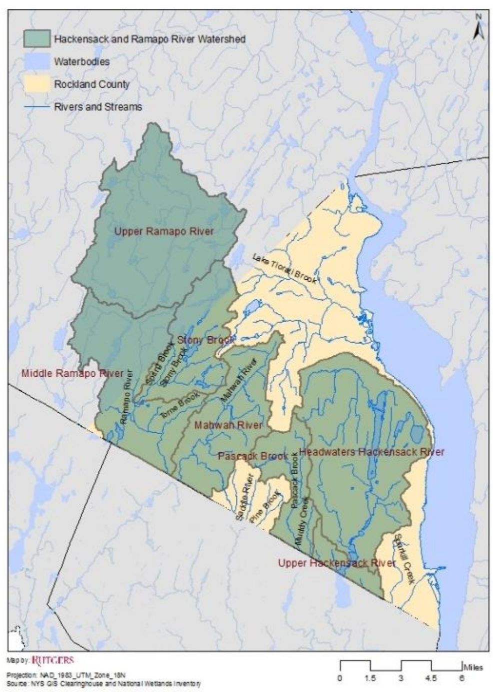
Preliminary Assessment of the Ramapo and Hackensack Watersheds in Rockland and Orange Counties



Prepared for the County of Rockland and the Rockland County Water Task Force

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Executive Summary and Recommendations

Rockland County is heavily dependent on three major water supply resources: bedrock wells in the Newark Basin formation; glacial valley-fill (or buried valley) aquifers along the Ramapo River and tributaries; and the Hackensack River with Lake DeForest. Each of these resources is subject to considerable stresses associated with land development, water quality concerns and changing precipitation patterns that can alter ground water recharge, stream flow patterns and the mobilization of contaminants. Rockland County will benefit from the development and implementation of watershed management plans for these two watersheds; the plans could also serve as the templates for additional plans to address the remainder of the county. The primary focus would be on issues related to water supplies (quantity and quality) but by necessity will also address issues of flooding and ecological needs that likely will affect water supply demands, constraints and availability over time.

The Ramapo River is a bi-county resource that becomes a bi-state resource. A watershed management plan must include consideration of watershed areas and resources in both Orange and Rockland Counties, and must address interstate issues related to flow and quality commitments to New Jersey. The aquifers are used by multiple water purveyors in both counties.

The Ramapo River contributes to water supplies in New Jersey. The Hackensack River also flows into New Jersey, raising similar interstate issues, but the headwaters are entirely within Rockland County and are the sole source of flow to Lake DeForest.

This report includes a preliminary assessment of readily available information to identify known critical issues, key missing information that must be developed in support of a complete watershed assessment, and a planning process that will result in plans that address the critical issues in a sound, science-based, implementable fashion. This preliminary assessment provides a solid foundation for development of a comprehensive watershed assessment and management plan in the two watersheds. As the project relies on readily available information, it is a low-cost effort compared to the comprehensive planning project. The report has a level of detail commensurate with the funding and schedule available, and so is not intended to be an exhaustive analysis but rather a focused effort that emphasizes the most critical issues.

Each component of the analysis identifies shortfalls in data, evaluation, modelling and assessment that should be addressed in a complete watershed assessment, and presents an approach for addressing these needs. The resulting recommendations are organized within a scope of work for the complete watershed assessment. Finally, a proposed watershed planning approach incorporates the watershed assessment process, an interested-party involvement process, and a planning methodology.

The primary findings of the Preliminary Assessment are:

- One major issue of the Ramapo River watershed is ongoing stresses to the Ramapo and Mahwah River buried valley aquifers regarding both flows and water quality, as the rivers are directly linked to the aquifers and the well fields draw much of their supplies from the rivers. The aquifers are fully allocated; optimization of management practices may marginally improve average yields, but this is primarily an operational issue for the water utilities.

- The Ramapo River watershed already is experiencing water quality degradation, and is subject to extensive development pressures in both Rockland and Orange Counties. Development will increase stormwater generation, water demands and wastewater generation, and also will reduce ground water recharge as soils are compacted and recharge areas are covered with impervious surfaces, all of which will add to existing stresses on both supply and quality of the water resources.

- The Hackensack River watershed is highly developed, and so the primary issues here are caused by existing land uses that have increased water pollution levels, degraded streams and their riparian areas, increased stormwater flows and reduced recharge. However, redevelopment and myriad small land use modifications can exacerbate these problems.

- Both watersheds are subject to minimum flow requirements at the New Jersey border. The State of New York is responsible for ensuring that these minimum flows are met, and does so through requirements of water allocation permits. These permits control the timing and volume of water supply withdrawals and releases from Lake DeForest. However, compliance with these requirements is more difficult as development alters stream flows, creating higher peak flows and lower dry-weather flows.

- The state is responsible for ensuring that water demands for any one water utility do not damage ecosystems or the water needs of others. The state is responsible for ensuring that wastewater treatment systems do not damage the water quality of streams or result in excessive transfer of water out of watersheds that have problems with stream flows. Finally, the state is responsible for determining how water quality can be improved to meet standards where they are currently not in compliance. In all three cases, the counties may advise and comment, but the state determines.

- There is no evidence that the combination of state, county and municipal land use regulations (e.g., zoning, subdivision ordinances, site plan ordinances, special ordinances) are sufficient to ensure that no further harm occurs to water resources in these watersheds. One reason may be the lack of clear technical evidence that specific new actions will achieve desired results.

- There is clear evidence that existing land uses are harming water resources, ranging from the development impacts noted above to the application of road salts in winter. In some cases, improved information will result in operational and behavioral changes by residents, businesses and governments that can mitigate impacts. In other cases, improved practices may need to be mandated by an appropriate level of government. As with land development regulation, better technical justification for these changes is needed.

- Multi-decade trends toward more intensive storms are placing more stress on stormwater management systems and exacerbating water quality impacts. These trends also tend to reduce stream flows during dry periods. Forecasts for climate changes suggest that more short-term droughts will also occur in the region, further exacerbating stream flow problems.

- Water demands have not increased despite rising population, and in fact have decreased somewhat both overall and on a per capita basis. Future population increases are projected, but also an overall aging of the county population. There are reasonable questions as to whether these factors will result in an increased or decreased water demand, and an increased or decreased summer demand when water supplies are most stressed. As with many water utilities, more aggressive reduction of water losses and improved water use efficiency and conservation can offset new metered demands. Again, the primary responsibility lies with the water utilities, but the nature, location and building standards applicable to new development and rehabilitation projects will have a significant effect on water demands.

- While water supply and wastewater treatment plants have been upgraded over time, the water supply, sewer and stormwater pipelines are largely the same age as the associated development. Over the next twenty years, much of this infrastructure will need to be rehabilitated, replaced or upgraded. Doing so will provide major benefits in terms of increased service life and utility efficiency, decreased water resource damages, and improved economic support, but will come at a major cost.

Recommendations

Funding for watershed management is limited and therefore should be targeted to those issues where the counties and municipalities have the greatest potential for effective action. For this reason, the counties should not focus on research or planning regarding aquifer yields, water supply operations, water supply infrastructure asset management, or wastewater discharge permits, as these are all clear functions of state government and the regulated utilities.

Rather, the most effective focus for further planning will be on several topics that can generate the technical foundation for action in both development regulation and the mitigation of harmful impacts from existing development. These actions should provide material benefits for water quality, aquifer recharge, stream flow and ecosystem protection, all of which will ultimately reduce future risks to and potentially enhance water supply quantity and quality without interfering with state regulatory roles. The first three projects are low-cost efforts that could result in significant benefits over time. The final three projects are more expensive but will provide sophisticated information in support of development, redevelopment and restoration requirements and projects. Important to note is that much planning in this field will benefit from or require updating of prior analyses that are now out-of-date due to continued development, new population data, etc.

All six projects will benefit greatly from involvement of the Rockland County Water Task Force and a broad spectrum of public interests, public leaders, volunteer experts and private interests. Because watershed management involves a public trust resource (water) and the management of myriad land uses and pollutant sources, it is uniquely dependent upon an engaged and willing public to understand the issues, consider alternative management approaches, and engage in protective actions. Traditional public participation approaches tend to work poorly or even generate opposition, such as public hearing or comment periods after a plan has already been developed. In this case, it is important for major interests to understand and participate in how and why the project is framed in a specific manner, so that they can better rely on the results. The projects should routinely “touch base” with the public so that the chain of information and logic is clear, and a trust is developed in moving from scope of work through information generation, analysis, evaluation of alternatives and conclusion, all with good opportunities for public engagement, not just reaction.

- Project 1: Road Salt Management. The evidence is clear that surface and ground water salinity levels have doubled, tripled or more since the 1960s, and that road salt is the culprit. This project would document the trends over time in road/lane miles, winter road salt applications, road salt applications per lane mile, and salinity levels, all using existing information and salt application data compiled from road maintenance departments. Areas with elevated salinity levels are priorities, especially where well fields are affected. The project would recommend and educate public elected officials and public works departments on specific practices that would reduce road salt levels without materially harming public safety. Such practices exist and are well known and applied in other areas. This project can be a county-wide effort, as salinity is increasing in all developed areas. **Anticipated Cost:** Minimal (likely less than $2000-$3000). The project can be conducted by existing county personnel if available, by college project studios or interns, or by part-time professional assistance. It also would be possible for a qualified non-governmental organization to undertake this project with a foundation or government grant, with county cooperation.

- **Project 2**: Assessment of Stream and Riparian Area Integrity. This project will use a combination of existing GIS data, remote sensing information (e.g., aerial photography) and field surveys to assess the integrity of stream channels and their associated riparian areas. Specific issues will be areas of stream channel disruption (e.g., scour, channelization), stream blockages (e.g., culverts, bridges, sediment areas), and riparian area losses and damages. Assessment methods similar to the “Stream Visual Assessment Protocol” (Natural Resources Conservation Service, 1998) or “Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State” (NYSDEC, 2014) can be used. The purpose of this project is to identify areas for protection, for site-specific restoration (e.g., through control of stormwater outfalls that are scouring a stream), for bridge culvert modifications as a co-benefit of bridge reconstruction projects, for reach- or subwatershed-level control of stormwater inputs to reduce channel erosion, and for large-scale restoration projects including dam removals. This project can be conducted in multiple phases, starting with county-wide GIS-based analyses and then watershed or subwatershed field investigations. The purpose of this project is development of plans that will lead to governmental and non-governmental projects to improve stream ecosystems, using local, state and federal funds, foundation grants, private sector contributions, natural resource damage funds, etc. **Anticipated Cost**: The initial GIS phase could readily be accomplished by county GIS staff if available, or by GIS consultants or qualified GIS students with assistance from Cornell Cooperative Extension (Soil and Water Conservation Districts), likely requiring between two and three weeks of work. The field analyses require professional assistance, with costs dependent on whether done in-house (days per subwatershed) or using consultants (perhaps $5,000 per HUC12 subwatershed). Costs might be reduced through the use of trained volunteers, a "citizen science" approach. Analysis of the results will require on the order of two weeks of professional time (60-80 hours) at in-house or consultant rates.

- **Project 3:** <u>Recharge Loss Evaluation</u>. This project will provide a preliminary analysis of recharge losses due to development at the subwatershed level, using a combination of GIS analysis of impervious cover, county surveys of stormwater outfalls, GIS analysis of likely storm sewer networks based on topographic evaluations (especially if LiDAR mapping is available), and simple ground water models. The project purpose is to identify the general extent of recharge losses by subwatershed, as a basis for municipal or county regulation of future development (e.g., requiring that post-construction recharge equal pre-construction recharge) and redevelopment (e.g., requiring restoration of some portion of lost recharge from the initial development). This project will also be useful in identifying stormwater basins that could be retrofit to provide recharge in addition to detention or retention, which will also provide potential water quality and flood reduction benefits. **Anticipated Cost:** The project can readily be accomplished with county GIS staff if available, or a graduate student with GIS expertise, with perhaps three to four weeks of effort. The project could rely on existing GIS data, reflecting recharge losses to a point in time, but would benefit by updated mapping of impervious surfaces at an additional cost. Another option is to engage a graduate student to undertake this project as the basis for a master's thesis in hydrogeology.

- **Project 4:** <u>Subwatershed Water Quality Plans for Nonpoint Source Pollution</u>. This project would focus on specific subwatersheds to identify the primary sources of pollutants identified through NYSDEC and county stream monitoring programs. Initially, we recommend a focus on two subwatersheds. One would be a Ramapo River subwatershed that is currently facing significant development pressures, as a method of improving land preservation, zoning and site design requirements for protection of the subwatershed. The other would be a Hackensack River subwatershed upstream of either Lake DeForest (for improvement of reservoir quality) or the Nyack water supply intake (for improvement of intake water quality). For each subwatershed, this project requires field monitoring of water quality during low flow and higher flow periods. Robust nonpoint source modeling will be developed, but not as sophisticated as a TMDL model for point source loadings. The plan would identify the major categories and locations of pollutant sources, and then recommend a combination of education, incentives, capital projects (e.g., stormwater system modifications), and regulatory requirements that will improve water quality. Runoff and stormwater pollutant reductions, reductions in pollutant generation from stream erosion (through stream restoration and the reduction of stormwater peak flows that cause scour) and base-flow augmentation (through increased stream base flows, not reservoir releases) can all be considered.

The purpose of this project is development of plans that will reduce pollutant and flow stresses on water supply streams and that are eligible for state and federal implementation funding, along with other funding sources. **Anticipated Cost:** Each subwatershed plan is likely to cost $150,000 to $300,000 depending on the level of water quality and flow monitoring costs involved to generate the model. The project can be implemented in phases, such as with development of a conceptual model, monitoring plan and monitoring implementation, and technical report as the first phase, and development of the management plan as the second phase. Public participation would occur throughout. For best results, updates to GIS information on land use/land cover, impervious surfaces, etc., would be developed as an additional cost.

- **Project 5:** <u>Stormwater Infrastructure Asset Management Evaluation</u>. Stormwater systems are shifting in function, from quick removal and discharge (regardless of stream damages) to a more integrated approach. No fee-based stormwater utilities exist in this region. Stormwater management functions are distributed among state agencies (e.g., NYSDEC and the Thruway Authority), counties (e.g., development review involving county-regulated streams, stormwater systems for county roads and facilities), municipalities (e.g., land development review, municipal separate storm sewer systems, or MS4s, for municipal roads and facilities) and property owners for on-site stormwater systems. This project will identify the location, design, current condition and functionality of stormwater infrastructure, and its impact on water resources; it will then identify infrastructure components that are inadequate for modern functions (e.g., insufficient design capacity, excessive discharge rates), degraded, or causing environmental harm. The purpose of this project is development of plans that will reduce pollutant and flow stresses on streams and that are eligible for property owner, municipal, county, state and federal implementation funding. The project would build on the ongoing efforts of the Rockland Soil and Water Conservation District. Given the complexity of this analysis, we recommend focusing on specific subwatersheds where problems have been identified under Project 2, or on the priority subwatersheds under Project 4. **Anticipated Cost:** Total effort for this project in the two watersheds is likely to require up to two work-years of professional effort spread across multiple governmental entities, with county GIS staff involvement and a county coordinator. We recognize that additional staffing may be required to implement this project at the county level. Some portions of the work can be outsourced to consultants, particularly field inspections of infrastructure integrity, but most of the information that needs to be compiled will be in county and municipal government files, such as system designs.

- **Project 6:** <u>Sewer Infrastructure Asset Management Evaluation</u>. The USGS estimates that 0.8 MGD of ground water is moving into sewers, diluting wastewater, increasing treatment costs, and reducing stream flows. Given that aging infrastructure will cause these problems to increase over time, implementation of an ongoing asset management program will help reduce (though not eliminate) infiltration and inflow, minimize the potential for sewer line failure, etc. This work involves an inventory of all wastewater utility assets, assessment of asset integrity, and a planned program of rehabilitation using cost-effective techniques. **Anticipated Cost:** As this should be a normal function of wastewater utilities, this work is viewed a responsibility of the utilities and not an appropriate use of watershed management planning funds.

I. Preliminary Assessment Overview

The preliminary assessment is based upon a compilation, summarization and assessment of relevant studies and available information as identified by the study team and as advised by Rockland County. Ongoing or proposed studies are discussed, such as the aquifer modelling process for the Ramapo Valley Aquifer. Mapped information has been complied in GIS where feasible. Major findings from the report are presented here in narrative summary without technical material or references. The following sections provide more detail and full citations.

Land Uses, Land Cover and Land Alteration

The Ramapo and Hackensack river watersheds are a study in contrasts, with the largest land use in the Ramapo being parks (83 percent) and the largest land use in the Hackensack being residential (41 percent). However, increasing development pressures in the Ramapo watershed are pointing to a reduction in this contrast. Development is spilling west along the New York State Thruway. Agriculture, once the dominant land use in the area, is no longer a significant land use.

The land development has significantly altered the extent of impervious surfaces. Municipal and county plans call for protection of open spaces and environmentally sensitive areas, but a combination of zoning, development regulations and variances appear to continue favoring ongoing greenfield development. Residential development, and specifically single-family residential, is the most common zoned land use in the area. It is interesting to note that even large preserved lands in the Ramapo watershed are zoned residential. Low-density residential zoning is often favored as a method of reducing impacts, but actually encourages sprawl and dissection of forested areas. Some municipalities have protections for critical areas through special zoning codes and overlays.

Rockland County conducted a build-out analysis in 2010 that estimated the potential for 17,000 additional housing units based on existing zoning and development codes, or roughly 50,000 people, with more in the relatively undeveloped Ramapo watershed than in the heavily developed Hackensack watershed.

Geology, Hydrography, Hydrology and Geography

Rockland County's location along the estuarine Hudson River presents major limitations on water supply, as most of its streams are headwaters streams or are small watersheds that drain directly to the Hudson; in both cases they lack sufficient ground water storage and stream flow to support extensive supplies. Only Lake DeForest on the Hackensack is of any size (5.6 billion gallons, BG), and even that reservoir is small relative to others nearby, such as the New York City Catskill reservoirs (ranging from 17.6 BG to 140 BG) or the Wanaque Reservoir (29 BG) in New Jersey. Further complicating this issue is the bi-state nature of the Hackensack River, where minimum flows must be met at the New Jersey border. Monitoring by the U.S. Geological Survey (USGS) is used to ensure these flows.

Even the Ramapo River and its associated aquifer are limited; though the headwaters are in Orange County, the river is relatively small upon entry to Rockland County. Aquifer supplies throughout Rockland County are limited by storage capacity (especially the Highlands region to the west and the Palisades diabase sill to the east), by direct aquifer connections to river flows in the buried valley aquifers, and by quality concerns in some areas.

The Ramapo and Mahwah buried valley aquifers are the most prolific aquifers in Rockland County and both appear to be fully allocated; the Mahwah may be overallocated based on stream flow impacts. In the Ramapo aquifer, over half of the well water is derived from river flows. In both cases, river flows have been reduced by aquifer pumping, which has interstate implications because river flows into New Jersey must be kept at or above specific levels. These rivers are routinely monitored by the USGS. The direct connection between the aquifers and the overlying rivers has significant implications for aquifer water quality, as well, given that water from the rivers is induced to flow into the aquifers. Suez-NY has begun development of a model for these buried valley aquifers. The scope of work for this project has been requested, so that the scope of work for further watershed planning will avoid duplication of effort and create optimum results.

The Newark Basin wells are in some cases prolific but in many cases of lower capacity than the buried valley aquifers, due to lower aquifer storage capacity in rock fractures than is possible in stratified sand and gravel deposits of the buried valleys. Roughly one-third of Rockland County's water is from this aquifer system. It is important to note that while the geologic structure is regional, the water for each well is comprised of recharge from nearby areas; the aquifer does not operate as a single system, but rather as a collection of somewhat interconnected systems. USGS research indicates that most of the Newark Basin wells show significant seasonal changes in level but generally are replenished in the non-growing season. However, they are sensitive to severe droughts and some wells must be taken offline during dry years. According to recent studies, only very limited additional supplies may be available from the Newark Basin. Portions of the Newark Basin have very limited storage capacity, and so streams in these areas can go dry during droughts, as the water table level falls below the stream bottoms. Where intensive well pumping occurs, these effects are seen more readily. Further, most water from the Newark Basin is used once and discharged to the Hudson River, allowing no reuse, and in addition the flow of ground water into sewer lines results in increased water losses to the aquifer.

Both the buried valley aquifers and the Newark Basin aquifers are close to the land surface and therefore at risk from pollution sources, including septic systems, leakage from sewer lines where they are located above the water table level, industrial sources, and increasing levels of salt from winter road salting are a concern in this region. Additional attention is needed to source water protection, a form of watershed protection specifically oriented to protection of water supplies through risk assessment and management. Governments need to recognize that public safety can damage public health, and so should use methods (such as the use of salt brine) that can greatly reduce road salt usage. In sum, it should be clear that **throughout the two counties the ground and surface waters are inextricably linked for both water quantity and quality issues – damaging one will damage the other in time**.

Topography has major implications for watershed management. The areas of highest topographic relief are in the Highlands region, much of which has been preserved. The Highlands area also has the greatest precipitation, nearly 10 inches greater than south-eastern Rockland County, which generates additional stream flow. The remainder of Rockland County and much of the Ramapo watershed in Orange County have more limited topographic relief, which (along with small watershed size) has limited the potential for major reservoirs. Historically, little development occurred in high-slope areas, but this is changing with increased development pressures and land values. One implication is that increased impervious surfaces and reduced forests in high-slope areas results in major increases in stormwater runoff and reduced stream water quality. The result is flashier streams (higher high flows and lower low flows) as identified by USGS, along with increased potential for downstream flooding and for harm to the buried valley aquifers as contaminated surface water is drawn into the aquifers. The Ramapo River at Suffern has the highest index of flashiness, among streams with flow monitoring. Municipal regulation of development on steep slopes is often inadequate, starting at a very high slope (25 percent), or completely lacking.

Stream channel and riparian area integrity are also critical to the proper functions of streams as ecosystems, flood regulation areas and water quality buffers. While the Rockland County stream regulations provide important benefits, they apply only to county-regulated streams. Similar regulations are needed to address all streams in both counties, including the smallest (first and second order) streams; these provide critical flow and quality functions, can comprise half of the total stream miles in many watersheds, and are often ignored as too small to be worthy of protection. In many cases, existing culverts and bridges were designed to address transportation needs, not the integrity of the streams that flow through and under them. These flow restrictions can have major ecological and flood-flow impacts that should be addressed over time, ideally when major reconstruction projects are needed on the overall structure, so as to reduce net costs. Likewise, dams exist in many areas, some of which no longer have any economic or recreational function. Dams damage stream flow regimes, increase stream temperature as the ponded water heats, and bar fish passage. A national movement focuses on elimination of dysfunctional or derelict dams, funded in part by the National Oceanic and Atmospheric Administration (NOAA) to improve stocks of anadromous fish. Rockland and Orange Counties could improve streams by cooperating in high-priority dam removal projects. Finally, wetlands and floodplains provide critical benefits regarding flood damage reductions and ecosystem support. Where these have been compromised in the past, human safety and property are imperiled.

Two additional issues related to both past and future development are the loss of ground water recharge and the increase in total stormwater generation due to increased impervious surfaces. Only recently have stormwater regulations in New Jersey and some other areas required maintenance of pre-development recharge rates. Very few areas nationally require that total stormwater volume leaving a site be no greater than pre-development volumes; most regulations focus on the rate of stormwater discharge rather than the total volume discharged. In both cases, these issues have downstream implications. Reduced recharge results in lower base flows of streams (stream flow during dry periods, which comes from ground water moving into the stream) and increased flooding wherever a stream encounters a flat area or flow impediment (e.g., bridge or culvert). Obviously, even new regulations to address these issues would apply only to new development or redevelopment, and not to existing development that has already impaired ground water and stream flow regimes.

All of these concerns will be compounded by a multi-decade trend toward more intensive storms; the region including Rockland and Orange Counties is seeing a higher percentage of total precipitation coming from intense storms, an increase of roughly 70 percent. This trend reduces the percentage of precipitation that becomes ground water recharge, because the rainfall happens too fast for soils to absorb and infiltrate the water, and therefore greater runoff is created, exacerbating flood potential. Meanwhile, increasing air temperatures will increase evapotranspiration (movement of water to the air from surfaces and plants), which reduces stream flows during summer months especially. Finally, the potential for short but severe droughts is forecast to increase. As a result, streams are likely to become even flashier, and low flows during summer months are likely to be more pronounced. Given the requirements for flow maintenance in the Ramapo and Hackensack rivers, these trends have the potential to reduce water availability for Rockland and Orange Counties. While the trend is clear, the magnitude is not yet clear and has not been modelled for this area.

Watershed-based stormwater and flood management models would provide an improved basis for management both new and existing development, regarding stormwater flows, channel protection, targeted dam removal or modification, flood damage reduction (e.g., identifying repetitive loss properties that could be targeted for transition to park lands), and land alteration within the floodplains, riparian areas and stream channels. Given the largely developed nature of Rockland County, restoration will be as or more important than regulation of new development, depending on the watershed involved. In Orange County and parts of western Rockland County, new development may be of greater concern. As a valuable adjunct, creation of a ground water recharge mapping methodology would help both counties understand which land areas contribute the greatest percentage of recharge and so should be preferentially protected. A recharge mapping methodology exists for New Jersey and is being used for regulatory purposes in the New Jersey Highlands region; it could be adapted for New York use.

It has been said that demography is destiny. Rockland County is both aging and growing. Of the five towns, Ramapo shows the greatest total growth and rate of change from 2000 to 2015. This growth adds to pressures on ground water recharge, stream flow regimes, stream structure integrity, flooding potential, water demands and water quality. As such, a focus on the most highly affected watersheds or subwatersheds in that area of Rockland County, and perhaps in Orange County as well, would be a high priority for addressing future concerns from development, as this area also has the largest areas potential available for new development.

A basic premise of watershed management is that no public or private interest has the right to damage public trust resources such as water, and that all governments have the responsibility of ensuring that water resources are provided to future generations in sound condition. Lack of knowledge in the past has resulted in existing damages, but most aspects of watershed management are now well understood and capable of being modelled in detail. **There is no excuse for additional watershed damages, as most negative consequences of new land development can be avoided, and what can't be avoided can be mitigated through improvement of existing degradation.**

Water Supply Availability and Demands

Within the Suez-NY system, Lake DeForest provides approximately 32 percent of water supplied each year, the Ramapo Valley Well Field provides 25 percent and the remaining system wells (e.g., Mahwah River well field and Newark Basin wells) provide 43 percent. Total water supplies for Suez-NY are currently calculated at 34.5 MGD (million gallons per day). All other water supply systems in the area (e.g., Suffern, Nyack) are small at roughly 2 MGD or less.

As discussed above, the Ramapo and Mahwah buried valley aquifers are considered fully allocated and rely heavily upon stream flow as a source of induced supply. In both cases, operational changes may provide limited supply benefits. The most recent model dates to 1982, and so an updated model using modern techniques and current information may provide new options; Suez-NY has begun work on such a model, but the detailed scope of work is not yet available. Minimum flows to New Jersey have been guaranteed for both rivers. The Newark Basin aquifer systems may have potential for 2-3 MGD of additional supply, which is being further evaluated by Suez-NY. Lake DeForest is also fully allocated, with 10 MGD for Rockland County through Suez-NY, and must provide flow to the Hackensack River supporting the Village of Nyack along with required flows to New Jersey. The three Letchworth Reservoirs have a very small capacity and extremely limited safe yield.

Average demand in the Suez-NY system was 29.4 MGD from 2000 to 2009, but has fallen since then to roughly 28 MGD (July 2015 through June 2017), ranging from monthly lows of 24 MGD to highs of 34-35 MGD. Single-family residential demand accounts for three quarters of metered water demand. This user group also has the highest seasonality, driven by outdoor water uses. Even so, per household and per capita demands are not high from a regional or national perspective, perhaps reflecting the generally rainfall-rich nature of the climate, and have been declining from 67 gpcd (gallons per capita per day) to approximately 57 gpcd even as population has grown, resulting in flat demands overall. However, some households have much higher demands. Some towns, notably Orangetown, Clarkstown, and Stony Point, have greater summer increases than Ramapo and Haverstraw.

Industrial demands are low and declining to 4 percent of metered demands, with little expectation of future increases. Commercial demands are 21 percent of metered demands and are likely to track residential demand, as the commercial sector includes government uses, schools, employment centers and retail support services, all of which are closely associated with population. Finally, water losses are roughly 20 percent of all system production, some of which are "real" (e.g., leaks) and others are "apparent" (e.g., accounting and meter errors, water theft). While no system is perfect, and at some point improvements are cost-prohibitive, improvements are possible here. New Jersey results from a recent study indicate that well-run systems in the northern part of the state, with similar geology and development patterns, achieve 15 percent total water losses.

Increasing air temperatures and the concentration of rainfall in more severe storm events may increase demand for lawn irrigation water during summer months, which is also when both aquifers and stream flows are most stressed. An increasing potential for short but severe droughts also would exacerbate outdoor water demands. Increasing temperatures and low stream flows will also increase the potential for algal blooms, affecting water supply quality. Therefore, changing conditions merit caution regarding the quantity and quality of water supplies into the future, and should be monitored and modeled.

Water Quality

Water quality in surface water is regulated through the federal Clean Water Act and analogous state legislation. Ground water quality is regulated through state legislation, primarily. Where surface water quality does not meet standards, a water quality plan is required to determine how standards should be met if existing regulatory actions are insufficient. (These plans are known as Nine Element Watershed Plans or Total Maximum Daily Loads, TMDLs, depending on their purpose). Where wastewater treatment facilities are a cause, changes to their SPDES permit discharge requirements must be made to comply with the water quality plan. Most wastewater treatment plants in Rockland County discharge to the Hudson, but several systems discharge to the Ramapo watershed, both providing replenishment of stream flow and introducing pollutants that can degrade ground water quality. Of the latter, the Suffern Sewage Treatment Plan has a history of non-compliance with their SPDES permit, and the Kiryas Joel WWTP likewise has been identified as a potential non-compliance issue. The Orange County Sewer District #1 was upgraded in the 1980s, providing improved river quality, but recently proposed an expansion that raises potential water quality issues for downstream water withdrawals from the Ramapo aquifer. Nonpoint sources are not regulated in the same manner, nor are stormwater outfalls (which are legally point sources but get most of their pollutants from land runoff and other nonpoint sources). These nonpoint sources and stormwater outfalls are the major source of pollutants in the many streams that have no major point sources, and are at least a significant pollutant source in all streams.

Streams and lakes in many areas of Ramapo and Orange Counties are identified as not meeting surface water quality standards by the NY State Department of Environmental Conservation (NYSDEC) due to chemical contamination (e.g., salinity and phosphorus, a nutrient), pathogens, sediments, low oxygen, algal blooms, and biological impairments. Stormwater runoff, industrial and municipal discharges and salt (sodium chloride) used for deicing have been implicated in the impairment of rivers, streams and waterbodies. Salinity from road salts has been rising rapidly across the area, doubling or tripling since the 1960s. Biological integrity has generally been decreasing or, at best, stable in most of the area; the Hackensack watershed shows the greatest reduction in biological integrity, which correlates with the high level of development and associated stormwater generation. Few assessed waters were deemed unimpaired, while a number of waters have not been assessed.

Ground water quality has exhibited similar problems with sodium chloride (especially near major road systems), and a significant number of private wells tested positive for indicators of pathogenic bacteria. Industrial contaminants such as solvents have been found in private wells, observation wells and public wells. Nitrates, which are highly mobile in ground water, have also been found but less than when Rockland County was more agricultural. Finally, a number of contaminated sites threaten or have contaminated ground water in the area, and also may contaminate surface water due to the direct linkage of the two resources.

Water quality in drinking water is regulated by the federal Safe Drinking Water Act and analogous state legislation. Maximum Contaminant Levels (MCLs) apply to public water supply systems, which are deemed “public” based on the user population, not the system’s ownership. MCL violations are not a major issue for public water supplies in the area, but increasing ground and surface water contamination can increase the risk of treatment failure, necessitating more robust treatment systems.

Ecological Resources

River, streams and lakes are important not only for human use but for ecosystems, and these features and ecosystems provide significant benefits for society in the form of flood damage reduction, water quality improvements, flow regulation and habitat. Natural Heritage Areas exist in both watersheds, but to a much larger extent in the Ramapo.

The Ramapo watershed has a large preserved area, representing nearly 70 percent of its total lands. Conversely, the Hackensack watershed is heavily developed with only 10 percent preserved lands. Development pressures in the Ramapo are focused in a relatively small area that is closely associated with the watershed’s water supplies and critical habitats, and so requires careful protection and land use management to ensure continued viability of these resources. This issue is especially critical in the New York State Thruway, Route 17 and Harriman areas. In the Hackensack watershed, redevelopment activity will be more common, but the remaining ecological values can be even more heavily stressed if not protected and, where feasible, restored. Much of the riparian area along the Hackensack River and its tributaries have been altered or lost, and most of the remaining riparian areas are under threat.

Alterations, restrictions and loss of stream flow can have major harmful effects on stream ecosystems, whether from dams, culverts, bridges, well pumping, or increasing stormwater flows. The needs of ecosystems should be incorporated into modeling, planning and regulatory actions associated with watershed management.

Water Infrastructure

Nearly all residents and businesses in Rockland County and the Ramapo watershed portion of Orange County are served by public water supply and wastewater systems, whether government-owned (the norm for sewers), investor-owned (the norm for water supply) or private entities. Relatively few use private wells and septic systems, even though the numbers sound large, at perhaps 6,000 to 8,000 residents in Rockland County.

The public systems are supported by water supply and wastewater treatment plants that must meet state and federal requirements for drinking water and wastewater effluent quality, respectively. Because many of the wastewater treatment plants discharge to the Hudson estuary, large volumes of drinking water (nearly 15 MGD, over half of the Suez-NY water demand) are removed from the natural systems and discharged to saline waters such that the effluent serves no additional water supply or stream flow augmentation purpose. On the other hand, increasing capacity of wastewater treatment plants discharging to the Ramapo River may maintain flows but also introduce pollutants. The Suffern Wastewater Treatment Plant and the Western Ramapo Advanced Wastewater treatment plant discharge to streams identified as impaired; more stringent effluent limits may be required in the future to address those issues.

The utilities also have extensive pipeline systems for distribution of drinking water and collection of sewage; Suez-NY alone has over 1,000 miles of water pipelines. Inevitably, these lines leak at least somewhat. Drinking water pipelines leak out to the ground (wasting treated water), while sewer lines may leak out (exfiltration, estimated at 0.8 MGD, which can contaminate ground and surface water) or in (inflow and infiltration, I&I, especially where the water table is high, which increases flows to the treatment plant). As physical systems, these pipelines lose integrity over time, and over time will lose integrity at an accelerating rate. Given that many sewer lines lead to Hudson River discharges, this increasing loss of water to I&I exacerbates aquifer and stream flow stresses. The only alternative is to invest in system maintenance, rehabilitation and replacement, which slow and reverse system degradation. As much of the development in Rockland County occurred during the 1960s and 1970s, many of the pipelines are nearing or reaching their average economic lifespan (i.e., the age where the cost of maintenance on average exceeds the cost of rehabilitation or replacement). Treatment plants generally need major rehabilitation at roughly 30 years.

Stormwater systems were created during the development process as well. Unlike drinking water and sewer systems, which are continuous and integrated systems, stormwater systems generally are highly localized. One town may have many hundreds of stormwater discharges, each associated with a small collection system. Most of these systems were constructed based on older regulations that did not address modern concerns for the rate or volume of stormwater discharge, and certainly not for recharge rates; instead, the concept for decades was removal of stormwater from the development site and rapid discharge to the stream system. In addition, these systems were not designed for the current pattern of intense storms, and so are more likely to flood than their designs anticipated. Finally, stormwater system maintenance is generally conducted only in reaction to problems, not for prevention. Rockland County is working with its municipalities to map and understand the current system of stormwater facilities, which will be valuable in developing watershed management plans.

II. Land Uses, Land Cover, and Land Alteration

The distribution of types of ecological communities coupled with human activities on land has a direct effect on waterways. An analysis of land use and land cover helps to guide and inform where improvements to the watershed can be made. The Multi-Resolution Land Characteristics consortium, a partnership of several Federal agencies, has tracked land cover in the US since 1999, which led to the release of the National Land Cover Database in 2001. This partnership stemmed from the US Geological Survey's work which has maintained land use and land cover (LULC) data since the late 1960s. The latest release from 2011 informs much of the data covered in this section. Parcel data from Rockland and Orange County Planning Departments provides localized land use information. Other sources include Heisig (2010) and municipal and county comprehensive plans (Town of Clarkstown, 2009; Town of Ramapo, NY, 2004; Vanderhoef & Cornell, 2011).

Land use history, current status and trends

Enormous population growth and changes in transportation, housing, and employment over the last 100 years has, as in many areas near major metropolitan centers, led to large areas of suburban development covered with single family houses. As development spread across the country, citizens began to urge preservation of tracts of forest. The Hackensack and the Ramapo watersheds are on either end of the preservation/development spectrum. The largest land use in the Ramapo watershed is preserved parkland largely comprised of Harriman State Park and portions of Sterling Forest. The largest portion of the Hackensack watershed is single family housing.

History

Historically, land use in the watershed was mainly agricultural, with pockets of commerce centered in villages, industry and manufacturing. There were several quarries in both the Hackensack and Ramapo watersheds and Rockland Lake was the source of ice for the largest ice company in New York, the Knickerbocker Ice Company (Diana, Pillmeier, & Church, 2010; Town of Clarkstown, 2009, p. 13). Large portions of the Ramapo watershed were preserved in 1900 with the acquisition of Harriman State Park. In 1955, the New York State Thruway and the Tappan Zee Bridge, a major connector across the Hudson to Westchester County and New York City, opened. In 1961, agriculture was the most common land use in Rockland County (**Figure II-1**), while residential development only comprised 14.2 percent of land (Ayer & Pauszek, 1963). In the post-war era and major improvements to road and bridge networks, land use changed rapidly with housing and commerce overtaking agriculture as the most common use of land, except for the large preserved parks. Land use data from the 1970s and 1980s shows significant increases in residential development, with only small pockets of agriculture remaining (**Figure II-2**, **Figure II-4**).

Current Land Use

Harriman State Forest and Sterling Forest together comprise almost 70,000 acres (83 percent) of the Ramapo watershed (**Figure II-3**, **Figure II-5**). The portions of the towns of Ramapo and Haverstraw in Rockland County and Tuxedo in Orange County that are within the watershed are largely composed of preserved state park. Little development has taken place in these state parks, though in Orange County, Tuxedo does own portions of both forests and there are pockets of development surrounded by the

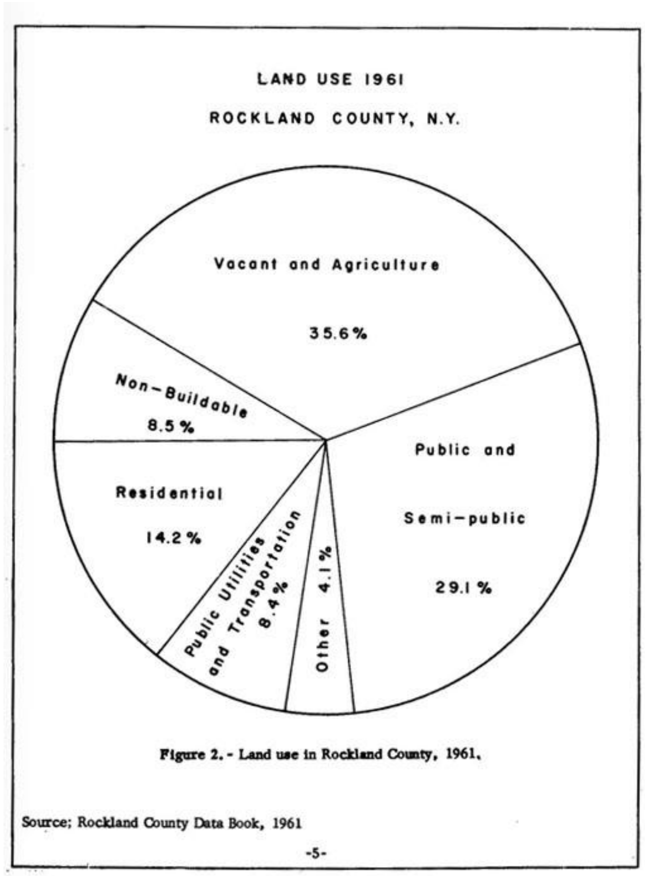
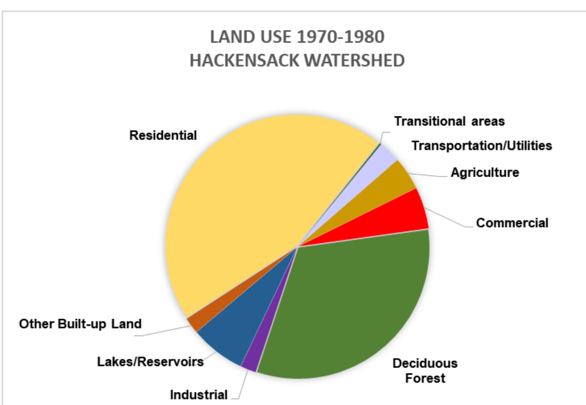


Figure II-1: Land Use in 1961 in Rockland County.
Source: (Ayer & Pauszek, 1963)



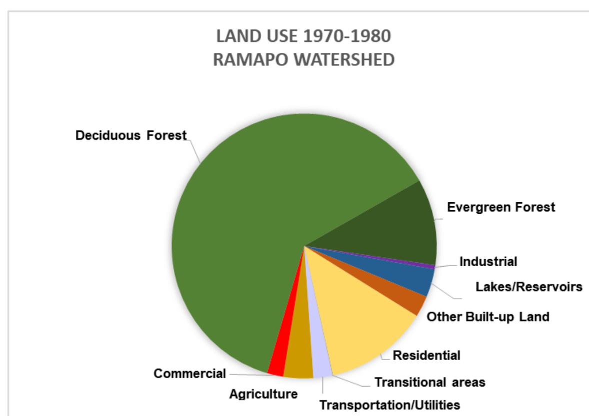


Figure II-2: Land Use in 1970-1980 in the Hackensack Ramapo watersheds.
Source: USGS

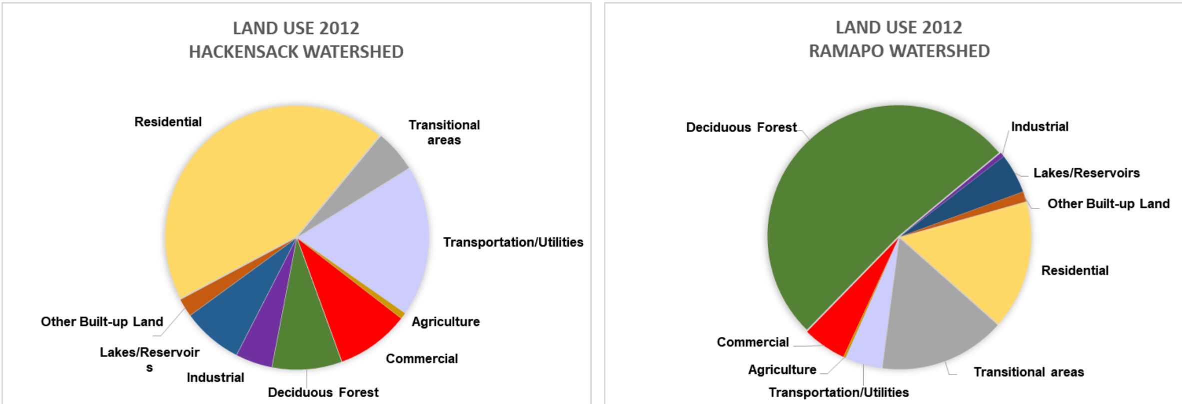


Figure II-3: Land Use in Hackensack and Ramapo watersheds, 2012.
Source: Rockland County Planning Department, Orange County GIS Division

park (Sonne, n.d.). On t he southeastern edge of the watershed, villages like Suffern and Hillburn have small dense centers of commerce and housing surrounded by large areas of single family houses. Towns with sprawling developments include Pomona and Montebello, and Wesley Hills in Rockland County. The New York State Thruway bisects a large portion of the watershed particularly at the western edge of Rockland County where this major highway, a train line, and the Ramapo cut through a narrow valley, the Ramapo Pass. The northern section of the watershed is comprised of large areas of single family housing in sections of Orange County, particularly Monroe, Kiryas Joel, and Woodbury (Vanderhoef & Cornell, 2011).

The Hackensack watershed is largely comprised of single family housing (41 percent) in Clarkstown and Orangetown, towns further comprised of numerous smaller hamlets. The watershed is divided through the middle (east to west) by the Thruway which supports sprawling commercial, industrial and institutional land uses, including the large regional shopping center, the Palisades Center Mall, which opened in 1998. Another major roadway which bisects the watershed from the southeast to the northwest, is the Palisades Parkway, though not considered a roadway by the county, but rather open space because it provides a connection to parks along its length (Vanderhoef & Cornell, 2011, p. 51). Preserved portions of the watershed include High Tor State Park and Rockland Lake State Park in the north and Hook Mountain State Park in the east. Village centers support more dense areas of commerce and housing, and there are pockets of industry, including two rock quarries, mainly near major rights of way. There is little undeveloped land in the watershed and most building efforts are aimed at redevelopment. Agricultural land use has almost disappeared from the watershed (1 percent) (Vanderhoef & Cornell, 2011).

Trends

Development of housing continues to be an ongoing pressure that is tempered by a recognition that water resources are valuable and need to be preserved. All municipalities' and counties' comprehensive plans discuss the need to develop and redevelop land in a manner that preserves water resources in the watershed. Reconstruction of the Tappan Zee Bridge (now Governor Mario M. Cuomo Bridge) will undoubtedly increase development pressures with improved travel and a potential for increased transit

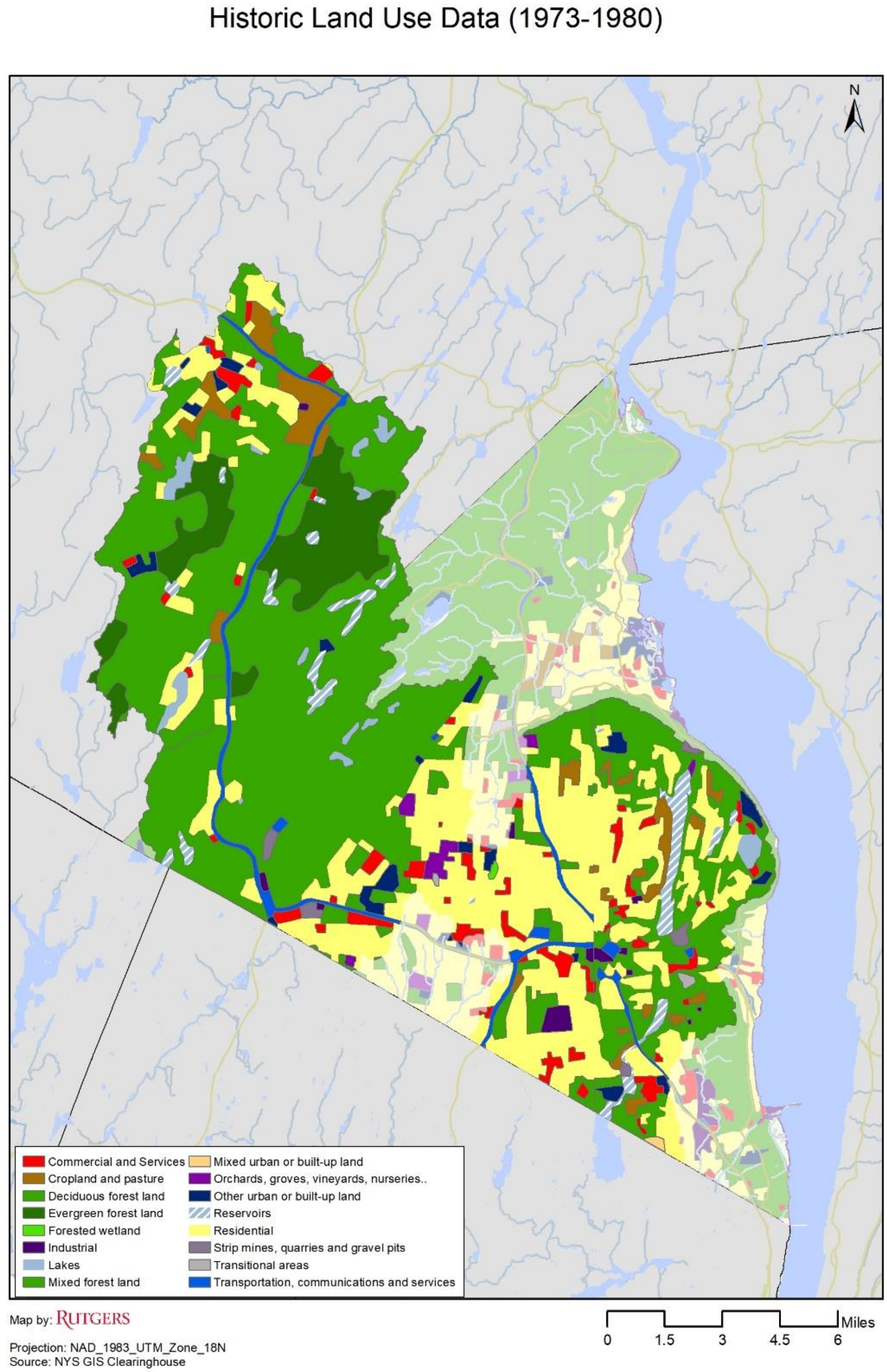


Figure II-4: Land use in the 1970 and 1980s compiled by USGS.
Source: NYS GIS Clearinghouse.

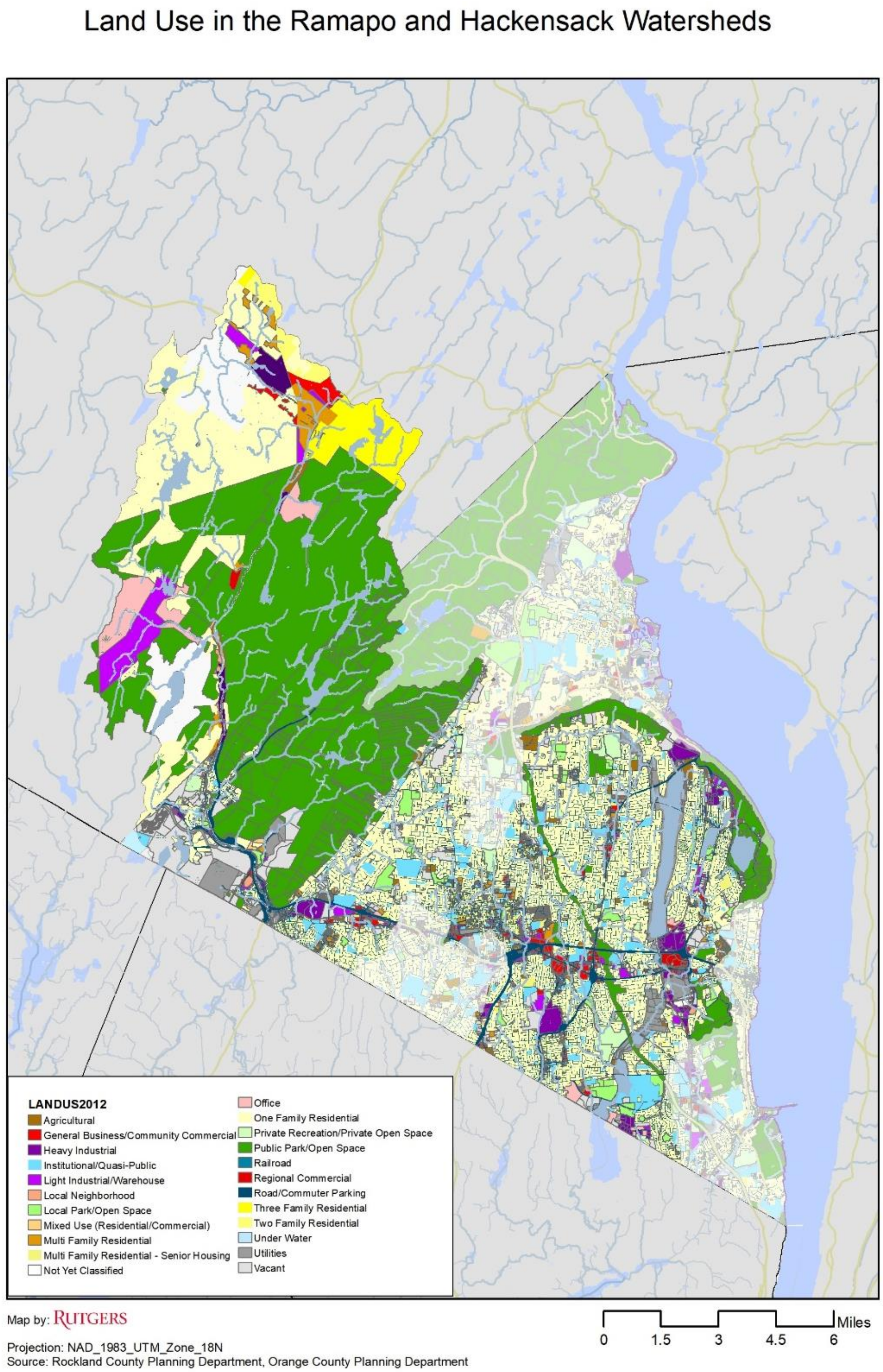


Figure II-5: Current (2012-2013) Land Use in the Ramapo and Hackensack watersheds compared to Rockland County as a whole.

Park land is the single largest land use, with single family housing as the next largest land use.

Source: Rockland County Planning Department, Orange County Planning Department to the region (Federal Highway Administration, 2012). Development projects have raised concerns in both watershed areas. In the Ramapo watershed, Patrick Farms in Ramapo, a 500-unit development to be built adjacent to the Mahwah headwaters on federally designated wetlands, was recently allowed to proceed following a court case brought by local residents (*Bodin v. Ramapo*, 2017). Buckley Farms, a 28 building, 200-unit development, and Schimpf Farm, a 7 building, 127-unit development in Clarkstown are planned to be adjacent to Demarest Kill and a tributary to Lake DeForest, respectively, and will require filling federally designated wetlands. Both are currently under review (Brooker Engineering & Emanuel, 2017).

Land cover history, current status and trends

Land cover is an assessment of the amount and type of developed or non-developed land an area. While these classifications are similar to land use, they delineate the type of ecosystem in the area, rather than solely human uses of the land.

History

Land cover changes over the century roughly correspond to land use changes. As above, historically, much of the land in the watersheds was agricultural with pockets of development centered in towns and villages (**Figure II-6**). Land acquired for state parks has been maintained or returned to forest, and changes in transportation, housing and employment has created large areas of developed land. A land cover map from the 1970s and 1980s show much of the Ramapo watershed is forest while significant portions of the Hackensack watershed have become developed. Small pockets of agriculture and wetlands make up the remaining portion of the watersheds.

Current Land Cover

Current land cover maps show large portions of the Hackensack watershed with development ranging from low to high density (**Figure II-7, Figure II-8**). The Ramapo is dominated by forest cover with significant building at the northern and southeastern edge of the watershed. The New York State Thruway is the spine that links areas of dense development. Agriculture has largely disappeared from the watershed area, and small portions of wetlands and barren land remain.

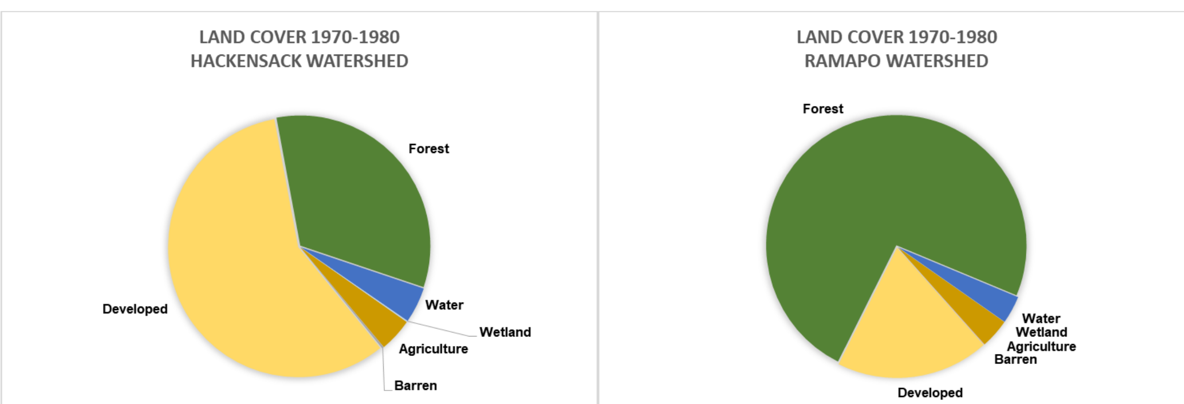


Figure II-6: Historic Land Cover, 1970-1980.
Source: USGS

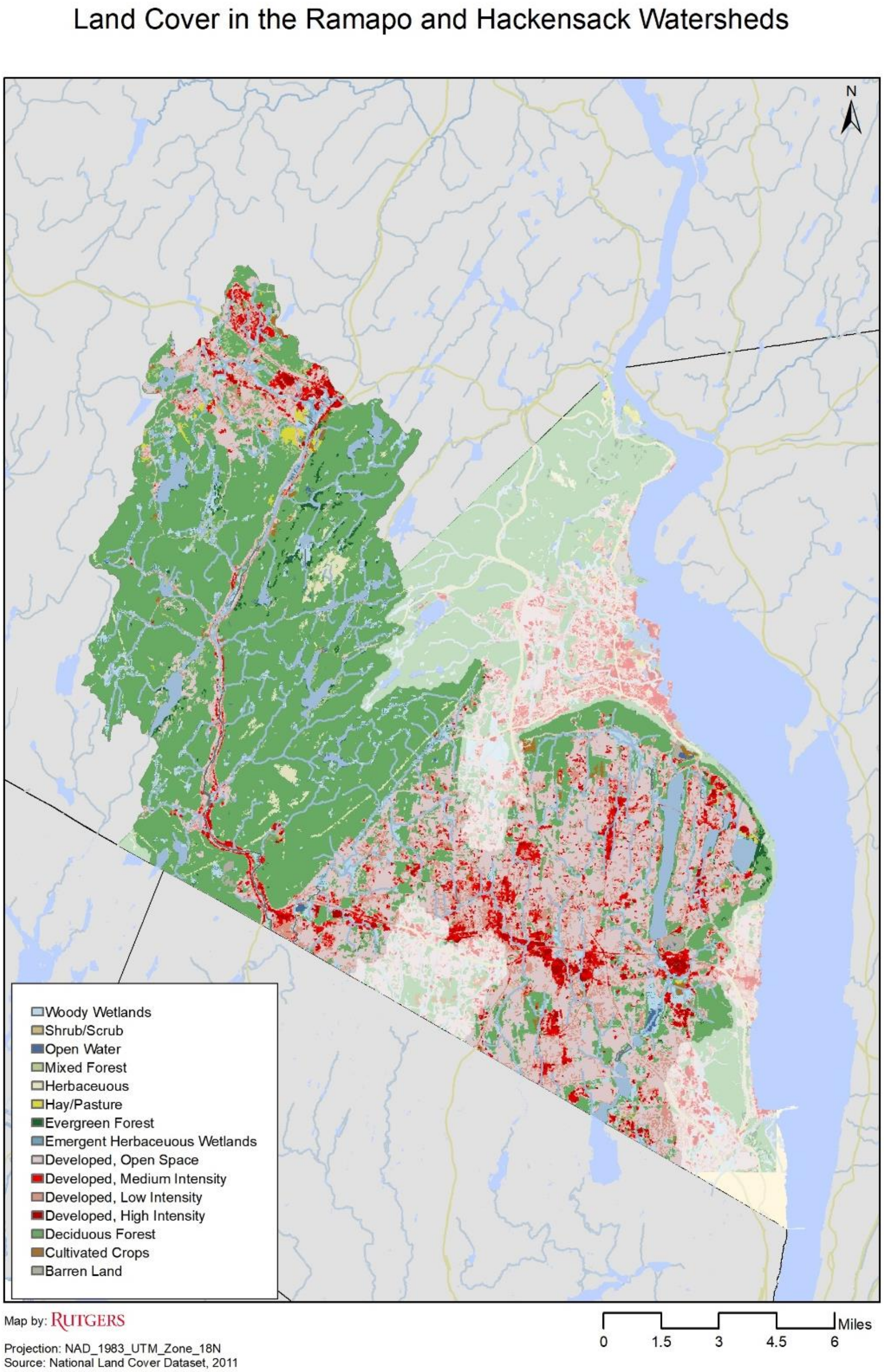


Figure II-7: 2011 Land Cover in the Ramapo and Hackensack watersheds.
Source: National Land Cover Dataset, 2011.

