



# STATE OF THE RARITAN REPORT

Volume 2

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## State of the Raritan Report, Volume 2

Sustainable Raritan River Initiative  
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### About the Sustainable Raritan River Initiative

Rutgers University launched the Sustainable Raritan River Initiative (SRRI) in 2009 to convene scientists, engineers, business and community leaders, environmental advocates and governmental entities to craft an agenda for the restoration and preservation of New Jersey's Raritan River, its tributaries and bay. A joint program of the Edward J. Bloustein School of Planning and Public Policy and the School of Environmental and Biological Sciences, the SRRI partners with other Rutgers units (through the Rutgers Raritan River Consortium) and with stakeholders from across the Raritan region to ensure multidisciplinary and transdisciplinary perspectives and contributions. Participants share a commitment to science-informed policies for sustaining the ecological, economic and community assets attributable to the Raritan.

The SRRI fosters university-based research and scholarship that is focused on the Raritan. This knowledge is then translated into practical educational programming and technical assistance to support regional planning, policy and business decision-making. We conduct conferences and topical workshops, provide technical assistance, and develop anchor projects that raise the profile of the Raritan River.

The SRRI and our watershed partners recognize the importance of a regional approach to resolving the complex issues associated with the restoration and future protection of the Raritan River, its estuary and all its tributaries.

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Image 1. Albany Street Bridge by Mario Burger



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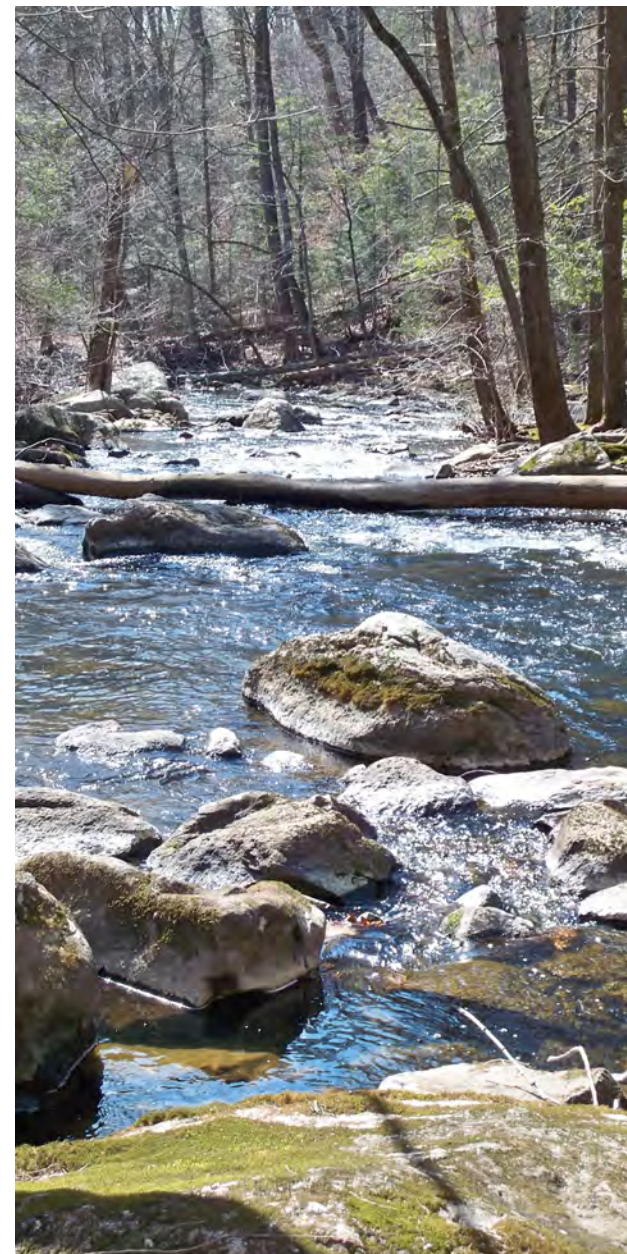
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*Image 2. Untitled view of a good trout fishing spot by Judy Shaw*

## Executive Summary

This document continues efforts to update key indicators of water quality and watershed health for the Raritan River Basin. The health of the Raritan Basin was originally assessed in the *2002 Raritan Basin: Portrait of a Watershed* as developed by the New Jersey Water Supply Authority and updated in the Sustainable Raritan River Initiative's *2016 State of the Raritan Report, Volume 1*. The objective of those reports, and this one, is to inform watershed management planning and water supply and natural resource protection needs in the Raritan Basin.

This *State of the Raritan Report, Volume 2* evaluates eight broad areas encompassing thirteen key indicators that could either impact water quality or watershed health or that influence quality of life in the basin. The eight areas and thirteen key indicators of watershed health assessed in this volume include: canopy cover; known contaminated sites; threatened and endangered species; restoration projects; open space; recreation trails including greenways and boat launches; grey infrastructure including stormwater basins, culverts, outfalls, bridges and dams;

and resilience as measured by FEMA flood insurance payouts for recent historic storms in the basin.

There was a slight uptick in the percent tree canopy for the Raritan Basin as a whole, but a decline in canopy cover in the upper headwaters region is concerning. The Emerald Ash Borer is expected to further reduce canopy cover.

*Image 3. Perth Amboy Riverwalk by Denise Nickel*



Only a little over a quarter of the known contaminated sites (including Superfund sites) have been “cleaned up”. Monitoring the integrity of previously remediated sites to ensure stability is a concern.

Over 50% of the total Raritan Basin serves as potential habitat for threatened and endangered species or species of conservation concern.

Lands held in fee and easement for public open space comprise 20% of the Raritan Basin. Less than half of that open space, however, is open access. Further, access to nearby open space is problematic especially in the more urban Lower Raritan. Recreational trails and greenways crisscross the basin and the main stem of the river has a number of boat launches and access sites, though accessing the upstream sections can be a challenge as much of the Raritan's shoreline is privately held, existing launch sites are generally poorly marked, or lack parking. No comprehensive central database of trails or launch sites exists.

The river is heavily affected by grey infrastructure: culverts, dams, bridges and

outfalls. Recently, a number of outmoded dams and culverts have been removed, and stormwater basins of diverse types have been installed. Most stormwater basins, however, are concentrated in more newly developed areas with older urban areas underrepresented. The effectiveness of these basins is poorly known.

A myriad of organizations are involved in restoration work in the Raritan. Over 43% of the HUC-14s in the Raritan have at least one restoration project implemented. Types of restoration projects include wetland, oyster, stream, shoreline and pond restorations; riparian buffer improvements; a variety of stormwater treatments; basin retrofits; reforestations; dam removals; and floodplain or other property acquisitions. In addition, the Natural Resources Conservation Service has conducted over 6,660 best management practices projects in the more rural/agricultural parts of the Raritan River Basin.

Climate studies indicate that the Raritan region may experience more extreme weather including more extreme precipitation and drought in the near future. Greater attention

to flooding, drought and even wildfire should be paid to promote enhanced resiliency for the Raritan region.

This report is the second in a series that will eventually assess a broad array of metrics of watershed health and livability for the Raritan Basin. The intent is to inform watershed management planning in concert with remediation, restoration and protection efforts at the state, regional and local levels.



Contents

Background .....1

About the Raritan.....3

Measuring the Health of a Watershed .....6

Key Indicators

    Canopy Cover .....7

    Known Contaminated Sites..... 12

    Threatened & Endangered Species Landscape Project Rankings ..... 16

    Open Space ..... 20

    Recreational Trails and Greenways..... 28

    Access to the River—Public Boat Launches ..... 32

    Stormwater Management Infrastructure Management ..... 35

        Stormwater Basins ..... 36

        Outfalls ..... 40

        Culverts ..... 42

    Bridges ..... 45

    Dams ..... 48

    Restoration Projects..... 53

    Resilience ..... 56

Conclusion..... 60

References ..... 62

List of Tables and Figures ..... 65

List of Images ..... 68



Image 4. Donaldson Park Boat Launch from the R/V Rutgers by Sara Malone

# Background

The Sustainable Raritan River Initiative (SRRI) produced Volume 1 of the *State of the Raritan Report* in December 2016 to update key indicators of water quality and watershed health for the Raritan River basin (Lathrop et al. 2016). The indicators in Volume 1 were originally assessed in the *Raritan Basin: Portrait of a Watershed* (informed by seven technical reports that

provided the basis for the *Portrait of a Watershed*) as developed by the New Jersey Water Supply Authority in 2002 (NJWSA 2002). The objective of these reports was to inform watershed management and water supply protection needs in the Raritan Basin.

Recent efforts to quantify the health of the Raritan include:

- 2002 *Raritan Basin: Portrait of a Watershed*, along with associated technical reports, NJ Water Supply Authority
- 2016 *State of the Raritan, Volume 1*, Sustainable Raritan River Initiative, Rutgers
- 2016 *Integrated Water Quality Assessment* with focus on the Raritan, NJDEP

Key Indicators	2002 Trend*	2016 Trend**	2016 Trend Impact
Population	Increasing	Increasing	Negative
Housing units	Increasing	Increasing	Negative
Urban land use	Increasing	Increasing	Negative
Impervious surface	Not sufficient data	Increasing	Negative
Wetlands	Decreasing	Decreasing	Negative
Upland forest	Decreasing	Decreasing	Negative
Prime agricultural land	Decreasing	Decreasing	Negative
Groundwater recharge	Decreasing	Decreasing	Negative
Bioassessment (stream integrity)	Mixed	Mixed	Undetermined
Riparian areas	Decreasing	Mixed	Undetermined
Known contaminated sites and groundwater contamination	Not sufficient data	Not sufficient data	Undetermined
* 2002 Trend from <i>Portrait of a Watershed</i> data			
** 2016 Trend from this analysis			

Table 1. Key indicator trends from *State of the Raritan Report, Volume 1*



Eleven key indicators were assessed for Volume 1 including: population; housing units; urban land use; impervious surface cover; forested, coastal and emergent wetlands; upland forest cover; prime agricultural land; groundwater recharge; fish and macroinvertebrate bioassessments; riparian area integrity; and known contaminated sites and groundwater contamination (Table 1). The trends evident between 1986 and 1995 are continuing in the same general direction though the rate of change in trends has varied over the longer time period (Table 1). The trend impacts over the 20 plus years were either trending negative for water quality or could not be determined.

Volume 2 of the *State of the Raritan Report* looks at a broader range of metrics for the health and livability of the Raritan River Basin. Our intent was to capture readily available data; in most instances, the data collected did not have available historic data to identify trends. The majority of data in this document is, therefore, a report of status only but is still valuable to inform future watershed planning efforts that address water quality concerns as well as quality of life in the basin.

Volume 2 indicators include: canopy cover; known contaminated sites; threatened and

endangered species; open space; recreation trails and greenways as well as boat launches; a summary of grey infrastructure including stormwater management basins, culverts, outfalls, bridges and dams; restoration projects; and resilience as measured by FEMA flood insurance payouts for recent historic storms in the basin.

Together, the two volumes will provide critical data to inform planning and decision-making in the basin as well as to identify data gaps and research needs that will set priorities for university-based efforts. Our ultimate goal is to develop a baseline of metrics that can be used in the coming years to identify strengths and weaknesses in efforts to restore and protect Raritan resources and to help inform basin-wide stewardship and regional planning efforts for the Raritan.

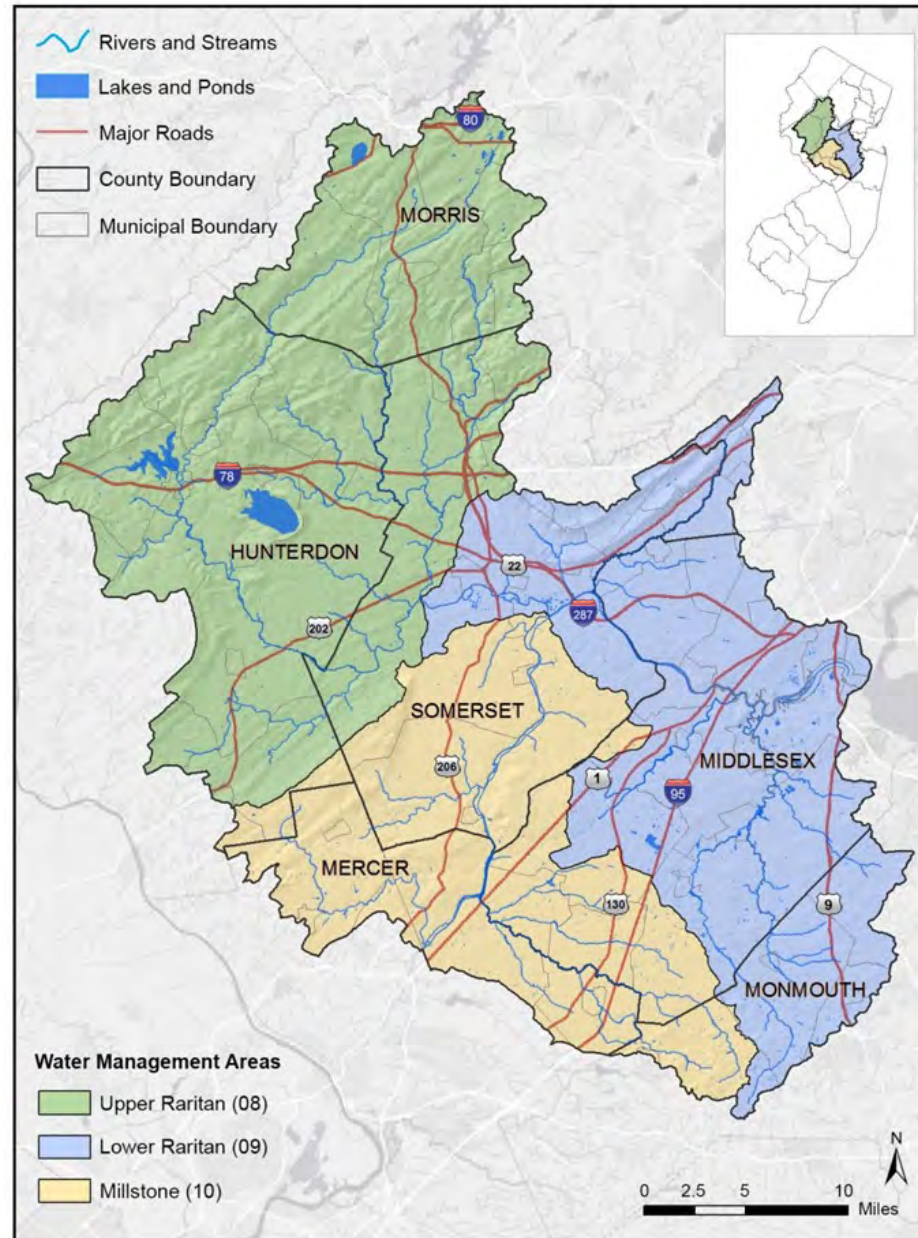
*Image 5. Student walking bike in May 2014 flood at New Brunswick's Boyd Park by Sara Malone*



## *Science informing Planning and Policy*

## About the Raritan

The Raritan River Basin, located in north-central New Jersey, is the largest watershed located entirely within the State of New Jersey. The total watershed area is approximately 1,105 square miles (706,900 acres) and is located in all or part of Hunterdon, Mercer, Middlesex, Monmouth, Morris, Somerset, and Union counties. The watershed is divided into three water management areas (WMAs): the Upper Raritan, the Lower Raritan, and the Millstone (Figure 1). The Upper Raritan (WMA 8), covers approximately 470 square miles and includes the North and South Branches of the Raritan that join to form the main stem of the Raritan near Branchburg Township at the top of the Lower Raritan watershed (WMA 9). The Millstone (WMA 10) encompasses approximately 285 square miles and includes the Stony Brook and Millstone River watersheds as well as a significant section of the Delaware and Raritan Canal that enters the watershed near the confluence of the Stony Brook and Carnegie Lake in Princeton Borough. The Millstone joins the main stem in the Lower Raritan watershed at Manville Borough just above the Island Farm Weir (aka Confluence) dam. The Lower Raritan watershed covers approximately 352 square miles and includes the Green Brook, Lawrence Brook, and South River. The Lower Raritan drains to Raritan Bay on the mid-Atlantic



*Figure 1. Map of location of Raritan River watershed in New Jersey*



Coast south of Staten Island. The tidal reach of the Raritan is approximately twelve nautical miles from Raritan Bay and extends to just upstream of Landing Lane Bridge in New Brunswick.

The Raritan Basin includes portions of three of New Jersey's physiographic provinces (Figure 2). The Highlands province to the north is characterized by rugged topography and discontinuous rounded ridges separated by narrow valleys comprised of predominately igneous and sedimentary rock (NJGS 2006). The beautiful Ken Lockwood Gorge and some of the best trout fishing in the state are located in the Highlands region, as are Budd Lake and the headwaters of the Raritan. The Piedmont province, at the southern contact of the Highlands, is mostly low rolling plains divided by higher ridges underlain by folded and faulted sedimentary and igneous rocks. This area is characterized by the Watchung Mountains to the east and the Sourland Mountains to the west, with good farmland in-between, and includes Spruce Run and Round Valley Reservoirs. The Raritan's upper and lower branches converge in the central section of the Piedmont. The Coastal Plain, at the southern contact of the Piedmont, is predominately unconsolidated deposits in low relief. The headwaters of the Millstone and South

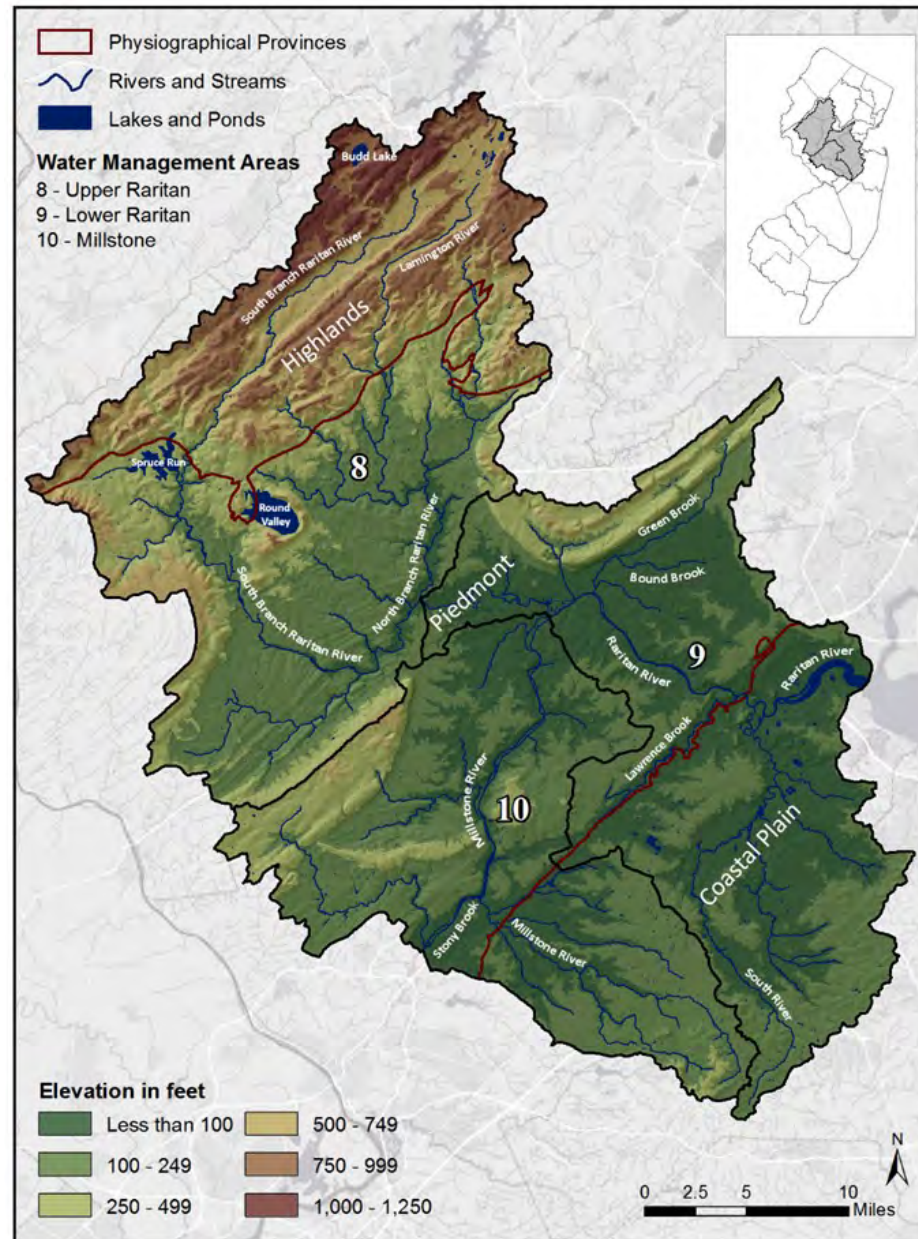


Figure 2. Map of streams, elevation and physiographic provinces in the Raritan River watershed



Rivers are in the Coastal Plain; both rivers flow north to join the main stem. The Lawrence Brook flows east along the contact between the Piedmont and Coastal Plain provinces. Raritan Bay is also in the Coastal Plain. Elevations in the Raritan Basin range from 1,250 feet in the Highlands province to mean sea level in the

Coastal Plain province.

Approximately 1.5 million people live in the Raritan Basin's 98 municipalities (US Census 2010) and more than 793,000 people work here (NJDOH 2014). The integrity of the Raritan Basin is central to quality of life in the region as a

valuable source of drinking water, for its role in commerce and industry, for its myriad recreational opportunities and the associated health benefits of access to aesthetic/open space, and as a natural wildlife corridor offering refuge to numerous threatened and endangered species.



*Image 6. Ambrose Brook by Margo Persin*

## Measuring the Health of a Watershed

In this assessment of the health of the Raritan, we evaluated eight broad areas that could either impact water quality or watershed health or that influence quality of life in the basin. Two of these categories – recreational trails and grey infrastructure – were reviewed as subcategories for a more complete view of that topic and its impacts on life in the region. The selected indicators reflect certain aspects of water quality and watershed health and represent some driver (e.g., human population or urban land use) or reflect on the resulting consequences (e.g., groundwater recharge). For each indicator, the current status (i.e., condition based on the most recent data available in the public domain) and, when multiple years of data were available, the temporal trends (as reflected by the measured change in the longest dataset available) have been characterized. For each indicator, a background, methodology, and status are described.

We have made an effort to summarize the indicator status in Volume 2 by both the Water Management Area (WMA) and Hydrological Unit Code HUC-14 (HUC-14) sub-basins. The WMAs consisted of WMA 8 – North and South

Branches of the Raritan Basin; WMA 9 – Lower Raritan Basin; and WMA 10 – Stony Brook-Millstone River Basin. The HUC-14 level of sub-basin delineation provides a finer level of spatial detail and complements the NJDEP's 2016 Integrated Water Quality Assessment for the Raritan water region. We anticipate that

future analysis of the indicators by HUC-14 in conjunction with the NJDEP's Water Quality Assessment will inform sub-basin planning, restoration and protection efforts that will benefit the basin as a whole.



*Image 7. Red-eared slider by Steven Weber*



## Key Indicator

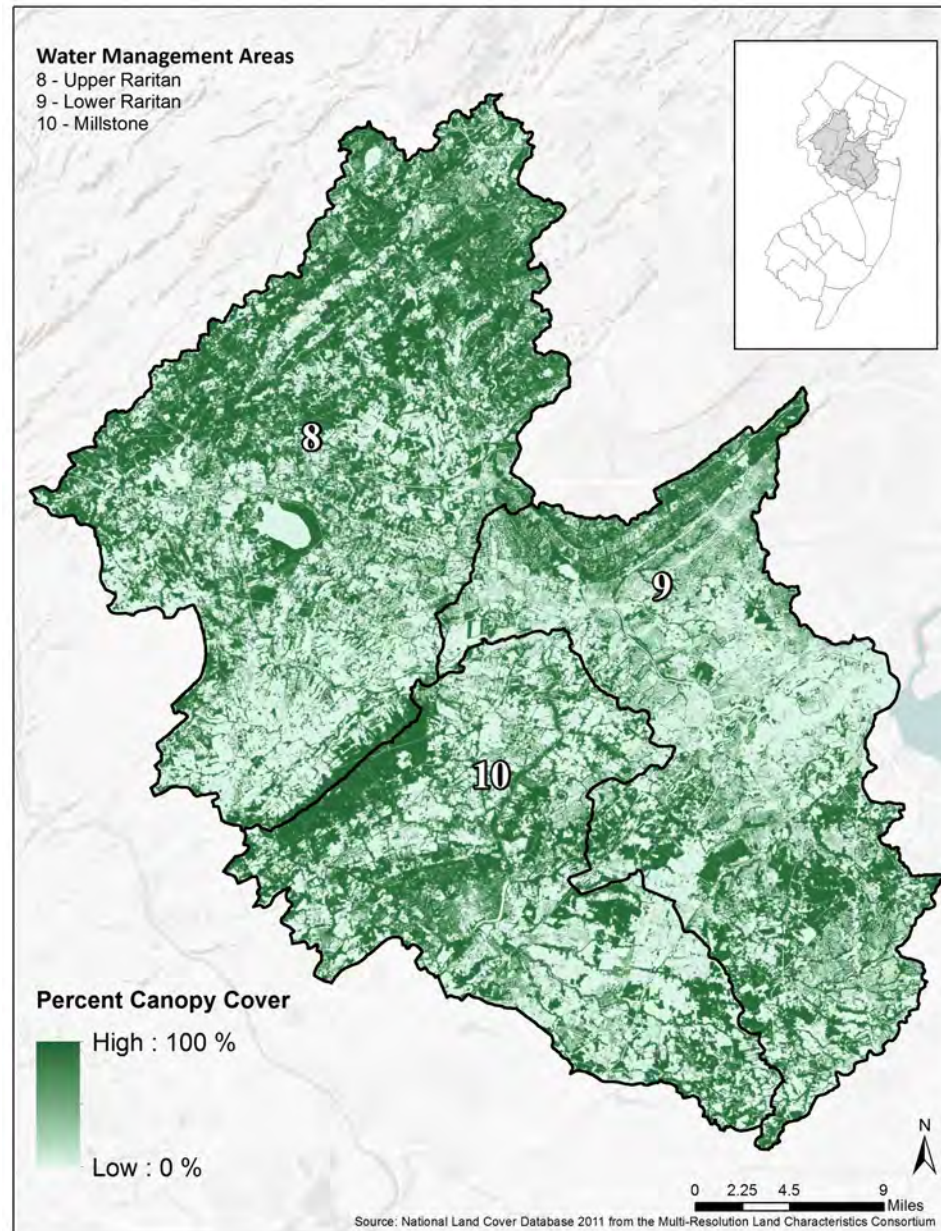
# Canopy Cover

### Background

Trees provide valuable benefits and contribute to the beauty of the Raritan region. They add value to our property, filter the air, provide oxygen, cool our homes and neighborhoods in the summer, block the wind to reduce our heating costs in the winter, capture and filter runoff to protect our streams, sequester carbon from the atmosphere, provide wildlife habitat, provide recreational opportunities, and enhance our mental and physical health and sense of well-being.

In Volume 1 we explored the trends in upland forest areas for various time ranges between 1986 and 2012 and quantified net gains and losses of upland forest to other land uses. In that analysis, upland forests lost 8,369 acres to other land uses basin-wide between 1986 and 2012.

In this analysis we utilized national landcover data sets to summarize the percent canopy cover across the Raritan Basin and by HUC-14 for 2011 and also calculated a change in canopy cover by HUC-14 for the ten years from 2001 to 2011. Think of canopy cover as the percent of a unit area on the ground that is covered by a canopy of trees or shrubs. While forest areas generally have high percent canopy cover (i.e. upwards of 75%), even urban areas with



*Figure 3. Map of percent canopy cover for the Raritan River Basin*



street or backyard trees will have some amount of measurable canopy cover.

## Methodology

The canopy maps were created with data available through the National Landcover Database at the Multi-Resolution Land Characteristics Consortium, using the “NLCD 2011 USFS Tree Canopy cartographic” dataset, and the “NLCD2001 Percent Tree Canopy (Version 1.0)” dataset (MRLC, n.d.).

The percent tree canopy dataset quantifies per pixel tree canopy fraction as a continuous variable from 1 to 100 percent.

## Status and Trends

In 2011, tree canopy covered approximately 40% of the Raritan Basin, with the highest percent cover observed in the forest tract areas of the North and South Branch, Millstone and South River headwaters, and the Sourland and Watchung Mountains. Tree cover is lowest in the agricultural areas of the Neshanic and Millstone Rivers and urban/suburban areas of the Lower Raritan Basin (Figure 3). Analysis at the HUC-14 level shows a much broader range of percent canopy covers with six HUCs having less than 16% average canopy cover compared to 25 HUCs that have between 55% and 77% canopy cover (Figure 4 and Figure 5).

