Princeton NJ's Water Story

Overview **2**

Watersheds **3**

Water Quality **6**

Stormwater **8**

Flooding 9

Impervious Cover 12

Green Infrastructure 14

The Stormwater System 16

Drinking Water **16**

Drinking Water Quality 17

Water Supply 18

Sewage **19**

Sewage Treatment 19

The Sewer System 20

Sewage Issues 21

What we can do **21**

Planning 21

Policy 23

Regional Collaboration 25

Individual Participation 26

Who owns the water? **26**

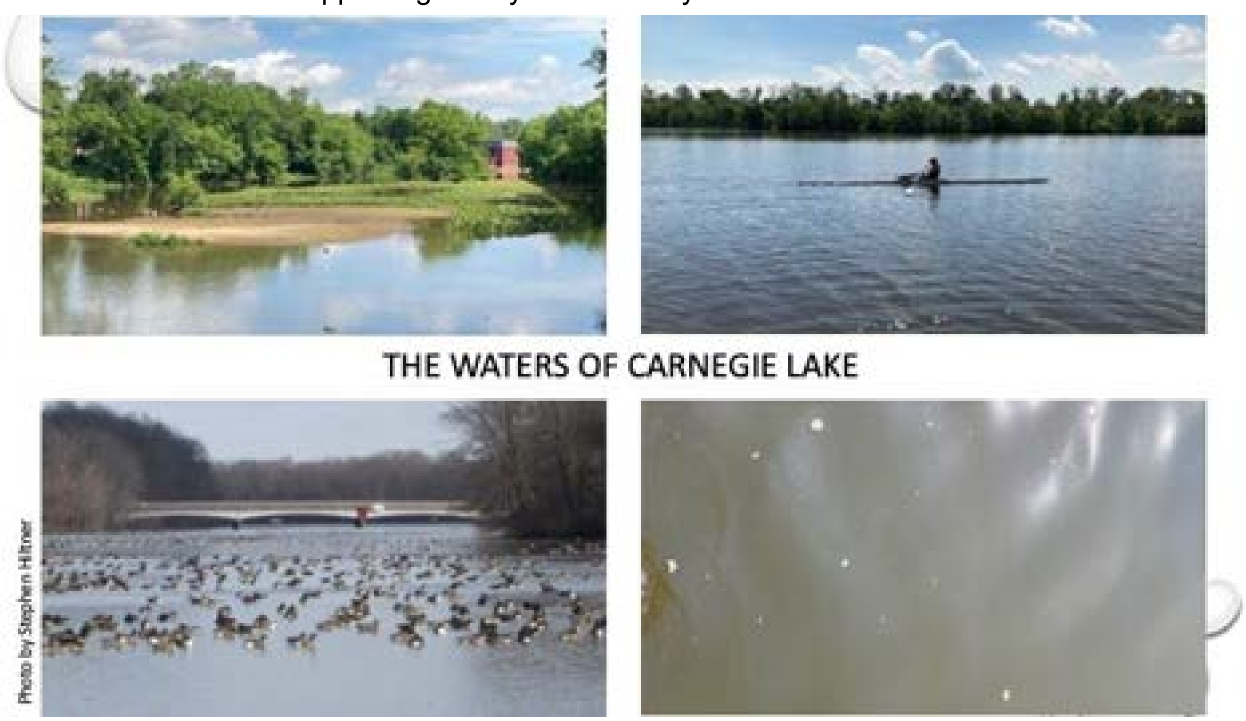
Acknowledgements **27**

Overview

This presentation of Princeton's Water Story is meant to help Princeton residents understand where our water comes from, what happens to it as it runs through town, and where it goes. It's the first step in a process laid out by Sustainable Jersey to help municipalities identify, solve, and manage our water resources.

Princeton is an enviable place to live in many ways. We have a mix of historical downtown and university properties, established residential developments, surrounded by some farmland, some parks, Carnegie Lake, and some wetlands. Environmentally, we have no heavy industry, a good allotment of preserved open spaces, and usually, enough natural water to keep our surroundings lushly green.

But our relationship to water is complicated. Take Carnegie Lake as just one example. As scenery, it's delightful. As a rowing venue, it's Olympic-class. If you were to fall in, however, the water becomes far less appealing. And you absolutely do not want to drink it.



Like much of the surface water in Princeton, the brownish waters of Carnegie Lake are technically classified as "impaired"[1], which means we have water quality problems - problems much of New Jersey shares. And on top of quality issues, there is quantity: storms can cause flooding along the banks of the lake and the waterways that feed into it.

[1] List and details of impaired waters are in the NJ Water Quality Assessment Reports

Being a state where home rule is dominant, a lot of the responsibility for protecting water falls to municipalities. So this Water Story asks: What are Princeton's water issues and how can we fix them?

It turns out the Water Story we were told as children is a bit of a fairy tale. The classic illustration of the water cycle - with its fluffy clouds raining upon pristine mountaintops and draining through scenic rivers to a majestic ocean - doesn't take human activity into account. Yet the impact of human activity on the water cycle is unavoidable, especially in our heavily-populated and long-industrialized state.

A thorough look at any community's water system has to include both the natural water cycles (precipitation, runoff, groundwater infiltration and flow, transpiration from plants, and evaporation) and human intervention, in the form of:

- Infrastructure: the pavements, roads and buildings that change the course of precipitation, and the wells, pipes and dams that divert the flow of water.
- Pollution: NJ has a legacy of heavy industrial pollution, but in largely residential communities like Princeton, property owners also pollute the water system through landscaping and household chemicals, pet waste, and stormwater runoff from impervious surfaces.
- Governance: how much does the public know about the policies that determine how we manage or mismanage natural resources?
- Awareness, or lack of it: taking water for granted for centuries of human development has harmed our environment, and only a shift in priorities can restore better water quality.

This report is intended to give the Princeton public a better understanding of water as a single, unified, and precious resource that is under threat from the pressures of human development. Beginning with the lay of the land, going through the various water-related systems, we conclude with some positive directions that are being taken to ensure that we treat our water better in the future than we have in the past.

Watersheds

Waterways create an intricate pattern of watersheds and sub-watersheds - the land area draining to a single river or stream - that determine how communities share water resources, and water problems.

Princeton is in the Raritan River Watershed.[2] That means our rain, runoff, streams, rivers, and canal waters all drain northward into the Raritan River - which is also, incidentally, the source of our drinking water. You can trace the downstream and upstream flows of any waterway using the USGS Streamer Map.

Rowan University has created an interactive Watershed Explorer map, which allows you to visualize many watershed features such as sub-watershed boundaries, impervious cover, floodplains, etc. This one shows the two sub-watersheds in Princeton, the Stony Brook, in yellow, and the Millstone River, in green. Rains that fall in the green section drain directly to the Millstone. Rains that fall in the lower left drain toward the Stony Brook.

When Princeton University's Nassau Hall was built in 1756 it was placed on a high vantage point, which turns out to be on the crest that divides Princeton into two sub-watersheds, the Stony Brook in the west (in yellow) and the Millstone River (Heathcote Brook to Harrison St.) in the east (in green).[3] The high school was also built on that crest.

---

[2] The United States Geological Survey (USGS) has divided the country into progressively smaller Hydrologic Units, based on geographic areas that drain into a common waterway or body of water. Each watershed is identified by a Hydrologic Unit Code (HUC). Sub-watersheds are identified with extra digits. Princeton thus falls into two HUC-11 watersheds (Stony Brook and Millstone River - Heathcote Brook to Harrison St.), and is further subdivided into nine HUC-14 watersheds, each drained by one of the smaller tributaries such as Harry's Brook, Alexander Creek, etc.