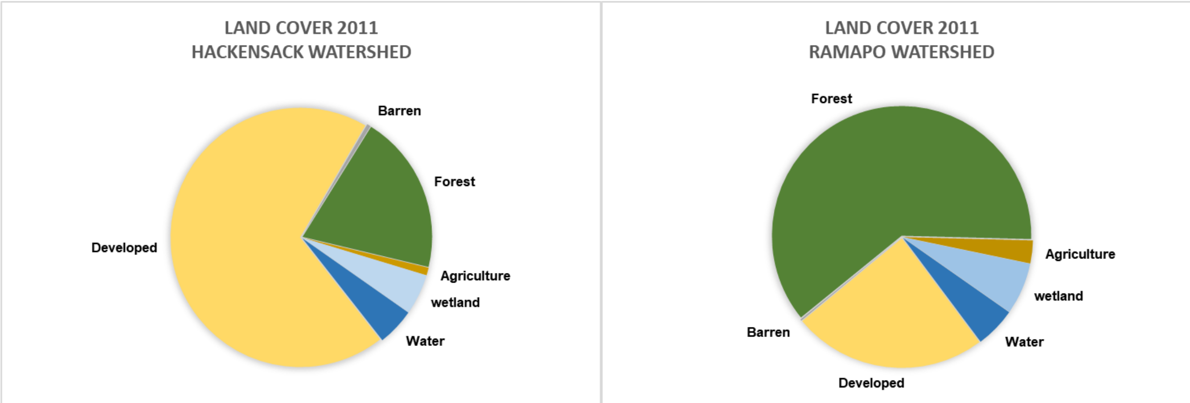


Figure II-8: 2011 Land Cover in the Hackensack and Ramapo watersheds.
Source: National Land Cover Database, 2011.

Trends

Building and construction continues to have an impact on the land cover, particularly in the Hackensack watershed (**Figure II-9**), with a rapid rise changes from one land cover type to another in the region. Between 1992 and 2001, 1.1 percent of forest, wetland, agricultural, or barren land changed to developed land cover in the Ramapo watershed, while 1.7 percent changed to developed in the Hackensack watershed. Between 2001 and 2011, 3 percent of land changed to developed land cover in the Ramapo watershed, and 8.5 percent of land became developed land cover in the Hackensack watershed. New land cover data (expected soon) will reveal further changes to land use and cover in the watersheds. While all comprehensive plans from counties and municipalities reflect the need to redevelop already developed land, rather than continue to use forested or agricultural lands, stronger regulations prohibiting building in riverine or riparian areas need to be developed, particularly in the Hackensack watershed.

Impervious surfaces history, current status and trends.

Roads, parking lots, sidewalks, buildings, ball fields and courts, and even expanses of lawn impede or prevent water from infiltrating into the ground, compared to forested land cover. Rainwater sheets off these surfaces and enters storm drains or catchbasins, which, in many communities, are discharged directly to waterways. In Rockland County much of this water is discharged out of the watershed and into the Hudson River.

History and Current

The agricultural and sylvan historical land cover in the region allowed approximately 90 percent rainwater to infiltrate into the ground. With increasing development, only about 10 percent of water remains on the surface of land in highly impervious areas. The amount of water that infiltrates to the soil is dependent upon the land cover, the type of soil and the slope of the land (**Table II-1**). Currently, the large forested region of the Highlands (79 percent of total land use) in the Ramapo watershed allows adequate storm water infiltration to the soil for evapotranspiration or ground water recharge. The majority of the Hackensack watershed (68 percent) is composed of impervious surfaces (**Figure II-10**), leading to reduced water quality and aquatic environments. This is a major threat to current water supply.

Runoff Coefficients for Various Surfaces	
Surface	Percent Runoff
Roof	95%
Pavement	85%
Porous asphalt/concrete and permeable pavers	70%
Green roof with four or more inches of growing media	70%
Synthetic turf athletic fields with subsurface gravel bed and underdrain system	70%
Gravel parking lot	65%
Undeveloped areas	30%
Grassed and landscaped areas	20%
Forest	15%

Table II-1: Stormwater runoff rates for various surfaces, assuming relatively flat land (0-2%) and loam soil.
Source: (NYC Department of Environmental Protection, 2012)

Trends

As with land cover, increasing development has reduced the perviousness of land in the watershed areas. Between 2001 and 2011, 5.5 percent of land became more impervious (National Land Cover Database, 2011). While current (2004-2011) county and municipal comprehensive plans discourage further development of undeveloped land, they do note that more housing is needed and consider the use of clustered development when building on forested, agricultural or marshland. Additionally, a challenge in Rockland County, as in other increasingly developed areas, is the variances from zoning regulations that allow larger houses and, thus, larger amounts of the highest impervious surface cover (Vanderhoef & Cornell, 2011, p. 228). Threats to the water supply remain, as mentioned above. A current assessment of changes in impervious cover is warranted.

Relationships of land use/land cover trends to water supply and quality

When land cover in the watershed area was used for agriculture or maintained as forest or wetland, water was able to directly replenish ground water through the thin soil over aquifers in much of the region. The granite and crystalline rocks in the Highlands have historically been rather poor ground water sources, but water does filter to bedrock aquifers through cracks. Trees and other vegetation absorbed and transpired large amounts of water, while the remaining water evaporated from the soil surface, or the surfaces of marshland, lakes and streams, and was returned to the atmosphere. Considered as a whole, this hydrologic system provided a natural filtering system for water through the dense roots and vegetation of wetlands and particles of soil. Organisms in soil and water further degraded contaminants, often to levels safe for drinking. With increasing population and corresponding development, this natural system of water movement has been broken.

Covering large amounts of surface with buildings or parking lots prevents adequate recharge to aquifers. Without recharge, ground water levels become lower, which has occurred particularly during dry periods. Impervious surfaces are constructed to quickly discharge water from their surfaces. House roofs are connected to storm sewers or to drain pipes, and roadways and parking lots are graded to

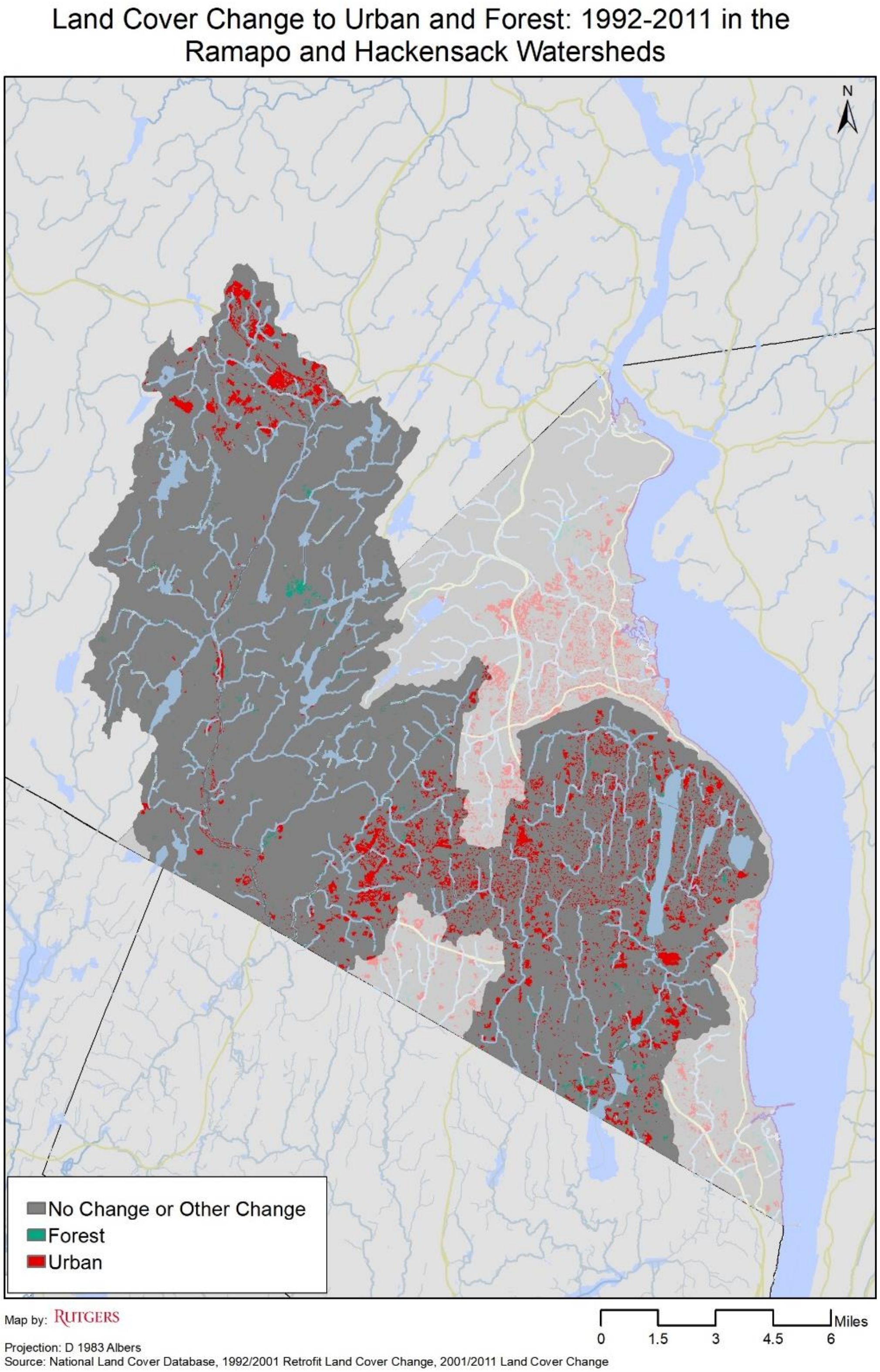


Figure II-9: Amount of land cover that has changed to urban (red) or forest (green) between 1992-2011 in the study area.

Source: National Land Cover Database, 1992 Retrofit Land Cover Change, 2001-2011 Land Cover Change.

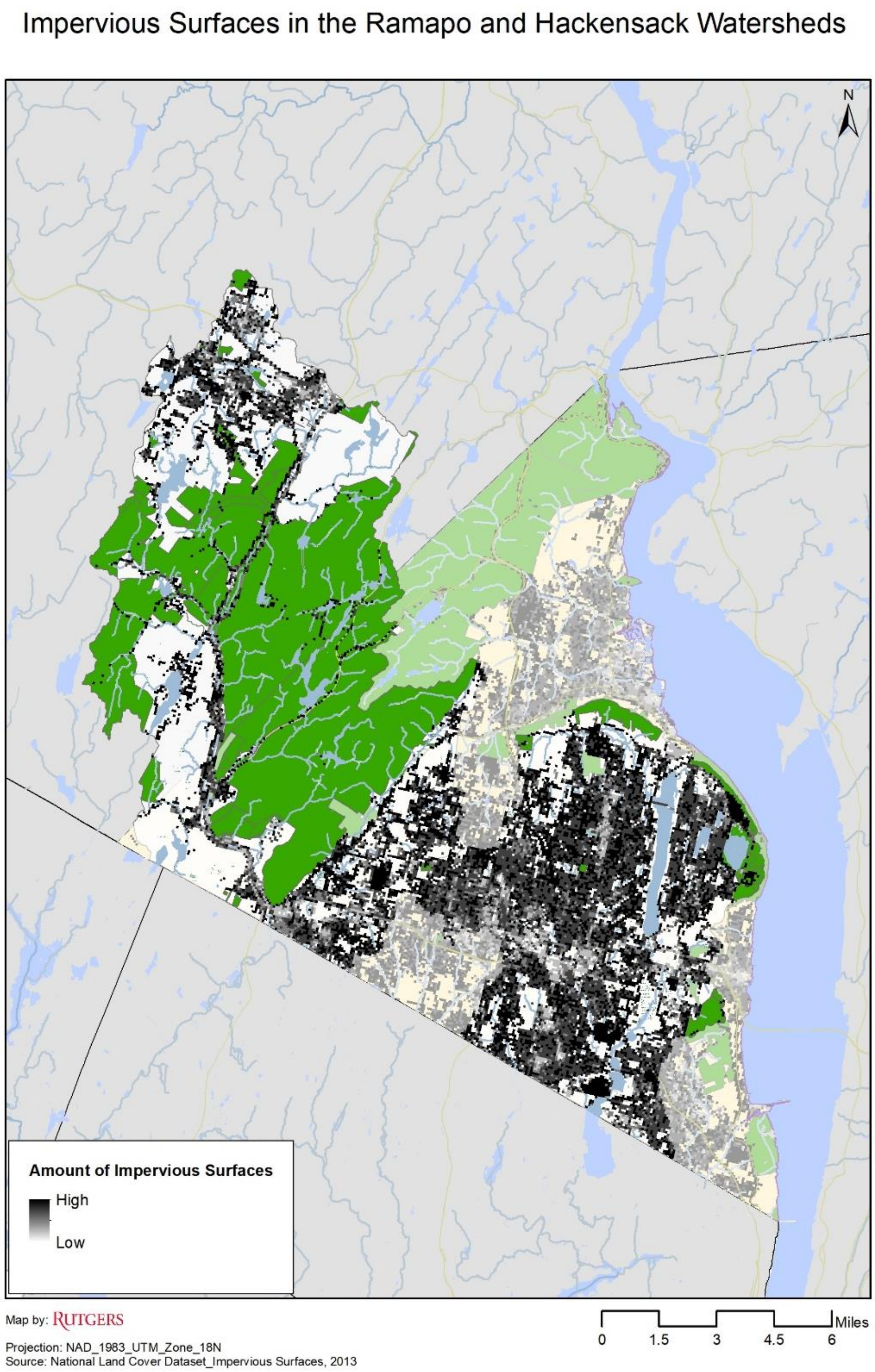


Figure II-10: Impervious surfaces in the watershed areas. The Hackensack watershed is dominated by impervious surfaces that prevent recharge to aquifers and streams.

Source: National Land Cover Data Set—Impervious Surfaces, 2013 storm drains which generally discharge to waterways. These scouring discharges pick up contaminants from the impervious surfaces that are washed into waterways and into areas that do recharge, contaminating the water, streambeds and ground water. This is particularly apparent near the NYS Thruway and areas of the densest road development in Spring Valley, where surface water and ground water have exhibited high levels of chloride from road salt used during the winter (Heisig, 2010, p. 71). Discharges from industry and municipalities directly affect the quality of the water. Even seemingly benign areas of development like yards, parks or ballfields can prevent adequate infiltration particularly in areas of high use or in areas that have been graded by heavy machinery, which compacts soil (Gregory, Dukes, Jones, & Miller, 2006; Kozlowski, 1999). Nutrient contaminants from fertilizers, contamination from herbicides and pesticides, and bacteria from animal feces wash into waterways. Trace amounts of herbicides and pesticides have been found in ground water quality samples, and nutrients like phosphorus and nitrogen have resulted in lakes in the watershed being placed on the priority water list. The amount of forest in a watershed has a direct relationship to water quality, as noted by a comparison (Nolan, 2016) of land use to biological water quality assessment scores (**Figure II-11**).

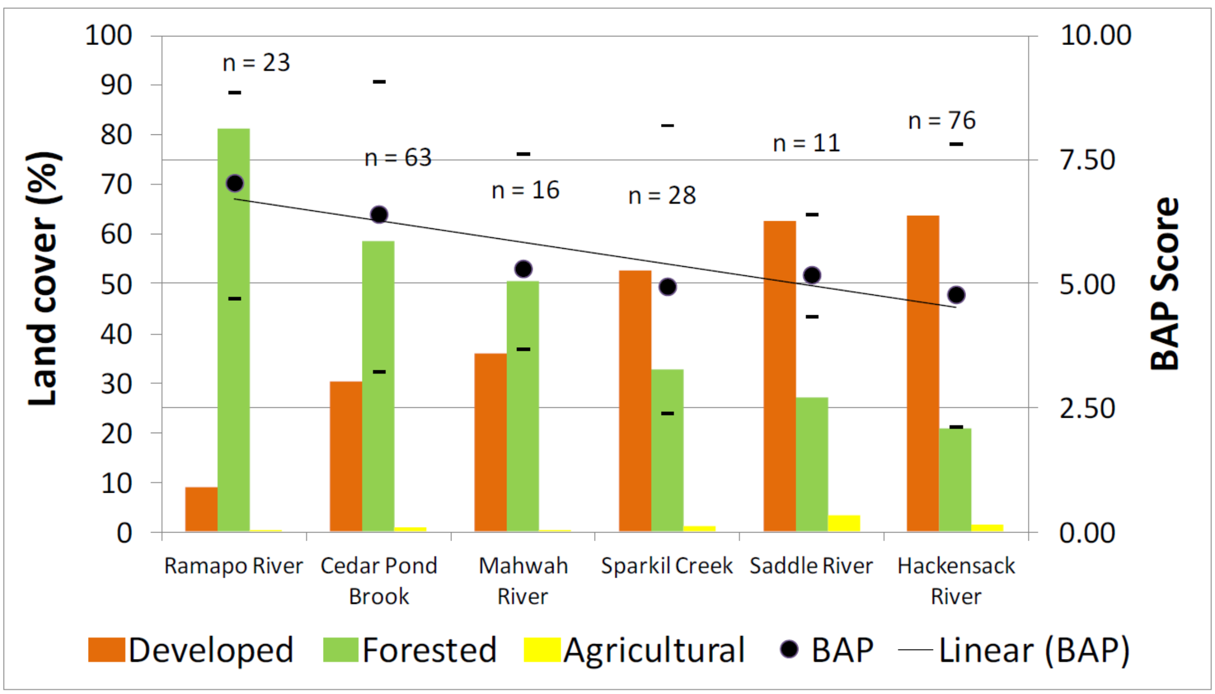


Figure II-11: Comparison of land use to biological water quality assessment scores.
Watersheds with higher amounts of forest, had high water quality scores. Source: (Nolan, 2016, p. 5)

Other land uses have varying effects on the water supply and water quality. Agriculture, while allowing more infiltration, has effects on water quality. Nutrients from fertilizer have affected waterways historically (Heisig, 2010). While agricultural land uses are nearly gone from Rockland County, ground water quality impacts will remain from historic operations, especially in the post-war period with increased fertilizer and pesticide uses.

Relationships of land use/land cover trends to riverine and riparian ecological resources

Land use and land cover choices affect ecological habitat of waterbodies and floodplains. Impervious surfaces and the accompanying scouring stormwater runoff contribute to degraded ecological habitat. Quick, directed movement of water erodes streams, disrupting fish spawning grounds and increasing sediment and nutrient loads in the water. Thermal pollution occurs from water that runs over hot pavement in the summer, transferring warm water directly to streams and killing organisms that depend on cooler water. Contaminants in runoff directly kill species: In 2009, a chlorine spill in the Nauraushaun resulted in a fish kill (Nolan, 2010). High nutrient levels from fertilizers used on lawns, parks and agriculture lead to algal blooms that disrupt the recreation potential of waterways and change oxygen levels in waterways, which also kills aquatic species. Draining or filling wetlands or removing riparian buffers directly harms protected plant and animal species, including the endangered American strawberry bush (*Euonymus americanus*) and bog turtle (*Glyptemys muhlenbergii*), and the threatened Northern Long-eared Bat (*Myotis septentrionalis*).

Zoning and build-out analyses

One tool that planners have to safeguard natural resources is to require sustainable choices is a zoning code. All municipalities in the watersheds have a town code which limits where different uses for land are located. These uses generally focus on human uses, but sensitive areas for protection can be addressed by the zoning code or overlay.

Reflecting the land use in the watershed area, the majority of land is set aside for single family housing—85.1 percent of land in the Hackensack watershed is residential of any kind, and 72.0 percent of land in the Ramapo watershed is zoned residential despite being preserved in large part (**Table II-2**). A large portion of Harriman State Park in Ramapo in Rockland County is zoned for rural residences that are on 80,000 acre lots. Some municipalities, such as Clarkstown, Sloatsburg and Stony Point in Rockland County and Warwick and Tuxedo in Orange County, have tried to focus development to protect sensitive areas through the use of special zoning codes and overlays that set land aside for recreation, increase the density of residences in already dense development zones, or limit development to relatively large lots to decrease the amount of impervious surface on any one parcel.

A build-out analysis is a method of estimating the potential for growth in an area based on current zoning and development practices. In addition to zoning and development, this analysis studies existing buildings and structures, waterbodies, wetlands, topography to understand where future building could be expanded and where the land has already been mostly developed, or "built-out." Rockland County's build-out analysis was completed in 2010 as part of the Rockland County Comprehensive Plan. An estimated 17,000 houses could be built in the county as of 2010. Compared by watershed, the Hackensack watershed has little land left for development, while the Ramapo watershed has more potential for building, particularly in the western corner of Rockland County in Ramapo (**Figure II-12**).

Portions of the Harriman and Sterling Forest do have zoning for rural single-family housing, though, they have a preserved forest overlay. The last build out analysis in the northern portion of the Ramapo watershed, occurred in 2007 in the South East Orange County Land Use Study, which encouraged densification of residences to reduce sensitive land development. A current build-out analysis and a

Zoning by Watershed						
Hackensack				Ramapo		
Zoning Designation	Total Acres	Percent		Zoning Designation	Total Acres	Percent
Low-Med. Density Single-Family Residence	16887	42.0%		Rural Single-Family Residence	26290	38.5%
Rural Single-Family Residence	8480	21.1%		Low-Med. Density Single-Family Residence	13775	20.2%
Low Density Single-Family Residence	5746	14.3%		Other (institutional/recreational)	12551	18.4%
Medium Density Single and Two-Family Residence	1869	4.6%		Low Density Single-Family Residence	6958	10.2%
Light Industrial	1563	3.9%		General Business/Community Commercial	3415	5.0%
Office	983	2.4%		Heavy Industrial	1293	1.9%
General Business/Community Commercial	969	2.4%		High Density Single and Two-Family Residence	1120	1.6%
Heavy Industrial	848	2.1%		Light Industrial	966	1.4%
Medium-High Density Multi-Family	791	2.0%		Medium Density Single and Two-Family Residence	704	1.0%
Regional Commercial	604	1.5%		Other Residential	397	0.6%
Other (institutional/recreational)	467	1.2%		Office	231	0.3%
Mixed Use	254	0.6%		Agricultural (Orange County)	218	0.3%
Local/Neighborhood Commercial	238	0.6%		Medium-High Density Multi-Family	162	0.2%
Other Residential	218	0.5%		Mixed Use	145	0.2%
High Density Single and Two-Family Residence	154	0.4%		Local/Neighborhood Commercial	72	0.1%
Low-Medium Density Multi-family	107	0.3%		Low-Medium Density Multi-family	61	0.1%
Laboratory Office	57	0.1%		Laboratory Office	0	0.0%
No Data	7	0.0%		Regional Commercial	0	0.0%
Agricultural		0%		No Data	0	0.0%
Total Residential	**34252**	**85.1%**		**Total Residential**	**49215**	**72.0%**

Table II-2: Zoning Classifications in the Hackensack and Ramapo watersheds, by size.
Source: Orange County and Rockland County Planning Departments. Rockland County classes are from Rockland County labels; Orange County classes are municipality labels. Agriculture is specific to Tuxedo in Orange County.

thorough understanding of building trends in both watersheds is warranted to accurately gauge water used demands in the future.

Implications of future development and redevelopment for water demands, water availability and water quality

Land is a finite resource in Rockland County, and continuing to build large single-family homes on undeveloped land will exacerbate current water supply and quality issues, particularly in the Hackensack watershed. Most municipalities have considered the steps needed to reduce the construction of homes

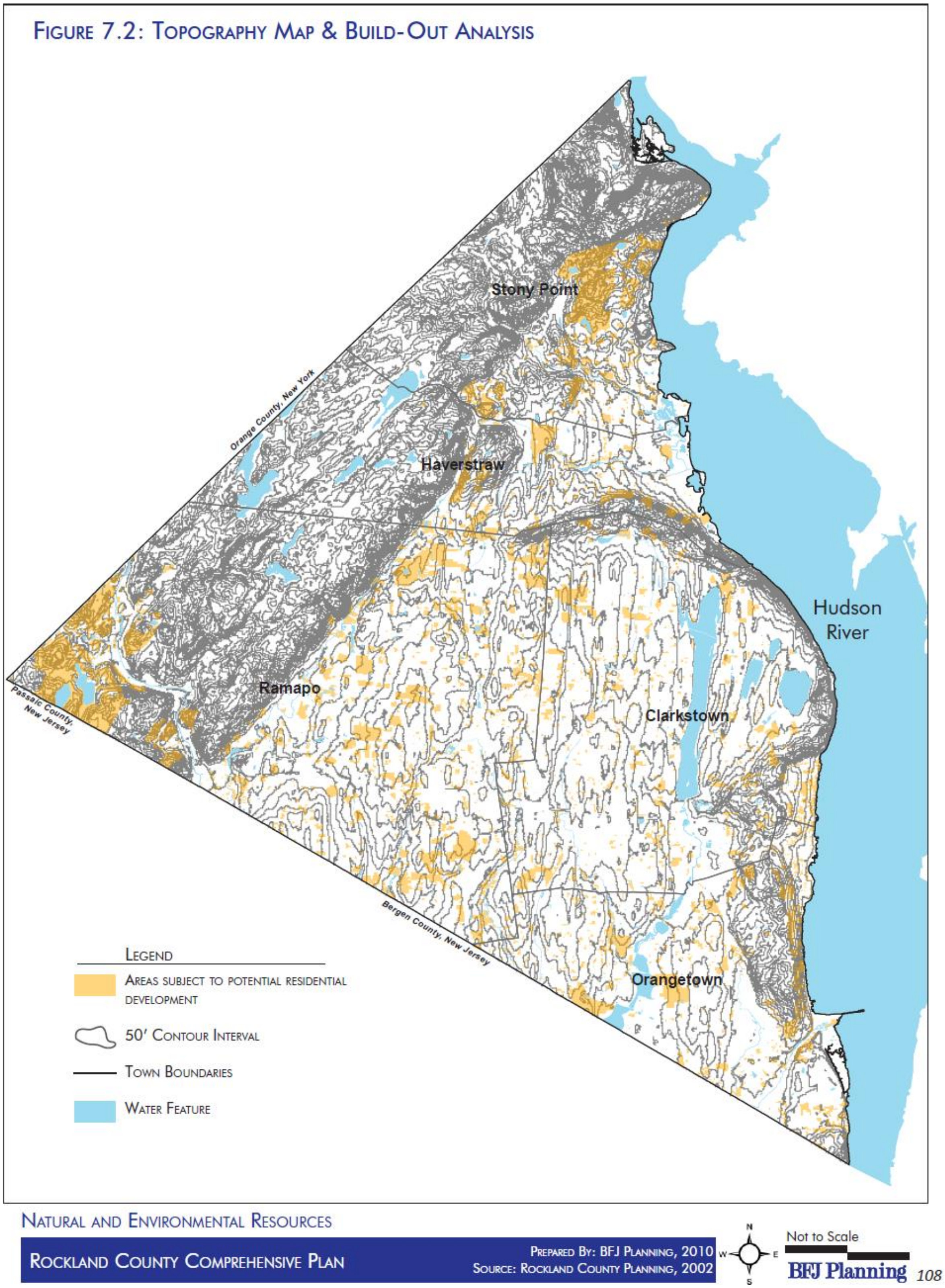


Figure II-12: Build-out analysis taking topography into consideration.

Little developable land is located in the Hackensack watershed.

Source: Rockland Tomorrow: Rockland County Comprehensive Plan, (Vanderhoef & Cornell, 2011)

on land that is currently forested, wetland or agriculture, and some have changed zoning classifications or code to begin to address these issues. Yet construction on undeveloped land continues, and buildings on current land get larger, increasing impervious surfaces. Land use planners need to balance competing interests of development and resource conservation, yet development will not continue if water supply and quality issues grow greater. Finding ways to use less land for development and more space for protection of water resources is necessary for continued growth.

Water demands can be tempered by stronger conservation measures that incorporate reduction of water use into new development projects, as well as continued education on the need to reduce demand, particularly during summer months. Water availability can be addressed through continued or improved vigilance on the protection of sensitive water areas, including blocks of forest, wetlands, rivers, and existing riparian buffers. Additionally, delineating recharge areas and strictly regulating their use will further help to address water supply demands. Prioritizing open space funds to purchase recharge areas, barren land, and riparian buffer parcels can address both water supply demands and quality. Other water quality measures include strong regulation of riparian buffers, wetlands and ground water protection zones, which have been addressed in the Rockland County Comprehensive Plan (**Figure II-13**). Reducing parking lots sizes through the use of minimum parking standards can stem commercial sprawl and encourage redevelopment of older commercial buildings. Again, education and outreach are valuable tools with a population interested in maintaining a drinkable water supply.

Available and proposed models

There were no available or proposed models for land use other than the build-out analysis from the Rockland County Comprehensive Plan, which predates the 2010 Census. An updated build-out analysis and a thorough understanding of building trends in both watersheds and throughout Rockland County is warranted to accurately gauge water used demands in the future. Build-out analyses are a fundamental tool of planning for land use, economic and social improvement purposes. The process of creating a build-out analysis is relatively straightforward, requiring identification of current zoning for all areas, identification of parcels that are either undeveloped or underdeveloped relative to their zoned capacity (excluding all preserved lands and areas that are constrained from development by state or federal regulations regardless of local zoning), and a method for determining the likely constraints on parcel development due to unusual parcel configuration and density losses due to required infrastructure (e.g., roads, parking areas, stormwater systems) and site-specific regulatory constraints in local zoning (e.g., stream buffers, steep slope controls). A build-out analysis can include consideration of constraints on total development due to existing water infrastructure capacity, but such constraints should be clearly separated from the build-out potential based on the attributes of the land itself. It is important to recognize that full build-out may never be achieved, due to future land preservation, zoning changes and such, but also may increase due to redevelopment agreements that make the nominal zoning irrelevant.

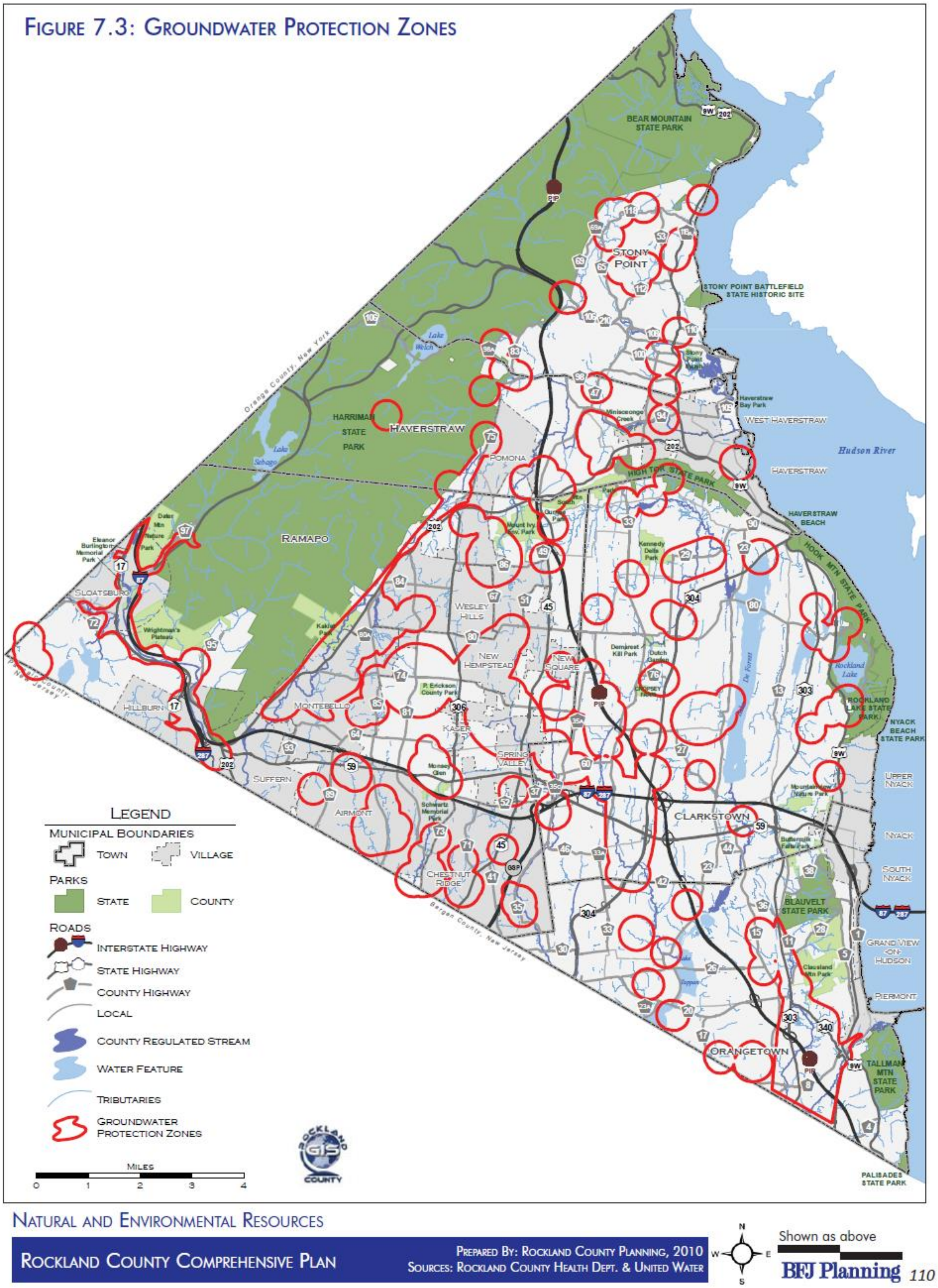


Figure II-13: Ground water protection zones.

Source: Rockland Tomorrow: Rockland County Comprehensive Plan, (Vanderhoef & Cornell, 2011).

III. Geology, Hydrography and Geography

Geology

Rockland County bedrock geology includes both formations of the Newark Basin (Piedmont physiographic province) and the Highlands physiographic province (**Figure III-1**). It is home to the headwaters of several streams and rivers such as the Hackensack and Mahwah Rivers, while the headwaters of the Ramapo River are in Orange County. The headwater drainage of the Ramapo River from Harriman to Monroe and Kiryas Joel in Orange County is generally characterized by thin sorted glacial deposits, mostly unconfined and underlain by glacial till, which has limited water storage capacity. Till is the thickest and most widespread glacial deposit in the headwater reach of the Ramapo in Orange County. Well yields are the highest in the valley bottom areas near the Ramapo River. Even though maximum reported test well yields have been of the order of hundreds of gallons per minute, the sand and gravel deposits in this region have indicated only moderate yields. The surficial aquifers are usually underlain by thick till which limits the migration of ground water from bedrock to the surficial aquifer. Ground water is constrained due to the discontinuous nature and limited thickness of saturated sand and gravel and by the presence of relatively small streams in the headwaters of the Ramapo in Orange County.

Rockland County has two significant buried valley aquifers, namely the Ramapo and Mahwah. The eastern and western bedrock geology of the county (the diabase sill along the Hudson and the Highlands to the west) are a restricted source of water supply leaving the central area which constitutes the Newark basin as the major bedrock aquifer. The principal bedrock types present in Rockland County include 1) metamorphic and igneous (crystalline) rocks of late Precambrian age, 2) metasedimentary rock of Cambrian and Ordovician age, 3) clastic sedimentary rock of late Triassic age, and 4) igneous intrusive and extrusive rocks of early Jurassic age.

The Newark basin is a geological structure of sedimentary rock that stretches from New York through New Jersey and into Pennsylvania, with a major fault line (the Ramapo fault) running along the western edge where it abuts the Highlands physiographic province.

The bedrock is covered with a layer of unconsolidated sediments, glacial in origin, which are typically thin and composed of recent alluvium in stream valleys. The most predominant glacial till is an unsorted mixture of sediments deposited by the ice sheet with a thickness of up to 190 feet. The stratified glacial deposits are limited to the stream valleys of the Ramapo, Mahwah, and Hackensack Rivers and the Minisceongo and lower Sparkill Creeks. Coarse grained stratified deposits of sand and gravel are widespread in the Ramapo and Mahwah Rivers and at the lower reach of Sparkill Creek, with a thickness ranging from 70 feet to 140 feet. The fine-grained deposits such as fine sand, silt, clay and peat are found in the north-south reach of the Hackensack River valley and the south reach of the Minisceongo Creek valley with a thickness reaching up to 90 feet. (Heisig, 2010)

Implications for Water:

The underlying geology has a direct effect on the amount and type of water resources available. In Rockland, the alluvial aquifers in the Ramapo and Mahwah river valleys plus the coarse-grained part of

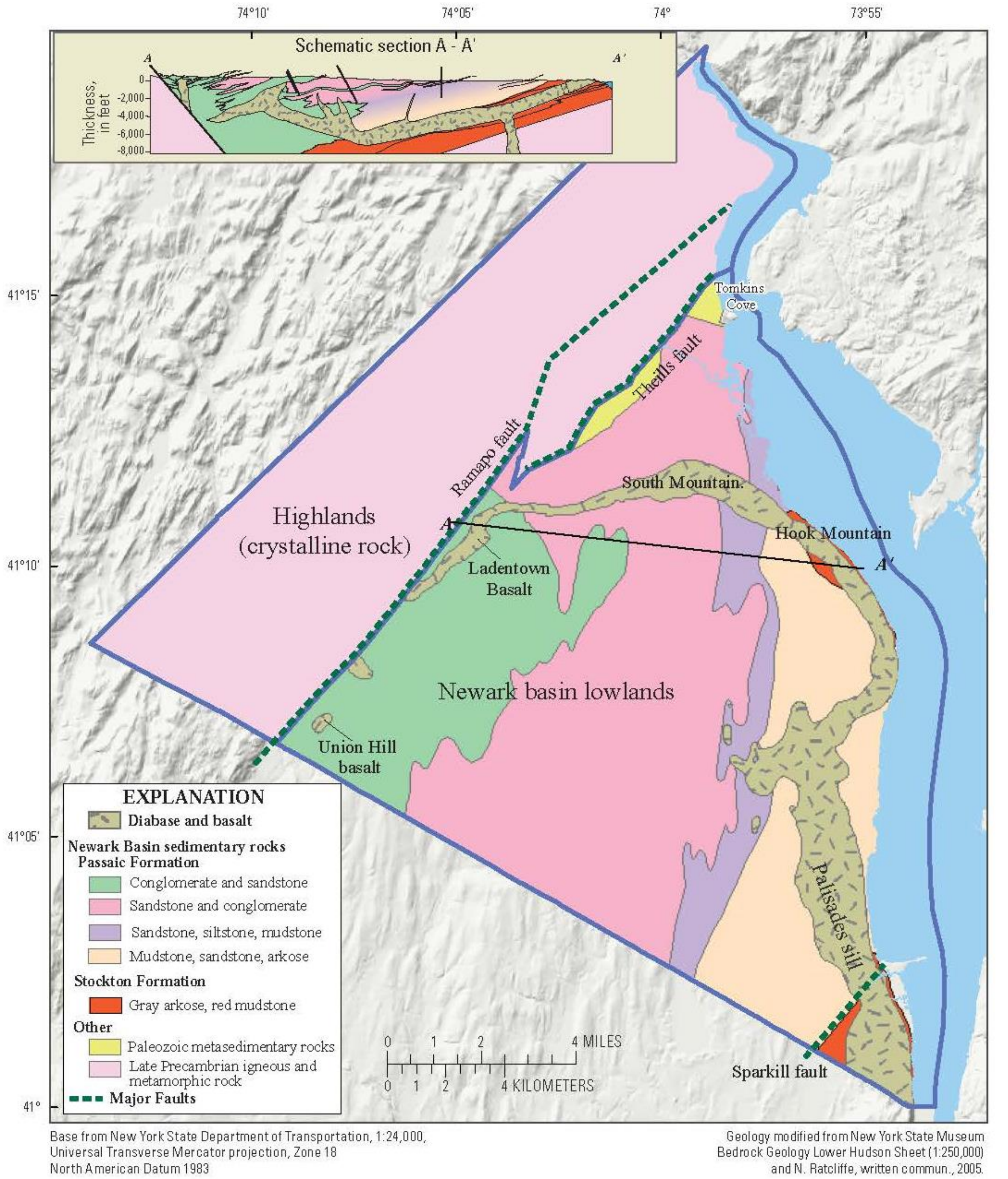


Figure III-1: Geologic Bedrock Map of Rockland County.

Source: Water Resources of Rockland County, New York, 2005–07, with Emphasis on the Newark Basin Bedrock Aquifer, Heisig, 2010.

the Newark basin sedimentary bedrock support the most productive wells of the county. In 2007, the maximum daily average pumping rates at individual supply wells ranged from 200 to 1,300 gal/min in the Ramapo valley aquifer, 180 to 950 gal/min in the Mahwah aquifer, and 75 to 800 gal/min in the Newark basin sedimentary bedrock. In the Newark basin, all the bedrock units with an exception of some areas of diabase and crystalline rock are capable of supplying water to domestic wells.

In areas with crystalline rocks, the maximum yields of large public wells rarely exceed 70 gal/min, and the limited aquifer storage in these crystalline rocks makes such wells susceptible to reduced yields during dry periods unless the wells are in hydraulic connection with surface water. Hence in the crystalline rock areas of the Highlands, surface water reservoirs are the most viable source of water supply. Since 2008, Suez-New York, a public water supply company began using the Letchworth reservoirs in Minisceongo Creek for this purpose.

In the southwestern part of the county, the Ramapo valley well field is the largest source of water supply to public wells. But despite its high yield, this river valley alluvial field is a limited resource. The Ramapo Valley well field and the Mahwah river valley aquifer field supply about 3.73 billion gallons (BG) per year, which is about 31 percent of the Suez-NY public water supply. Most of the water in this valley well field is derived by induced infiltration of Ramapo River through the permeable sand and gravel.

Topography and implications for water resources

The topography of Rockland is primarily determined by the underlying bedrock type. Rockland County can be broadly divided into the Uplands along the northwestern boundary of the county and the Lowlands which lie to the south and where most of the development is concentrated as shown in **Figure III-2**. The western portion of the county contains the most significant topographic relief because of the Hudson Highlands which run across Rockland and Orange County boundaries. In the southeastern region of the county, the Palisades ridge runs along the Hudson River.

Crystalline bedrock which underlies the upland area in the north west of the county is primarily composed of resistant gneisses and granite rocks that form a mountainous plateau which is about 4 miles wide. The northern part of the upland area is known as the Hudson Highlands and the southern section is known as the Ramapo Mountains. The lowland area of Rockland County is the northernmost extent of the Newark basin. The Ramapo fault bounds the basin to the west. The topography in the eastern and northern parts of the basin is dominated by a north south trending ridge. Both these regions are deeply incised at the Hudson River Valley and Ramapo River valley at the northeast and southeast corners of the county.

The 100-foot contours for the entire County and 10 meter contours for the portion of the Ramapo and Hackensack watershed that falls in Rockland County are shown in **Figure III-3**.

With the increase in population growth, development has expanded to steeply sloped areas which were once considered prohibitive and too expensive to build. Despite much of the higher locations in the county being reserved for parkland, the build out analysis suggests a couple of areas in steep slopes as potential for future residential development as shown in **Figure III-4**. Most of the towns and villages have regulations limiting the development on steep slopes but these regulations aren’t consistent. For

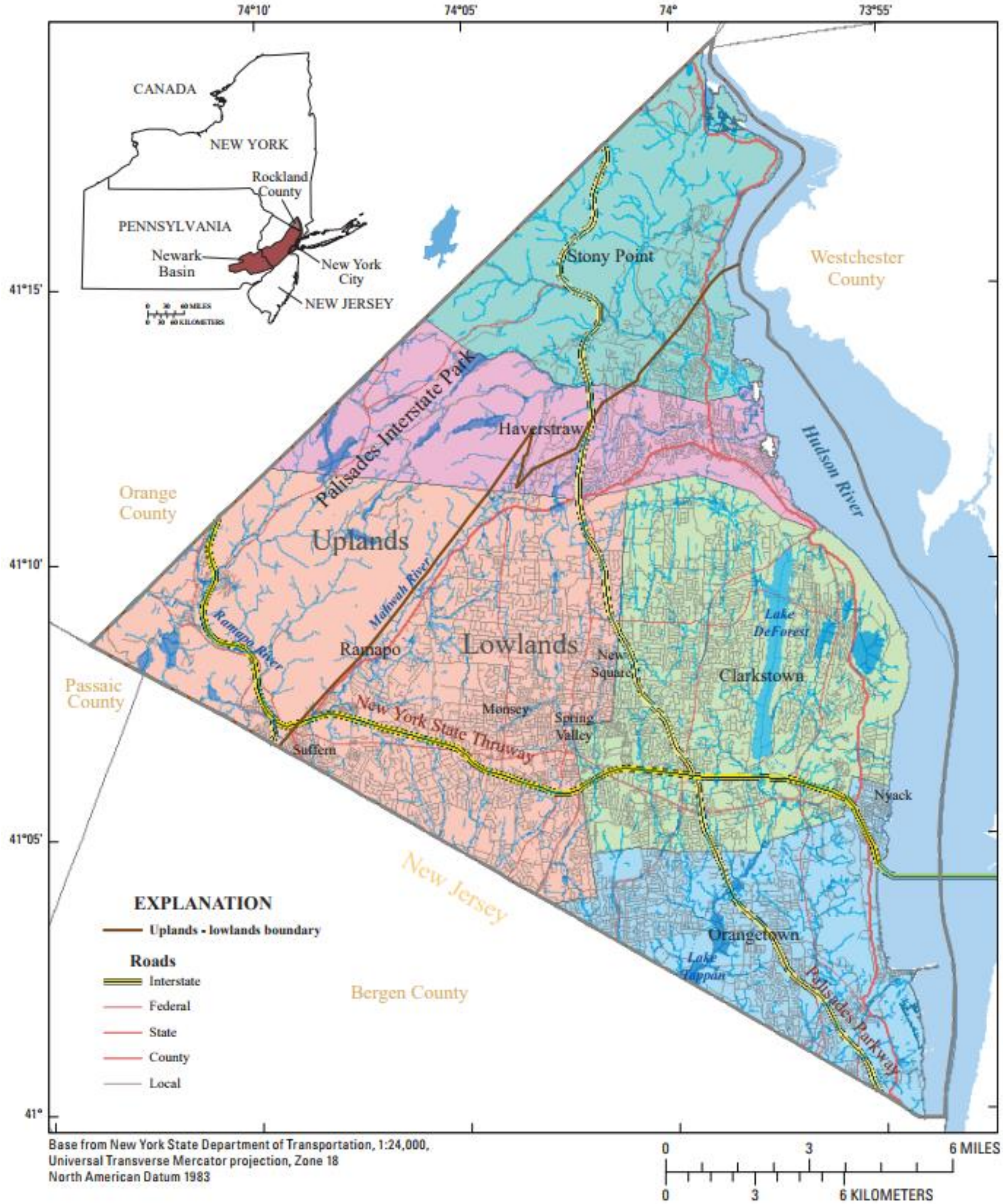


Figure III-2: Uplands and Lowlands of Rockland County.

Source: Water Resources of Rockland County, New York, 2005–07, with Emphasis on the Newark Basin Bedrock Aquifer, Heisig, 2010.

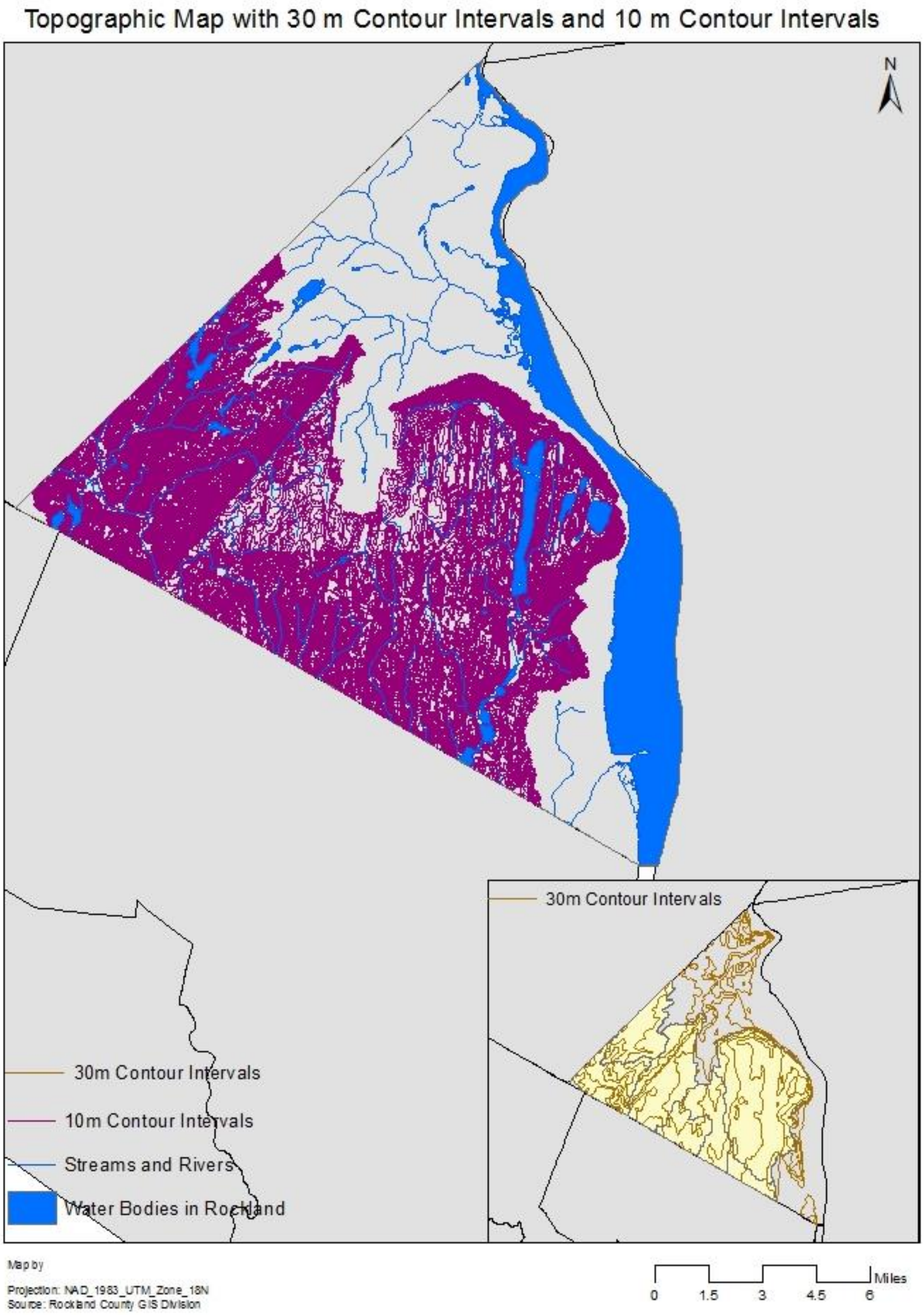


Figure III-3: Topography of Ramapo and Hackensack watersheds with 10m and 30m contour intervals.
Source: Rockland County Planning Department.

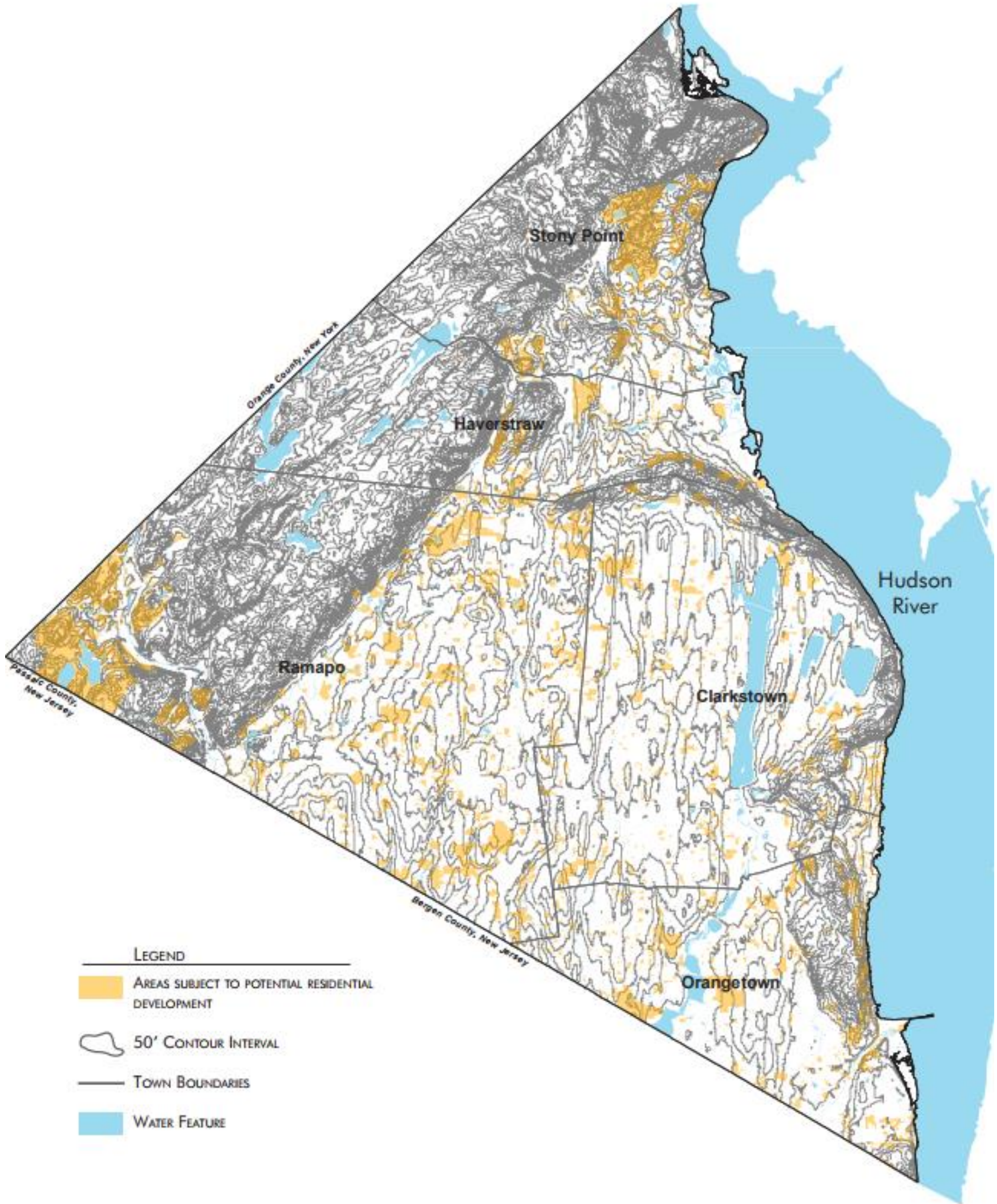


Figure III-4: Potential residential development on steep slopes, Build out analysis.
Source: Rockland Tomorrow: Rockland County Comprehensive Plan, Vanderhoef & Cornell, 2011

example, a few towns do not recognize slopes under 25 percent and have no limitations on development while others specify constraints for development on slopes. Unless development on steeply sloped regions is not regulated, there is potential for it to cause the loss of top soil and vegetation, erosion and potential slides.

Watersheds and subwatersheds

Rockland County crosses seven primary watersheds: Hackensack River, Peekskill Hollow Creek-Hudson River, Quassaick Creek-Hudson River, Ramapo River, Saddle River, Saw Mill River-Hudson River, and Wanaque River. These primary watersheds are further broken down into 15 sub watersheds. Nine small watersheds which represent 21 percent of the county area drain into the Hudson and the other six extend beyond the borders of Rockland County into Bergen County. In the Ramapo and Hackensack River watersheds there are seven sub-watersheds (HUC 12 per the USGS delineation system) as shown in **Figure III-5**, with three in the Hackensack watershed and four in the Ramapo.