Overall, the basin-wide average percent canopy cover has increased 3.6% in the ten-year period between

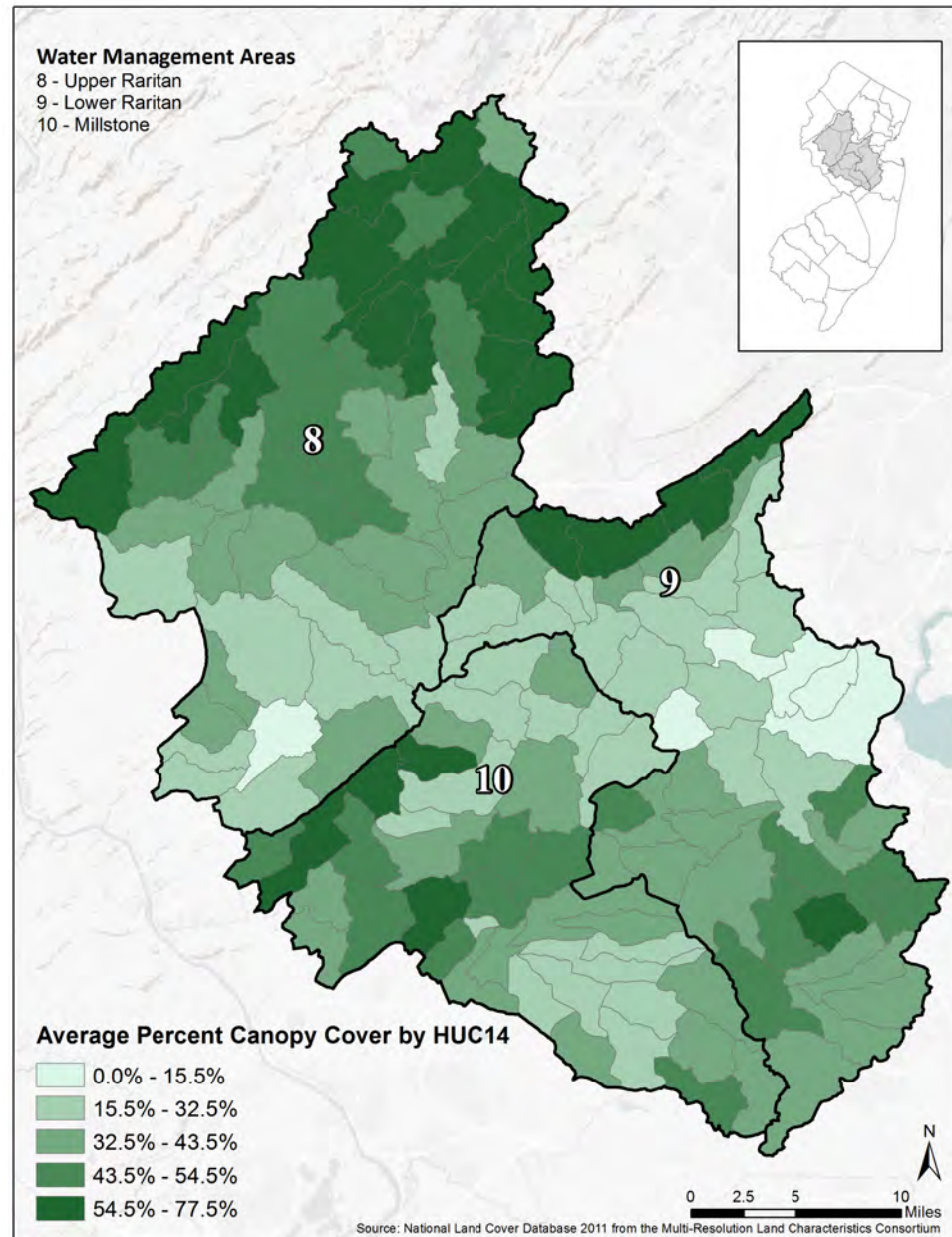


Figure 4. Map of average percent canopy cover by HUC-14

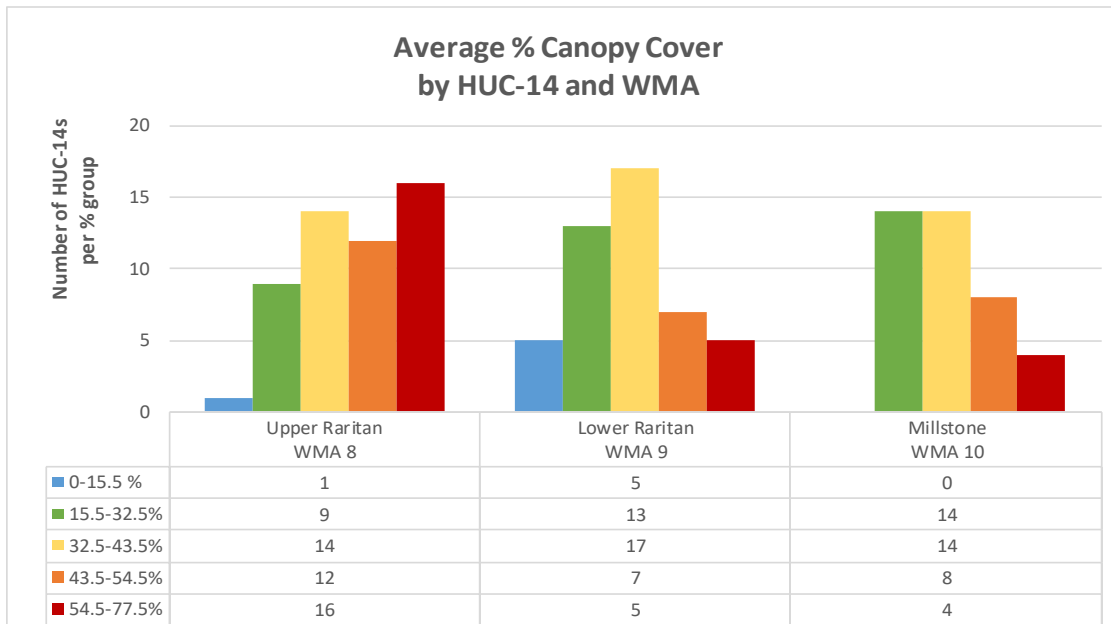


Figure 5. Average percent canopy cover by HUC-14 and WMA

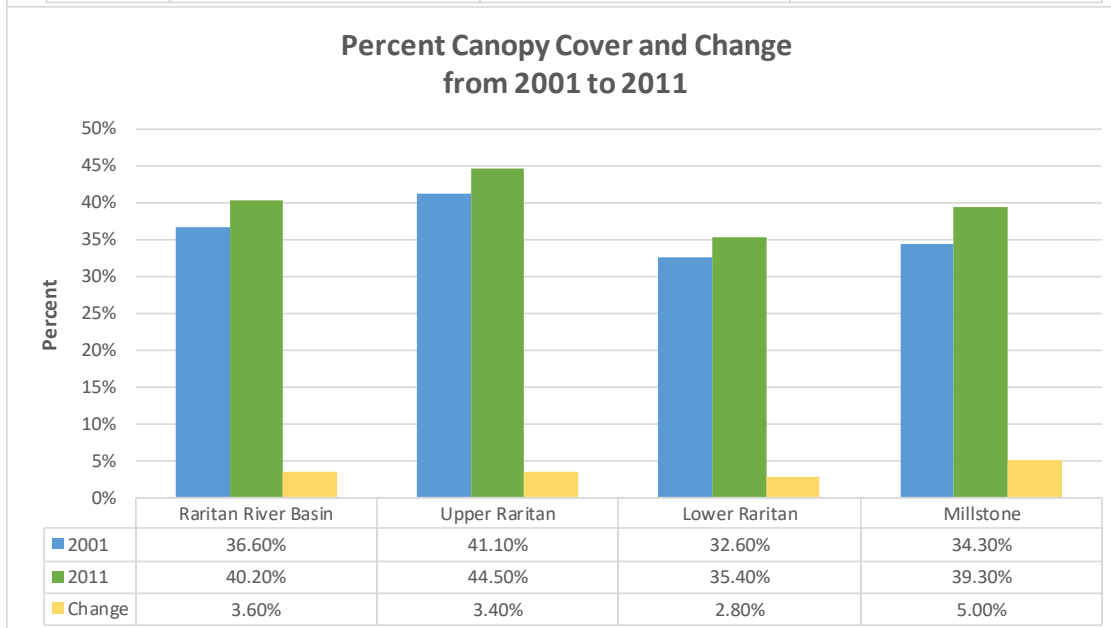


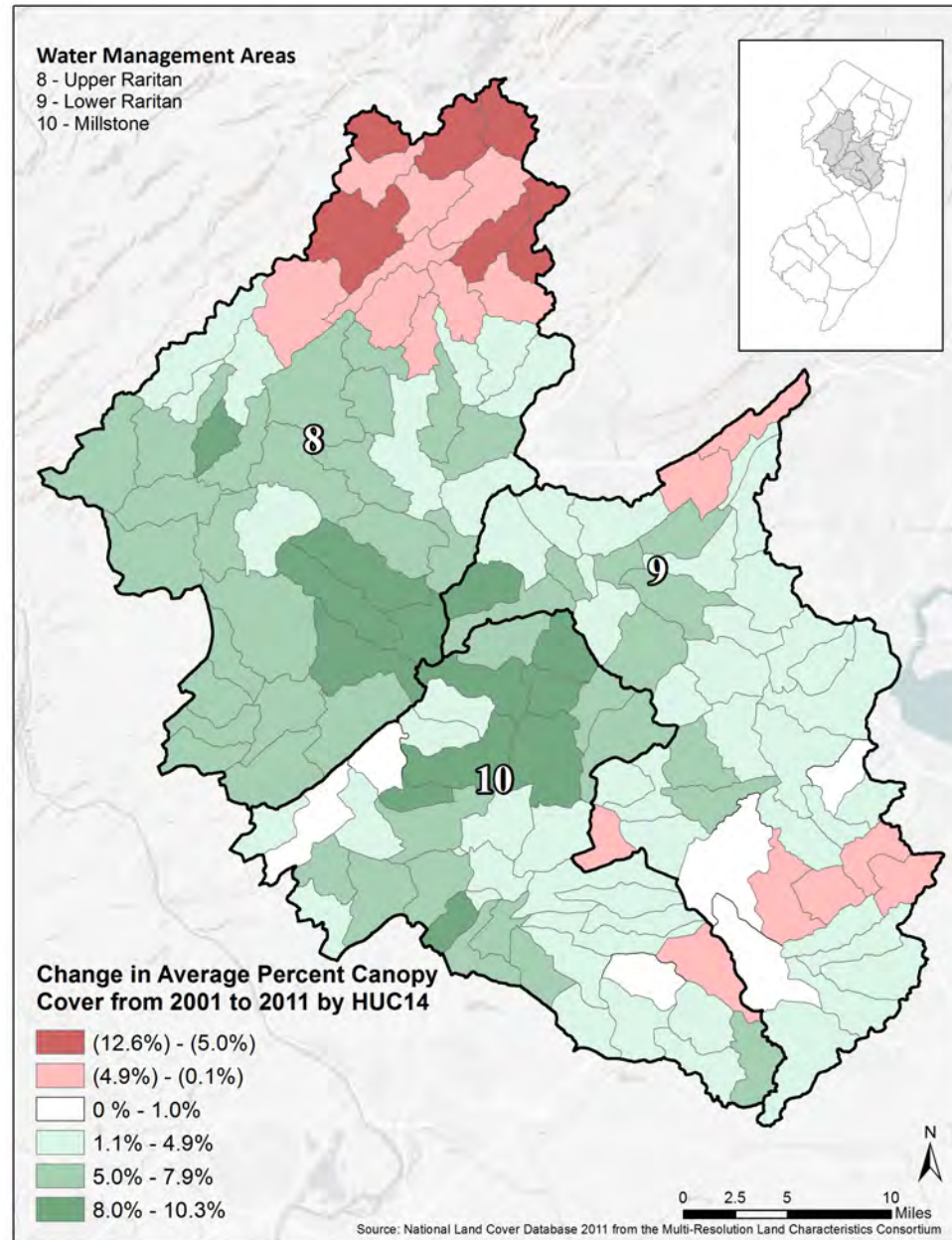
Figure 6. Percent canopy cover and change from 2001 to 2011 by HUC-14

2001 and 2011. Looking more closely at the three major sub-basins (Figure 6 and Figure 7), the Upper Raritan had the densest canopy with 44.5% canopy cover, up from 41.1% ten years earlier. The Millstone's canopy expanded from 34.3% to 39.3% over the ten years. The Lower Raritan experienced the smallest, but still positive, change in canopy, expanding from 32.6% to 34.4%.

While the overall change in canopy cover was positive, analysis at the HUC-14 level shows much greater disparity with some sub-basins gaining cover by as much as 10.3% and others losing cover by as much as 12.6% (Figure 8). The Upper Raritan had 15 HUC-14s trending losses of canopy cover, with six of those losing more than 5% and up to 12.6% of their cover. In the Lower Raritan, seven HUC-14s lost up to 5% of their canopy cover, while in the Millstone, only one HUC-14 showed a decline in cover.

## Summary

While there are positive signs with a slight uptick in the percent tree canopy for the Raritan Basin as a whole, the decline in canopy cover in the upper headwaters of the North and South Branches of the Raritan is concerning. Some HUC-14s in the Upper Raritan Basin saw a decline of over 10%. Volume 1 documented a net decline in upland and wetland forest area of 2,722 acres (2,628 of upland forest and 94 acres of wetland forest) for the Upper Raritan between 1986 and 2012. How much of the decline in percent canopy cover is due to conversion of forest stands and how much to a



*Figure 7. Map of change in average percent canopy cover from 2001 to 2011 by HUC-14*



general diminution of tree canopy in forest areas versus in urban/suburban/exurban in these HUC-14s remains to be determined.

It is also important to note that the Emerald Ash Borer (EAB), an exotic invasive beetle that attacks ash trees, has been found in all Raritan Basin counties. Untreated trees infected with EAB can be expected to die within a few years. EAB is projected to kill 99.7% of ash trees in the state over the coming decade (similar to impacts seen in forests in Michigan, Ohio and Pennsylvania) (Wright 2016). Ash trees are more concentrated in the northern parts of the region. Based on average percentages of ash trees to other species in New Jersey forests, from 6% to over 9% of canopy cover may be lost to EAB (USDA 2014; NJDEP 2016). The expected loss of ash trees will apply even greater pressure on Raritan assets through the loss of tree canopy cover and associated benefits in the Raritan region.

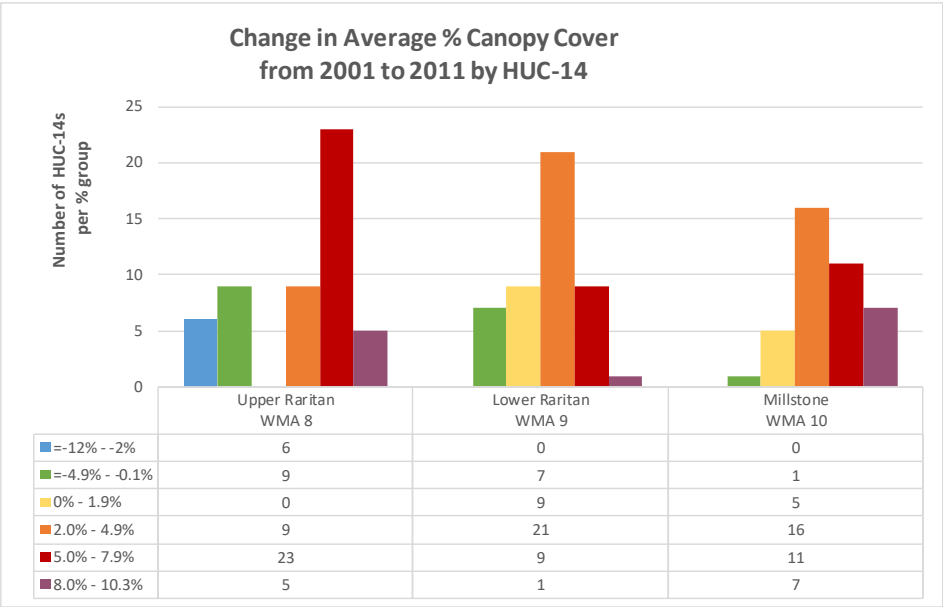


Figure 8. Change in average percent canopy cover from 2001 to 2011 by HUC-14

### Take-Away—Canopy Cover

Trees provide valuable benefits to our communities including filtering the air, capturing and filtering runoff, sequestering carbon, providing habitat, reducing energy costs by cooling our homes in summer and providing wind breaks in winter, and enhancing our mental and physical health and sense of well-being. Tree canopy covers approximately 40% of the Raritan Basin. While canopy cover as a whole increased slightly across the basin, headwater regions showed a general decline in canopy cover. The Emerald Ash Borer is expected to decimate nearly 10% of the region’s canopy cover over the next decade.

## Key Indicator

### Known Contaminated Sites

#### Background

Pollutants from contaminated sites can seep into groundwater or run off into adjacent surface waters where they can negatively impact water supplies and cause ecological damage to wildlife and fisheries, as well as pose a hazard to public health. Superfund sites in the Raritan region are under the jurisdiction of the US EPA Region 2 in cooperation with the NJDEP's Site Remediation Program. The Site Remediation Program is also responsible for overseeing remediation of other known contaminated sites. Since 2012, remediation of known contaminated sites (with limited exceptions such as unregulated heating oil tanks or landfills under the NJDEP's Solid Waste program) is conducted under supervision of a Licensed Site Remediation Professional (LSRP). The NJDEP monitors progress on cleanups through review of forms and reports submitted by the LSRP as remediation milestones are reached. Details about specific sites are available through the state's Open Public Records Act.

#### Methodology

Data was derived from the Known Contaminated Site List through the NJDEP Bureau of GIS and downloaded as of January 17, 2018 (NJDEP 2018a).

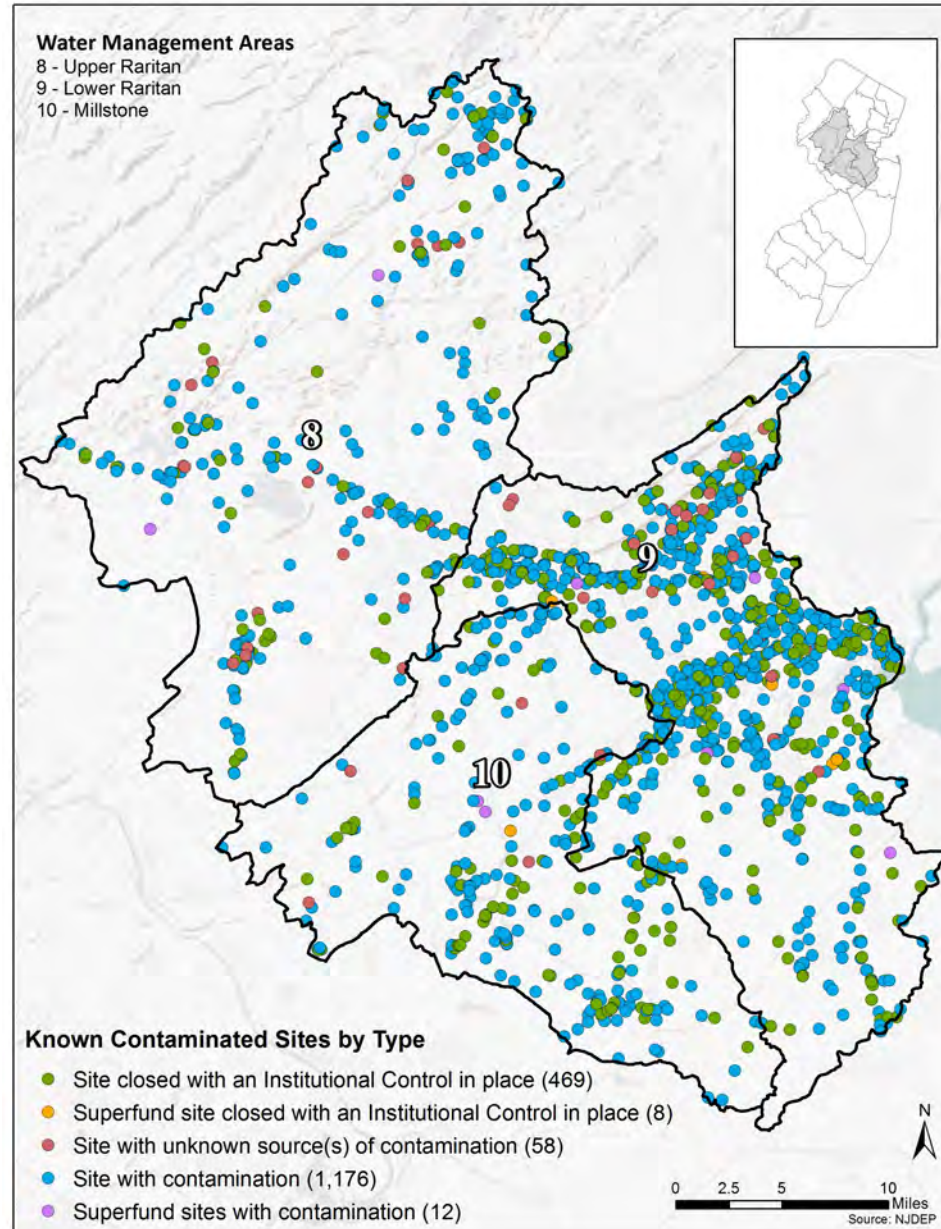


Figure 9. Map of known contaminated sites by type in the Raritan Basin

The categories for known contaminated sites were defined by the NJDEP; Superfund site categories were designated by their final National Priorities List (NPL) status. Locations provided in the known contaminated sites GIS dataset are largely an approximation of the facility front door location and may not reflect the actual location of the contamination. The Known Contaminated Sites by HUC-14 map (Figure 9) was tabulated using the ArcGIS frequency statistics tool.

Status

The Raritan Basin has the dubious distinction of being home to 1,723 known contaminated sites. Figure 9 shows the location of known contaminated sites by type around the Raritan. Twenty of these sites are Superfund sites – only eight of which have been closed (i.e., no active or pending cases associated with the site) with controls in place. Of the other 1,703 known contaminated sites, only 469, or just over 27% of the sites have been closed with institutional controls (i.e., a mechanism used to limit human activities at or near a contaminated site) in place. Sixty-nine percent of those sites have known contamination but are not yet fully remediated/closed (sites with in-situ contamination), and 58 sites have yet to be thoroughly investigated (i.e., the source of contamination is unknown as defined by the NJDEP Bureau of GIS) (Figure 10).

The number of known contaminated sites by HUC-14 is shown in Figures 11 and 12. Only five HUC-14s, or less than 4% of watersheds for the Raritan’s tributaries and streams, are free of known contaminated sites (under NJDEP jurisdiction). Nearly 63% of HUC-14s have at

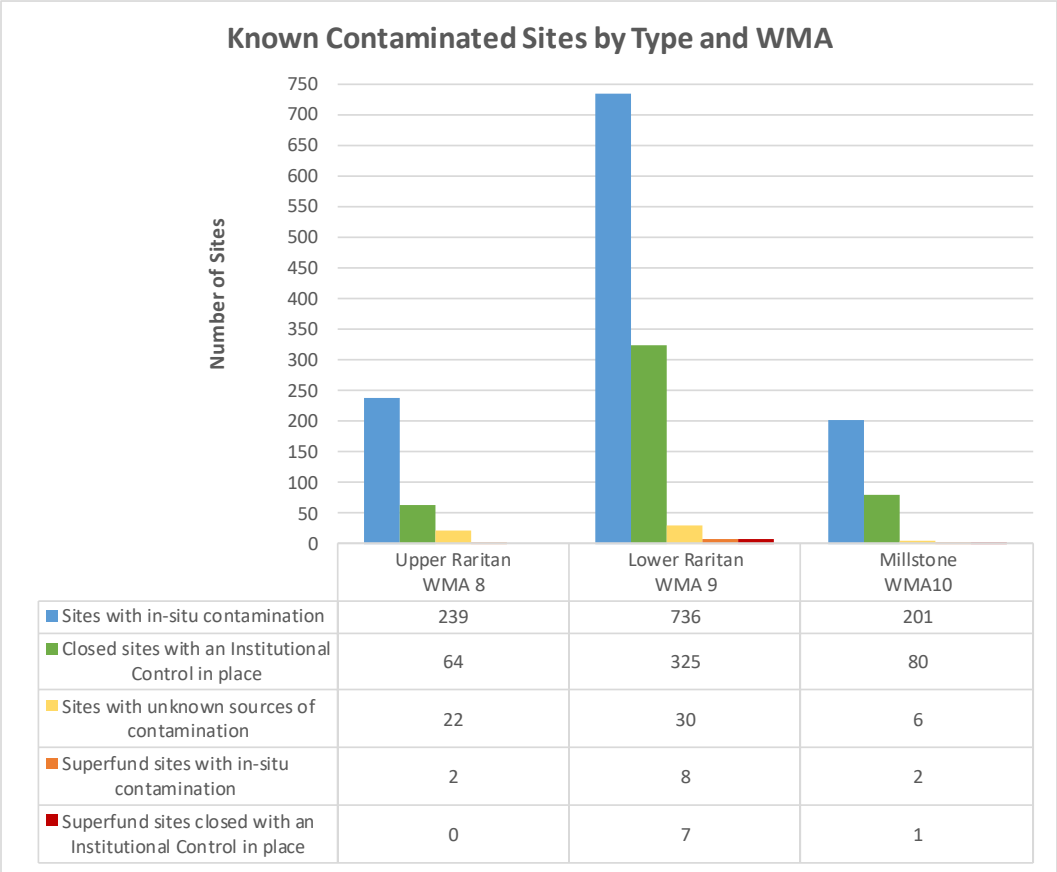


Figure 10. Known contaminated sites by type and by WMA



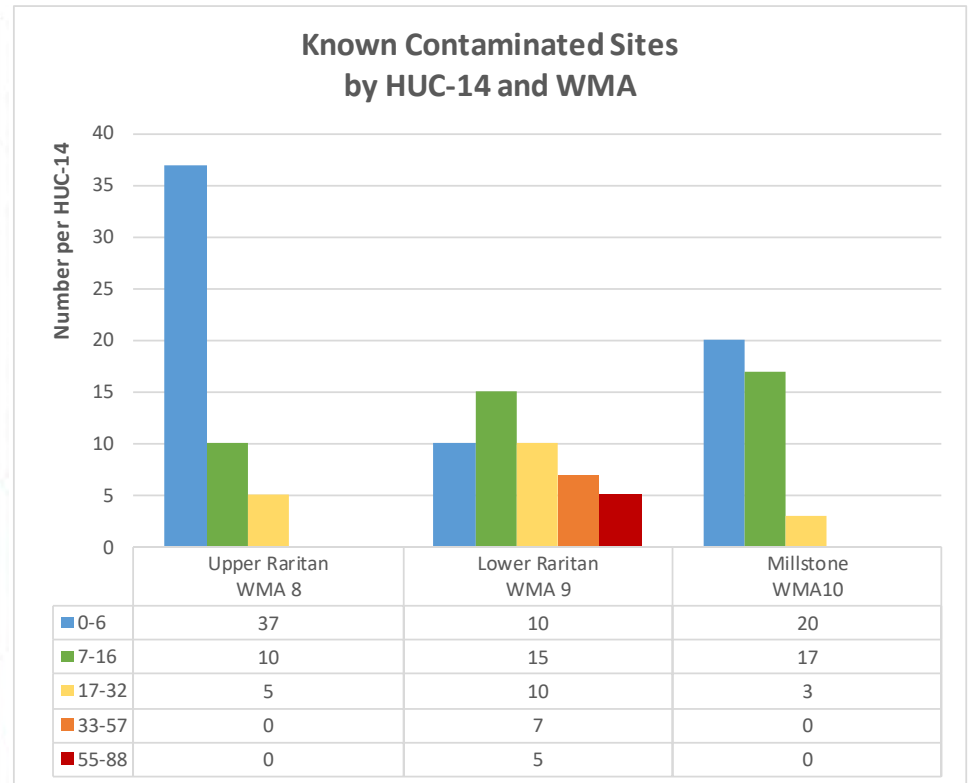
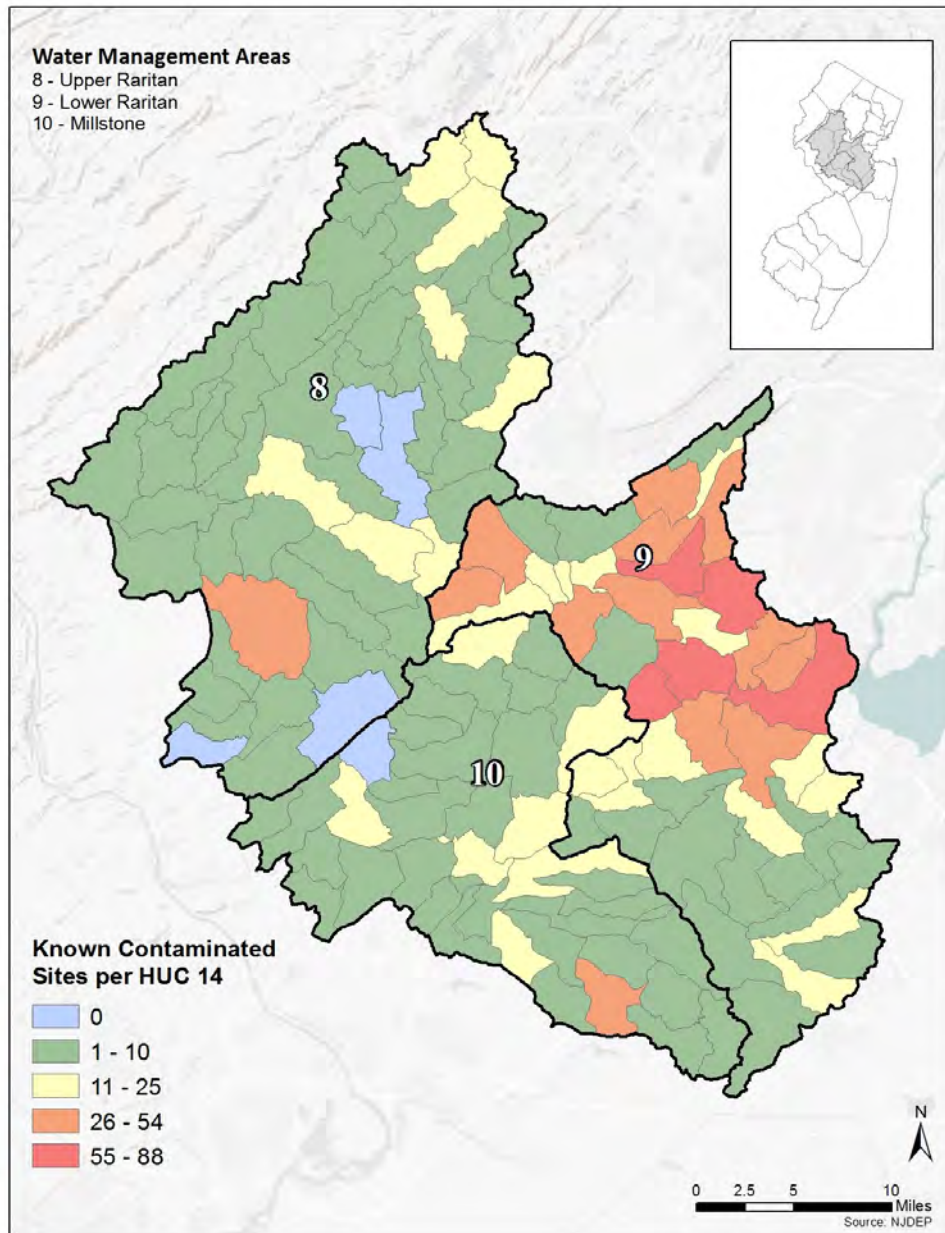


Figure 12. Known contaminated sites by HUC-14 and WMA

Figure 11. Map of known contaminated sites per HUC-14

least one and as many as ten contaminated sites, 21% of HUC-14s have between 11 and 25 sites, 13% of HUC-14s contain more than 26 sites. The Lower Raritan has five HUC-14 subwatersheds with between 55 and 88 known contaminated sites.

## Summary

The extent to which contaminants are leaching from the known contaminated sites into the groundwater and eventually into the surface waters of the Raritan Basin is not fully known, nor is the extent to which contaminants are resident in river and wetland sediments. Recent work by Artigas et al. (2018) documents several hotspots of heavy metal contamination (e.g., copper, mercury, nickel, arsenic) of the bottom surficial sediments of the Raritan River. These hotspots include the stretch of river between the Route 1 and Turnpikes bridges, near Crab Island and the mouth of the river east of the Route 35 bridge. The origin of these contaminants are not known and could be due to earlier industrial as well as wastewater discharges, as well as runoff

and leachate from known contaminated sites. On average, Artigas et al. (2018) found that nickel and mercury were the only metals in the river sediments that exceeded the effects range median (ERM) screening criteria, which means that in 50% of the case studies examined benthic organisms were adversely affected. When compared with earlier work conducted between 2000-2006, the 2017 sampling showed some degree of attenuation for chromium, nickel and antimony but no attenuation for mercury. Conversely, organic contaminants (such as PCB and OCP) showed decreased concentration.

Accessing current information on the status of known contaminated sites continues to be of concern. In 2015, a pilot study conducted by Dr. Steven Yergeau and supported by the EPA, (Yergeau et al. 2015) reviewed data related to known Superfund, Brownfield and contaminated sites, and point and non-point source pollution for 22 municipalities in the Lower Raritan. The EPA Rutgers Raritan Data Project resulted in an interactive tool to assist stakeholders in accessing previously fragmented data. The study

identified the need for a more comprehensive monitoring program to help fill data gaps, the need for a plan to update and maintain the portal's water quality data, as well as a need to better integrate existing water quality data into a format that can be used for monitoring and planning purposes.

Sea-level rise, storm surge and more intense and frequent storms may increase the likelihood of flooding or inundation of Superfund and other contaminated sites. Climate related changes could affect sites undergoing remediation as well as those considered closed. All historic, active and closed sites in the Raritan Basin should be assessed for climate and weather related vulnerabilities. When needed, adaption measures should be identified and implemented.

## Take-Away—Known Contaminated Sites

Pollutants from contaminated sites can seep into groundwater or runoff into adjacent surface waters, damaging the ecosystem and posing a hazard to wildlife, fisheries and human health. The Raritan Basin contains 20 Superfund sites and 1,703 other known contaminated sites. Only eight Superfund sites and 469 other sites have been closed with institutional controls in place. Both the status and pace of contaminated site cleanup in the Raritan is difficult to track. Monitoring the integrity of previously remediated sites to ensure stability is also a concern. Further, climate related changes could affect the stability of known contaminated sites—both open and closed—and should be considered in basin-wide planning.