[3] Watershed maps courtesy of the NJ Map Project and its Watershed Explorer, created by Rowan University's School of Earth and Environment.

You can use the Watershed Explorer map to see where any address sits in the lay of the land:
1. Go to the Watershed Explorer. There is then a rich menu of layers to choose from, depending on what watershed features you want to explore.
2. Click on the layers you want to visualize, such as street map, town boundaries, and watersheds. You can add rivers, streams, and floodplains.
3. If you want to know where your house sits in this landscape, simply type your address in the search bar.

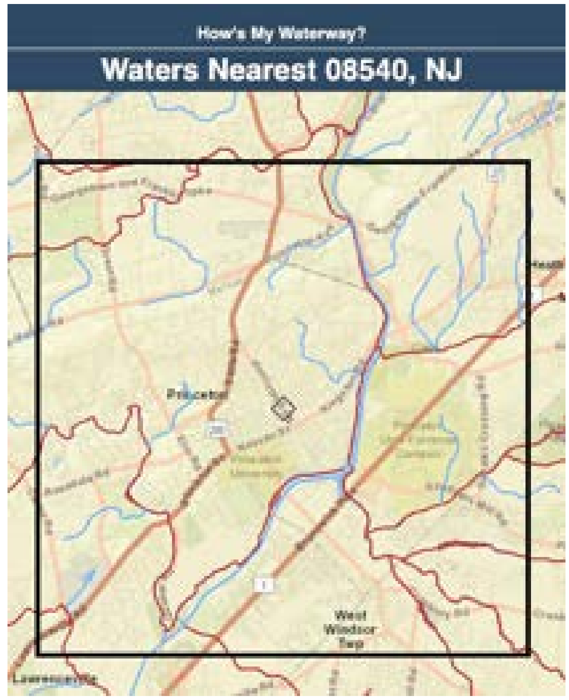
The Millstone River starts in Millstone Township in Monmouth County (east of Princeton) and flows west toward Carnegie Lake. It has multiple tributaries, including the Stony Brook. At Carnegie Lake, the Stony Brook feeds into the Millstone which then continues flowing north to join the Raritan River at Bridgewater. As a whole, the Millstone Watershed drains approximately 184,300 acres or 288 square miles. The watershed includes portions of five counties and 26 municipalities.[4]

There are more than 48 miles of streams running through Princeton, about one quarter of which are considered “headwater” streams that start within our boundaries and essentially form the basis of many “mini-watersheds” throughout the municipality.

In addition, the Delaware & Raritan (D&R) Canal - a popular state park that forms the border between Princeton and West Windsor - brings water from the Delaware River over and across the Millstone River in a man-made aqueduct before it too flows into the Raritan River, about 20 miles downstream.

[4] Millstone River Watershed, Flood Damage and Mitigation Analysis Report (2004)

Two of Princeton’s recreational bodies of water are formed by dams: Carnegie Lake (owned and maintained by Princeton University) and Mountain Lakes (maintained by the municipality). Carnegie Lake is primarily used for fishing, rowing practice and races, and the occasional small boat. Mountain Lakes (also known as Palmer Lake) is the heart of a preserved open space laced with hiking trails. No swimming or boating is allowed there.

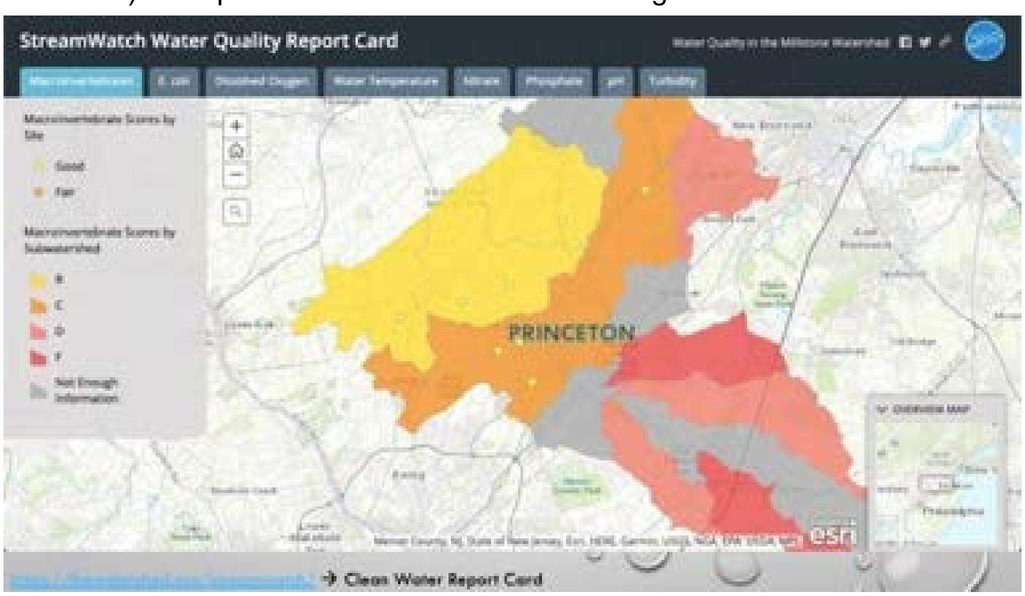


Water Quality

The federal Environmental Protection Agency offers an online “Surf Your Watershed” tool that maps the streams in any neighborhood by assessed water quality. A search by the Zip Code 08540 yields the following map, with “polluted” waterways marked in red (blue means “unassessed”).

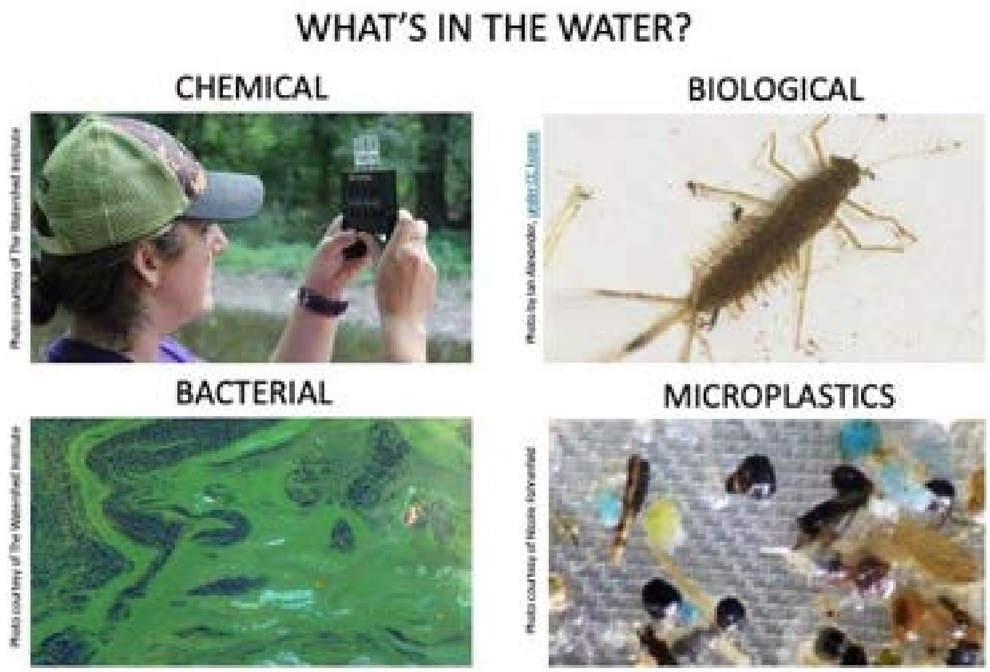
But this just gives you a general idea. To know the specific types and sources of water pollution takes a lot more work by a lot more people. To test a constantly moving environment like water is a challenge.