Surface waters and alterations

Streams:

The main sources of water supply in Rockland County are three of its major rivers (Mahwah, Ramapo and Hackensack) as well as many lakes, ponds and streams dispersed around the county. The largest streams which originate in the County are the Hackensack River in the east and the Mahwah River which joins the Ramapo south of the New York border. Several of the surface water resources are included among the county regulated streams, which impose restrictions on development related activities within their 100-year floodplain. More specifically these stream regulations, which were updated in 2000, prohibit filling, dumping, construction, excavation and other activities that undermine stream bank stability, normal flow and disrupt water recharge areas in 100-year floodplain areas. Even though these stream regulations address important implications of development on water quality, they only address some of the streams in Rockland County as shown in **Figure III-6**. There are still large parts of the county where smaller streams go unregulated, for example northern Stony Point, Southern Ramapo and western Clarkstown. The regulation of smaller streams in the county should be explored and stream regulations should be differentiated based on open natural environments and urbanized environments.

Culverts:

Streams and rivers that pass under roads are conveyed by culverts and or bridges. Localized flooding occurs throughout the county during heavy rainfalls. One contributing factor is that many of these drainage systems were installed prior to the development within the watershed and the pipes, culverts, or bridges do not have capacity to pass the developed runoff. A contributing factor is the maintenance and cleaning of the drainage system, which results in blocking of the inlets, pipes, and culverts that causes flooding during heavy rains. Culverts and other artificial modifications on lakes and streams are shown in **Figure III-7**. Additional concerns of culverts and bridges include the potential for overtopping or washouts of the structure in severe flood events, causing roads to fail or become impassable; sediment deposition upstream of the structure; constriction of flow which increases flooding concerns;

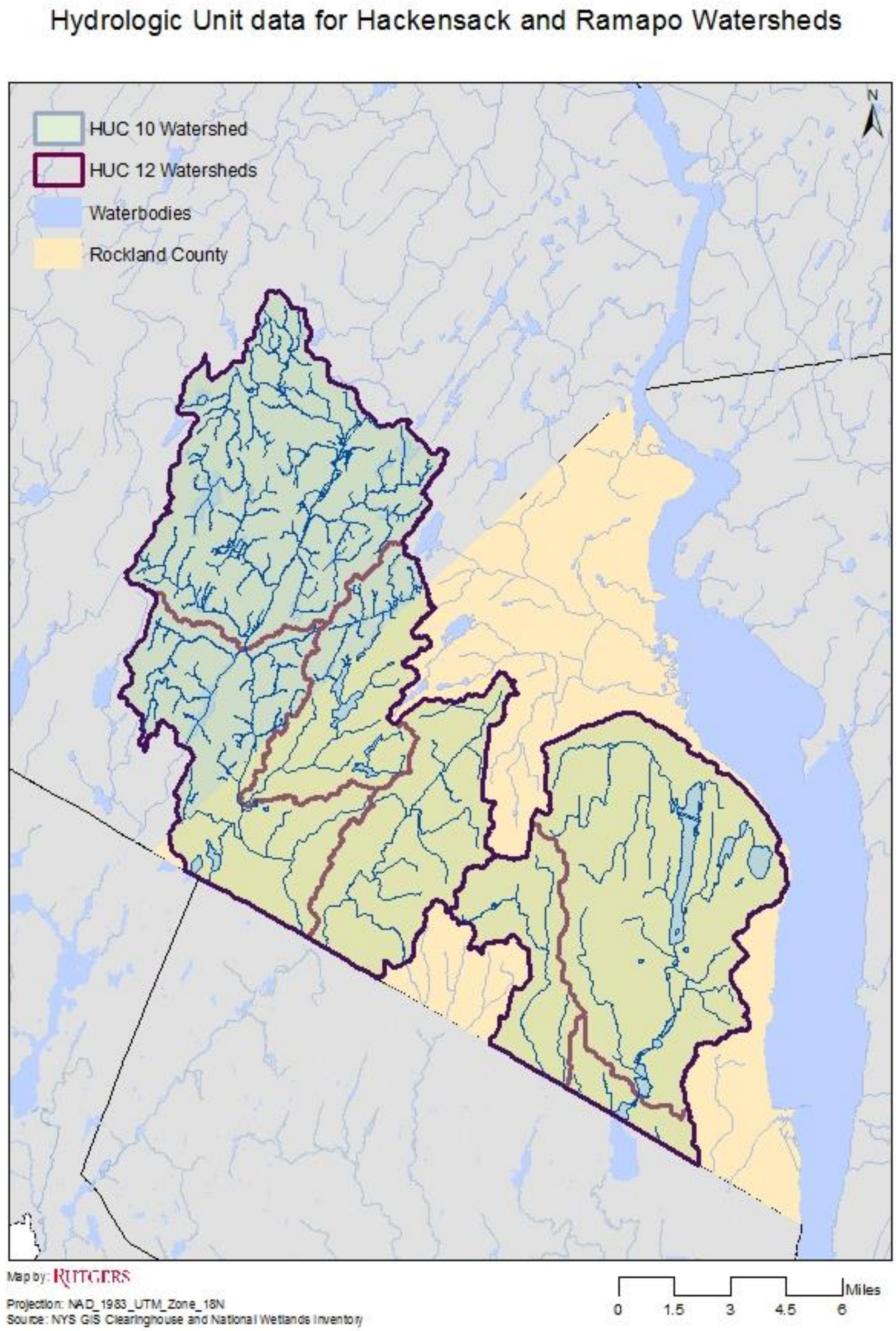


Figure III-5: Hackensack and Ramapo Watersheds.
Source: NYS GIS Clearinghouse and National Wetlands Inventory

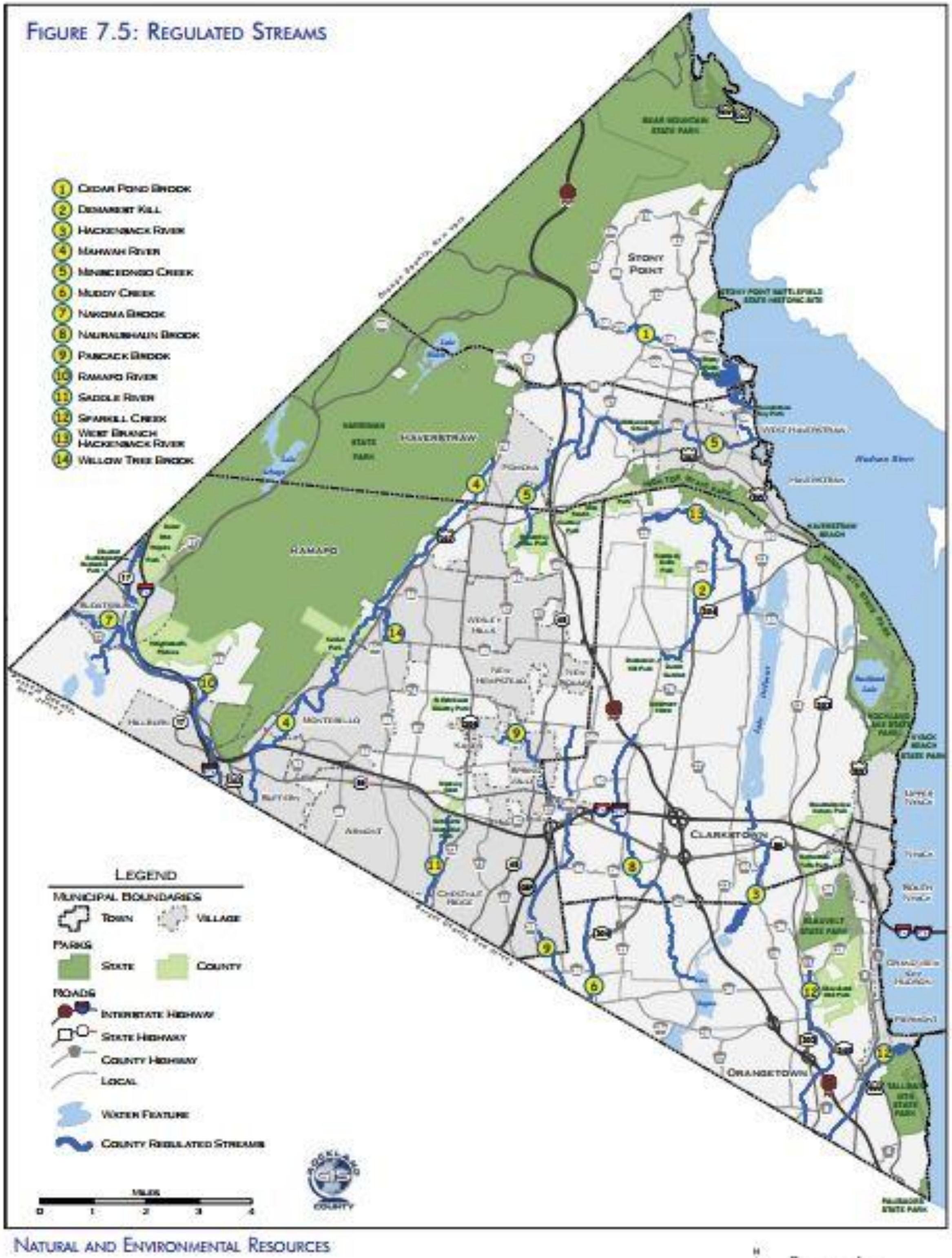


Figure III-6: County-Regulated Streams in Rockland County.
Source: Rockland Tomorrow: Rockland County Comprehensive Plan, (Vanderhoef & Cornell, 2011)

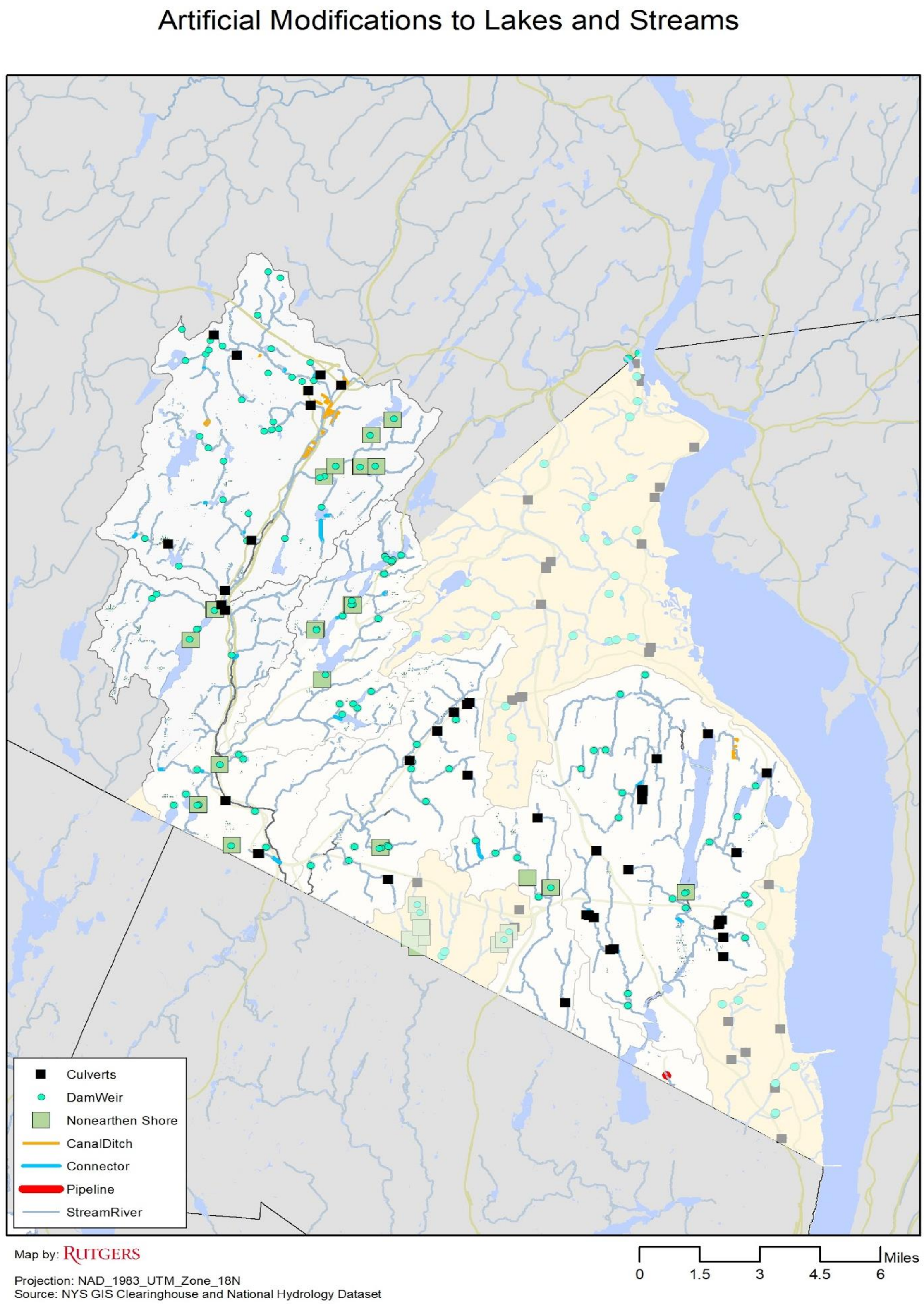


Figure III-7: Artificial modifications of Streams and Lakes.
Source: NYS GIS Clearinghouse and National Hydrology Dataset.

inlet drops and outlet drops which can cause scour pools that change the benthic environment of a stream and impact water quality overall. Lastly, migratory fish and riparian organisms cannot move through the structure properly if the flow is too fast, the structure type does not allow for water flow, or the drop is too high to allow movement from downstream to upstream.

Dams:

Dams in Rockland County have been classified based on their potential safety hazard should they fail. The hazard classification is done based on a particular physical characteristic of a dam and its location, not on the actual likelihood of failure. There are 77 Class A or low hazard dams, 15 Class B or intermediate Hazard dams, 16 Class C or High Hazard dams and 11 Class D or Negligible or No Hazard dams as shown in **Figure III-8**.

Streamflow:

In response to suburban development, surface water conditions have changed over the past 50 years. With an increase in impervious surfaces, the frequency and intensity of wet-weather stream flows have increased. Conversely, the increases in ground water extracted and the shift from domestic well withdrawals to more concentrated withdrawals and localized stresses by high capacity production wells in both bedrock and sand and gravel have decreased the stream flow during drier periods. The result is streams that are flashier, with larger differences between their low and high flows. (Heisig 2010)

Primarily the quality of stream flow has improved over the years, as the regulations for industrial discharges to streams and wastewater to treatment plants has become stricter. However, with the expansion of development, surface water has degraded in certain ways, such as the increase in chloride from road deicing application. (Heisig, 2010)

Effects of Impervious Surfaces on Streamflow:

In the early 1960s all stream drainages in the Newark basin aquifer were affected by some degree of development. Even back then stream flows were altered from natural conditions by discharges from wastewater treatment plants and industry and by flow regulation from upstream ponds, reservoirs and mills. Impervious cover began to increase with development and as a result there was an increase in peak stream-flows and decrease in base flows. Peak stream flows are further increased when drainage infrastructure connects impervious surfaces to streams. Reduced infiltration also results in the reduction of evapotranspiration from vegetation, soil moisture, and ground water recharge. Additionally, reduced ground water recharge decreases ground water levels in the aquifer and results in less discharge to streams, thereby failing to sustain stream base blow during dry periods. (Heisig, 2010)

Ground water and aquifer units and recharge areas

In Rockland County, ground water primarily flows through the sedimentary rocks of Newark basin. The unconsolidated deposits or primary till that overlays the Newark basin, allow the infiltration of water to the aquifer. Due to the high development in the Newark basin area, the amount of ground water is marginally augmented by the leakage of water from sewer and water distribution networks (Heisig, 2010). The ground water in the Newark basin is assumed to approximately flow within the upper 500 feet of the fractured bedrock, based on the estimated well yields, even though the formation ranges

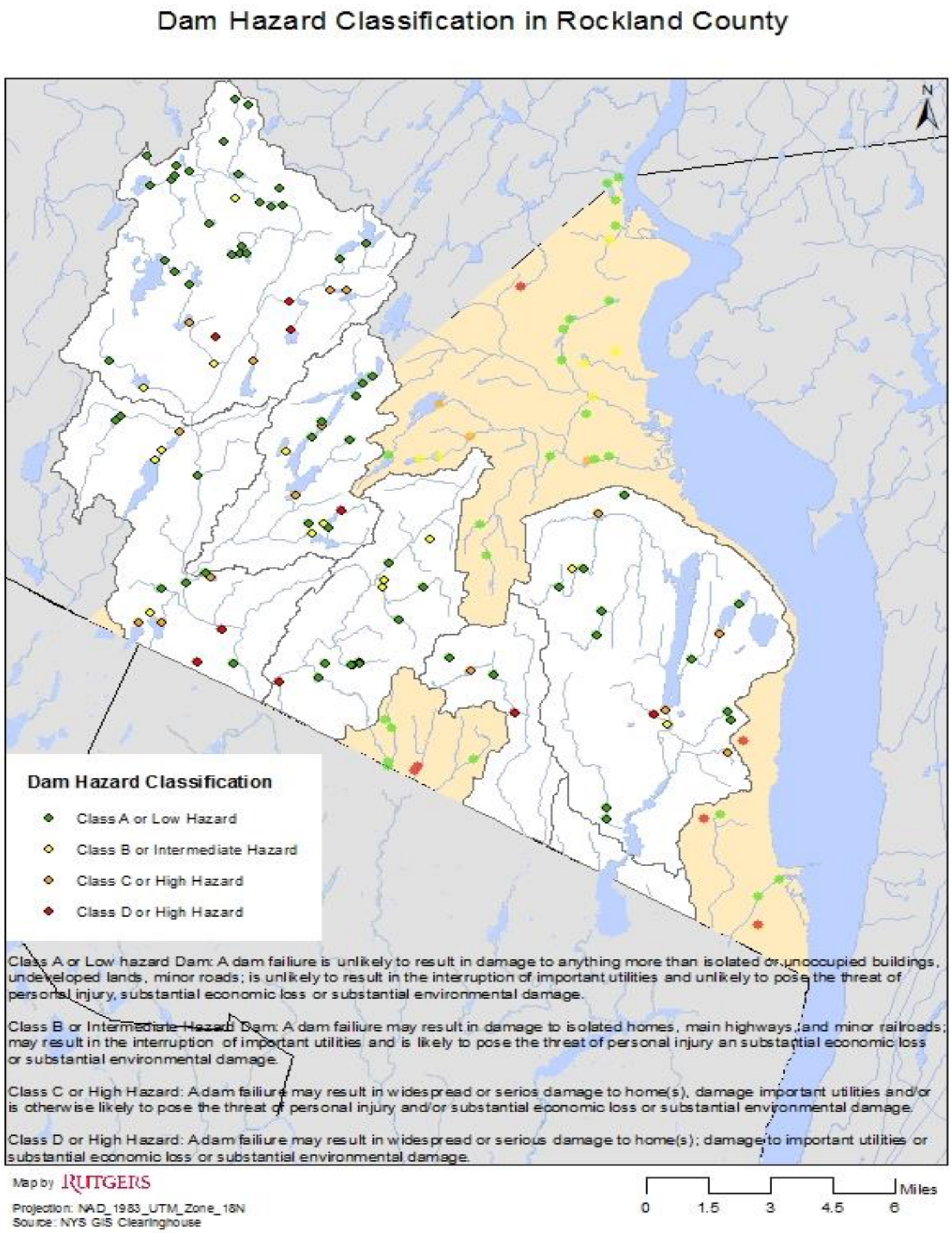


Figure III-8: Dam Hazard Classification in Rockland County.
Source: NYS GIS Clearinghouse.

from 2000 feet to 6000 feet from the east to the west. The water table lies within unconsolidated deposits in the low land areas; little water is available in the wells or streams due to low permeability of till and lacustrine sediments that constitute the confining layer above the bedrock. In the uplands, the water table is below the bedrock surface, therefore the aquifer is unconfined in these areas.

The Newark basin aquifer provides about 3.9 BG/year or 32 percent of the Suez-NY public water supply. There has been a shift in water supply from individual supply wells of low/moderate yield (<100 gal/min) that served domestic, institutional, commercial, and industrial water supplies (Perlnutter, 1959) to a more widely spaced network of deeper, higher-yield production wells. The 'Water Resources of Rockland County, New York, 2005–07, with Emphasis on the Newark Basin Bedrock Aquifer' study (Heisig, 2010) evaluated the ground water conditions in the aquifer through ground water level measurements at nearly 250 observation wells and water level pumping data from 45 wells owned by Suez. A total of 18 wells were continuously monitored for three years in both natural (relatively unstressed) and stressed areas of the aquifer. Most observation wells were observed to be between 100 and 259 feet deep. The Newark basin aquifer varies in confinement; shallow bedrock is usually unconfined unless it is overlain by poorly permeable till. The effects of ground water withdrawals were apparent in certain parts of the county where a hydraulic connection existed between the production wells and observation wells. Water withdrawal fluctuations associated with withdrawals from production wells ranged from a fraction of a foot to 65 feet at distances as great as 1 mile. The areas affected by withdrawals from production wells provided local information on the structure and the degree of confinement in the bedrock aquifer.

The Ramapo River valley aquifer in the western part of the county is a limited resource despite the high yield of the well field. The Ramapo Valley well field in conjugation with the Mahwah River valley well aquifer supply about 3.73 BG/year or 31 percent of the Suez-NY water supply. The withdrawal from the well field is subject to a permit between NYSDEC and Suez-NY that requires a minimum flow of 8 MGD or 12.6 ft3/s down river from the well field to New Jersey. According to this permit, the pumping in the wells must be stopped once the flow in the river falls below the threshold. Thus, in summers when the precipitation is low in the Ramapo area, the resource may be unavailable when it's needed the most.

In the eastern part of the Newark basin aquifer, the lack of available land, poor water quality, and potential impacts or liability issues with existing domestic supplies hinders new water supply production. New water supply availability is restricted to the Newark basin aquifer. Water can be drawn from a distributed network of low yielding wells in areas that are unaffected by existing supply wells (Heisig, 2010). The availability of limited additional water supply resources is evidenced by the existence of or historical information regarding former supplies that were used by small developments, bungalow colonies, summer camps and institutions.

Seasonal Variations:

However, the greatest limitation of the Newark basin aquifer and Mahwah River alluvial aquifer is the seasonal declines in ground water. In both the aquifers the ground water levels and the productivity both decline during the dry, hot summer periods as the water demand increases and the aquifer recharge and storage decrease. At the end of summer, low ground water levels have recovered as the demand declines and the recharge increases during the fall, winter and spring during the 1989-2005 period. This pattern indicates that during normal periods, summer stresses are offset by non-summer recharge. However, the response of these aquifers to an extended and severe drought is an issue. (Heisig, 2010)

Recharge Estimates:

The replenishment of ground water is crucial in Rockland County as a substantial portion of its water supply is derived from ground water resources. Recharge rates across the county for any given time period are variable, and year-to year variations can be large. The precipitation amounts, texture and thickness of glacial deposits are important factors that determine amount of recharge in a given area. The USGS study (Heisig, 2010) indicates that the recharge rates of the Rockland county aquifers, of approximately 18 to 27 inches for 2006 are greater than those estimated for 2001 and 2002 or from the recharge rates predicted in the 1979 estimates, thus implying that the recharge levels are higher than expected.

In the Newark basin, glacial till is the most predominant glacial deposit allowing recharge in the basin. It is assumed that the till, which is derived from coarse sedimentary and crystalline rocks in the western part of the Newark basin, is more permeable than till that is derived from finer grained sedimentary rocks in the eastern part of the basin. Stratified sand and gravel deposits are more favorable for recharge and storage than till. Recharge is constricted to shallow ground water flow systems in flood prone areas and adjacent to hillslopes, and eventually drains into local valley streams. These shallow ground water systems can be diverted into alluvial well field and valley bottom well fields where the valley bottom deposits are permeable.

The recharge in Ramapo valley and Mahwah Valley are dependent on induced recharge from Ramapo River and Mahwah River, respectively. A number of factors affect the rate of induced recharge, such as area of slope adjacent to streams, thickness of glacial deposits, areas of impervious surface etc. The USGS study reported that the effect of impervious areas mapped in 2000 reduced the recharge to the Newark basin by about 5 percent, or 770 MGY.

The Highlands Province bedrock to the west and in the Palisades sill to the east are limited ground water units. In parts of these regions the recharge estimates are 14.3 inches per year and in the other parts it is 35 inches per year. The USGS study (Heisig, 2010) reported that in the three major basins the aquifer withdrawals are equivalent to 20 percent of recharge.

No method currently exists for identifying the location and relative rate of ground water infiltration and recharge in this region. A method was developed for similar soils and geology in New Jersey (Charles et al., 1993) that may be relevant and perhaps transferable to the Ramapo and Hackensack watersheds. The method uses precipitation information, soil classifications, land use/land cover, and stream baseflow information. This method has been updated to be used on GIS. Further analysis would be needed by a qualified hydrogeologist to determine whether the method is readily transferable to this region.

Wetlands and wetland classifications

Wetlands provide a multitude of ecological, economic and social benefits. The wetlands in the Hackensack and Ramapo watersheds are classified into Freshwater emergent wetland, Freshwater Forested/Shrub Wetland, Freshwater pond, Lake and Riverine as per the National Wetland Inventory. The Ramapo watershed supports a couple of lakes, freshwater emergent wetlands and a few freshwater ponds and freshwater forested/ shrub wetlands. The Hackensack watershed has larger lakes and a few freshwater forested/scrublands as shown in **Figure III-9**.

Flood plains and flood prone areas; flood history; flood impacts

The flood hazard areas identified on FEMA Flood Insurance Rate Maps (FIRMs) are identified as Special Flood Hazard Area. **Figure III-10** shows the flood zones of Hackensack and Ramapo watersheds. Areas along the lakes and river have a flood zone of A or AE but the rest of the county in Zone X where the areas fall outside the 1 percent flood zone. Insurance purchase is not required for federally-insured mortgages in Zone X.

The USGS in cooperation with the New York state Department of Transportation, compiled known stages and discharges of New York streams from 1865 to 2011. The highest peak recorded was 14,700 cubic feet per second (cfs) recorded at Ramapo River at Suffern during Tropical Storm Irene in August 2011. The second highest discharge during Hurricane Irene of 13,700 cfs was recorded for the Ramapo River at Ramapo stream gauge, upstream of Suffern. The Hackensack River at West Nyack has the third highest known discharge in the county, with the same rate on two different flooding events during Hurricane Irene in 2011 and Hurricane Floyd in 1999, at a discharge of 1,740 cfs.

In order to determine how flashy a particular stream is, the base flow index of the streams is compared. Flashiness of a stream refers to the frequency and rapidity of short term changes in streamflow especially during storm events. A stream which has higher peak flows and less base flow represents a flashy stream. The base flow index is the ratio of the base flow to the total flow in the stream, which is always less than one (1), and lower numbers indicate flashiness that can contribute to flooding. When the base flow index for a stream declines over time that is a strong indication that the potential for flooding during storms is increasing.

Base flow index rates recorded at stream gauges are available for a couple of streams in Rockland County as shown in **Table III-1**. From the Base Flow indexes of the available streams, the lowest Base Flow Index is of Ramapo at Suffern indicating that this is the flashiest stream. This could be attributed to higher run off in this region on account of the vast impervious cover as a result of local development. On the other hand, the Hackensack River at Brookside Park, upstream of the Hackensack River in an area of lesser development just south of High Tor Park, has the highest base flow index indicating that it is a less flashy stream.

In order to jointly address the impact of floods in New York and New Jersey within the Hackensack River watershed, the Rockland Bergen Flood Mitigation Task Force was created in 2014. The Task Force uses its advisory powers to make recommendations to communities on the impact of zoning and planning

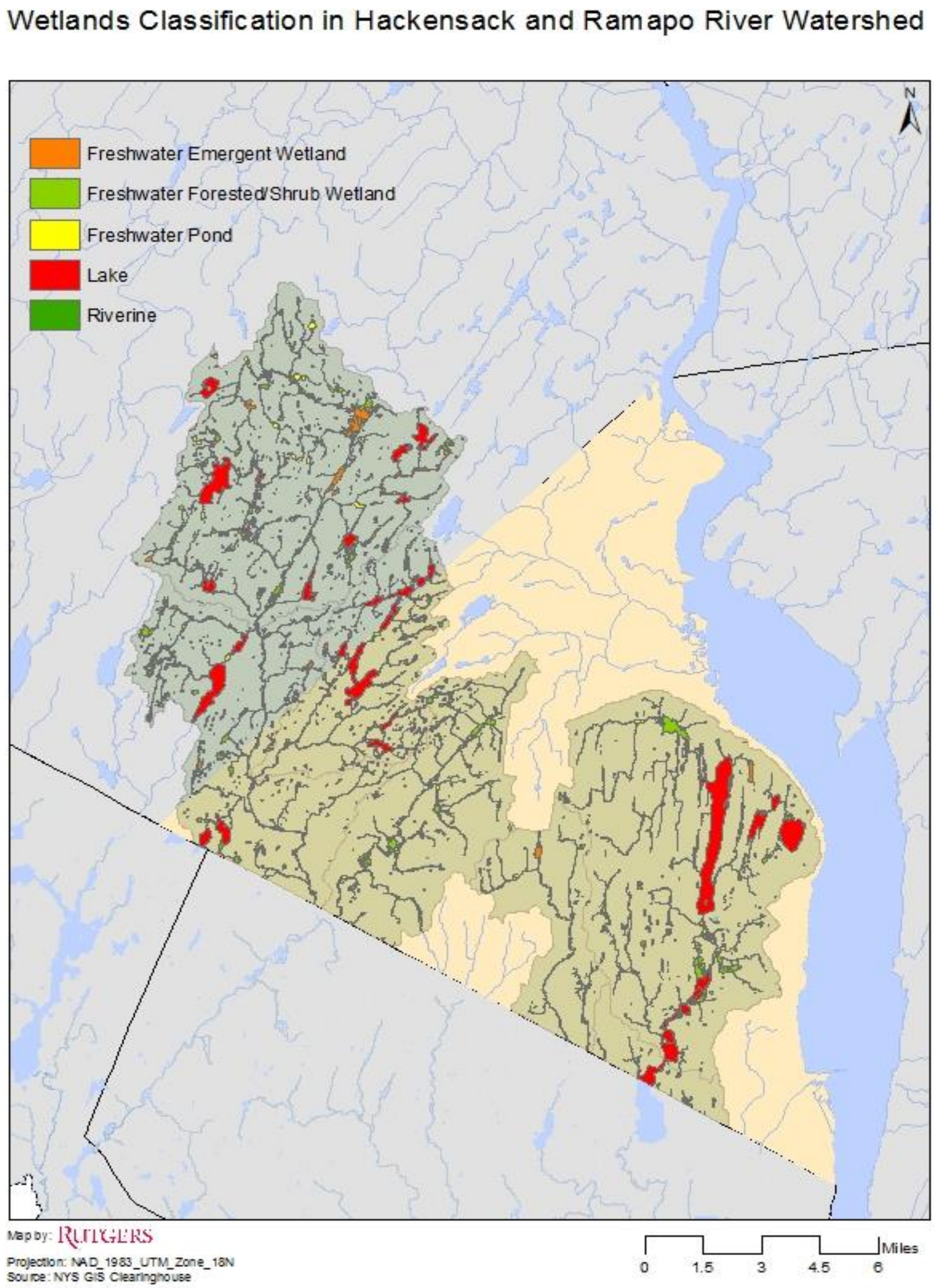


Figure III-9: Wetlands in Hackensack and Ramapo River Watershed.
Source: NYS GIS Clearinghouse.

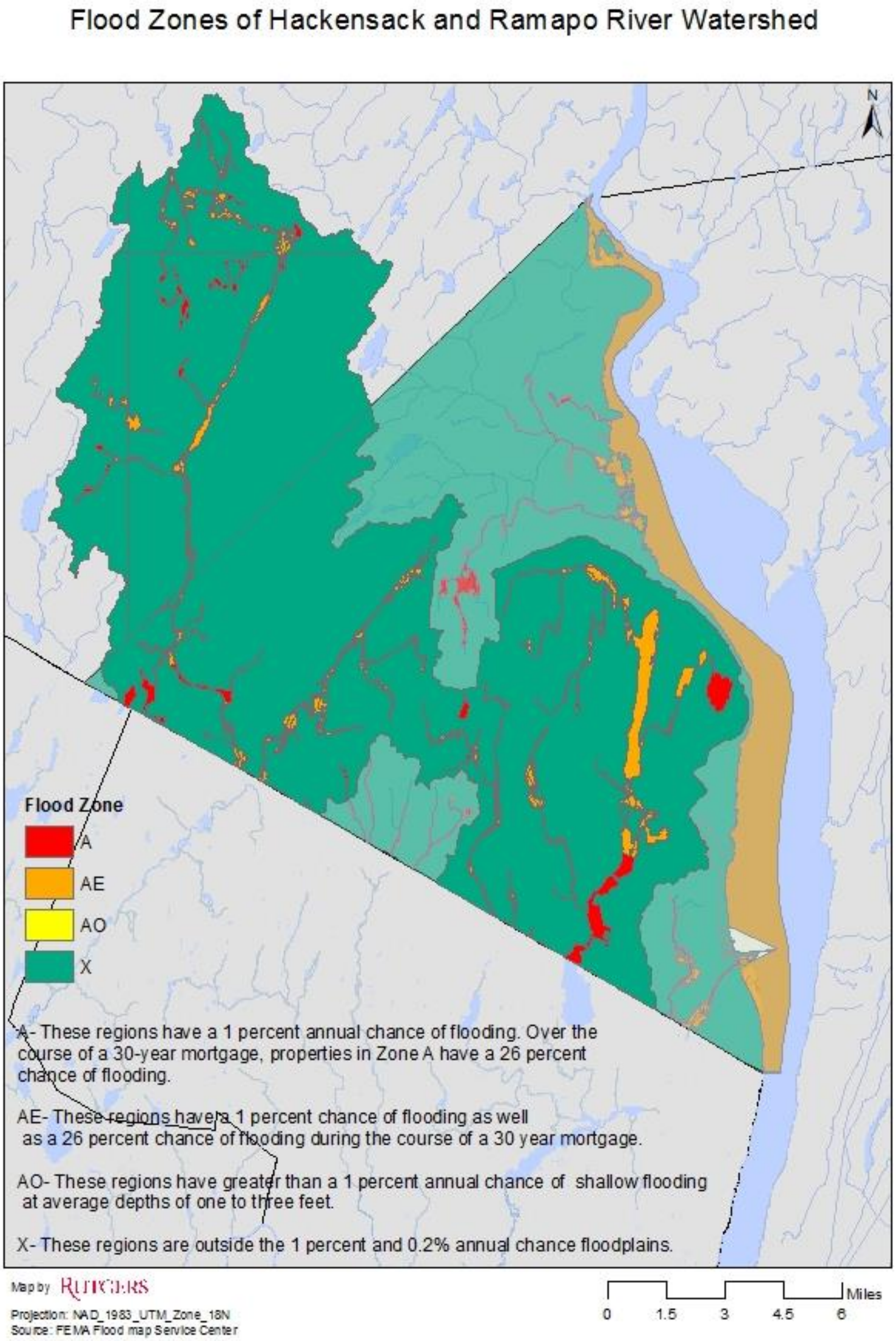


Figure III-10: Flood zones of Hackensack and Ramapo watersheds.
Source: FEMA Flood Map Service Center.

S.No	Station name and location	Latitude	Longitude	County	Period(s) of record		Drainage area (mi^2)	Index (Ratio)
					Dates	**code**		
01387250	Ramapo R At Sloatsburg, Ny	411005	741126	Orange	1960–63	C	60.1	0.471
					1975–79	P		
					1999–2000	C		
01387350	Nakoma Bk At Sloatsburg, Ny	410914	741137	Orange	1960–78	P	5.40	
01387300	Stony Bk At Sloatsburg, Ny	410944	741109	Orange	1960–62	C	18.2	---
					1963–69	P		
01387400	Ramapo R At Ramapo, Ny	410825	741007	Rockland	1980–2017	C	86.9	0.458
01387410	Torne Bk At Ramapo, Ny	410834	740943	Rockland	1960–2002	P	2.60	---
01387420	Ramapo R At Suffern, Ny	410706	740937	Rockland	1980–2017	C	93.0	0.420
01387500	Ramapo Near Mahwah, Nj	410553	740946	Bergen	1902-2017	C	120.0	0.479
1387450	Mahwah R Nr Suffern, Ny	410827	740700	Rockland	1959–95	C	12.3	0.465
					1996–2005	P		
					2006–17	C		
01387480	Mahwah R At Suffern, Ny	410654	740845	Rockland	1960–62	C	20.7	
					1963–65	P		
01376600	Hackensack R At Brookside Park, Ny	411018	735823	Rockland	1960–63	C	13.2	0.551
					1967–80	P		
01376690	E Br Hackensack R Nr Congers, Ny	410732	735722	Rockland	1960–80	P	6.90	---
01376800	Hackensack R At West Nyack, Ny	410544	735750	Rockland	1959–2017	C	30.7	---
01376900	Hackensack R @Nauraushaun, Ny	410316	735854	Rockland	1960–62	C	44.6	---
					1963	P		
01376850	Nauraushaun Bk At Nauraushaun, Ny	410342	735940	Rockland	1960–63	C	5.89	
01377000	Hackensack At Rivervale, Ny	405957	735921	Bergen	1960-2017	C	58.0	0.535
01377180	Pascack Bk At Spring Valley, Ny	410645	740159	Rockland	1972–80	P	2.10	---
01377200	Pascack Bk Trib At Spring Valley, Ny	410615	740156	Rockland	1960–62	C		
					1963–80	P	4.19	

Table III-1: Base flow Index at Stream Gauges.

US Geological Survey, 2017a

decisions on flooding, dredging silt and debris from riverbeds and of raising bridges (Pinzow, 2014). However, no information appears to be available regarding the results of this task force, if any.

Repetitive Loss Properties

Repetitive loss property is defined as any insured building which has received payment on two or more claims of more than $1,000 from the National Flood Insurance Program (NFIP) within any rolling 10-year period since 1978. According to FEMA's repetitive loss property records, there were 230 'non-mitigated' properties located in Rockland County as of 2008. These properties are associated with a total of 611 individual losses and almost $4.9 million in claims payments under the NFIP since January 1979. The distribution of repetitive loss properties across the county is presented in **Figure III-11**. The majority of the repetitive loss properties are clustered in Clarkstown, the Village of Suffern and the Village of Spring Valley. Single Family Residential buildings comprise the majority of all repetitive loss properties in Rockland; 7% are other residential buildings and 5% are non- residential. The majority of repetitive loss properties (70%) are located in zones which are identified as 'Low Risk' by FEMA whereas only 28% of the repetitive loss properties are located in the 100-year flood plains and the remaining 2% are located in moderate flood risk areas.

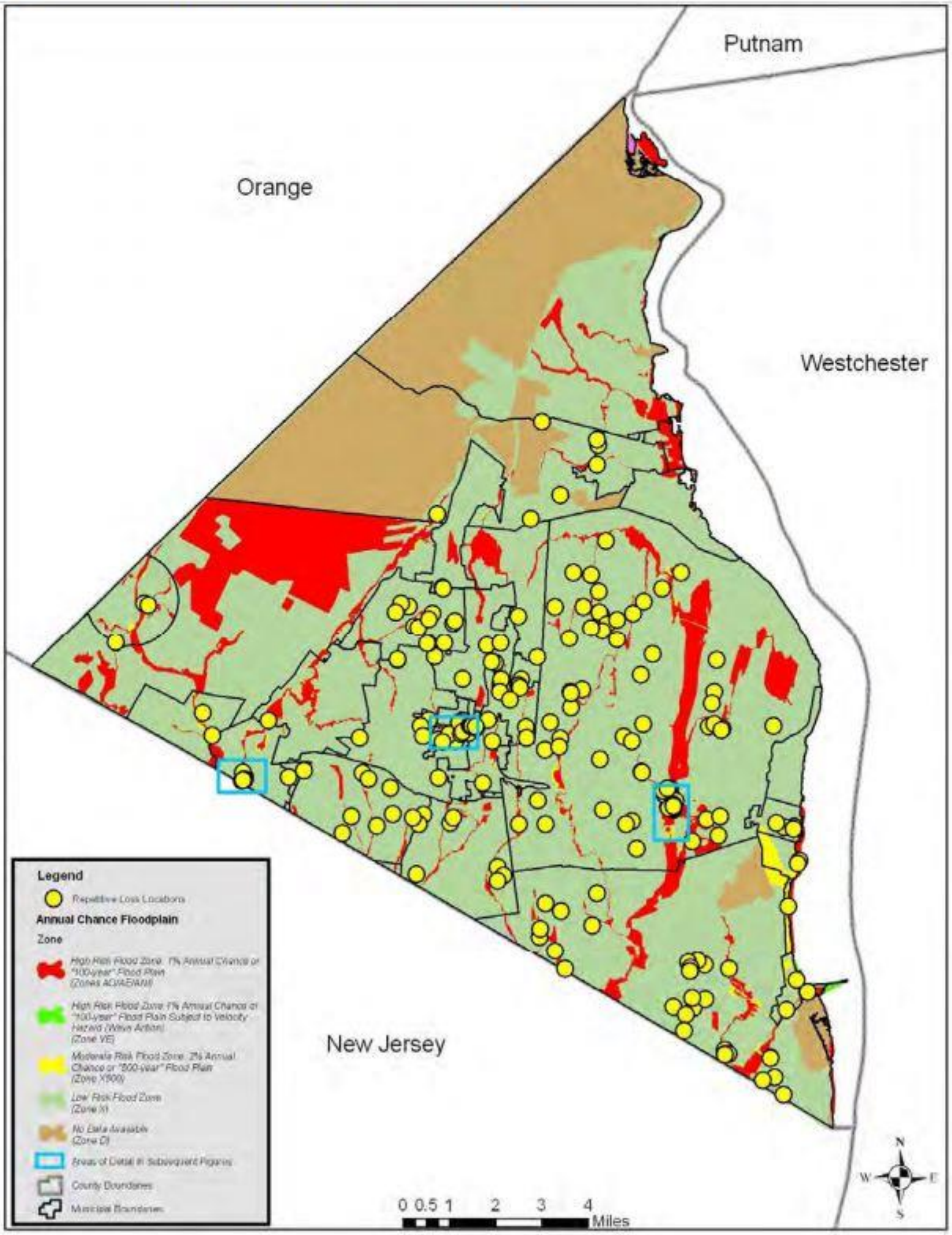
Severe Repetitive Loss Properties are defined as any property that has at least four NFIP claim payments (including building and contents) over $5000 each and the cumulative amount of all the claims exceeds $20,000 or a property for which at least two separate claim payments (building payments) have been made with the cumulative amount of the building portion of the claims exceeding the market value of the building. As of 2008, twelve Rockland County properties were listed as Severe Repetitive Loss Properties by FEMA.

Local jurisdictions and communities at times buy properties that are located in the areas where there is repetitive flood loss in order to reduce flood damages. FEMA funds are available through its Hazard Mitigation Grant Program (after a flood that receives a disaster declaration) or its Pre-Disaster Mitigation Grant Program, on a competitive basis for buyouts. According to FEMA's Q-3 flood mapping, 11% of Rockland County's land and 1.5% of all residential properties lie in the 100-year floodplain. Rockland is ranked the most vulnerable to floods out of the 62 counties in New York State. Additionally, Rockland County ranks seventh for the number of repetitive loss properties out of the 62 counties in New York State.

Demographic status and trends

Demographic factors such as population size, distribution and composition have a direct impact on water resources. The population increase of Rockland County was stimulated in 1950s with the construction of the Tappan Zee Bridge between Rockland County and Westchester County. In the 1960s and the 1970s growth proceeded rapidly, but there was a slow decline between 1980 and 2000. The population growth in the 1980s and the 1990s combined was less than the population growth in the 1970s.

Figure 3a.19: Rockland County NFIP Repetitive Loss Properties



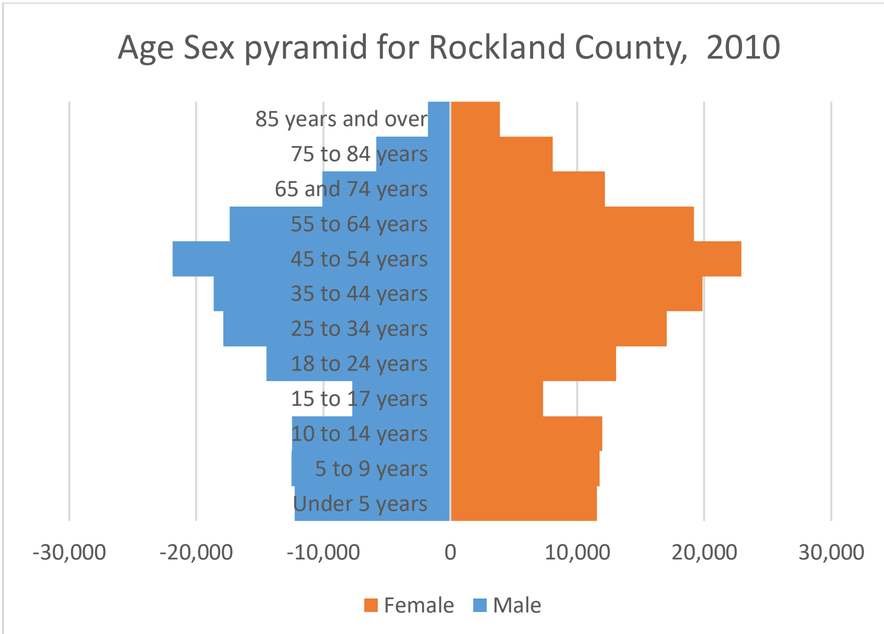
Source: FEMA Q3 Data, 2006, Towns and Villages, 2001; ESRI, US Counties, 2005

Figure III-11: Distribution of Repetitive Loss properties across Rockland County

Source**:** Multi-Jurisdictional Natural Hazard Mitigation Plan Rockland County

Comparison of age sex pyramid between 2010 and 2016

Census information indicates that the county population is aging. The age structure of the population of an area has an effect on the demands for facilities. Age pyramids by gender for 2010 and 2016 were created for Rockland County and are shown in **Figure III-12**. The broad scale of the middle-aged inhabitants is the baby boom generation while the tapering of the graph at the top represents the group belonging to the retirement cohorts.



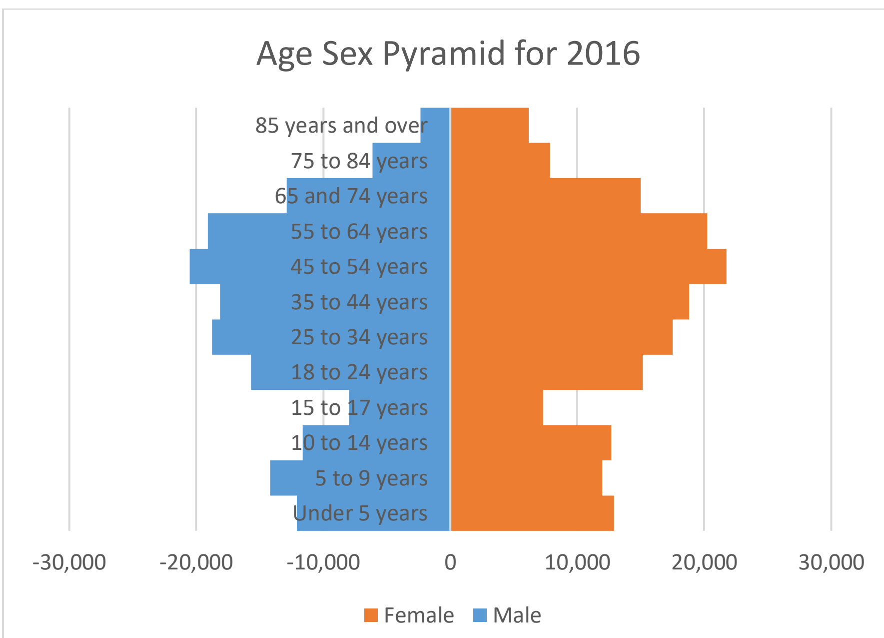


Figure III-12: Age gender pyramid for Rockland County for 2010 and 2016.
Source: U.S. Census Bureau

On comparing the two it can be seen that the composition of both the genders is more or less the same. The only significant change that is observed from 2010 to 2016 is the increase in the population of the females in the 85 years and above group. And the population of both the males and females in the 65-74 age groups has considerably increased in 2016 as compared to 2010. However, in both charts a major issue is the very small populations at the earliest ages, especially compared to the nation as a whole, indicating that Rockland County is not attracting or retaining those who are raising children at the same rates as prior generations.

Population by Town

Rockland County is comprised of five towns, within which there are 19 village and unincorporated areas. **Figure III-13** shows the population changes for the five towns, with Ramapo Town showing by far the greatest total and rate of growth from 2000 to 2015, and Stony Point Town showing the least.

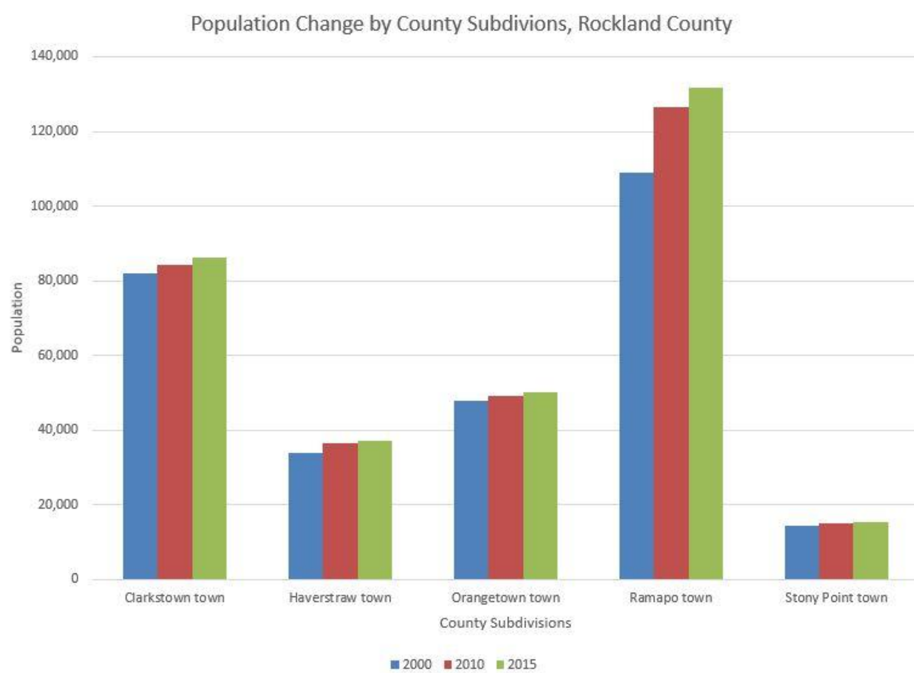


Figure III-13: Population from 2000 to 2015 by Town, Rockland County,
Source: U.S. Census Bureau

Population density change

Figure III-14 is a map that represents population density change from 2000 to 2010 on a census tract basis. From the map it can be inferred that between 2000 and 2010 the highest increase in population density has been in the south-central region of the county. The population density increased by 4793 to 6534 persons per square mile in this time period. A decline in population density is observed in the census tracts close to New York City. The close proximity of Rockland County to New York has had a huge influence on the population of Rockland County, and it can be seen that all the census tracts close to New York have observed a decline in population density.

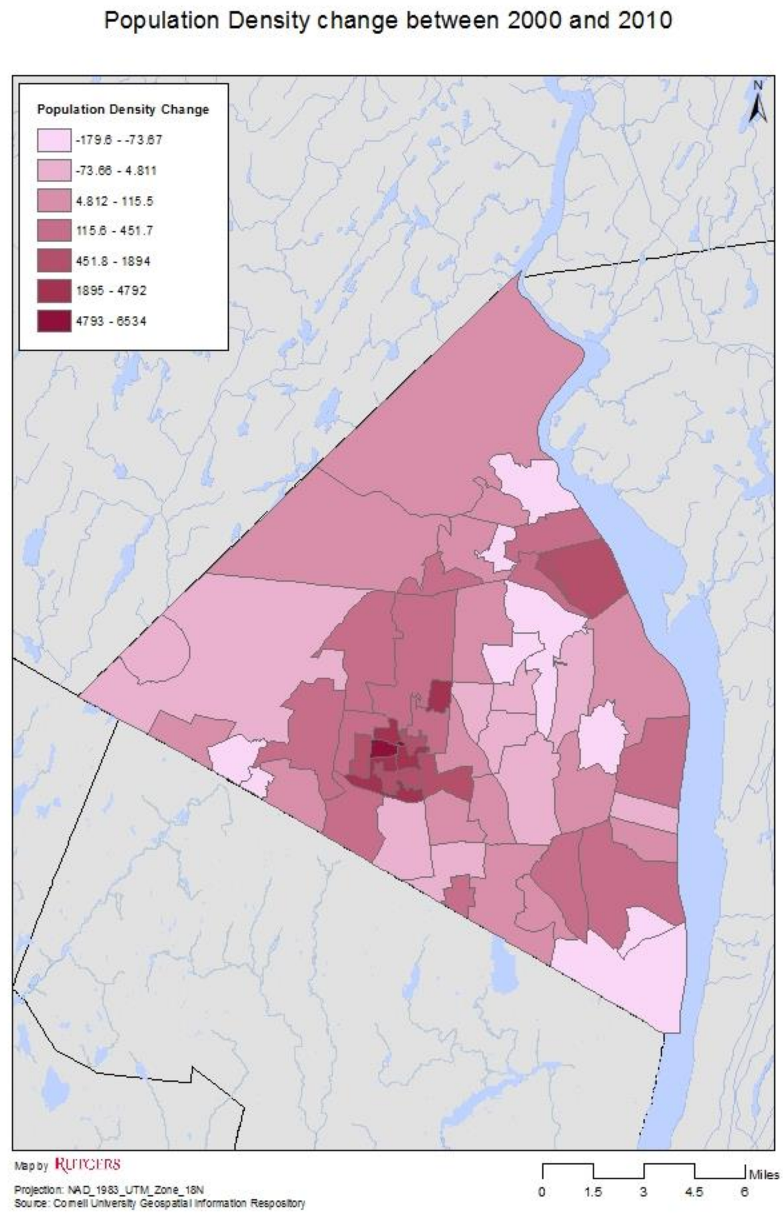


Figure III-14: Population density change between 2000 and 2010.
Source: U.S. Census Bureau

Future demographic projections:

The county comprehensive plan (Vanderhoef & Cornell, 2011) projects an increase in Rockland's population by 49,000 between 2005 and 2035. (Population has increased by roughly 15,000 from 2010 to 2016, according to Census Bureau estimates.) Consistent with the national and demographic patterns the number of seniors in Rockland County is expected to grow in both actual numbers as well as a share of the population. Additionally, it is predicted that of the total increase 48 percent of the population will be 65 or older. In essence, it means that by 2035, 17 percent of Rockland's total population will be over the age of 65.

The county build-out analysis indicates that nearly 18,000 additional housing units theoretically could be developed based on current zoning and constraints, for roughly 54,000 people assuming three persons per household. Market conditions and municipal responses could decrease this potential through poor markets for marginal properties, or increase it through a combination of market demand, zoning changes and redevelopment agreements. The largest areas "with residential development potential" (potentially but not necessarily equating to the largest number of housing units) are concentrated in southwestern Ramapo Town (Sloatsburg and the area south of Sloatsburg to the state border) and central Stony Point Town (east of Harriman State Park). However, significant lands are also scattered within Orangetown, Haverstraw and eastern Ramapo Towns (**Figure III-15**). The build-out analysis raises major questions regarding the impacts of future development on the Ramapo aquifer particularly.

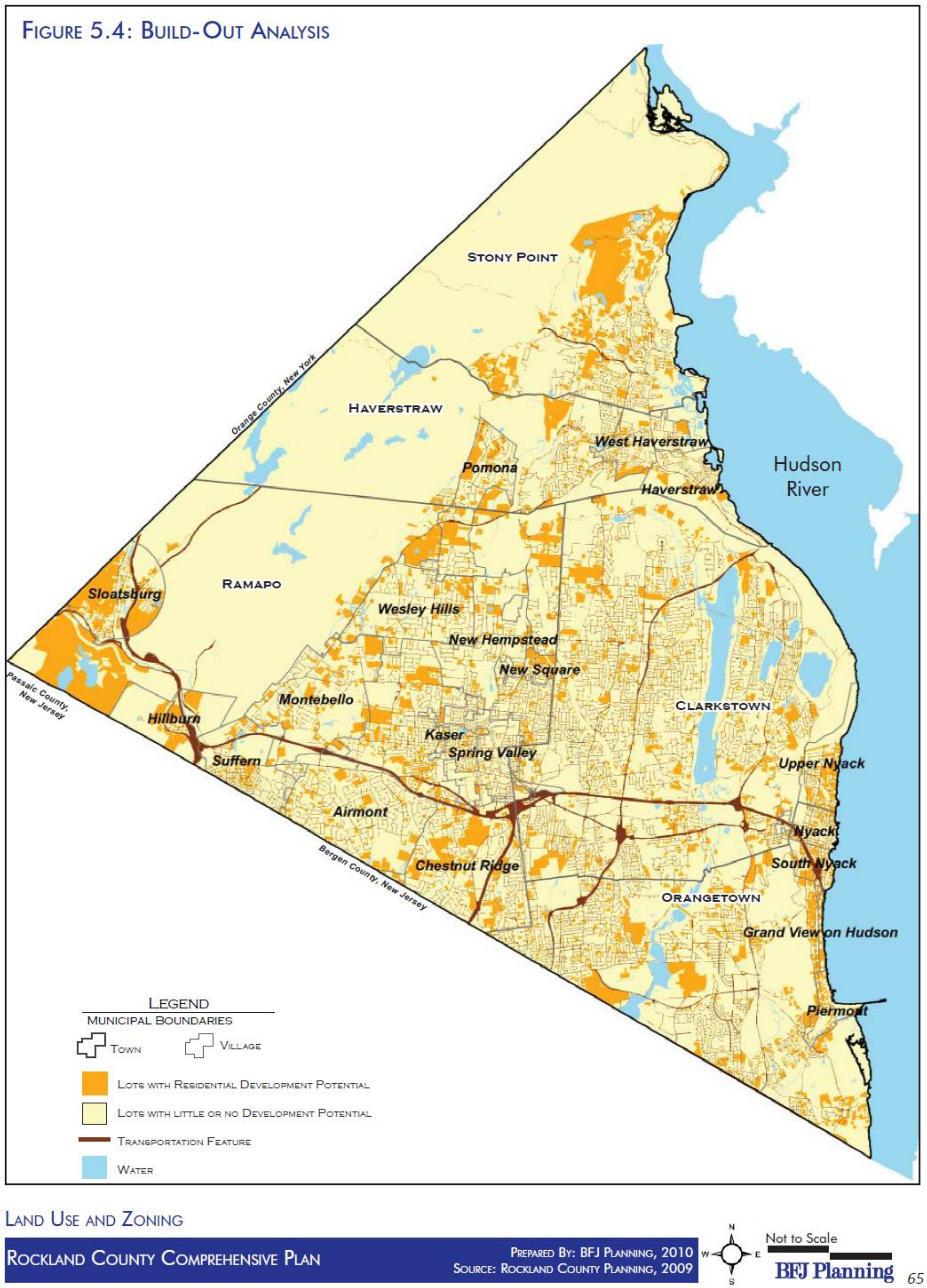


Figure III-15: Parcels with Residential Development Potential.
Source: Rockland Tomorrow: Rockland County Comprehensive Plan, (Vanderhoef & Cornell, 2011)

IV. Hydrology

Understanding the flow and interaction of water in the environment is essential for water resource management. Predictable patterns of surface and ground water flow allows water managers to efficiently use and conserve resources. Precipitation, surface water and ground water have strong connections in both the Ramapo and Hackensack watersheds, which influences water supply, infrastructure, quality, land use, and ecology. Drawing large amounts of water from wells without ensuring adequate recharge of aquifers leads to reduced use of wells during drought periods, which is likely to increase with climate change. Ground water is susceptible to contamination by surface water carrying pollutants that infiltrates through permeable soils and rock deposits to aquifers below. Dams and impoundments reduce water quality, recreational uses and habitability of surface waters.