## Key Indicator

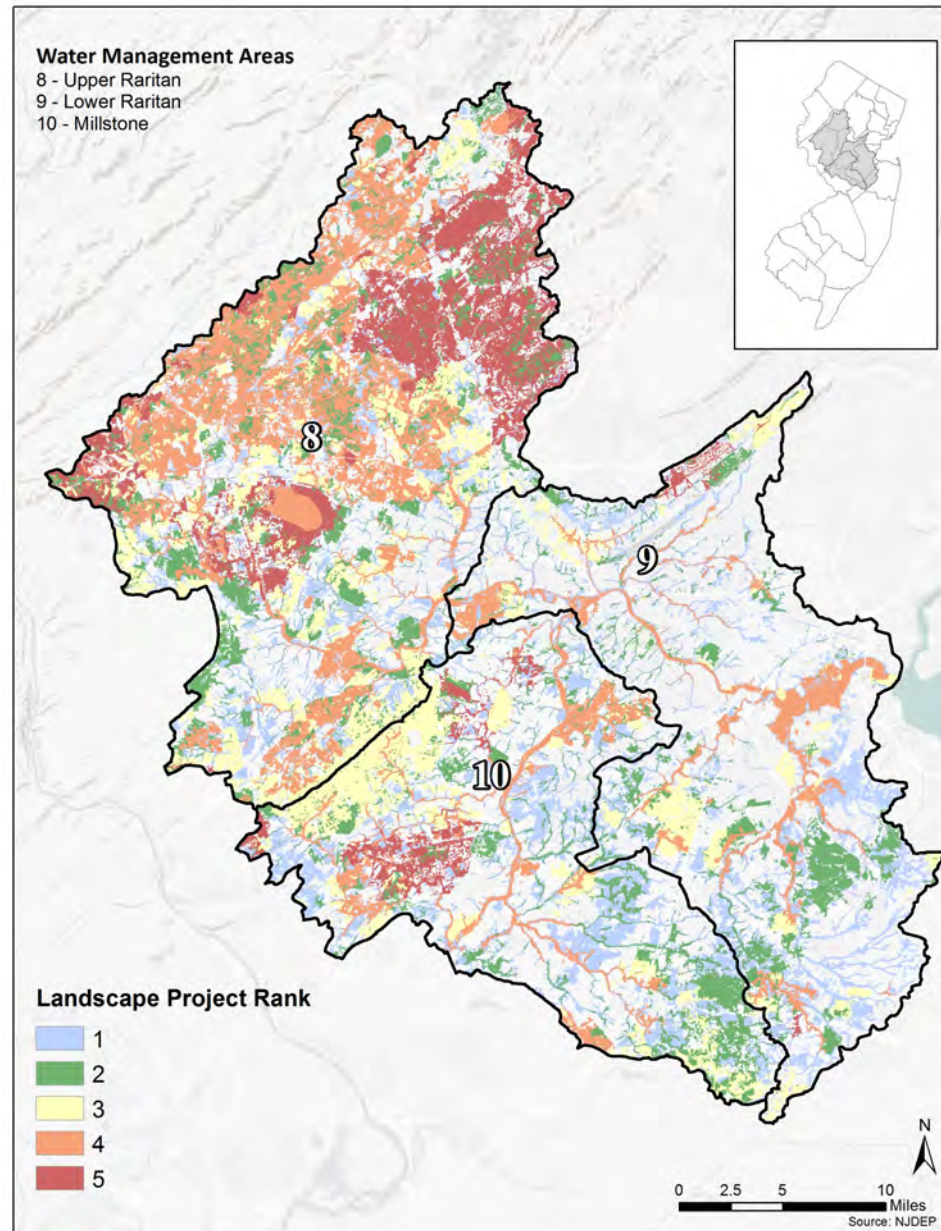
### Threatened & Endangered Species Landscape Project Rankings

#### Background

New Jersey's natural landscape supports an amazing array of habitats that provide critical services including flood storage, water and air filtration, recreation, and support for wildlife including endangered, threatened and special concern species. New Jersey's Landscape Project, was initiated by New Jersey's Endangered & Nongame Species Program in 1994, to document habitat for threatened and endangered species—such as the bog turtle, Indiana bat, bobcat, and red-shouldered hawk—and “serve as a tool to help facilitate growth patterns more sensitive to the needs of wildlife and their habitats.” (NJDFW 2017, 6) The associated maps provide a “foundation for proactive land use planning” and can be used to “minimize conflict and protect imperiled species.” (NJDFW 2017, 8)

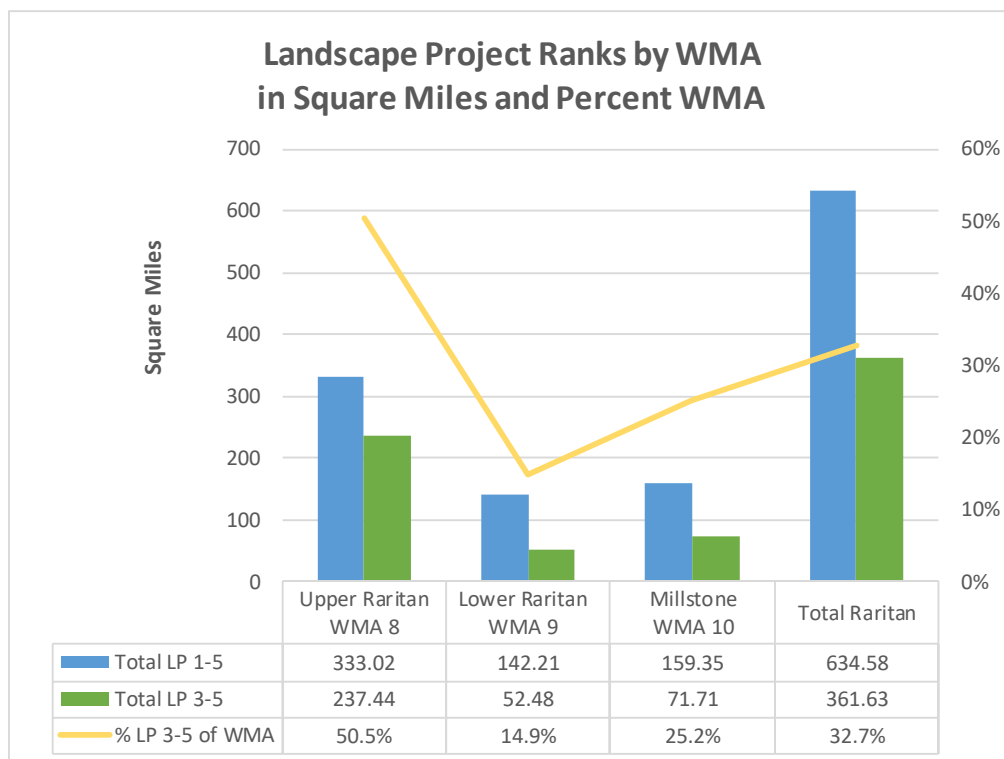
The Raritan Basin and bay encompass two landscape regions identified in the Landscape Project – the Piedmont Plains landscape and the Skylands landscape. The Piedmont Plains landscape includes portions of the Piedmont and Coastal Plain physiographic provinces while the Skylands landscape region primarily covers the Highlands and Ridge and Valley physiographic provinces (Figure 2).

Landscape Project data layers are classified in five



*Figure 13. Map of  
Landscape Project ranked  
areas in the Raritan Basin*





*Figure 14. Landscape Project Rank in square miles and percent for each WMA and the total Raritan*

ranks that are linked to species-specific habitat patches. Rank 1 includes habitat that is suitable for endangered, threatened or special concern wildlife species but for which no occurrence of these species have been documented. Rank 2 is for habitat patches where species of special concern have been documented. Rank 3 identifies habitat where State threatened species have been documented. Rank 4 is

assigned to habitat with documented occurrences of State endangered species. Rank 5 is for habitat patches with documented occurrences of Federally listed endangered or threatened species.

Protection of Landscape Project areas ranked 3, 4, and 5 not only protect habitat for the region's at-risk species, but also preserves habitat that provides services critical to clean and resilient water

resources.

## Methodology

The amount of Landscape Project area by category 3, 4, and 5 were calculated from the most recent Landscape Project data from NJDEP Bureau of GIS (NJDEP 2018b) (Figure 13).

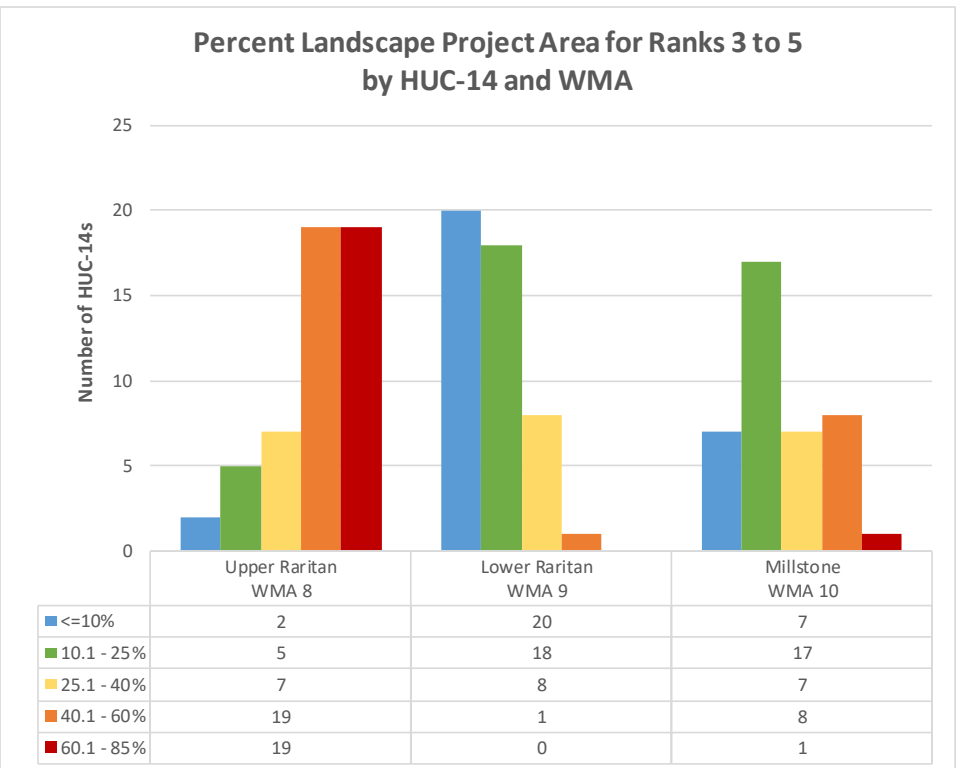
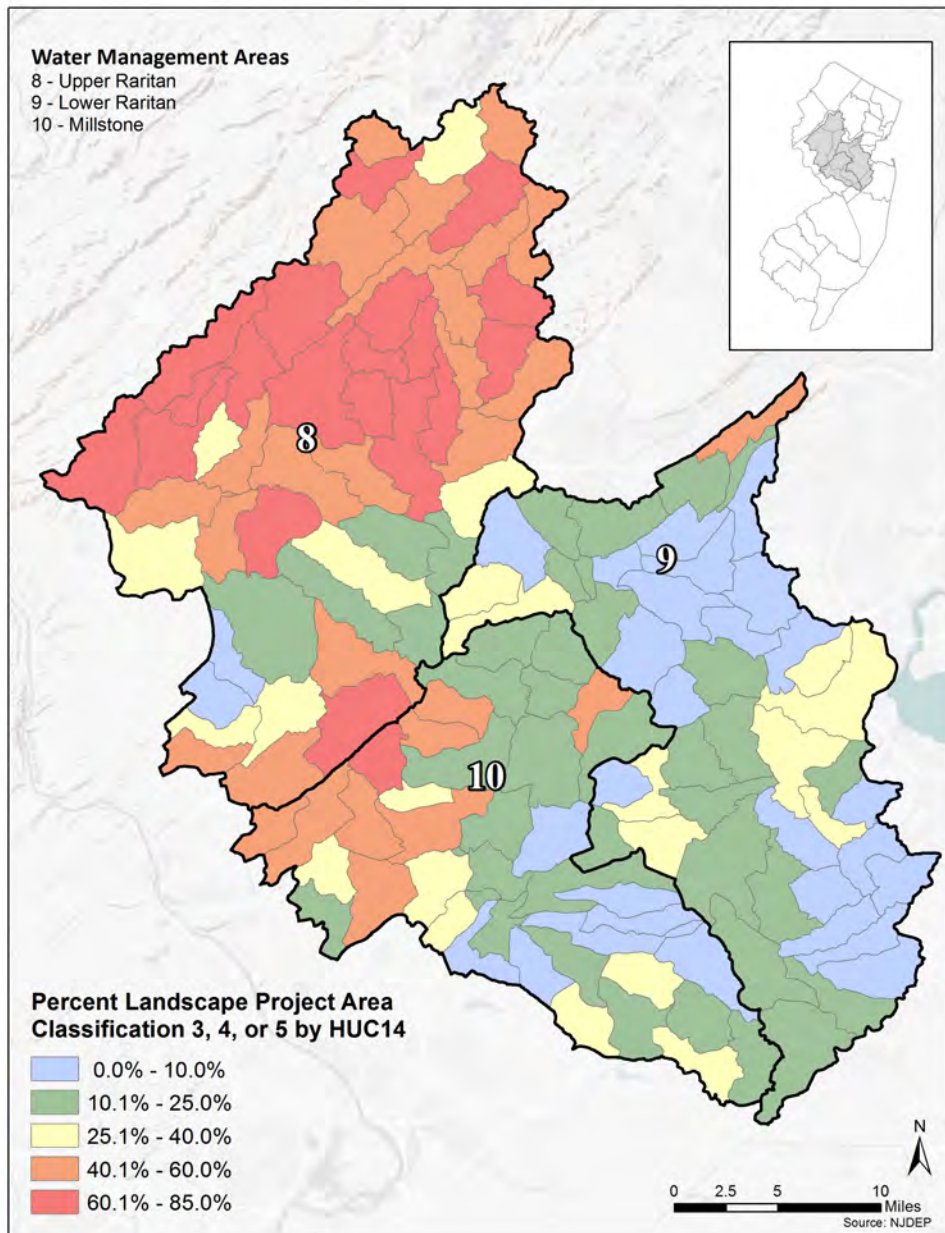


Figure 16. Percent coverage Landscape Project area for ranks 3 to 5 by HUC-14.

Figure 15. Map of percent coverage Landscape Project area for ranks 3 to 5 by HUC-14.

## Status

Over half of the Raritan Basin's land area consists of habitat patches that could presently serve endangered, threatened and special concern species (i.e., Landscape Project Ranks 1-5). The total amount of area in the Raritan Basin ranked as potential habitat for threatened and endangered species (i.e., ranked as 3-5) is 362 square miles, or approximately 33% of the total area (Figure 13 and Figure 14). The Upper Raritan, which includes portions of the Skylands and Piedmont regions, contains the highest amount of potential threatened and endangered species habitat with 237.4 square miles (or approximately 50% of WMA 8). The Lower Raritan and Millstone contain 52.5 (15% of WMA 9) and 71.7 square miles (25% of WMA 10) of potential threatened and endangered species habitat, respectively. Figures 15 and 16 show the number of HUC-14s for each WMA and the total Raritan by percentage of land cover meeting rank 3 through 5 classifications. In the Millstone Basin, only one of the

40 HUC-14 subwatersheds has over 60% of its land area mapped as potential threatened and endangered species habitat (HUC-14 in deepest red shade), while the Upper Raritan has 19 of 52 HUC-14 subwatersheds meeting that threshold of support.

## Summary

The Upper Raritan WMA contains large swaths of potential habitat for a number of New Jersey and federally listed threatened and endangered species. The other two WMAs have a much more restricted amount. The Raritan River and its main tributaries represent an important corridor of potential threatened and endangered habitat threading through the entire basin.

## Take-Away—Threatened & Endangered Species Landscape Project Rankings

New Jersey's Landscape Project documents habitat as classified in five ranks that are linked to species-specific habitat patches. Ranks 3 through 5 support at-risk species, but also provide habitat that provides services critical to clean and resilient water resources. The total amount of Landscape Project area in the Raritan basin (all Ranks) is 634.6 square miles, or approximately 57 percent of the total area. The most critical habitat ranks of 3, 4 and 5 encompass 362 square miles or approximately 33% of the Raritan Basin.



## Key Indicator

# Open Space

### Background

Open space provides a myriad of enhancements to quality of life in the Raritan. These spaces are often vegetated and minimally developed, providing many of the same benefits as canopy cover such as species habitat, carbon sequestration, temperature modification, oxygen generation and air purification. Open space can also store floodwater or filter runoff to enhance water quality. Extensive literature points to the mental and physical health benefits that access to open space provides to people living near open space or using it for recreation. Open space provides opportunities for physical activity, reducing obesity and reducing stress. Parks and open space provide economic benefits as well. Proximity to parks and open space can enhance property values and tourists visiting an area to utilize open space often contribute to the local economy.

### Methodology

Open space GIS data were compiled from various sources to generate seamless raster data encompassing the Raritan River watershed. The primary dataset used was the Open Space and Preservation Resources Inventory (OSPRI) Protected Areas database of the United States (PAD-US) vector

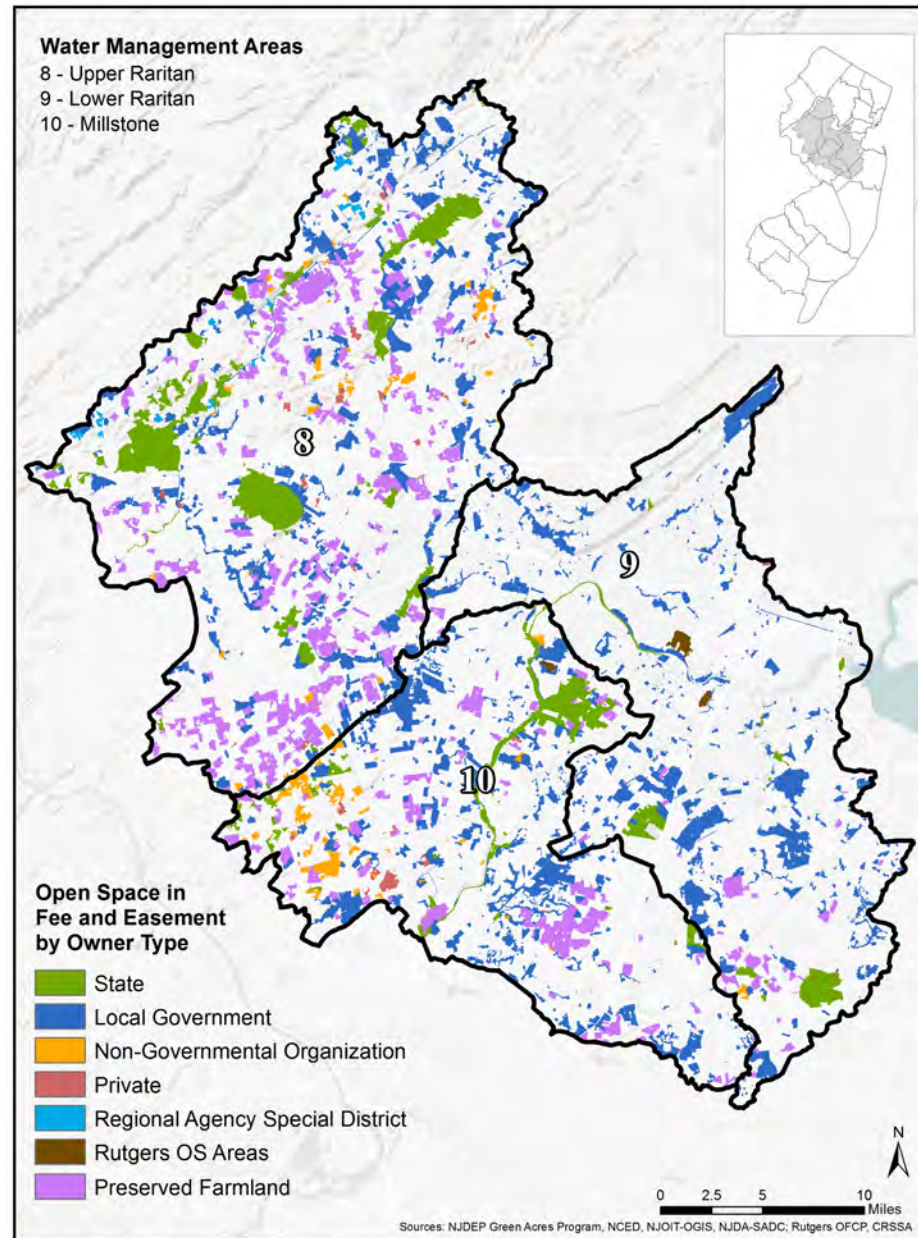


Figure 17. Map of open space in fee and easement by owner type

data, with the NJ Department of Agriculture (NJDA) Farmland Preservation areas and Rutgers University open space properties providing categories not mapped in OSPRI.

The type of owner was defined using the PAD-US schema and the NJDEP type (preserved farmland). The type of access was defined using the PAD-US schema as well and by web verification for areas added to the PADUS layer (state/local government, non-government).

Data set credits: Open Space and Preservation Resources Inventory (OSPRI) in Protected Areas Database of the United States (PAD-US) schema of New Jersey (version 201710); U.S. Geological Survey, Gap Analysis Program (GAP), Protected Areas Database of the United States (PAD-US) and National Conservation Easement Database (NCED), version 2.0; NJDEP Green Acres Program. Farmland Preservation data (version 20170127): New Jersey Department of Agriculture (NJDA), State Agriculture Development Committee (SADC); Rutgers University Facilities and Capital Planning.

Status

Approximately 147,142 acres or 20.8% of the land in the Raritan Basin is held as open space/conservation lands in fee and easement (Figure 17). The Upper Raritan contains 75,825 acres or 52% of basin-wide open space held in fee and easement, while the Lower Raritan and Millstone contain 29,863 (20%)

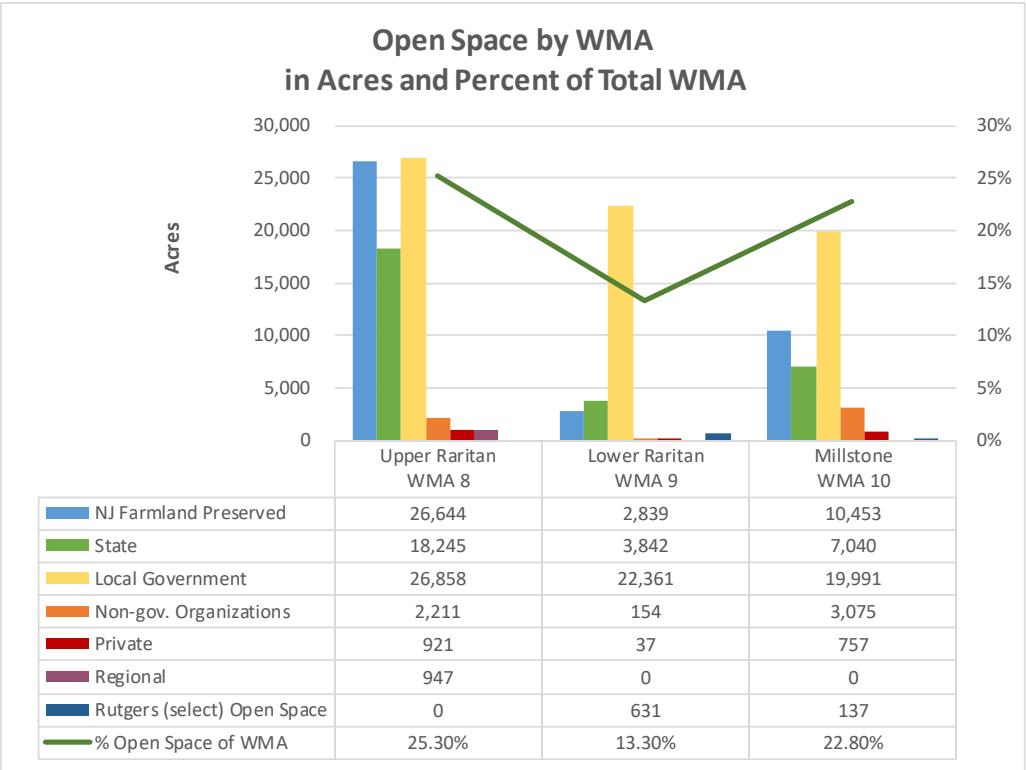


Figure 18. Open space in acres and percent by owner type and WMA

and 4,454 (28%) respectively. Across the basin, open space is owned or held by the State of New Jersey, local governments, non-governmental organizations, private ownership, regional agencies, Rutgers University, or as State preserved farmland. There is

no Federal ownership of land in the Raritan. Municipalities control almost half of the open space in the Raritan Basin, while over a quarter of open space is in State preserved farmland (Figures 18 and 19). A significant portion of the open space in the basin is

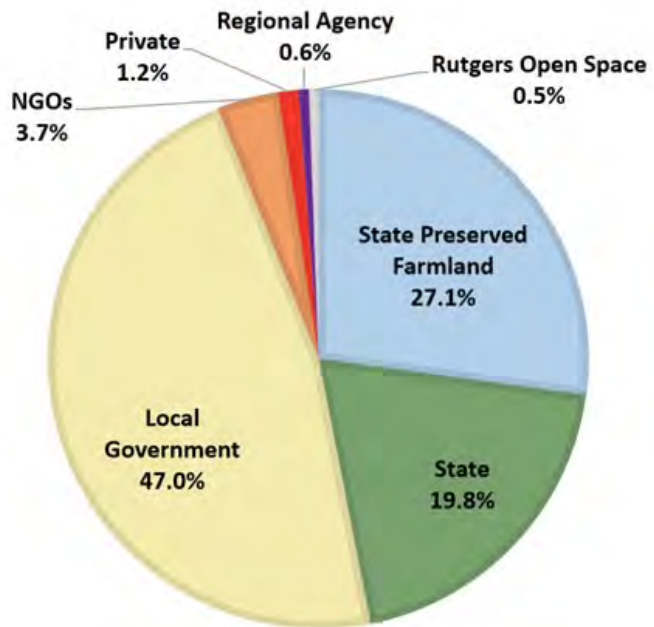


Figure 19. Percent acreage of open space/conservation land by owner type

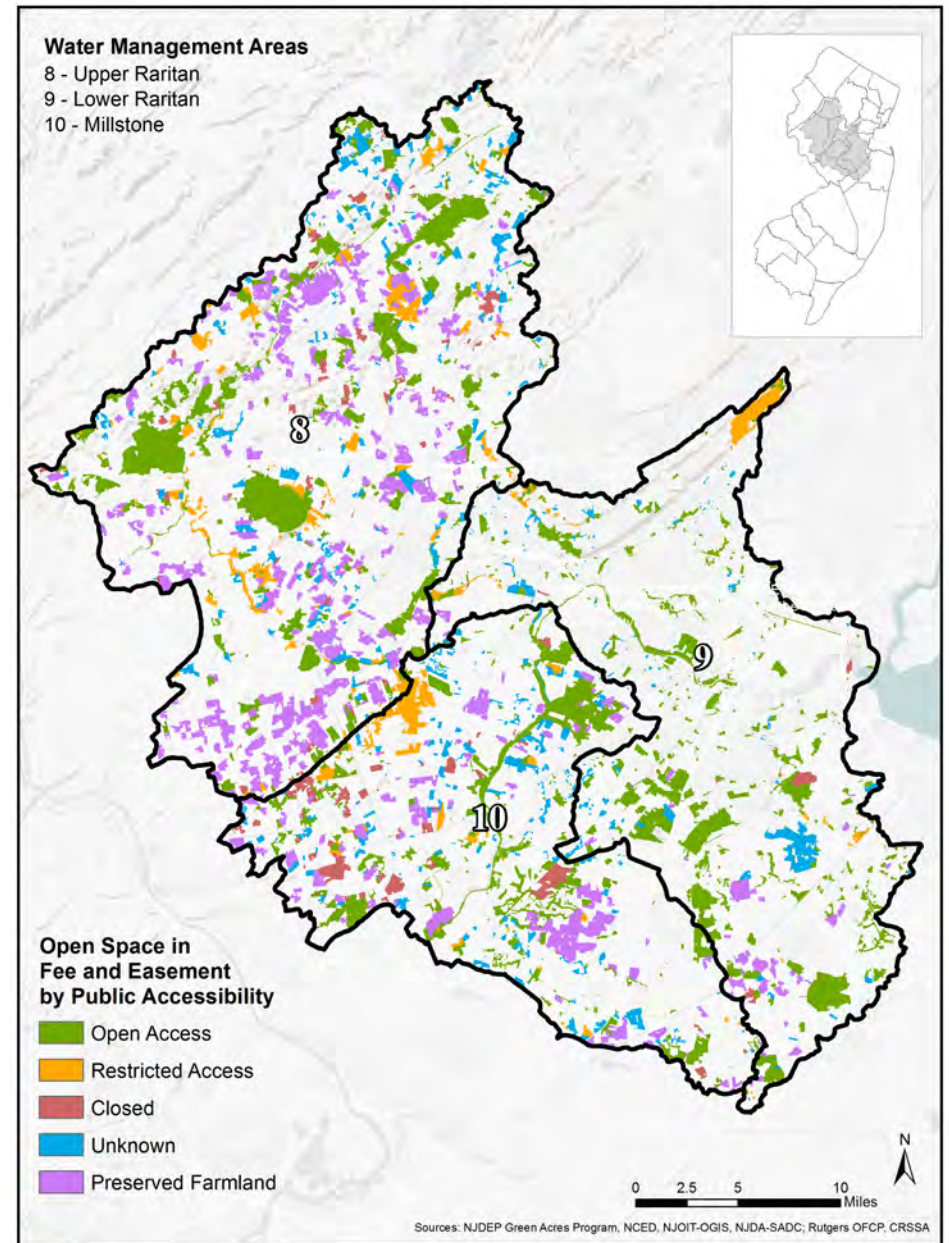


Figure 20. Map of open space in fee and easement by public accessibility



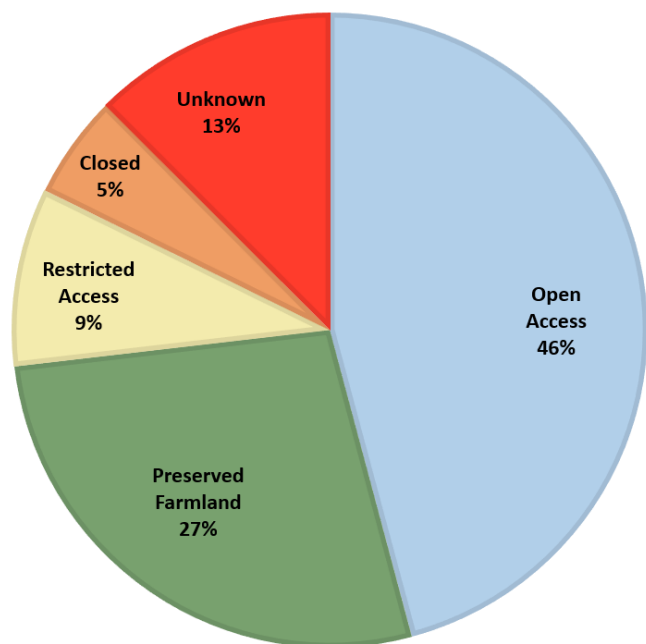
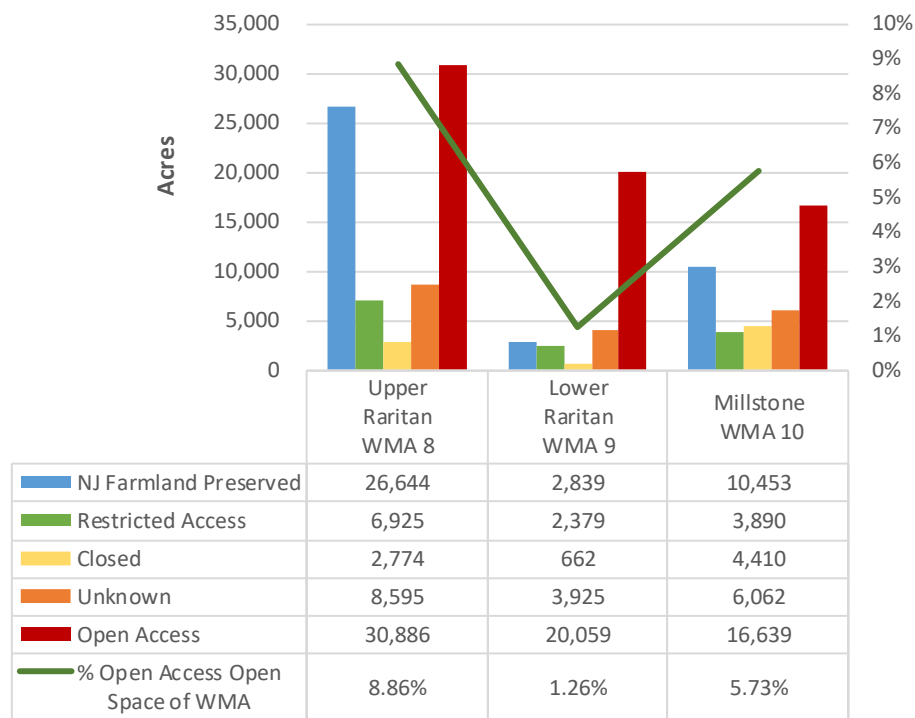


Figure 21. Percent acreage of open space by type of access

Figure 22. Open space access in acres and percent by type of access and WMA

### Open Access Open Space by WMA in Acres and Percent of Total WMA



not accessible open space (Figure 20). While the Raritan has nearly 21% of its land area designated as open space, 39,936 acres or 46% of that is classified as Open Access (Figure 21). Thus, 9.6% of the Raritan River Basin is open access open space. The remaining open space acres are classified as restricted access,

closed, unknown, or preserved farmland (Figure 22). For the subwatersheds, the Upper Raritan has 75,825 acres of land classified as open space, of which, 30,886 acres or 10.3% is open access; the Lower Raritan has 29,863 acres of open space, with 8.9% (20,059 acres) open access; and

the Millstone has 41,454 acres of open space with 9.1% (16,639 acres) of the subwatershed as open access open space.