The Watershed Institute in Pennington has issued a “[Streamwatch report card]” for the region which assigns the Princeton area surface waters a “C” to an “F” in several categories including macroinvertebrates; E. coli (an indicator of harmful bacteria); nitrates and phosphates (both are nutrients). This pollution can’t be blamed on a single source.



Surface waters are generally tested in several ways:

1. Chemical testing includes temperature, acidity, nitrate and phosphate levels (usually from fertilizer residue, turbidity (how cloudy the water is from suspended particles) and dissolved oxygen.
2. Biological testing looks for macro-invertebrates that act as canaries in a coal mine - if you examine a water sample under a microscope and find a mayfly nymph in the spring, for example, that's an indicator of a reasonably healthy stream.
3. Bacterial testing mainly looks for e.coli, which can indicate sewage or animal waste contamination.
4. In addition, studies have confirmed the presence of microplastics in the Raritan River, although testing for microplastics is still not being done on a regular basis.



According to the Princeton Environmental Resource Inventory, the main source of pollution of Princeton's waterways is stormwater runoff, and it is referred to as "nonpoint source pollution", meaning that the sources are "diffuse, widespread, and cumulative".

> Stormwater runoff and other nonpoint source pollution (pollution coming from a wide variety of sources rather than from a single point such as a discharge pipe) have the most detrimental effect on the water quality and channel health of streams in Princeton. These sources are also the most difficult to identify and remediate because they are diffuse, widespread, and cumulative in their effect. Most nonpoint source pollution in Princeton is known to derive from stormwater drainage off paved surfaces, such as streets and parking lots, commercial/industrial areas, residential sites (with and without detention basins), and lawns, and from agricultural fields that lack adequate vegetative buffers.[5]

[5] From Princeton Environmental Resource Inventory, (2010) p.73

In other words: the chemicals we use in the course of everyday home and garden maintenance, the road salts, the animal and goose feces that in many cases go straight into the surface water without the benefit of ground filtration - all of these become a toxic soup that drains into our waterways with every storm.

Stormwater

The Garden State likes rain, of course. Just not too much or too little.

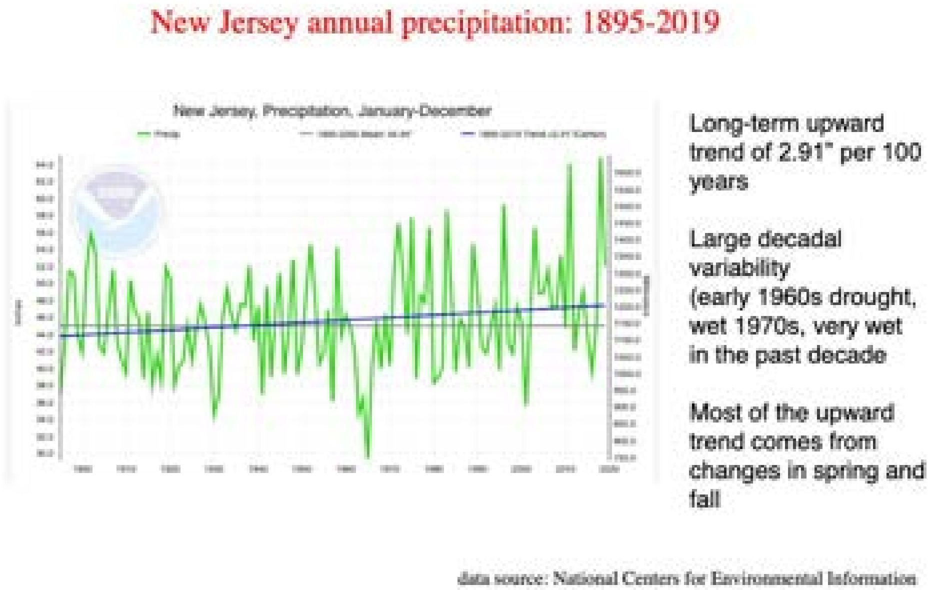
Mercer County gets a median annual precipitation of 45 inches[6], although our rainiest year since records have been kept was in 2018, when nearly 65 inches of precipitation were recorded. Five of the last 15 peak crest flood events on the Millstone happened in 2018.[7] The surface water (rivers, streams and wetlands) in the Raritan Basin comes from precipitation directly or indirectly, but not all precipitation runs into streams.

Generally, over half of it goes back into the atmosphere, either through evaporation or transpiration from the leaves of plants. Over one quarter of the water becomes runoff and exits the Basin via streams and rivers into the Raritan Bay. The remaining water infiltrates into the soil, becoming groundwater, which then moves slowly back to the streams.[8] The groundwater is a critical source of flow during dry periods, while runoff during storms creates larger but short-lived stream flows.

Climate change projections predict more precipitation for THE eastern U.S., and more weather extremes worldwide. The latest NOAA climate report indicates that nine of the ten hottest years on record for NJ have occurred since 1990. At the same time, annual precipitation for NJ has been about 8% above average over the last 10 years.[9] In addition, the frost-free season in the northeast US is now 10 days longer than it was a century ago.[10] Even more dire are the predictions for continuing sea-level rise, which may not affect Princeton directly at first, but have dark implications for NJ as a whole.

---

[6] Detailed precipitation rain records are available at the Rutgers State Climatologist Climate Tables site.
[7] From a conversation with Zenon Tech-Czarny and USGS.
[8] From Raritan Basin: Portrait of a Watershed, (2002) p.11
[9] NOAA climate report
[10] From the 2014 National Climate Assessment, as presented by NJ State Climatologist David Robinson.



Flooding

Severe downpours often result in flooding. Princeton lies at the edge of the Piedmont Plateau, which means its soil types are generally slow to absorb precipitation, leading to large amounts of surface drainage, flooding, and siltation.[11] Princeton also has a relatively high water table, which is one reason our floods are often “flashy”, that is, when rain hits the flows increase quickly and die down quickly, because not less water is absorbed into the ground.

For example: At the corner of Meadowbrook and Braeburn in the Littlebrook section of Princeton, there once stood a family home known to the neighbors as “the flood house”. A succession of floods eventually made this house unlivable, and the municipality bought the property and demolished the house altogether.