Climate and Precipitation

Rockland County climate is typified by warm humid summers and cold wet winters, but, like much of the temperate northeast, experiences wide variations in temperature and precipitation. Mean annual temperature recorded for Suffern, NY, between 1981 to 2010 is 51°F, with January as the coldest month (mean monthly temperatures 19°F - 37°F) and July as the warmest month (mean monthly temperature 63°F - 84°F). In West Nyack, NY, mean annual temperature between 1981 to 2010 was 43°F, with January as the coldest month (mean monthly temperatures 11°F - 28°F) and July as the warmest month (mean monthly temperature 55°F - 76°F) (Northeast Regional Climate Center, 2017). The presence of the Hudson River moderates temperatures in eastern Rockland County, while the Suffern's location on the south facing slope of the uplands contributes to warmer temperatures (Manteghi, Limit, & Remaz, 2015; McCutchan & Fox, 1986). Mean annual temperatures from 1990-2016 (51.5°F), have been 1°F higher than from 1895 to 1989 (50.5°F) (NY Climate Change Science Center, 2017)

Precipitation in Rockland County averages 49 inches, based on 1895 to 2016 data analyzed using PRISM, a method of interpolating rain gage data while accounting for elevation changes. The amount of rainfall is quite variable from year to year with a high of 76.75 inches in 2011 to a low of 32.93 inches in 1965 (**Figure IV-1**). Individual rain gages in the county vary in their period of record (**Table IV-2**). Current rain gages are located at Suffern with a record from 11/3/2016 to present, and at West Nyack with a record from 4/23/2014 to present. Both gages are unheated and thus do not record accurate winter precipitation. Records from 2012 to present are available at the West Nyack 1.3 WSW station monitored by NOAA. Stewart Field, a USGS gage in Orange County, has data available from 1942 to present. USGS also has two current temporary rain gages at Nanuet and Suffern that record data for four months, but are not maintained and thus cannot provide information suitable for archival study (US Geological Survey, 2017b).

Historic records of rainfall are available from NOAA at Sparkill and Spring Valley from 1948 to 1953, Sterling Forest from 1980 to 1985, and Suffern, NY from 1956-1999. Nearby Woodcliff Lake, NJ, three miles south of Rockland County has records from 1948 to 1980 from USGS and 1919-2012 data from NOAA.

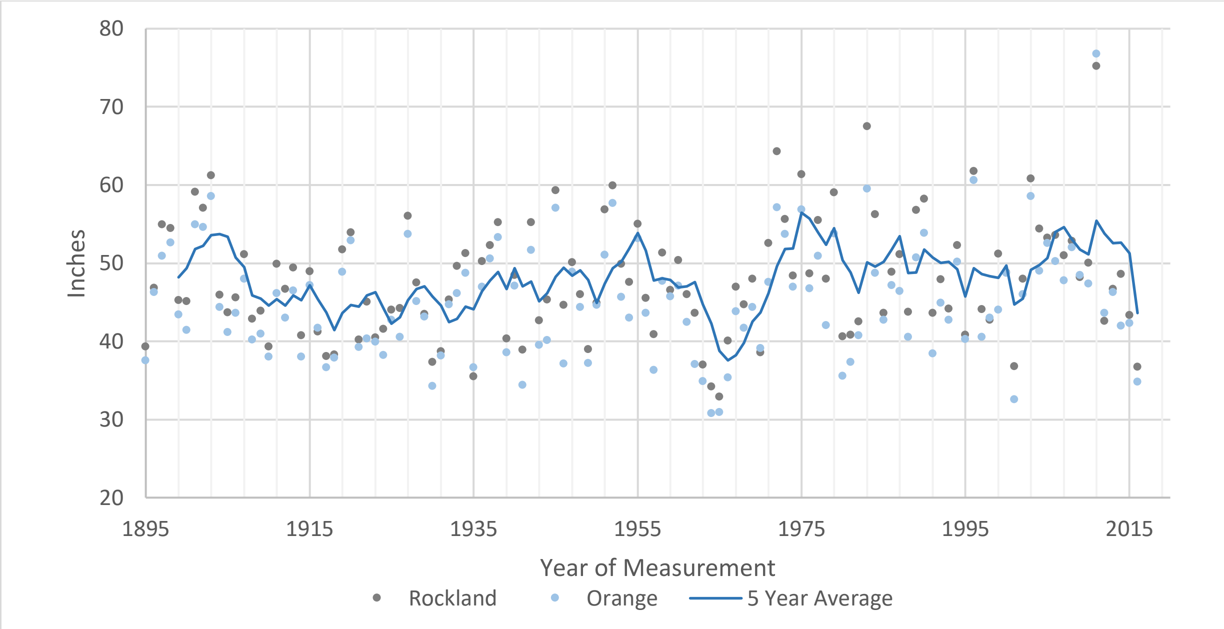


Figure IV-1: Mean Annual Precipitation from 1895-2017.
Source: NY Climate Change Science Clearinghouse, 2017

Location	County	ID	Type	Years of Data	Lat.	Long.	elev_m
Nanuet	Rockland	410518074020300.00	USGS Temp	2017	41.0883	-74.0342	
Sparkill	Rockland	COOP:308072	USGS	1948-1953	41.0333	-73.9333	18
Spring Valley	Rockland	COOP:308130	USGS	1948-1953	41.1167	-74.0500	137
Suffern	Rockland	SUFF	NY Mesonet	2016-2017	41.1304	-74.0899	178
Suffern	Rockland	410828074065801.00	USGS Temp	2017	41.1411	-74.1161	
Suffern	Rockland	COOP: 308322	NOAA	1956-1999	41.1128	-74.1600	270
West Nyack	Rockland	WNY	NJWCN	2014-2017	41.1058	-73.9699	27
West Nyack	Rockland	COOP:309270	NOAA	1990-1998	41.0833	-74.9667	190
West Nyack 1.3 WSW	Rockland	US1NYRL0005	NOAA	2012-2017	41.0835	-73.9930	268
Sterling Forest	Orange	COOP:308223	USGS	1980-1985	41.2331	-74.2367	238
Stewart Field	Orange	WBAN: 14714	USGS	1942-2017	41.5000	-74.1000	177
Woodcliff Lake	Bergen	COOP: 289832	USGS	1948-1990	41.0139	-74.0425	31
Woodcliff Lake	Bergen	COOP: 289832	NOAA	1919-2012	41.0139	-74.0425	103

Table IV-1: Current and historic rain gages in or near the study area.
Current rain gages are in bold. Sources: USGS, NOAA, NJWCN, and NY Mesonet.

USGS precipitation gages in 2005-2007 found more rainfall in the Highlands (about 58 in.) which decreased in volume to a low of 47 inches near the southeast corner of the county (Figure IV-2). Averages of total monthly rainfall from 1981-2010 recorded 50.3 inches in the Highlands at Suffern, NY and 48.9 inches at lower elevation in Woodcliff Lake, NJ (Northeast Regional Climate Center, 2017). Precipitation varies with local thunderstorms and altitude (Heisig, 2010, p. 6).

Evapotranspiration (ET) is the amount of water returned to the atmosphere coupled with that used by plants during the growing season to maintain function and grow. Randall (1996) estimated the amount of transpiration to be 22 inches/year. Heisig (2010) apportioned this total based on temperature and rainfall and estimated July to have the high ET at about 4.5 inches. Evapotranspiration is calculated at the West Nyack Station using the Penman-Monteith method and has records from 2014-2017 (NJWCN). ET had a mean yearly total of 15.8 inches and monthly mean totals range from a low of about 0.1 inches during December and January to a high of 27 inches during July (**Figure IV-3**). These amounts were based on unusually low precipitation levels. Further years of data can help to provide an accurate assessment of ET in the Hackensack watershed. The ET measurements in the Ramapo watershed has been estimated at 20 inches/year (Vecchioli and Miller, 1973) or 22 inches/year (Randall, 1996). There are no recorded measurements of ET in the Ramapo watershed.

Variability

Rainfall tends to be about the same each month—about 3 to 4 inches—though amounts can vary widely from month to month and from year to year. Heisig (2010, p. 7) found February to have the lowest median value (3 inches) in his analysis of the Letchworth Station gage from 1940-2001. Two year data from West Nyack, NY found wide variations in rainfall with a maximum of 5.25 inches, a low of 1.79 inches (New Jersey Weather and Climate Network, 2017).

Trends

Climate change trends have predicted and shown that there is and will be an increasing severity and variability in storms in the region. Since 1958, the amount of rainfall occurring in very intense storms (heaviest 1 percent of all storms) has increased 70 percent (Horton et al., 2014). Models of rainfall at Woodcliff Lake, NJ show the intensity and duration of 2-year 24-hour rainstorms increasing 10 percent in the next 20 years and with subsequent increases of 15-20 percent over the next 80 years depending on the amount of carbon dioxide in the atmosphere. The chance of receiving 4 inches of rain in 1 hour is rising 20 percent over the next 20 years, and from 50 to 80 percent over the next 80 years (Northeast Regional Climate Center, 2015). Increased flooding is likely due to more intense periods of rain. At the same time, climate forecasts predict lower average rainfall for the period 2035 to 2065, indicating potentials for increased periods of drought (46.5 inches compared to the current 50 inches) as shown in **Figure IV-4** (NY Climate Change Science Center, 2017).

Drought is difficult to define, but in NYS, five stages of drought are designated by a particular combination of low precipitation, reservoir storage, streamflow, and ground water level, which is dependent on the region of the state (Drought Management Task Force, 1988). Rockland County defines five stages of drought dependent on low precipitation, storage at Lake DeForest, and Potake

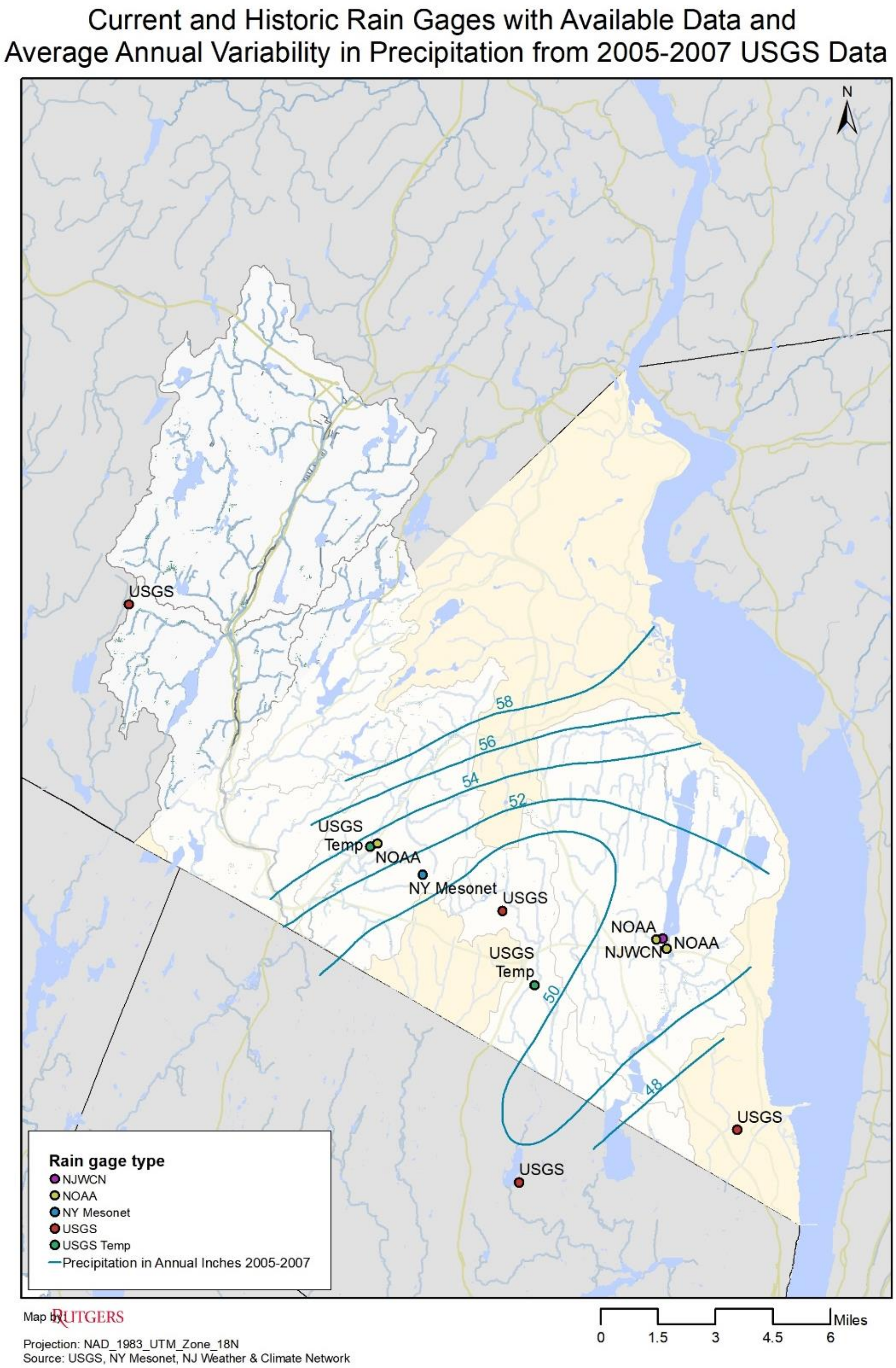


Figure IV-2: Precipitation variability across the county and location and type of current rain gages.
Sources: Heisig, 2010; USGS, NY Mesonet System; NJ Weather and Climate Network; NOAA.

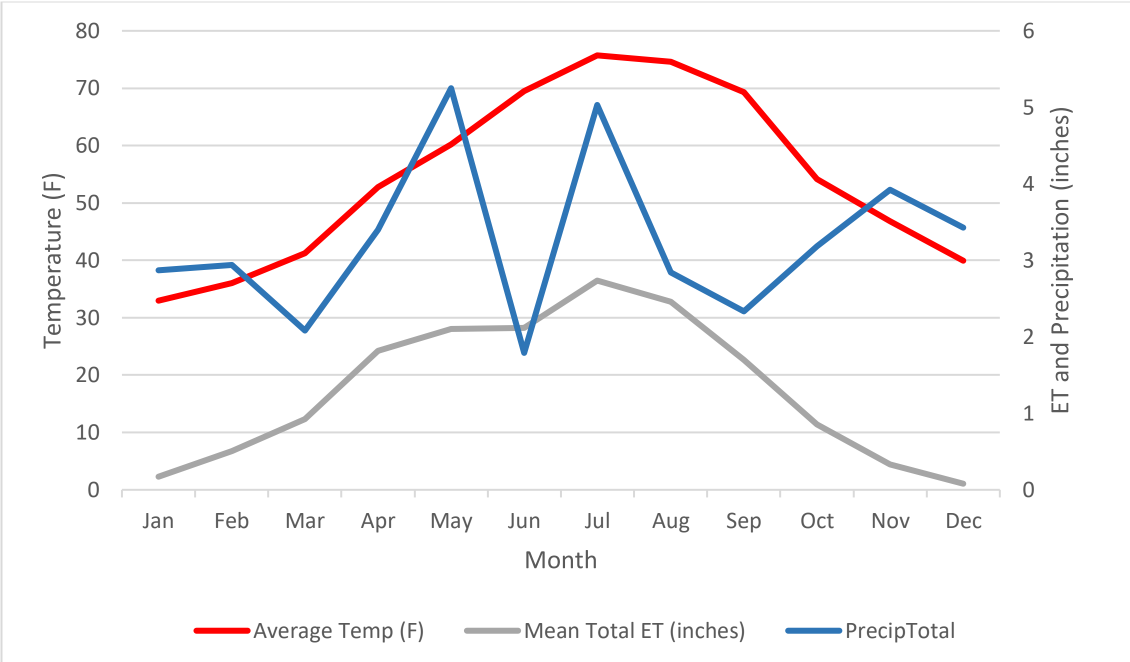


Figure IV-3: Mean Monthly Precipitation, Evapotranspiration and Temperature from West Nyack, NY Station from 2015 to 2017.
Source: New Jersey Weather and Climate Network, 2017.

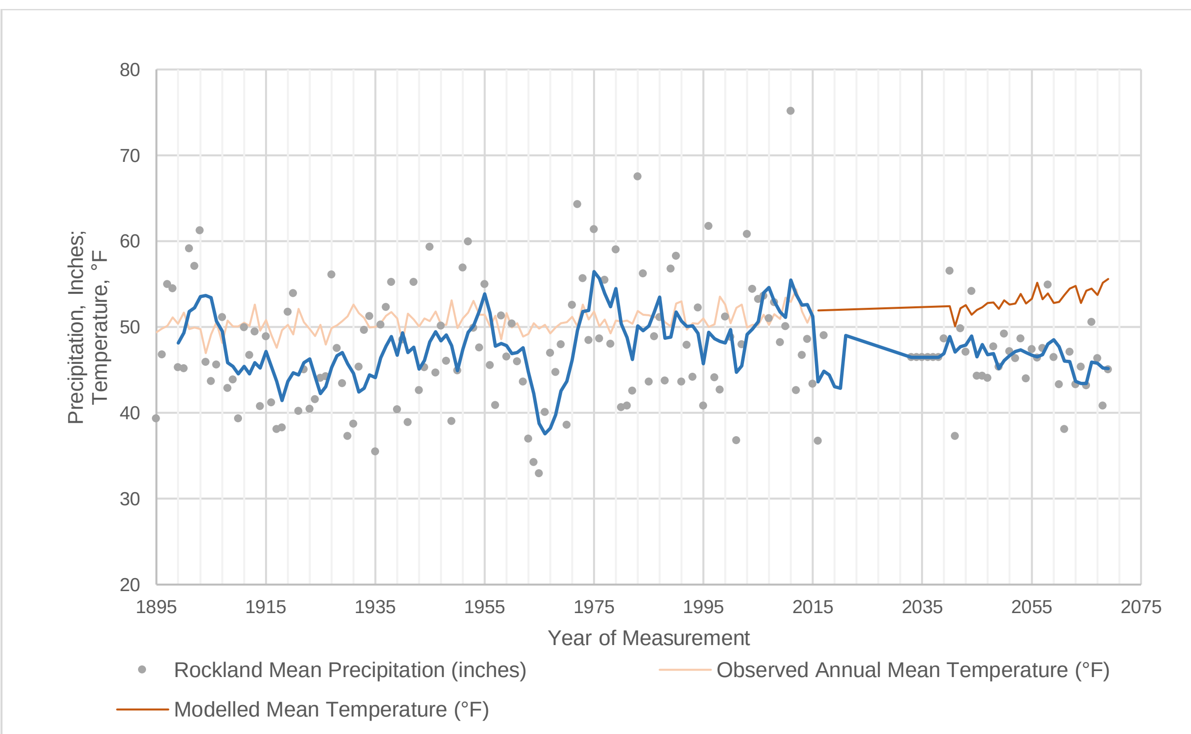


Figure IV-4: Climate change projections for Rockland County, modelled from past rainfall and temperature data.
Source: NY Climate Change Science Center, 2017

Pond and flow of the Ramapo River (Rulli, 2016). Changes in precipitation amounts influence the amount of water flowing in both streams and ground water.

Stream Flow

The National Hydrography Dataset (U.S. Geological Survey, 2017) provides spatial data about the water drainage network of the US and includes information about length and area of waterbodies, flow direction, and method of conveyance of the water (**Figure IV-5**). The Ramapo and Hackensack rivers originate in the north and flow generally southward into New Jersey. The headwaters of the Ramapo originate in Orange County and passing through 7 miles of the southwest corner of Rockland County, while the Hackensack originates in Rockland County and flows through the eastern, more developed part of the county. Stream flow is altered and regulated on both rivers by impoundments for water supply and by well withdrawals. Increases in population and development, diversion of flow caused by wastewater treatment plant discharges to the Hudson and Ramapo, and changes in water withdrawal methods from private wells to production wells have further altered stream flow. (Heisig, 2010, p. 5). Tributaries of the Ramapo include several unnamed streams in Highlands in Orange County, Stony Brook and Torne Brook, and drainage from Cranberry and Potake Ponds. The largest tributary of the Ramapo, the Mahwah River originates in the Highlands and flows southward on the divide between the uplands and lowlands in the county and joins the Ramapo River just south of Suffern, in New Jersey. Tributaries of the Hackensack include several unnamed tributaries to Lake DeForest, Nauraushaun Brook and Pascack Brook, the last of which originates in the central portion of the county, flows southward to meet the Hackensack in New Jersey.

The flow of rivers is measured on a continuous basis by USGS stream gages (**Table IV-2**). Gages are labelled with numbers corresponding to their location within a watershed. The mainstem branch of a river is assigned an eight-digit number ending with a factor of 100, which increase from a low number upstream to a higher number downstream, while tributary streams are labelled intermediate numbers. Gages are also identified by the town nearest the gage. The Ramapo River currently has two continuous stream gages operating in Rockland County, with another stream gage over the border in New Jersey. Historical records exist for another 3 continuous stream gages. One of these gages is in Rockland County and the other 2 are further upstream in Orange County. The Mahwah River has 1 continuous gage and 1 historic gage. The Hackensack River has 1 continuous stream gage in Rockland County currently operating, with another gage within 5 miles downstream of the New York/New Jersey border. Pascack Brook has a continuously operating gage at the hydroelectric plant near the NY/NJ border. Historical records exist for another 5 gages in Rockland County) Only the Mahwah near Suffern gage (USGS 01387450) measures unregulated flow, though there is occasional regulation from an unknown source and production wells along the stream that influence the flow (US Geological Survey, 2017c).

Stream flow is monitored in both states to ensure adequate flow is maintained from New York to New Jersey from the Hackensack by NYSDEC Water Supply Application (WSA) no. 2189, and from the Ramapo by NYSDEC WSA permit no. 6507, particularly from the Ramapo River. Releases from Lake

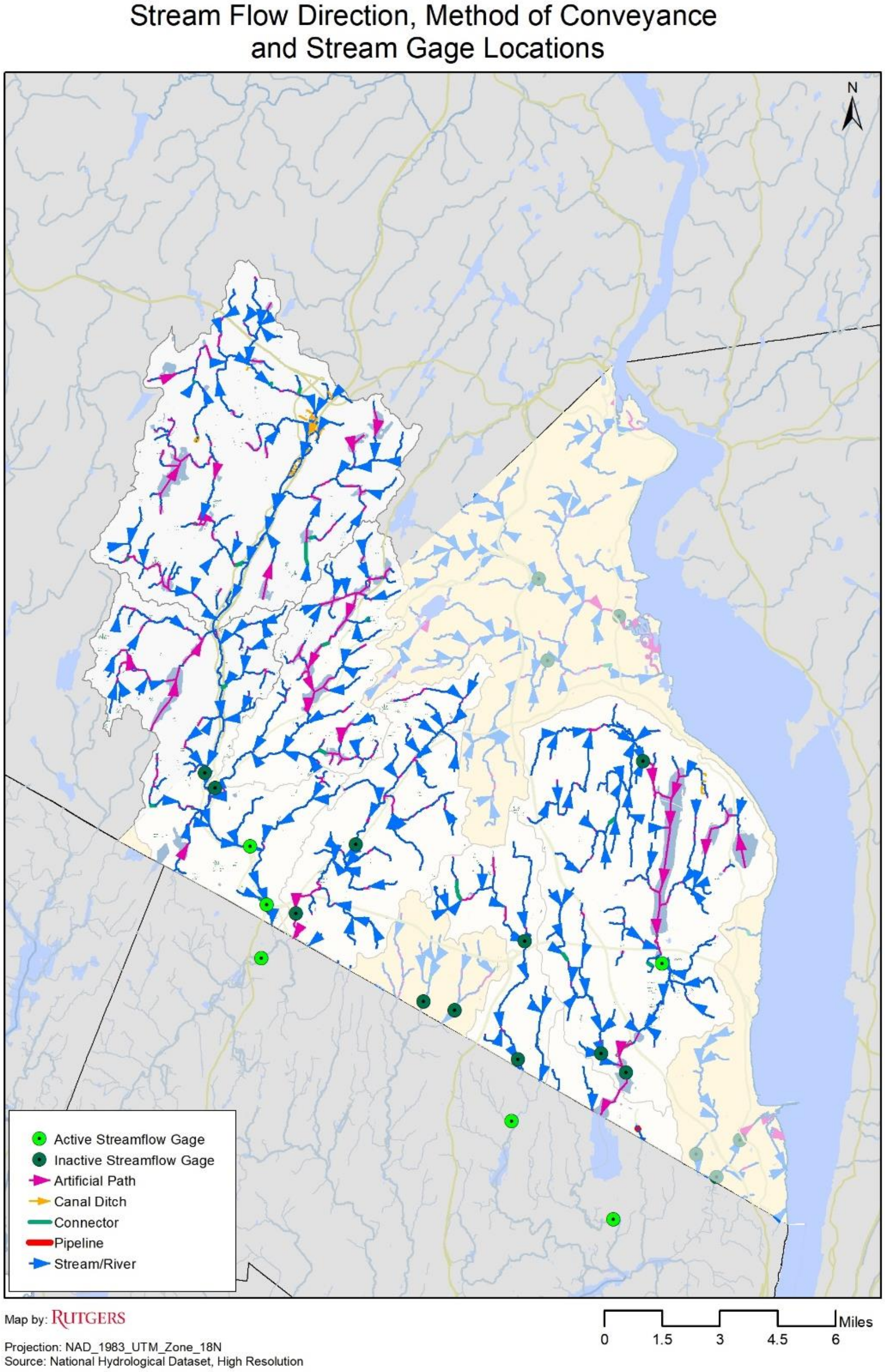


Figure IV-5: Streamflow direction, method of conveyance and current and historic USGS stream gage locations.
Source: USGS, 2017

Station number	Station name and location	Latitude	Longitude	County	Period(s) of record		Drainage area (mi^2)	Mean Annual Precipitation (inches)	Mean Annual Runoff (inches)	Median Daily Flow (cfs)	Flow/ Area (csm)
1382750	Ramapo At Sloatsburg, NY	411681	741904	Orange	1959-2000	P	---	49.06	27.61	64.00	1.06
01387300	Stony Bk At Sloatsburg, NY	410944	741109	Orange	1960–1962	C	18.2	50.06	28.22	15.00	0.82
01387400	Ramapo R At Ramapo, NY	410825	741007	Rockland	1980–2017	C	86.9	49.24	27.66	99.00	1.14
01387410	Torne Bk At Ramapo, NY	410834	740943	Rockland	1960–2002	P	2.60	49.66	27.71		1.14
1387450	Mahwah R Nr Suffern, NY	410827	740700	Rockland	1959–1995	C	12.3	49.94	2.30	14.00	0.97
					1996–2005	P					
					2006–2017	C					
01387480	Mahwah R At Suffern, NY	410654	740845	Rockland	1960–1962	C	20.7	---	---	20.00	---
					1963–1965	P					
01387420	Ramapo R At Suffern, NY	410706	740937	Rockland	1980–2017	C	93.0	49.21	27.61	96.00	1.03
01387500	Ramapo Near Mahwah, NJ	410553	740946	Bergen	1902-2017	C	120.0	46.00		139.00	1.16
01376600	Hackensack R At Brookside Park, NY	411018	735823	Rockland	1960–1963	C	13.2	---	---	12.00	0.91
					1967–1980	P					
1376800	Hackensack R At West Nyack, NY	410544	735750	Rockland	1959–2017	C	30.7	---	---	22.00	0.72
01376900	Hackensack R At Nauraushaun, NY	410316	735854	Rockland	1960–1962	C	44.6	---	---	49.00	1.10
					1963	P					
01376850	Nauraushaun Bk At Nauraushaun, NY	410342	735940	Rockland	1960–1963	C	5.89	---	---	3.70	0.63
01377000	Hackensack At Rivervale, NJ	405957	735921	Bergen	1941-2017	C	58.0	44.00	---	59.00	1.02
01377200	Pascack Bk Trib At Spring Valley, NY	410615	740156	Rockland	1960–1962	C	4.19	---	---	3.40	0.81
					1963–1980	P		---	---		
1377300	Pascack at Pearl River, NY	41.05982	-74.036	Rockland	1960-1963	C	9.83			13.00	0.97
01377370	Pascack At Park Ridge, NJ	410212	740221	Bergen	1960–2017	C	13.4	---	---	9.600	0.98

Table IV-2: USGS Stream gages in the Ramapo and Hackensack Watershed in Rockland and Orange County.
Bolded station names are currently active. Source: US Geological Survey, 2017a

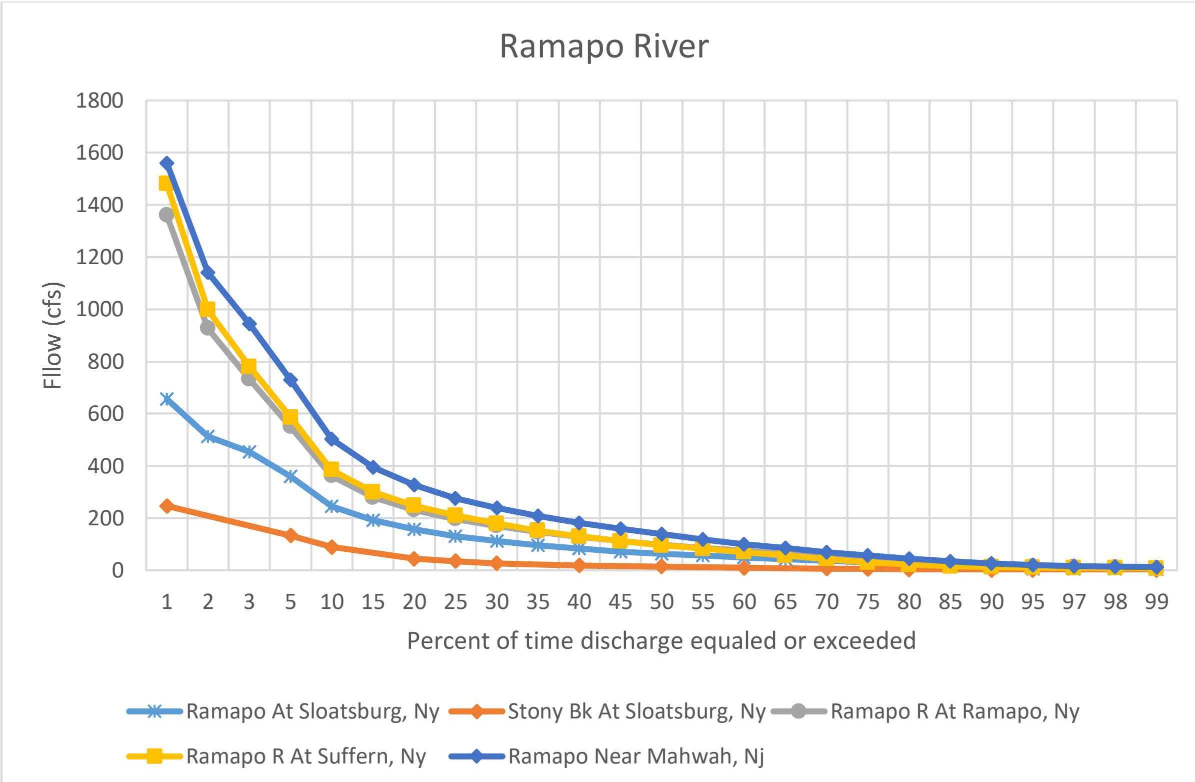
DeForest must allow 9.75 MGD downstream for uses in Nyack (2 MGD) and New Jersey (7.75 MGD), while the Ramapo must allow at least 8 MGD downstream. Water is released from the Lake DeForest and Lake Tappan reservoirs during low flow periods on the Hackensack. Releases from Lake Potake to the Ramapo River are permitted to augment flow to New Jersey, but flow must be maintained at 8 MGD at the Suffern gage. (CDM Smith & AKRF, 2015). During periods of drought, wells have been taken offline due to low flow in the Ramapo River.

Major studies of the surface water flow were completed by Ayer and Pauszek (1963), Lumia (1982) and Heisig (2010. Lumia (Lumia, 1982) created rainfall-runoff models for 10 stream sites in Rockland County. Heisig (2010) compared historic and current streamflow, particularly during low flow. Duration curves have been calculated or estimated for all major streams in the watershed from current and historic records (**Figure IV-6** and **Figure IV-7**). Duration curves are percentile rankings of daily flow in cubic feet per second (csf). Calculations of median flow per square mile (csm) of drainage basin (**Table IV-2**) facilitate comparison between streams and rivers in both watersheds. In the Ramapo watershed, highest median flow per unit is recorded in the Ramapo at Mahwah (1.16 csm), while Stony Brook at Sloatsburg records the lowest (1.14 csm), indicating little difference between the river and its tributary. In Rockland County, the Mahwah River at Suffern stream gage recorded the lowest flow (0.97 csm), likely due to ground water withdrawals, as noted by Heisig. In the Hackensack watershed, highest flow per area is recorded at Hackensack at Nauraushaun, NJ (1.10 csm), not greatly different from the Ramapo River estimates, and the lowest is estimated at Nauraushaun Brook at Nauraushaun (0.63 csm) (US Geological Survey, 2017a). The Nauraushaun Brook watershed has several factors that contribute to lower stream flow compared to waterways with higher flows, including a less steep channel gradient, lower rainfall, and high levels of ground water withdrawals. The low stream flow value indicates that most base flows (the river flow in periods between precipitation-affected flows) are unusually low.

Variability

Streams in Rockland County are dependent on precipitation for their flow, directly or indirectly through base flows, which creates a high variability in stream flow as amount of precipitation changes from year to year (**Figure IV-8**). Base flows are dependent upon infiltration (recharge) of precipitation into the subsurface and movement of that water to the streams over time. Base flow is heavily dependent on the ability of soils and geologic formations to infiltrate and store water. The Highlands area of Rockland County have very limited ground water storage potential, due to rock formations that have few fractures. A simulation using a model of the Newark Basin found baseflow in the Pascack Brook approached zero during both short and long term drought (O'Rourke, 2016).

Streams in the higher precipitation areas of the Highlands tended to have higher streamflows (Ayer & Pauszek, 1963, p. 100; Heisig, 2010, p. 84). Ground water withdrawals, development which limits recharge, diversion of flow into wastewater discharges to the Hudson and Ramapo, and underlying dense bedrock with little storage capacity contribute to very low and dry streambeds during the summer when evapotranspiration rates are highest. Streams with sand and gravel deposits tend to store water that slowly releases during low flow periods, while streams with adjacent wetlands tend to have lower



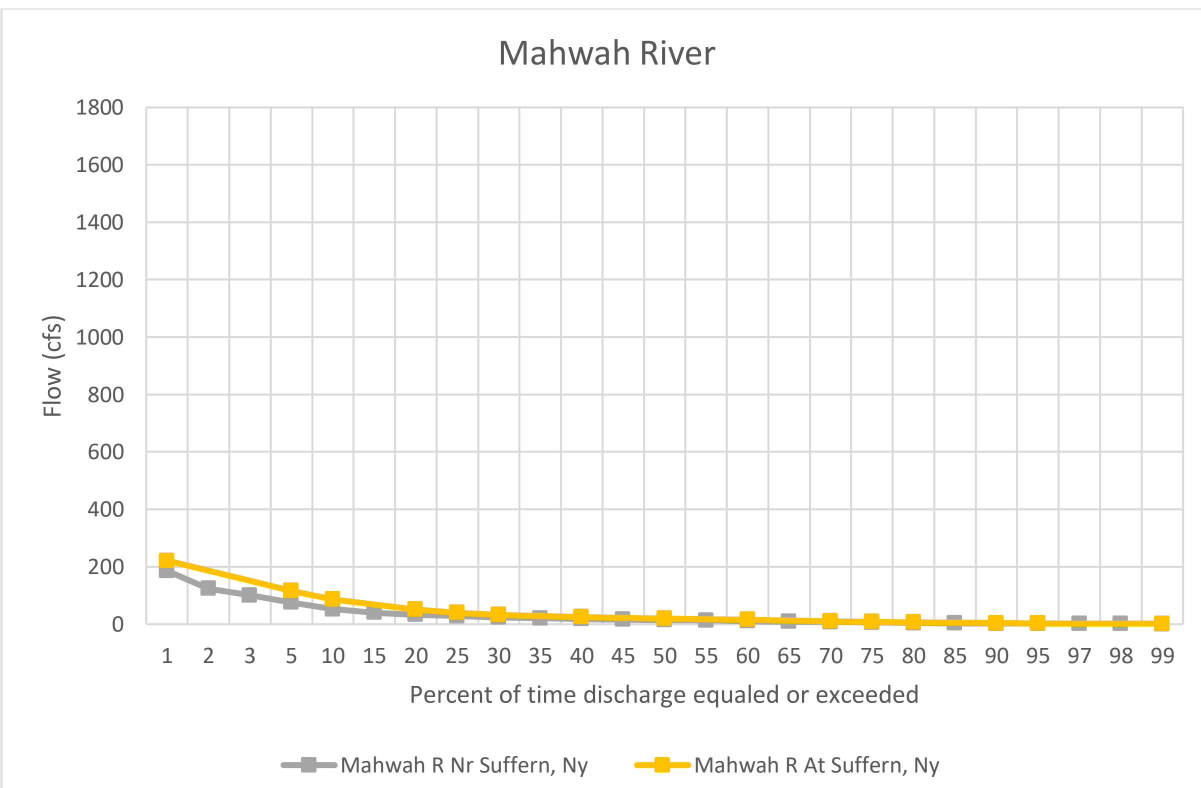
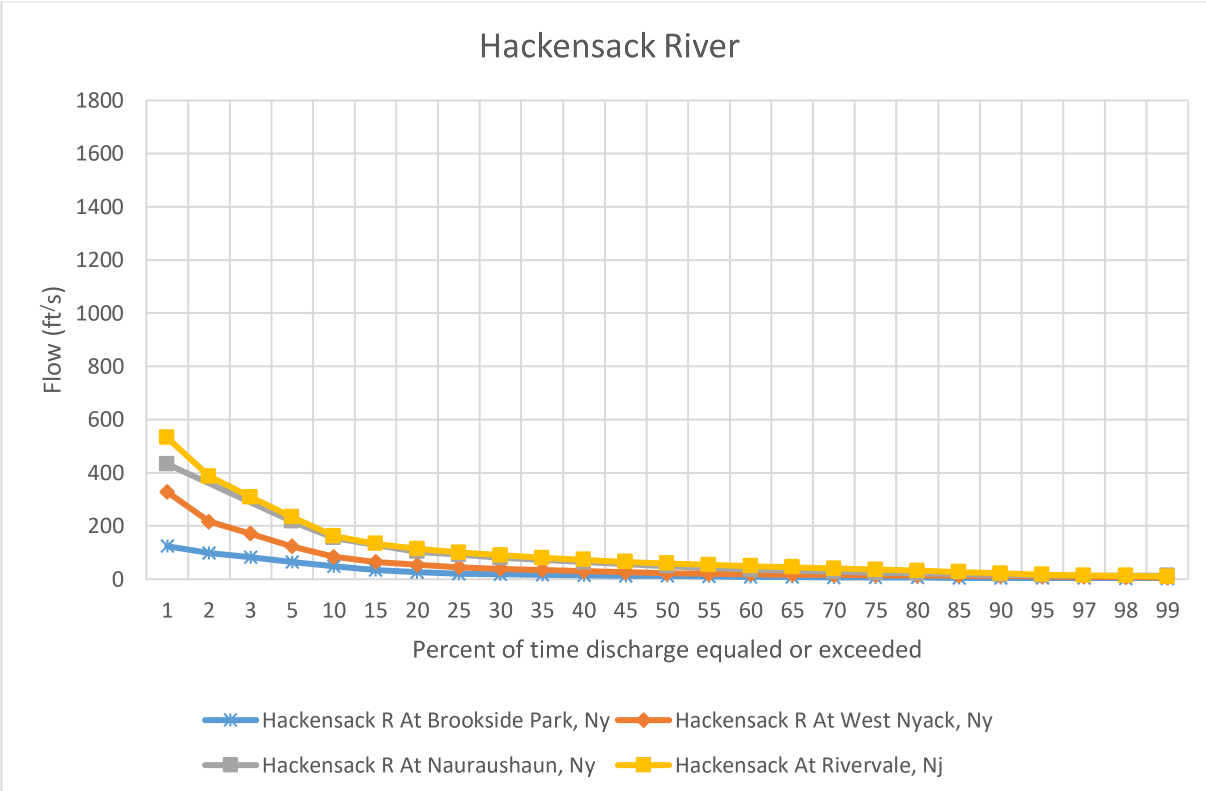


Figure IV-6: Duration Curves for the Ramapo and Mahwah Rivers at USGS current and historic stream gages.
Source: US Geological Survey, 2017a



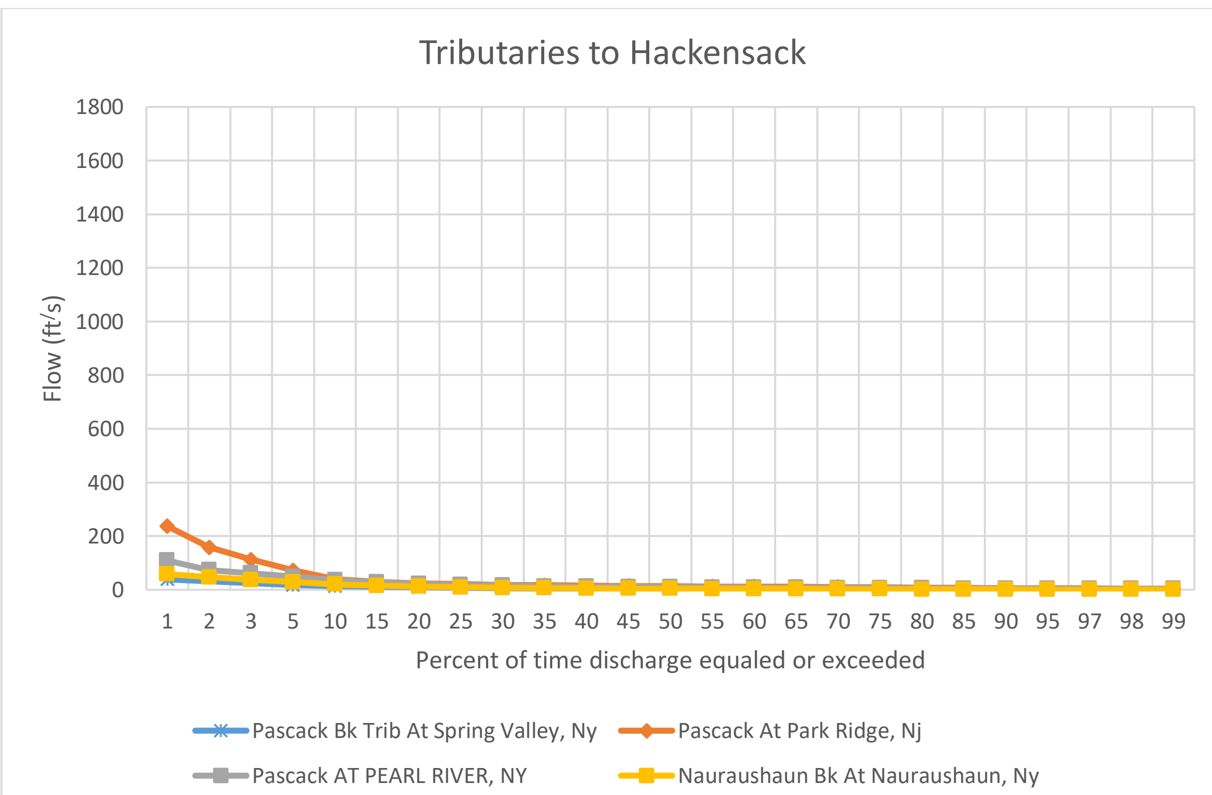


Figure IV-7: Duration Curves for the Hackensack River and its tributaries at USGS current and historic stream gages.
Source: US Geological Survey, 2017a

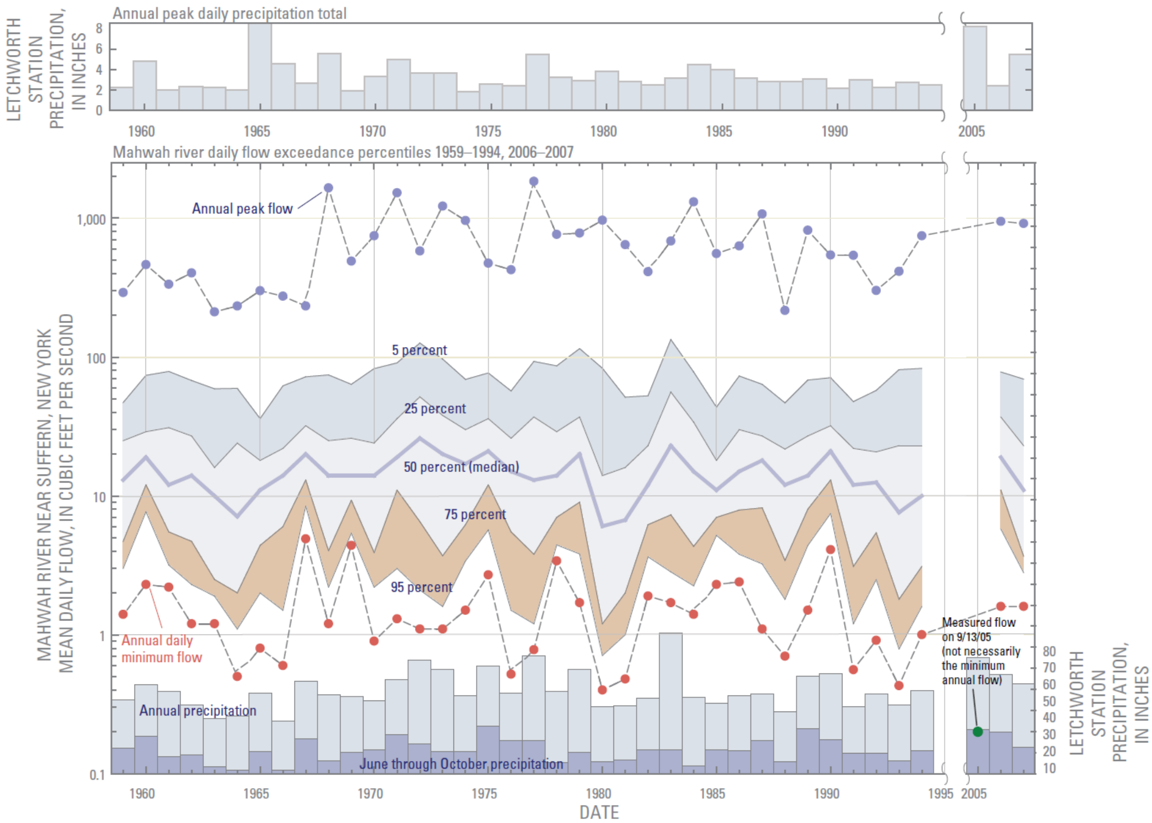


Figure IV-8: Mahwah River comparing exceedance statistics to streamflow.
Showing the clear effect of rainfall on the stream. Source: Heisig, 2010, p. 83

streamflows, due to higher evapotranspiration rates from the ponded water. Channel slope and channel length divided by drainage area had a slight influence on low flow statistics. (Randall & Freehafer, 2017, p. 8).

Heisig (2010) measured streamflow at 71, 73 and 99 percent exceedances using temporary current and temporary gages (**Figure IV-9**). Hackensack watershed streams in the Newark Basin lowlands with no nearby production wells had the highest flow during an extreme low flow period (September 2005—99 percent exceedance). During this same period, the Mahwah had the lowest flow, most likely due to ground water withdrawals. This is unique among rivers flowing from the Highlands' higher levels of precipitation (Heisig, 2010, p. 82). During 71 percent exceedances, the Mahwah continued to have the lowest flow compared to other streams in the Highlands.

Based on current duration curves, in the Hackensack watershed the lowest flow during 99 percent low flow (0.09 csm) comes from the Nauraushaun Brook. Lowest flows in the Ramapo watershed during 99 percent exceedances were from Stony Brook at Sloatsburg (0.06 csm). In both cases, these streams drain areas with low storage capacity and higher areas of wetlands. The Nauraushaun has relatively little sand and gravel aquifer adjacent to the stream bed (10 percent of length), and Stony Brook is underlain by crystalline bedrock. The Mahwah's low flow during this period is 0.13 csm, which is likely affected by ground water withdrawals.

Trends

Comparisons of streamflow are difficult: precipitation varies in intensity and amount from year to year and land use continually changes. Heisig (2010) did compare the Mahwah's streamflow measurements to Ayer and Pauszek's 1961 measurements at 71, 73 and 99 percent exceedances (**Figure IV-9**) and found similar stream flows during the 71 and 73 percent exceedance flows. During 99 exceedance, stream flow in 2005 tended to be about 0.2 csm less than the 1961 measurements, but rainfall was particularly low during the 2005 measurement period and further reinforces the dependence of streams on precipitation (Heisig, 2010, p. 82).

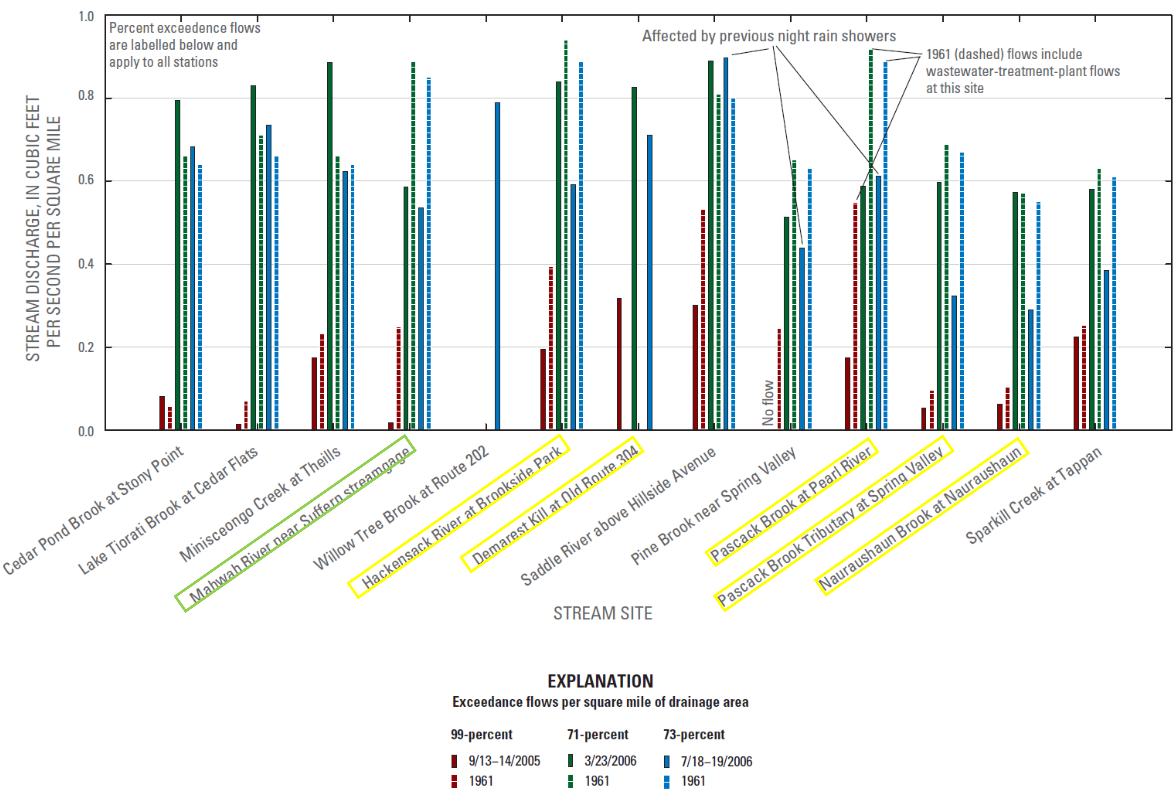


Figure IV-9: Streamflow measurements in flow per square mile at 99, 73, and 71 percent exceedances. Hackensack (yellow) and Ramapo (green) streams are highlighted. Source: Heisig, 2010, p. 81

Ground water storage

Ground water is stored in two types of aquifers in the study areas. The Newark Basin underlies the Hackensack watershed and the Ramapo and Mahwah are dependent on flow from water stored in adjacent sand and gravel aquifers. Storage in the Newark Basin in Rockland County was mapped by Heisig in 2005-2006, building on Perlnutter's extensive documentation of aquifers and geology in 1959. Vecchioli and Miller collected data in 1973 to understand water resources in the New Jersey area of the

Ramapo basin. Leggette, Brashears, and Graham, Inc. have completed a number of studies of ground water flow in the Ramapo and Hackensack watersheds. A 1979 study estimated water supply potential in the Newark Basin (as mentioned in Heisig, p. 17), a 1982 study tracked ground water flow in the Ramapo well field (as mentioned in Hill, 32), a 1992 study tested flow in the Spring Valley Well Field (Heisig, p 17), and a 1994 study in Orange County tested yield and demand of ground water by municipality (1994). Simulations using a model of the Newark Basin provides information on ground water levels during drought (O'Rourke, 2016)

The Newark Basin is a large sedimentary bedrock aquifer which lies under a majority of the south part of Rockland County. Ground water stored in the Newark Basin falls into four zones dependent on underlying bedrock, gamma log patterns, aquifer transmissivity (T), well yields, and proximity to the Ramapo fault or Palisades sill (**Table IV-3**, **Figure IV-10**). Gamma log patterns are a method of detecting varying lithologies underground and aquifer transmissivity is the rate at which ground water flows through an aquifer. Well yields are based on production wells, rather than domestic wells. Zone A is in the western edge of the basin near the Mahwah River and composed of pebbly sandstone with basaltic rock from the Highlands. This zone is tipped toward the east and has low well-yields of 20-70 gal/min and low transmissivity (<100 ft^2/d). The three other zones are tilted on average 10 degrees toward the northwest. Zone B is composed of pebbly sandstone and has the highest well yields (125-700 gal/min and the highest transmissivity (700-1300 ft^2/d). Zone C is composed of a mix of pebbly sandstone layered with fine grained rocks that tend to dissolve and erode at wellbores. Well yields range from 65-600 gal/min and transmissivity ranges from 300-700 ft^2/d. Zone D is composed of finer grained sandstones that have medium well yields (200-350 gal/min) and a lower transmissivity (100-300 ft^2/d) (Heisig, 2010, p. 26).

Storage

Water in the Newark Basin is stored in fractures that run parallel to the plane of the bedrock layers, and follow roughly the boundaries of Zones A to D (p. 31, 63). These fractures are at a relatively low angle for much of the bedrock, though high angles do exist near the fault that separates the Highlands from the lowland area of the county (28). Low angled fractures can hold more water than high angled fractures. Depths of storage varies by zone—as the underlying rock becomes more coarse-grained and pebbly, and altitudes increase, productive depths generally increase (p. 28). The most productive yields came from relatively shallow depths of 200 ft. in Zone D, to deeper fractures of 350-400 ft. in Zone B.

In the Ramapo watershed, alluvial aquifers along the Ramapo and Mahwah Rivers store water between pores of sand and gravel particles. These deposits are from prior glaciation of the region, which resulted in the filling of river valleys with sedimentary materials. The typical thickness of sand and gravel in these valleys are 40-60 ft (up to 140 ft at Suffern, NY) in the Ramapo and Mahwah watersheds, much shallower than similar deposits in parts of northern New Jersey. There are some other small deposits of sand and gravel over bedrock along stream sides, which may not store as much water, though they do induce flow from the stream (Heisig, 2010, p. 21). Smaller aquifers in the Highlands have not been characterized but are considered to have low yield due to underlying crystalline bedrock (Heisig, 2010, p. 13).