Figures 23 and 24 show percent open space by HUC-14 for the Raritan watersheds. Forty percent of the HUCs in the Upper Raritan contain between 25% and

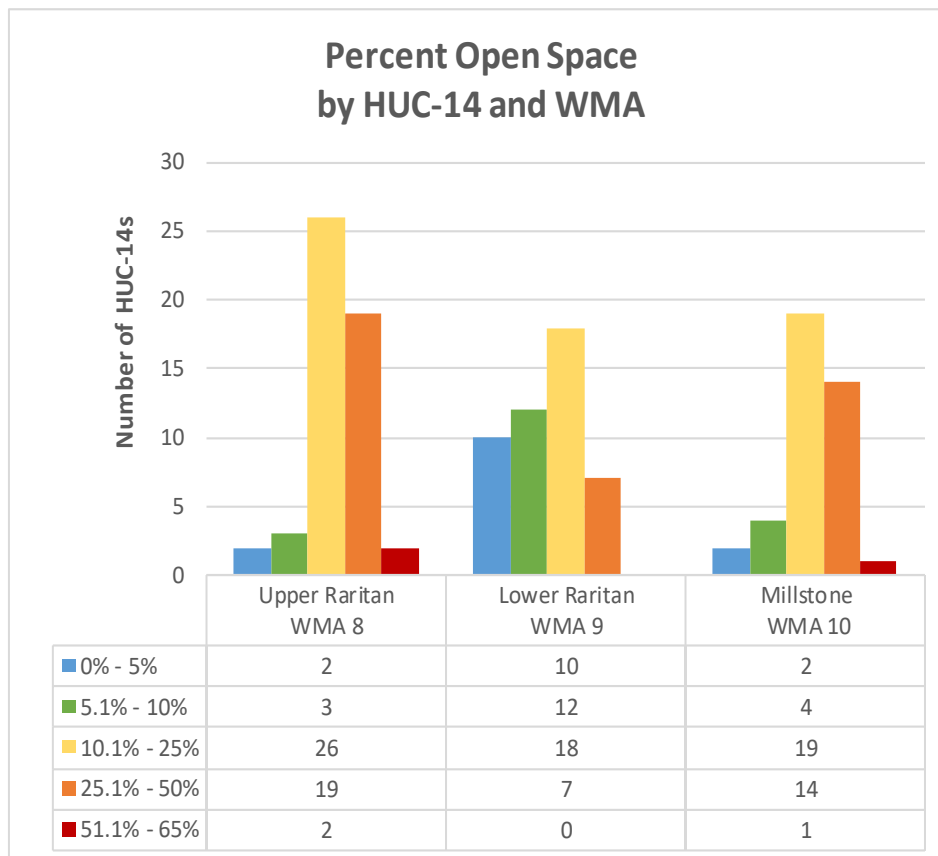
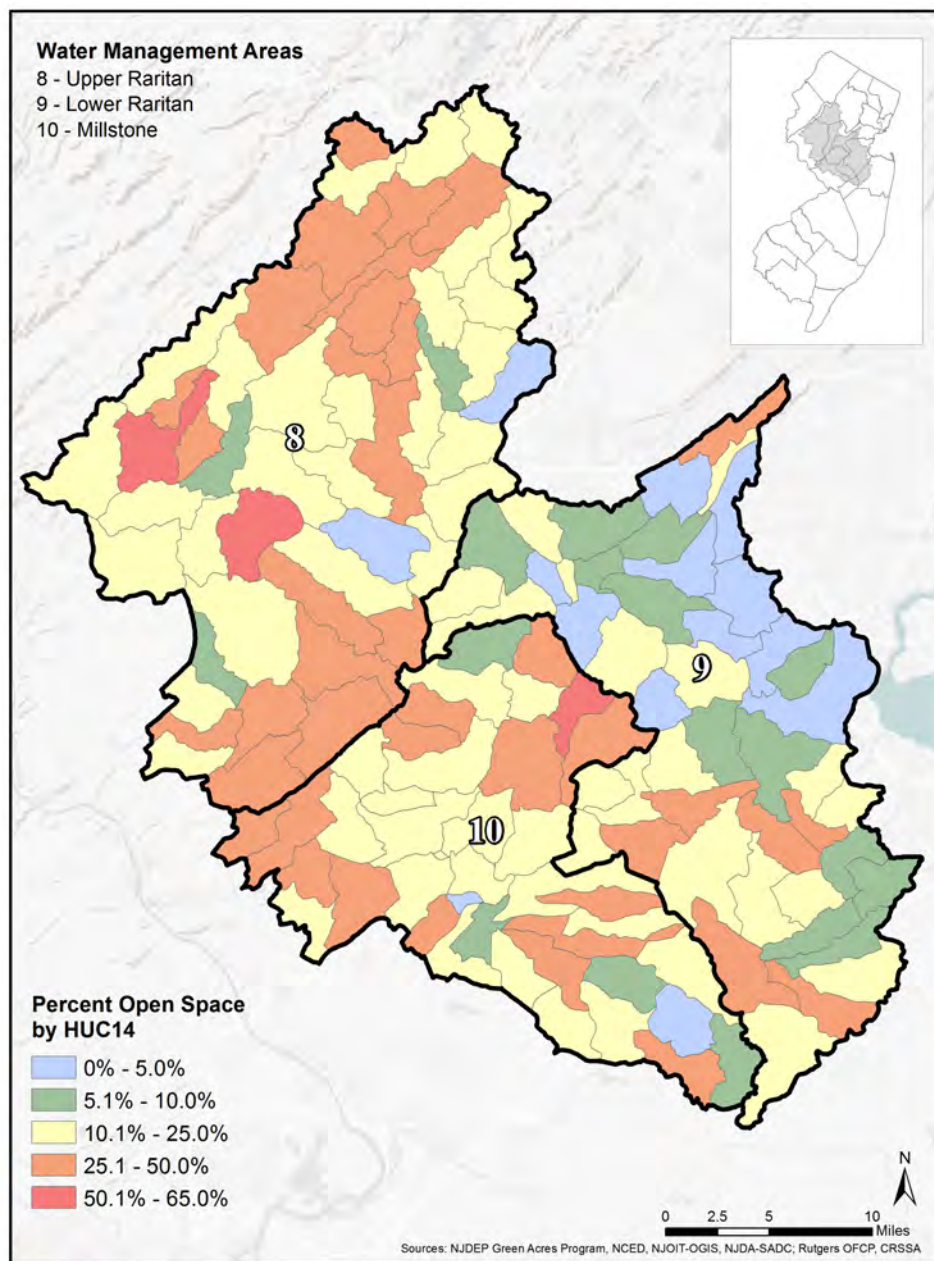
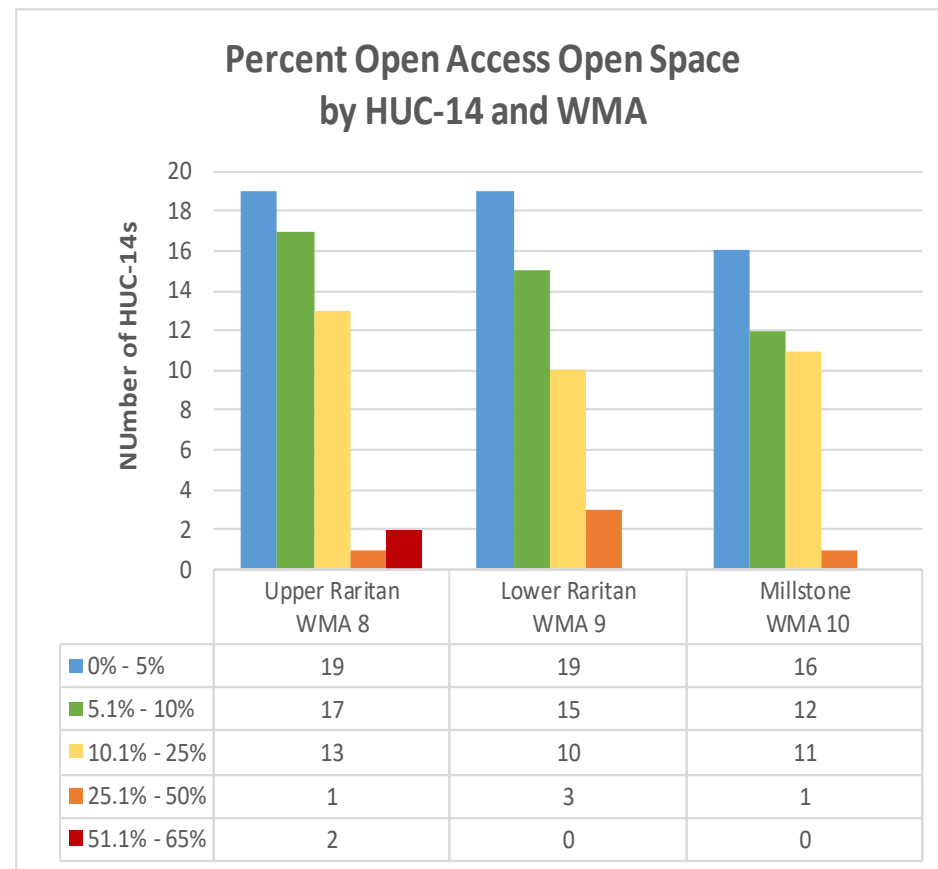
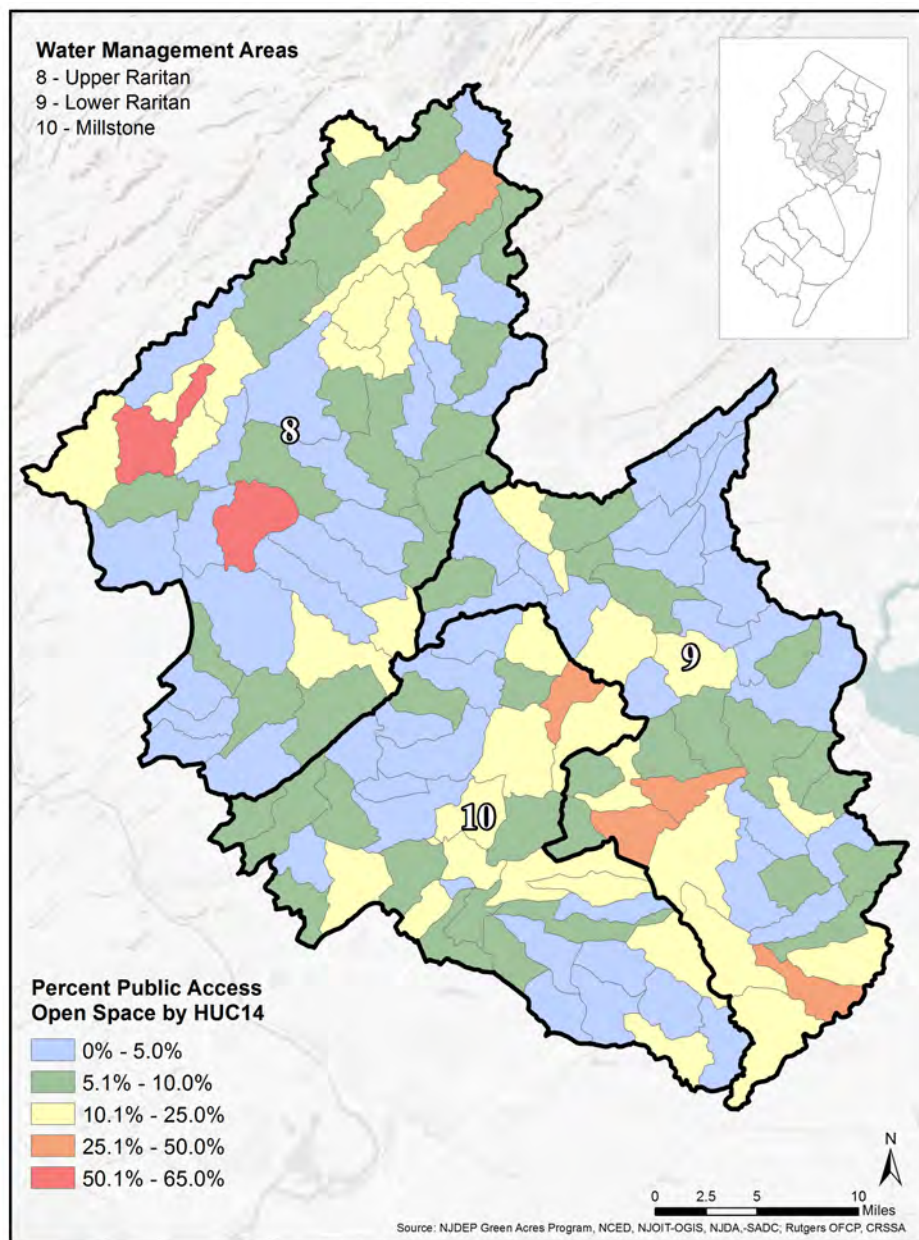


Figure 24. Percent open space by HUC-14 and WMA

65% open space. Thirty-eight percent of the Millstone HUC-14s contain between 25% and 65% open space, while the Lower Raritan has only 15% of its HUCs with between 24% and 64% open space.

Examining only the open access open space, we find that 6% of the HUC-14s in the Upper Raritan have

Figure 23. Map of percent open space by HUC-14



*Figure 26. Percent open access open space by HUC-14 and WMA*

between 25% and 65% accessible open space. The Millstone has less than 8% of its HUCs in that range and the Lower Raritan has only one HUC (or 2% of total HUCs) with between 25% and 65% open access open space. (See Figures 25 and 26).

*Figure 25. Map of percent public access open space by HUC-14*



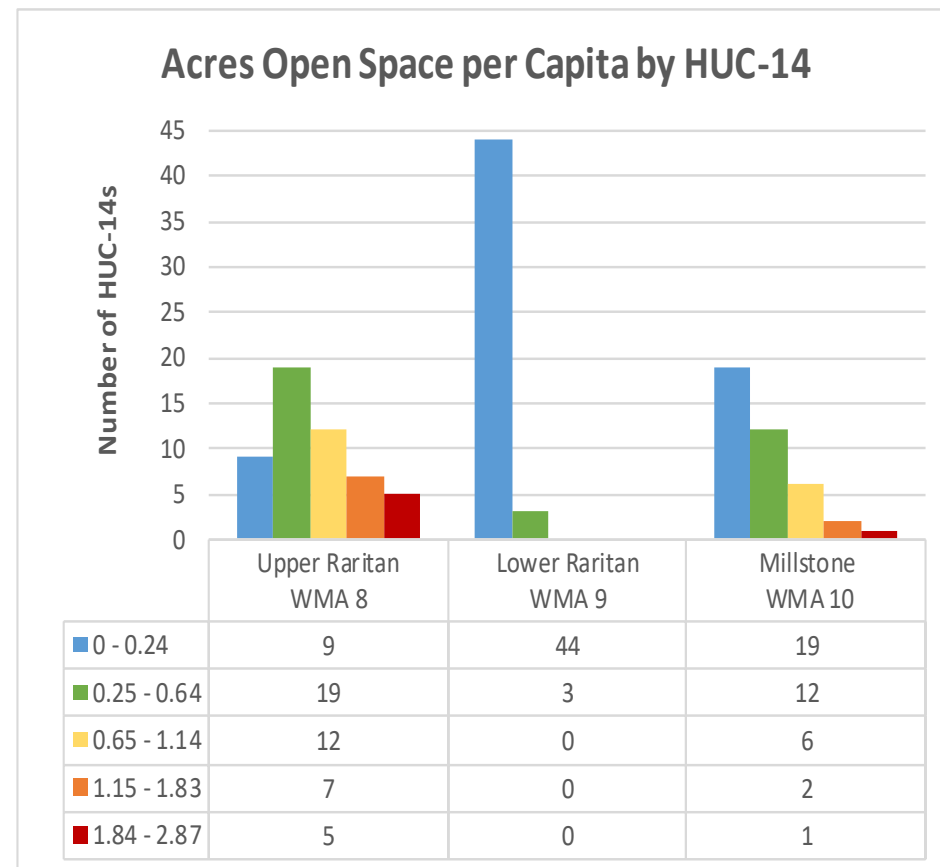
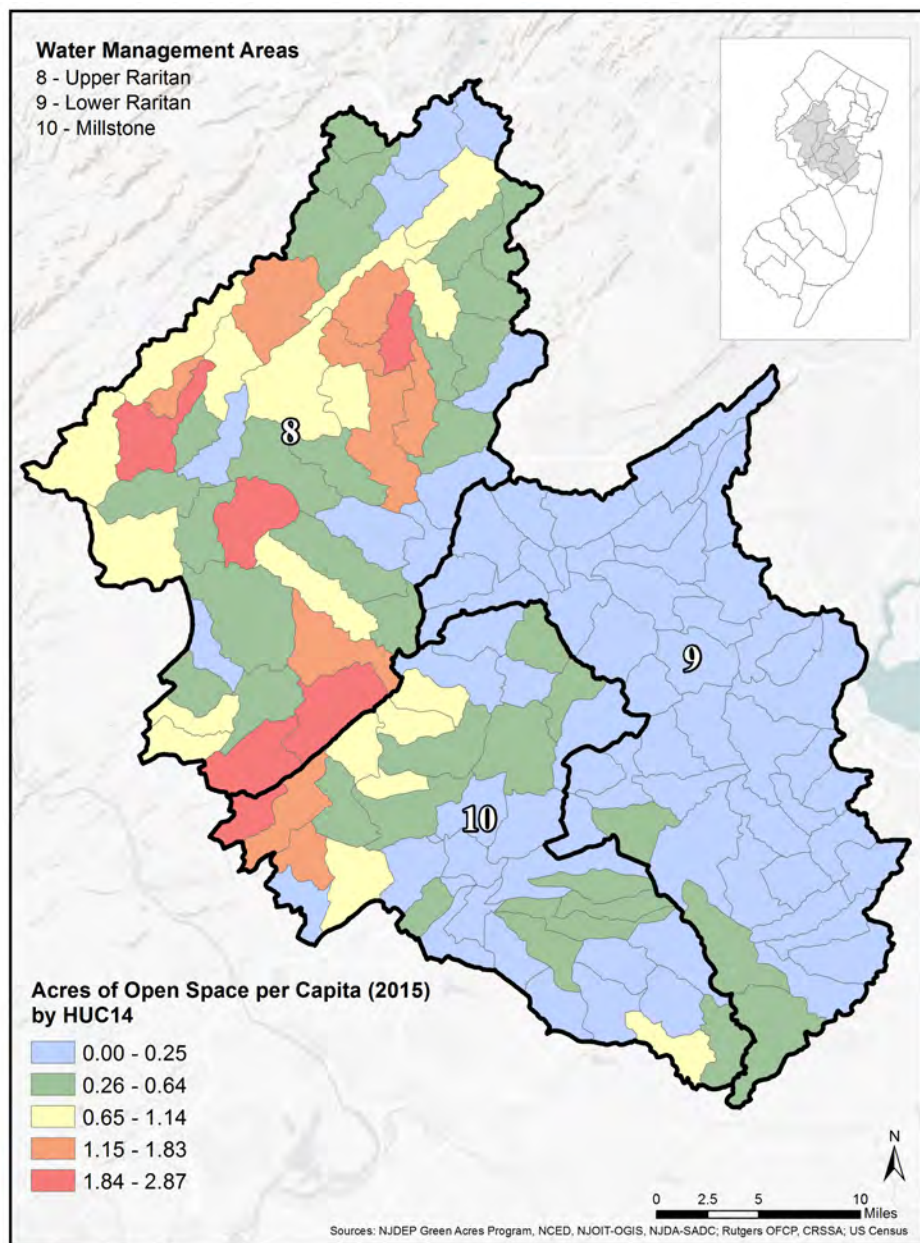


Figure 28. Acres open space per capita by HUC-14

Figure 27. Map of acres of open space per capita by HUC-14

As noted in the background, open space has value for mental and physical health for local populations. Figures 27 and 28 show acres of open space per capita for each HUC in the basin. Not surprisingly, in the more densely populated Lower Raritan, 94% of its HUCs offer less than a quarter of an acre of open space

per person. This contrasts with the Millstone and the Upper Raritan where a majority of the HUCs have more than a quarter-acre of open space per person (53% and 60% for the Millstone and Upper Raritan respectively).

## Summary

The Raritan River basin contains significant amounts of open space/conservation lands (approximately 147,142 acres or 20.8% of the land) with the majority found in the Upper Raritan (52%) followed by the Millstone (28%) and then the Lower Raritan (20%). Though the Upper Raritan does have a significant portion of the overall Raritan open space, it is largely composed of preserved farmland where public access is often restricted. When considered on a per capita basis, the unequal distribution of open space is more readily apparent with the Lower Raritan having much lower percentage of open space per person.

### Take-Away—Open Space

Lands designated as open space are owned or held by the State of New Jersey, local governments, non-governmental organizations, private ownership, regional agencies, Rutgers University, or are State preserved farmland. The Raritan has 147,142 acres (20.8 percent of the total basin) of open space held in fee or easement. Open space, whether accessible or not, provide significant public health, economic and water quality benefits.

## Key Indicator

### Recreational Trails and Greenways

#### Background

A myriad of trails and greenways crisscross the Raritan Basin. They range in size and popularity from the 69.5 mile Delaware and Raritan Canal State Park Trail that enjoyed over 1.38 million visitors last year (NJDEP 2018c), to the 15 mile Columbia Trail along the South Branch of the Raritan in Hunterdon/Morris counties, to small out-and-back trails like the two mile Farrington Lake trail in Middlesex County. Trails provide opportunities for recreation with health benefits previously outlined for open space. Trails function as transportation corridors for walking and biking – connecting neighborhoods, shopping and entertaining areas, schools and more. Greenways also function as buffers between built and natural environments, they add value to open space for the public by providing access, and they enhance quality of life in communities by providing a sense of place and opportunities to interact with neighbors (NPS 2008)

There are several greenway projects in the region focused on enhancing access to the Raritan and connecting communities across the basin. These include the East Coast Greenway Alliance, the Middlesex Greenway, the Raritan River Greenway project, the Holland Brook Greenway project, and the

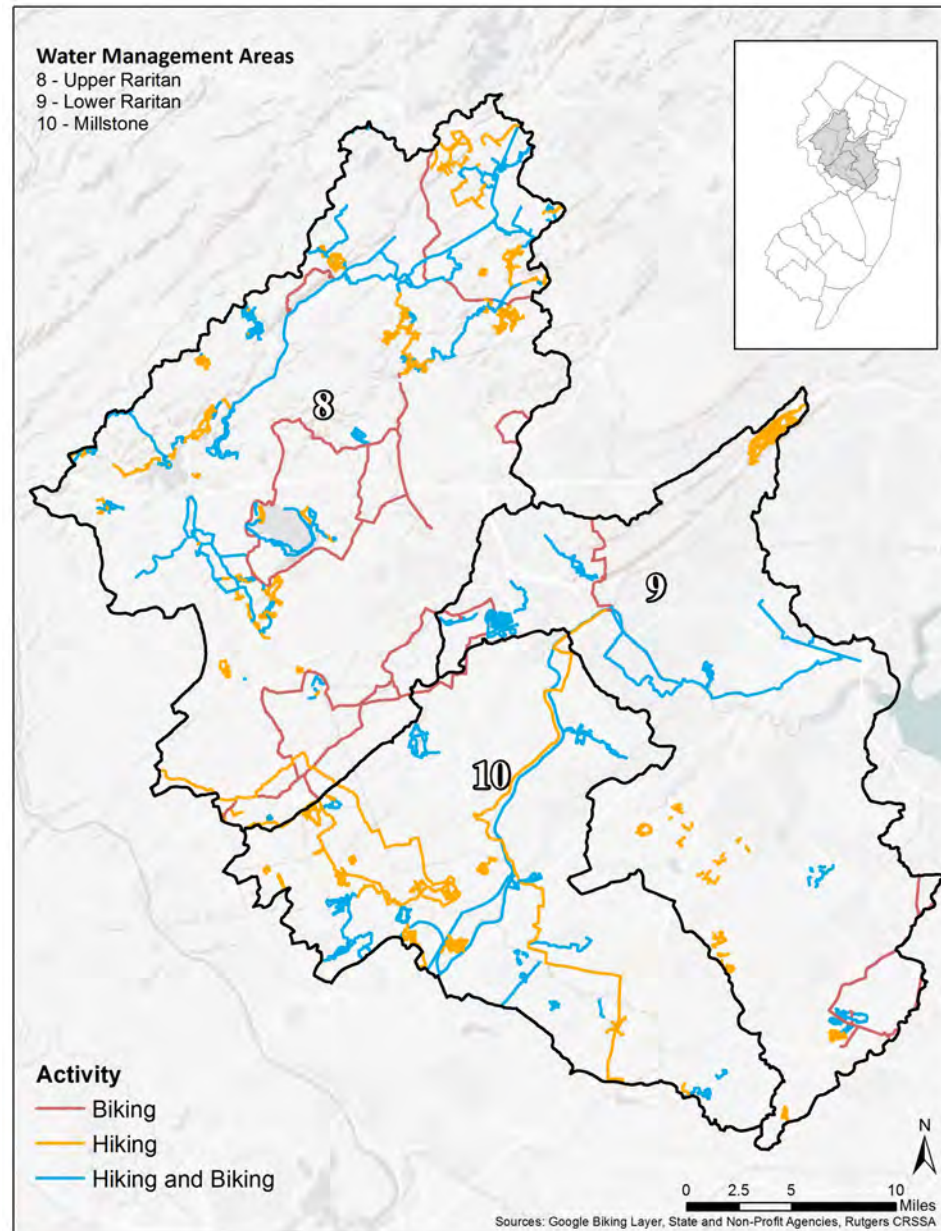
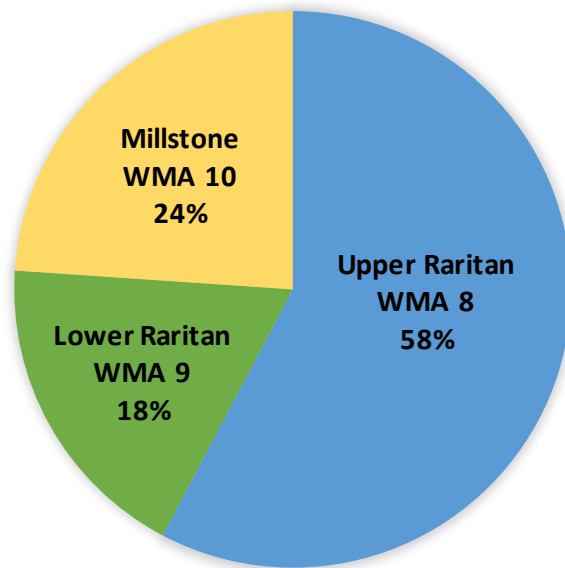


Figure 29. Map of trails by type in the Raritan Basin



## Percent Total Trails by WMA



*Figure 30. Percentage of hiking, biking and combined hiking and biking trails miles by WMA*

Black River Greenway project to name a few (SRR 2009).

### Methodology

The trails data layers were compiled from a number of sources: Hunterdon County Division of GIS; Middlesex County Office of GIS; Monmouth County Division of Planning, GIS; Morris County Office of

Information Technology, GIS Section; Somerset County Office of Information Technology, GIS, and Mercer County Planning Department provided maps prepared by the Delaware Valley Regional Planning Commission. No data was obtained from Union County.

In addition, data was downloaded for the East Coast Greenway and from HART Commuter

Information Services for Hunterdon County (now GoHunterdon.org), or was digitized using the Google Biking Layer.

All trail attributes were grouped into three trail type classifications for hiking, biking, or hiking and biking combined to indicate the types of permitted trail activities. Trail length was calculated in ArcGIS.

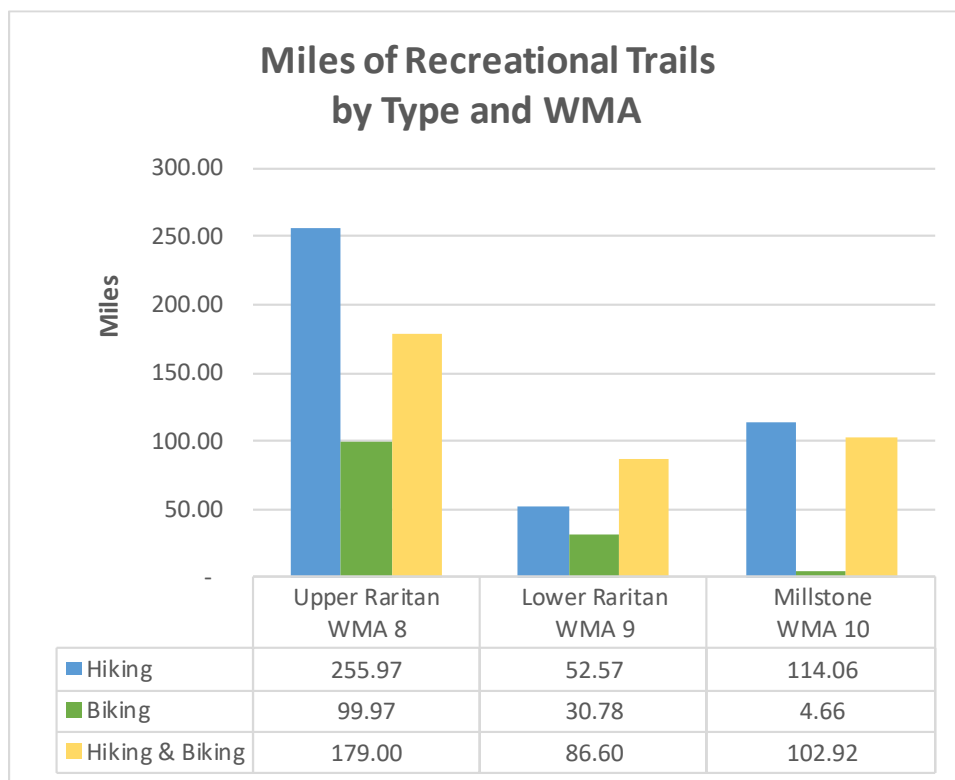
### Status and Trends

This summary includes data on approximately 926.5 miles of trails and greenways in the Raritan Basin that are classified for use as either hiking, biking or both (Figure 29). The Upper Raritan Basin contains over 58% (534.9 miles) of the overall basin's trails mileage, while the Millstone and Lower Raritan contain 24% (221.6 miles) and 18% (170.0 miles) respectively (Figures 30 and 31). Hiking and combined hiking/biking trails predominate versus biking only (Figure 32).

### Summary

No comprehensive central database of trails across the basin exists. While we have attempted to compile an inventory from readily available sources, we believe there are many more miles of trails not included in this summary such as trails maintained by municipalities, land trusts and other non-profit organizations.

Not included but significant to recreation in the nearby Raritan Bay is the Henry Hudson Trail in Monmouth County. This 24-mile long multi-use trail starts in Freehold and connects through Marlboro, Matawan,



*Figure 31. Length of  
recreational trails (in miles)  
by WMA*

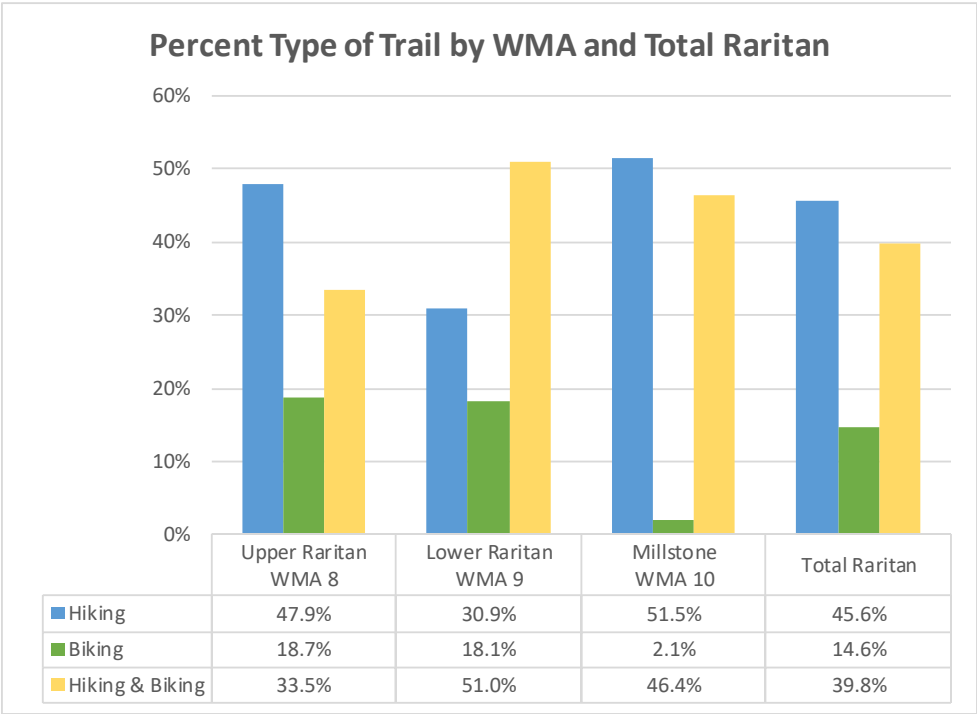
Aberdeen/Keyport, Union Beach, North Middletown and Atlantic Highlands, terminating in the Highlands at Popamora Point. The trail is not yet continuous and has several breaks in the route south of Marlboro and Aberdeen. The trail is a former railroad right-of-way.

Several of the hiking/biking trails are directly adjacent to the Raritan River or its main tributaries providing many direct access points to these water bodies for fishing and wildlife viewing. The Delaware & Raritan (D&R) Canal towpath, part of the D&R Canal State Park, is of special note as it provides

a walking/biking trail that extends many miles with the D&R Canal on one side and the Millstone and main stem of the Raritan River on the other. In Duke Island County Park, the Raritan River Greenway, a paved pathway, extends from the Headgates Dam for several miles to downtown Raritan. This trail is slated to link

up to Duke Farms (crossing the river via a repurposed road and now pedestrian bridge in the near future) and eventually with the Peters Brook Walkway in Somerville.

Despite numerous trial connections across the region, there is no current comprehensive trail or greenway map for the Raritan Basin. Many more miles of trails exist across the region. These trails are managed by land and conservation trusts, “friends of” organizations, and municipal and regional organizations. A concerted effort at compiling mapped information on the basin’s trails is needed. A further challenge will be to keep the database updated and readily accessible to the public.