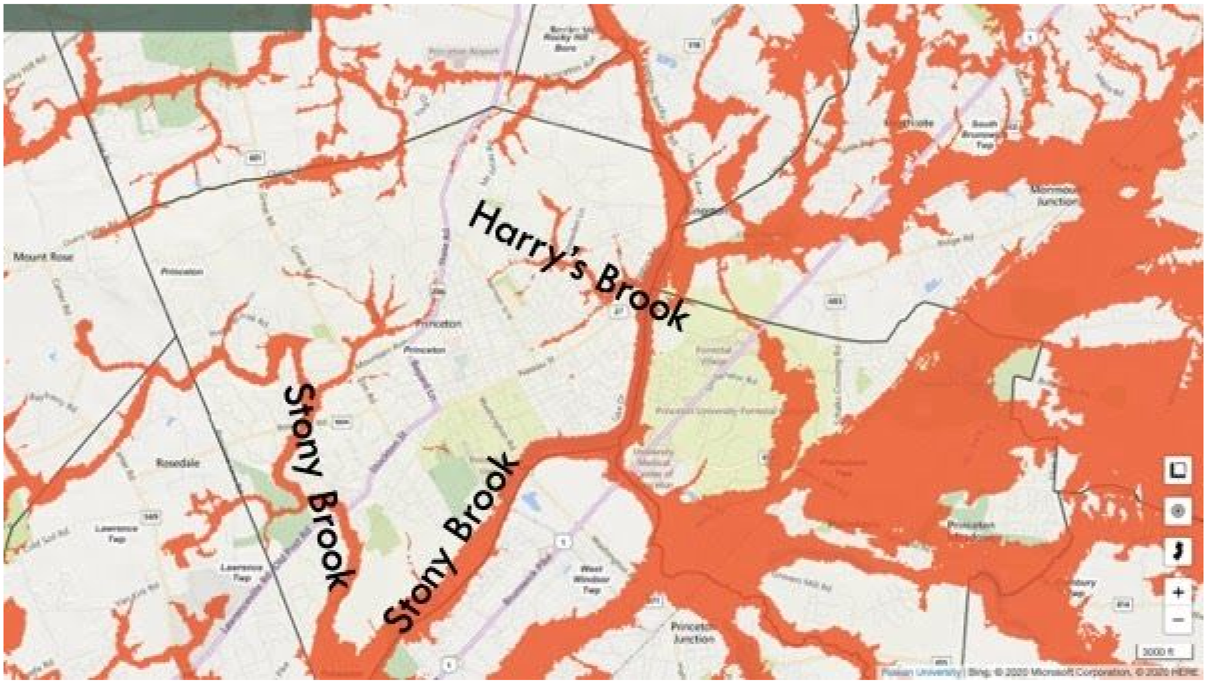
Kory Kresieder, Stormwater Specialist with the Watershed Institute, says she watched during a rainstorm as the rushing waters of the small unnamed stream that ran through that property broke down and eroded the banks. Few people realize, she says, that one inch of rain falling over one acre can generate 29,000 gallons of runoff.[12] In a year, over one million gallons can fall on that same acre.

This map shows Princeton’s floodplains in red.

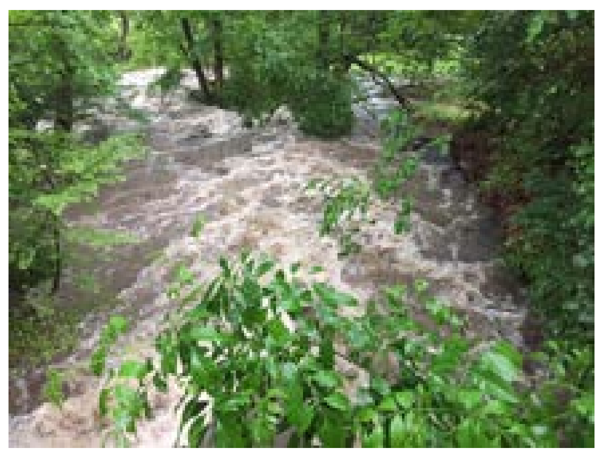
---

[11] From Princeton Environmental Resource Inventory, (2010) p.34

[12] From a conversation with Kory Kresieder, Stormwater Specialist with the Watershed Institute



Most of Princeton's floodplains lie along the Stony Brook, Harry's Brook, and Mountain Brook.



Harry's Brook (left) on a sunny day and (right) after a 10-minute intense rain)

Property damage tends to be more costly along Harry's Brook because there are more homes nearer to the stream, some of which, like "the flood house", were built before federal flood maps were implemented. Also, Harry's Brook starts underneath the densely developed Palmer Square and flows underground until Harrison Street, giving its waters no chance to soak into the ground until then. This is in sharp contrast to the Harry's Brook tributary that starts in the Herrontown Woods preserve and flows unimpeded until it joins Harry's Brook in the Littlebrook section of town. In addition to flooding, property owners report streambank erosion due to the velocity and volume of surface water flowing during storm events.[13]

Stony Brook has a wider riparian buffer which helps the ground absorb and filter water more readily. Riparian buffer zones, usually planted with trees, help stabilize stream banks, reduce pollution, and improve water quality. That's why the NJDEP requires a 300-foot buffer zone along both sides of any stream that is considered "Category One" (C1) - in our case, the Stony Brook.

How much do trees help in flood mitigation? According to the National Tree Benefit Calculator, a white oak in Princeton, 30 inches in diameter, will intercept more than 12,000 gallons of stormwater runoff a year. If it were to be cut down, that's how much extra water would be added to the stormwater flow. Shrubs and native grasses have a similar benefit, though in some areas they may have to compete with shade trees for sunlight.

Half of the Princeton area (11,750 acres) is forest (5,159 acres) or forested and emergent wetlands (1,165 acres), which provide many benefits for water flow and quality and sustaining a healthy diversity of plant and animal species.[14] However, Princeton also has a lot of developed land, which makes flooding a significant concern where the development is within the floodplain.

[13] Flood damage costs derived from a survey conducted for the Princeton 2005 Flood Mitigation Plan.
[14] From Princeton Environmental Resource Inventory, (2010) pp.91-100

Impervious Cover

The main obstacle to the natural flow of rainwater is man-made: impervious surfaces such as parking lots, roadways and roofs that go up with any new building development. Generally speaking, areas with an impervious cover of 10% or more begin to show signs of environmental degradation such as more stormwater runoff and pollution; at 25% there is a steep drop-off in water quality, and any sub-watershed with more than 25% impervious cover is classified by the EPA as a “non-supporting” waterway, which exhibits eroding banks, poor biological diversity, and high levels of bacteria. Princeton is no exception. The DEP’s 2012 land-use data showed 11.5 percent of the Millstone sub-watershed was impervious surface, up from 10.4 ten years earlier. As of 2017, 14.4% of Princeton’s acreage was covered with impervious surfaces.[15] This steady increase is a concern for water resources.

The following table of impervious surfaces in Princeton’s sub-watersheds is from the ERI:

[15] Waltman, Jim. “Managing Stormwater: Addressing Flooding and Water Pollution.” Watershed Institute, (2017, Jan) https://www.princetonnj.gov/meeting-archive/council-meeting-archive

HUC14	Sub-watershed Name	Acres In Sub-watershed	Acres Covered by Impervious Surfaces	% of Sub-watershed Covered by Impervious Surface
02030105090060	Stony Brook Rt 206 to Province Line Rd)	5,150.7	495.0	9.6%
02030105090070	Stony Brook (Harrison St to Rt 206)	3,309.1	432.0	13.1%
02030105110020	Millstone River (Heathcote Bk to Harrison St)	3,445.8	790.6	22.9%
02030105110030	Millstone River (Beden Bk to Heathcote Bk)	5,132.8	482.9	9.4%
02030105110050	Beden Brook (below Province Line Rd)	6,488.6	453.9	7.0%

Source: NJDEP, DVRPC

With the Watershed Explorer map you can visualize the expansion of Princeton's impervious surfaces over the years. This video starts with data from 1986 and goes up to 2015. The darker the purple, the higher the percentage of impervious cover. Princeton is pretty much built out already, but you can see dramatic building out along Routes 1 and 206.