Aquifer Zone	Natural-Gamma Radiation Pattern	Lithology	Well Yield Range (Wells greater than or equal to 250 ft deep (gal/min)	Most common range of aquifer transmissivity (ft^2/d)	Maximum aquifer transmissivity (ft^2/d)
A	Low baseline levels, with regular low peaks that are less than double the baseline in the upper 200ft. Larger peaks below 200 ft.	Interbedded conglomerate, pebbly sandstone and sandstone	20-70	<100	760
B	Low baseline levels, with regular low peaks that are less than double the baseline	Mostly interbedded conglomerate, pebbly sandstone and sandstone	125-700	700-1,300	13,370
C	Low baseline levels, with regular high peaks that are mostly more than double the baseline. Boundaries transitional.	Pebbly sandstone and sandstone interbedded with thin (10' or less) fine grained micaceous or clayey layers at intervals of about 5 to 20.'	65-600	300-700	1.060
D	High baseline levels, with low peaks every 5 – 10 ft.; few low-gamma zones of "clean" sandstone. Low-gamma zones increase in thickness and frequency toward the west.	Sandstone, siltstone, mudstone, and shale	25-150	100-300	3,800
D.1	No data	Sandstone and shale	200-350	100-300	3,800

Table IV-3: Aquifer zones and characteristics.
Source: Heisig, 2010

Patterns

Ground water flows vary across the Newark basin, depending on hydraulic pressure, topography of the bedrock, transmissivity, wells in the area, and confinement of the aquifer (Figure IV-11). Ground water drains across the bedrock from a major divide running northwest to southeast—roughly along the Palisades Parkway—and flows from high elevation areas to low elevation areas of the bedrock. A divide is an area of high topography and/or hydraulic pressure from which water flows in different directions. Ground water flows parallel to strike (most readily along the line of fracture) toward the northeast and the Hackensack River or southwest to the Ramapo River. A second divide runs approximately north and south, which directs flow to the Mahwah River and Pascack Brook. There is some flow perpendicular to the fractures where the parallel flow is impeded by bedrock changes, though this is generally shallow and small in area. Wellbores can disrupt the normal flow of ground water when holes are drilled through two or more fractures. This interconnection between fractures can affect the pressure of the well depending on its location topographically within the aquifer (Heisig, 2010, pp. 36, 63, 66–67).

Smaller more local divides further direct flows to low pressure areas of the aquifer. Interestingly, well pumping has shifted ground water divides from areas of high elevation to areas that are not accessed by water pumps. For example, Spring Valley well field pumping has moved the ground water divide south

Hydrogeology of the Newark Basin Aquifer System in Rockland County

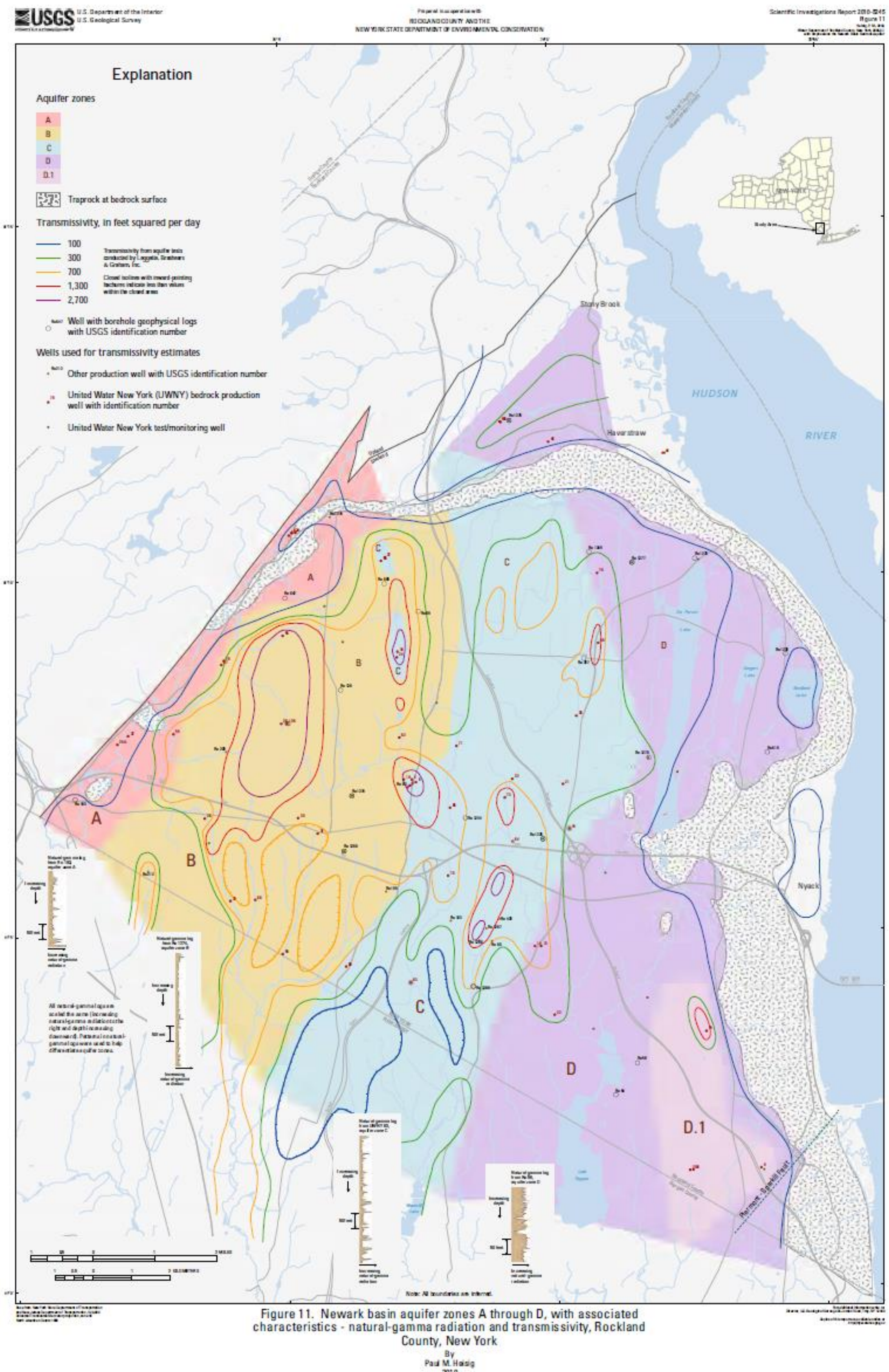


Figure IV-10: Newark Basin aquifer, Zones A-D with natural-gamma radiation and transmissivity measurements.
Source: Heisig, 2010, p. 25

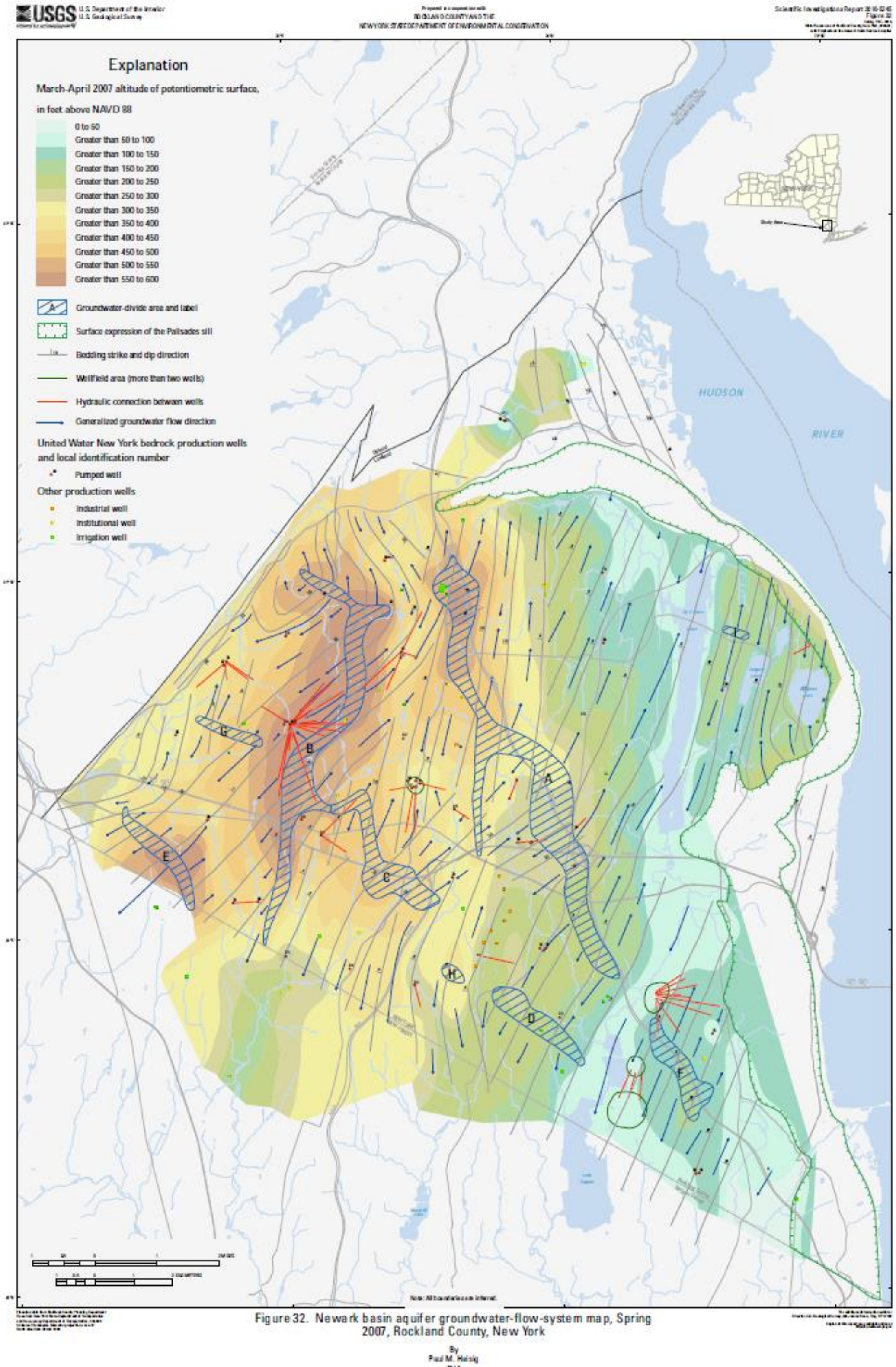


Figure IV-11: Ground water flow pattern across the Newark Basin in Rockland County.
Source: Heisig, 2010 p. 66.

to a marshy area along the NYS Thruway. Numerous springs that flowed in Spring Valley have dried up as the locus of ground water has shifted with increased pumping. Additionally, the 6000+ domestic wells drilled in the Newark Basin have accelerated ground water flow toward wells, particularly those areas with a high number of production wells (Heisig, 2010, pp. 67, 36).

Sand and gravel aquifers along the Ramapo and Mahwah Rivers hold water in the spaces between the coarse-grained fill of these glacial deposits. Some of these aquifers, particularly those near Arden and Harriman, are confined with more fine-grained sand, clay and silt. Additional sandstone and carbonate bedrock fractures hold water under the sand and gravel aquifers in the upper reaches of the Ramapo in Orange County and ground water in bedrock is a more easily accessible source of drinking water in these areas (Heisig, 2014, p. 7; NJ Highlands Water Protection and Planning Council, 2008, p. 10). Crystalline bedrock in the Highlands does not hold much water and drainage tends to be poor in this area, though water does enter and is stored in some fractures. The limited thickness and localization of sand and gravel aquifers limits ground water storage. (Heisig, 2014, pp. 8, 11). Ground water tends to flow downhill from the uplands into the valleys and then parallel to the direction of the stream at an average rate of 0.0014 foot per foot (ft/ft) in NJ, but "much higher" in NY (Hill, Lennon, Brown, Hebson, & Rheaume, 1992, p. 29). Leggette, Brashears and Graham (1981, cited in Hill, 1992, p. 18) reported hydraulic conductivity (movement through the aquifer) of 13 ft/d to 660 ft/d two miles north of the Suffern well field. Streams with alluvial aquifers depend on outflow from the streams to ground water when precipitation is high, and inflow from ground water to streamflow during low flow. Production wells in the alluvial aquifers interrupt the flows from ground water to streams during low flows, and can induce the movement of surface water into the aquifers, further reducing stream flow during critical low flow periods.

Variability

One area of concern for water resources in Rockland County is the variability of ground water depths and flow rates in both the Newark Basin and the Ramapo and Mahwah watersheds. During the summer growing season, as shallow ground water is withdrawn, reducing water levels in the aquifer, well yields decline (**Figure IV-12**). During particularly dry years, wells have been taken offline during low flow months. Low ground water levels create risks for air entrainment in the water pumps, which may damage the pumping mechanisms or enter the distribution system. Lowering pumps or installing clear wells to prevent these air bubbles from entering the system has occurred in the water system. Shallow ground water is recharged as demand decreases and precipitation increases (Heisig, 2010, pp. 47–52; McClane, 2013, p. 7). O'Rourke (2016) found that water table levels could decline more than 50' during a three-year simulated drought.

Differences in seasonal flow variability are zonal and depend on the underlying geology and transmissivity. Heisig found flows from wellbores in Zones B and C to be the highest, corresponding to high T values, high yields from deep wells, topographic changes and ground water-withdrawal rates. Lowest flows were in Zone D corresponding to low T, yields, topography and ground water withdrawal rates. Water flowed downward in the wells as ground water from shallower fractures flowed into deeper fractures. Zone D is highly susceptible to decreased ground water due to the shallowness of its aquifers (Heisig, 2010, p. 36).

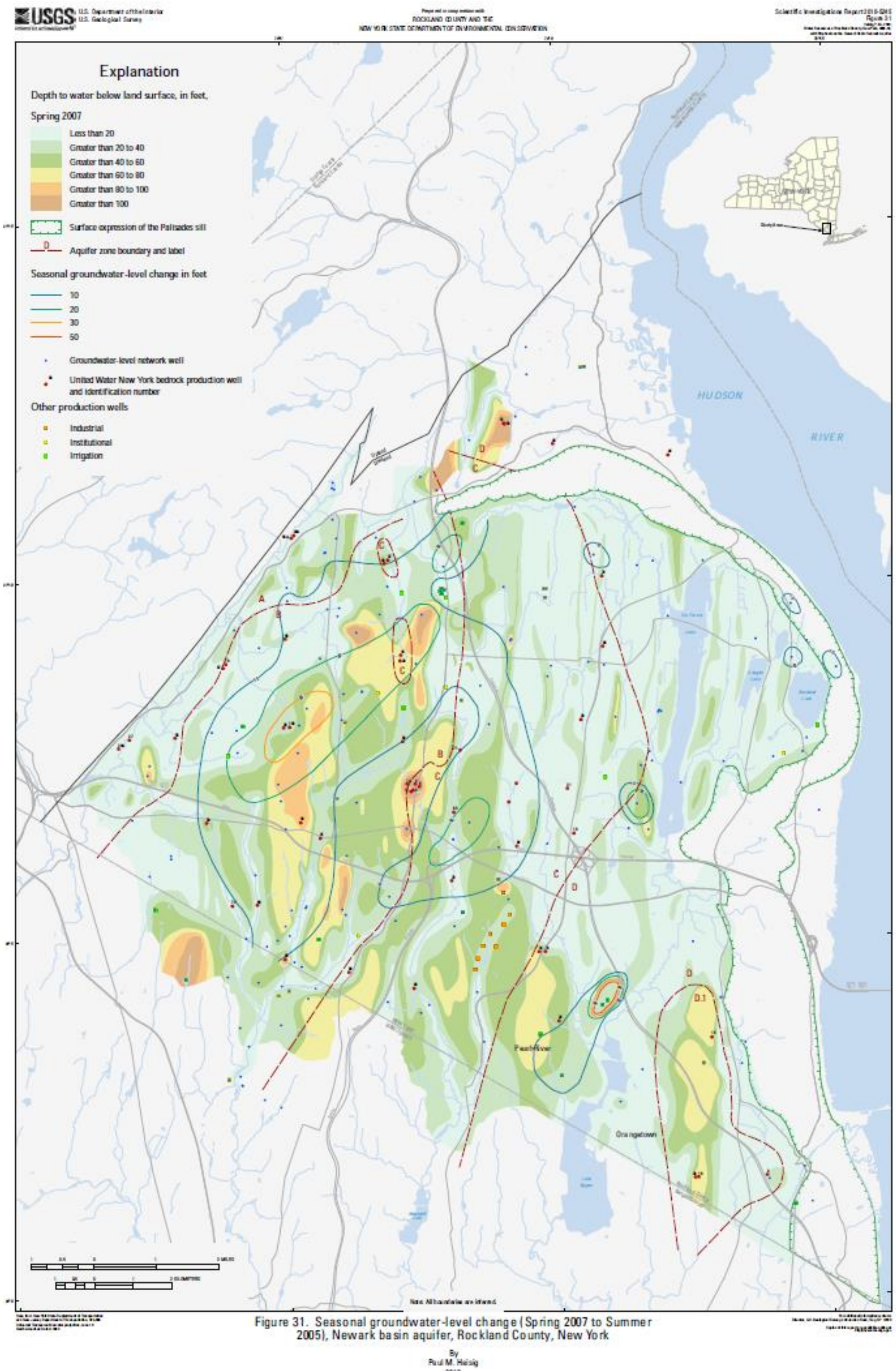


Figure IV-12: Seasonal Fluctuation in ground water Levels (spring 2007-summer 2005).
Source: Heisig, 2010, p. 65

Ground water also seeps into the sewer system at an estimated net 0.8 MGD, resulting in treatment and discharge out of the source watershed (Heisig, 2010, p. 112; Yager & Ratcliffe, 2010, p. 20). Reducing demand during summer months, halting water loss system wide, and ensuring that stormwater and wastewater discharges return to source watersheds can help to maintain ground water levels during low flow months (Heisig, 2010, pp. 114–116; McClane, 2013, p. 19).

One USGS ground water observation well exists in the Hackensack watershed, which has been monitored from 2007 to 2017 (**Table IV-4**). Average depth to water level ranges from about 5 feet below land surface in the winter and spring to almost 10 feet below surface in summer and fall months (Figure IV-13) (US Geological Survey, 2017d). These data corroborate the seasonal variability noted by Heisig. Well depth is influenced by precipitation levels: less decline in water levels occurred after a very wet summer (2012), while two consecutive very dry years (2015 and 2016) show less recharge in the winter and greater depth in the summer. This corroborates Heisig's connection between the shallow aquifers of Zone D and low ground water rates. The 2017 growing season has had higher than average rainfall, which will add useful data to assess if this is a long-term trend. Simulations of ground water withdrawals using Yager and Ratcliffe's model (2010) found a general decline from 1960 to 2002 in amount of water in upland aquifers (Yager & Ratcliffe, 2010, p. 64). No long-term trend is shown by the data, indicating that the aquifer in this location is not being over-drawn.

In the Ramapo and Mahwah watersheds, seasonal fluctuations in the aquifers are not as well understood. Suez New York is developing a model of the Ramapo watershed (CDM Smith & AKRF, 2015) (personal communication, David Stanton, Sept. 2017).

Well Number and Site	USGS Ground Water Gage Number	Watershed	Depth of Hole	Type of Well	Period of Record	Type of Record	Average Monthly Mean	Lowest	Date	Highest	Date
RO-543, Rockland Lake	410853073554001	Hackensack	153'	bedrock	10/1/2007-8/26/2017	C	7.375	10.7	10/7/2005	5.08	5/1/2014

Table IV-4: Ground water depth gage and statistics.
Source: US Geological Survey, 2017d

Trends

Withdrawals of ground water in the Newark basin peaked in 1975 (Yager & Ratcliffe, 2010, p. 16) compared to withdrawals in 2005. Losses of water occur when water is pumped from wells and then discharged as wastewater to the Hudson and Ramapo Rivers. This has decreased recharge in the Newark Basin, though there is no evidence of long term decline (Yager & Ratcliffe, 2010, p. 64). However, the dependence of both watersheds on precipitation can limit the availability of ground water during periods of drought. Climate change and its high variability of precipitation and drought creates a more urgent need to protect ground water resources and ensure adequate replenishment of aquifers.

Surface water/ground water interactions

Periods of drought significantly reduce ground water levels because both the Ramapo and Hackensack watersheds have areas of surface water and ground water interaction, which influences flow of streams, water levels in aquifers, and susceptibility to contamination. Connections occur at and under streams and waterbodies, depending on the type of underlying geology, as well as in areas where thin soils

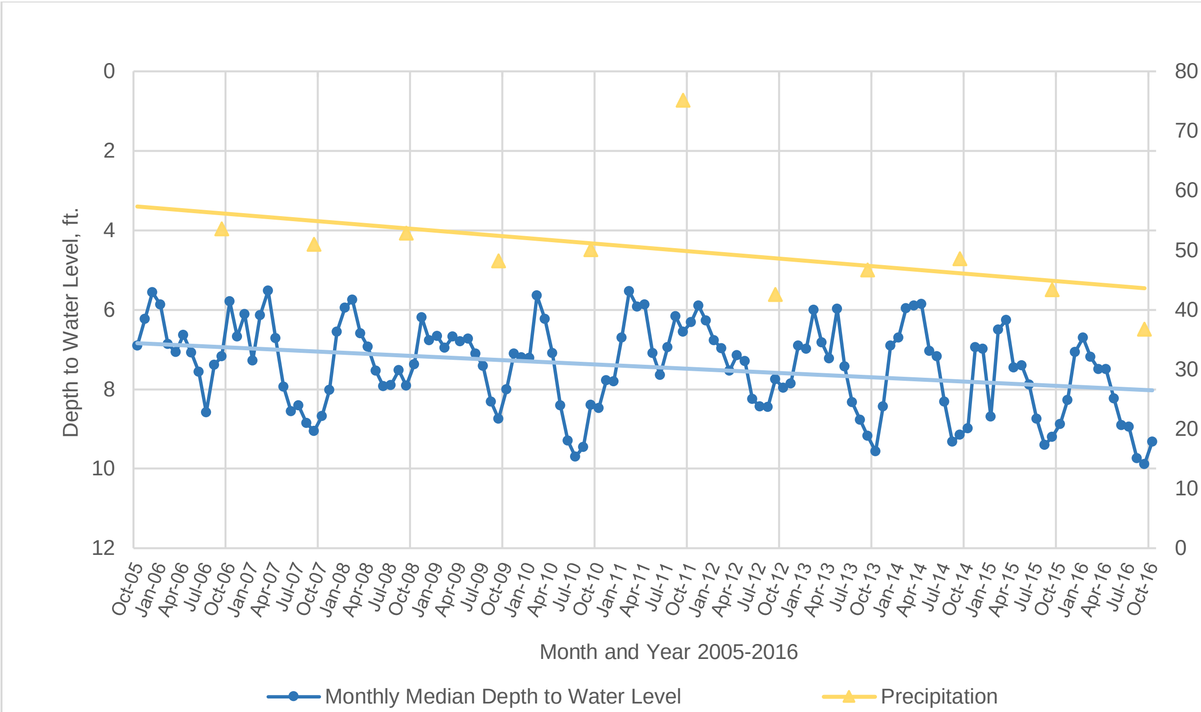


Figure IV-13: Yearly and seasonal variability in depth levels at well RO-543, Rockland Lake.
Precipitation variability influences well level variability as evidenced in unusual highs (2011) and lows (2016). Source: USGS, 2017d

overlay aquifers. Rainfall infiltrates through these soils to aquifers, and as streams are filled with stormwater from runoff, into sand and gravel deposits on and under streambanks. These alluvial deposits tend to hold large amounts of water in the spaces between sediments, which is then slowly released to the stream during dry periods. Bedrock underlying streams does not have the same storage capacity as sand and gravel streambeds, which contributes to reduced flow in these streams when precipitation is low. One exception is carbonate formations in the Ramapo River watershed, where solution cavities provide additional water storage.

In the Newark Basin, Heisig surveyed dry streambeds and tested specific conductance in surface and ground water, in order to understand the interconnections between the two flows. Dry streambeds typically occurred in two areas of Rockland County: in the Highlands and near the Palisades, where streams have less storage in bedrock and steep gradients; and on the southwest side of the major ground water divide where production wells are withdrawing water, and, hence, drawing ground water levels below the stream bottom (**Figure IV-14**) (Heisig, 2010, p. 85). Similar specific conductance measurements of adjacent ground and surface waters are indicative of a connection between these flows, and elevated measurements point toward high levels of developed land use. In Rockland County, elevated levels of specific conductance occur at the Thruway, Palisades Parkway and in Spring Valley which have a large number of local roads.

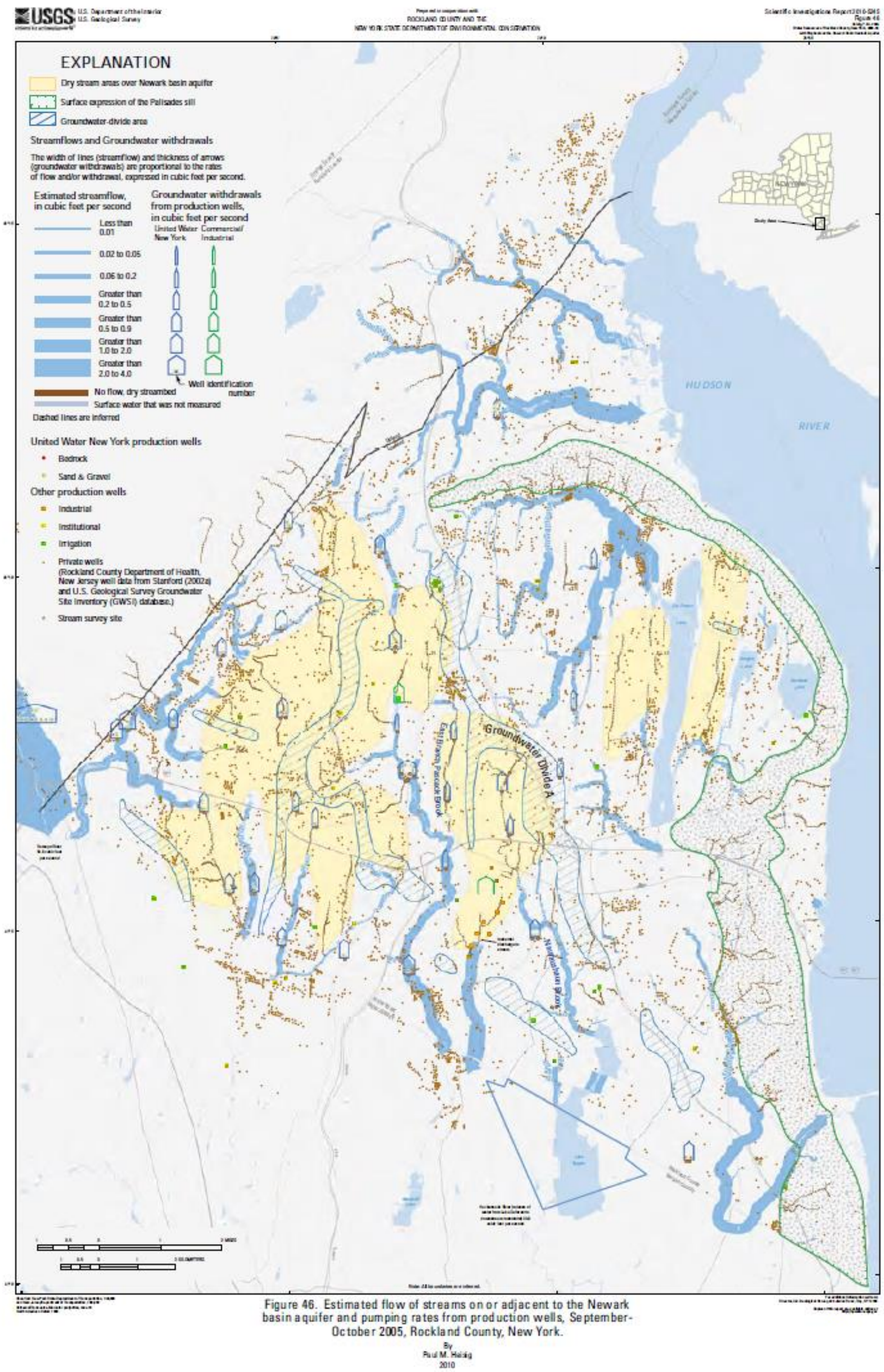


Figure IV-14: Pumping rates at production wells (September to October 2005); Streamflow in adjacent streams; and dry areas of the Newark Basin aquifer.

Source: Heisig, 2010, p. 87.

In the Ramapo watershed, geology, elevation, and human uses affect surface water and ground water interactions. In the Highlands and Upper Ramapo, rainfall infiltrates through cracks in bedrock or glacial deposits, and this water flows downslope through fractures to springs, streams and aquifers in at lower elevations. Where tributary streams flow into larger rivers in valley bottoms, deposits of alluvium (alluvial fans) induce inflow from the streambed into aquifers. Hydrostatic pressure increases at lower elevations and pushes water closer to the surface in valleys (Heisig, 2014, p. 12). Wellheads tapping ground water in sand and gravel aquifers in river valleys induce flow directly from streams for drinking water. This flow connection been studied by Vecchioli and Miller (1973, p. 57-58) in New Jersey, who recommended pumping induced river water from the Ramapo for consumption, and by Moore (Moore, 1982), who discussed stream flow reductions during production well tests, as well as contamination of ground water by surface land use. Leggette, Brashears and Graham, 1982 A. B, p. 11) found that after removing 8.5 MGD from 6 wells within a 1.5-mile reach of Ramapo, after 30 hours 60 percent of the water was accounted for by reduced flow in the Ramapo.

If flows in the Ramapo decrease to the lower threshold in the water allocation permit, wells are taken offline, and/or water is released from Potake Pond to maintain flow to New Jersey (CDM Smith & AKRF, 2015; Hill et al., 1992). The interaction between the Ramapo River, ground water removal at wells, and storage capacity at Potake Pond is not well understood, and the pending study by Suez New York will include a model to evaluate the Ramapo watershed to maintain optimal well yields and flow downstream (CDM Smith & AKRF, 2015).

Artificial modification of hydrologic systems

Artificial modification of hydrologic systems changes the interaction of ground water and streams. Dams, culverts, impoundments, and channelization in urban streams disrupts the flow and deposition of sediments downstream which disturbs recharge areas, reduces riparian vegetation that provides flood mitigation and maintains water quality, changes ground water storage patterns, and disrupts animal migration and habitat (Kondolf, 1997). Channelization of a streambed is meant to reduce flooding, but may not prevent large floods (Roni & Beechie, 2013). Releases of water to maintain a constant minimum flow, degrades ecosystems dependent upon natural variability downstream. Cumulatively, these disturbances contribute to poor health of the freshwater ecosystem (Richter, Mathews, Harrison, & Wigington, 2003). The NYSDEC has quantified 69 dams in the Ramapo and Hackensack watersheds in Rockland County (Figure IV-15). These dams form reservoirs like Lake DeForest and Tappan Lake, small to medium lakes such as Mombasha Lake, and Tuxedo Lake, and many small impoundments in the two counties. The NYSDOT has recorded 38 culverts in the study area which channel water under federal and state roads in the watershed areas. Culverts from county and surface roads have not been recorded, though the Rockland County Water Management Task Force is planning to quantify them. The USGS also maintains data about artificial modifications of waterways such as dams, sections of streams with non-earthen shores, pipelines, canals, ditches, and connectors which are underground connections between two waterways that are not ditches or pipelines. They have quantified 46 dams, 41 of which are made of concrete or other non-earthen material. Removing or limiting the impact of these modifications can restore a more natural, variable flow to both watersheds, which improves the health and resiliency of the watershed in Rockland County and downstream (Roni & Beechie, 2013).

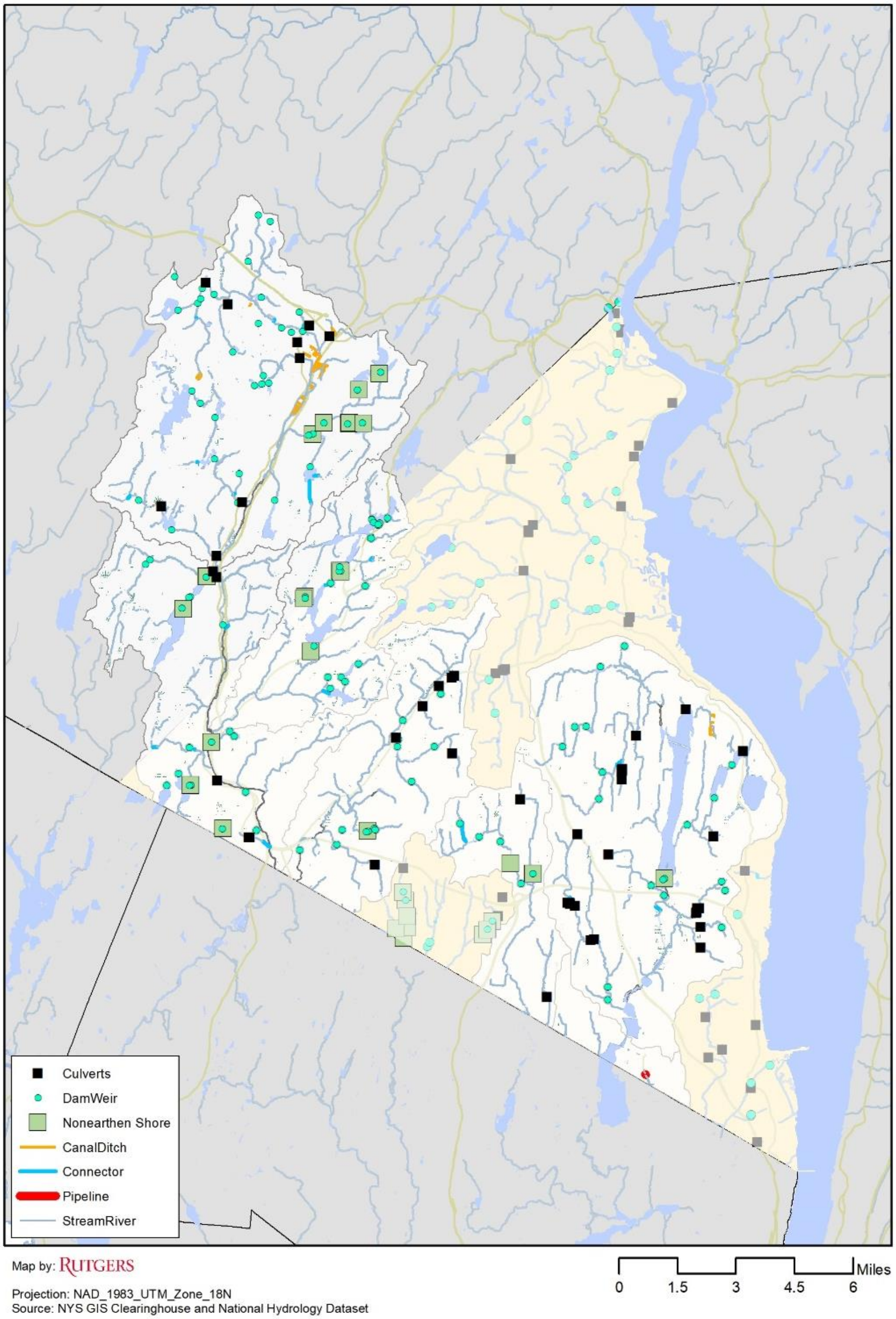


Figure IV-15: Modifications to streamflow in the Hackensack and Ramapo watersheds.
Sources: NYSDEC, and National Hydrology Dataset.

Available and proposed models

A number of models have been created to understand streamflow and ground water in Rockland County (Table IV-5). Early models include Leggette, Brashears and Graham's 1982 model of the Ramapo Valley fill aquifer ground water flow (mentioned in Hill et al, 1992, p. 18). The same year, Liu analyzed the Lake DeForest to understand the optimal amount of water to release to the Hackensack River to maintain minimum flows downstream, and Lumia (Lumia, 1982) created rainfall-runoff models for 10 stream sites in Rockland County. Hill and others (1992) produced a model to study ground water/streamflow interaction in the Mahwah, NJ wellfield. Beckman and Slaybach (n.d.; c. 1980's) created a model to simulate aquifer withdrawal from the Ramapo Valley aquifer while maintaining minimum flow downstream to New Jersey. In 2010, Yager and Ratcliffe produced a model of ground water flow in the county, which has been used by O'Rourke (2016) to simulate flows under drought. CDM Smith and AKRF (2015) produced a model studying the feasibility of using Pine Meadow Lake in the Highlands to augment flow to the Ramapo during drought. (Section 4.4). Suez NY will be making a model of the Ramapo watershed to assess water supply in two phases. Phase 1 will encompass data collection and a scope definition, while Phase 2 will consist of development and application of the modeling tool (CDM Smith & AKRF, 2015, p. 4.3).

Model	Year	Topic	Watershed	Type	Findings
Leggette, Brashears and Graham, Inc.	1981	Ground water flow	Ramapo	--	Hydraulic conductivity ranged from 13ft/d to 660 ft/d and storage coefficients ranged from 1×10^{-4} to 3×10^{-1} along a 2-mi length of the Ramapo Rver Valley upstream from the Suffern Water Department well field. (Hill et al., 1992, p. 18)
Liu	1982	Release of water from Lake DeForest	Hackensack	Monthly Simulation Model	Spring Valley Water Company, a subsidiary of Hackensack Water Company can release more than the minimum 9.5 mgd and still maintain 1.4 bg in Lake DeForest.
Lumia	1982	Floods	Ramapo and Hackensack	Rainfall-runoff models	Used to update flood frequency estimates, and design floodplain and drainage systems.
Hill	1992	Ground water flow/streamflow relationship	Ramapo	Finite-Difference Numerical Method	Shallow confining units reduce hydrauic connection between river and wells. Move the out flow upstream or downstream to area of increased connection (no confining units)
Beckman and Slaybach	1980's	Downstream flow	Ramapo	USGS (Trescott, Pinder, and Larson, 1976)	Ramapo Valley well field can pump 8-10 mgd with adequate flow downstream.
Yager and Ratcliffe	2010	Ground water flow	Newark Basin	SUTRA	General decline in ground water in upland areas, estimation of ages of ground water and well field capture zone size, transient flow simulations
CDM Smith	2015	Flow augmentation suitability	Ramapo		Pine Meadow Lake will be too costly to connect to the Ramapo for flow augmentation
O'Rourke	2016	Drought simulations	Newark Basin	SUTRA by Yager and Ratcliffe (2010)	Short and long term droughts had localized, significantly affected water tables and baseflow.
Suez	proposed	Water supply	Ramapo		Water supply availability

Table IV-5. Models about waterways in the study area by year.

V. Water Supply Availability and Demands

Aquifer yields, sensitivity analyses and uncertainties

The protection of aquifers is fundamental to sustaining ground water resources, and for the protection of natural ecosystems. Water supply in Rockland County relies heavily on ground water resources for public water supply, therefore making the protection of aquifers a top priority. The intensity of water demands is shown in **Figure V-1** from the U.S. Forest Service study of the Highlands Region, showing the location and relative intensity of aquifer demands within the region. Information was not available to provide a Rockland County figure with wells across the full county.

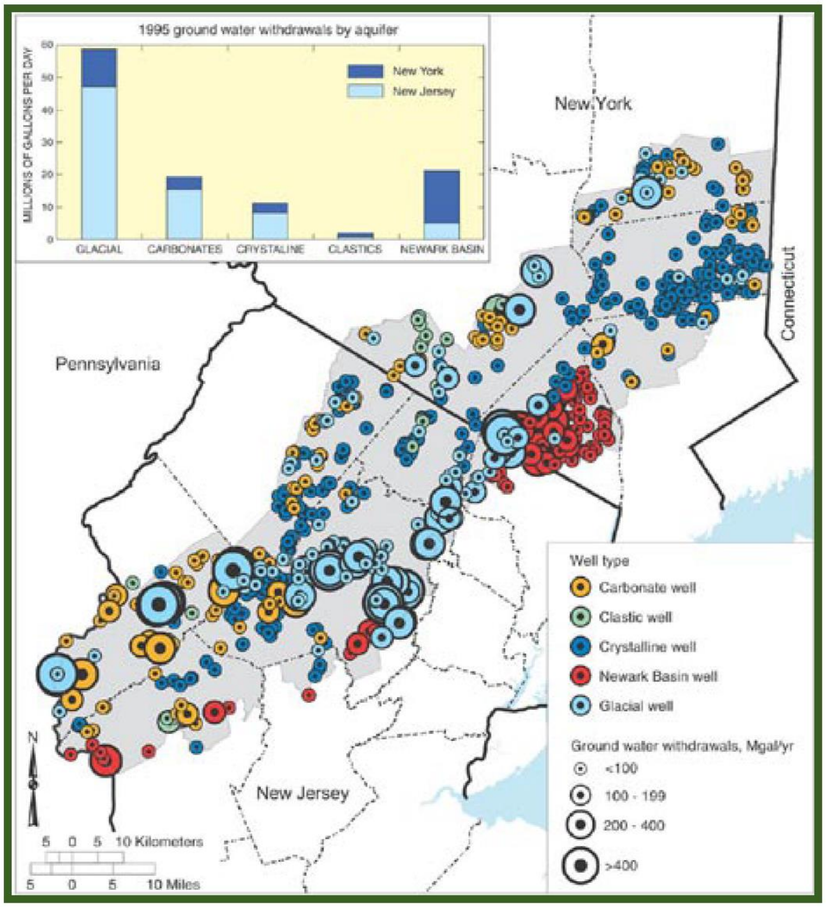


Figure V-1: Withdrawal from high-capacity wells of the Highlands Region

Source: U.S. Forest Service, 2002, New York-New Jersey Highlands Regional Study: 2002 Update.

Newark Basin Bedrock Aquifer

The USGS assessed the state of water resources in the Newark Basin of Rockland County for 2005-2007. In this assessment, the Newark basin aquifer was classified as A, B, C and D zones based on the lithology, gamma- log patterns and intensities of well yields, proximity to the Ramapo fault and proximity to the Palisades Sill (Heisig, 2010). The classification is shown in **Figure IV-10**.

Four synoptic surveys were conducted from 2005 to 2007 in the Newark basin to understand the ground water occurrence. On comparison of these data with historic water level data compiled from 1920s to the 1950s, it was inferred that in the higher altitude areas of the aquifer the ground water is on a decline.

The pumping rate gathered by USGS since 1989 indicates that there is no year to year aquifer-wide downward trend in the water levels. However, water levels at individual wells have declined and so have the aquifer levels in response to the new stresses as production wells have come on line and especially in cases where they have been in operation continuously. Ground water levels in the central part of the aquifer which is the most productive region has declined due to the withdrawals.

Undeniably the greatest concern for the sustainability of ground water resources is the aquifer response to the annual increase in pumping rates during the growing season; an increase of 25 percent in pumping rates was observed for 2005. In these conditions, investigation of pumping rates and water levels indicate that the wells decline below what is expected under natural conditions and the effective aquifer yield can decrease as water levels drop or as entrained air from stressed aquifer conditions creates problems in the distribution system.

Aquifer vulnerability

Ground water pumped from the sedimentary bedrock aquifer that underlies southeastern Rockland County is a major source of public water supply. Extensive suburban development has increased water-supply demands over the last 40 years to the point where the aquifer is considered fully developed in terms of wellfield spacing. Continued development in the County has led to progressive increases in withdrawals from existing wellfields. This situation raises serious concerns about the sustainability of withdrawals from the aquifer.

The chemical quality of ground water is an additional concern, as contamination decreases the water supply or requires costly treatment. Bedrock aquifers are particularly susceptible to contamination from human activities at land surface, and several supply wells in this aquifer have been taken off line or have had treatment systems installed to remove contaminants.

Seasonal Variations:

Large seasonal fluctuations in ground water levels appear to occur in areas with the greatest depths to water and the most productive well fields. Large seasonal variations in ground water levels were observed in areas with greatest depths to water and in the most productive well fields. The seasonal variations were the highest in aquifer zone B where the variations ranged between 10 to more than 20 ft. across the aquifer followed by aquifer Zone C where the variations in a limited area exceeded 10 ft. and the water level fluctuation in only one exceeded 20 ft. In Zone A and Zone D water levels typically fluctuated less than 10 ft. In general, well yields are known to decrease during the growing season because the most productive water bearing fractures are shallow and therefore they are more prone to lose yield or go dry as water levels decline. These seasonal changes in ground water are shown in **Figure V-2.**

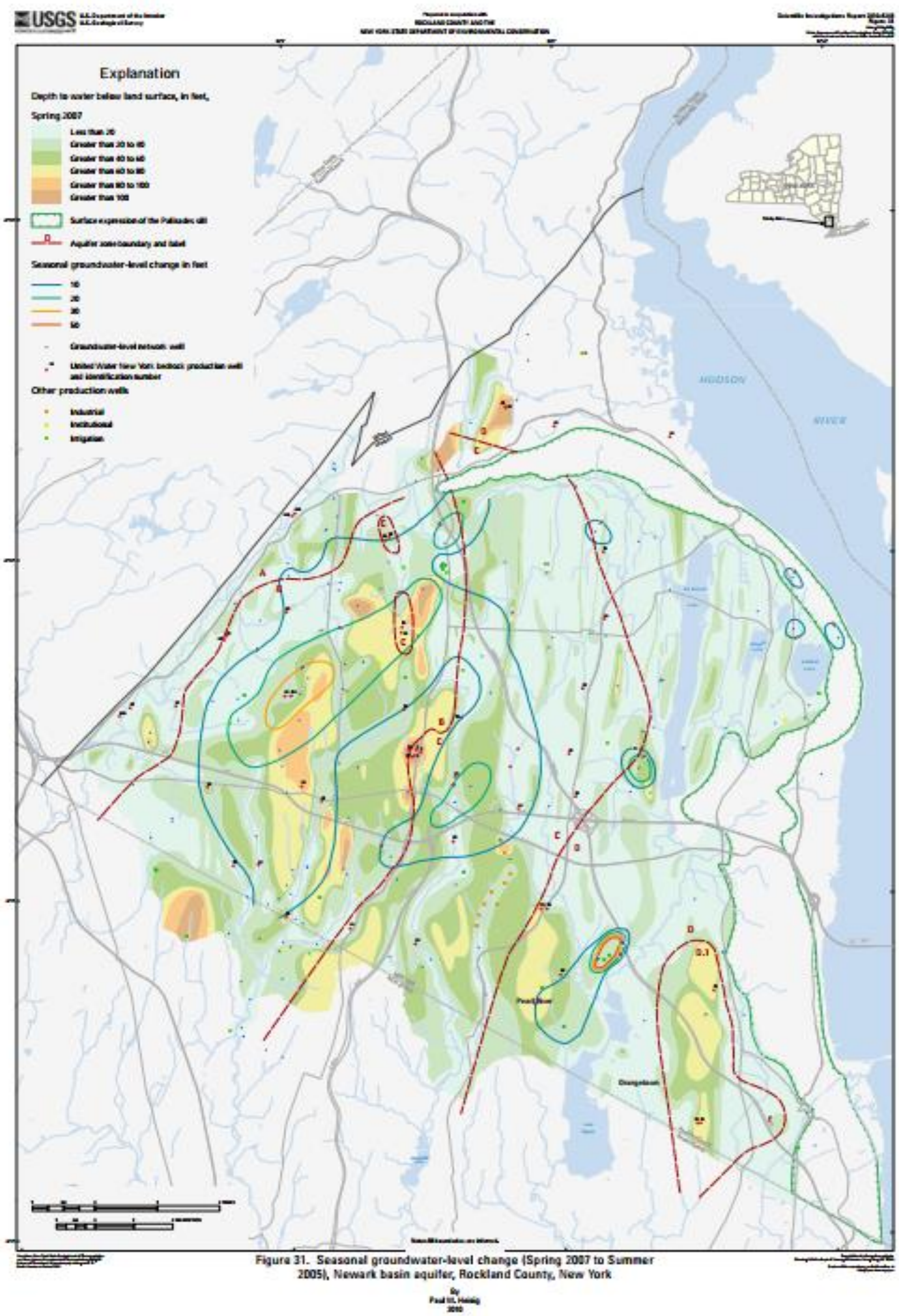


Figure 31. Seasonal groundwater-level change (spring 2007–summer 2005), Newark basin aquifer, Rockland County, New York. (Click to view full-size map at http://pubs.usgs.gov/sir/2010/5245/plates/Figure31.pdf)

Figure V-2: Seasonal Variations in ground water in Newark Basin
Source: Heisig (2010)

Aquifer potential

The bedrock aquifer is considered fully developed in terms of well field spacing (Heisig, 2010). The USGS study did not find any potential for long term aquifer-wide declines but a few areas of decline near bedrock wells were identified. Seasonal variations were observed in bedrock stresses, the summer season resulting in unsustainable pumping stresses only to be replenished in the other parts of the year. The USGS estimated that in severe droughts, 10-15 wells would have to be prohibited from operating. Some wells in the aquifer were observed to show as much as a reduction of 50-65 foot in monitoring wells nearly a mile from the well fields. They also noticed that some wells were used year-round with almost no change in water level, thus implying that there is large storage or an inflow source (such as a river) is balancing the withdrawals.

The USGS study suggests that the most productive areas of the aquifer have capability to provide for large capacity wells but limitations such as the water quality, lack of land area for well buffers, and potential interference with existing wells pose constraints. USGS recommends that instead of having large wells in a concentrated manner, small wells that are disbursed would be able to distribute the stress on aquifers. One of the disadvantages of constructing small wells compared to large wells is that the small wells cost more per MGD than large wells, especially if they are not easily connected to the existing water system. The USGS study validates the Suez claim that the bedrock aquifers in Rockland are not being depleted currently. This has encouraged Suez to investigate 10-15 new wells that would be capable of providing an additional 2-3 MGD of water. CDM Smith (2015) also supports the proposition that the bedrock aquifer is the only possibility for additional water given that the Ramapo and Mahwah aquifers are entirely allocated according to Heisig (2010). Previous work by Suez and in conjunction with the USGS assessment claimed that 10 sites with a potential of 2.5 MGD can be identified in the bedrock aquifer.

Sensitivity analyses:

The water level declines under conditions of continuous pumping, a worst-case scenario, assuming no change in yield over the summer indicates that between 25 and 35 percent of production wells would not be able to pump through the entire growing season. In such a situation pumping rates would have to be reduced in response to the decline in the aquifer yields. It should be noted that this analysis indicates the fragility of the aquifer given the fact that the recent years have been recently wet. However, the recharge in the non-growing season has been sufficient to replenish the aquifer for the next growing season. To maintain this replenishment, protection of aquifer recharge areas is critical.

Ramapo and Mahwah Aquifers

The Ramapo and Mahwah aquifers are unconfined, surficial aquifers that are susceptible to contamination as their water bearing soil and rock formations are close to the land surface. In addition, the soil which overlies the aquifers is highly permeable therefore enabling the potentially contaminated water to easily reach the aquifers. Further, the sensitivity of the Ramapo and Mahwah aquifers is made more critical as some parts of both the aquifers are located in areas that are largely not connected to the sewer system, such as the western area of the Ramapo Town and a few portions of Mahwah river valley (Town of Ramapo Comprehensive Plan). Areas that are not served by a sewer system use septic tanks as their facilities which can cause contamination to the ground water. As a result, the Rockland

County Sewer District #1 is pursuing an extension of sewer services to the villages of Hillburn and Sloatsburg and to the western portions of the incorporated town of Ramapo. (Rockland County, 2011) Not only can the sewer system protect the health of the residents from contamination due to failing septic systems, but it has the potential to use the effluent from the treatment plant to recharge the aquifer. While treated sewage effluent will include some level of contaminants, they can be treated to a better level than is true for septic systems.

The Ramapo Valley well field is located in the Ramapo aquifer. It derives most of its water by inducing infiltration of Ramapo River through the permeable sand and gravel to the supply wells. Restrictions on withdrawals have been imposed by the NYSDEC that requires a minimum flow of 12.6 ft3/s (roughly 8 MGD) in the Ramapo River so as to protect downstream water users in New Jersey. Potake Pond is used by Suez to augment the river flow so that pumping can continue. According to CDM Smith, the aquifer is fully allocated, and has no physical additional capacity except for improvements to management strategies that meet the existing regulations including the potential for the combined management of withdrawal between Suffern and Suez to maximize the yields.

The most recent aquifer model for the Ramapo valley aquifer dates back to 1982 when the NYSDEC permit was granted. Suez has proposed the development for a new aquifer model that will allow it to test out alternative management strategies. However, Suez is not anticipating any extensive increased yield due to the complex restrictions in the Ramapo Valley Well field. The model needs to account for demands of the Village of Suffern, downstream of the Suez well field, and also demands upstream in Orange County.

Similar to the Ramapo Valley well field, induced recharge and intercepted ground water flow are primary water sources for the Mahwah valley field. The Mahwah River also drains into New Jersey, therefore flow requirements are instituted to protect the downstream users. The aquifer is considered fully allocated and used with no potential for additional yields.

Reservoir yields, sensitivity analyses and uncertainties

Lake DeForest, Lake Tappan, Woodcliff Lake and Oradell Reservoir comprise the Hackensack reservoir system. Lake DeForest is entirely in Rockland County, Lake Tappan overlaps the border with New Jersey, and the last two reservoirs are entirely within New Jersey. The entire system has a capacity of about 13.3 billion gallons and the breakdown of the water allocated to its various water entities is as follows: 74 MGD to Suez-New Jersey, 10 MGD to Suez-New York, and 2 MGD to the Nyack water department. The capacity of the Lake DeForest is approximately 42 percent of the total system storage, thus indicating the prime importance of the Lake DeForest.

Lake DeForest supplies 33 percent (one third) of the water supply to Suez-New York. It is a 985-acre reservoir which relies entirely on precipitation as the source of water and holds up to 5.6 billion gallons of water. The reservoir became operational in 1965 and is a source of much of the water supply for the eastern portion of the Suez-New York area. The water from this reservoir is treated at the Lake DeForest water treatment plant at the southern end of the reservoir before being pumped into the water distribution system.

Safe yield of Lake DeForest:

The safe yield of Lake DeForest or the amount of water that can be withdrawn or discharged from Lake DeForest during a repeat of record drought conditions is equivalent to 19.75 MGD. The NYSDEC water supply permit for Lake DeForest (WSA 2189) requires the release of some of that yield to downstream users and to ensure river flows. Suez-NY is obligated to maintain daily flow of at least 9.75 MGD in the Hackensack River just above the Village of Nyack intake works. The village of Nyack is permitted to withdraw 2 MGD, leaving the remaining water to flow downstream (WSA 2189, Condition I).

According to the Lake DeForest water allocation permit, 10 MGD of water from Lake DeForest must at all times be reserved for the residents of Rockland County and may not be transported out of the county (WSA 2189, Condition L). In order to meet this condition, Suez operates Lake DeForest to withdraw an annual average of 10 MGD for Rockland County customers, withdrawing a higher flow only during peak summer months, and reducing the flow at other times of the year to maintain a total average. For example, for the year 2005, the summer demand required the withdrawal of 20 MGD from Lake De Forest, the withdrawal for the months of October and November were reduced to 7 MGD and for the month of December the withdrawal was further reduced to 5 MGD in order to limit the annual average withdrawal to 10 MGD. In 2002, when a stage 3 drought was declared, restrictions were imposed on the extraction of water from the reservoir, prohibiting the watering of lawns and further restrictions on watering of golf courses and plant nurseries and on vehicle washing. It should be noted that the 10 MGD for Rockland County is a minimum, not a maximum, but the combination of this quantity and the 9.75 MGD flow above Nyack is approximately equal to the total safe yield of 19.75 MGD.

The Lake DeForest was developed by Spring Valley Water Company (now Suez-New York), which was at the time of permitting a subsidiary of the Hackensack Water Company in New Jersey (now Suez-NJ). In response to the 1980-1981 drought, the NYSDEC initiated a study of the permit and then adopted revisions in 1982 to incorporate more detailed reservoir release requirements through use of a reservoir rule curve that modified Conditions H and I of the permit (Sixth Modifying Decision for Water Supply Application No. 2189). The amount of water discharged to the Hackensack River not only depends on the water supply in Lake DeForest but also on the condition of the three downstream reservoirs – Lake Tappan, Woodcliff Lake and Oradell Reservoir. The Lake DeForest rule curve or WSA 2189 is illustrated in **Figure V-3**. The permit conditions that are defined by the rule curve are as follows:

a) "If the storage at Lake DeForest is below the Rule curve at any time of the year, the release from Lake DeForest will be <u>restricted</u> to a daily average flow of 9.75 MGD in the Hackensack River immediately above the intake of village Nyack.
b) If the storage in Lake DeForest is above the rule curve at any time of the year, and:
    1) When the total storage in the downstream three reservoirs (Lake Tappan, Woodcliff Lake and Oradell Reservoir with a total combined available storage capacity of 7.74 billion gallons) is more than 50% of their capacity or 3.87 billion gallons, release from DeForest Reservoir <u>shall be made</u> to maintain a <u>daily</u> average flow of 9.75 MGD in the stream immediately <u>above</u> the intake works of the Village of Nyack.
    2) When the total storage in the three downstream reservoirs is less than 50% of their capacity and at a higher percentage storage than the percentage storage of DeForest

Reservoir, a larger release <u>may</u> be made to maintain a <u>monthly</u> flow of up to 15 MGD in the stream immediately <u>below</u> the intake at the Village of Nyack.

3) When the total storage in the three downstream reservoirs is less than 50% of their capacity and at a lower percentage than the percentage storage in DeForest Reservoir, a larger release <u>may</u> be made to maintain a <u>monthly</u> average flow of up to 25 MGD in the stream immediately <u>below</u> the intake of the village of Nyack." (emphasis added)

In essence, these permit conditions establish a maximum flow of 9.75 MGD in the Hackensack River above Nyack when Lake DeForest is below the rule curve, and allows <u>but does not require</u> higher releases when the Lake DeForest has adequate water and the downstream reservoirs are less than 50 percent full. These flows are measured at different points, above and below Nyack's intake works. The higher releases in (b)2 and 3 are capped.