*Figure 32. Percentage of recreational trails (in miles) by type and WMA*

### Take-Away—Recreational and Greenways

Trails and greenways provide opportunities for recreation, connect our communities, provide health benefits, add value to our homes, enhance the livability of our communities, and function as buffers between built and natural environments. This summary captured data on approximately 926.5 miles of trails and greenways for hiking, biking or combined hiking and biking. The Upper Raritan contains 58% of those trails with the Millstone and Lower Raritan offering 24% and 18% respectively of recreation trails reported. No comprehensive central database of trails across the basin exists; we believe there are many more miles of trails not included in this summary that are maintained by municipalities, land trusts and other non-profit organizations.



## Key Indicator

### Access to the River/Public

### Boat Launches

#### Background

Traveling by boat is one of the best ways to reap the salutary effects of blue spaces like the Raritan. The main stem of the Raritan offers over 75 paddling miles occasionally interrupted by dams and weirs with the first (Island Farm Weir) approximately 20 miles upstream from the river's mouth in Perth Amboy. Getting onto the river from land, however, can be a challenge. Much of the Raritan's shoreline is privately held and thus not accessible, and many launch sites are poorly marked or lack parking. No comprehensive water trail map exists for the Raritan and its tributaries.

#### Methodology

Information on points where the public has access to the main stem of the Raritan River or its larger tributaries and the Delaware & Raritan Canal for boats launched from a ramp or via hand carry launch sites were compiled from numerous sources including the New Jersey Boater's Ramp Guide (n.p.), Raritan Riverkeeper's Raritan River Access Point Report (2009), individual park websites, the New Jersey Clean Vessel Act program's NJBoating.org, NY-NJ Harbor and Estuary Program's Public Waterfront Spaces map, and personal knowledge. Select points

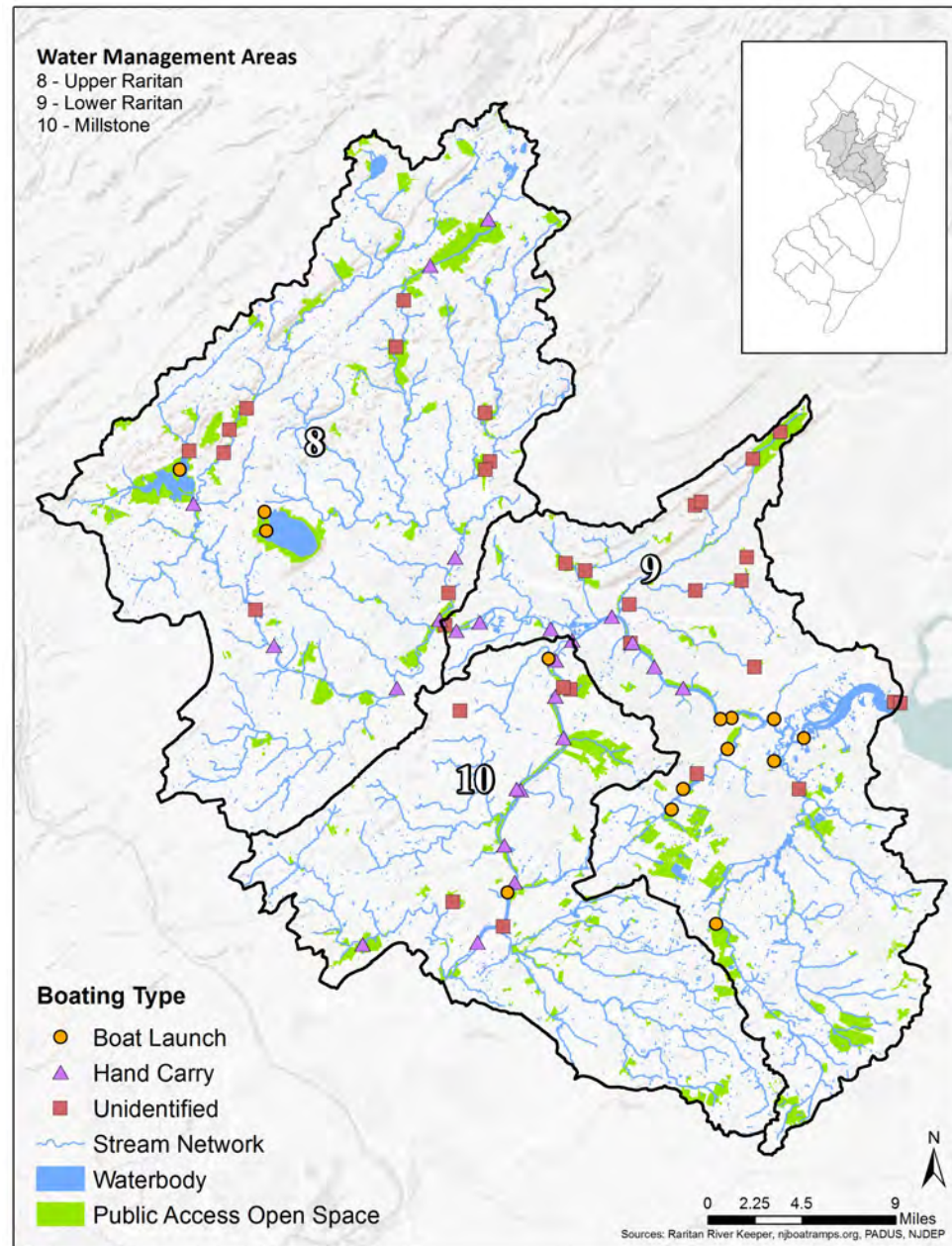
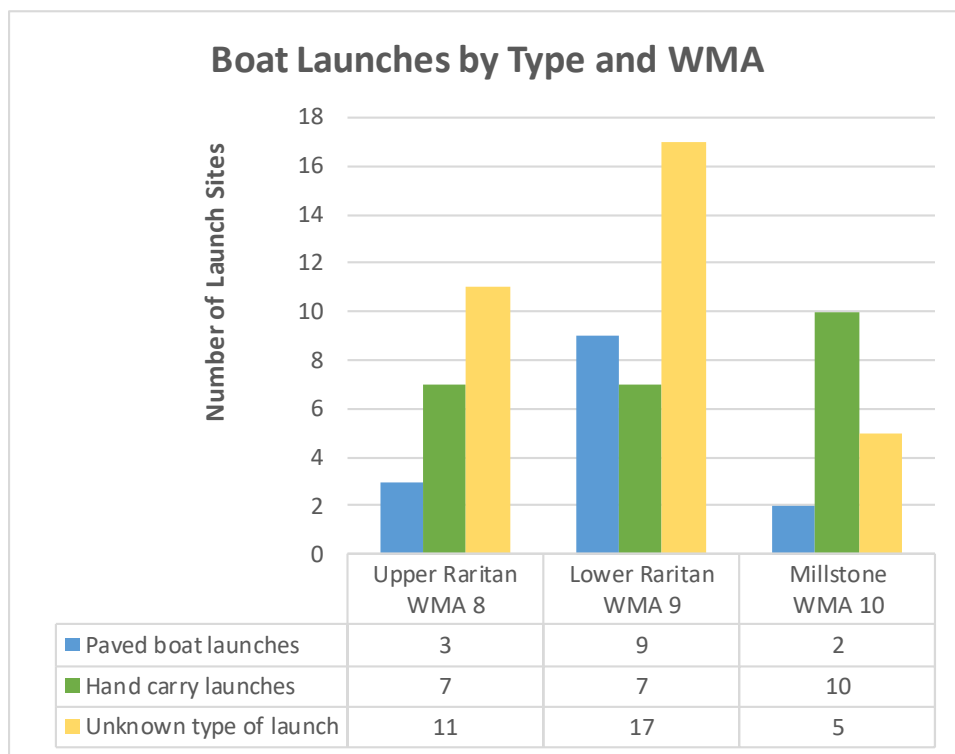


Figure 31. Map of boat launches by type in the Raritan Basin



*Figure 34. Boat launches by type for each WMA*

were verified by aerial photo interpretation or ground visits.

Potential waterfront access was identified by selecting the Publicly Accessible Open Space Areas, from the Open Space map, that surround water bodies or large streams and exporting those shapefiles into a new layer. All of the open space in

this map is public access open space and does not include preserved farmland.

### Status

Figure 33 features 71 boat launches in the Raritan River Basin. Fourteen launches are paved (yellow dots on map), 24 are hand carry launches (shown as

pinkish triangles) and the nature of the remaining 33 launches (shown as red squares) could not be determined from available data (Figure 34).

Potential areas that may offer additional waterfront access were identified by overlaying the open space category of Publicly Accessible (defined as Open Access) over streams and water bodies. Those areas

that show overlap are indicated in green. Over 50,240 acres of publicly accessible open space were identified as connecting to major streams and water bodies in the Raritan Basin. Over 45%, or 22,784 of these acres are in the Upper Raritan watershed, 33% or 16,512 acres are in the Lower Raritan and the remaining 10,944 acres (22%) are in the Millstone watershed. Additional analysis would be required to determine if any of these areas presently have informal access or if they could be developed into additional access points for boating.

Much of the North and South Branch of the Raritan as well as the mainstem is suited for paddling canoes and kayaks. Constraints to public access by motorized boat between New Brunswick and the confluence of the North and South branches of the Raritan are shallow waters and shifting shoals upstream of Boyd Park in New Brunswick. The low profile Raritan Bay Swing Bridge crossing at the mouth of the Raritan between Perth Amboy and South Amboy that carries Conrail and New Jersey Transit rail services further impedes motorized boat access on the Lower Raritan.

The swing bridge, damaged during Superstorm Sandy, is slated to be replaced over the next six to seven years. (NJTransit, n.d.). The new bridge design employs a vertical lift structure that will open to 110' clearance (a height that is similar to the Route 35 Victory Bridge crossing just upstream), the width of the opening will increase from two channels at 125 feet each to one 300 foot-wide channel; and the bridge deck will be approximately 10 feet higher than the existing bridge deck—making it more resilient at 2.5 feet above Federal Emergency Management Agency's Base Flood Elevation or approximately 18 feet above mean high water.

Despite several independent efforts to map the Raritan access points and to characterize the amenities available at each launch site, no current publicly available basin-wide water trail map exists for the Raritan. Such a water trail map should be developed to promote both non- and motorized boating recreation. The map resource would need to be regularly updated to include new launch sites as they are opened. While this report was being

developed, a new kayak/canoe launch site opened in Bound Brook under the Queen's Bridge; Sayreville announced plans for a mixed use waterfront project (on the former National Lead site) that is slated to include a marina; and Manville has included two boat ramps in draft plans for the proposed Lost Valley Nature Park.

### **Take-Away—Access to the River/Public Boat Launches**

The main stem of the Raritan offers over 75 paddling miles with an estimated 71 launch sites. Fourteen launches are paved, 24 are hand carry launches, and conditions at the remaining sites could not be determined from data collected. Getting onto the river, however, can be a challenge as much of the Raritan's shoreline is privately held (and so not accessible), existing launch sites are generally poorly marked or lack parking. Though there have been several independent efforts to map Raritan access points, no comprehensive water trail map exists.



## Key Indicator

# Stormwater Infrastructure Management Systems

### Overview

Effective and properly engineered storm water management systems (SWMS) represent one of the most important water resource protection strategies available to counter the most deleterious impacts of nonpoint source pollution and surface runoff associated with development (Dillon 2005; Goonetilleke et al. 2005; Debo and Reese 2003; USEPA 2004a; Center for Watershed Protection 2010). In addition to larger-scale infrastructure such as stormwater basins engineered to handle entire subdivisions, a whole host of runoff reduction practices (e.g., from rain barrels/gardens to permeable paving) are being employed at the individual homes scale (Chesapeake Stormwater Network 2009). The planning and management of SWMSs involves diverse stakeholder groups: from municipal to county to state government agencies involved in land use planning, engineering, transportation, environmental/natural resource protection and public health to the private development community and associated engineering/environmental consulting firms.

New Jersey has been a leader in advocating for SWMSs for new construction, requiring municipalities to have a municipal storm water management plan (MSWMP) as mandated by its Phase II, Municipal Stormwater Regulatory Program. The Municipal

Stormwater Regulation Program was developed in response to the U.S. Environmental Protection Agency's (USEPA) Phase II rules published in December 1999. The NJDEP issued final stormwater rules on February 2, 2004 and four NJ Pollutant Discharge Elimination System (NJPDES) general permits authorizing stormwater discharges from municipalities, as well as public complexes, and highway agencies that discharge stormwater from municipal separate storm sewers. MSWMPs document the strategy that a specific municipality has adopted to address stormwater-related impacts of proposed development/redevelopment to water availability (i.e. water quality and quantity) (NJDEP 2004, 2006). The MSWPs must incorporate design and performance standards for SWMS infrastructure and practices that focus on three areas:

- maintaining groundwater recharge;
- minimizing flooding; and,
- minimizing the water quality impact on state waters.

Improperly designed, constructed or maintained SWMS basins can lose their value in protecting water resources. Likewise, as a watershed is further developed, the hydrology, hydraulics and nutrient loadings change in ways that may not have been accounted for in the initial design of existing retention/detention basins. For example, surface runoff volumes and nutrient runoff from nonpoint sources may increase with increasing impervious surface and managed lawn area (USEPA 2004a). Addressing inadequately performing SWMS basins to restore their proper function is receiving increasing

scrutiny as a means of restoring impaired watersheds and coastal waters (BBNEP 2000; Marcoon and Guo 2004). Increasingly the goal is to reduce the volume of runoff by increasing infiltration to the groundwater system (USEPA 2007, 2008; Chesapeake Stormwater Network 2009; Center for Watershed Protection, 2010). For example, the conversion of detention basins into vegetated biofilters or bioretention cells are being promoted as a best management practice (BMP) for enhancing aquifer recharge, reducing surface runoff and streambank erosion and improving downstream water quality (USEPA 2004b, 2008; Hunt et al. 2008). Without a comprehensive SWMS database, there is no systematic way of identifying and prioritizing retention/detention basins that may be contributing to impaired watersheds for targeted restoration (Lathrop et al. 2012). To help address this need, the New Jersey Department of Agriculture spearheaded the development of the New Jersey Hydrologic Modeling Database (NJHMD). The NJHMD consists of an electronic, web-based database of the summary forms containing land use and hydrologic design data for most of the development sites in New Jersey that were large enough to warrant the use of at least one stormwater basin (available at <https://hydro.rutgers.edu/about/>). While the most comprehensive SWMS database available at present, the database is not complete.

To address possible data gaps, the NJDEP Bureau of Nonpoint Pollution Control has developed and made available a number of free online tools to help municipalities map and inventory their stormwater management infrastructure ([https://www.nj.gov/dep/dwq/msrp\\_map\\_aid.htm](https://www.nj.gov/dep/dwq/msrp_map_aid.htm)).

## Key Indicator

### SWMS—Stormwater Basins

#### Background

Stormwater basins are meant to protect downstream areas from flooding and erosion by capturing and then slowly releasing rainwater and melting snows. They generally take the form of retention basins, detention basins, infiltration basins or some hybrid of these. Retention basins have an outlet higher than the base elevation of the basin and may retain a permanent pool of water. Retention basins can enhance the quality of released waters by capturing sediment and attached pollutants. Detention basins have outlets at base elevation of the basin and so usually dry out between precipitation events. Detention basins are designed to control peak stormwater flows. Infiltration basins are constructed of pervious materials that capture suspended solids and recharge to groundwater. All types of stormwater management basins require regular maintenance to ensure they function as designed.

#### Methodology

Data on the location of stormwater management (SWM) basins were downloaded from the New Jersey Hydrologic Modeling Database at [hydro.rutgers.edu](http://hydro.rutgers.edu) in January 2018. These data were classed by type and mapped (Figure 35).

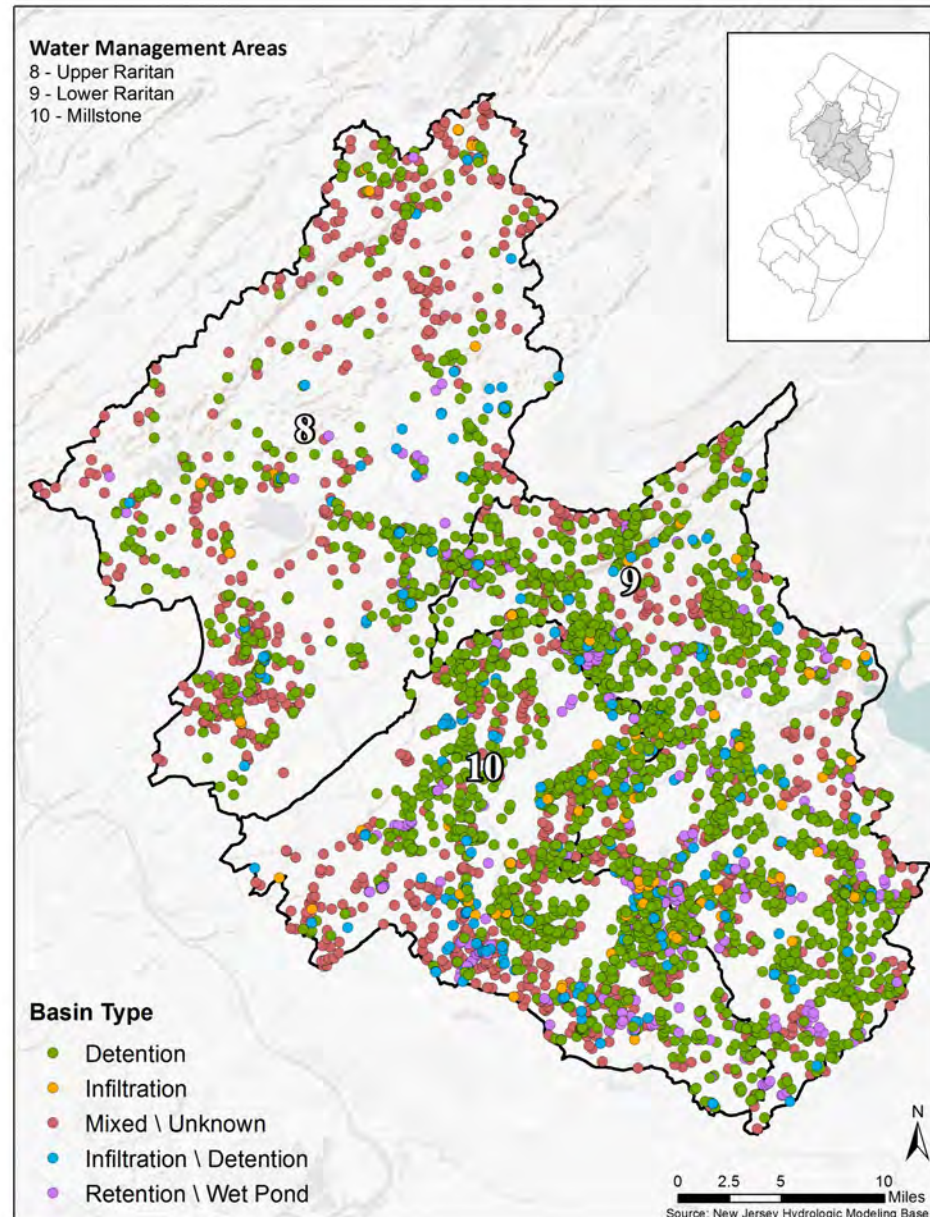
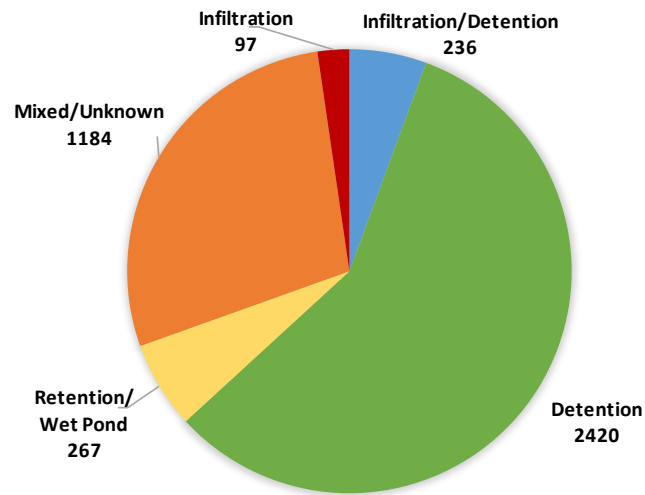
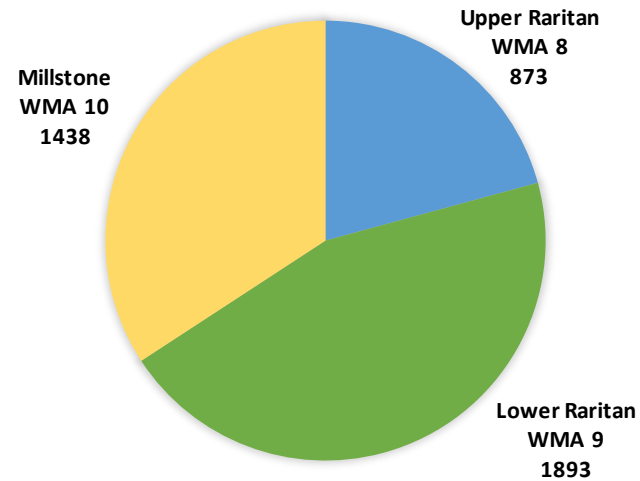


Figure 35. Map of stormwater management basins by type in the Raritan Basin



*Figure 36. Distribution of stormwater management basin types in the Raritan Basin*



*Figure 37. Distribution of stormwater management basins by WMA*

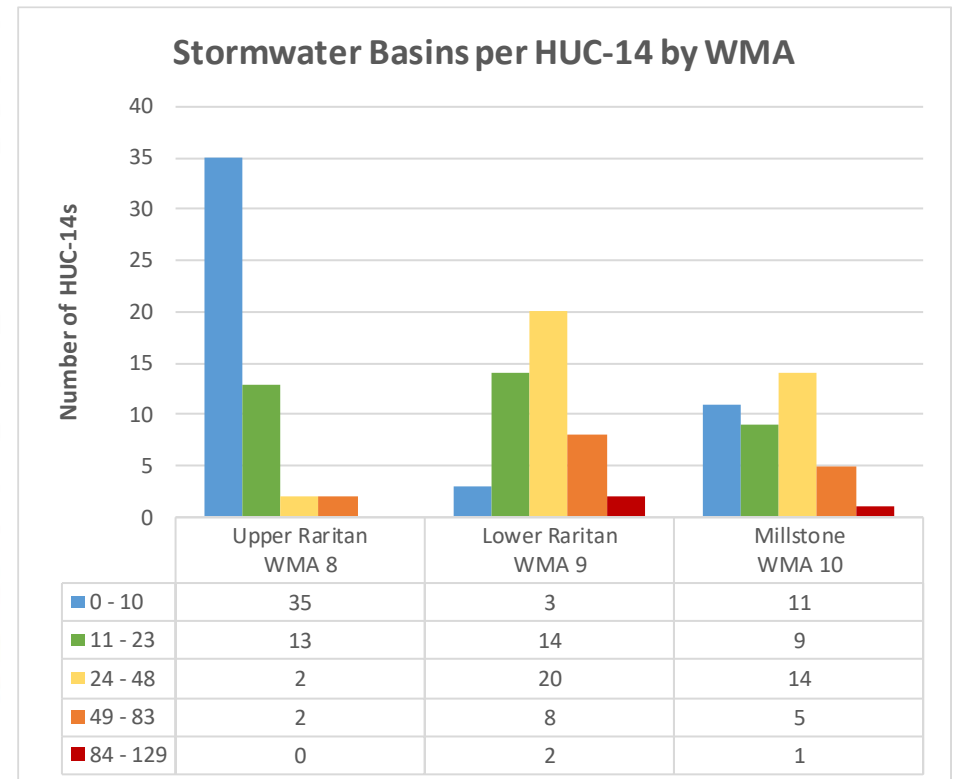
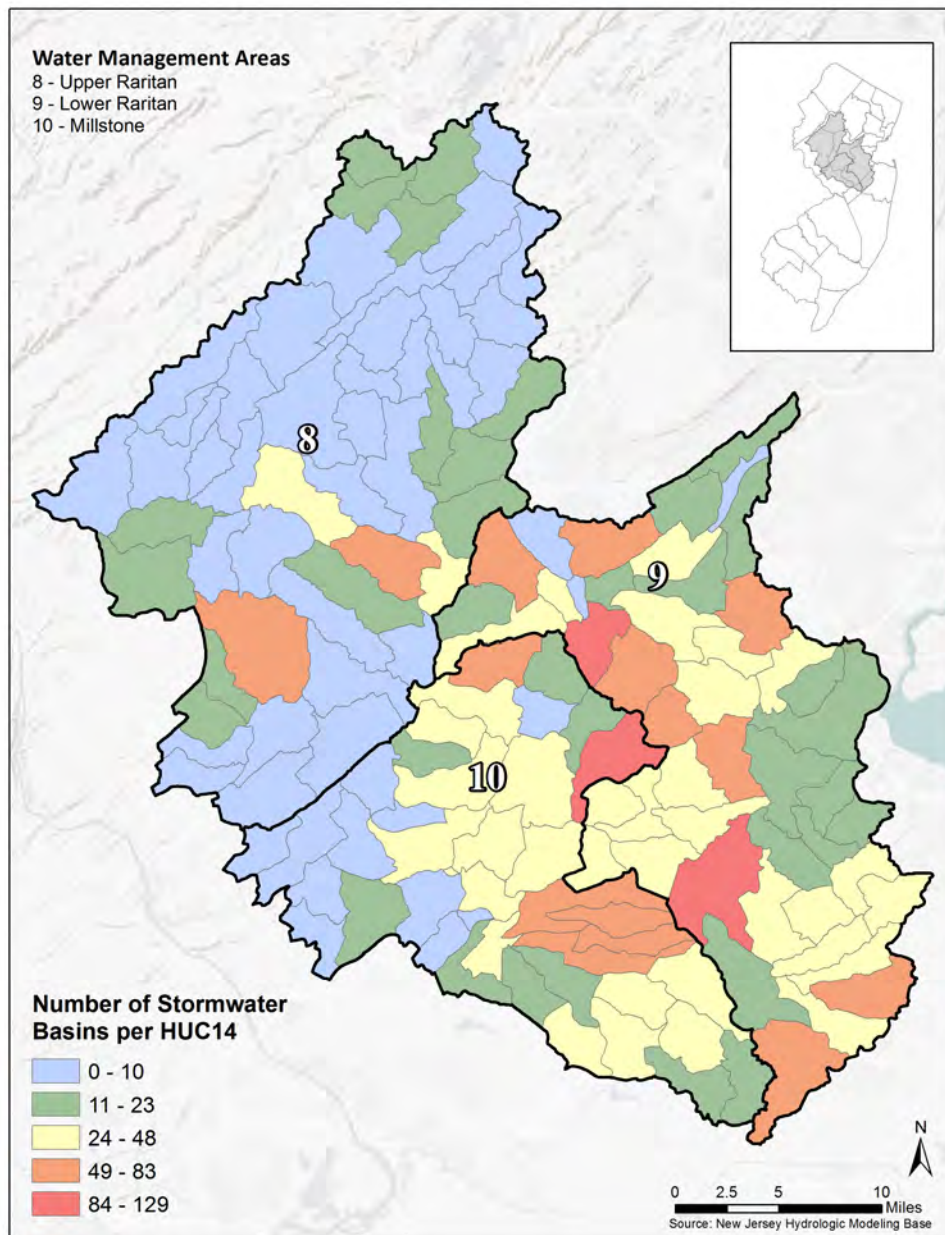
## Status

A majority (58%) of the mapped stormwater management basins in the Raritan River Basin are detention style basins (Figure 36). These, as well as retention basins, are generally not as effective in infiltrating water to the subsurface and recharging

groundwater as specifically designed infiltration basins. As might be expected, the more heavily urbanized Lower Raritan and Millstone WMAs have a greater number of SWM basins (1,893 and 1,438, respectively) as compared to the Upper Raritan WMA (873 basins) (Figure 37).

The spatial distribution of SWM basins do not necessarily correspond with the most intensively developed, highest population areas. These areas were often developed and built-out before stormwater management regulations were fully implemented. The HUC-14 sub-basins with the highest number of SWM basins are often those suburban areas outside of the





*Figure 39. Number of stormwater management basins by HUC-14 and by WMA*

*Figure 38. Map of number of stormwater management basins per HUC-14*

original urban core (Figure 38). Three HUC-14 subwatersheds contain between 84 and 129 stormwater basins each. One of these HUCs is in the Millstone and two are in the Lower Raritan (Figure 39). Fifteen HUC-14s contain between 49 and 83 stormwater basins each; 36 HUCs have between 24 and 48 of the structures. Slightly more than a third of

the HUC-14s in the Raritan basin contain 10 or fewer stormwater basins.

## Summary

There has been widespread appreciation that many stormwater management basins are not performing as they were originally designed (i.e., failing to properly recharge groundwater and reduce surface runoff) and not adequately protecting downstream water quality. Thus there is a recognized need to “retrofit” these basins (i.e. to reconstruct or otherwise physically alter the basin to enhance their water quality protection performance) or restore these basins (BBNEP 2000; Center for Watershed Protection 2010; Chesapeake Stormwater Network, 2009; Hunt et al. 2008; Maroon and Guo 2004; USEPA 2004b, 2007, 2008). By retrofitting basins, the focus is usually changed from solely retaining and delaying stormwater runoff, to enhancing infiltration of stormwater and nutrient (pollutant) removal.

Local non-governmental organizations have become engaged in the issue and are pushing municipal and county governments to improve stormwater management and retrofit or restore poorly performing basins. However, there is not a comprehensive inventory of “failing” basins. To do so would require extensive on-site evaluations for the hundreds of SWM basins in the watershed, though some prioritization at the HUC-14 level could be undertaken to streamline the process. Such an inventory should include use of the NJDEP’s free stormwater facility mapping application or equivalent technology that, at a minimum, has the same attributes as the Department’s application (see page 39 of the Draft Renewal of Master General Permit No. NJ0141852 (Category Code R9)) for Tier A Municipal Separate Storm Sewer Systems (NJDEP 2017), so the data may be uploaded and used by the Department. Information captured should include data on outfall pipes, stormwater management basins, subsurface infiltration/detention systems,

manufactured treatment devices, green infrastructure, and storm drain inlets. Photographs and inspection notes, such as facility condition, maintenance activity, date(s) of inspection, and evidence of flooding should be recorded. The existing New Jersey Hydrologic Modeling Database or NJDEP’s MS4 permit platform ([https://www.nj.gov/dep/dwq/msrp\\_map\\_aid.htm](https://www.nj.gov/dep/dwq/msrp_map_aid.htm)) provides potential platforms that could be built on to house and make the data widely available. However, as the experience in the Barnegat Bay Watershed Management Area reveals (Barnegat Bay Partnership 2018), retrofitting SWM basins on a large scale is an expensive undertaking with associated costs varying widely depending on the type of retrofit and size of the basin.

## Take-Away—SWMS—Stormwater Basins

Stormwater management (SWM) basins are meant to protect downstream areas from flooding and erosion by capturing and then slowly releasing rainwater and melting snows. Nearly 65% of basins in the Raritan are detention or retention style basins that are generally not as effective in recharging groundwater as infiltration basins (that make up about 6% of SWM basins in the Raritan). Many SWM basins do not perform as originally designed and require retrofits. There is, however, no comprehensive inventory of basin conditions to aid in retrofitting failing basins. The NJDEP’s free stormwater facility mapping application, equivalent technology, or the NJ Hydrologic Modeling Database could be built on to house and make data widely available.