(link to animated map: https://www.njmap2.com/landchange/impervious/?override=1&zoom=13&lat=40.357271365580644&lng=-74.66729164123537&sc=0&basemap=Google%20Satellite&layers=&ois=16&oms=impervious&po=)

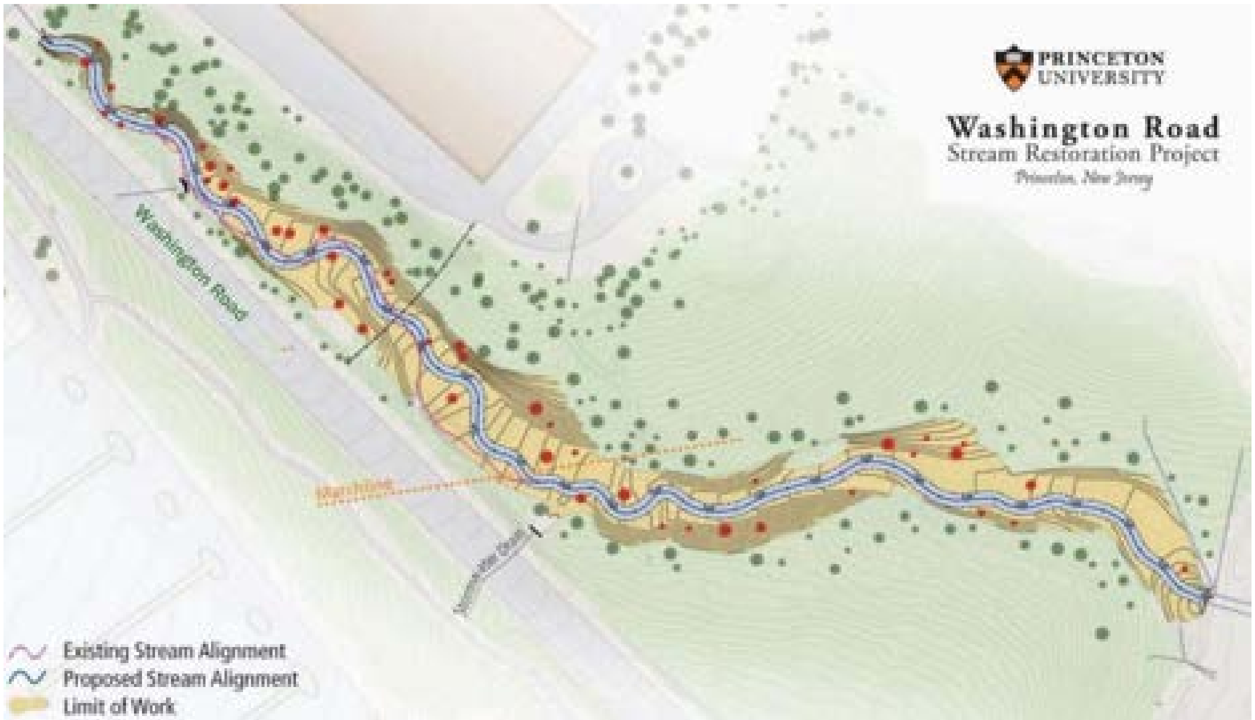
Impervious cover contributes to polluted stormwater runoff, which leads to water impairment. The identification of potential sites for green infrastructure in town is just the beginning. There are some practical speed bumps to overcome, such as zoning limits, assignment of responsibility for maintenance, and a general cultural shift in municipal maintenance away from the old ways of stormwater management. One approach could be to “disconnect” impervious surfaces from the stormwater infrastructure by diverting it to green infrastructure.

Green Infrastructure

One way to help the ground absorb more rainwater and compensate for impervious surfaces is by replacing the so-called “grey infrastructure” solutions of the previous decades with “green infrastructure”. Grey infrastructure includes catch basins and storm sewers, detention basins with concrete channels, and river walls that just divert water flow. Green infrastructure mimics nature’s way of absorbing and filtering the flow of water through the use of rain gardens, plantings, natural restoration, and other principles of conservation.

The newest version of New Jersey’s stormwater regulations requires the incorporation of green infrastructure to meet pollution and runoff standards and decrease the risks of flooding. A Green Infrastructure Municipal Toolkit has been put together by NJ Future and a Green Infrastructure Manual by Rutgers to help municipalities implement more ecologically-sound stormwater solutions. Separately, the Clean Stormwater and Flood Reduction Act was passed in 2019 that allows towns to establish stormwater utility fees to pay for this work.

Princeton does have some green infrastructure on private properties. Some years back the stream that runs through the Princeton University campus, alongside Washington Road, was seriously eroding its banks. The stream was partially channeled through concrete ducts, giving the water little chance to infiltrate into the ground. The University drew up a plan to restore the natural flow of the stream. After reshaping the streambed and landscaping the buffer with hundreds of newly-planted trees and other plants, the [Washington Road Stream Restoration] was completed in 2014 and now flows unimpeded to Carnegie Lake.[16]



Finding someone who is familiar with green infrastructure can be a challenge. Finding someone who knows how to design, install, and maintain something like a rain garden can be even harder. It is possible to take a more relaxed approach to rain gardens. Environmental activist and blogger Stephen Hiltner, who has created and maintains a few rain gardens over the years, proposes “simply digging a depression in an area of the yard that water tends to flow towards, using the dug soil to make a berm, and then planting with the main attractive native wildflowers, sedges, and rushes that thrive in wet ground. If the water doesn't get too deep, it will infiltrate before mosquitoes can breed. For someone who can recognize intended plants and weeds, a rain garden is easier to maintain than a perennial border because its soft ground is easier to weed, and the desired plants tend to be robust.”[17]

The concept of green infrastructure is only just beginning to make inroads into the landscaping repertoire of the average New Jersey contractor. In February 2020, the Watershed Institute launched a certification program to help the landscaping industry - and the individual homeowners they service - adopt more sustainable practices to reduce the number one source of pollution in Princeton’s surface waters: us.

---

[16] Those involved, however, admit that the cost of such restoration was probably beyond the means of any institution that does not have the benefit of an endowment as generous as Princeton University’s.
[17] Stephen Hiltner contributed notes to this report.

The Stormwater System

The Stormwater system is the property and responsibility of the municipality. In the words of one Princeton municipal engineer, the highest priority in the coming year is to map and understand what we have. Stormwater outfalls need to be mapped by March of next year to comply with NJ's new stormwater regulations, but beyond that, it would be helpful to have a complete map, inventory and integrity assessment of both stormwater and sewer systems. Only then can we get an idea of how resilient our stormwater system will be in the face of future storm events, as they are expected to become stronger and more frequent with the advance of climate change.

An upcoming departmental reorganization will put sewer and stormwater planning under Princeton's Municipal Engineering Department, while day-to-day operations will come under Operations and Facilities.

Also high on the priority list of the Engineering Department, in collaboration with the newly-formed Flood and Stormwater Commission, is to update local Stormwater Ordinances to align with the new statewide stormwater legislation. The Flood and Stormwater Commission makes recommendations to the Mayor and Town Council regarding flooding and stormwater management issues.