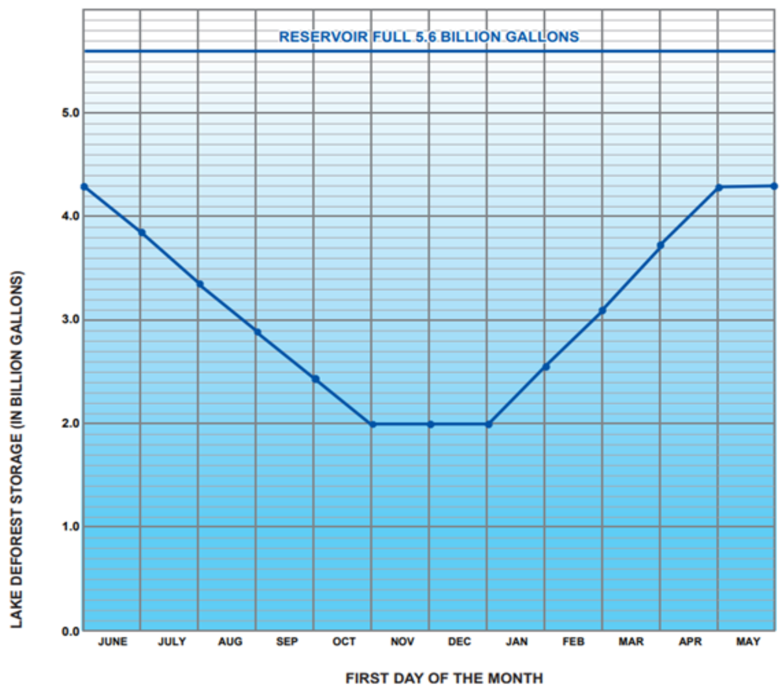


Figure V-3: Lake DeForest Rule Curve

Source: Haverstraw Water Supply Project: Draft Environmental Impact Statement

Letchworth Reservoirs:

The three Letchworth Reservoirs, located within the Highlands in Harriman State Park on the Minisceongo Creek watershed, have a total capacity of 173 million gallons. Historically, the Letchworth reservoir system served as the water supply for the former state psychiatric institution at Letchworth Village (in the Towns of Stony Point and Haverstraw). It is now operated as a minor supply by Suez.

Existing demands and demand trends

Water demands from recent and previous years help to understand the patterns and trends in the use of water across Rockland County. The annual pattern of water use shows seasonal variations. The limitation of this report is that only information on the demand trends of the Suez customers was available so the customers using private water supply sources and other public water supply sources are not accounted for.

The water consumption can be calculated by average demand and peak demand. The average demand evaluates sustained demand of water resources over an extended period of time (annual or multi-year), whereas the peak demand is calculated by the maximum demand, such as the amount of water used on a single day or month of the highest demand.

Water demand varies greatly from year to year, depending on population increases, commercial and industrial demands, and the weather, particularly the amount of growing season rainfall as indoor demands remain fairly stable from month to month while outdoor demands for lawn irrigation and such cause both daily and monthly peaks during the growing season. Between 1980 to 2010, the general trend has been towards an increased annual average daily and peak daily water demand. **Figure V-4** illustrates the variability that exists in peak day demand.

CDM Smith (2010) assessed the water use for Rockland County by evaluating the billing data of Suez customers from 2000 through 2009. The annual average daily production during this time period was approximately 29.4 MGD while the maximum daily production was as high as 42 MGD. From July 2015 through June 2017, the pattern was similar, with average annual demands of approximately 28 MGD and monthly demands ranging from lows of 24 MGD to highs of 34-35 MGD (Graziano, 2017).

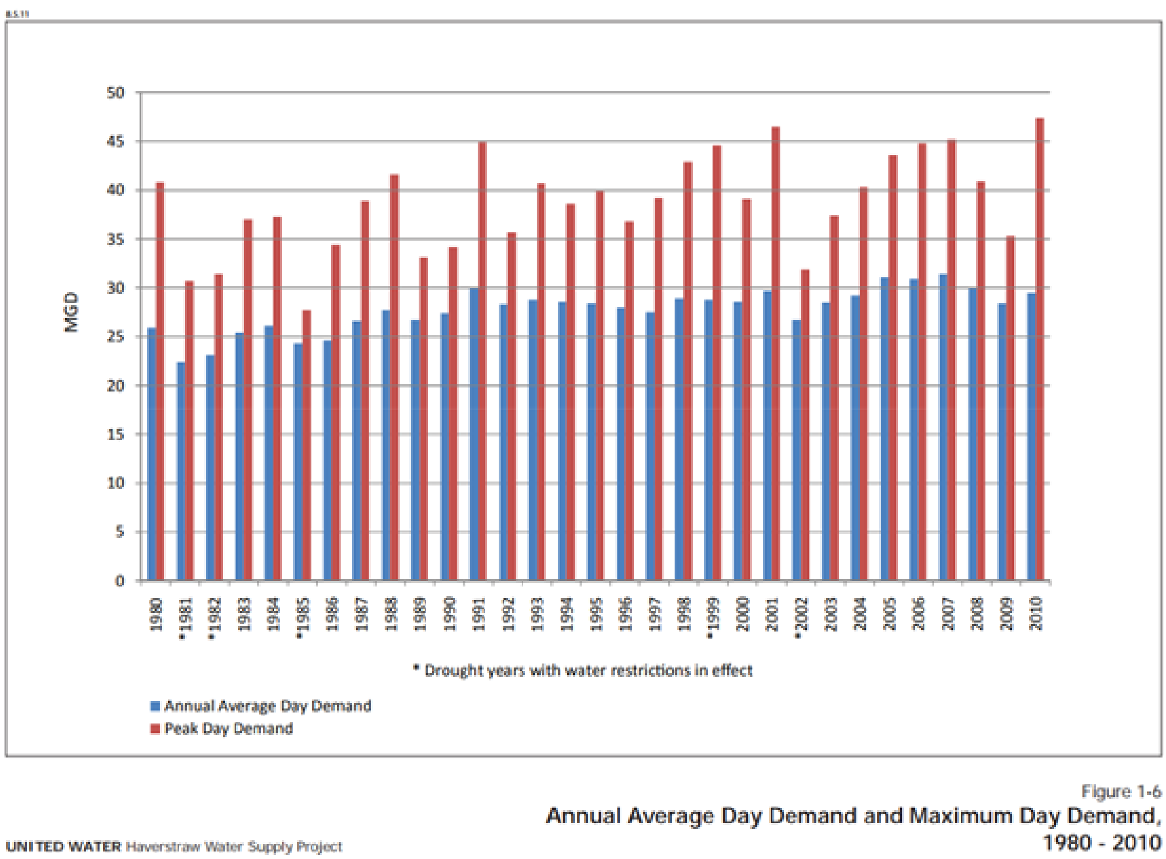


Figure V-4: Annual Average daily and Peak daily water demand
Source: Haverstraw Water Supply Project: Draft Environmental Impact Statement

Water use by sector

According to the 'Appendix 1.6 Future Water Demands and Conservation Issues' study by CDM Smith (2010) the customer account percentages by the single family residential sector accounts for the highest water use, at 89 percent of Suez accounts. Commercial customers constituted the sector with the second highest number of accounts of 6.3 percent. Apartment and multifamily accounts made up for the 3 percent of the accounts followed by hospitals, industries, schools, warehouses and municipal accounts that made up 2 percent of the accounts. The breakup of the water use by sectors is illustrated in **Table V-1**. Black & Veatch (2016) assessed water demands by customer class, with 73 percent being residential, 21 percent commercial, and 4 percent industrial.

Seasonality in Water Use:

The water use patterns show a distinct variation by seasons, with water use increases in the growing season months between July through October and decreases in the winter months, suggesting that the seasonality is due to outdoor irrigation and other summer water use patterns. The **Figure V-5** illustrates water use of various sectors, with the water use of each sector is added on top of the preceding sector, thereby creating a cumulative graph. From this figure it can be inferred that the residential single-family sector uses most water and has a clear seasonal trend (CDM Smith, 2010). The water use pattern of apartments, multifamily units, high-rise buildings and industrial accounts show less seasonal variation in comparison to commercial accounts that show a distinct seasonal variation. **Figure V-6** shows seasonality for each year, with both residential and commercial showing significant seasonality.

Table 1. Number of UWNY Customers by Sector 2000-2009

Sector	2000	2001	2002	2003	2004	2005	2006*	2007	2008	2009	average%
Apartment	956	965	969	972	979	996	1,027	1,066	1,122	1,143	1.5%
Commercial	4,122	4,184	4,244	4,330	4,388	4,442	4,490	4,527	4,569	4,626	6.3%
Hi-Rise	3	3	3	3	3	3	3	3	3	3	0.0%
Hospital	84	85	84	82	78	80	79	79	83	83	0.1%
Industrial	168	167	169	167	171	172	173	176	175	179	0.2%
Municipal	252	249	250	251	249	253	263	269	279	281	0.4%
Res Single Family	59,579	60,301	60,925	61,456	61,964	62,416	62,911	63,317	64,026	64,789	89.4%
Res Multi-Family	797	804	819	834	830	827	833	867	935	980	1.2%
School	481	487	491	495	509	513	518	534	538	539	0.7%
Warehouse	76	76	76	76	75	76	79	79	79	79	0.1%
Building Rates	-	-	-	-	-	-	-	-	-	0	0.0%
Resale	1	1	1	1	1	1	3	3	3	3	0.0%
Total	66,519	67,322	68,031	68,667	69,247	69,779	70,379	70,920	71,812	72,705	100.0%

Table V-1: Suez-NY Water Customers by Economic Sectors

Source: CDM Smith (2010) Appendix 1.6 Future Water Demands and Conservation Issues

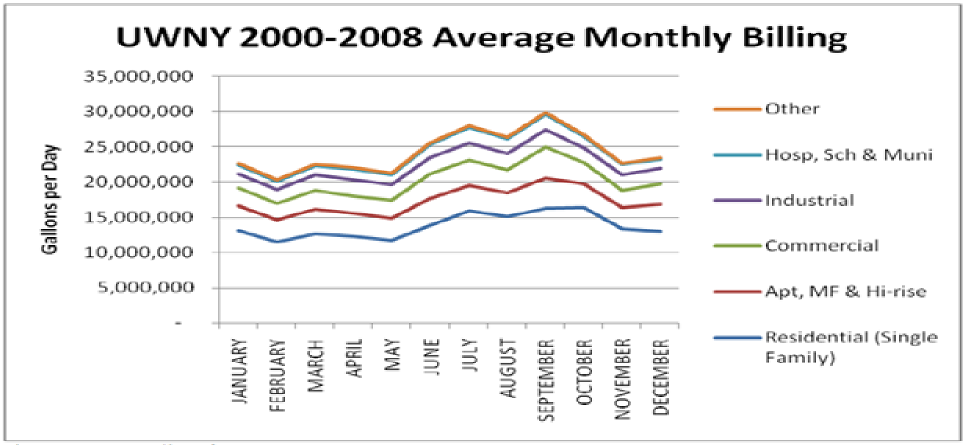


Figure 1 Seasonality of UWNY Customers

Figure V-5: Average Suez water use of various sectors by month, 2000-2008
Source: CDM Smith (2010) Appendix 1.6 Future Water Demands and Conservation Issues

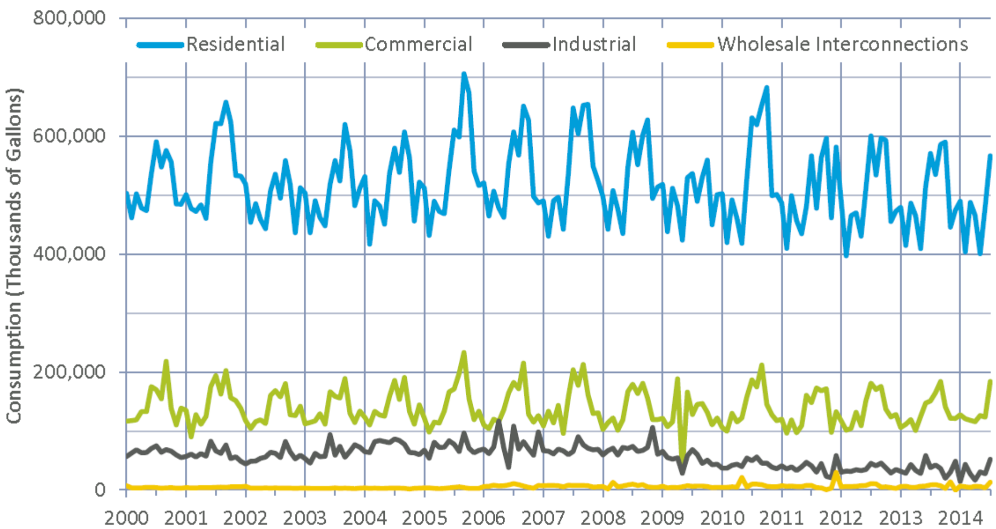


Figure V-6: Suez water use of various sectors, 2000-2014
Source: Black & Veatch (2016), Figure 3-1

The seasonal variations between hospitals, municipalities and schools were further compared by CDM Smith (2010) and are illustrated in **Figure V-7**. The seasonal variation of hospital and municipal use is quite significant whereas that of water use for schools doesn't indicate any drastic variation. The seasonality for hospital use can be attributed to the increased water needs for water cooling purposes and the seasonality of water use for municipalities can be attributed to the predominance of outdoor irrigation in summer. Schools are closed during the summer and generally do not engage in outdoor irrigation.

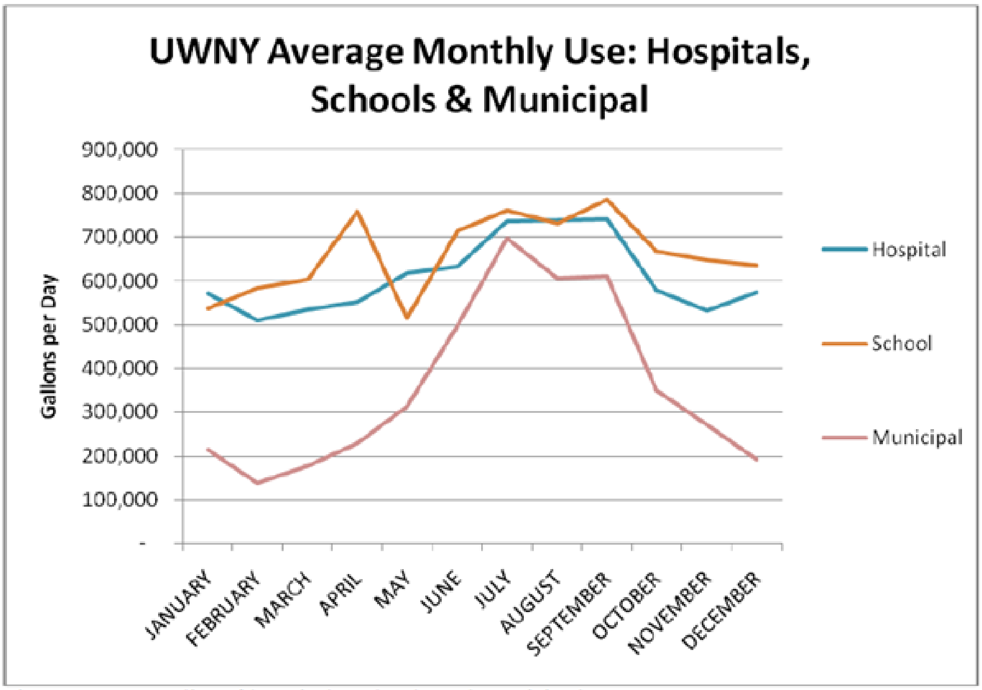


Figure 2 Seasonality of hospitals, schools and municipal accounts

Figure V-7: Seasonal variations between Hospitals, Municipalities and Schools
Source: CDM Smith (2010) Appendix 1.6 Future Water Demands and Conservation Issues

Water Use Metrics:

Water use metrics were calculated by CDM Smith in 2010 (Appendix 1.6) based on the average population, household and employment values for 2000-2009 in conjunction with the Suez 2000-2009 production and billing data.

The Suez residential water use metric was calculated to be 209.9 gallons per day (gpd) per household which is relatively conservative in comparison to residential water use metrics in the other regions. A detailed study of residential end uses of water across US and Canada carried out by the American Water Works Association (AWWA) measured the water use in twelve systems and found the average water use per household to vary between 192 to 825 gpd per household with a mean of 400 gpd.

Further, the AWWA study analyzed the indoor water use which was in a range of 109 to 267 gpd per household with a mean of 173 gpd per household. On a per capita basis the indoor water use ranged from 57 to 84 gallons per capita per day (gpcd) with an average of 69 gpcd.

On comparison of the water use per household, the Suez total average residential water use of 209.9 gpd per household is slightly higher than the AWWARF average indoor water use of 173 gpd per household and well below the AWWA total average demand. On comparing the per capita water use, the Suez total residential use of 67 gpcd is slightly lower than the AWWRF average indoor water use of 69 gpcd, implying that even with outdoor water use the Suez residential customers are water efficient relative to customers from other systems.

Residential water consumption

As the population of the Suez customers has increased by 13.5 percent in the period of 2000-2014, a decline in the per capita water consumption has been observed for the same period as seen in **Figure V-8**. For the year 2014, the total per capita consumption measured in the aggregate way of total residential use divided by the estimated population is approximately 57 gpcd on an annual basis, lower than the long-term average of 67 gpcd (Black & Veatch, 2016).

Single Family Residential Customer Trends:

Within the single family residential customers, the average consumption rates for more than 50 percent of the Suez customers is between 50 and 200 gallons per household per day. The **Figure V-9** depicts that there are large variations between the amounts of water consumption between the various customers. The green in the figure represents that more than 50 percent of the customers serviced by Suez have consumption rates between 50 and 200 gallons per household per day while the long tapering tail towards the right of the graph represents the customers whose consumption levels are more than 250 gallons and less than 1000 gallons per household per day.

Single Family residential trends between towns:

Suez provides water to approximately 290,000 residents in Rockland County. The expanse of the Suez service extends to five towns in Rockland County, namely Clarkstown, Haverstraw, Orangetown, Ramapo and Stony Point. There is seasonal variation as well as geographic variation in water use in the

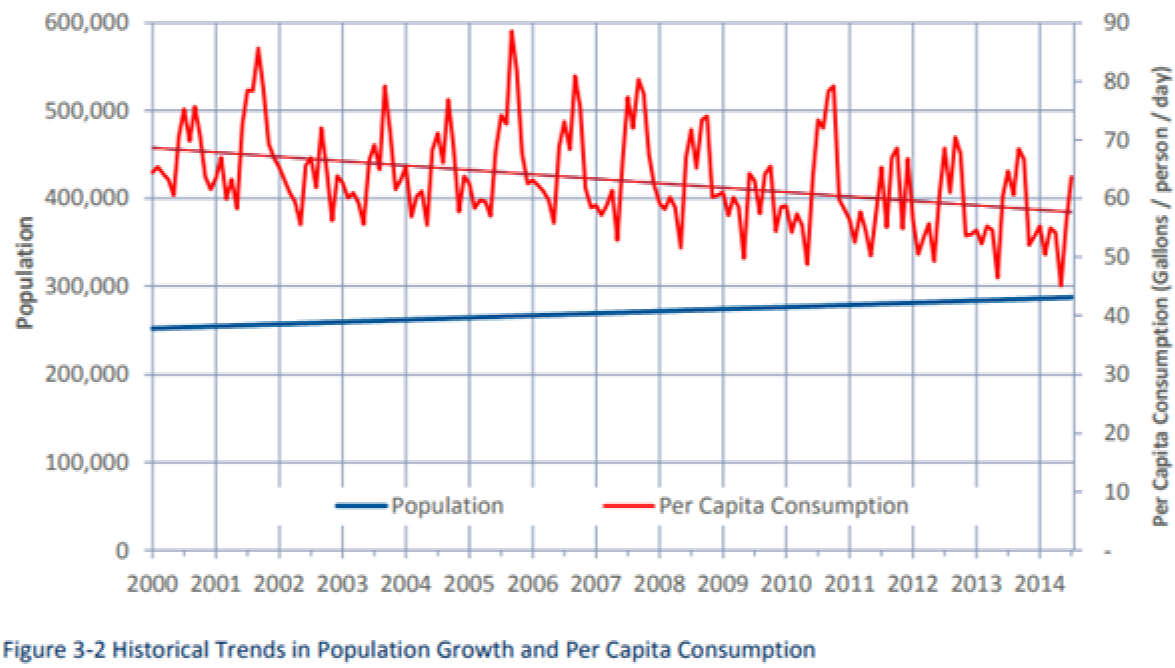


Figure V-8: Decline in Suez per capita water consumption

Source: Appendix 1.6 Future Water Demands and Conservation Issues

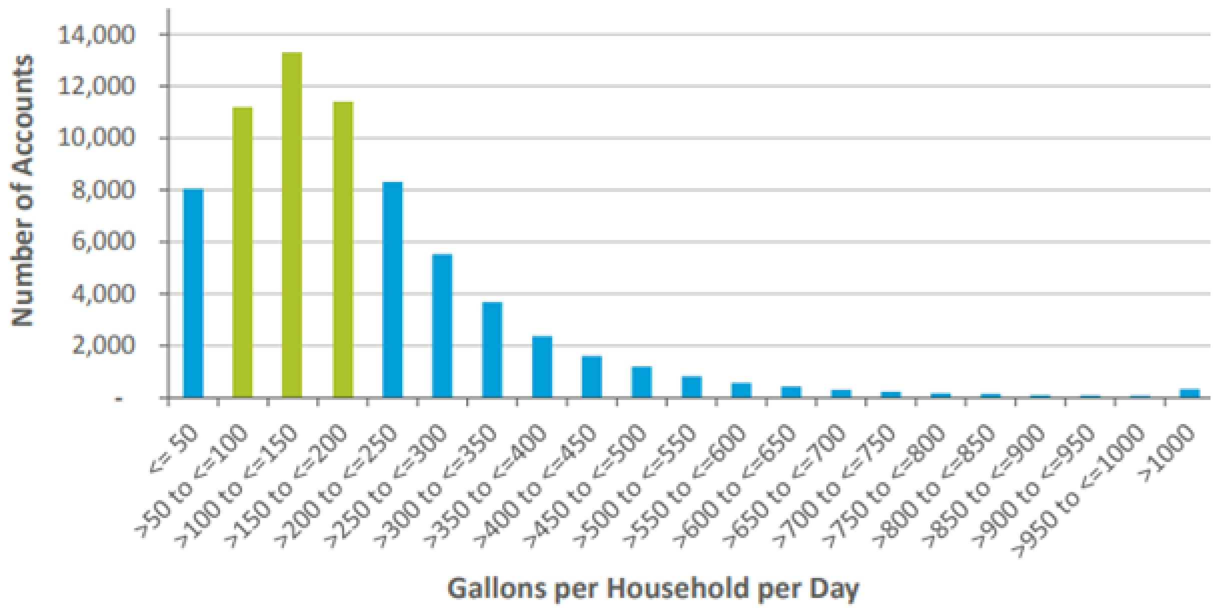


Figure 3-4 Distribution of Single-Family Residential Household use (2015)

Figure V-9: Large variations between amounts of water consumption for various Suez customers

service areas of Suez as shown in **Figure V-10**. In this normalized curve, the average annual daily use is represented as 100 units on the y axis. Therefore, the peaks of each of the towns can be compared in relation to each other as well as the total average water consumption. The graph indicates that the summer water consumption increases more in the towns of Orangetown, Clarkstown, and Stony Point relative to Ramapo and Haverstraw.

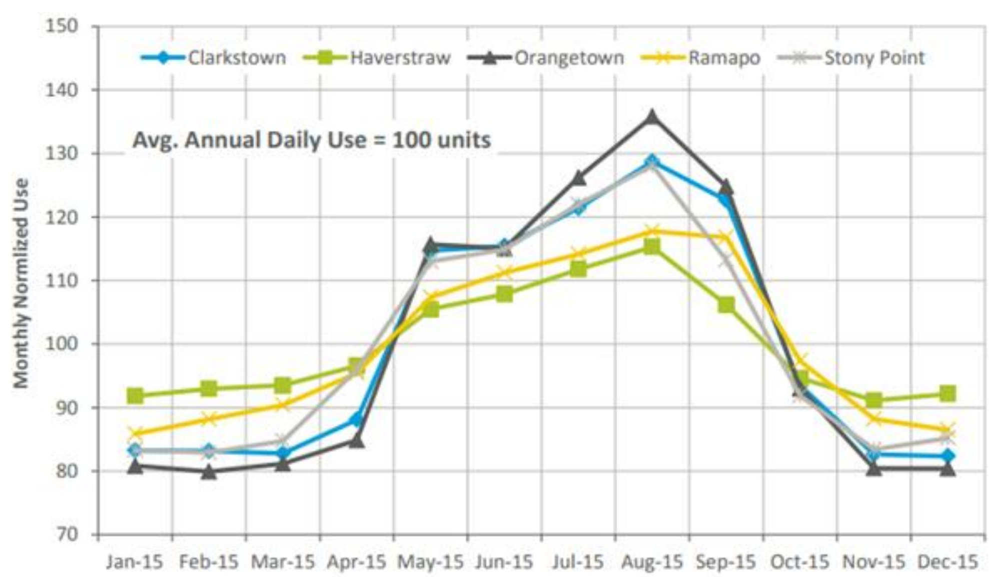


Figure 3-6 Seasonality of Use for Single-Family Residential Households by Town (2015)

Figure V-10: Seasonality of Suez use for single family residential households by town

Source: Appendix 1.6 Future Water Demands and Conservation Issues

Multifamily Residential Customer trends:

There are approximately 16000 multifamily residential customers in the Suez system. Multifamily residential connections are those where a single meter provides water to multiple individual dwelling or residential units. The seasonal variations for this category are lesser than that of single family residential customers.

Commercial Customer Trends:

There are approximately 4,400 commercial customers in the Suez system. According to the Black and Veatch report for Suez, the commercial and institutional demand is roughly 21 percent of total demand. Although the demand has declined by 5 percent from 2000 through 2014, the numbers of accounts have increased. The commercial sector includes sub-sectors such as institutional uses like schools and government buildings. The water demand in summer for commercial customers increases due to the general increase in business activity from sub-sectors such as hotels and restaurants and also the need for HVAC cooling towers. The demands associated with the commercial sector are closely related to the total population trends, as the outflow or inflow of people into the county affects services such as banks, retail stores and restaurants. In Rockland County, employment growth is anticipated in the future in the fields that will require office buildings such as professional and technical services, healthcare and social assistance. Since the office space is aging there is a need for rehabilitation to meet the modern office standards. An outcome of the retrofitting of office fixtures would be reduced demand per employee (Van Abs, 2016).

Industrial Customer trends:

There are approximately 90 industrial customers in the Suez system. According to the Black & Veatch report for Suez, industrial demand is roughly 5 percent of the total demand, and has declined 50 percent from 2000 to 2014. There has been a decline in the water demand from the industrial sector due to the loss of several large water-using customers. There are seasonal variations in the industrial water demands but they are more erratic as compared to the other sectors. In tandem with other suburban areas, large industrial campuses in Rockland County are shifting from single corporation use to multi-tenant or mixed uses. A commonality amongst suburban regions is their aversion to promoting a manufacturing economy; therefore, growth in manufacturing should not be expected for Rockland County. Even the New York State Department of Labor forecasts a continued decline in manufacturing employment. In any case, given that the total industrial growth in Rockland County is such a small portion of the overall water demand, the uncertainty about the future of industrial growth in Rockland County is unlikely to cause any major differences. Vickers notes that the top 20 percent of industrial customers generate 93 percent of industrial demand, but even the top 50 percent of customers are only 39 accounts. Therefore, a very limited potential for savings of 0.2 to 0.3 MGD is estimated. Suez is targeting industrial customers for on-site water audits and rebate programs for water efficient fixtures (Van Abs, 2016).

Water demands in four towns:

Suez conducted a customer survey in 2015 to analyze the water demands and for the development of a conservation plan. 1535 surveys were collected from the towns of Clarkstown, Haverstraw, Orange town, Ramapo and Stony Point. Ramapo has a higher number of persons per household compared to the other four towns. The towns with the highest percent of renters were in Ramapo and Haverstraw. The survey information from the 1535 households was overlaid with monthly water usage data to estimate total water use in gallons per capita per day as shown in **Table V-2**. The indoor water use was determined by taking the water consumption for the winter months of January, February, and December of 2015. From the data gathered from these four towns it can be inferred that the highest average indoor water use and total water use was reported in Clarkstown for 2015.

Non-Revenue Water:

The CDM Smith study which gathered data from the Suez customers for the years of 2000-2009 calculated the volume of non-revenue water. The non-revenue water of 5.3 MGD, representing the difference between the average daily production and average daily consumption was recorded during this study. Non-revenue water is comprised of apparent loss and real loss. Apparent loss represents the

Table 5-1 Per Capita Consumption (Gallons per Capita per Day)

TOWN	INDOOR USE (GPCD)		TOTAL USE (GPCD)	
	AVG.	MEDIAN	AVG.	MEDIAN
Clarkstown	57.8	51.6	70.7	58.9
Haverstraw	54.4	49.9	59.8	54.4
Orangetown	54.8	50.4	66.3	55.2
Ramapo	54.1	48.0	62.6	55.5
Stony Point	54.6	48.1	69.6	58.1
All Survey Data	**55.2**	**49.6**	**66.2**	**56.3**

Table V-2: Per Capita Water Use from Clarkstown, Haverstraw, Orangetown, Ramapo and Stony Point
Source: Appendix 1.6 Future Water Demands and Conservation Issues

water that consists of meter inaccuracies, unauthorized consumption, and data errors whereas real loss represents the leakage of mains, overflows and leakage at service connections prior to the customer meter. The analysis of the non-revenue data for 2007 and 2009 indicates that the percent of real loss is higher than the apparent loss in the Suez system. The apparent loss for the year 2007 accounted for an estimated 7.5 percent of total production while the real water loss accounted for about 13 percent of the total production for a total non-revenue water of 20.5 percent of the water production in 2007. Similarly, for the year 2009 the apparent water loss was an estimated 6.5 percent of the total production while the real water loss accounted for 17.3 percent of the total non-revenue water of 23.8 percent, representing that the magnitude of the losses may be on the rise over the years (non-revenue water can vary year by year) and that efforts have to be made to curtail these water losses.

The unavoidable real loss refers to the leakage from the distribution network which is inescapable even for a newly designed or perfectly maintained system. It is calculated based on the length of the pipes, number of connections and average pressure of the system. The Infrastructure Leakage Index (ILI), ratio of real loss to unavoidable real loss indicates that half of the real loss could be avoidable. The reduction of the real to the unavoidable real loss can potentially reduce the non-revenue water loss to 7 percent of the total production. The SUEZ has an underground infrastructure renewal program in place to reduce the real water system losses. CDM Smith suggests that a reduction to 7 percent would not be realistic given the financial and operational constraints, therefore recommends that the apparent losses can be reduced to 5 percent by the transfer of the unbilled accounts to billed consumption and realistically the total losses could be reduced to 13 percent of the total production (i.e., 8 percent real losses). (CDM Smith- Appendix 1.6) Even though Suez has an underground renewal program to reduce real system loss, a target of completely obliterating real losses excluding unavoidable water loss may not be realistic as it depends on financial, operational, and water resources considerations of the system.

Demand scenarios and forecasts/projections

Demand forecasts based on a linear regression through historical data from 1980 onwards were prepared by the Rockland County Department of Health and were subsequently used in the 2006 Rate order by the Public Services Commission. Two separate projections were prepared, one where the Annual Average Daily (AAD) demand per year was used and the other where the maximum daily demand per year was used. A water demand projection with 95 percent confidence interval for the AAD demand was calculated in order to account for the year to year variation in demand, indicating a potential peak rate of demand (i.e., having only a five percent chance of being exceeded in any one year). The 95 percent confidence interval water demand forecast was undertaken with the intent of reevaluating the linear regression every year as new data became available. The Average Annual Demand (AAD) was estimated to reach 33.3 MGD by 2020 and 36 MGD by 2035. At the upper bound of a 95 percent confidence interval, the forecasts estimated that the water demands would reach 35.4 MGD by 2020 and 39 MGD by 2035 as shown in **Figure V-11**. These evaluations were considered reasonable at the time based on available information and modeling capabilities, but have been superseded by later modeling using different techniques that are not comparable to the linear regression approach.

An estimated 6,000 active private wells exist in Rockland County based on the records compiled by the Health Department, out of which an estimated 5,800 are domestic wells. The population of 17,400 served by the domestic wells was estimated by multiplying the number of wells with an average three occupants per house. Roughly 250,000 people are estimated as being served by the Suez. The remaining population was estimated to be served by other public community water supply systems such as Nyack and Suffern. Currently as per the estimations of the Suez, 86.9 percent of the county population is served by Suez. It is estimated that by 2040 the Suez would serve 91.9 percent of the county population. Suez serves 87 percent of the county employment through commercial, industrial and institutional customers. This proportion is estimated to remain the same in the future (CDM Smith, Appendix 1.6).

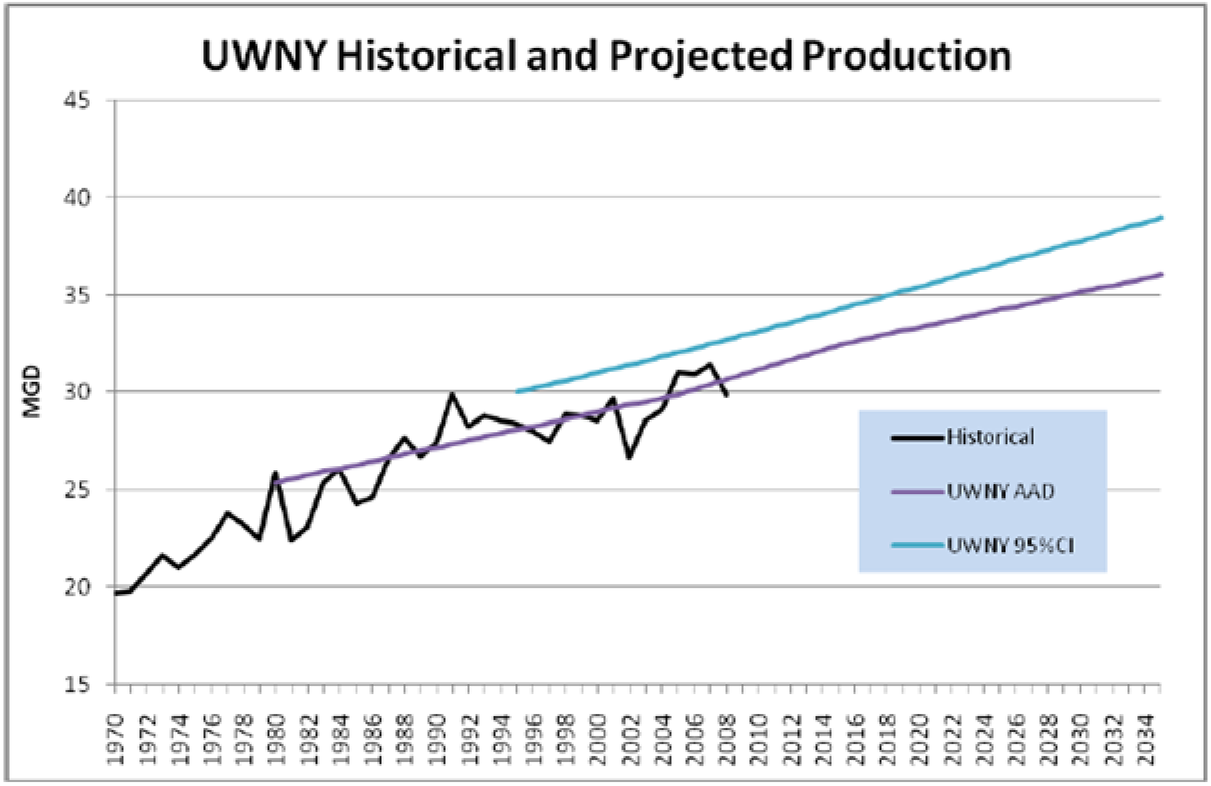


Figure 3 Historical and Projected Annual Average Demand with 95% Confidence Interval

Figure V-11: Suez-NY Water demand forecast with 95% Confidence Interval

Source: Appendix 1.6 Future Water Demands and Conservation Issues

The alternative population projections based on forecasts by Woods & Poole Economic projections, RCDP projections and NYMTC projections are compared in **Figure V-12**. The Suez projection with a 95 percent Confidence Interval is nearly the same as the projections of these three alternatives for the year 2020. (CDM Smith, Appendix 1.6)

On June 30, 2015 the Suez presented a strategy outlining a strategy for conservation, water management measures, and smaller incremental water supplies that collectively have the potential to meet the demand for the next ten years, till 2025. The strategy includes:

1. The creation of District Meter Areas that would break the Suez system into smaller areas thus improving the management of registered individual meters and reduction of NRW

2. The development of a model for the Ramapo River

3. The incremental addition of supply wells providing up to 2-3 MGD water as feasible by constructing 10-15 wells throughout Rockland County, recognizing that these wells could have a potential to interfere with the 6,000private wells that are present in the county.

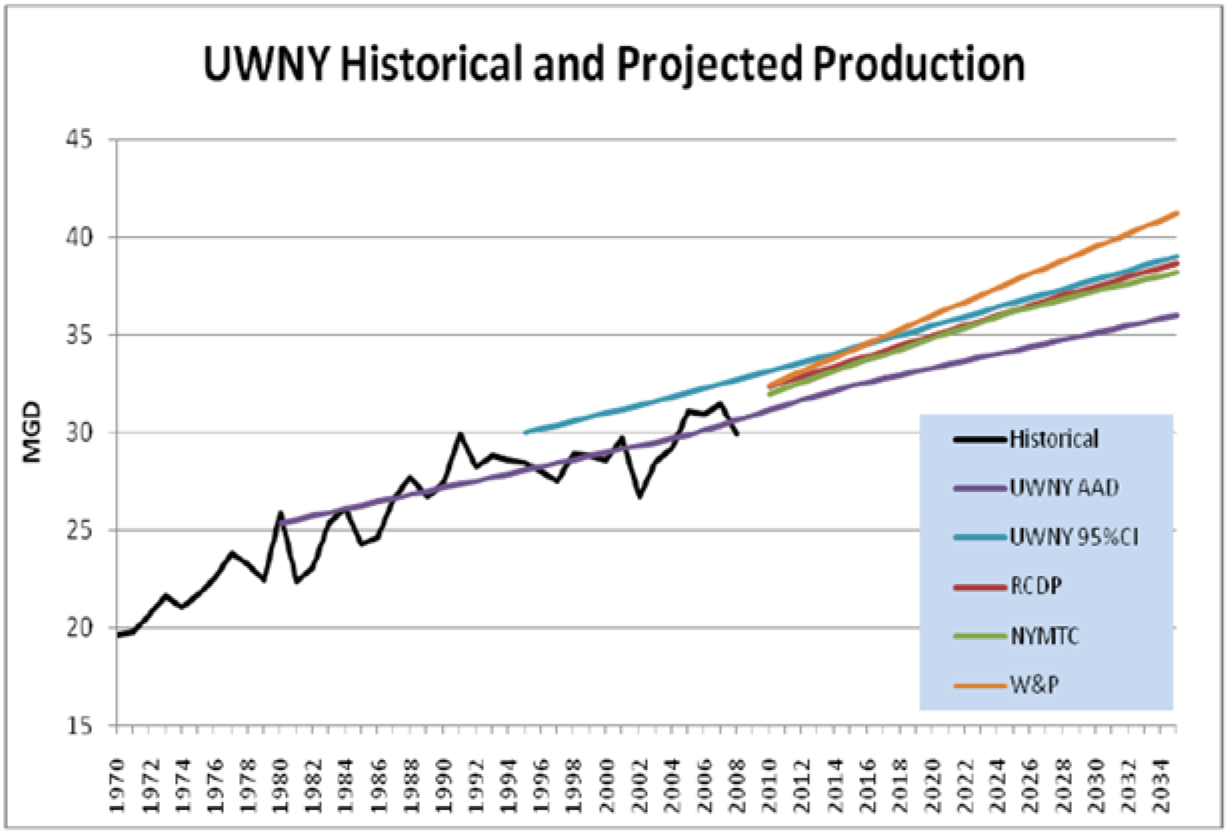


Figure 5 Alternative Per Capita Projections in comparison with 2006 Projections

Figure V-12: Alternate water demand projections by Woods & Poole Economic projections, RCDP and NYMTC

Ramifications for reduction of NRW:

Since 2007, the Suez has rehabilitated 23 miles of mains as part of the infrastructure renewal program. On an average this represents a renewal rate of approximately 0.24 percent per year; Suez intends to reach a renewal rate of 0.7 percent by 2020. (Testimony of Christopher J. Graziano)

Net water supply availability

The New York State Public Services Commission (PSC) issued a 2006 rate order to Suez to develop and implement a major long-term water supply project, as response to a history of droughts and limited water supply availability. Water demand projection for 2016 was conducted prior to the issuance of the 2006 rate order. This water demand projection for 2016 was based on the water demands, so in order to verify the 2006 projection results a water demand forecast was conducted in 2010 for the year 2016 based on population projections for the Suez service area. The 2010 water demand forecast predicted that the annual average demand would reach 33.6 MGD in 2015 and 34.4 MGD by 2018. The 2010 demand forecast supported the results of the 2006 demand forecast. Further, once the Census 2010 population data was released the water demand information was updated, which further supported the 2006 water demand forecast. **Figure V-13** illustrates the forecasts in comparison to the average supply that was predicted to be available at the end of 2015 and beyond in the absence of a long-term water supply project. As per this graph the water supply availability by the various Suez water sources is a constant 34.5 MGD for the year 2015 in the absence of new the water supply projects. The water demand in comparison to the average water supply is projected to rise considerably from 2019 onwards.

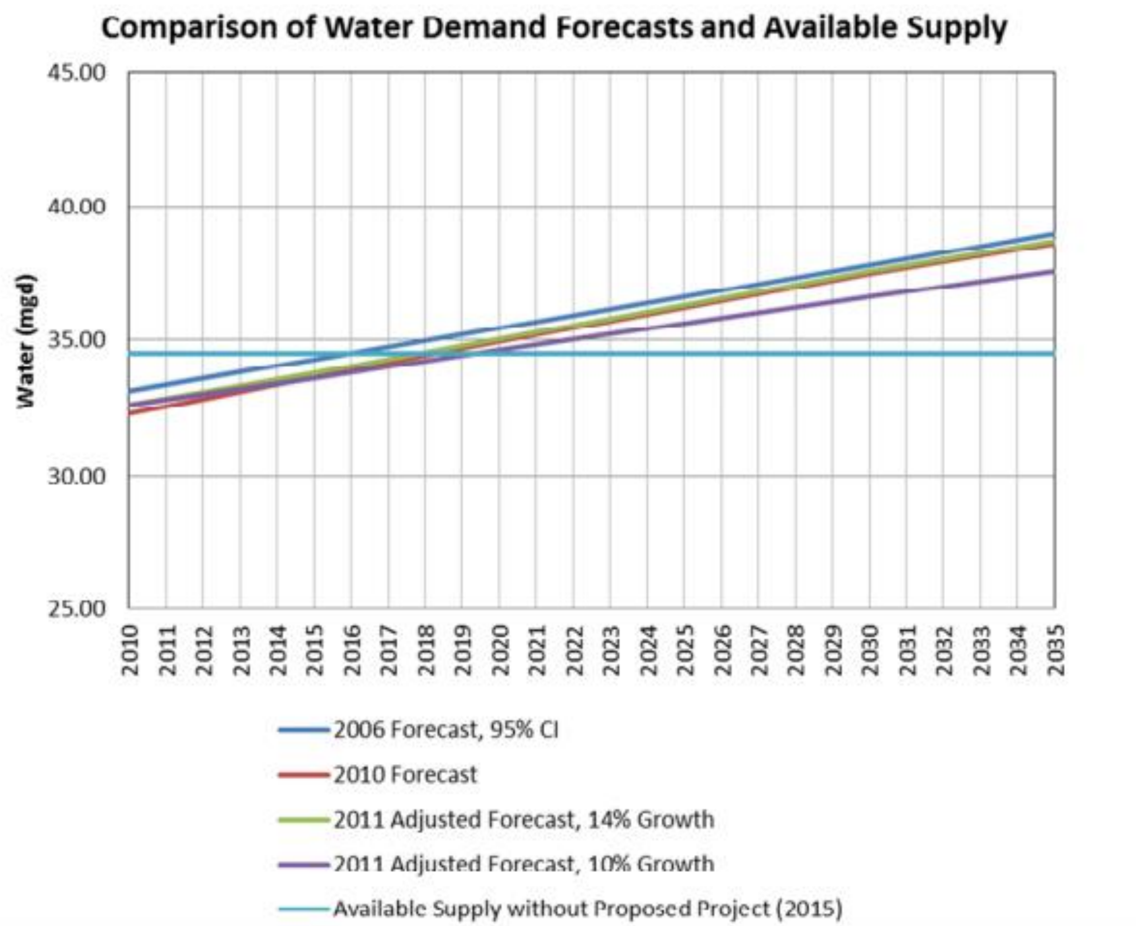


Figure V-13: Comparison of water demand forecasts and available supply

Source: United Water New York Inc. Report on the Most Recent Information Relating To Projected Demand And Need For A New Long-Term Water Supply Source In Rockland County.

Source: CDM Smith, 2010

However, on comparison to the recent data available for the annual average demand as shown in **Table V-3** for the period of July 2015 to June 2016, the annual average demand was calculated to be 28.6 MGD, falling short off the predicted demand by quite a margin. Further, the current running annual average daily demand for July 2016 to June 2017 was calculated to 27.69 MGD, tentatively indicating a decline in the water demand.

Previous	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16	RAA
Total	1,012.84	1,085.72	994.31	842.02	746.71	746.90	781.84	729.31	772.43	770.20	871.53	1,029.59	865.28
ADD	32.67	35.02	33.14	27.16	24.89	24.09	25.22	25.15	24.92	25.67	28.11	34.32	28.36
MDD	36.47	37.90	38.29	30.76	26.90	26.28	26.49	28.32	26.57	29.14	34.12	40.84	
Rainfall (inches)	3.47	1.58	3.21	3.62	2.42	4.97	1.90	4.67	1.01	2.55	3.35	1.79	2.88

Current	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	RAA
Total	1,058.12	969.62	946.16	858.46	748.78	770.33	790.09	692.45	775.73	755.23	838.84	909.03	842.74
ADD	34.13	31.28	31.54	27.69	24.96	24.85	25.49	24.73	25.02	25.17	27.06	30.30	27.69
MDD	38.85	33.93	35.47	32.21	27.70	27.54	27.18	25.69	26.06	27.34	31.84	35.93	
Rainfall (inches)	5.60	2.86	1.20	3.15	5.11	2.89	4.22	2.36	3.50	3.88	7.10	1.69	3.63

All units listed in Million Gallons except rainfall which is in inches
RAA- Running Annual Average for past 12 month period-Rockland County
ADD- Average Day Demand for the Month- Rockland County
MDD- Maximum Day Demand for the Month-Rockland County
Rainfall- Total inches of Rainfall as measured at Lake Deforest
There have been no additions to average day production or safe yield for 2017

Table V-3: Suez-NY water demand for 2015-2016 and 2016-2017
Source: Graziano, 2017. Quarterly report from SUEZ-New York

Suez along with the USGS report (Heisig, 2010) identifies six options for additional water supply for further consideration on account of the constrained availability of additional yield from the Newark basin and the seasonal limitations during the growing season. In order to augment the current water supply, the following alternatives were suggested:

1. Recharge Ramapo aquifer by reuse of water generated at a new advanced treatment plant located in Hillburn (to be constructed) and replenish the Hackensack River by the reuse of water from an upgraded Rockland County Sewer District (RCSD) No.1 wastewater treatment plant in Orangeburg. Both the plants would be required to treat the water to a level that meets or exceeds NYSDEC Class A water source requirements and US EPA guidelines for water reuse when using municipal effluent for augmenting water supplies.
    a. Upgrading RCSD No.1: Currently the wastewater treatment plant in Orangeburg is capable of treating about 29 MGD during a maximum 30-day period while still meeting the current SPDES requirements. The upgraded system would generate 15 MGD of class A reusable water, by three modules capable of treating 5 MGD each. At present the Mahwah pump station pumps wastewater to the existing RCSD No. 1 wastewater treatment plant which is located in Orangeburg. In this plan, redirecting Mahwah's flow to the proposed Western Ramapo treatment plant would return water to where it originated within the Ramapo basin rather than diverting it to Hudson River.
    b. Western Ramapo Advanced Wastewater treatment plant: A new wastewater treatment plant with a capacity of treating 5 MGD of wastewater would be constructed at Hillburn.
2. Replenish Ramapo and Hackensack River flows via reused water generated from an upgraded RCSD No. 1 wastewater treatment plant at Orangeburg. In this option, construction of a wastewater treatment plant at Hillburn isn't required. It is proposed that all the flow from western Ramapo be diverted to the existing RCSD No.1 treatment plant by conveying it through a single pump station located at Hillburn. From here, all the flow would be conveyed to the RCSD No. 1 WTP located at Orangeburg. Post-treatment, 10 to 15 MGD of reuse water would be given back to the Hackensack River while 5 MGD would be given back to Ramapo

and 5 MGD to Mahwah watersheds. The proposed upgrade to the facility would provide an advanced treatment of up to 20 MGD of flow. The 20 MGD design is based on the Suez's calculations of the volume of water required to replenish the Hackensack basin and the Ramapo river basin.

3. UNWY would build a new reservoir upstream of Lake DeForest to supply additional water to Rockland County.
4. UNWY would construct a desalination facility using the Hudson River water to supply additional water.

Option #4 has been deleted as an option through subsequent PSC orders, and the other three options were not selected due to cost and other considerations. Instead, the PSC has ordered that conservation, water loss reductions and limited new well construction be preferred over major capital projects for water supply development to meet future needs.

Potential effects of climate changes

One of the most indisputable impacts of climate change is predicted to be the increase in temperature. A rise in temperature is further predicted to catalyze the process of evaporation from surfaces and transpiration from plants leading to a decline in the water available for recharging the ground water, especially during the growing season.

The other imminent impact of climate change is predicted to be the increase and variability in precipitation. Climate change in this region has the potential to either increase both average and per-event precipitation (both of which have already been documented) resulting in floods or to lessen precipitation leading to frequent droughts. In either of the cases, climate change is predicted to lead to variability in water availability. Not only will there be variability in water availability but the quality of water is subjected to change.

The intensity of precipitation has a direct influence on the magnitude of evapotranspiration. Precipitation with great intensity leads to more runoff and less infiltration. Less water is available for evapotranspiration. Additionally, higher temperatures catalyze the process of evaporation from the surface, which reduces ground water recharge. In effect, higher evapotranspiration leads to lesser recharge. The net effects are in some cases counterbalancing. For Rockland County as shown in **Figure V-14** the precipitation predicted through the year 2075 doesn't indicate too much variability in the precipitation levels from current conditions.

Infiltration and Recharge Rates:

Climate scientists have high confidence that global temperatures will continue to rise for decades to come. Higher temperatures would lead to longer growing seasons. As a result, there would be an increase in evaporation and as more plants capture water for transpiration, both these activities would result in a reduction in recharge.

Runoff rates:

With an increase in precipitation as well as an increase in the intensity of precipitation, the runoff rates are likely to increase. Runoff has both positive as well as negative impacts; run off augments the reservoir water levels when they are low during the summer months and the dry periods. On the other hand, run off brings water of poor quality thus impairing the water quality of reservoirs.

Drought Potential:

Droughts have a detrimental impact on the recovery of reservoir levels and aquifer storage. The USGS study of Rockland County aquifers noted that impervious surfaces have increased the intensity of runoff in various watersheds; this increase will be exacerbated by increased intensity of storms with a higher annual rainfall. The more intense storms can exceed the soil capacity for infiltration, resulting in an

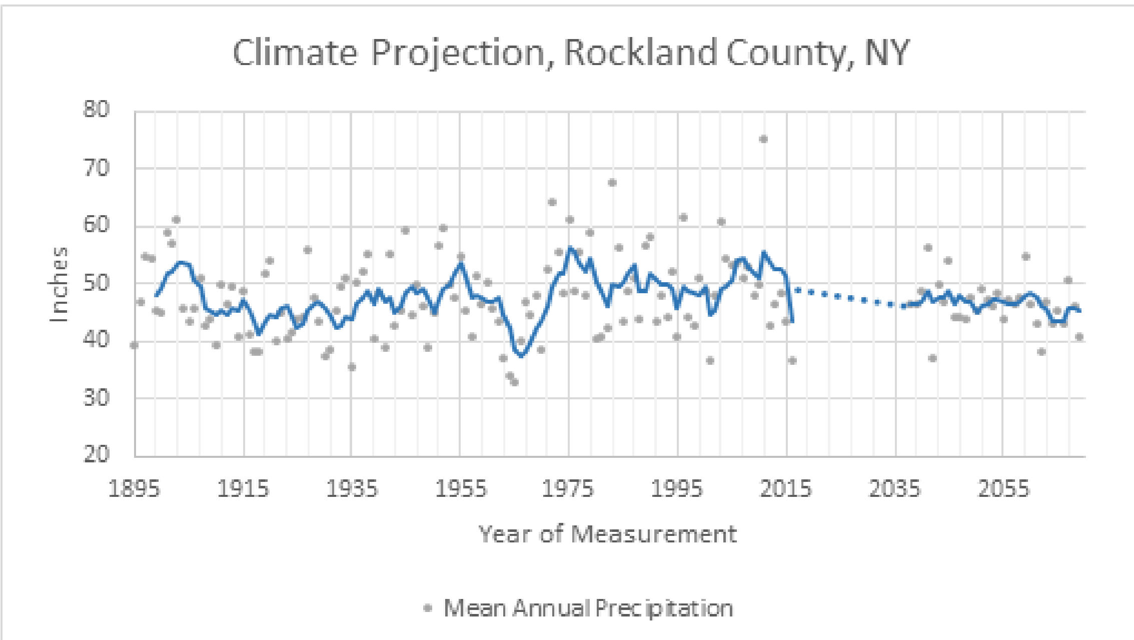


Figure V-14: Precipitation prediction through 2075
Source: NY Climate Change Science Center, 2017

uncertain impact on the aquifer recharge that is critical for streamflow and well field withdrawals. Increased storm intensity also can reduce water quality in reservoirs.

Even if moderate droughts are frequent, they raise the potential for sequential droughts that do not allow for recovery of reservoir levels or aquifer storage. Therefore, the consistent recurrence of moderate droughts has the potential of severely affecting water supply capabilities. Scenario testing for droughts should be conducted for Rockland County to determine the sensitivity of supplies in disparate conditions.

The Global Circulation models which assess the potential for climate change globally, indicate that on an average the northeastern region may experience more frequent short summer and fall droughts. Due to Rockland County's relatively small watersheds and limited aquifers, Rockland County is predicted to see sharper effects of small droughts than areas with major aquifers and larger reservoirs.

Sea Level Rise

One of the major implications of climate change that is going to affect Rockland County is sea level rise. The eastern boundary of Rockland County is along the Hudson River estuary. A sea level rise of three feet by the end of the century will have implications for land uses in low-lying areas, but is unlikely to harm water supply sources in the county.

Water Quality Impacts:

With a rise in global temperatures it is understood that the increase in temperatures has the capacity to change the water chemistry without any further addition of pollutants and can change the terrestrial ecosystem in ways that affect the water sources. Warmer waters hinder the absorption of oxygen thus leading to the increase in the mobility and bioavailability of heavy metals, and increased stress to organisms that require higher oxygen, such as trout. Higher temperatures will lead to an increase in the pathogen load of waters as bacteria and viruses will survive for a longer duration in warmer water. Additionally, increased temperatures support algal blooms which require a more extensive water treatment system for treatment to address taste, odor and cyanobacteria toxicity issues. The treatment can increase disinfection byproducts, with adverse effects on human health, unless carefully controlled through additional treatment.

While precipitation totals and intensity are increasing, temperatures are as well, both on average and as peaks levels (Horton, et al., 2014). Evapotranspiration rates will increase with a combination of extended growing seasons (Melillo et al., 2014) and plant stress during summer periods will as well. Adding to this effect are results of Global Circulation Models (GCMs) that on average indicate that the northeastern region may experience more frequent short summer and fall droughts (Horton, et al., 2014). Rockland County, with its relative small watersheds and limited aquifers, would tend to see sharper effects of small droughts than other areas with major aquifers.

Available and proposed models

Suez is developing a model of the Ramapo Aquifer. A request was placed with Suez for a copy of the scope of work for this study but was not available by the finalization of this report.

VI. Water Quality

The fluid nature of water makes protecting it from pollutants challenging. Rainfall sweeps up contaminants on the earth's surface, seeps through contaminants in the soil, and discharges these pollutants to streams and ground water. Pollutants in our waterways affect human health, aesthetic qualities of water, recreational uses of water, plant and animal health, and raise costs for consumers when drinking water must be treated to reduce pollutant load, and reduce available water for consumption. Regulations by federal and state agencies to limit pollution of our waterways have improved water quality immensely in the US, but threats still remain.

Regulatory Framework

The Federal Clean Water Act (33 U.S.C. §1251 et seq. (1972) (CWA) regulates and enforces the release of contaminants into wastewater. The goal of the act is to eliminate pollution discharges into the nation's waterways and to return water to a quality suitable for drinking water, recreation and habitat. Originally, these regulations applied to point source pollution, including overseeing the construction and operation of wastewater treatment plants, but a 1987 amendment provided funds for grants to states to enact non-point source control measures, as well (Copeland, 2016, p. 4). Wetlands are also protected from pollution under Section 404 of the CWA (Copeland, 2016, p. 6). In order to track and attempt to reduce pollutant discharge, the EPA requires entities that discharge pollutants, including stormwater runoff, to obtain a permit under the National Pollutant Discharge Elimination System (NPDES) program. Acceptable ambient concentration levels are set for 115 different contaminants including metals, chemicals, bacteria and other pollutants (Copeland, 2016, p. 6).

The EPA requires water quality standards to be set for each waterway based on its best use—water supply, recreation, and/or aquatic life. Waterways that are too polluted to allow these uses are considered impaired and, depending on the pollutant, remediated. For specific pollutants, waterways that that are not able to achieve compliance through NPDES permits and other actions, such as technology-based controls, are placed on the Section 303(d) List of Impaired/TMDL Waters. Total Maximum Daily Loads (TMDLs) are created for each non-compliant waterway to further regulate the contaminants to be discharged. A TMDL is the amount of particular pollutant that can be discharged to waterways while maintaining quality, and includes a management plan to reduce the pollutant to that level. For water degradation that is the result of land use or flow modifications, but not a specific pollutant, TMDLs are not required, but other remediation actions are warranted. (US EPA, 2017c).