## Key Indicator

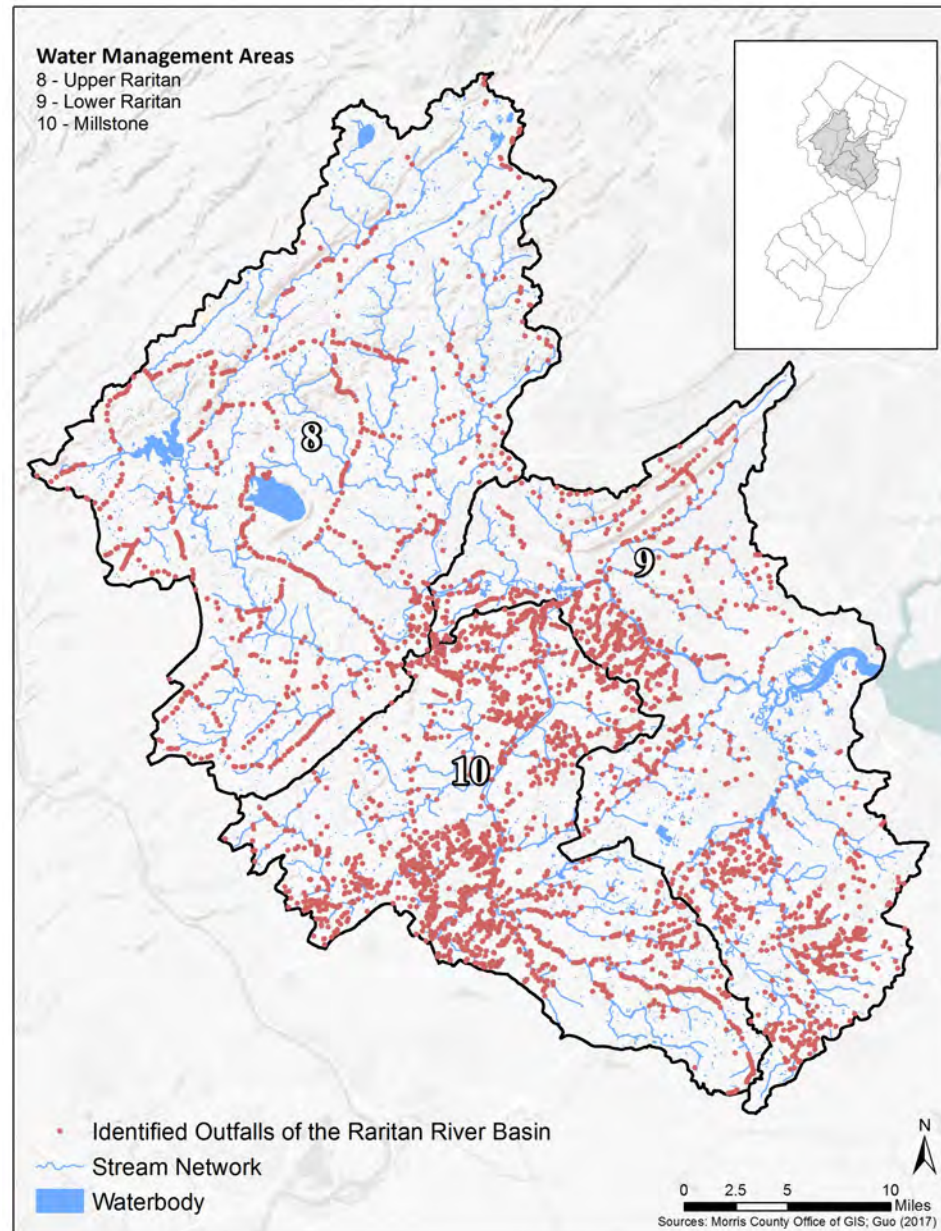
# SWMS—Outfalls

## Background

Much of the older urban development in the Raritan Basin was not designed to route runoff through stormwater management basins. Instead, the stormwater drainage systems collect runoff from dwelling roofs, yards, driveways and streets (i.e., on-street storm sewer grates) and discharge it directly into the nearest stream (i.e., at an outfall) with no treatment. River stretches with a high frequency of outfalls often suffer water quality degradation as well as streambed/bank scouring, especially during or after high flow events.

## Methodology

The literature describes outfalls as the location where stormwater leaves the site and enters the receiving stream. Unfortunately, data on outfall locations has not been compiled and mapped in a consistent fashion across the entire Raritan Basin but is only available for selected locations. Available data on outfall locations were gathered from the report titled, “Inventory of Water-Related Infrastructure in Raritan River Basin” (Sukkar and Guo 2017), which included outfall data from the Watershed Institute (formerly Stony Brook-Millstone Watershed Association), Somerset County Engineering Department and the Manville



*Figure 40. Map of reported outfall locations in the Raritan Basin*



Public Works. Additional data was obtained from the Morris County Office of GIS website.

## Status

Due to the incomplete nature of the available data on outfall locations, the resulting map (Figure 40) is skewed towards those areas that have more complete surveys. For example, nearly half (over 48%) of the mapped outfalls are located in the Millstone Basin. We suggest that this statistic may be an artefact of incomplete data for the other WMAs.

## Summary

Outfalls should be retrofitted with BMPs that promote infiltration to the greatest extent practical, but where space limitations occur, upstream pre-treatment strategies such as green stormwater infrastructure BMPs should be utilized. Drainage areas with direct discharge outfalls should be determined and those having the largest drainage areas should be prioritized

for the installation of BMPs. Such a prioritization effort will require that a consistent survey and mapping of outfall locations be undertaken across the entire Raritan Basin. As with SWMS basins, the NJDEP's mapping and inventory tools provide a potential platform to work from ([https://www.nj.gov/dep/dwq/msrp\\_map\\_aid.htm](https://www.nj.gov/dep/dwq/msrp_map_aid.htm)).

Many of the smaller infiltration type BMPs such as rain barrels, rain gardens and pervious pavement can be implemented in areas with larger amounts of impervious cover, such as high-density residential areas, commercial shopping centers and industrial complexes. Watershed protection and restoration plans developed for a number of other New Jersey watersheds provide good examples of appropriate BMPs such as for the Metedeconk River WMA (CDM Smith 2013).

## Take-Away—SWMS—Outfalls

Much of the older urban development in the Raritan region collects stormwater runoff from dwelling roofs, yards, driveways and streets and discharges it through outfalls directly into the nearest stream with no treatment. River stretches with high frequencies of outfalls can suffer water quality degradation as well as streambed/bank scouring, especially during or after high flow events. There is no comprehensive inventory of outfalls in the Raritan region and mapped data skewed results to those areas having more complete surveys. Drainage areas with direct discharge outfalls should be prioritized for installation of BMPs that promote infiltration. Such an effort will require a consistent survey and mapping of outfall locations across the entire Raritan basin.

## Key Indicator

# SWMS—Culverts

## Background

Culverts, constructed of concrete, brick/clay, iron, corrugated steel and corrugated aluminum, are commonly used to enable stream crossings for roadways. If not properly positioned, sized and maintained, they can impede fish passage, restrict stream flows, increase stream velocity, become clogged with debris and sediment, increase the likelihood of contaminated road runoff entering waterways, and generally disrupt the connectivity of rivers and streams. Of particular concern are culverts that are too small to carry peak flows and those that are located above the natural stream bed (perched) in fish-bearing streams. The former can cause flooding and bank erosion while the latter can scour stream beds; both may impede fish passage.

The NJDOT maintains a database of state-owned culverts with openings greater than five feet and less than 20 feet (openings greater than 20 feet are categorized as bridges) and inspects them on a four-year cycle. While there is no state or federal requirement for statewide inspection of county or municipal culverts, in 2007, the NJDOT announced it would fund local inspections and would develop a culvert inventory system that included municipal and county culverts (NJDOT 2007).

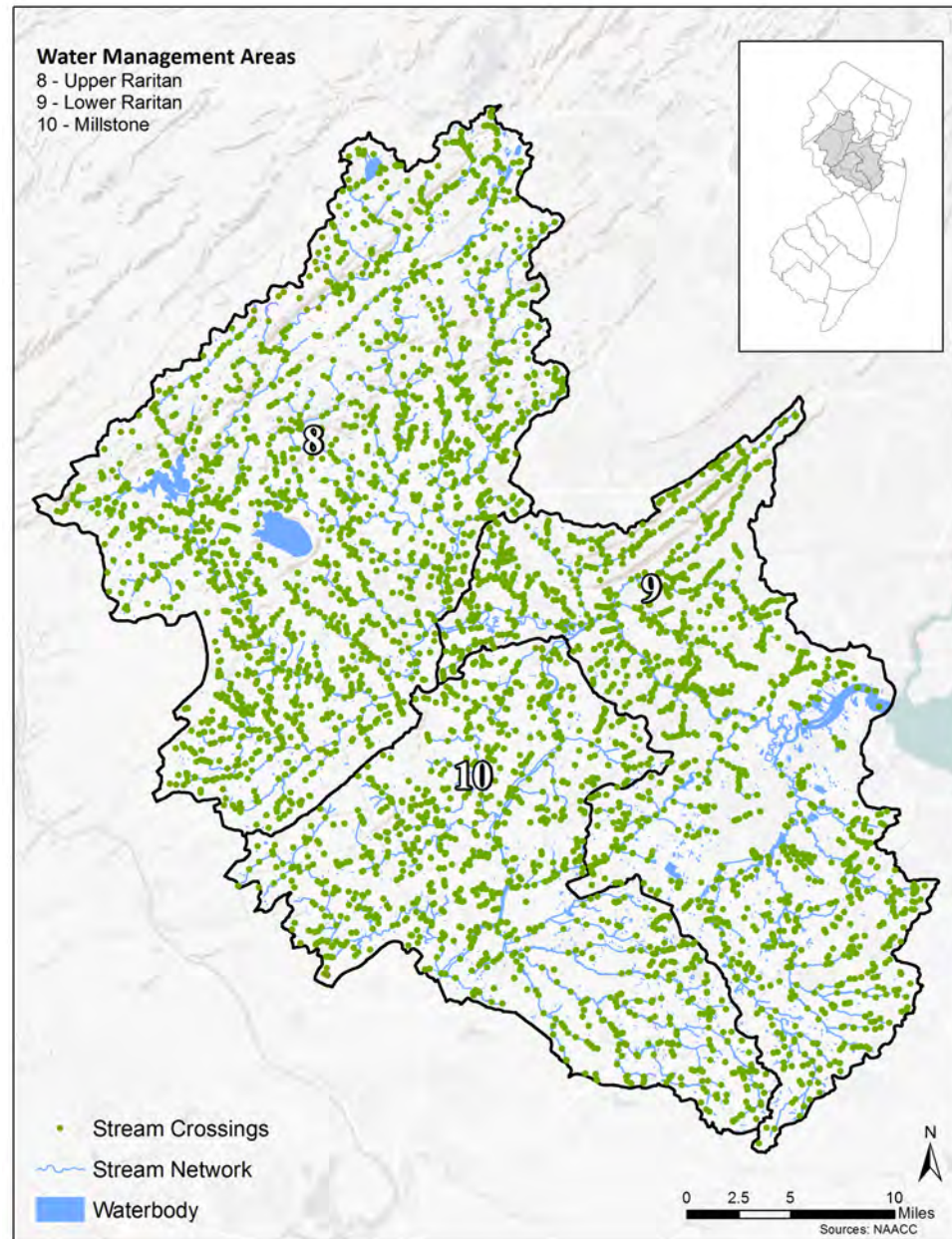
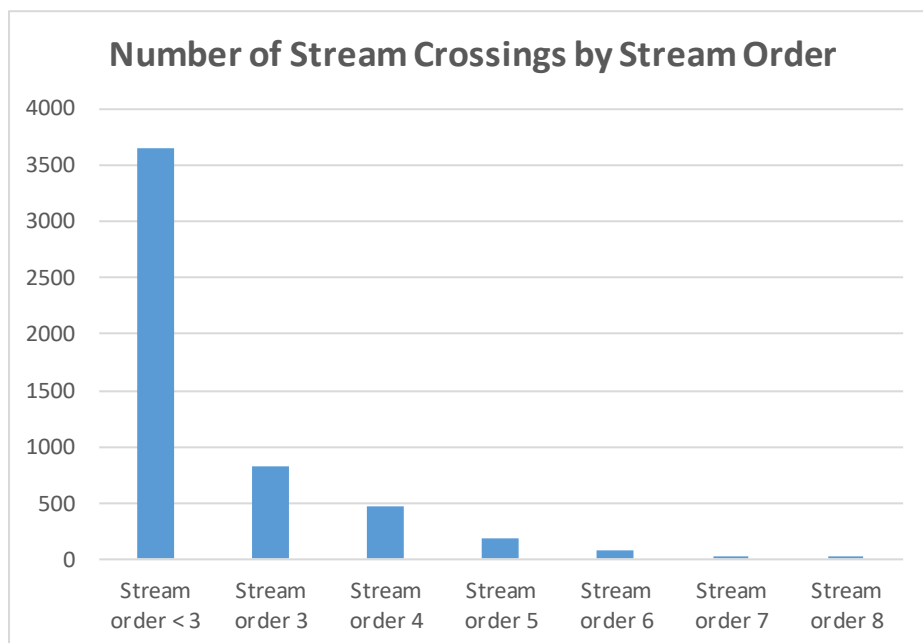


Figure 41. Map of stream crossings by stream order in the Raritan Basin



## Methodology

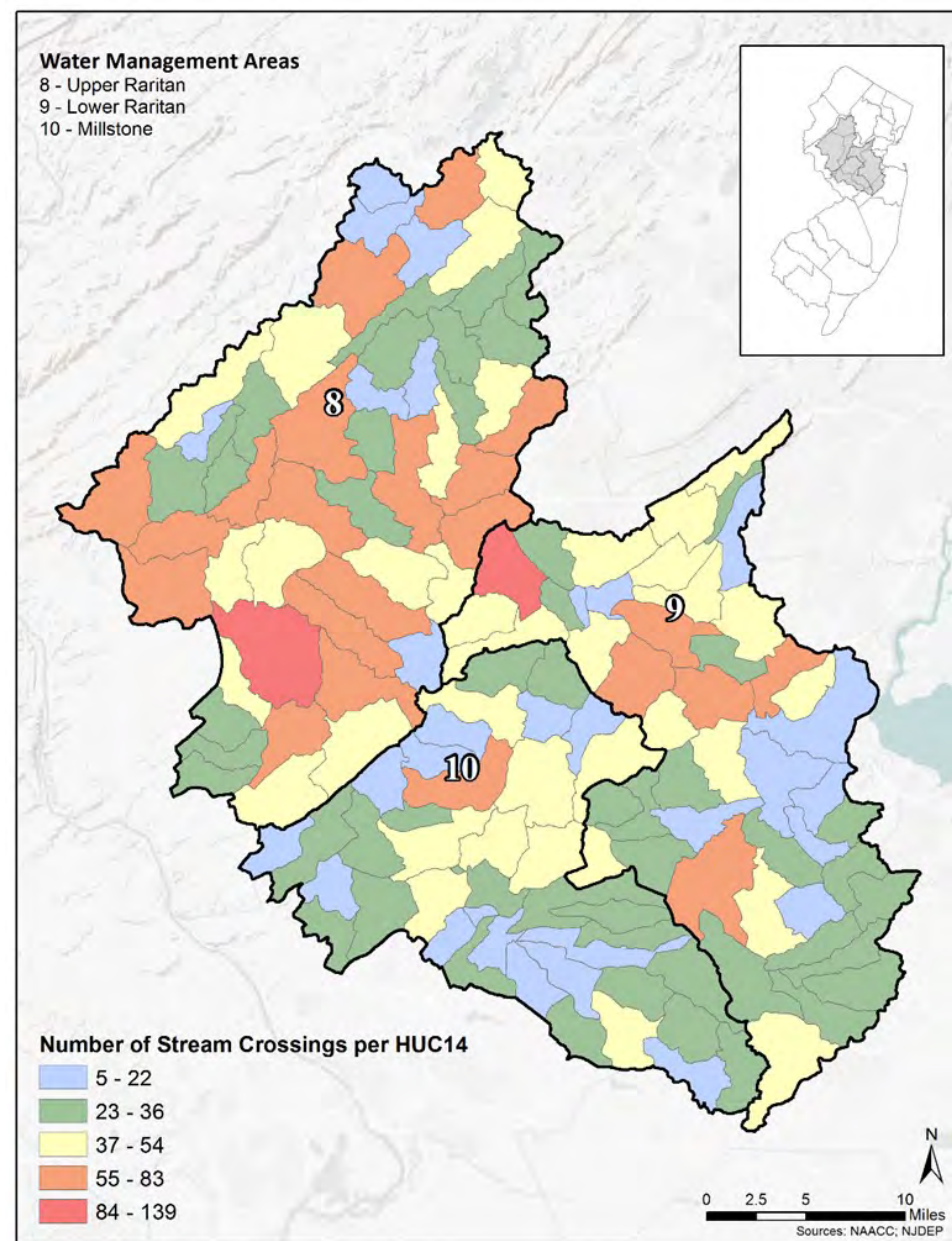
Mapping data was derived from the North Atlantic Aquatic Connectivity Collaborative Stream Continuity Database (NAACC 2018).

The breakdown of culverts by stream order (referred to as stream crossings) were assigned to only larger volume streams (i.e., Stream Order 3-8).

## Status

Raritan rivers and streams are impacted by 5,247 culverts or stream crossings with the majority of those (nearly 70%) crossing first and second order streams (Figure 41). Figure 42 shows the number of crossings

*Figure 42. Number of stream crossings by Stream Order in the Raritan Basin*



*Figure 43. Map of number of stream crossings per HUC-14 in the Raritan Basin*



for each order of stream in the basin.\*

The Upper Raritan has 2,280 crossings, the Lower Raritan has 1,812 and the Millstone has 1,155 stream crossings. The highest number of stream crossings per HUC-14 is in the Upper Raritan with one HUC containing 139 stream crossings while almost a third of the HUCs contain between 55 and 83 stream crossings (Figures 43 and 44). Comparatively, the Millstone has only one HUC with 65 stream crossings while the majority of HUCs (77%) have fewer than 37 stream crossings. In the Lower Raritan, one HUC contains 120 crossings, but the majority of HUCs in the subbasin (68%) has between 23 and 54 stream crossings.

### Summary

Regular inspection and maintenance of culverts can enhance stream quality and minimize impacts on associated species. Culverts that are not aligned with natural stream channels, are undersized, frequently clog, or create waterfalls should be identified and upgraded.

*\*Strahler stream orders indicate the level of branching in a river system. The numbering begins at the top of the watershed as first order streams and increase by a whole number as same order streams join them. First, second and third order streams are considered headwater streams. In this analysis, the main-stem of the Raritan is an eighth order stream.*

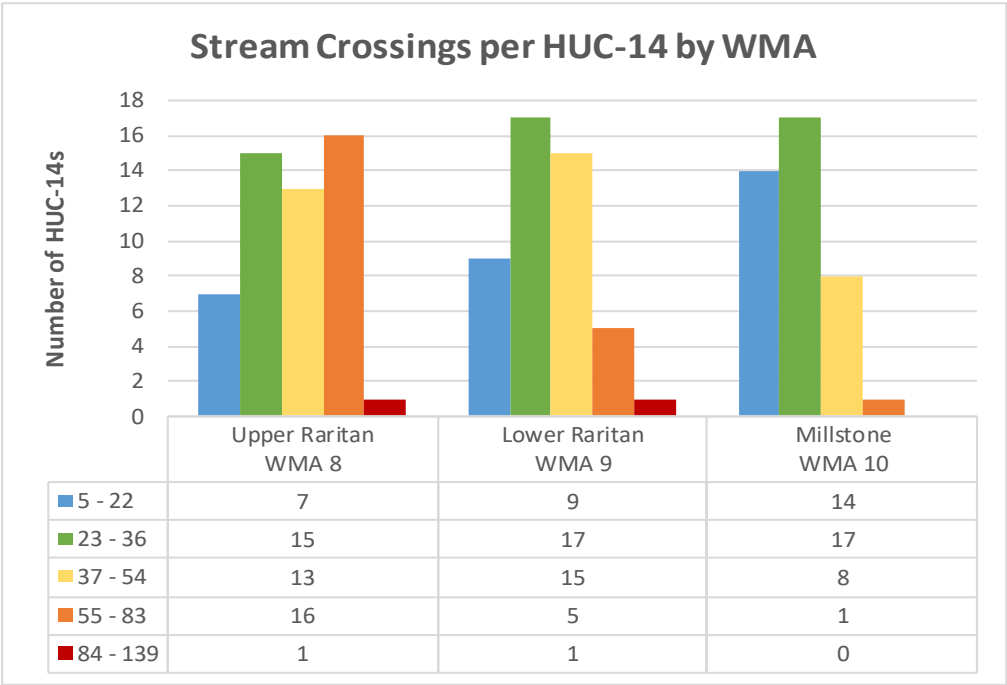


Figure 44. Number of stream crossings by HUC-14 and by WMA

### Take-Away—SWMS—Culverts

Culverts are commonly used to enable stream crossing for roadways. If not properly positioned, sized, or maintained, they can impede fish passage, alter stream flow characteristics, and negatively impact water quality. Raritan rivers and streams are impacted by 5,247 culverts or stream crossings with nearly 70% of those crossing First or Second Order headwater streams. Regular inspection and maintenance of culverts can enhance stream quality and minimize impacts on associated species. The NJDOT inspects state-owned culverts with openings between 5 to 20 feet on a four-year cycle. There is no requirement for inspection of smaller state-owned culverts or of county or municipal-owned culverts.

## Key Indicator

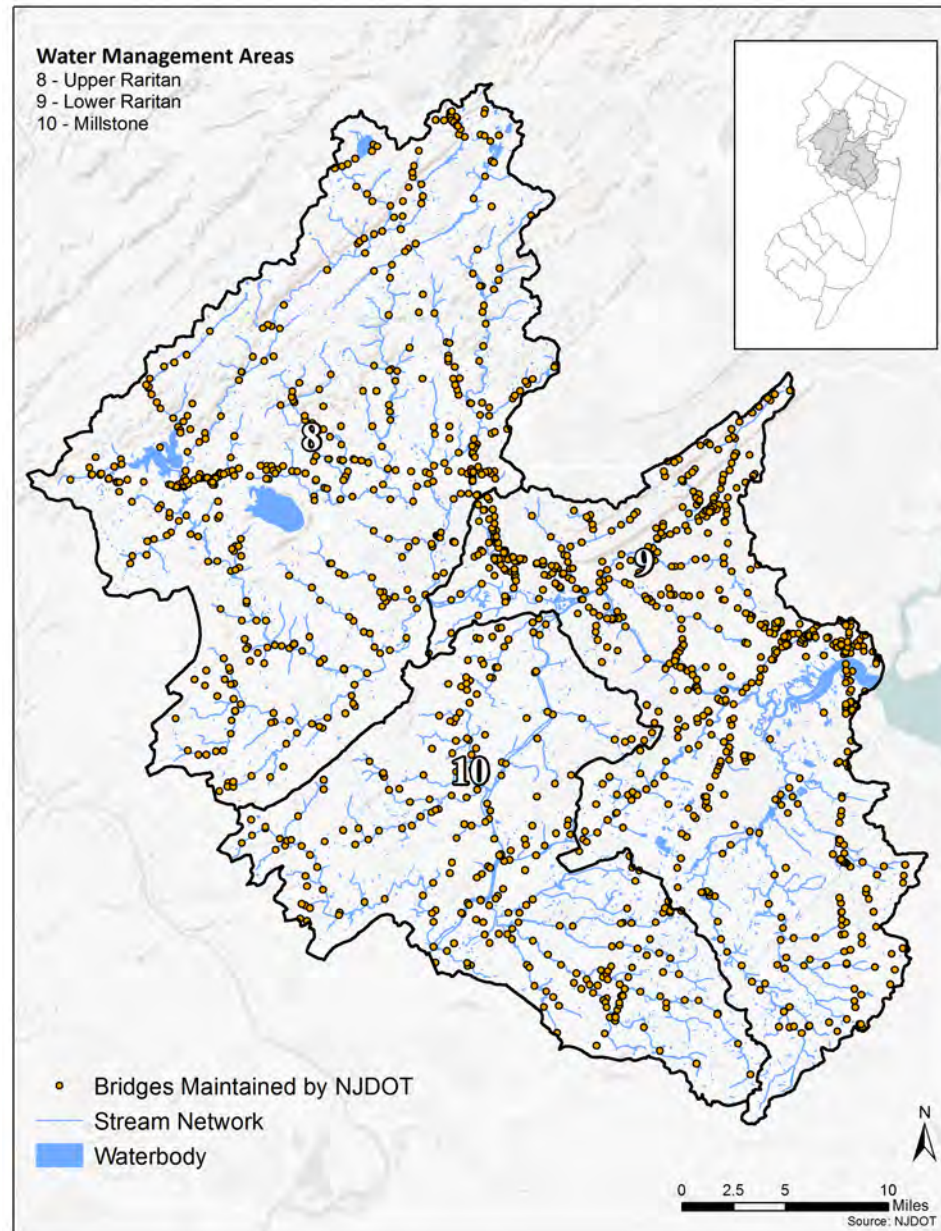
# Bridges

### Background

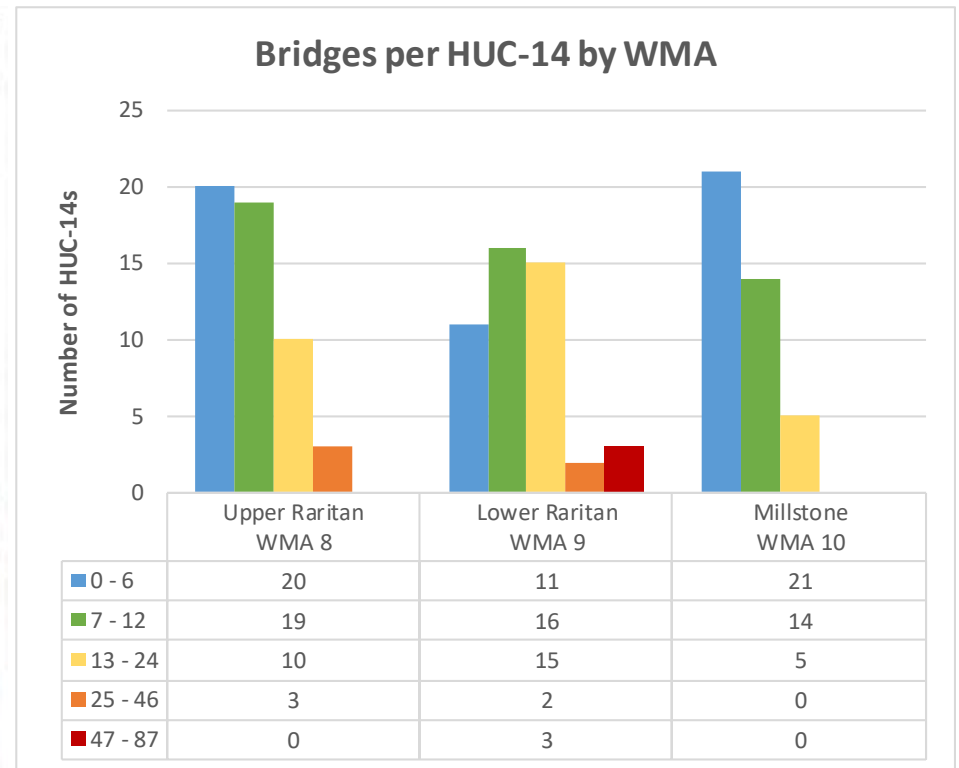
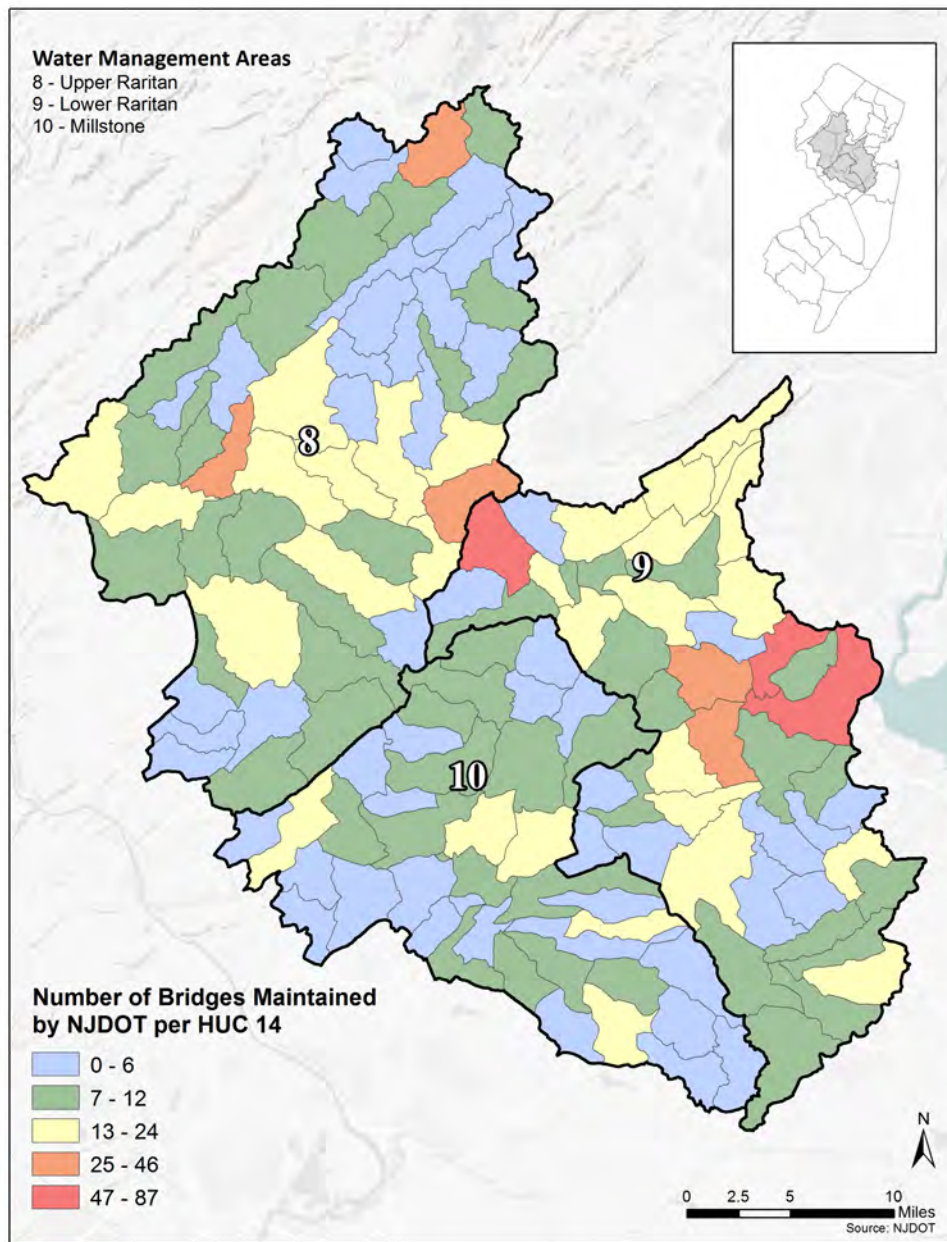
Bridges can impact quality of life on the Raritan in a number of ways. They may be a direct source of potentially contaminated runoff, bridge structures may impede boat travel along the river, or the structures may capture debris during high flows and exacerbate local flooding.

Many bridge surfaces drain directly to water bodies they cross. Potential contaminants associated with runoff include nutrients, solids/particulates, pesticides, trace metals, road salt/brine, polycyclic aromatic hydrocarbons (PAHs), oil and gas, and garbage tossed from passing vehicles. Excess nutrients cause eutrophication; metals and salts and associated increased chloride concentrations are toxic to aquatic vegetation and wildlife – especially young fish (NJDEP, n.d.; TRB 2002; USGS, n.d.). PAHs are also a concern for toxicity (USGS 2018). While runoff from bridges over sections of the river with deeper flows may be diluted enough to not cause measurable damage to local species, runoff to smaller streams may have significant impacts.

Numerous bridge structures in the Raritan and its tributaries capture floating debris. The debris can be caught up in the support structure and can alter flow



*Figure 45. Map of location of bridges maintained by NJDOT in the Raritan Basin*



*Figure 47. Number of bridges maintained by NJDOT by HUC-14 and by WMA*

patterns potentially causing scour that mobilizes sediment around and downstream of the bridge piers and abutments (Martinez-Martinez et al. 2017). The accumulated debris can also essentially dam the river or stream, exacerbating local flooding during high flow events.

A main impediment to boat navigation from the mouth to the tidal reach of the Raritan is the Raritan River

*Figure 46. Map of number of bridges maintained by NJDOT per HUC-14 in the Raritan Basin*



swing bridge that carries New Jersey Transit's North Jersey Coast Line trains between the Amboys. The existing bridge has a low clearance of only eight feet above mean high water for boats to pass under the closed structure and the bridge has limited opening times that can slow boat traffic. A new bridge has been proposed (the FONSI was issued by the Federal Transportation Authority in October 2017) (NJ Transit, n.d.) that would increase the mean high water clearance for boats to pass under the structure by another ten feet (also see related details in the Public Boat Launches section of this report).

## Methodology

Bridge data is from the "Inventory of Water-Related Infrastructure in Raritan River Basin" (Sukkar and Guo 2017). Shapefiles for the report were obtained from the NJ Department of Transportation (NJDOT). Bridge locations were displayed as points.

It should be noted that bridges maintained by other counties, by municipalities, or under private maintenance are not included in this analysis.

## Status

The data collected showed 1,526 bridges in the Raritan Basin (Figure 29). The Upper Raritan has 518 bridges, the Lower Raritan has 722 bridges and the Millstone watershed has 286 bridges.

Figures 46 and 47 summarize bridges maintained by the NJDOT by HUC-14. Those HUCs with higher numbers of bridges would likely have more impacts associated with bridges—though lower order streams may be more susceptible to impacts than higher order streams. In the Upper Raritan, 25% of the HUCs contain more than 12 bridges. In the Lower Raritan, 43% of the HUCs contain more than 12 bridges with three of those containing more than 46 bridges. In the Millstone, 12.5% of the HUCs have more than 12 bridges.

## Summary

Data presented is only for bridges maintained by NJDOT and may not include bridges maintained by other entities. A complete inventory of bridges in the

region would ensure a better sense of water quality impacts. Annual campaigns on minimizing salt usage and working with municipalities and counties to use alternate treatments can help mitigate the adverse impacts of road salt.