To summarize some of the stormwater issues Princeton faces:

- Flooding and erosion
- Pollution from runoff
- Too much impervious cover
- Natural stream flows impeded by grey infrastructure
- Outdated and incomplete maps of the system.
- Ensuring enough staffing and funding for stormwater management
- Preparing for climate change

Drinking Water

Many people take tap water for granted, and many users don't know where, geographically, their drinking water comes from, nor what it goes through to become potable. Princeton's drinking water comes from the same river that our stormwater and treated wastewater drains to - the Raritan. Besides drinking, tap water is used for landscaping, cleaning, and other non-potable use.

NJ American Water treats and supplies our drinking water. The investor-owned company is a subsidiary of American Water and the largest water utility in NJ. NJ American Water owns and maintains the pipes that bring the treated water to Princeton, but the water company ownership ends at the (usually) curbside valve. Curb to home is the customer's property and responsibility. Some limited areas of the municipality still have water supplied by private wells.

Less than twenty miles downstream of Princeton, just north of where the Millstone River meets the Raritan is the intake point for New Jersey American Water's Raritan-Millstone Water Treatment Plant in Bridgewater. It purifies up to 135 million gallons (MGD) per day and sends it back to Princeton as drinking water. The company maintains a second, 80 MGD water treatment plant on Canal Road that supports its service area. Its intake point is within 50 feet of the other plant, and each facility can provide a backup supply for the other.

Drinking Water Quality

In their most recent infrastructure report card (2017), the American Society of Civil Engineers (ASCE) gave NJ a "C" for drinking water, saying, "the ability of these systems to provide adequate services is threatened by age, lack of reinvestment, and a short-term focus."

The standards for the quality of drinking water are set by the EPA and NJDEP under the federal and state Safe Drinking Water Acts. They require that drinking water meet health-based thresholds, unless it is not feasible to either treat or measure[18] to that level, at which point the lowest measurable, treatable concentrations are used. While scientific consensus exists on most regulated contaminants and new standards are periodically published in response to new science, for some contaminants there is still considerable controversy regarding the most appropriate levels. New Jersey American Water regularly tests water coming in and leaving the plant, and publishes the results of its testing, most recently in Consumer Confidence Reports (CCR), most recently in the 2019 CCR report.

The results of the CCR report are good. Everything is in compliance except for sodium and manganese as secondary contaminants. Secondary contaminants are those that affect the color, taste, or smell of the water, but do not generally pose an actual health risk. The sodium may be an issue for people on a salt-restricted diet, as the highest detected level was double that of the recommended upper limit. For most people, the salt would only present a taste issue. Manganese can affect the color, taste, and smell of water, but because it poses no risks, it is usually left alone as it would be very expensive to remove. The manganese odor can be noticeable even in very small amounts - it (smells like oil or asphalt).[19]

---

[18] Measurable (also called quantifiable) is not the same as detectable. Contaminants generally can be detected at concentrations far below levels at which sufficient certainty exists regarding the actual concentration. Regulatory agencies rarely impose standards based on detection, which is a yes/no answer regarding the existence of a contaminant.

[19] The CCR was evaluated for this report by Amy Rowe, a county agent for Rutgers Cooperative Extension.

NJ American Water describes the water treatment process on its website as a sequence of steps including settling out the larger solids, filtering the smaller ones, and disinfecting with chlorine before storage and distribution.

Although independent studies have confirmed the presence of microplastics in the Raritan River, NJAW does not yet look for the presence of microplastics[20]. NJAW does measure turbidity.[21]

New Jersey has recently adopted some of the most stringent standards in the nation to control certain PFAs, (short for per- and polyfluoroalkyl) chemicals used in manufacturing that have been linked to cancer.

Water Supply

The NJ Statewide Water Supply Plan (2017-2022) says we are using less tap water per capita these days because of more efficient water fixtures. But water-intensive landscaping, agricultural, and recreational use are on the increase, canceling out those savings during summer periods. The EPA estimates that nationwide, one-third of public water is used in landscaping, and that we use ten times more fertilizer to grow lawns than we use to grow food.

Fertilizer is just one of many substances that are then washed by rains into the water that drains through our watershed. It leads to higher than normal rates of nitrates and phosphates in the water system, something which contributed to the harmful algal blooms that closed several large lakes in NJ to recreational use, most recently in the summers of 2019 and 2020.

In recognition of the need for water conservation, the Rutgers Cooperative Extension Water Resources Program has published recommendations for residents, businesses, municipalities and educators on how to reduce the use of water resources across the board. The NJ Statewide Water Supply Plan affirms this:

> Reducing water waste and improving water efficiency continues to be the most cost-effective, least disruptive, and most environmentally sound means of decreasing demands on our water resources. Most critical is the increasing trend of consumptive water losses.[22] Much of the increase occurred in the public water supply and non-agricultural irrigation sectors, and specifically includes activities such as outdoor lawn/landscape irrigation, recreation, and household maintenance. The potable supply sector accounts for nearly 60% of the State's total consumptive water loss, which has steadily increased since 1990.[23]

[20] NOAA defines microplastics as any plastic fragment less than 5 mm in length.
[21] From a conversation with Scott Baxter-Green, Water Quality Manager, NJ American Water. Mar 12, 2020.
[22] Consumptive loss means water is removed from the source, used, and lost, generally through evapotranspiration.
[23] From NJ Water Supply Plan, 2017-2022.

Sewage

The implication of the idiom “down the drain” is that something is gone forever. But that is not true of water, for which the drain is just one more step in a cycle that brings it back for our use.

Back in the 19th century, Princeton - like most communities - used to rely on nature to clean its dirty water. Wastewater drained into sewer fields at the bottom of Elm Road and filtered into the ground, until the 1930s, when the first sanitary system came online.[24] In 1978 the Stony Brook Regional Sewerage Authority’s (SBRSA) wastewater treatment facility at 209 River Road in Princeton became operational.

The SBRSA is a consolidated municipal service established by Princeton, South Brunswick, West Windsor, Hopewell and Pennington. The municipality owns, operates and maintains the collection system up to the point where it is handed over for treatment. Sewer laterals serving private property are solely the responsibility of the property owner from the collection main to the structure.

The SBRSA River Road facility is rated for 13.06 million gallons per day. The average throughput is 10 million gallons per day, coming from six municipalities in the area. Princeton accounts for about one third of the total. Heavy rains have been known to boost the peak flows to as high as 18 million gallons per day, due to a combination of infiltration from groundwater moving into the sewer through sewer line cracks and joints, and inflow of runoff and foundation drains into sewer lines. The municipal sewer systems feed into an SBRSA-owned interceptor sewer which conducts the wastewater to the treatment plant.

Sewage Treatment

Treatment of our sewage is another step in the water cycle that we often take for granted, but it is a multi-step process to remove organic and inorganic waste and restore chemical balance. A key step in the process is the use of an enormous number of helpful bacteria to “clean up” the organic waste we have flushed down the toilet and drained from our sinks. The sludge in a sewage treatment plant is essentially a bacteria farm that accelerates the work of nature.

[24] From a conversation with David Goldfarb, Chair of the Sewer Operating Committee.

This summary of operations is based on the SBRSA virtual tour:

1. Wastewater arrives at the plant's Headworks facility, where it passes through a mechanical screen to get out the most obvious solids and grit.
2. Two biological/activated sludge processes remove about 60% of the organic material in a series of aeration tanks that use microorganisms to convert the suspended solids into settleable solids.
3. Settling tanks separate biological growth (now a sludge) from the rest of the wastewater.
4. Another biological process converts ammonia to nitrates.
5. The final sludge is thickened, dewatered, incinerated, and disposed of as ash at an approved sanitary landfill.
6. The treated wastewater enters a filtration process to remove solids. The filter consists of layers of coal, sand, and gravel.
7. That water is disinfected through chlorination, and then removal of the chlorine before discharging back into the Millstone. Effluent is re-aerated to ensure the proper level of dissolved oxygen.