The Safe Drinking Water Act, passed in 1974, with major amendments in 1986 and 1996, regulates public drinking water supply and quality for systems with at least 25 regular consumers or 15 service connections. Regulations are aimed at preventing contaminants from reaching customers of drinking water supplies originating from both ground and surface water sources. These standards are based on the type and size of the water service provided (Tieman, 2017) and are regulated under the National Primary Drinking Water Regulations (NPDWR), in which the EPA establishes Maximum Contaminant Levels (MCLs) of substances that may harm human health. Most MCLs are the same for all systems, but public noncommunity water supply systems may have less stringent standards for some parameters.

Additionally, the EPA has established National Secondary Drinking Water Standards (NSDWRs) as non-enforceable guidelines for management of drinking water aesthetics and taste (US EPA, 2015).

After new chemical compounds or other substances are approved for use, methods exist to track and understand their effect on ecosystems and human health. For trace amounts of pesticides and their degradants, the EPA publishes Health Advisories and Human Health Benchmarks for Pesticides but does not regulate their release (US EPA, 2012, 2017d). Additionally, the EPA and the USGS track contaminants that can be detected at trace levels in drinking water such as pesticides and Volatile Organic Chemicals (VOCs). Every 5 years, beginning in 1998, the EPA publishes a Contaminant Candidate List (CCL) which considers the threat to human health from chemicals that are not currently regulated under the NPDWR (US EPA, 2014b). Public water suppliers are required to publish a report of contaminant test results each year. Suez NY has published these results, and reported high levels of total trihalomethanes (TTHMs), a byproduct of water disinfection, during one test in the 2016 report, but subsequent reports found no further evidence of the contaminant (Suez, 2016). No other issues were reported regarding MDL exceedances.

The EPA has delegated the monitoring and regulation of the CWA and SWDA to state-based programs. In New York State, the NYS Department of Health (NYSDOH) oversees the SDWA, including monitoring and testing drinking water systems in the state, as well as regulating septic systems and testing domestic wells during real estate transactions (NYS Sanitary Code; Volume A (Title 10); Title: Part 5). The Department of Conservation (NYSDEC) oversees monitoring and enforcement of the Clean Water Act. NYSDEC has encoded the use classifications for waterbody under Title 6 CRR-NY 860.5 and 865.6 (Table VI-2), and track and monitor pollutant discharges to waterways through the State Pollutant Discharge Elimination System (SPDES) program. Safe amounts of pollutants to discharge to waterways are published under Technical and Operational Guidance Series (TOGS) reports (Zambrano & Stoner, 1998). Amendments for TOGS are published regularly which update safe levels of pollutants as more sensitive tests are developed (New York State Department of Environmental Conservation, 2008). Nutrients plans are being developed to track and control the release of phosphorus and nitrogen in waterways. (New York State Department of Environmental Conservation, 2011).

Waterways that are listed as impaired by the NYSDEC are addressed either through TMDLs or creation of a “Nine Element” (9E) Watershed Plan that is intended to achieve the same result as a TMDL. While both plans address pollution in waterways, TMDLs are primarily used where point source pollution is a major issue, while 9E Watershed Plans focus on watersheds where the primary issue is non-point source pollution. States manage the TMDL program, with approval and oversight by the EPA.

It is important to note that water quality modelling differs for point and nonpoint sources. Point sources are incorporated into models using discharge-specific effluent quality information. Nonpoint sources cannot be monitored cost-effectively, and so general pollutant loading factors are used, based on research from similar areas. Therefore, the nonpoint source pollutant loadings will be somewhat more uncertain than point source loadings, but proper calibration and validation of the model can reduce the uncertainty if sufficient stream water quality monitoring takes place to provide an understanding of ambient quality conditions. Modelling without monitoring can only provide a very rough sense of the sources and relative loadings for nonpoint source pollutants. This level of modeling may be sufficient to develop educational programs, technology-based regulations (e.g., retention basin standards) and incentive-based programs, but might not be sufficient to support direct regulation of specific nonpoint sources with mandatory water quality objectives.

One exception to NYS oversight is the SWDA's regulation of underground injection wells, which discharge waste products into water-bearing zones that may be or are used for water supply. All classes of underground injection wells are overseen and issued permits by the EPA. NYS does issue permits for brine wells, of which there are none in the Ramapo or Hackensack watersheds.

Several local and county laws reinforce state and federal clean water statutes. Rockland County Article II tracks and monitors discharges to sewers and Ramapo has developed the Aquifer and Well Field Protection Zone statute (Rockland County, 1984; Town of Ramapo, NY, 2004).

Surface water quality

Current and historic information exists to gauge the quality of water in surface waters as well as trends. These data include reports from NYSDEC, Professional External Evaluators of Rivers and Streams (PEERS), and the US EPA. Surface waterways are assessed by the NYSDEC every five years through the Lake Classification and Inventory (LCI) program and the Rotating Integrated Basin Studies (RIBS) program. As a supplement to RIBS, PEERS has conducted yearly (2005 - 2017) macroinvertebrate assessments and chemical and physical analyses of surface waterways, which include measures of specific conductance, salinity, dissolved oxygen, pH and temperature. The results of these studies, supported by the Rockland County Soil & Water Conservation District (RC SWCD) are submitted to the NYSDEC and US EPA for long term monitoring, and are the most comprehensive information available about the quality of surface waterways in the study area. This information can be found online at http://rocklandgov.com/departments/environmental-resources/protecting-our-streams-and-waterways/. Additionally, Heisig (2010) compared stream water quality from his 2005-2006 study to a major assessment of surface water quality from 1963 (Ayer & Pauszek, 1963). Reports from NYSDEC and the EPA will be summarized, followed by a section that addresses the more detailed information from the PEERS data.

States are required by the EPA to record information about impaired waterbodies and to publish a list of these waters every two years. New York State maintains a Waterbody Inventory/Priority Waterbodies List (WI/PWL) database to inform the publishing of the Section 305(b) Water Quality Report and the Section 303(d) List of Impaired/TMDL Waters to report to the EPA. The WI/PWL is a more comprehensive list of water impairment than the Section 303(d) list, which is reserved for waters needing TMDLs. In this list, NYS classifies waterbodies as "Impaired," in which water bodies are known to have contaminants that do not support their classification; "Minor Impacts," water bodies have or are suspected to have contaminants, and don't always support uses; "Needs Verification," where pollutants are unconfirmed, but some uses are not supported; "Threatened," in which the water body has known contaminants, but uses are fully supported; and "No Known Impacts," in which contaminants are not present and fully support uses (**Table VI-1**). These labels are based on information from RIBS, yearly macroinvertebrate testing, and information from the Citizen Science Lake Assessment Program (CSLAP),

US EPA 305(b) Integrated Reporting Categories	NYS WI/PWL Assessment Categories	Use Level of Severity	Evaluation Confidence Level
Impaired/Threatened Waters (IR Category 4 or 5)[1]	Impaired	Precluded-all uses unsupported	Known
Impaired Waters (IR Category 4 or 5)[1]	Impaired	Impaired—all uses periodically unsupported	Known
Waters Attaining Some Standards (IR Category 2)	Minor Impacts		Suspected
Waters with Insufficient Data (IR Category 3)	Needs Verification		Unconfirmed
Waters Attaining All or Some Standards (IR Category 1 or 2)[2]	Minor Impacts	Stressed—some uses occasionally unsupported	Known, Suspected
Waters with Insufficient Data (IR Category 3)	Needs Verification		Unconfirmed
See Below[3] (IR Category 1, 2, 4 or 5)	Threatened	Threatened[2]	Known
Waters Attaining All or Some Standards (IR Category 1 or 2)[2]	No Known Impacts		Suspected
Waters Attaining All or Some Standards (IR Category 1 or 2)[2]	No Known Impacts	Fully Supporting—all uses supported	Known, Suspected
Waters with Insufficient Data (IR Category 3)	Unassessed		Unconfirmed
Waters with Insufficient Data (IR Category 3)	Unassessed	Unassessed	N/A

[1]Category 4 waters are impaired but do not require a TMDL, due to the type or management of pollutant; Category 5 waters require a TMDL because the pollutant can be reduced with this strategy. Determination made on a case-by-case basis.
[2]Determination made on a case-by-case basis.
[3]The NYSDEC uses a broader definition of *Threatened* than the EPA in order to begin restoration and protection efforts and to track declining water quality. Assigning a use level category assists in this documentation.

Table VI-1: Classifications of Impaired Waters by NYS and EPA.
Source: NYSDEC and US EPA

a volunteer program, managed by NYSDEC and New York State Federation of Lake Associations (NYSFOLA), which provides water quality assessments of lakes throughout New York State.

Reports of surface water quality are available from the NYSDEC as WI/PW Lists (2008, 2010) and a 303 (d) List (2016). Several documents from a basin-wide assessment of surface water quality in the Ramapo and Hackensack watersheds were published in 2008 (NYS Department of Environmental Conservation, 2008). Additional WI/PWL information is available from a 2010 survey as GIS data (Figure VI-1). The most recent information available from NYSDEC about surface water pollution is a 303(d) report

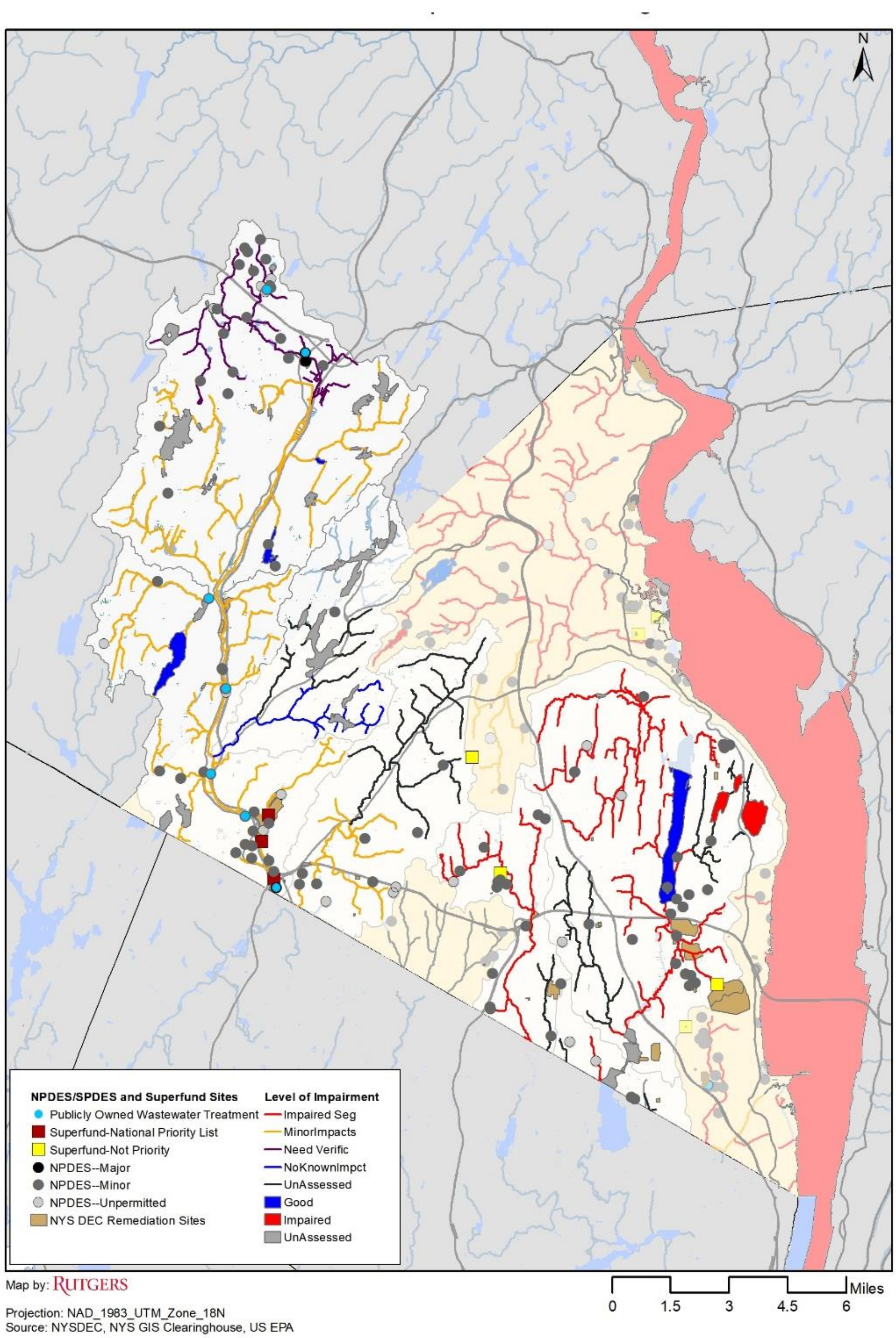


Figure VI-1: Classification of waterbodies on the NYSDEC Priority Waterbody List compared to wastewater treatment plants and other NPDES sites, Superfund, and remediation sites.
Source: NY DEC (2008 data), US EPA.

(Department of Environmental Conservation, 2016), which requires TMDLs to be completed for Congers Lake and Swartout Lake due to high phosphorus levels from urban stormwater runoff from 2010 and 2012 assessments, respectively (**Table VI-2**). Portions of the Hackensack River, Nauraushaun Brook, tributaries to Lake DeForest, the West Branch of the Hackensack River and Pascack Brook are listed as "Needs Verification" because 2010 assessments show biological degradation based on macroinvertebrate sampling and implicate possible stresses from stormwater runoff. These results require further assessment of water quality. These waters are tested because they are considered Class A waters for drinking and have a high susceptibility to threats (NYS Department of Environmental Conservation, 2008, p. A-10). Additional results are expected from the next 303(d) report which is due in June 2018.

The EPA publishes 305(b) reports of waterway quality and lists those that are impaired on the 303(d) List of Impaired Waterways Needing TMDLs (**Table VI-3**). The biennial reports from 2002 to 2014 are available online, and highlight the variation in assessment from year to year. Several waterways were listed on the 303(d) report from 2012, but in 2014 were listed as "good" though no TMDL or other remediation was completed. The Water Quality Assessment Status for 2014 has listed the Hackensack River and its tributaries, Nauraushaun Brook, tributaries to Lake DeForest, Pascack Brook and its tributaries, Rockland Lake and Congers/Swartout Lake as impaired. In 2012, these waterways and the entire Ramapo River, the Lower Mahwah and tributaries, Tuxedo Lake, Lake Stahahe, Lake Tappan, and Lake DeForest were also listed as impaired. Only Stony Brook, a tributary to the Ramapo and a small section of an unnamed tributary in Orange County had tested as unpolluted. Much of the upper portion of the Mahwah River was unassessed, as well as the stream portion of the East Branch of the Hackensack River (US EPA, 2017b). A thorough assessment of water quality is warranted.

The US EPA lists typical contaminants for the Hackensack and Ramapo waterways in the 2012 assessment as nutrients, pathogens, aquatic plants, salinity, sediments and low oxygen. Acute aquatic toxicity, which is a measure of the number of organisms that can survive exposure to water directly at a point of NPDES permitted facilities' discharge, was reported for many of the impaired waterways in the 2010 report. Stormwater runoff, industrial and municipal discharges and chlorine used for deicing have been implicated in the impairment of rivers, streams and waterbodies in the region in 2004 reports. (US EPA, 2017a).

The largest permitted polluters in the watersheds are the Orange County Sewer District #1 Harriman Sewage Treatment Plant (STP) and the Suffern STP, both of which discharge wastewater that exceeds allowable limits regularly. In 2017, Orange County #1's top pollutants discharged to the Ramapo River include total oxygen demand, ammonia as NH3, nitrogen, phosphorus, of which the first two pollutants exceeded permitted levels. Past violations also include BOD, total suspended solids, and high temperatures. The Suffern Sewage Treatment Plant in Suffern discharges wastewater with high levels of oxygen demand, coliform, ammonia as NH3 into the Ramapo River. They are in significant violation of regulations and are currently in non-compliance, which is the only NPDES facility with both distinctions in the study area. A third major NPDES permitted discharger is ELT Harriman, LLC which is now a Superfund site. (US EPA, 2017).

Class	Uses	Discharges/Restrictions	Watershed	Number in Watershed	Trout Waters (T)*
AA-S	• Drinking water, • Primary and secondary contact recreation, • Fishing, • Fish and shellfish habitat and propagation	• No discharge into water, • No floating or deleterious substances in water, • no high levels of nutrients, • no alteration of flow that will impact water quality	Ramapo	0	0
			Hackensack	0	0
A-S	• Drinking water, • Primary and secondary contact recreation, • Fishing, • Fish and shellfish habitat and propagation	International Boundary Waters Considered safe if impurities are removed and the water is disinfected	Ramapo	0	0
			Hackensack	0	0
AA	• Drinking water, • Primary and secondary contact recreation, • Fishing, • Fish and shellfish habitat and propagation.	Considered safe if impurities are removed and the water is disinfected.	Ramapo	1	1
			Hackensack	0	0
A	• Drinking water, • Primary and secondary contact recreation, • Fishing, • Fish and shellfish habitat and propagation	Considered safe if impurities are removed and the water is disinfected and filtered.	Ramapo	17	2
			Hackensack	57	5
B	• Primary and secondary contact recreation, • Fishing, • Fish and shellfish habitat and propagation		Ramapo	39	3
			Hackensack	11	0
C	• Fishing, • Fish and shellfish habitat and propagation • Perhaps primary and secondary contact recreation, if advisable.		Ramapo	44	15
			Hackensack	116	29
D	• Fishing, • Perhaps primary and secondary contact recreation, if advisable.		Ramapo	2	0
			Hackensack	2	0
N	• Aesthetics of water way. • Drinking water, • Primary and secondary contact recreation, • Fishing, • Fish and shellfish habitat and propagation	• `	Ramapo	0	0
			Hackensack	0	0

Table VI-2: Classifications of Standards for Waterbodies in New York State.

Source: New York State Department of Environmental Conservation, 2017b, 2017a

Waterbody	Code	Impact-2014	Use Score	TMDL	Sources	Contaminants	Past Reports
Hackensack River/Lake Tappan	1501-00008	Good	A	Y	None listed	Nutrients	2012, 2010, 2002[1]
Hackensack River, Lower, and minor tribs	1501-0026	Impaired	A	Y	Industrial and Municipal Discharges, Stormwater Runoff	Unknown Toxins, Acute Aquatic Toxicity, Phosphorus, Sediment, DO	2012, 2010—partial impairment (good for water source)
Nauraushaun Brook, Lower, and tribs	1501-0010	Impaired	A	Y	Not listed	Unknown Toxins, Sediment	2012, 2010, 2002
Lake DeForest	1501-0007	Good	A	Y	Not listed	Nutrients, pathogens, Salinity, Sediment	2012, 2010,2006, 2004, 2002
Minor Tribs to Lake DeForest	1501-0029)	Impaired	A	Y	Industrial and Municipal Discharges, Stormwater Runoff	Acute Aquatic Toxicity, Phosphorus, Sediment, DO	2012, 2010—partial impairment (good for water source)
West Br.Hackensack, Upper, and tribs	1501-0009	Impaired	C(T)	Y	Industrial and Municipal Discharges, Stormwater Runoff	Unknown Toxins	2012, 2010, 2004, 2002
Pascack Brook and tribs,	1501-0015	Impaired	C	Y	Industrial and Municipal Discharges, Stormwater Runoff	Unknown Toxins	2012, 2010, 2006, 2004, 2002-but stormwater discharge noted
Lake Lucille	1501-0017	Good	B	Y	None listed		2012, 2010, 2004, 2002
Rockland Lake	1501-0021	Impaired	B	Y	None listed	Phosphorus	2012
Congers Lake, Swartout Lake	1501-0019	Impaired	B	Y	None listed	Excess Algal Growth Phosphorus	2012, 2010, 2006, 2006, 2002
Mahwah River, Lower and Tribs	1501-0011	Unassessed	A	Y	None listed	Nutrients, Pathogens, Salinity	2012, 2010, 2006, 2004, 2002
Ramapo River, Lower, and minor tribs	1501-0012	Good	A (T)	Y	None listed	Metals, Nutrients, Pathogens, Sediments	2012, 2010, 2006, 2004, 2002
Tuxedo Lake	1501-0050	Good	AA (T)	Y	None listed	Other cause	2012, 2010, 2004
Ramapo River, Middle, and tribs	1501-0036	Good	A (T)	Y	None listed	Sedimentation, Phosphorus	2012, 2010
Lake Stahehe	1501-0053	Good, Threatened-2012	A	Y	Pathogens, Other cause	Coliform	2012, 2010,
Ramapo River, Upper, and tribs	1501-0037	Unassessed	B	Y	Stormwater Runoff	Sedimentation, Phosphorus	2012, 2010

Table VI-3: Impaired Waterbodies listed on the EPA 303(d) report, with selected unimpaired water sources on the 305(b) list.

All major waterbodies appeared on the 2012 303(d) list. Subsequent testing in 2014 found some waterbodies “Good.” Past report dates that are red indicate impairment, green dates indicate good water quality, orange dates indicate a source of impairment was noted, but a TMDL was not required. Source: (US EPA, 2014a)

New York State tracks accidental discharges from publicly owned treatment works and publicly owned sewer systems through the Sewage Pollution Right to Know law enacted in 2013. After discovery, sewage spills are to be reported within two hours to the NYSDEC and within four hours to the public, and this information is maintained in a database by the NYSDEC. There were 91 accidental sewage discharges from 2013 to present within the Hackensack and Ramapo watersheds (**Figure VII-3**). The systems involved include Clarkstown Sanitary Sewer, Rockland County Sewer District #1, Orangetown SD #2, Ramapo POSS, Suffern WWTP, and Orange County SD #1. Reasons for spills were blockages (45%) mainly of grease, rags and wipes, infrastructure failure (22%), pipe breaks (6%), and heavy rain events (2%). Several locations had repeat issues and areas with a high density of releases (in points per square mile) include the streets near Cherry Brook in Pearl River (6), an area along the NY/NJ border southeast of Lake Tappan (6), an area along the northeast shore of Lake Tappan (4), and several less dense areas in Spring Valley and Monsey. Continuing to educate households about the perils of flushing baby wipes or grease down the sewer may help stem the release of sewage to local waterways.

Tests for salinity, specific conductance and other chemical and physical parameters have been completed every year from 2005 – 2017 during PEERs assessments. Specific conductance is a rating of electrical conductance (µS/m) and is used to estimate the concentrations of salt, chlorides and total dissolved solids in water. High levels of salinity are detrimental to freshwater fish and other organisms. Current levels (2012-2016) of salinity range from 180 to 580 mg/l, and specific conductance ranges from 376 µS/m to 1171 µS/m (**Figure VI-3**). Salinity levels over 500 mg/l are detrimental to the majority of freshwater aquatic life, including fish. Even levels above 250 mg/l have affect water quality for drinking and aquatic life (Kaushal et al., 2005). The Hackensack watershed has three streams with measurements over 500 mg/l, including portions of the Pascack Brook and Muddy Brook, a tributary of the Pascack. The Ramapo has no measurements over 500 mg/l. Development and impervious surfaces generally increase specific conductance measures, while salinity is caused by road salt runoff. In Orange County, a spike in specific conductance from 2005 to 2012 alerted authorities to the high levels of pollutants from the Kiryas Joel WWTP (Watershed Assessment Associates, 2013).

Road salt or sodium chloride (NaCl) is a popular deicer because it is inexpensive. In addition to contaminating surface and ground water, road salt corrodes metal and degrades concrete surfaces. While there are alternative deicers, none are perfect and all have a higher initial cost. Municipalities need to weigh the added costs of road salt degradation, the higher costs of alternative deicers, and road safety. Many state and local governments have attempted to reduce road salt use through a four-pronged approach: reduction of salt use through best management practices (BMPs), education, alternative deicers, and novel designs of drainage systems in sensitive areas.

Numerous BMPs exist to reduce salt use and are focused on monitoring, application and targeting. Close monitoring of weather and temperature ensures that application of salt is warranted or useful. Software or algorithms (Trenouth, Gharabaghi, & Perera, 2015) can help to determine the appropriate amount of salt to use for predicted weather events, and filling trucks with these prescribed amounts limits waste and the impulse to empty the truck. Temperature sensors and application regulators on trucks vary the amount of salt applied based on local conditions. Several methods help to manage the scatter effect of dry salt and ensure the deicer sticks to the road, which reduces the amount

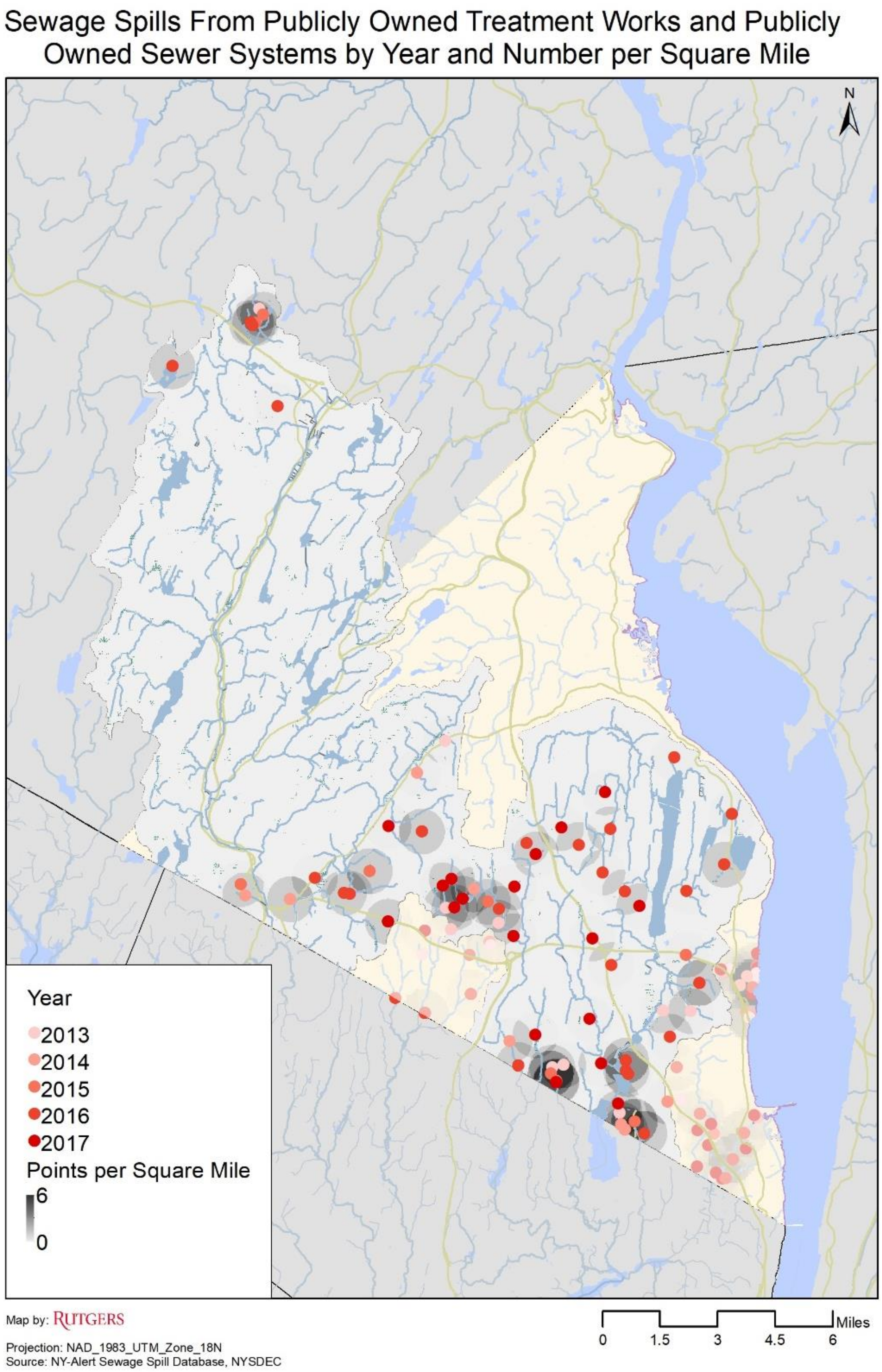
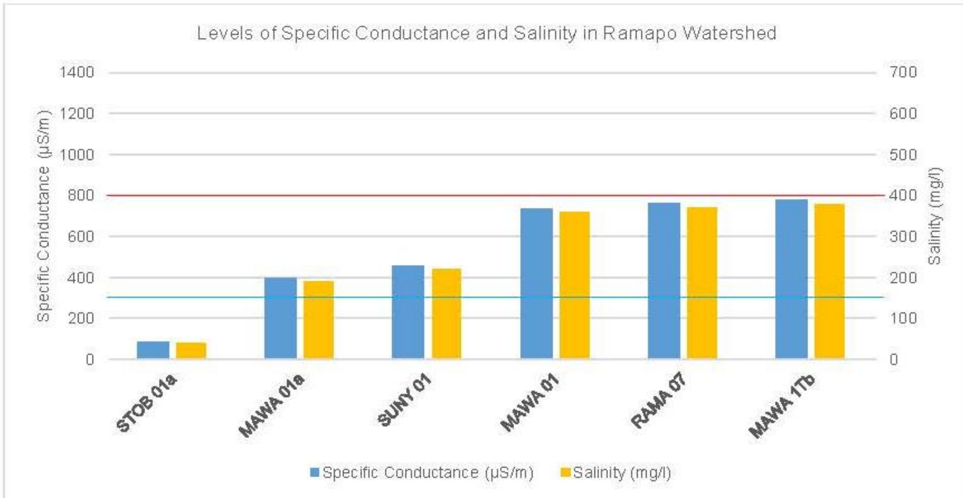


Figure VI-2: Sewage Release points by year (2013-2017) and by density (points per square mile).



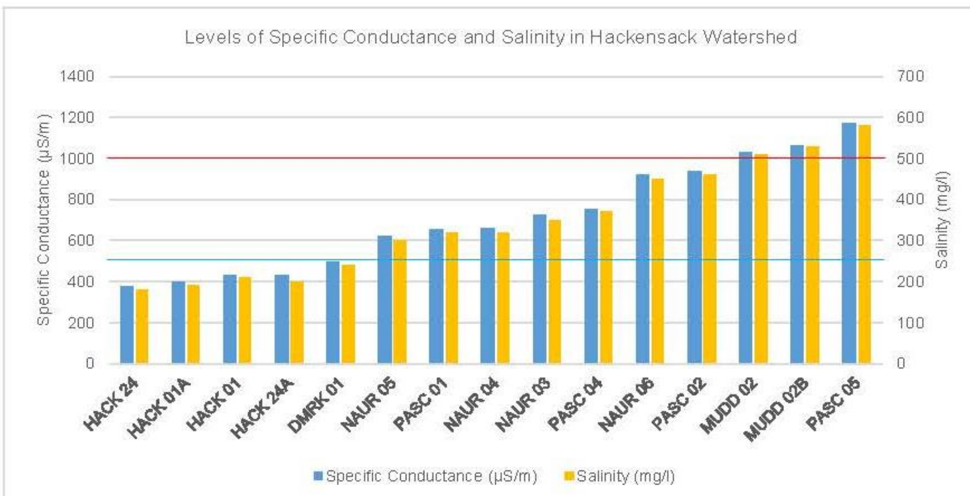


Figure VI-3: Levels of Specific Conductance in Ramapo and Hackensack waterways in Rockland County. Salinity levels above 0.5 PSS (red line) lead to decreases in freshwater organisms not tolerant of saltwater, including fish, while levels above 250 mg/l (blue line). Source: Rockland County Task Force in Water Resources Management.

of salt used. Brine applications to roads before snow events prevents ice from forming, prewetting salt reduces scatter, and applying salt to the center of a road uses cars to distribute deicer to the edges of the road. Maintaining logs of application rates, type of snowfall, and temperature tailors the amount of salt used to the localities. Various entities in Rockland County use this approach, apparently.

Education is a tool to reduce road salt use. Road salt is mostly ineffective under 16°F and increasing the amount of salt on the road during low temperature snowfall will not increase its effectiveness. Ensuring that municipalities, applicators and drivers know this fact can have the twin effect of reducing applications and driver expectation of smooth driving during snowy weather. Drivers can be warned of the dangers of fast driving in snowy conditions through the use of digital road signs and driver education classes. Salt truck operators and public works departments should be educated of the hidden costs of over-application of salt and how to monitor temperatures to use the appropriate amount of salt.

Numerous alternative deicers are available and include calcium magnesium acetate (CMA), combinations of sodium chloride and other substances such as beet juice, magnesium chloride, and/or other proprietary ingredients (**Table VI-4**). In general, research under field conditions indicate that these deicers, particularly those that are liquid, tend to work faster and at a wider range of temperatures (Hossain, Fu, & Lake, 2015; Lee, Choi, Kim, Kim, & Yang, 2017). Unfortunately, these products are often more expensive and have deleterious to undetermined effects on the environment, which limits their usefulness (Schuler et al., 2017). Some municipalities have used less environmentally degrading, but more expensive, deicers like CMA or Geomelt only in particularly sensitive ground water recharge or aquatic environments to reduce costs. Consideration of these alternatives would be appropriate for well field areas.

Product	Cost/ton	Low Effective Temperature	Corrosive	Aquatic Toxicity	Other Effect
Road Salt - NaCl	$55	16	yes	moderate	Increases salinity, kills plants,
Magnesium Chloride - $MgCl_2$	$120	5	yes	very	Mg in soil
Calcium Chloride - CaCl	$140	-25	very	moderate	Ca in soil
CMA	$650	0	No	indirect	Reduces aquatic oxygen
Jiffy Melt - NaCl, $MgCl_2$	$350	-5	Less than NaCl	indirect	Changes in ecosystems
ClearLane - Pre-wet NaCl, $MgCl_2$	$72	0	Less than NaCl	Less than NaCl	Salinity
Urea	$736	12	No	Indirect	Reduces aquatic oxygen
Ice Breaker - NaCl, CaCl, KCl, CMA	$210	-10	Less than NaCl	indirect	Reduces aquatic oxygen

Table VI-4: Road Salt alternatives compared by cost and environmental impact.
Sources: Schoenberg Salt, pers. comm. 11/29/2017.

Other design solutions on roadways include the use of hedgerows to decrease snowdrifts and watershed-based approaches to designs for drainage systems in sensitive areas that, while more expensive than simple swales, decrease the amounts of a variety of toxins including chlorine that drain into sensitive waterways (Trenouth, Gharabaghi, & Farghaly, 2018).

Tracking state, county, and local roads by lane mile per square mile of subwatershed reveals where high levels of road salt are likely to be used and can target areas to use more environmentally friendly products in particularly sensitive areas. The Hackensack watershed has the highest density of roads per watershed area.

The water quality of lakes is assessed by volunteer groups working with Citizen Science Lake Assessment Program (CSLAP), which is managed through the NYSDEC and New York State Federation of Lake Associations (NYSFOLA) and provides water quality assessments of lakes throughout New York State. Lake Lucille in the Hackensack watershed is currently studied, while 3 lakes in the Orange County section of the Ramapo watershed have current assessments: Tuxedo Lake, We Wah Lake, and Little We Wah Lake. Water quality measures include nutrients, algae type and amount, plankton type, conductivity, pH, temperature and aesthetics. Lake Lucille studies for 2015 noted high levels of chloride, low water clarity, and some large algae blooms. The lake was classified as impaired for swimming and recreation due to the low water clarity (NYS Department of Environmental Conservation, 2015b). Tuxedo Lake examinations reported high nutrients, algae levels, pH, and moderate levels of chloride, which were considered a threat to drinking water, aquatic life, and recreational uses. We Wah Lake reports noted high levels of algae, pH, phosphorus and specific conductance, which degraded the water for swimming, recreation and aquatic life. Little We Wah Lake assessments reported high chloride, algae and nutrient levels, and low clarity, which contributed to impairment for recreational uses (NYS Department of Environmental Conservation, 2015a).

Additionally, a database of harmful algal blooms is maintained for lakes throughout New York State. The most recent records are from 2016, in which Rockland Lake appeared on the list for 10 weeks from 6/2/16 to 10/28/16, and Little We Wah Lake in Orange County for 2 weeks in July (NYSDEC, 2017).

Variability

Amounts of pollutants in streams vary over the course of the year depending on precipitation and temperature. Low flow times during droughts and hotter summer months can increase the concentrations of contaminants in waterways (Nolan, 2010). Stream flows in the Ramapo River during extreme droughts, result in water that is about half wastewater that has not treated to drinking water standards (Kecskes, 2015). Higher summer water temperatures produce algae blooms in lakes, which degrades drinking water quality and aquatic habitat, and discourages recreational uses.

Trends

Historic data about water quality provides a temporal comparison of pollutants in water in the study area. CSLAP volunteers have noted decreasing water quality and clarity in the lakes within the study area. Lake Lucille, which has records from 1986 to 1990 and 2012 to 2015, found increasing conductivity measurements and water temperatures. Assessments of Tuxedo Lake, We Wah Lake and Little We Wah Lake have reported generally higher levels of nutrients, water temperatures and specific conductivity since measurements began in 2008 (NYS Department of Environmental Conservation, 2015a).

Trends in specific conductance show that levels are rising in the county from historic levels, indicating increasing dissolved solids and salinity levels. In 1905, chloride levels were measured at 1.4 mg/L in the Ramapo and Mahwah Rivers (Jackson, 1905). The 1963 study by Ayer and Pauszek found Hackensack River specific conductance levels to average 204 µS/m, while today they average 426 µS/m. The Pascack averaged 260 µS/m during 1963 samples and today averages 880 µS/m. The Mahwah averaged 187 µS/m, and now averages 639 µS/m. The Ramapo's 1963 conductance levels were 206 µS/m, while they average 764 µS/m. Comparing 2006 to 2014 specific conductance levels showed variable rates throughout the 12 years, but no distinct trend.

Waterways in Rockland County appear to have increasing levels of nutrients and other pollutants when comparing 2002-2006 EPA Water Quality Reports and 2010-2014 Water Quality Reports. A 2012 assessment found most waterways in both watersheds impaired (US EPA, 2014a). EPA 305s(b) reports from 2004 noted stormwater runoff as a source of water quality impairment, but did not label the waterbody as impaired. It is difficult to ascertain whether increasing regulation and scrutiny of stormwater runoff is the source for the increasing impairment of the waterbodies. The NYSDEC's introduction of the 9E Watershed Plan and the proposed Nutrient Standards for waterways are intended to address increasing levels of nutrients from municipal and industrial runoff. Clarkstown has implemented a stormwater management program to address the rising impairment of waterbodies in the Hackensack watershed. Continued water quality sampling is needed to gauge the success of these programs.

Biological indicators of surface water quality

An important assessment to determine surface water quality is the evaluation of benthic (bottom-dwelling) macroinvertebrates in streams. Samples of macroinvertebrates are collected in kicknets from stream beds, and the variety and number of species, coupled with physical and chemical assessments of the streams, provides the parameters for calculation of the Biological Assessment Profile (BAP), a 1-10 rating scale of impairment (Nolan, 2006). A score of >7.5 is considered non-impacted and has the most variety and number of macroinvertebrates, 5.0-7.5 is slightly impacted, scores less than 5.0 are not meeting their use classification and require remediation, scores 2.5-5.0 are moderately impacted and <2.5 score means the stream is severely impacted (Smith, 2016). The probable source of pollution is determined from the pattern of the score for each parameter. (Smith, 2016, pp. 52–81)

Streams have been assessed regularly since 2006 in a partnership, originally between Hudson Basin River Watch (HBRW), Rockland County Soil and Water Conservation District (RC SWCD), and Watershed Assessment Associates, Inc., and currently through Rockland County Task Force in Water Resources Management (Nolan, 2016). Additional samples of streams in Rockland County took place in 2002 and in the Ramapo River in 1986, 1991, 1993 and 1998 (Bode, Novak, Abele, Heitzman, & Smith, 2004). In Orange County, the Ramapo and a tributary has been tested at three sites between 2005 and 2012 (Watershed Assessment Associates, 2013).

The current status of streams in the Hackensack watershed from the most recent measurements (2012-2016) shows 14 sites had moderate impacts (BAP ranging from 2.64-4.98) and the remaining six 6 sites had slight impact (BAP 5.08 to 6.31) (**Figure VI-4**). In the Ramapo watershed, one testing site has no impact (BAP 7.63), 6 had slight impact (BAP 5.19-7.39), and one was moderately impacted by pollution (BAP 4.82). The source of the pollutants comes from impoundments, nutrients from stormwater, municipal and industrial discharges, or a combination of the three (Nolan, 2012, 2013, 2014, 2015, 2016). In Orange County, the last testing in 2012 showed one site on the Ramapo and the tributary with moderate impairment (BAP 5.47 and 4.05, respectively), and one site on the Ramapo with slight impairment (5.01).

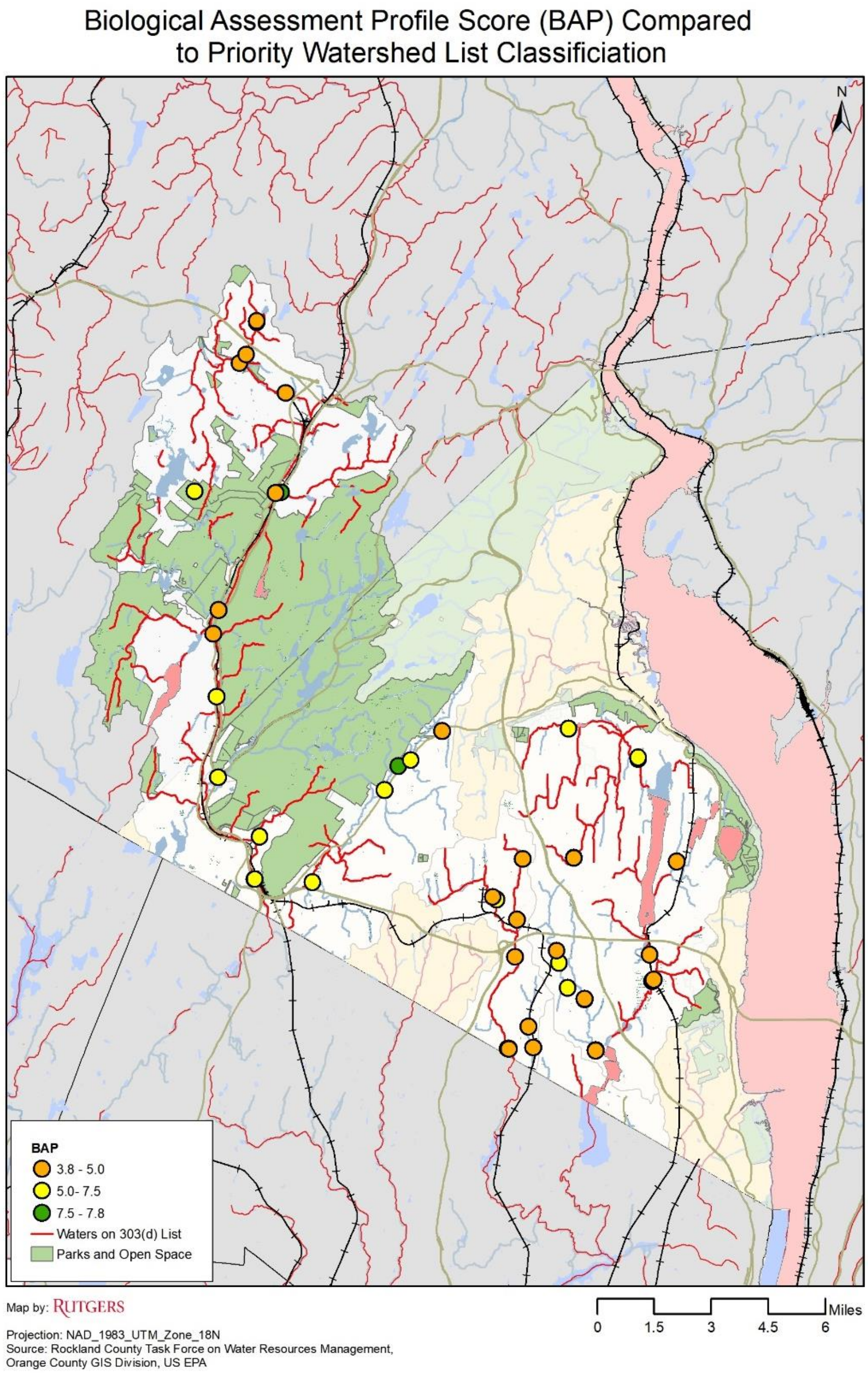


Figure VI-4: Biological Assessment Profile (BAP) compared to impaired waterbodies on the US EPA's 303(d) list.
Source: US EPA and Rockland County Task Force in Water Resources Management.

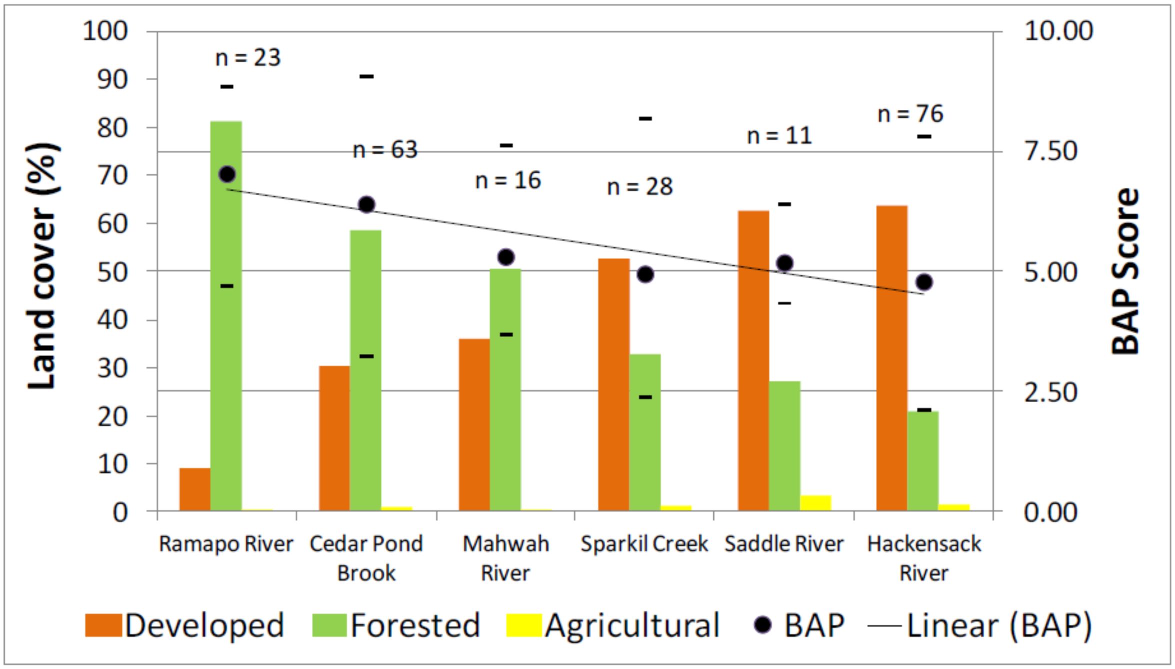


Figure VI-5: Graph comparing land use and mean BAP scores 2006-2016 within major watersheds in Rockland County from *Rockland County, New York Lotic Scene Investigation (Lsi) 2016 Stream Biomonitoring Water Quality Project.*

Source: Nolan, 2016, p. 5.

Variability

The Hackensack River Basin is becoming more polluted with increased development in the watershed, as the amount of impervious land near the waterways has a direct impact on the quality of the water. Nolan (2016) compared the percentage of land use to the average BAP scores for years 2006-2016 to illustrate the effect higher amounts of development have on streams and rivers (**Figure VI-5**). Rivers with high amount of developed, impervious land have lower water quality scores, due to increased discharges and increased amounts of stormwater runoff, which sweeps pollutants into streams and waterways and also disrupts stream beds and banks.

Amounts of precipitation can change the scores from year to year. In areas with industrial and municipal discharges, large amounts of rainfall can dilute pollutants. In areas with large amounts of impervious surfaces, increased precipitation can increase the amount of substances that wash into waterways. Major storms also can scour stream beds, disrupting macroinvertebrate communities. The amount of pollutants depends on the type and size of the rainstorm and the number of days without rain between rainfalls.

Trends

Several years of data from benthic sampling provides a snapshot of the general trends in water quality in the study area over the past 15 years. A period of sampling was completed by the NYSDEC between

1986 and 2002, while Watershed Assessment Associates completed yearly studies in Rockland County from 2006-2016 and in Orange County from 2004-2013.

Between 1986 and 1998, four macroinvertebrate studies were completed at eight points between zero and seven miles downstream from the Orange County Sewer District #1. The first two years captured the impact of the untreated wastewater from the overtaxed WWTP with water severely to moderately impacted. Following upgrades to the treatment facility, beginning in 1987 but fully implemented in 1992, the two subsequent years showed marked improvements in water quality to only slightly impacted (Bode, Novak, & Abele, 1998, p. 3, Bode et al., 2004, p. 6) (**Figure VI-6**).

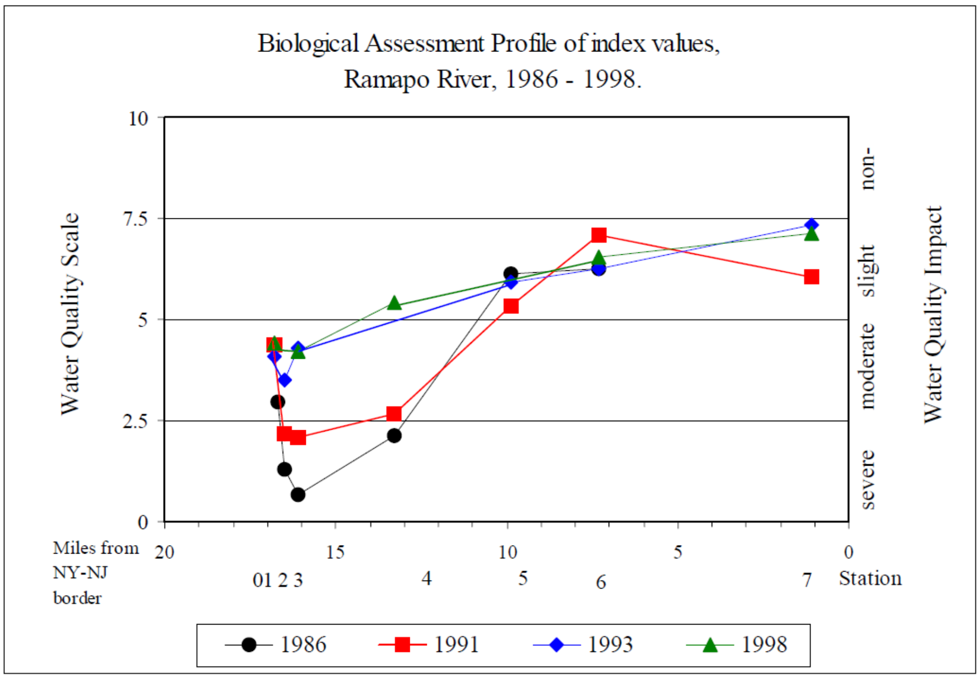


Figure VI-6: Graph comparing change in water quality over 12 years before and after improvements to Orange County Sewer District #1 (1992).

Point represent distance from OCD#1 outfall. Source: Bode et al., 2004, p. 344

Several streams were first assessed during the 2002 macroinvertebrate sampling season. The Mahwah River tested as slightly impacted, most likely due to urban and nutrient runoff (Bode et al., 2004, p. 343). The Hackensack and its tributaries, the Nauraushaun Brook, and the Pascack Brook, tested as moderately impacted during the 2002 benthic sampling season. Sources of pollution were likely municipal and industrial discharges and nutrients in stormwater runoff.

Between 2006 and 2016, water quality generally declined or remained neutral rather than improve (Nolan, 2016, p. 7) (**Figure VI-7**, **Figure VI-8**). The Ramapo in Rockland County has been rather variable over its testing history, with BAPs ranging from 7.58 in 2009 to 5.84 in 2016. There has been a general decline over the past 10 years and there is a 19 percent difference between the 2006 and 2016 score. Three other tributaries to the Ramapo in Rockland County have declined gradually over the past 10 years, while two, Torne Brook and the Mahwah have remained relatively stable. In Orange County,

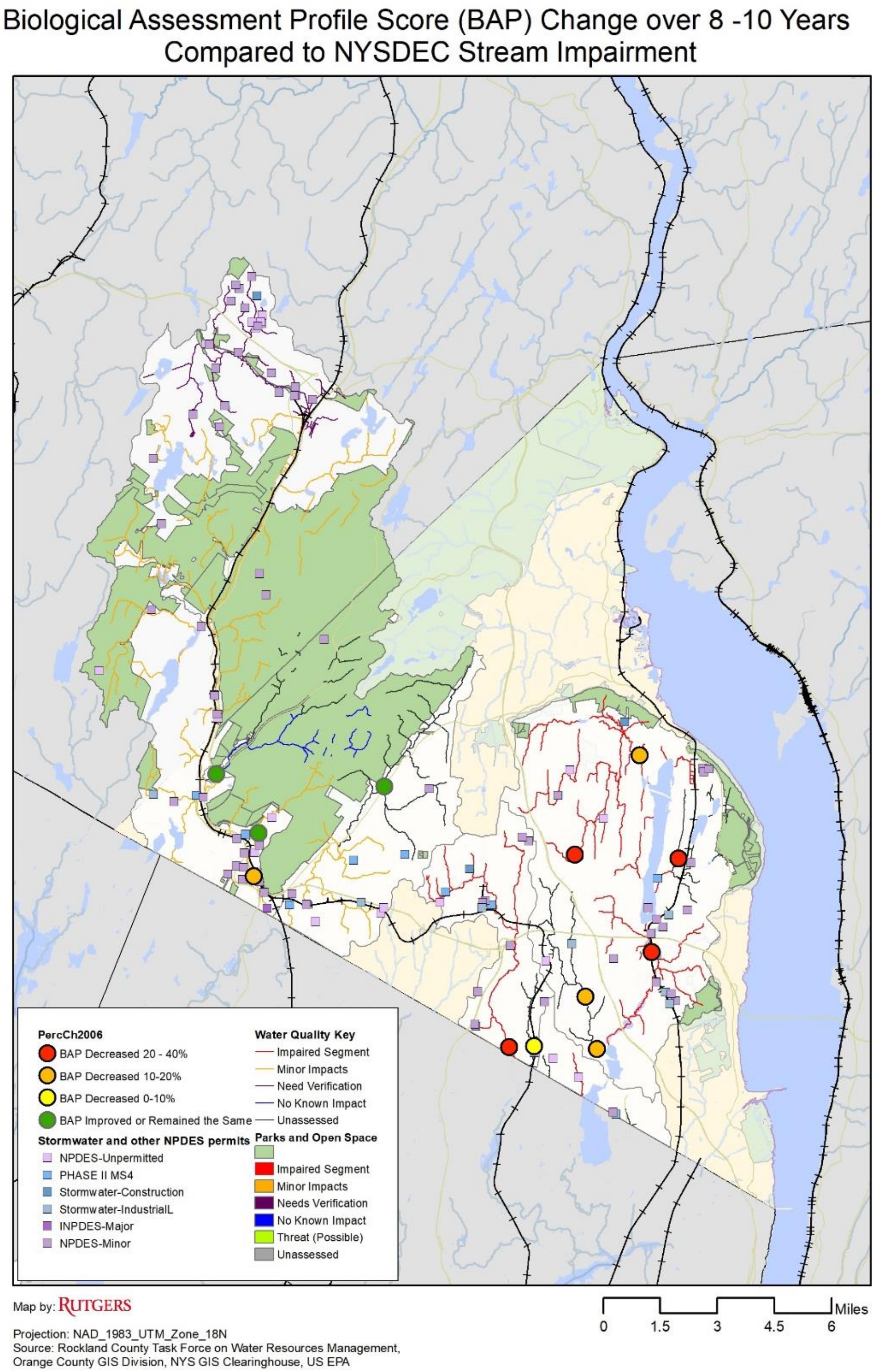


Figure VI-7: Percent BAP change from 2006 to 2016 in Rockland County and 2005-2013 in Orange County compared to NYSDEC's 303(d) list of Impaired Waters Needing TMDLs, and MS4, Industrial and Construction Stormwater permits, and other NPDES permits.

Source: US EPA, NYSDEC, Rockland County Task Force in Water Resources Management, Orange County Planning Department.

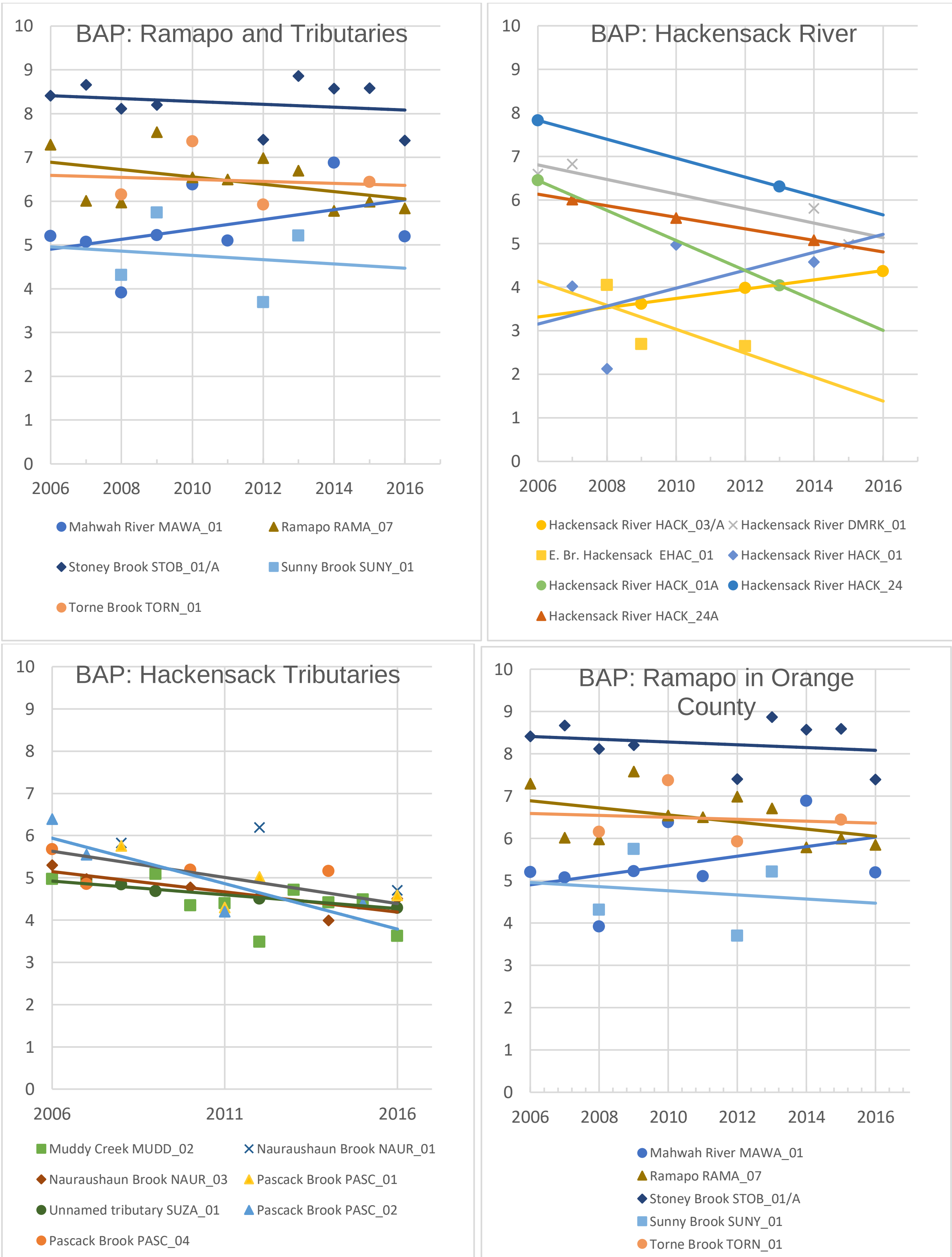


Figure VI-8: Biological Assessment Profile (BAP) Scores and trendlines, 2006-2016 for Ramapo in Rockland County, Hackensack River, Hackensack River Tributaries and 2005-2013 for Ramapo in Orange County.
Source: Rockland County, 2017

the Ramapo and its tributaries declined over the period of testing from 2005-2013. Increased precipitation during the 2013 study year may have led to increased amounts of pollutants from runoff in the Ramapo (Watershed Assessment Associates, 2013, p. 4). Sources implicated include stormwater runoff and municipal and industrial discharges.

