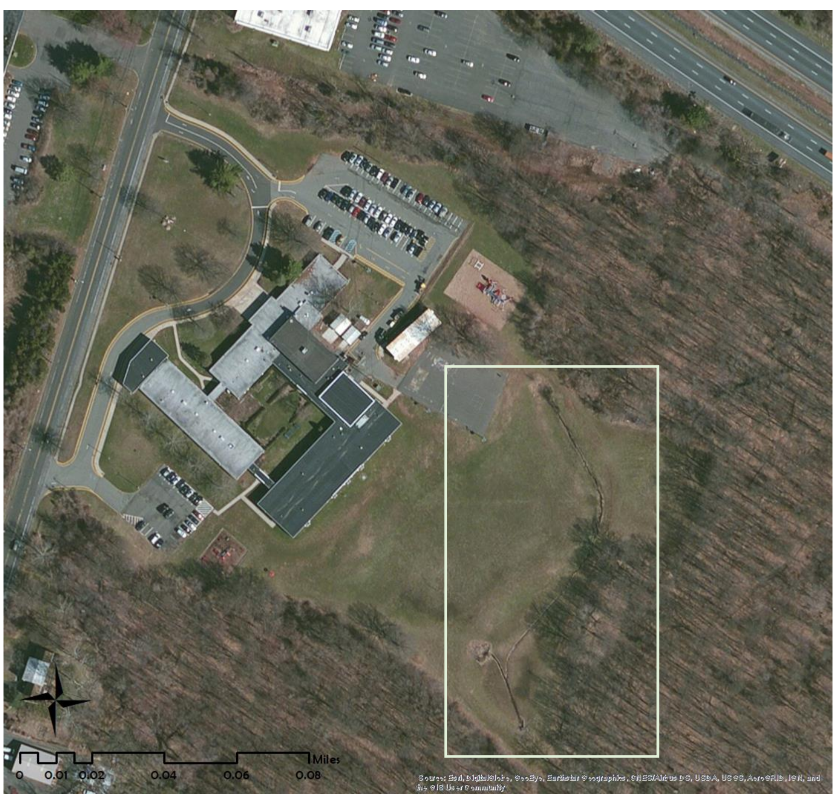


Cedar Hill Prep School:

Stormwater detention basin borders parking lots.

In riparian area, bordering Fox Creek

Figure 12. Above: Cedar Hill Prep School, Below: Elizabeth Avenue Elementary School



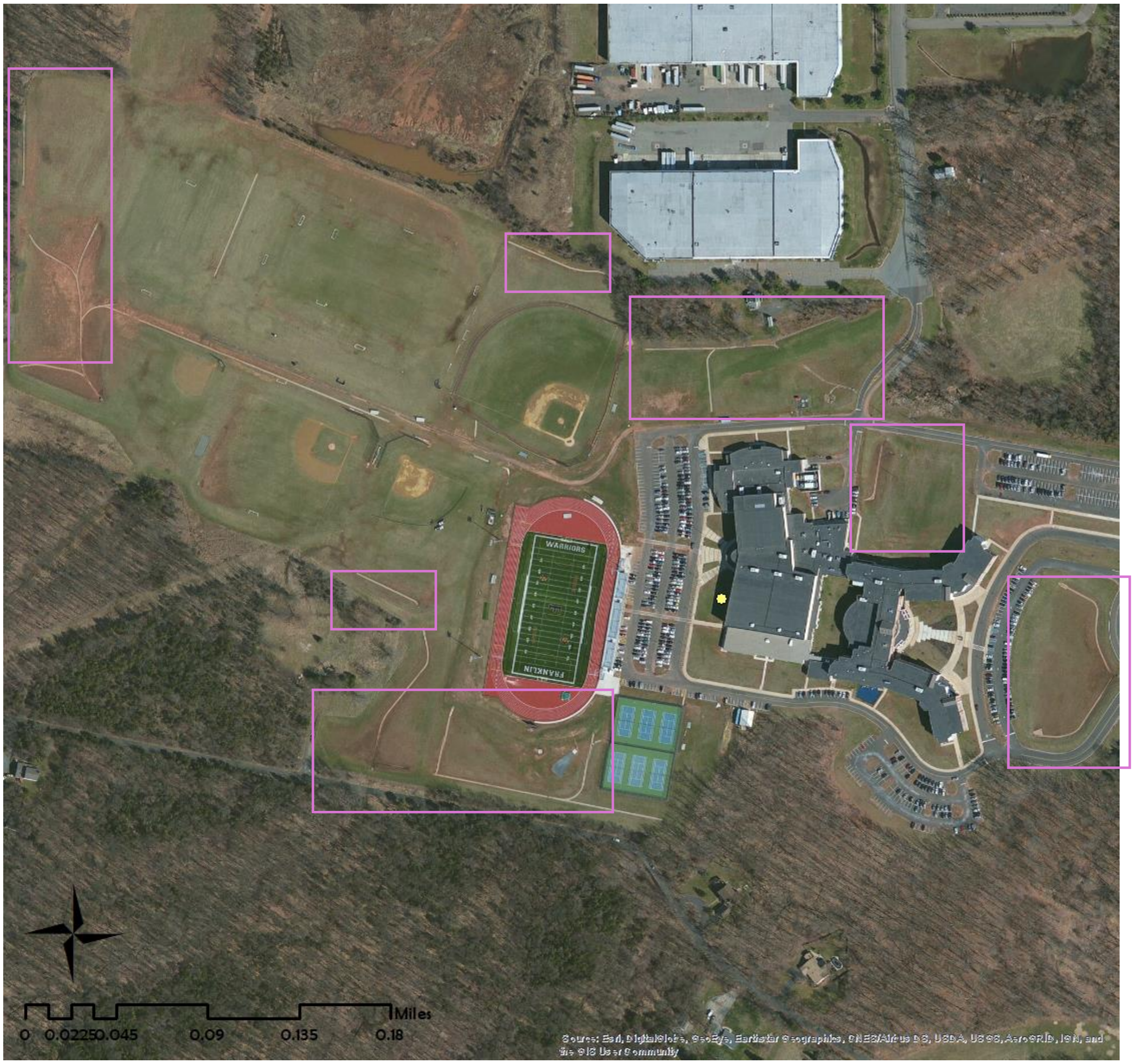
Elizabeth Avenue Elementary:

Stormwater detention at rear of play yard

In riparian area

Borders forested area, natural transition

Figure 13. Franklin High School, Somerset County. The detention basins are out of control.