Additional steps are taken along the way to reduce and contain the odors that once wafted through nearby areas. The water is treated and released into the Millstone River at a point just downstream of Carnegie Lake.[25] The sewage treatment bill costs Princeton about $4.5 million/year.

The Sewer System

Because Princeton is an old settlement, its infrastructure has grown over successive generations. A total overhaul is not realistic. Repairs are done on an as-need basis, often coinciding with road improvements, which offer the best opportunity to inspect and if needed, replace pipes. However, NJDEP is promoting the use of more robust asset management programs that target lines for repair, rehabilitation or replacement based on improved data and assessments.

The municipality owns and operates both the sewage and stormwater systems, but is still working with incomplete sets of possibly outdated and largely non-digital maps. Most of the residents of Princeton are covered by municipal sewer services, although sewer repairs to sewer laterals on private property are the responsibility of the owners, some of whom have been dismayed to find terracotta pipes dating back to the building of their houses, more than a few decades ago. A few homes in the northwestern part of the town have their own septic systems.

[25] From Princeton Environmental Resource Inventory, (2010) p.123

Sewage Issues

Princeton's stormwater and sewage systems are not combined, which spares us the cross-contamination problems that plague some other Jersey municipalities. But clean groundwater leaks into the sewage system and gets unnecessarily treated, a problem called Inflow & Infiltration (I&I) that raises both the cost of sewage treatment and the risks of overtaxing the system in times of flood. The Chair of Princeton's Sewer Operating Committee, David Goldfarb, estimates that one third of our wastewater is not sewage, but groundwater that has seeped into the sewer system through leaky connections and manholes. Since SBRSA fees are based on volume, there is a great potential for savings if the leaks could be identified and fixed. Some years back, Princeton had been tackling the replacement of pipes, laterals and manholes that leaked into the wastewater system, but work on that stopped 4-5 years ago because of a staffing shortage. Town engineers are also working to comply with NJDEP's new stormwater regulations which require all municipalities to map their outflow by the end of this year. The two projects could provide enhanced benefits.

What we can do

So far we've been focused on the physical influences of human intervention in the water supply. But directly or indirectly, our water is also affected by our choices and behavior, as individuals and as a society.

- How are we PLANNING for future climate change scenarios, including more flooding or drought?
- What POLICIES would be most effective?
- And what opportunities are there to PARTICIPATE at both the collective and individual levels.

Planning

New Jersey has had to cope with three destructive hurricanes in the past 20 years: Hurricane Floyd in 1999, Hurricane Irene in 2011 (followed quickly by Hurricane Lee), and Hurricane Sandy in 2012. The first of these caused over $1 billion in damages across the state, (more than $500,000 million in Princeton alone). By 2005, Princeton had commissioned a Flood Mitigation Plan.

Hurricane Floyd was also a wake-up call for NJ American Water, which had to shut down the Raritan-Millstone plant after floods caused significant damage to the electrical system and other equipment. Its Canal Road plant, which sits at a slightly higher elevation, was able to take up the slack. Since then the flood walls at the Raritan-Millstone plant have been raised and emergency systems upgraded to theoretically cope with the so-called "500-year frequency" storm event. The capacity of the Canal Road plant was doubled to provide redundant capacity.

In 2019, the Princeton town council adopted a Climate Action Plan developed by Sustainable Princeton, outlining strategies to both reduce greenhouse gas emissions at the local level, and plan for greater resilience in the face of the impacts of climate change, including "flooding from heavier rains and … infrastructure damage from flooding and storms."

Among the Climate Action Plan recommendations are: to develop a stormwater mitigation plan and update the ordinance to match; establish a utility to help fund that plan; adopt best practices for flood mitigation including maintenance of stormwater systems; and promote the training in and use of green infrastructure projects on municipal lands.[26]

It's not just flooding we need to prepare for. Climate change will generate more weather extremes, which means the possibility of extended drought as well as floods. Reducing water use is the single best solution, but if it should come to creating new water sources, some of the ideas that have been floated include converting the Trap Rock Quarry in Kingston into a reservoir. (However the quarry business has been doing well and is unlikely to consider that option in the near future.)[27]

In addition, the Princeton Office of Emergency Management, which handles hurricane season preparedness among other things, recently added a Climate Change Hazard Annex that addresses the risks of more frequent and intense floods.[28]

> The primary issue with flood risk and climate change is that increased rainfall and runoff from more frequent or severe storms may create more frequent and/or more intense flood events… There are distinct areas of Princeton that are now flooding during heavy rainfall that had not presented issues in previous decades. The underlying factors creating increased flood issues are heavier rainfall, saturated grounds (from frequent events), increased impervious cover, and greater demands on stormwater drainage. Flooding and saturated ground also increase risks for downed trees as root systems in wet soil are susceptible to toppling due to high winds or the tree's own weight. Downed trees can damage utility lines and structures. The Princeton Climate Action Plan (PCAP) recommends mitigating practices for flooding following 3.3" of rainfall in 24 hours, and for developing a system for better understanding where storms will trigger flooding.[29]

The Princeton Community Master Plan was adopted in 1997, but is being updated and made more environmentally relevant this year with the addition of a "Green Building and Environmental Sustainability Element", which hopes to incorporate the latest "green" tools and

---

[26] From The Princeton Climate Action Plan, "Objective 11", pp 55-56.
[27] From New Jersey Water Supply Plan 2017-2022. p. 71.
[28] These risks can have tragic consequences. During Hurricane Irene in 2011, a Princeton EMT lost his life trying to reach a flooded car on Rosedale Road.
[29] From the Princeton Climate Change Hazard Annex.

principles into better land-use practices. Climate change mitigation and best practices for water management are part of the revisions, with the goal of decreasing the current impervious cover percentage of Princeton from 14.4% to 10% or below. [30]

Planning is also being done in the private sector. Princeton University unveiled its own campus stormwater management plan in 2019, and pledged to incorporate green infrastructure features such as porous pavement, stream restorations, rainwater harvesting, green roofs and rain gardens, into all future campus development plans.

Policy

While a lot of our water supply and quality is governed by Federal and State regulations, the local and regional responsibility for protecting our waters is especially important in New Jersey, where home rule is SO dominant.

- The federal Clean Water Act has had a huge and lasting positive impact on the quality of our surface waters. It is not, however, immune from attempts to roll back some of these protections, as is happening right now under the direction of the Trump administration.
- The federal and state Safe Drinking Water Acts set the standards for safe drinking water nationwide.
- The 1981 Water Supply Management Act in NJ requires regulation and regular reporting of water withdrawals from sources that can supply more than 100,000 gallons/day.
- The 2017 Water Quality Accountability Act of NJ requires water providers of a certain size OF(more than 500 service connections) to do asset management and replacement, valve testing and other requirements.
- By March 2, 2021, NJ's new Stormwater Management Rules go into effect, requiring the use of green infrastructure by regulated developments to better protect water quality by reducing polluted runoff.

Princeton is typical of many NJ municipalities in that responsibility for our water resources and outflows is distributed, and sometimes siloed, across several administrative entities.