Frequent inspections and maintenance of bridges identified as accumulating debris would reduce the probability of debris associated scour or debris dams exacerbating flooding.

## Take-Away—Bridges

Bridges can be a direct source of potentially contaminated runoff, bridge structures may impede boat travel along the river, or the structures may capture debris during high flows and exacerbate local flooding. There are 1,526 NJDOT-maintained bridges in the Raritan Basin. A complete inventory of bridges, including bridges maintained by counties, municipalities, or private entities that were not included in this analysis, would ensure a better sense of potential water quality impacts. Campaigns to minimize salt usage and frequent bridge inspections to address accumulated debris can help mitigate associated negative impacts.

## Key Indicator

# Dams

## Background

With its history of industry and farming, dams were built on the Raritan and its tributaries since the 1600s to supply water for private and municipal use, for agriculture, hydropower, water supply (canal), navigation (canal), fire suppression, to power mills, and for recreation including fishing, boating, and swimming. While some dams continue to serve specific purposes including water supply or flood control, many dams have outlived their useful lives and contribute to degradation of water quality and habitat. Depending on their construction and condition, dams can impede movement of resident and migratory fish and other aquatic organisms, restrict access to habitats, divide populations, and cause further decline of native populations (Craig et al. 2012). As noted by Craig, Goll and Shaw, “By converting a free-flowing river to an impounded one, dams dramatically alter the species composition of the aquatic community and lead to elevated water temperatures. They also interrupt sediment transport, which often causes geomorphic impacts downstream (i.e., incision, widening) and deprives instream habitat features of necessary sediment supply. Furthermore, sediment impounded behind a dam can create additional maintenance responsibilities (i.e., sediment dredging and lake management) and many affect flooding in adjacent

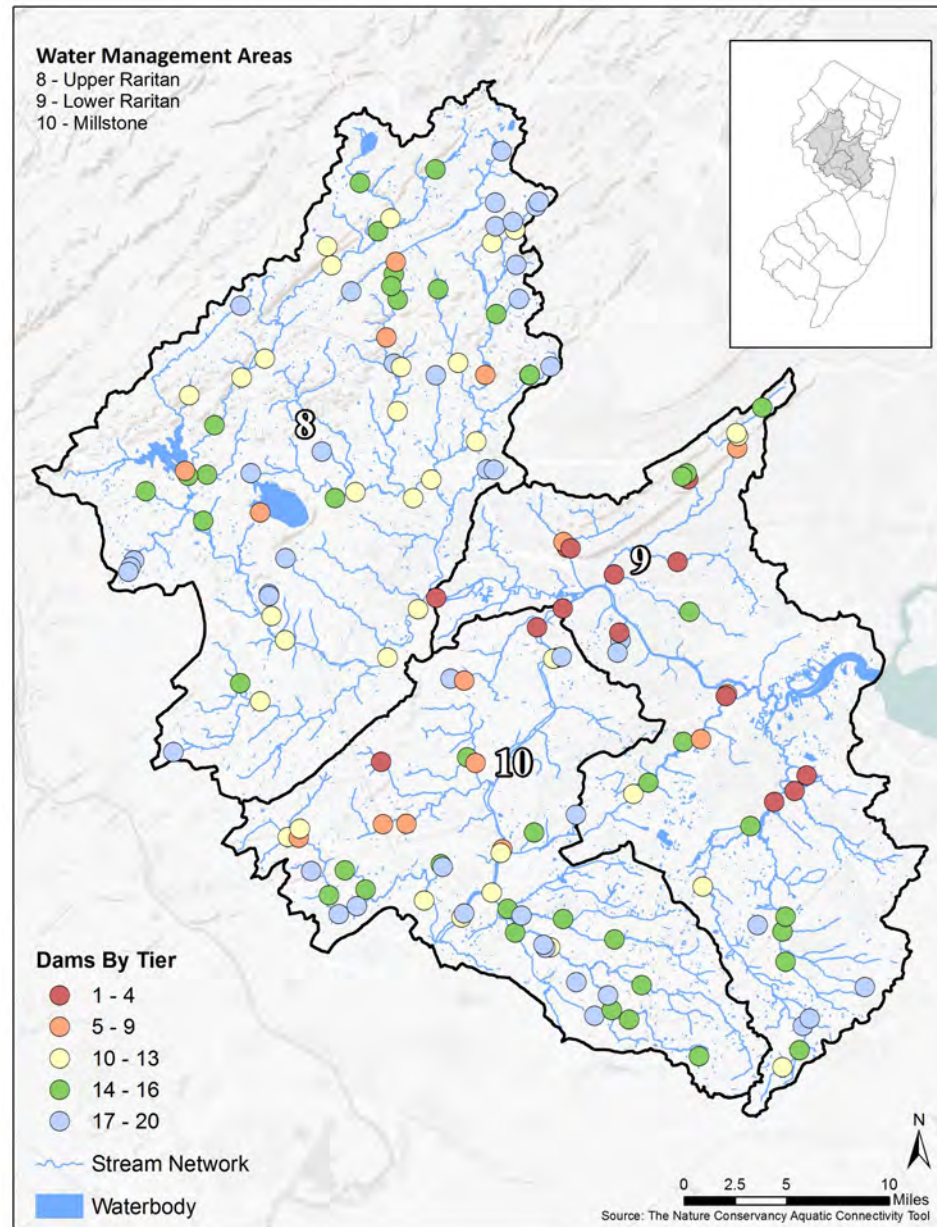


Figure 48. Map of location of dams by tier in the Raritan Basin

residential area. Human communities are also directly affected by aging, obsolete dams [that] pose a drowning hazard, exacerbate upstream flooding, and are at risk of failure.”

## Methodology

Data was obtained from the Freshwater Network’s Northeast Aquatic Connectivity (NAC) project (<http://maps.freshwaternetwork.org/northeast/#>), a tool that analyses numerous metrics about dams to aid in removal decisions. Metrics include upstream functional network (i.e., the miles of streams between the dam and the next upstream obstruction), passability (ability of fish to get around the dam or obstruction), and the number of anadromous fish found below the dam. Two of the metrics available through the tool were utilized in our analysis: the built-in tier or rank for each dam and the miles upstream of the dam to the next obstruction (i.e., another dam, an outfall, or a waterfall that restricts fish passage). The tier designation ranks dams by upstream functional network, passability for fish, and the number of anadromous fish found below the dam (among other things). Tiers with lower numbers (e.g., 1 through 4) have the most potential to be gained from a passage restoration project. Removal of that dam may open more miles of stream to fish migration, may significantly improve water quality in the area, and may address improvements to other amenities such as recreation and safety. Dams with higher tier numbers (e.g., 16 to 20) would offer fewer benefits from

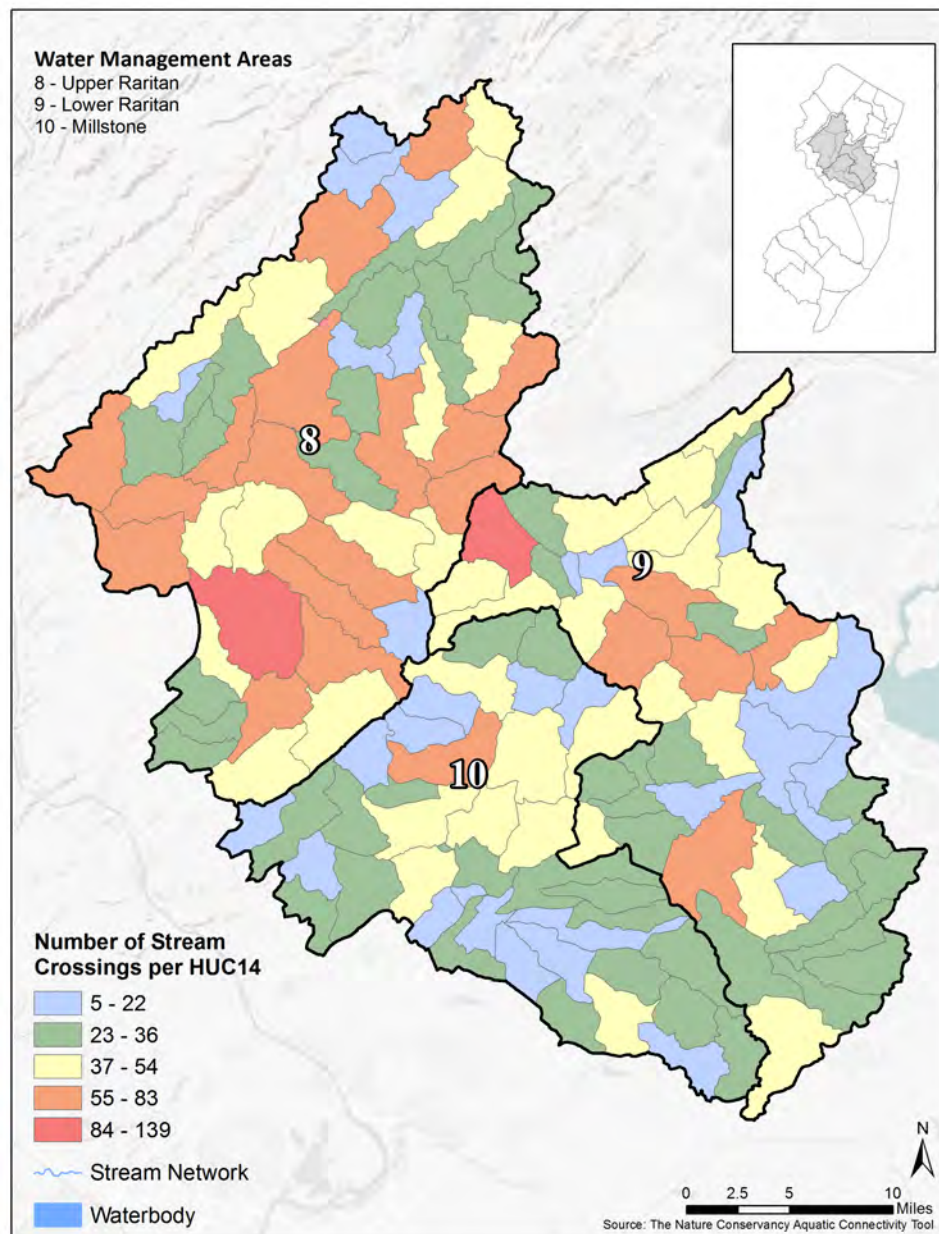


Figure 49. Map of number of dams per HUC-14 in the Raritan Basin



removal.

The NAC tool only captures dams of 5’ or more elevation and this analysis is limited to those structures.

Status

According to the American Rivers Dam Removal Database (American Rivers 2017), since 1985, all or part of seven Raritan Basin dams have been removed. These are: Pottersville Dam (1985) in Califon on the Cold Brook that drains to the Upper Raritan; Fieldsville Dam (1990) in Somerset on the Raritan; Calco Diffusion Weir Dam (2011) in Bridgewater Township on the Raritan River; Sylvan Lake Dam (2012) in Skillman on the Rock Brook that drains to the Millstone; Roberts Street Dam (2012) in Bridgewater on the Raritan River; Nevius Street Dam (2013) in Raritan Borough on the Raritan River; and, the Weston Mill Dam (2017) in Manville on the Millstone River.

Of the nearly 1,700 dams in the state (that are over 5’ or higher), 149 dams restrict natural flows in the Raritan Basin (Figures 48). Sixty-six dams are in the Upper Raritan watershed where dams influenced flows in 73% of the HUC-14s. The Lower Raritan has 38 dams impacting 47% of its HUC-14s. And there are 45 dams in the Millstone that impede flows in 58% of its HUC-14s. (Figure 49 and 50).

Of the 149 dams reviewed, 14 are tier 4 or lower ranked, indicating there could be significant benefits gleaned from removing them. Twelve of those are in

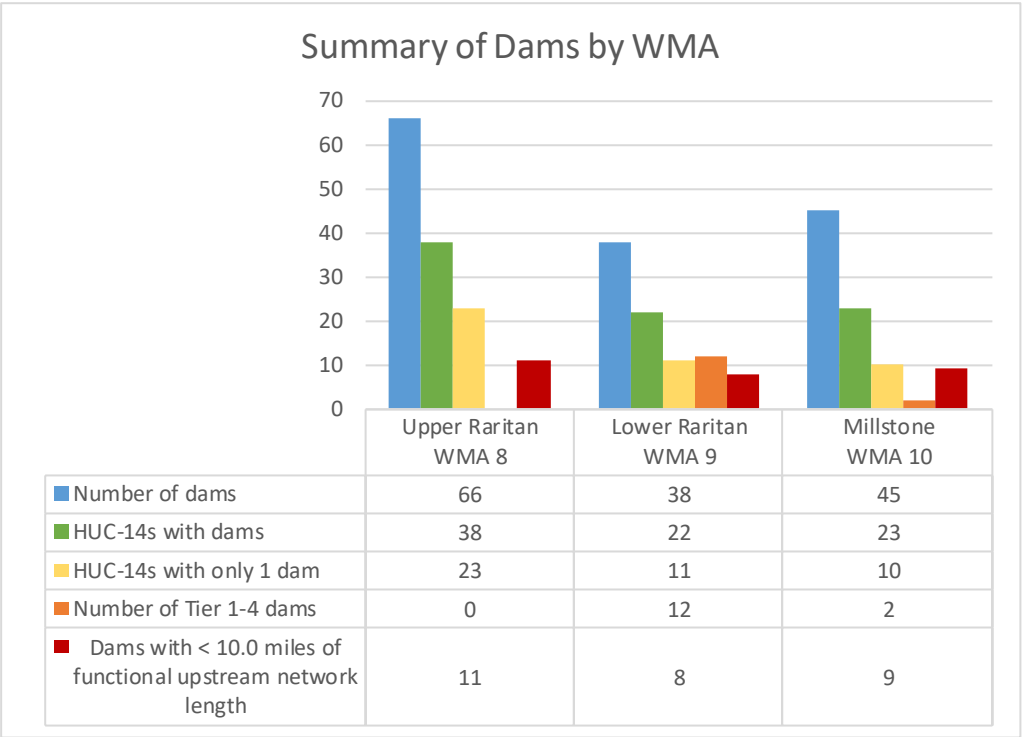


Figure 50. Summary of dams by WMA

the Lower Raritan and two are in the Millstone watershed.

Figures 51, 52 and 53 show the dams and HUC-14s relative to the functional upstream network length. This is a measure of the number of miles between the downstream dam/obstruction and the next upstream

dam/obstruction.

Dam removal is complex and resource intensive. Further analysis would be required to determine the feasibility of removing any dam in the region, but tools such as the Northeast Aquatic Connectivity project tool can help inform the process.

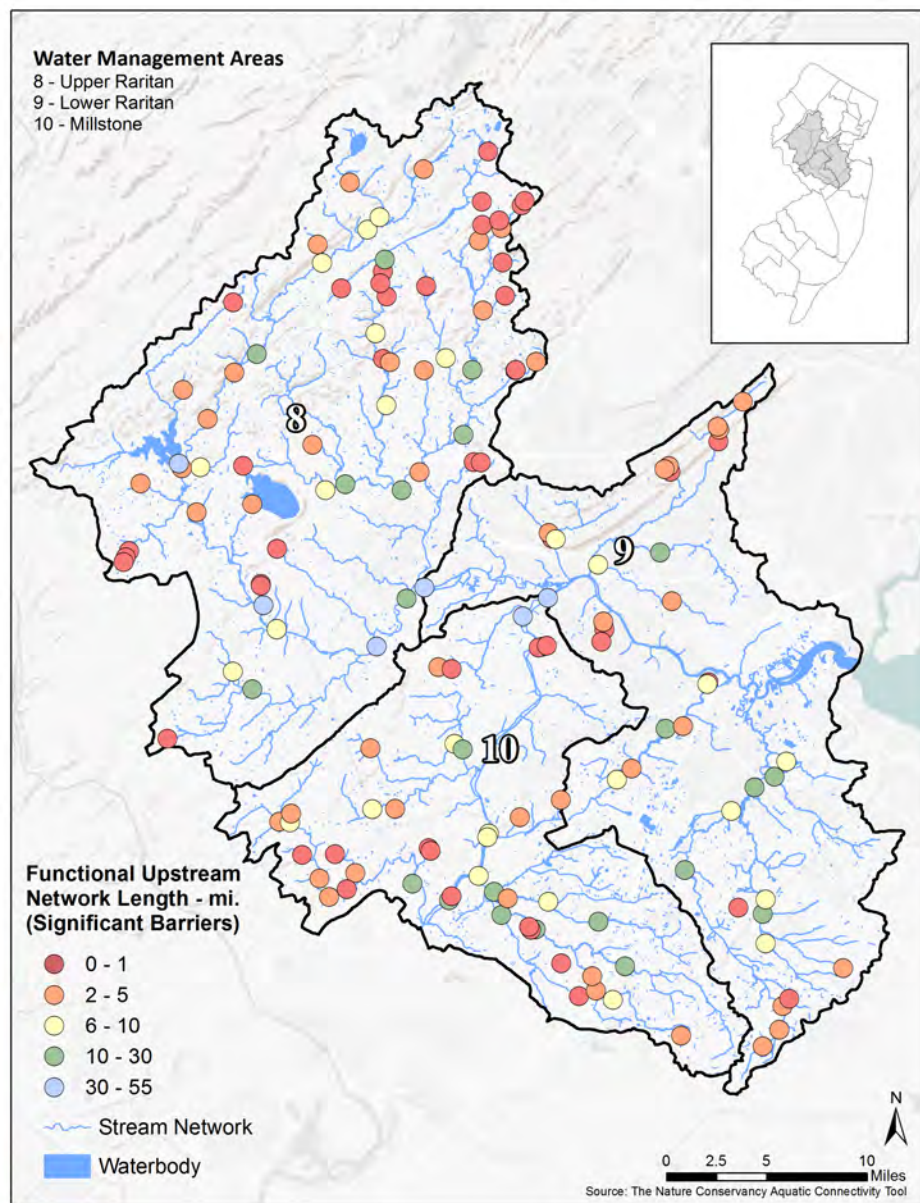


Figure 51. Map of functional upstream network length (for tier 1 to 20 dams) in the Raritan

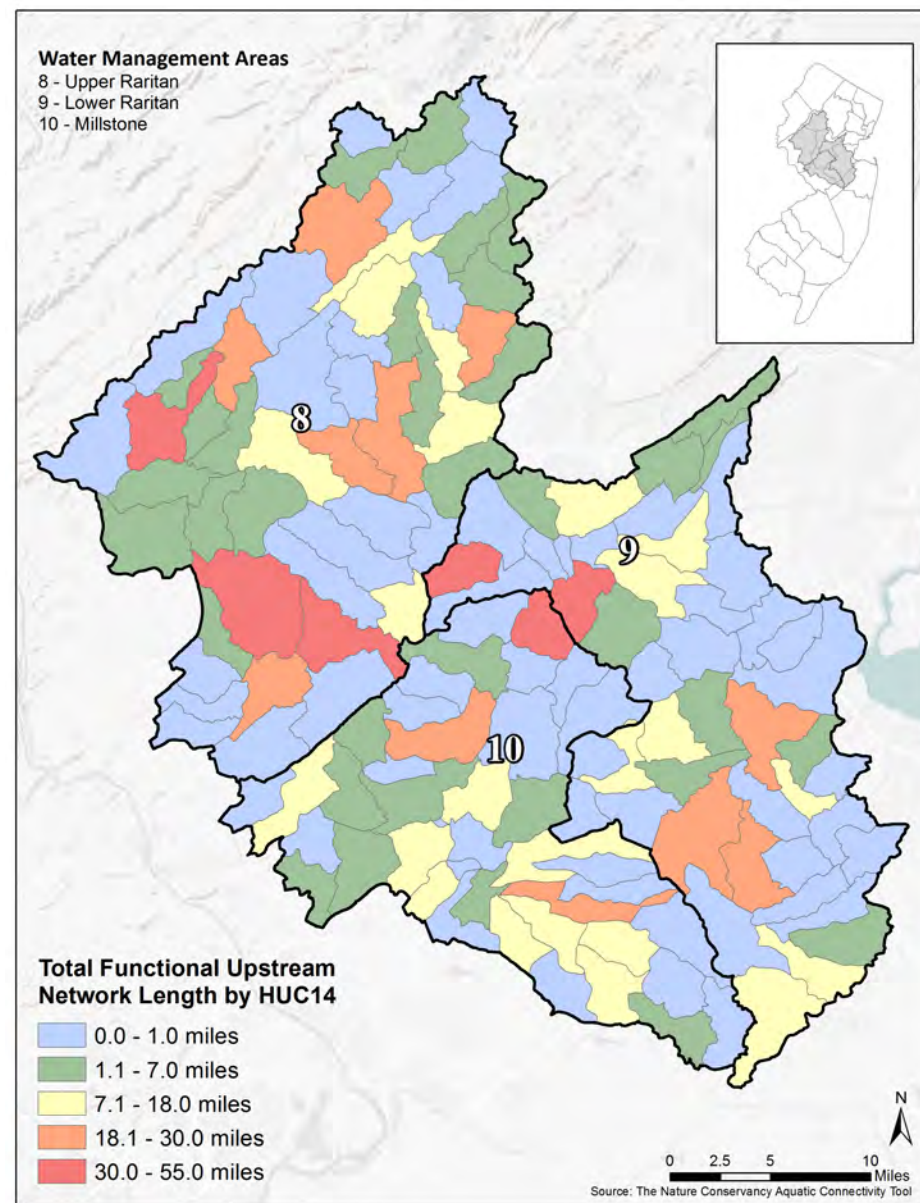
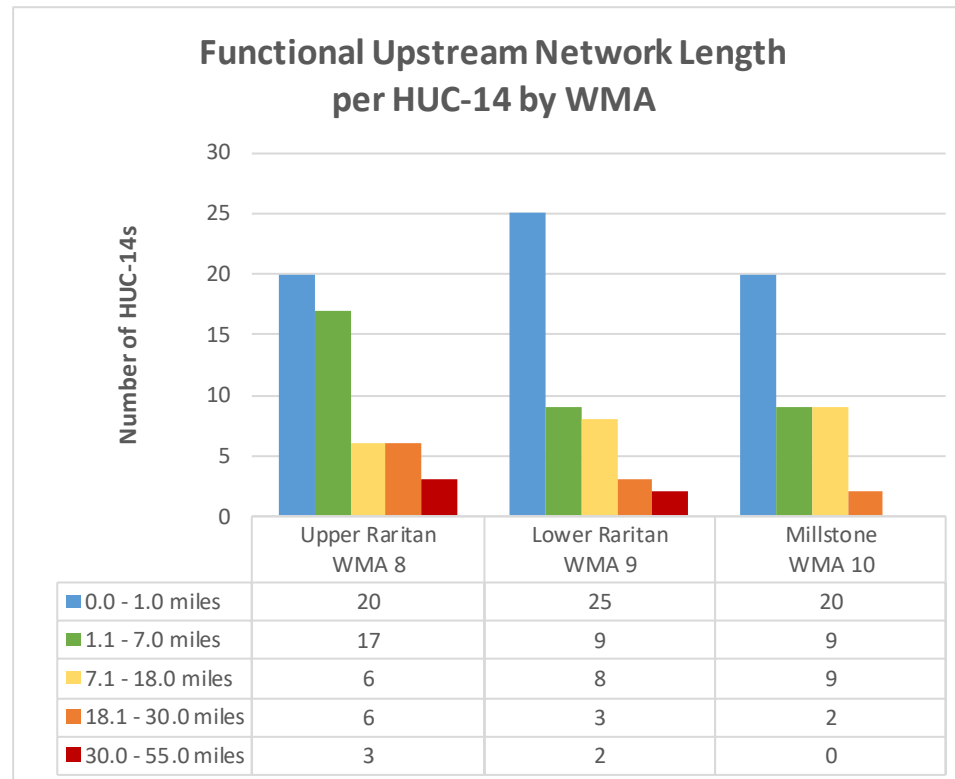


Figure 52. Map of total functional upstream network length by HUC-14 in the Raritan Basin

## Summary

The state has convened a collaborative partnership to identify and prioritize dams for removal in the state. The partnership includes federal, state, regional and non-profit members including representatives from the Raritan Basin and Rutgers. We recommend continued collaboration with the NJ Statewide Dam Removal Partnership ([njdams.org](http://njdams.org)), but also recommend conducting parallel prioritization work within the Raritan Basin as it is likely that statewide priorities and resources will not align with local and Raritan regional dam removal priorities.

We also recommend conducting an inventory of smaller dams (under 5') that are not captured by the Freshwater Network tool or considered in the SDRP work. These smaller dams should be assessed as part of a basin-wide dam removal prioritization process.



*Figure 53. Functional upstream network length per HUC-14 by WMA*

## Take-Away—Dams

Dams were built on the Raritan and its tributaries since the 1600s to supply water for a myriad of private and municipal uses. While some dams provide for water supply or flood control, many of these dams have outlived their useful lives and have contributed to degradation of water quality and habitat. Though seven dams have been partially or completely removed since 1985, 147 dams over 5' in height continue to restrict natural flows in the Raritan Basin. The state has convened a collaborative partnership to identify and prioritize dams (5' or higher) for removal. We recommend conducting parallel prioritization work within the Raritan as well as conducting an inventory of smaller dams (under 5') as no centralized inventory of smaller dams exists.



## Key Indicator

# Restoration Projects

## Background

The compilation of restoration projects summarized in this section came out of a partnership with the NJDEP's Bureau of Environmental Analysis, Restoration and Standards (NJDEP-BEARS) to assist them in conducting stakeholder engagement for their 2016 Integrated Water Quality Assessment Report that has a focus on the Raritan River watershed. While the NJDEP had captured information about restoration projects they had funded (e.g., through the 319(h) grant program to address nonpoint source pollution), they were lacking information about restoration projects done through other partner programs (i.e., USDA) or that were conducted/funded by municipalities or non-profit stakeholders. The SRRI solicited restoration information from these other stakeholders, combined it with data prepared by the NJDEP-BEARS for the Integrated Assessment and summarized it by HUC-14 and by type of restoration.

## Methodology

Data on restoration projects was gathered from a number of groups: NJDEP-BEARS; NY-NJ Harbor & Estuary Program; Rutgers Water Resources Program; The Nature Conservancy, Roots for Rivers Projects;

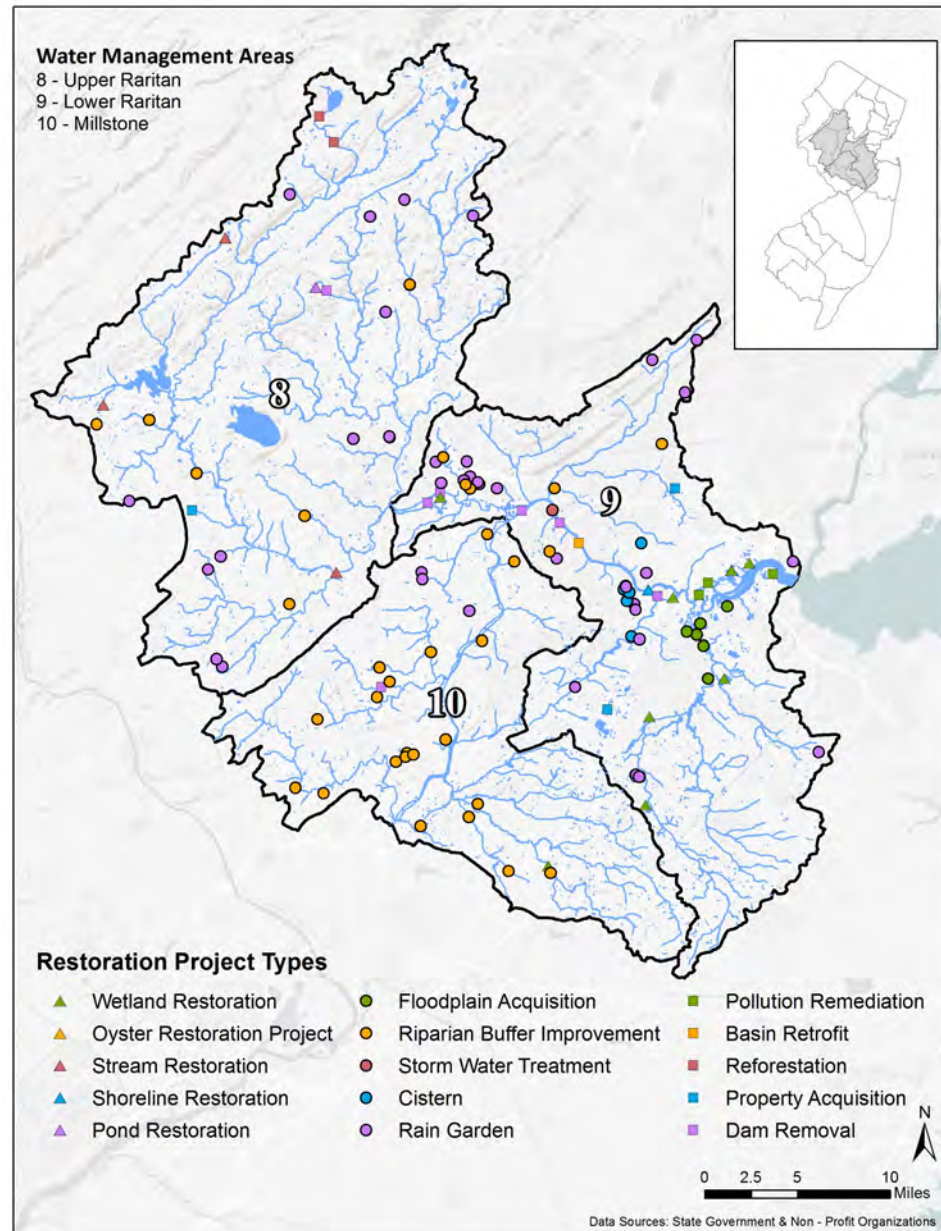


Figure 54. Map of restoration project types in the Raritan Basin

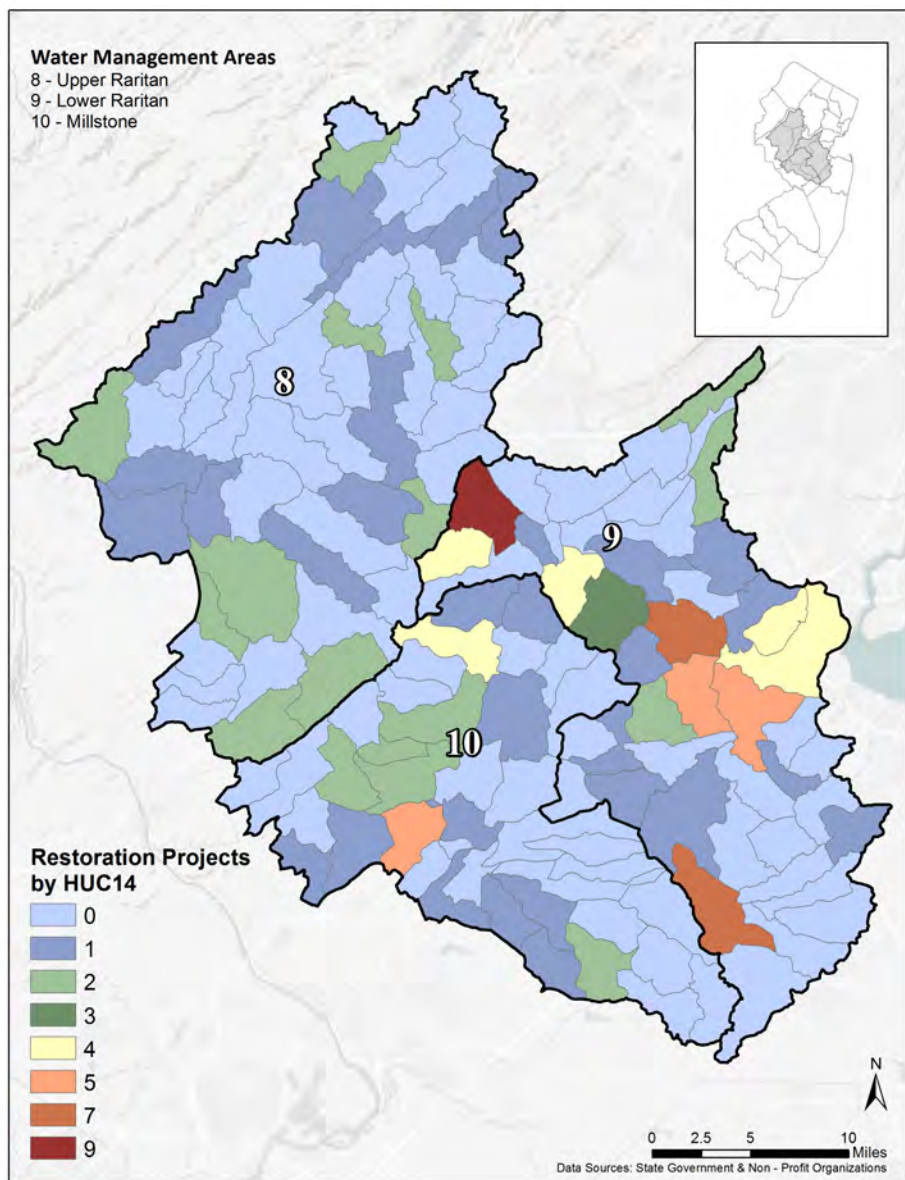


Figure 55. Map of restoration projects by HUC-14 in the Raritan Basin

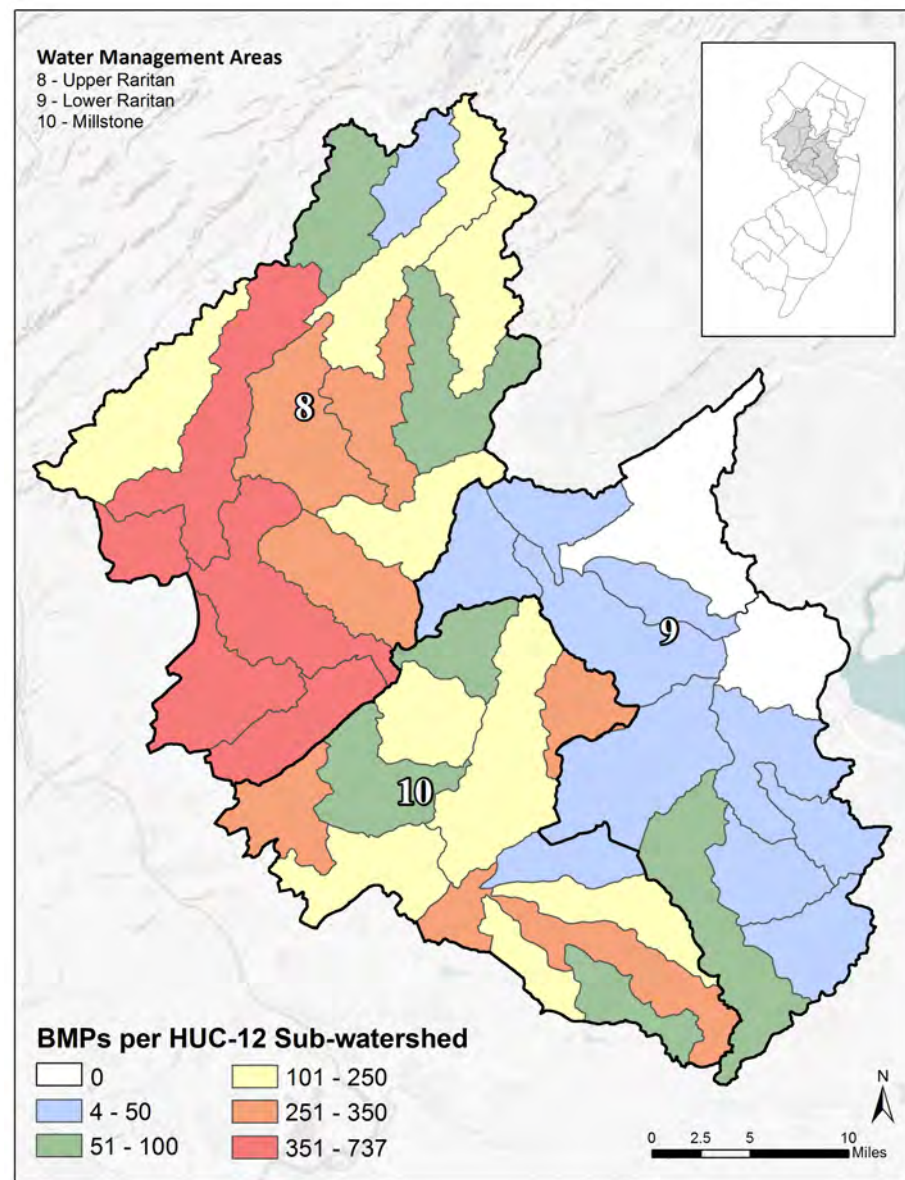


Figure 56. Map of NRCS BMP projects (2007-2016) by HUC-12 in the Raritan Basin



Duke Farms; PS&S for Federal Business Center; Lower Raritan Watershed Partnership; The Land Conservancy of NJ; NJ Water Supply Authority; Middlesex County Office of Planning; Rutgers Cooperative Extension; USDA Natural Resources Conservation Service; and Tewksbury Township.