Franklin High School is perhaps the best opportunity. The high school has eight different detention basins surrounding it. These include one at the entry which could attract a lot of positive attention. There are also basins at the rear of the athletic fields, which would be much less visible if that were more desirable. The school borders forest area, so the transition from a vegetated detention basin to the forest would be natural. This high school is on the border of the LRW and the Stoneybroook-Millstone watershed, so it would be a true partnership project.

Corporate Porch Book

While the school typology has the positive aspect of public visibility, there are also a number of drawbacks. Schools may not welcome high vegetation for safety reasons, and there aren't nearly as many schools as there are detention basins. In this area of Franklin, a more efficient approach would be to renovate basins in corporate or industrial areas (Figure 14). The next step in this process is to study the landscape context of these basins, understand incentives that might exist, and create and standard "porch book" to work get a large number of basin retrofitted in this area.

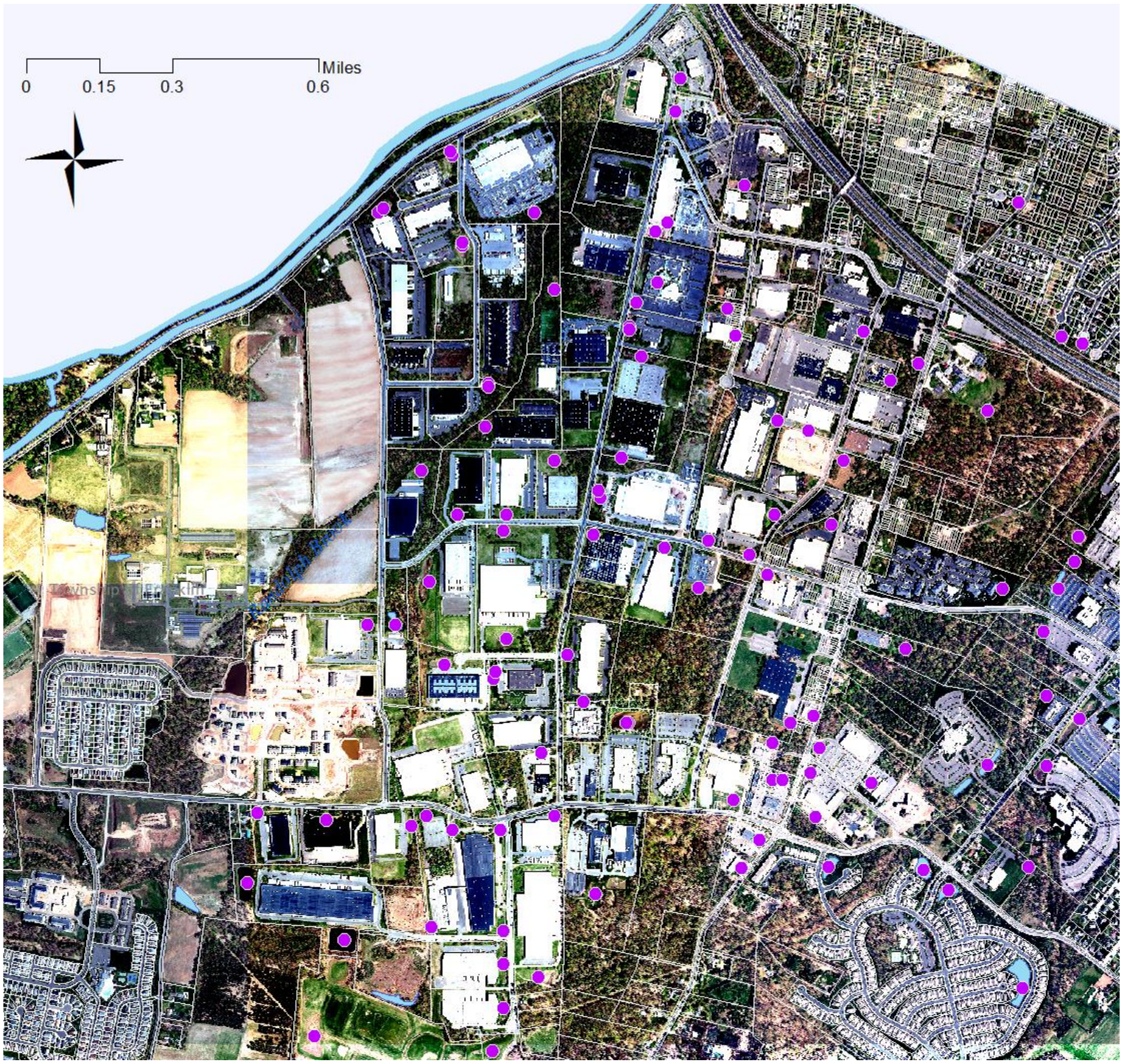


Figure 14. Focus area for retrofitting detention basins at corporate locations. Franklin Township, Somerset County. Source: NJ Information Warehouse and NJ Hydrologic Database.

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