- In New Jersey, all Clean Water Act regulations are implemented by the NJDEP. Relating to stormwater, Municipal Separate Storm Systems (MS4) must obtain a permit to be authorized to discharge stormwater into local streams. Princeton has an MS4 permit from NJDEP.
- On wastewater issues, the town engineers coordinate with the Sewer Operating Committee. Princeton's sewer system is outlined in a chapter of the Mercer County Wastewater Management Plan.

---

[30] Updating other portions of the Master Plan are currently under discussion.

- Implementation of the municipality's Tier A MS4 stormwater permit is the responsibility of the Engineering Dept. The newly-formed Flood and Stormwater Commission makes recommendations to the Mayor and Town Council regarding flooding and stormwater management issues. The Engineering Department, in collaboration with the Stormwater Commission, is working on updating local Stormwater Ordinances to align with the new statewide stormwater legislation. All development applications, including minor individual site improvements, are reviewed to determine if stormwater management is required.
- Private wells and septic systems are the responsibility of the property owners, but their permitting comes under the purview of the town's Health Department.
- In addition, Princeton is entirely within the "review zone" of the Delaware and Raritan Canal Commission – a state agency that reviews and regulates development affecting the Canal State Park. All water courses that enter the canal are subject to the commission's regulations on stream corridors, impervious cover, stormwater management, and other influences on the environment. As state regulations, they take precedence over less-restrictive local ordinances.[31]

The dispersed nature of water management at the municipal level is a good argument for an integrated water plan. That's just one of several recommendations from Sustainable Jersey, a statewide collaboration that recommends and certifies best practices at the community level. Princeton has already earned Sustainable Jersey's "Silver" status.

A new set of "gold" standards has just been unveiled for water issues. This would involve taking some or all of the following actions:

- Green Infrastructure Planning and Implementation
- Enhanced Stormwater Management through an ordinance, mapping, monitoring, and maintenance
- Water Conservation Education and ordinance
- Forestry Management Plan
- Integrated Water Planning
- Restoring and Protecting Groundwater Recharge
- Volunteer water monitoring
- Riparian Buffer Area Ordinance
- Winter road salt management
- Watershed-wide stream restoration

Knowing our Water Story is the first step. Formulating an overall water strategy is the next. And with enough momentum, Princeton could be the first Jersey municipality to achieve Water Gold.

[31] From the Princeton ERI, p. 49.

Regional Collaboration

Individual municipalities can't just push their water problems downstream, nor can they make water plans in isolation. Watershed boundaries are typically not used as the basis for water protection legislation, so collaboration both upstream and downstream is essential to protecting any water resources.[32]

Fortunately, a number of successful collaborations already exist. Invaluable expertise in water and other environmental matters is provided by independent nonprofits such as:

- Sustainable Jersey which was the catalyst for this water story
- The Watershed Institute, with a host of activities at the individual, educational, and policy levels
- Jersey Water Works, which addresses water infrastructure issues
- Association of NJ Environmental Commissions
- Alliance for NJ Environmental Education
- The NJ Sustainable Business Council
- and so many more.

Some of these nonprofits are hosted or supported by research institutions based in higher education.

There is also the largely untapped potential for crowdsourcing solutions. Crowdsourcing can help raise public awareness of our daily interaction with water. Organizations involved in water quality testing are already mobilizing an army of volunteers to enrich our database. On a local level, direct input from residents is also under consideration in a couple of ways:

- The Watershed Institute is working on an app that would allow anyone who comes across water they suspect is degraded to send a picture and some data to a centralized databank.
- Access Princeton, which years ago deployed the SeeClickFix app to alert officials of problems on the streets, could enlarge the scope of its use to include reporting on storm and flooding events.

---

[32] Upstream from Princeton, the Millstone River and Stony Brook flow through the following counties and towns:

- Millstone
  - Monmouth County: Millstone Township
  - Middlesex County: Monroe Township
  - Mercer County: East Windsor, West Windsor, Princeton
- Stony Brook
  - Hunterdon County: Amwell
  - Mercer County: Hopewell Township, Lawrence Township, Princeton

Individual Participation

Some of Princeton's most innovative ecological projects have sprung up from the grassroots, so to speak. Take for example the Eco-Lab at Princeton High School, an idea fostered by long-time environmentalist Stephen Hiltner to teach kids good environmental practices.

There are many other ways to participate as individuals. Anyone can contribute to good planning and policies through:

- Civic participation. Most of the commissions and nonprofits involved in sustainability work in Princeton rely on the dedication of citizens, often volunteers, sometimes retired experts in their field, to take on tasks ranging from citizen-scientist roles like water testing, to citizen oversight on boards and commissions.
- Education. Green infrastructure solutions such as rain gardens, rain barrels and porous pavements can be implemented at the level of the individual homeowner. Sustainable Princeton is one of several nonprofits that host occasional educational programs on these water-friendly options. Among the programs created to raise awareness of more environmentally-friendly gardening practices is the NJ River-Friendly Partnership, which offers certification in land stewardship, and the Rutgers Cooperative Extension's courses for Green Infrastructure Champions and Environmental Stewards. Jersey-Friendly Yards has given workshops on how to build a rain garden in as little as two days, for as little as $500.
- Awareness. New Jersey residents are fond of their lush green lawns, but largely unaware of the environmental impact of maintaining them. NJ has fairly strict laws regulating fertilizer use, but they are not well known, not enforced, and insufficient. Residents, and corporations, and landscapers need to be convinced of the urgency of preventing further seepage of harmful chemicals into our groundwater.

Who owns the water?

In New Jersey, all natural waters are considered public trust resources, held and managed on behalf of the public (including future generations) by the State. The State can allow people to use the water, through the water allocation process, but (unlike western states) those users don't "own" the water. Private owners may own the land underneath surface waters, but even then, as in the case of wetlands, the public retains a public trust ownership that allows transit, and prevents landowners from damaging the water resources (including the ecosystems), etc.[33]

We all own it. We all use it. We should all protect it.

Acknowledgements

This report benefited from the input of a wide range of experts in the field of water and environmental studies. I would like to thank the Rutgers Environmental Stewardship Program for introducing me to the fundamental science and supporting this as an internship project. Sustainable Princeton is a co-sponsor, and Sustainable Jersey is the instigator of the Water Story and Water Gold Standards.

I would also like to thank the following people for imparting their knowledge to this report: Michele Bakacs and Amy Rowe of the Rutgers Environmental Stewardship Program, Anne Heasly of Sustainable Jersey, Jenny Ludmer, Molly Jones and Christine Symington of Sustainable Princeton, Sophie Glovier and Zenon Tech-Czarny of the Princeton Environmental Commission, John Hasse of Rowan University's School of Earth and Environment, Deanna Stockton and Ian Baker of the Princeton Municipality's Engineering Department, Scott Baxter-Green of NJ American Water, Jennifer Feltis-Cortese of NJ DEP, Toni Pchola and Robert Kunert of the SBRSA, David Goldfarb of the Princeton Sewer Committee, Erin Stretz and Kory Kreiseder of the Watershed Institute, Dan Van Abs, who now teaches at Rutgers after devoting his career to water resource management in NJ, Kristen Thoft (architect), Natalie Shivers and Sean Gallagher of Princeton University, Stephen Hiltner, and a general tip of the hat to the many people across the state who are working selflessly to awaken the public to the importance of taking care of our natural world.

[33] Email exchange with Dan Van Abs, Princeton resident and Rutgers professor with an extensive and storied career in water resources management and public service. May 1, 2020.