Individual projects were recorded as point locations and the number was tabulated for each HUC-14 (excluding NRCS projects). While some larger rain gardens were individually geolocated, multiple rain gardens were often aggregated as one restoration project and recorded by HUC-14. Similarly rain barrels were aggregated as one project and recorded by HUC-14.

The Natural Resources Conservation Service (NRCS) offers voluntary programs to help plan and implement best management practices (BMPs) that improve watershed health and related resources on agricultural lands and non-industrial private forest land. NRCS

projects undertaken between FY2007-2016 were summarized by HUC12.

## Status

Raritan partners reported 127 projects implemented to restore and protect water quality in the region. The Upper Raritan had the greatest number of restoration projects implemented with 52, followed by the Lower Raritan with 47 and the Millstone with 40 restoration projects. The variety of restoration interventions implemented included: oyster beds, and shoreline and wetland restorations in saltwater and estuarine environments; forest, pond, and wetland restorations in the uplands; urban solutions such as cistern and rain garden installations, basin retrofits and stormwater treatment; riparian treatments such as riparian buffer improvements and stream restoration; as well as larger scale efforts including pollution remediation, property acquisition

and dam removals (Figure 54). Of the 139 HUC-14s in the Raritan Basin, 60 subbasins or just over 43% had at least one restoration project implemented (Figure 55).

Between 2007 and 2017, the NRCS conducted over 6,660 individual BMPs in the Raritan River Basin. NRCS projects are primarily concentrated in the agricultural areas of the Upper Raritan and Millstone WMAs (Figure 56).

## Summary

The Sustainable Raritan River Initiative is committed to working with Raritan stakeholders to continue to capture restoration data as it becomes available and to share it through a publicly accessible platform (under development). This up-to-date view of restoration work in the Raritan will help inform best practices and assist in prioritizing future restoration efforts to enhance water quality and habitat throughout the Raritan Basin.

## Take-Away—Restoration Projects

A myriad of organizations is involved in restoration work in the Raritan. Data was captured in conjunction with the NJDEP Raritan Integrated Assessment and from other stakeholder groups who collectively implemented 127 projects to restore and protect water quality in the region. Over 43% of the HUC-14s in the Raritan have at least one restoration project implemented. Types of restoration projects include wetland, oyster, stream, shoreline and pond restorations; riparian buffer improvements; a variety of stormwater treatments; basin retrofits; reforestations; dam removals; and floodplain or other property acquisitions. In addition, between 2007 and 2016, the NRCS conducted over 6,660 (primarily agricultural) BMP projects in the Raritan Basin. The SRRI is committed to working with Raritan stakeholders to continue capturing and sharing restoration work and BMPs, and to assist in prioritizing future restoration efforts.



## Key Indicator

# Resilience

## Background

As the Raritan's riparian areas are converted to other land uses (both urban and agricultural), and as other pervious surfaces are converted to more impervious surfaces, the Raritan region has become increasingly vulnerable to flooding and its impacts.

Transitional areas between terrestrial and aquatic ecosystems are vital to watershed health. Riparian areas and natural floodplains protect streambanks and remove sediments and nutrients from runoff, reduce flooding, protect aquatic ecosystems, and provide habitat for terrestrial and aquatic organisms.

Hard infrastructure can increase the speed and volume of potentially contaminated runoff into streams that exacerbate the effects of precipitation events and further degrade riparian zones as streams cut into banks and become disconnected from their floodplains.

## Methodology

Maps were compiled using FEMA Flood Insurance Payout (NFIP) data for each Raritan community for payouts related to Hurricane Floyd, Irene and Sandy. The total map included NFIP data aggregated by

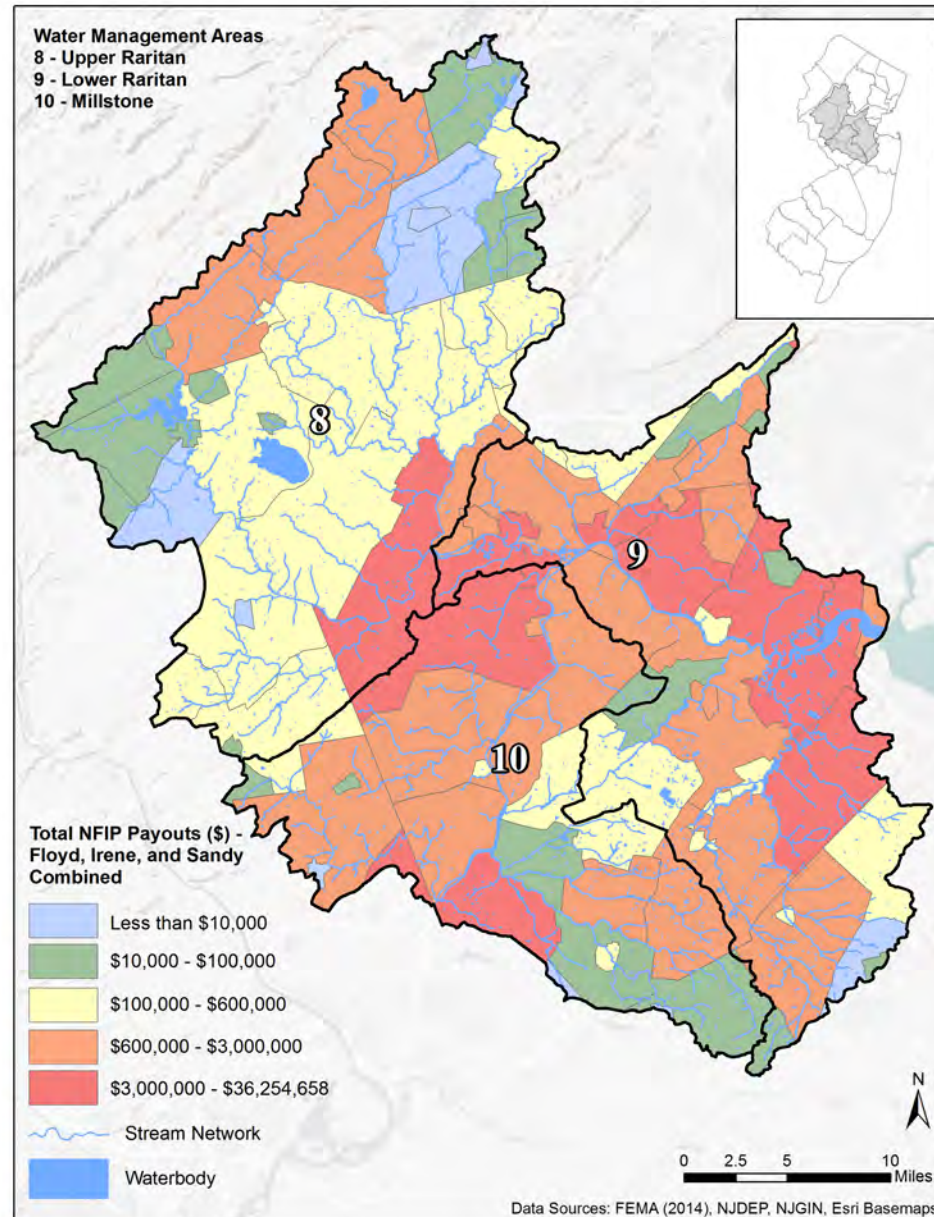


Figure 57. Map of total NFIP payouts by municipality for Floyd, Irene and Sandy combined

municipality. The square miles map averaged payout by square mile.

Summary

We have summarized the effects of three major storm events in the Raritan region utilizing flood insurance payout information as an indicator of damage from the storms. The three events, Hurricanes Floyd, Irene and Sandy, all occurred in the past two decades and surpassed all previously recorded storm events in New Jersey for precipitation amounts and the extent of flood and storm surge damage.

Hurricane Floyd, a strong Category 4 hurricane and historically the most costly to hit New Jersey to date, struck the Raritan region on September 16, 1999, as a powerful tropical storm that caused extensive flooding from record rainfalls. Somerset County and parts of Middlesex County were the hardest hit. Rainfall peaked at 13.34” in Somerville, NJ. The Raritan flood was 4.5 feet higher than previous records with severe effects for Manville, South Bound Brook and Bound Brook that experienced a 42-foot flood crest. President Clinton declared the area a federal disaster on September 17. Raritan counties included in the declaration were Hunterdon, Mercer, Middlesex, Morris, Somerset and Union.

Almost twelve years after Hurricane Floyd, Hurricane Irene struck New Jersey on August 28, 2011. Irene, a Category 3 hurricane, hit the New Jersey shores as a tropical storm carrying heavy rains and winds gusting to

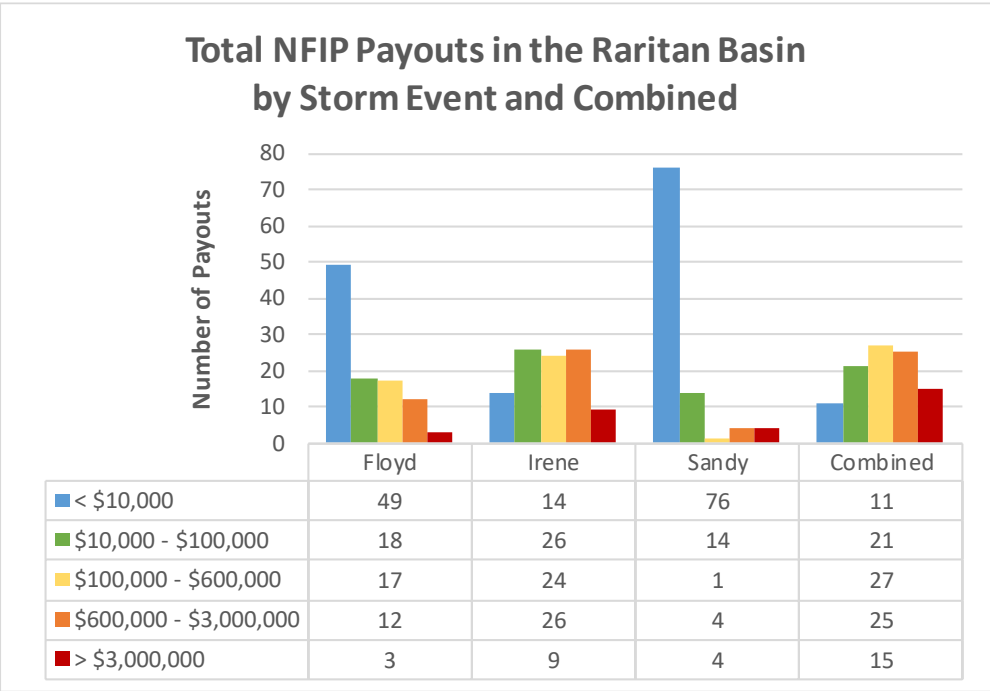
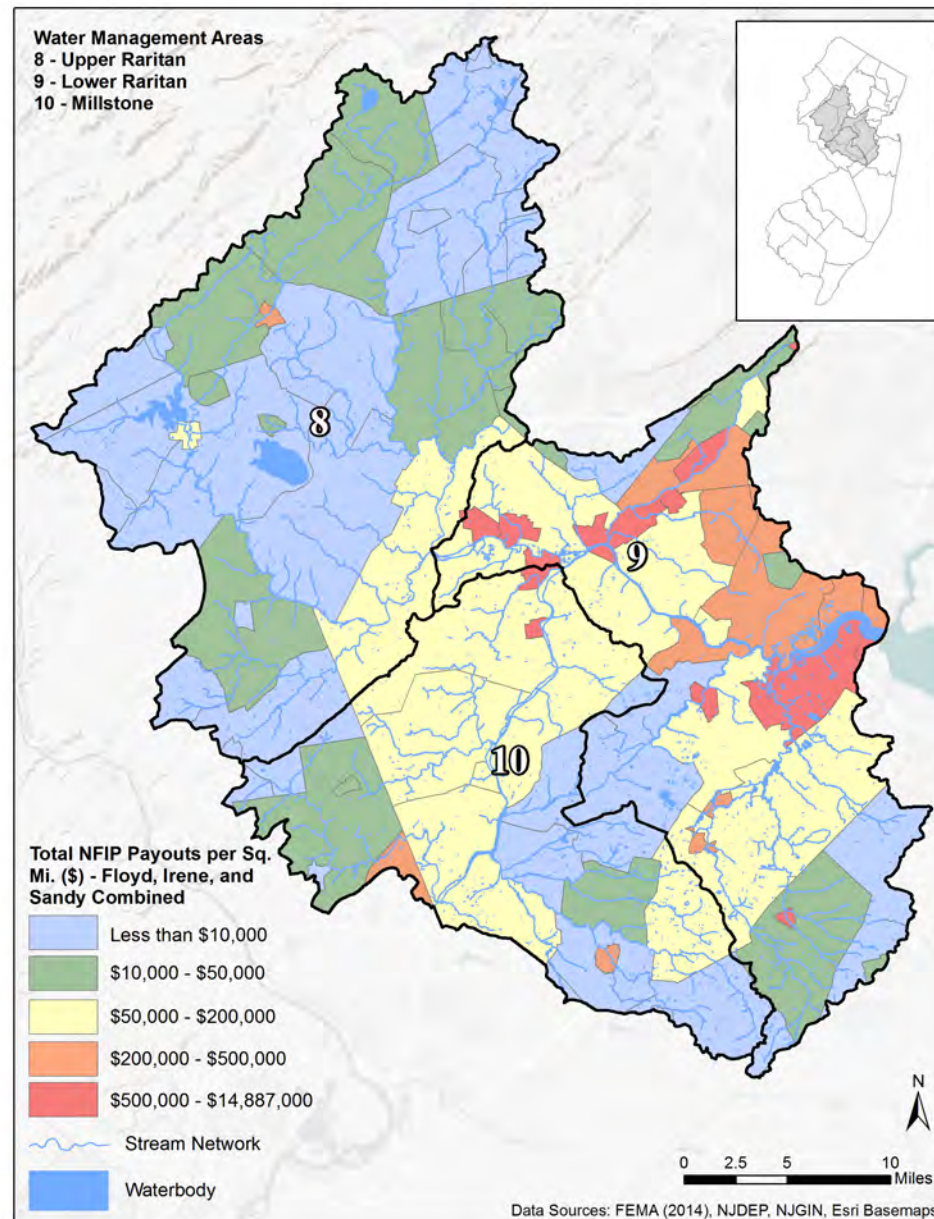


Figure 58. Total NFIP Payouts for municipalities in the Raritan Basin by storm event and combined (nominal values)

70 mph. Flooding and wind damage was exacerbated by already saturated ground conditions. Freehold recorded the highest rainfall at 11.27 inches. Power outages from downed wires lasted almost ten days. The storm surge at Sandy Hook was 4.63 feet (above normal astronomical tide) or 9.75 feet above mean lower low water (Avila & Cangialosi 2011).

Based on the NFIP Payout data, the damage from Irene was more widespread than Floyd and more costly. Where Floyd's payouts above \$100,000 were concentrated in communities near the confluence of the Raritan and Millstone Rivers and also where the Green Brook and Middle Brook join the main stem (i.e., Somerset and parts of Middlesex counties), the damage from Irene in the \$100,000 plus ranges covered a good portion of the entire Raritan Basin (Figure 57 and 58). The top NFIP payout for Floyd was \$15.8 million, while the top payout for Irene was \$25.1 million. The area was declared a federal disaster by President Obama on August 31.

Thirteen months later, Hurricane Sandy struck the New Jersey coast on October 29. Also a Category 3 at its strongest, it was downgraded to "superstorm" status with 80 mph winds when it landed near Brigantine, NJ. The damage from Sandy was predominately from the nine-foot storm surge that came in on a high tide of five feet—essentially sending a fourteen foot storm surge up the Raritan. President Obama declared an emergency for New Jersey on October 28 before Sandy came ashore. The concentration of NFIP payouts for the region was near the mouth of the Raritan with the



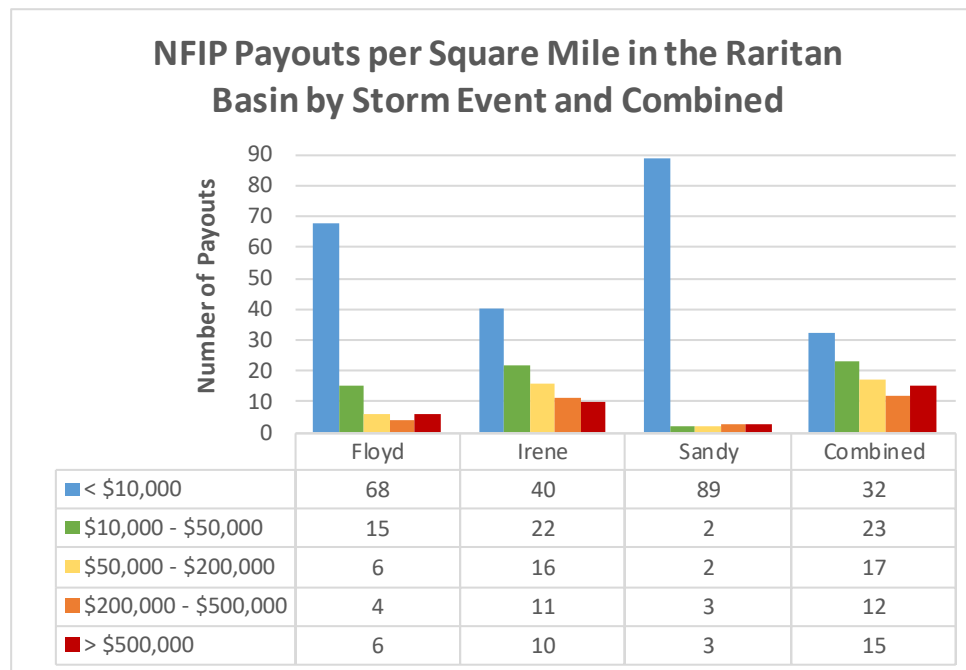
*Figure 59. Map of total NFIP payouts per square mile for Floyd, Irene and Sandy combined*



highest municipal payout of \$13.9 million.

Figures 59 and 60 show the total combined NFIP payouts per square mile in Raritan Basin communities for Floyd, Irene and Sandy. The combined payouts exceeded \$203.78 million dollars.

While this analysis is focused on storm related flooding in the Raritan Basin, the devastating wildfires affecting the west coast of the United States in the Fall of 2018 should be a warning to assess the local and regional forestry management practices that could lead to fires in drought years. Given the basin's extensive canopy cover (40% of basin) and the declining condition of some forested areas due to insect or disease, resilience planning should include extreme dry conditions as well as extreme wet conditions.



*Figure 60. NFIP Payouts per square mile in the Raritan Basin by storm event and combined (nominal values)*

## Take-Away—Resilience

Climate studies indicate that the effects of climate change will be detrimental to the Raritan region and may include more extreme weather including more flooding and drought. Climate change and associated weather events will risk significant impacts on the Raritan's natural resources, built infrastructure and populations such as those experienced in the region's most recent impactful hurricanes of Floyd, Irene and Sandy. Recent wildfires out west of the United States should be a warning that drought and fire should also be considered in resilience planning for the Raritan region.

## Conclusion

In this assessment of the health of the Raritan, we evaluated eight broad areas that could either impact water quality or watershed health or that influence quality of life in the basin. The selected indicators reflect certain aspects of water quality and watershed health and represent some driver (e.g., human population or urban land use) or reflect on the resulting consequences (e.g., groundwater recharge).

Methodology varied by indicator but relevant data for each indicator was processed using the ArcGIS platform. For most indicators, the analysis was performed on the Raritan Basin as a whole as well as on the three watershed management areas (Upper Raritan, Lower Raritan and Millstone). Further, where possible, data was summarized by HUC-14 sub-basin to depict the spatial heterogeneity at a finer level of resolution.

The areas assessed include: canopy cover; known contaminated sites; threatened and endangered species; restoration projects; open space; recreation trails including greenways and boat launches; grey infrastructure including stormwater basins, culverts, outfalls, bridges and dams; and resilience as measured by FEMA flood insurance payouts for recent historic storms.

Trees are vital to sustaining watershed health. While

there are positive signs with a slight uptick in the percent tree canopy for the Raritan Basin as a whole, the decline in canopy cover in the upper headwaters of the Raritan is concerning. It is anticipated that the Emerald Ash Borer, which has been identified across the Raritan Basin, will kill between six to ten percent of trees in the region, further reducing canopy cover.

Pollutants from contaminated sites can seep into groundwater or runoff into adjacent surface waters,

damaging the ecosystem and posing a hazard to wildlife, fisheries and human health. Only a little over a quarter of the known contaminated sites (including SuperFund sites) have been “cleaned up”. Monitoring the integrity of previously remediated sites to ensure stability is also a concern.

The presence of threatened and endangered species are an indicator of watershed health; the ability of the watershed to support rare species adds to overall



*Image 8. 2018 Raritan Conference stakeholder working session by Sonia Szczesna*

biodiversity as well as quality of life. It is promising that over 50% of the total Raritan Basin serves as potential habitat for threatened and endangered species or species of conservation concerns.

The available and accessible open space lands and waterways greatly enhances the quality of life for citizens of the Raritan Basin. The Raritan Basin is blessed with over 20% of its land area in public open space held in fee or easement, however less than half of all open space is actually open access. Further, access to nearby open space is problematic in some sub-basins, especially in the more urban Lower Raritan. Recreational trails and greenways crisscross the basin providing opportunities for recreation, and enhance the livability of our communities. While the main stem of the river has a number of boat launches and access sites, getting onto the river or accessing the upstream sections can be a challenge as much of the Raritan's shoreline is privately held (and so not accessible), existing launch sites are generally poorly marked or lack parking. Though there have been several independent efforts to map Raritan trails and river access points, no comprehensive central database of trails or launch sites exists.

As a result of the Raritan Basin's long history of human development, the river is heavily affected by grey infrastructure: culverts, dams, bridges and outfalls. All these features can impede fish passage, alter stream flow characteristics, and negatively impact water quality. Recently, there have been a number of promising developments with outmoded

dams and culverts removed; more needs to be done. As a means of controlling the adverse effects of urban development on runoff and nonpoint source pollution, stormwater basins of diverse types have been installed. Hundreds of these basins dot the landscape. Most, however, are concentrated in more newly developed areas with older urban areas underrepresented. The status of these basins in terms of meeting their design standards is poorly known.

To help correct for the sins of the past, a myriad of organizations is involved in restoration work in the Raritan. Over 43% of the HUC-14s in the Raritan have at least one restoration project implemented. Types of restoration projects include wetland, oyster, stream, shoreline and pond restorations; riparian buffer improvements; a variety of stormwater treatments; basin retrofits; reforestations; dam removals; and floodplain or other property acquisitions. In addition, the NRCS has conducted over 6,660 BMP practices in the more rural/agricultural parts of the Raritan Basin.

Climate studies indicate that the Raritan region may experience more extreme weather including more extreme precipitation and drought in the near future. While great strides have been made to reduce the adverse effects of flooding on some the basin's most vulnerable communities, the risk of extreme weather and attendant flooding is expected to increase. Greater attention to flooding, drought and even

wildfire should be paid to promote enhanced resiliency for the Raritan region.

This report is the second in a series that will eventually assess a broad array of metrics of watershed health and livability for the Raritan Basin. The intent is to inform watershed management planning in concert with remediation, restoration and protection efforts at the state, regional and local levels.



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# Tables and Figures

Table 1. Key indicator trends from State of the Raritan Report, Volume 1.....	1
Figure 1. Map of location of Raritan River watershed in New Jersey.....	3
Figure 2. Map of streams, elevation and physiographic provinces in the Raritan River watershed .....	4
Figure 3. Map of percent canopy cover for the Raritan River Basin.....	7
Figure 4. Map of average percent canopy cover by HUC-14 .....	8
Figure 5. Average percent canopy cover by HUC-14 and WMA .....	9
Figure 6. Percent canopy cover and change from 2001 to 2011.....	9
Figure 7. Map of change in average percent canopy cover from 2001 to 2011 by HUC-14.....	10
Figure 8. Change in average percent canopy cover from 2001 to 2011 by HUC-14.....	11
Figure 9. Map of known contaminated sites by type in the Raritan Basin .....	12
Figure 10. Known contaminated sites by type and by WMA .....	13
Figure 11. Map of known contaminated sites per HUC-14 .....	14
Figure 12. Known contaminated sites by HUC-14 and WMA .....	14
Figure 13. Map of Landscape Project ranked areas in the Raritan Basin .....	16
Figure 14. Landscape Project ranks in square miles and percent for each WMA and the total Raritan .....	17
Figure 15. Map of percent Landscape Project area in ranks 3 to 5 by HUC-14 and WMA.....	18
Figure 16. Percent coverage Landscape Project area for ranks 3 to 5 by HUC-14 and WMA .....	18
Figure 17. Map of open space in fee and easement by owner type .....	20
Figure 18. Open space in acres and percent by owner type and WMA .....	21
Figure 19. Percent acreage of open space/conservation land by owner type .....	22
Figure 20. Map of open space by in fee and easement by public accessibility .....	22
Figure 21. Percent acreage of open space by type of access .....	23
Figure 22. Open space access in acres and percent by type of access and WMA.....	23

# Tables and Figures continued...

Figure 23. Map of percent open space by HUC-14.....	24
Figure 24. Percent open space by HUC-14 and WMA .....	24
Figure 25. Map of percent public access open space by HUC-14.....	25
Figure 26. Percent open access open space by HUC-14 and WMA.....	25
Figure 27. Map of acres of open space per capita by HUC-14 .....	26
Figure 28. Acres open space per capita by HUC-14.....	26
Figure 29. Map of trails by type in the Raritan Basin .....	28
Figure 30. Percentage of hiking, biking and combined hiking and biking trails miles by WMA .....	29
Figure 31. Length of recreational trails (in miles) by WMA .....	30
Figure 32. Percentage of recreational trails (in miles) by type and WMA.....	31
Figure 33. Map of boat launches by type in the Raritan Basin .....	32
Figure 34. Boat launches by type for each WMA .....	33
Figure 35. Map of stormwater management basins by type in the Raritan Basin .....	36
Figure 36 Distribution of stormwater management basin types in the Raritan Basin .....	37
Figure 37. Distribution of stormwater management basins by WMA.....	37
Figure 38. Map of number of stormwater management basins per HUC-14.....	38
Figure 39. Number of stormwater management basins by HUC-14 and by WMA .....	38
Figure 40. Map of reported outfall locations in the Raritan Basin .....	40
Figure 41. Map of stream crossings by stream order in the Raritan Basin.....	42
Figure 42. Number of stream crossings by Stream Order in the Raritan Basin .....	43
Figure 43. Map of number of stream crossings per HUC-14 in the Raritan Basin.....	43
Figure 44. Number of stream crossings by HUC-14 and by WMA.....	44
Figure 45. Map of location of bridges maintained by NJDOT in the Raritan Basin.....	45

# Tables and Figures continued...

Figure 46. Map of number of bridges maintained by NJDOT per HUC-14 in the Raritan Basin..... 46

Figure 47. Number of bridges maintained by NJDOT by HUC-14 and by WMA..... 46

Figure 48. Map of location of dams by tier in the Raritan Basin ..... 48

Figure 49. Map of number of dams per HUC-14 in the Raritan Basin..... 49

Figure 50. Summary of dams by WMA ..... 50

Figure 51. Map of functional upstream network length (for tiers 1 to 20 dams) in the Raritan Basin ..... 51

Figure 52. Map of total functional upstream network length by HUC-14 in the Raritan Basin ..... 51

Figure 53. Functional upstream network length per HUC-14 by WMA ..... 52

Figure 54. Map of restoration project types in the Raritan Basin ..... 53

Figure 55. Map of restoration projects by HUC-14 in the Raritan Basin ..... 54

Figure 56. Map of NRCS BMP projects (2007-2016) summarized by HUC12 in the Raritan Basin..... 54

Figure 57. Map of total NFIP payouts by municipality for Floyd, Irene and Sandy combined ..... 56

Figure 58. Total NFIP payouts for municipalities in te Raritan Basin by storm event and combined (nominal values)..... 57

Figure 59. Map of total NFIP payouts per square mile for Floyd, Irene and Sandy combined ..... 58

Figure 60. NFIP payouts per square mile in the Raritan Basin by storm event and combined (nominal values) ..... 59



# Images

Image 1. Albany Street Bridge by Mario Burger..... i

Image 2. Untitled view of a good trout fishing spot by Judy Shaw ..... ii

Image 3. Perth Amboy Riverwalk by Denise Nickel .....iii

Image 4. Donaldson Park Boat Launch from the R/V *Rutgers* by Sara Malone..... v

Image 5. Student walking bike in May 2014 flood at New Brunswick’s Boyd Park by Sara Malone ..... 2

Image 6. Ambrose Brook by Margo Persin..... 5

Image 7. Red-eared slider by Steven Weber ..... 6

Image 8. 2018 Raritan Conference stakeholder working session by Sonia Szczesna ..... 64



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