In the Hackensack River, there has been a sharp downward trend in water quality in the past 10 years with most testing sites experiencing between 9 and 37 percent decline in water quality. Two sites reported a 10 to 20 percent improvement over the past years. Tributaries to the Hackensack have shown a more gradual decline over the study period (**Table VI-5**), with most changes ranging around 10 percent decline. One testing site, Pascack Brook 2, has a sharp decline of 30 percent.

Ground water quality

Ground water quality is important for maintaining quality drinking water. Increases in the built environment can harm ground water, limit areas for new well creation, and have led to at least 13 well closures or water quality retrofits in the county (Heisig, 2010, pp. 2, 67). Current information for ground water quality come from the NYSDEC and USGS. Data from well testing during real estate transactions in Rockland County (2005-2011) provides a map of general ground water conditions in the county (Thapa, 2016). Heisig (2010) assessed ground water quality in 2005-2006. Perlnutter (1959) compiled data from 500 wells, including water quality measures, and Leggette, Brashears and Graham studied ground water quality in several reports (1979, 1994, and 1999).

An analysis of six years of data (2005-2011) from 784 initial private well tests in Rockland County found that 32 percent of samples had positive results for coliform and 5.5 percent tested positive for *E. coli*. Tests were positive for organic chemicals in 9 percent of samples, of which 11 percent exceeded MCLs.

Sodium was elevated in 44 percent of samples, with measurements ranging from <20 mg/l to >250 mg/l, and 12 percent of samples had high iron test results, which violates secondary drinking water standards (Thapa, 2016).

Ground water quality in the Lower Hudson Basin is evaluated every five years through the NYSDEC/USGS Ambient Ground Water Monitoring Program, which assesses water in observation wells (not active drinking water wells) for Maximum Contaminant Level (MCL) exceedances using EPA and NYSDOH standards, as well as Secondary Drinking Water Standards and other pollutants that may exceed health advisory guidelines. In 2013, three wells in Rockland County were tested for ground water quality, one in the Ramapo watershed, well RO 560, and two in the Hackensack watershed, wells RO 853 and RO 513 (**Table VI-5**). Well RO 853, in the Hackensack watershed, showed high pH (10.2) and detectable levels of trichloromethane (0.1 µg/L). Well RO 560, in the Ramapo watershed, had detectable levels of trichloromethane (0.3 µg/L) and radon 222 (430 pCi/L) as well as measurable levels of dieldrin (0.003 µg/L), metolachlor (0.005 µg/L), prometon (0.003 µg/L), and simazine (0.005 µg/L). Well RO513, in the Hackensack watershed, was measured only in 2013 and had trace levels of prometon (0.003 µg/L). These levels are not as high as MCLs, but higher than the relevant National Secondary Drinking Water Standards and Health Advisories. Additional tests are scheduled for 2018 (Scott, Nystrom, & Reddy, 2015).

Well number	pH, field, in standard units[3] (00400)	Specific conductance, field, in µS/cm @ 25°C[3] (00095)	Water temperature, field, in °C[3] (00010)	Dieldrin, filtered, in µg/L[2] (39381)	Metolachlor, filtered, in µg/L[2] (39415)	Prometon, filtered, in µg/L[2] (04037)
Sand-and-gravel wells						
RO 513	7.4	542	14.0	<0.008	<0.012	**0.003**
Bedrock wells						
RO 560	6.7	607	11.9	**0.003**	**0.005**	**0.003**
RO 853	**10.2**	243	15.0	<0.008	<0.012	<0.012

Table VI-5: Ground water testing results for 3 wells in the Ramapo/Hackensack watershed area. Several trace occurrences of pesticides residue and VOCs were detected in RO 560, while RO 853 had pH that exceeded National Secondary Drinking Water Standards. Source: Scott et al., 2015

In a separate study, ground water testing in 2005-2006 found varying levels of chlorine, nitrates, sulfates and pH. These maps were created from plots of approximately 800 samples of residential wells from the Rockland County Department of Health as well as the USGS (Heisig, 2010, pp. 19, 71). The purpose was to understand the flow of ground water into and within the aquifer, but the information regarding contamination loads is a secondary benefit of this analysis. Deicing salts, used on roads in increasing amounts since the 1950s, have resulted in an increase in chlorides in ground water and a concomitant increase in water hardness. Heisig found 81 percent of ground water samples were contaminated with road salt (Heisig, 2010, p. 68). Chloride concentrations in ground water are greater than 20 mg/L today with a high of 200 mg/L in areas near roadways, particularly where alluvial deposits are relatively permeable or shallow (Heisig, 2010, p. 71) (**Figure VI-9**).

Tracking state, county, and local roads by lane mile per square mile of subwatershed reveals where high levels of road salt are likely to be used and can target areas to use more environmentally friendly products in particularly sensitive areas. Not surprisingly, the more developed Hackensack watershed has a higher density of local roads to watershed area than the Ramapo watershed **(Figure VI-10**). Pascack Brook has the highest density of all roads at 31.3 lane miles per area of watershed. All subwatersheds had generally similar densities of state and county roads. One exception was the Upper Hackensack watershed which had a slightly higher density of lane miles to area of watershed density. All watersheds in the Hackensack had local road densities of at least 10-25 lanes miles to area, while the Ramapo had lane densities of 0.5 to 10 miles per square mile.

Measures of specific conductance in ground water are also an indication of road salt leachate, and tend to occur in areas with many roads or near the NY State Thruway. Most of the Hackensack and Ramapo watershed in Rockland County had specific conductance levels ranging from 300 to over 1000 µS/m. (Heisig, 2010, pp. 70, 89)

Nitrates are also present in ground water to varying degrees, probably stemming from fertilizer runoff from residences, golf courses and other large grass expanses. Levels of nitrates were higher in historic samples from the 50s, when the county had more land in agriculture. Areas with high concentrations of septic systems may have an increase in nitrates as well, but much of the developed area in Rockland County is served by public sewers (Heisig, 2010, p. 76) (**Figure VI-11**). Sulfates in water can violate secondary drinking water standards and create discolored water and cause laxative effects as well as

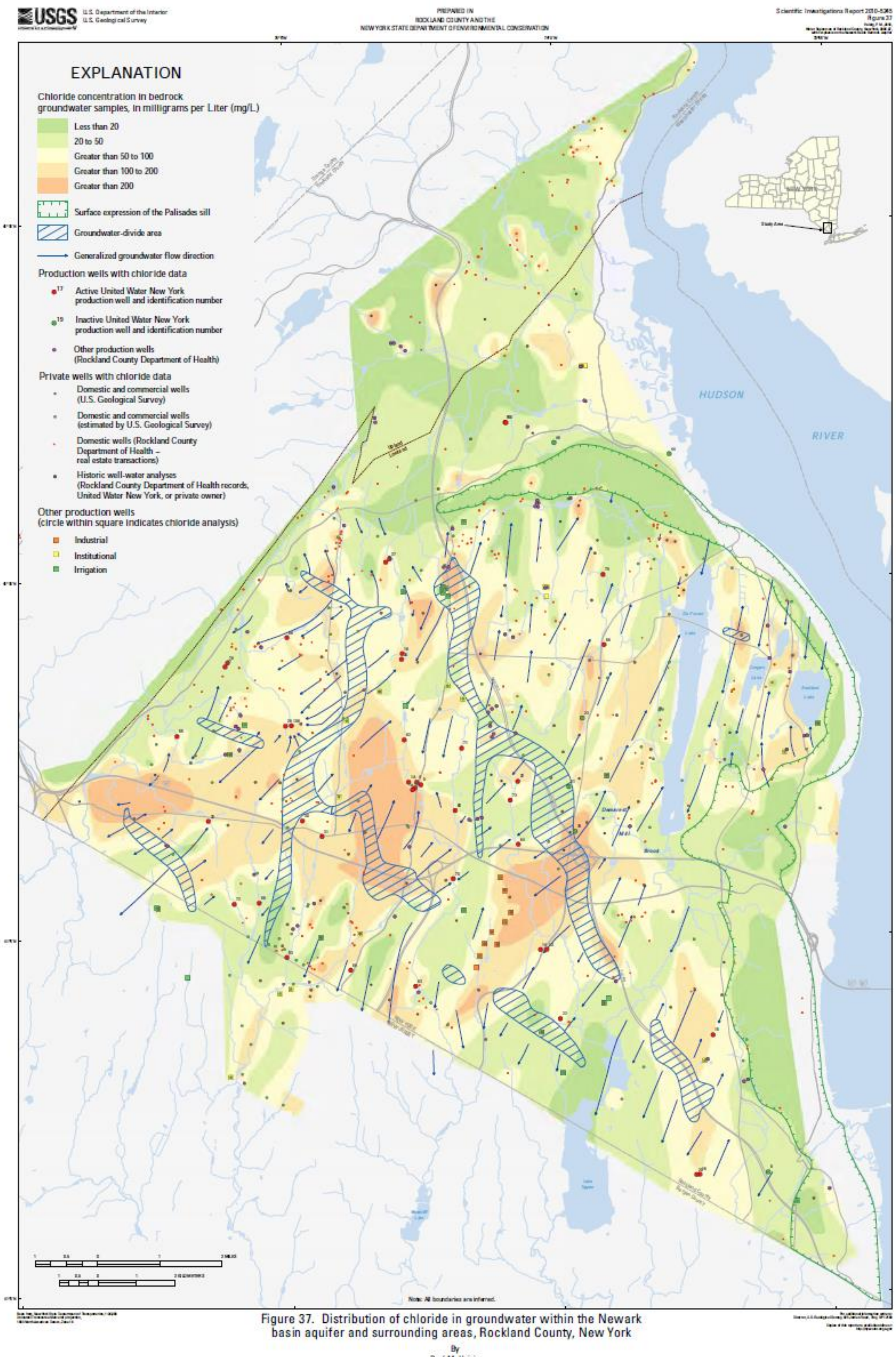


Figure VI-9: Chloride distribution in ground water within the Ramapo and Hackensack watersheds in Rockland County, NY.

Source: Heisig, 2010, p. 74

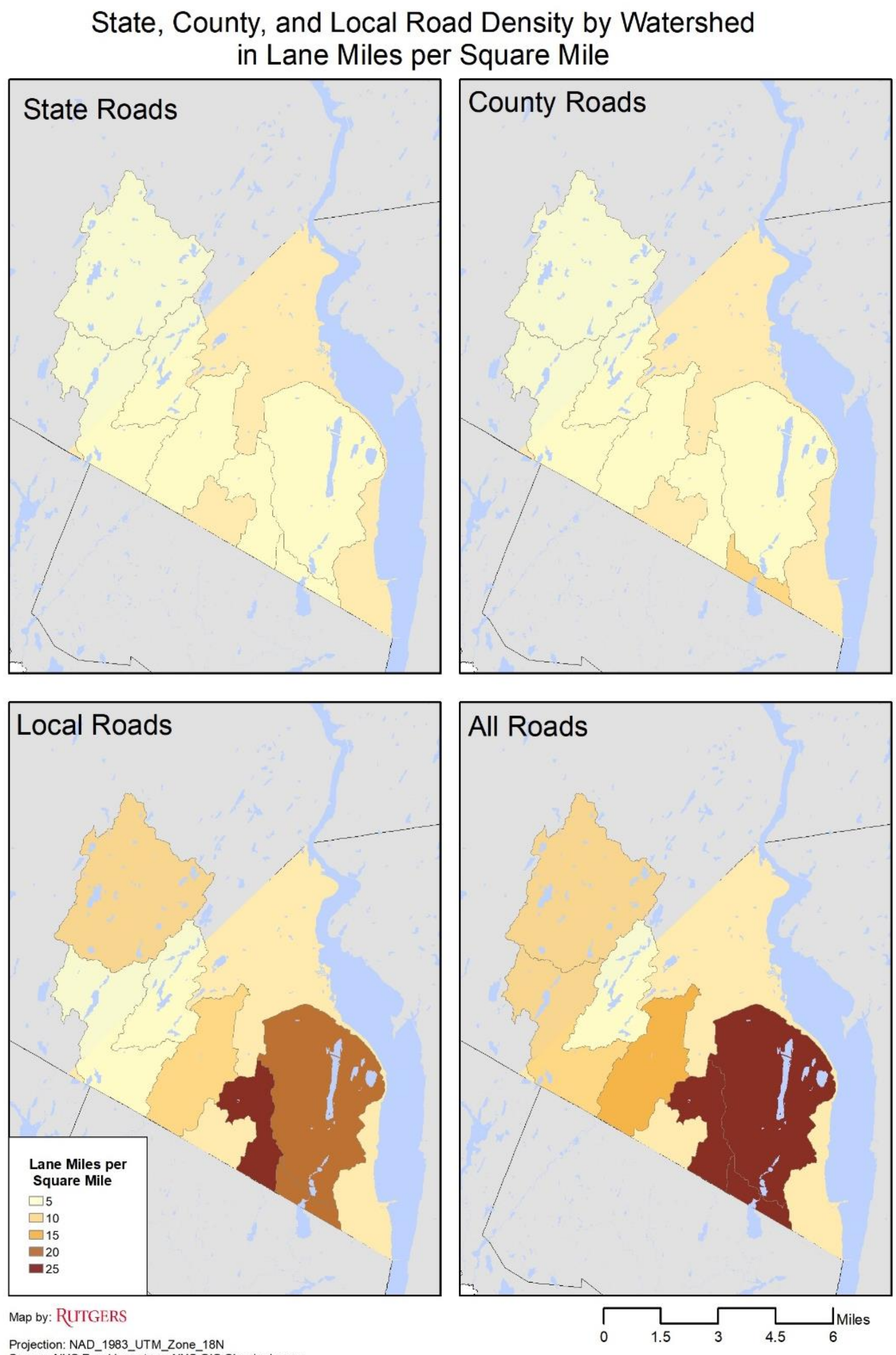


Figure VI-10 Road lane miles per subwatershed area.
Source: NYS GIS Clearinghouse

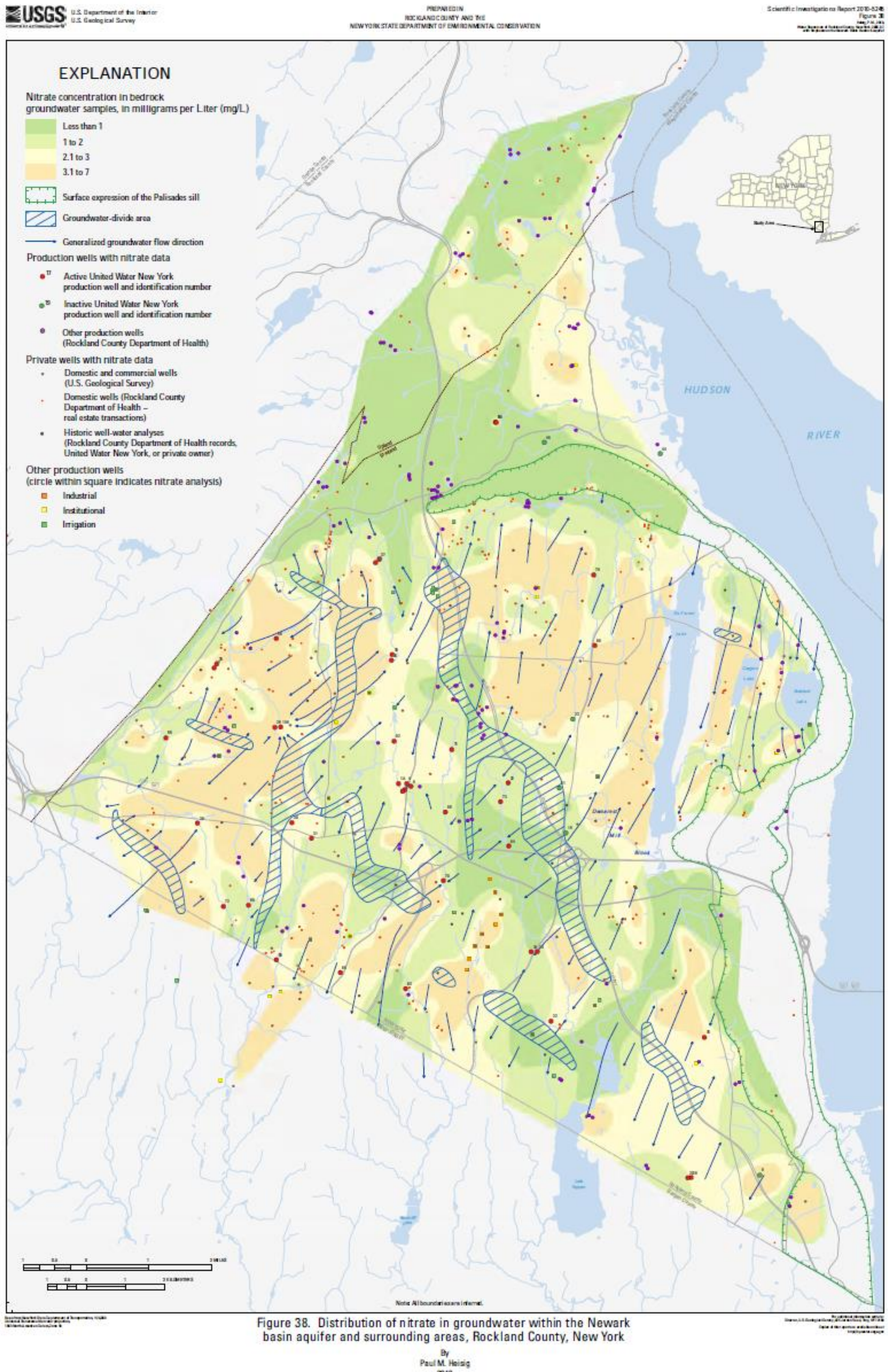


Figure VI-11: Nitrate distribution in ground water within the Ramapo and Hackensack watershed in Rockland County, NY.

Source: Heisig, 2010, p. 75.

encourage mold in water. The northeast corner of the aquifer has some naturally occurring sulfates weathered from gypsum in the aquifer or appear in runoff from fertilized lawns (Heisig, 2010, p. 78) (**Figure VI-12**).

Variability

In the Newark Basin, ground water quality in the study area is dependent on the thickness of the soils overlaying the ground water, the amount of development and impervious surfaces in the area, the nature of the geology, and the amount of recharge. Thin soils permit increased recharge to aquifers, but also tend to be more susceptible to surface contamination leaching into ground water as demonstrated in elevated levels of chloride, nitrate and sulfate above. Precipitation washes contaminants off large amounts of impervious surfaces into recharge areas and streams (Heisig, 2010, p. 94). Ground water in the Ramapo watershed is also threatened by potential contamination from human activity above ground, such as salt and fertilizer runoff and industrial inputs (Heisig, 2014, p. 12)

During drought, the decrease in the amount of streamflow and subsequent increase in amount of wastewater discharged Ramapo from the Orange County Sewer District can affect ground water quality in well fields in the watershed. Water flows from the streams to the ground water during low flow periods, which is then pumped to the water supply in the adjacent aquifers (Kecskes, 2015).

Trends

Ground water quality is subject to human activity aboveground, though current ground water quality information is not particularly robust and needs more data to make accurate comparisons of trends. Past measurements at NYSDEC test wells show varying levels of substances within the ground water. Two wells were tested in Rockland County in 2008 (**Table VI-6)**. Ground water in these heavily developed sections of the county are sensitive to runoff from utility and residential use of herbicides and pesticides. Source: Scott et al., 2015.). Well RO 853, in the Hackensack watershed, had elevated levels of sodium (74.4 mg/L) and pH (8.8) that exceeded NSDWS standards, as well as detectable levels of toluene (0.1 µg/L) and trichloromethane (1.0 µg/L). Tests 5 years later showed reduced levels of sodium and toluene, but higher pH (10.2) and detectable levels of VOCs and pesticide residues. Well RO 560, in the Ramapo watershed, had detectable levels of MTBE (0.2), tetrachorethene (0.2 µg/L), trichloromethane (0.2 µg/L) and radon 222 (370 pCi/L). In 2013, this well also had measurable levels of VOCs, pesticide residues and radon, Again, these amounts are not higher than MCLs, but are more than National Secondary Drinking Water Standards and Health Advisories recommend. Continuing assessments of current data from well testing following real estate transactions could clarify ground water quality trends in the study area.

Relationship of water quality to watershed modification and legacy pollutant sources

Past land uses can have a lasting effect on water quality. As mentioned above, ground water nitrate levels were elevated in the 1950s by agricultural practices in areas that are now developed. The reduction in nitrate levels since then is an indication that ground water cycles through the aquifer relatively quickly. Municipal and industrial discharges prior to current regulations, illegal dumping and

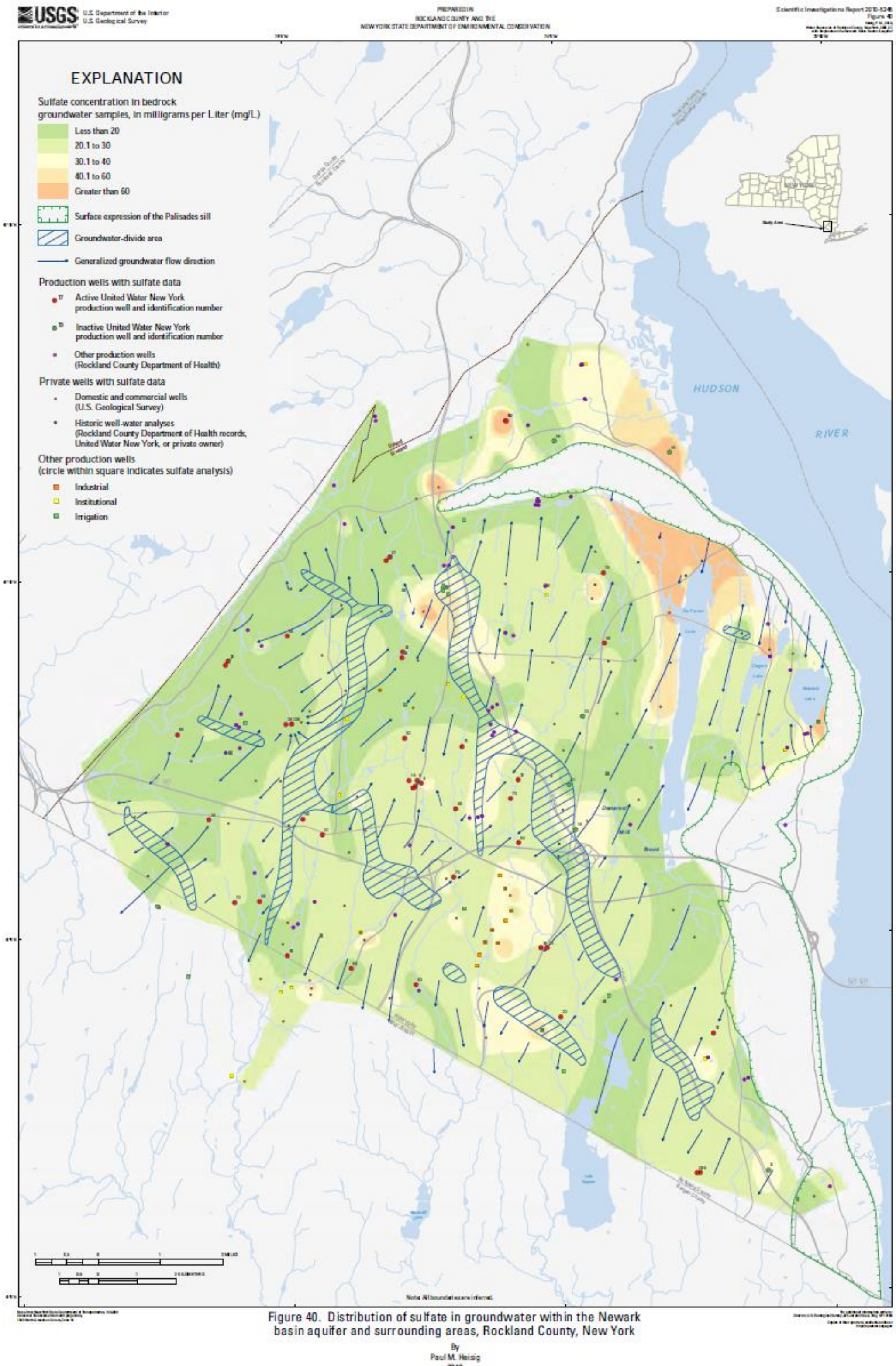


Figure VI-12: Sulfate distribution in the Ramapo and Hackensack watersheds in Rockland County, NY.
Source: Heisig, 2010, p. 79

Well number[1]	Sample date	pH, field, in standard units[3] (00400)	Sodium, filtered, in mg/L[3] (00930)	Dieldrin, filtered, in µg/L (39381)	Metolachlor filtered, in µg/L (39415)	Simazine, filtered, in µg/L (04035)	Methyl *tert*-butyl ether, filtered, in µg/L (78032)	Tetra-chloro-ethene, filtered, in µg/L (34475)	Toluene, filtered, in µg/L (34010)	Trichloro-methane, filtered, in µg/L (32106)	Radon-222, unfiltered, in pCi/L[7] (82303)
RO 560	9/3/2008	6.5	26.3	<0.009	<0.010	E0.005	**0.2**	**0.2**	<0.1	**0.2**	**370**
RO 560	8/1/2013	6.7	28.4	**0.003**	**0.005**	**0.005**	<0.2	**0.1**	<0.1	**0.3**	**430**
RO 853	9/3/2008	**8.8**	**74.4**	<0.009	<0.010	<0.006	<0.2	<0.1	**0.1**	**1.0**	110
RO 853	7/24/2013	**10.2**	50.7	<0.008	<0.012	<0.006	<0.2	<0.1	<0.1	**0.1**	**390**

Table VI-6: Comparison of ground water testing from 2008 to 2013.
Ground water in these heavily developed sections of the county are sensitive to runoff from utility and residential use of herbicides and pesticides. Source: Scott et al., 2015.

accidental spills have degraded the quality of well water and waterways in Rockland County. Of 39 remedial sites listed by the NYSDEC in the study area, 18 have contaminated ground water and surface water. Of those, 14 are active or monitored sites (Table VI-7). Bram Manufacturing, Chromalloy, Clarkstown Landfill site, and the Grant Hardware in Rockland County, and Nepera in Orange County are currently active, pose a threat to human health and have contaminated ground water. The Clarkstown Landfill does reduce the quality of water in the Hackensack, but is several miles upstream from a potable water intake; the Chromalloy site may affect the Hackensack through contaminated ground water, but this has not yet been detected. Three sites, COSCO, Xerox Corporation, and Hudson Technologies, require ground water to be extracted and treated, and the leachate from the Ramapo Town Landfill is treated at the Suffern WWTP. COSCO's waste disposal practices contaminated well water in the Spring Valley Well Field. Suffern Valley Well Field had also been contaminated by an industry located across the Ramapo River, but this contamination has since been remedied. The Ramapo Paint Sludge Site, which involved illegal disposal of paint from the Ford Motor Company at several sites in Ramapo, including the North of Ramapo Well Field and within the 100-year floodplain of Torne Brook, has not affected the ground water or the river's water quality. Contaminants in the ground water and the brook are not consistent with those from the contaminated ground, and are likely from another source or are naturally occurring (NYS Department of Environmental Conservation, 2014). Current regulations limit direct injection of wastes into the ground and the dumping of hazardous waste, though spills do occur and wastewater continues to be discharged to receiving waterbodies. When accidents occur or waterways become more impaired due to wastewater discharges, state and federal regulators employ tools to bring polluters into compliance.

Current regulatory drivers for water quality maintenance and improvement

Regulations by the NYSDEC and overseen by the EPA attempt to limit the amount and toxicity of contaminants discharged to waterways. NPDES and SPDES permits allow tracking of contaminant releases, and attempt to limit the amount of contaminant released with effluent guidelines and technology-based treatment of wastewater. When standard guidelines and treatment doesn't improve water quality or waterways become impaired in spite of these efforts, other measures are taken to bring streams and river into compliance. Water Quality-Based Effluent Limits (WQBELs) and TMDLs are developed to decrease the amount of specific pollutants discharged to waterways. TMDLs limit the amount of a contaminant that can be released in the waterway, which is shared by all dischargers.

WQBELs limit the amount of a contaminant a polluting entity can release. For stormwater runoff which contributes to pollution in waterways, NYSDEC issues MS4 permits to industries, construction sites that disturbs more than one acre of land, and municipal separate storm sewer systems that are within urbanized areas with population densities of more than 1000 people per square mile. An urbanized area is a continuously developed area with a population of 50,000 or more.

Permits are required to discharge to, alter, or extract from streams, wetlands, waterbodies, and ground water. Under some conditions, local governments can oversee regulations of freshwater wetlands.

The NYSDEC Division of Remediation working in concert with the NYSDOH oversees releases of contaminants that may affect drinking water supplies. The NYSDOH makes decisions regarding the contaminant's risk to public health, while the DER is responsible for investigating and analyzing pollutants in the water supply. If water is contaminated, an alternative water supply is provided by the responsible party or, if unavailable, through state and federal funds. The alternative water supply is discontinued when ground water is not affected by the contamination, nor will be in the future; or when contaminant concentrations are not more than 50 percent of the NYS MCL for one year, do not affect the taste or odor of the water, and no longer pose a health risk (Washington, 2008).

Available and proposed models

Understanding the movement of contamination in water helps to remediate accidental spills. The Yager and Ratcliffe model (2010) of the Newark Basin models ground water flow and, hence, potential plumes of contamination in underground aquifers. No other models exist to assess or determine ground or surface water pollution.

EPA Site Code	Site Name	Site Class	Locality	County	Problem	Management	Currently Affected
344055	Bram Manufacturing	2	Congers	Rockland	Dumping of VOCs	Chemical and Bioremediation of Ground water	Ground water is affected, but not used
344039	Chromalloy (SEQUA)	2	West Nyack	Rockland	Spill of TCE	Remediated and Monitoring	Ground water affected-wells offline. May flow to Hackensack, but not detected.
344001	Clarkstown Town Landfill	2	Central Nyack	Rockland	Landfill	Control leachate. Monitor	Ground water. River impacted, but not near potable water intake.
344031	Grant Hardware	2	West Nyack	Rockland	2 spills of VOCs	Bioremediate and Monitor Ground water	Ground water.
344042	Cornell Manufacturing Co. Inc.	4	Orangeburg	Rockland	Potential Spill	Remediated Ground water,	--
344035	COSCO	4	Spring Valley	Rockland	Disposal of waste in ground	Ground water extracted and treated.	Ground water is affected, but not used.
344014	Orange & Rockland Utilities	4	West Nyack	Rockland	Spills, potential for spills	Remediated and Monitoring	Ground water is affected, but not used
344004	Ramapo Town Landfill	4	Ramapo	Rockland	Landfill within100 feet of water supply wells.	Monitor ground water, Treat leachate at Suffern WWTP	Ground water, but not affecting nearby wells.
344021	Xerox Corporation	4	Orangetown	Rockland	Spills from USTs	Ground water extracted and treated. Monitoring	Ground water is affected and treated
344051	Hudson Technologies	A	Hillburn	Rockland	Spills	Ground water extracted and treated.	Ground water, near Ramapo but not affected
344045	O&R - Suffern MGP	A	Suffern	Rockland	Dumping, also affects NJ	Excavate soil, cap and monitor.	Ground water is affected, but not used
344064	Ramapo Paint Sludge Site	A	Ramapo	Rockland	Dumping	Excavate affected soil, cap,	Soil only
344018	Spring Valley Well Field	N	Ramapo (Spring Valley)	Rockland	Chemicals detected in production wells, (COSCO, garage)	Aeration of ground water to reduce contaminants	Ground water
336006	Nepera Inc. - Harriman	2	Harriman	Orange	Dumping adjacent to Ramapo, NPDES, SPDES	Bioremediation of ground water. Ongoing	Ground water, Soil

Table VI-7: Sites in the State Superfund Program that are currently active or have affected ground water. Source: NYSDEC Remedial Sites, EPA Region 3.

Site Class Key:

On Registry (Poses a threat to human health): 2—Disposal has been confirmed; 4—Site has been properly closed, but is being monitored.

Non-Registry (Investigated or remediated in brownfield program): A—Active; N—No further action.

VII. Ecological Resources

Water is essential not only for human potable water uses, but also to maintain our ecosystem. One of the uses mandated by the EPA and NYSDEC is to maintain waters for fish and shellfish habitat and breeding. Preserving fish habitat also ensures a quality biome for all types of species. The Ramapo watershed has a rich ecological legacy with nearly 69 percent of land preserved as natural land, while the Hackensack has high levels of development with only 10 percent of land preserved in its natural state (Figure VII-1). Communities in both watersheds have placed value on preserved land, yet continue to threaten riverine and riparian ecosystems.

Riverine and riparian ecological resources of concern

Rivers and streams are important for all types of animals, including non-aquatic species, who need access to waterbodies for drinking water. Land cover has a strong influence on water quality, access to water and biodiversity. Riparian areas—land adjacent to waterbodies where surface and underground water influences the community of plants and animal found on the land—help provide storage of floodwaters, reduce water velocity, trap and filter pollutants, cycle nutrients, and provide habitat for a vast array of animals and plants (Johnson, Bentrup, & Rol, 1999). Streams originating from large interconnected blocks of forest have higher water quality than those from urban or agricultural land uses (US Geological Survey, 2002). Protection of land helps to preserve valuable ecological resources.

Both Rockland and Orange County have established trusts to acquire land for preservation. New York State recognizes sensitive ecological areas for which protection is needed through the Natural Heritage Program and the Critical Environmental Area (CEA) Program. The Natural Heritage Areas Program is managed in partnership with the NYSDEC and SUNY College of Environmental Science and Forestry, and focuses on conservation of rare animals, plants and ecosystems. Entry into the NHA program is initiated by an agency responsible for the property who alerts the NYSDEC to the presence of rare animals or plants or unique biomes, which is then subject to review. NHA designation does not protect an area from development, but does add a level of review to the permitting process. While protected communities are specific about location, the protected plants and animal listings are generalized to prevent disruption of that community, including by illegal collectors of endangered species. Endangered, rare and threatened species that are dependent on particular water conditions and that have been seen in the Ramapo and Hackensack watersheds are listed in **Table VII-1**.

The Ramapo watershed has numerous areas that are in the Natural Heritage Areas Program (2013 data) (**Figure VII-2**), including Harriman State Park and Sterling Forest State Park which cover almost 66,000 acres of the Ramapo watershed. Harriman State Park, established in 1900, and Sterling Forest, bought by NYS and NJ in 1998 in an effort to protect development in sensitive watersheds (Berger, 1998), has numerous protected species and biota. The large intact chestnut-oak forest and rocky summit grasslands are important ecosystem communities. This designation excludes many of the tributaries to the Ramapo, curiously. A large area along the border between Orange and Rockland County (almost 58,000 acres) is protected for endangered animals, but excludes the Ramapo River. Both Rockland and

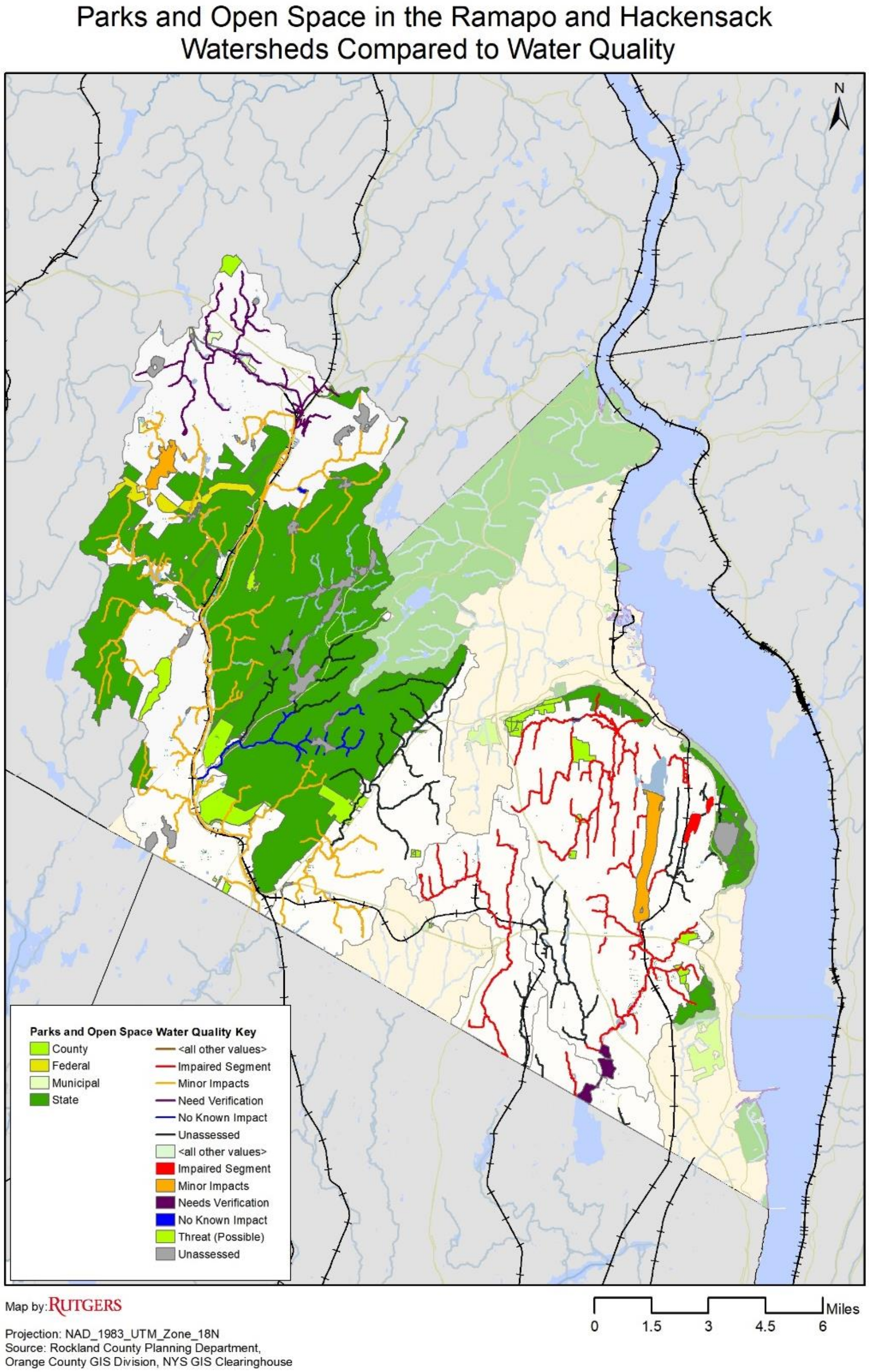


Figure VII-1: The amount of preserved forest and open space in the Ramapo and Hackensack watersheds have a direct impact on the quality of water.

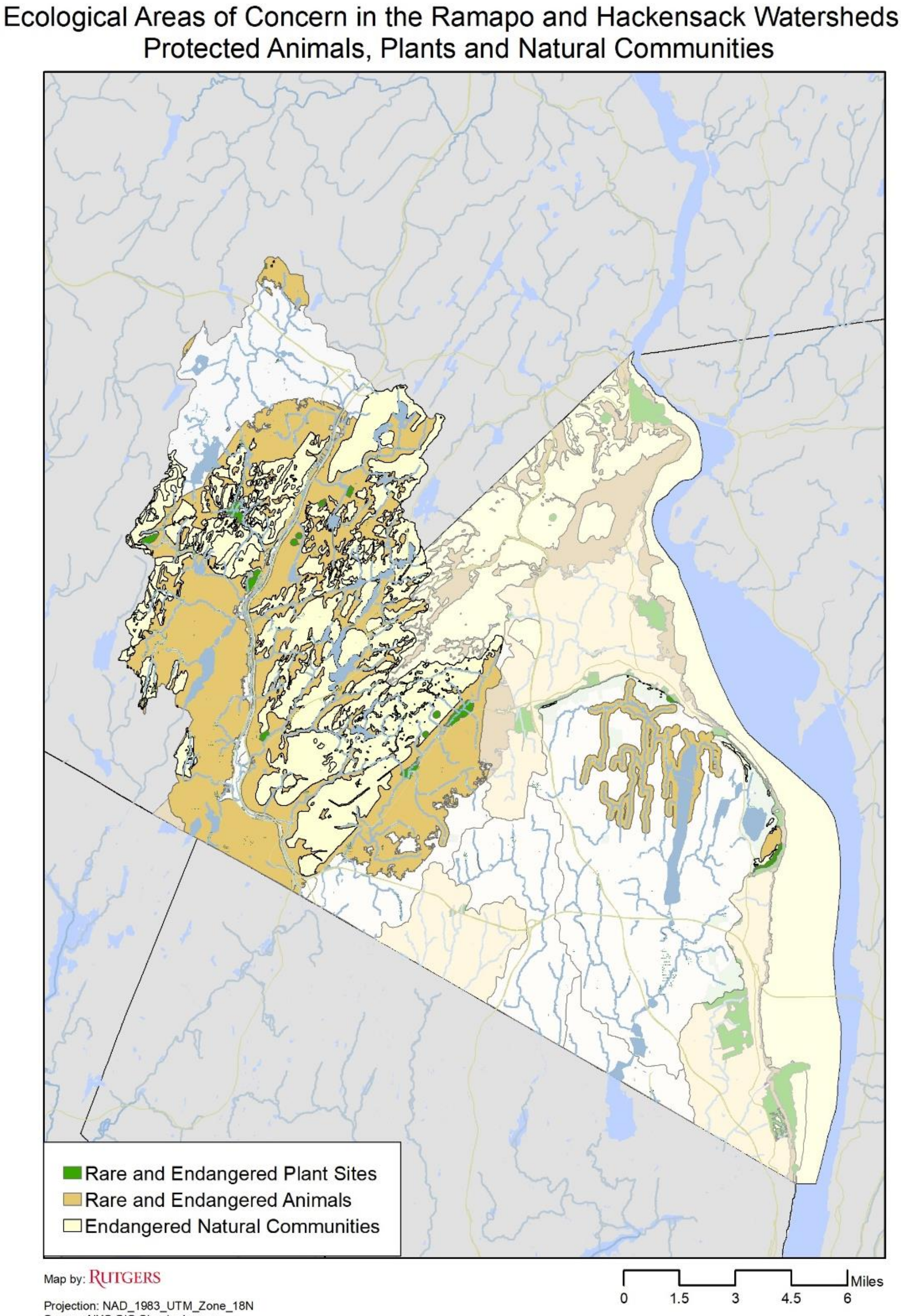


Figure VII-2: **Natural Heritage Areas which protect land with unique communities, endangered animals or plants**. Source: NYS GIS Clearinghouse, 2013 data.

Animal	Scientific Name	Common Name	Protection Status	Federal	Found in
Amphibian	*Acris crepitans*	Northern Cricket Frog	E	--	Bogs
Bird	Ardea alba	Great Egret	P	MBTA	Marsh & Lakes
Bird	*Ardea herodias*	Great Blue Heron	P	MBTA	Marsh & Lakes
Bird	*Geothlypis formosa*	Kentucky Warbler	P	MBTA	Streams
Bird	*Haliaeetus leucocephalus*	Bald Eagle	T	MBTA	Lakes
Bird	*Melanerpes erythrocephalus*	Red-Headed Woodpecker	SOC	MBTA	Swamps
Bird	*Podilymbus podiceps*	Pied-billed Grebe	T	MBTA	Marsh
Bird	*Vermivora chrysoptera*	Golden-winged Warbler	SOC	MBTA	Ramapo swamps
Fish	*Enneacanthus obesus*	Banded Sunfish	T	--	Upper Ramapo
Insect	*Tachopteryx thoreyi*	Gray Petaltail	SOC	--	Springs
Mammal	*Myotis lucifugus*	Little Brown Bat	Not listed	--	Lakes
Mammal	*Myotis septentrionalis*	Northern Long-eared Bat	T	T	Streams
Mollusc	*Alasmidonta varicosa*	Brook Floater	T	--	Streams-E
Reptile	*Glyptemys muhlenbergii*	Bog Turtle	E	T	Wet Meadows
Plant	*Bidens bidentoides*	Delmarva Beggar-ticks	R	--	Marsh
Plant	*Carex lupuliformis*	False Hop Sedge	T	--	Marsh
Plant	*Cuscuta cephalanthi*	Button-bush Dodder	E	--	Marsh
Plant	*Eleocharis ovata*	Ovate Spikerush	E	--	Marsh
Plant	*Euonymus americanus* L.	American Strawberry-Bush	E	--	Swamps
Plant	*Hottonia inflata*	Featherfoil	T	--	Ponds
Plant	*Juncus subcaudatus*	Woodland Rush	E	--	Marsh & Stream
Plant	*Liparis liliifolia*	Large Twayblade	E	--	Marsh
Plant	*Pedicularis lanceolata*	Swamp Lousewort	T	--	Ponds and Fens
Plant	*Potamogeton pulcher*	Spotted Pondweed	T	--	Ponds in Highlands

Table VII-1: Protected species reliant on water for habitat or food in Ramapo and Hackensack watersheds in New York.
Source: http://www.dec.ny.gov/natureexplorer/app/location/watershed/results.8
Key: E-Endangered; R-Rare; SOC-Species of Concern; T-Threatened.
MBTA-Migratory Bird Treaty Act. E-Extirpated from area. O-Orange County only.

Orange Counties have acquired or conserved land adjacent to these large forest blocks in an attempt to protect water resources. Additionally, Rockland County Open Space Acquisitions Program has purchased 350 acres of wetlands and floodplains to protect local water resources (**Figure VII-3**).

The Hackensack watershed has two Natural Heritage Areas. The first, protected for its endangered animals, includes almost 4,000 acres of riparian buffer along most (about 16 miles) of the West Branch of the Hackensack, including Lake Lucille and the northern shore of Lake DeForest. A 175-acre section of mature oak-tulip tree forest on Hook Mountain near Rockland Lake is classified as a Natural Heritage Area for endangered plants, animals and communities. Thirty-two acres of South Mountain Reservation and High Tor State Park are designated for their rocky summit grasslands. Critical Environmental Areas are spaces that are designated by local or state agencies as benefits or threats to human health and may include areas with ecological, social, historic, archeological, recreational or educational value that may

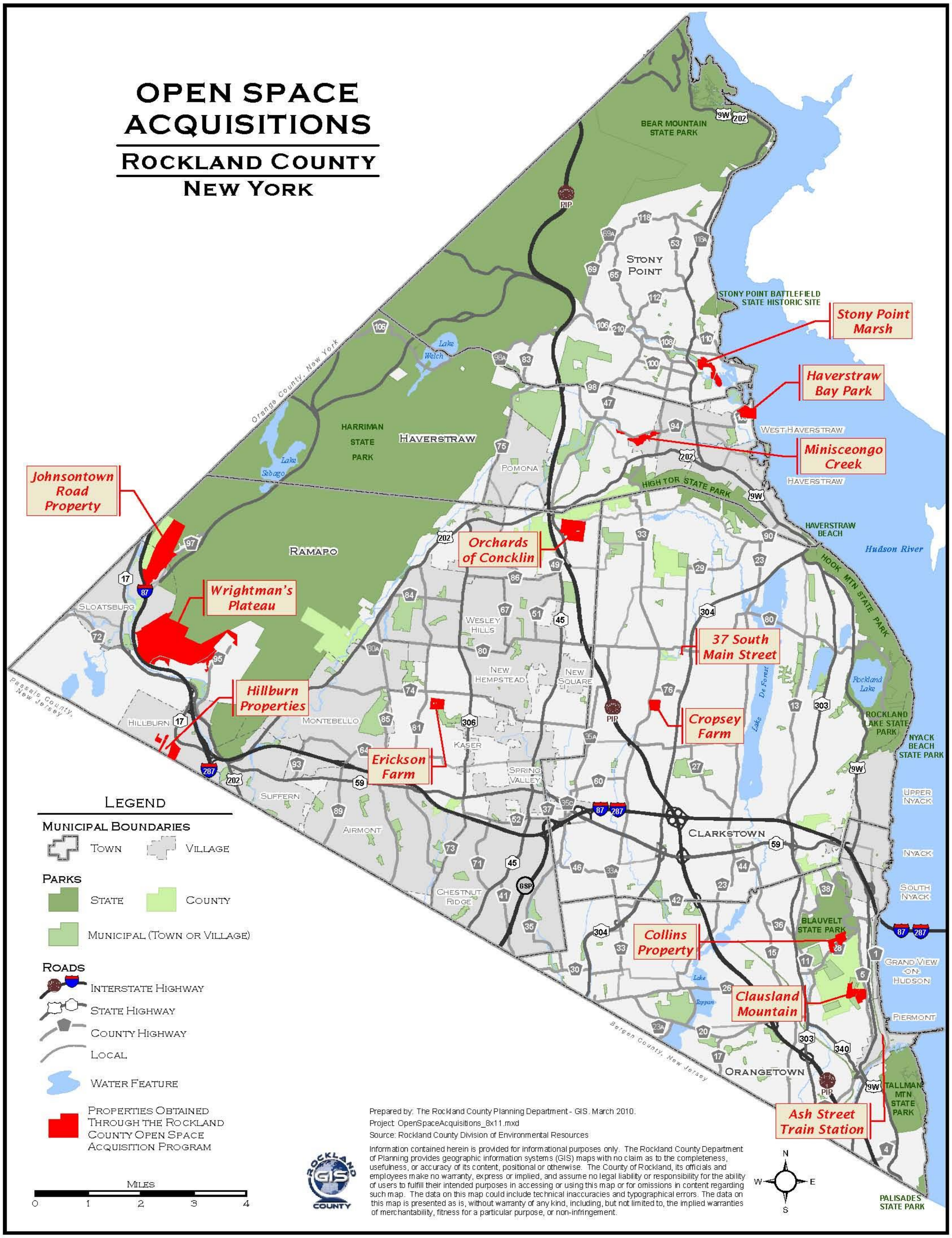


Figure VII-3: Open Space Acquisitions, 2010.
Source: Rockland County Planning Department

be harmed by disturbance. Locations that are considered Critical Environmental Areas are subject to more intense scrutiny during permitting of non-residential projects, zoning changes greater than 25 acres or changes in laws affecting the environment, and may involve the completion of an Environmental Impact Statement (EIS) (NYSDEC, 2017). Local organizations use CEA designations to protect and ensure consideration of sensitive ecological areas. Classifying an area as a CEA is not meant to substitute for strong government protection like zoning controls, restrictive easements, or acquisition and management of the property.

There are no areas in the Hackensack or Ramapo watersheds that are CEAs, though Clarkstown is considering use of CEA for the entire Hackensack River, as well as major wetlands and the island at the south end of Lake DeForest (Town of Clarkstown, 2009, p. 33). Stronger protection of the wetland areas around the upper Hackensack and its tributaries has been recommended by the Fish and Wildlife Service in 2007 (Tiner & Bergquist, 2007). Further delineation and protection of riparian zones will improve habitat and water quality in the watershed.

Both watersheds are sensitive to the pressures of urbanization in the region. Intense development in the headwaters of the Ramapo has degraded water quality, and WWTP discharges have been implicated in decreasing macroinvertebrate populations (Bode et al., 2004; Orange County Water Authority, 2013), which are indicator species for fish habitat. The NYS Thruway and a heavily used commuter railroad are generally within a quarter mile and, necessarily, upland of the river from the NJ border until Harriman in Orange County. In the Ramapo Valley, chlorine from road salt used for deicing has increased the salinity of the of surface and ground water (Heisig, 2010). Increased salinity stresses and kills sensitive plant and animal species (Hintz et al., 2017). Pressures to build and develop unused areas of land continue to threaten rivers and riparian areas. Ramapo was fined for a violation of the Clean Water Act for filling wetland areas during construction of a baseball stadium (Incala, 2014).

The Hackensack River is surrounded by intense development with little protection of the river, its tributaries or riparian areas. Areas that are protected by easements are under threat by illegal development, for example, the western edge of Lake DeForest (Town of Clarkstown, 2009). Development pressures continue to impinge on riparian areas

Almost all towns in Rockland County have a provision for controlling the alteration of natural flood plains, stream channels, and natural protective barriers which are involved in the protection of flood waters under the umbrella of 'Flood Damage prevention'. The Town of Haverstraw has defined a minimum of fifteen-foot buffer that is to be maintained adjacent to any one year floodplain. The ordinance of the Village of Suffern has a provision for a 'Critical Environmental Area Overlay District' that provides additional measure to protect areas which are generally recognized for vegetative features or ecological communities, including natural vegetation along lakes, rivers, floodplains, wetlands and streams. New York State DEC has a general website with guidance material on riparian buffers (http://www.dec.ny.gov/chemical/106345.html). Similarly, Tompkins County in New York has a model stream buffer ordinance.

Outside of Rockland County, New Jersey in 2008 released a Riparian Zone Model Ordinance (www.nj.gov/dep/wqmp/docs/riparian_model_ordinance.pdf) that would be relevant to Rockland and Orange Counties due to the similarities in geography and hydrology. Likewise, riparian area provisions of the Highlands Regional Master Plan in New Jersey would be relevant, as mentioned in the Model Land Use Ordinance for Planning Area Municipalities (sections 4.3.3 and 6.2 at http://www.highlands.state.nj.us/njhighlands/planconformance/model_docs/Model_LUO_Planning_Area_July2016.doc). The Township of Bernard in Somerset County, New Jersey has a 'Stream Buffer conservation' ordinance under its 'Critical Area Regulations'. It mentions a Stream Buffer Management plan which prohibits construction, development, use, activity, encroachment or structure within the stream buffer. Stream buffers are delineated to intercept surface water runoff, wastewater, subsurface flow and/or groundwater flows from upland sources to buffer the effects of associated nutrients, sediment organic matter, pesticides or other pollutants before entry to the stream. The stream buffer is divided into two zones, Zone 1 and Zone 2, the former being adjacent to the edge of the stream with a minimum width of 25 feet and the latter emerging at the outer edge of Zone 1 spanning a minimum width of 50 feet. There is restriction placed on the type of vegetation that is permitted in the stream buffer. The vegetation that consists of a variety of native trees, shrubs and tall grasses is to provide stream bank stabilization in Zone 1 whereas native trees and shrubs are to provide soil stabilization in Zone 2.

According to the Zoning law of the Town of Ancram, New York, a stream buffer is to be delineated which covers 100 feet of area extending along both sides of a watercourse measured from the edge of the waterway and any adjacent wetlands, floodplains in order to protect the water quality and ecological health of streams. The zoning ordinance for the Village of Trumansburg, New York requires a riparian buffer for all perennial streams that is to maintain native vegetation in a natural state.

High levels of species biodiversity and quality of habitat are measures of ecosystem robustness, which, in aquatic ecosystems, correlates to high levels of water quality. Unpolluted water supports many types of aquatic and riparian plants and animals, including amphibians, fish, crustaceans, shellfish, and other species. Riverine and riparian ecosystems function to their greatest potential when stream flow is unmodified and land use is less developed.

Potential impacts of flow modifications

Streams and riparian areas are formed by a complex interaction of water, earth, plants and animals. Changes to one or more of these variables ultimately affects the entire system. Both the Hackensack River and to a lesser degree, the Ramapo River are subject to flow regulations intended to provide a specific amount of water downstream to New Jersey. Stream flow regulation is generally achieved by releasing water from dammed reservoirs when rainfall does not provide enough water to maintain a passing flow. Similar results can be achieved by reducing ground water withdrawals where the wells have an immediate effect on stream flows. Arresting natural flow in a waterway disrupts many hydrological processes: Impoundments cause sediment deposition behind dams, reducing habitat for a wide variety of animals and plants in locations that are formed from transported soil particles such as floodplains or estuaries. Fish are blocked during migration to prime feeding or spawning grounds. Passing flow requirements alter seasonal fluctuations of stream flow and reduce biodiversity in the watershed. Development on the banks of a river or stream disrupts floodplains and riparian edges, directly degrading water quality with non-point source pollution, while removing some of the most biodiverse areas of an ecosystem. Clearing trees and other vegetation from stream edges also removes the roots which help stream banks resist erosion, decreases nutrient and energy flow into the water system from falling leaves and wood, reduces denitrification of ground water moving toward the stream, and increases sunlight access to water, which encourages algal growth. Increases in impervious surfaces near a stream create scouring flows of pollutant laden stormwater which destroys animal habitat (Roni & Beechie, 2013; Van Abs, 2013). The difference in water quality between the heavily flow-regulated Hackensack and the lightly flow-regulated Ramapo are testaments to the disruptive nature of flow modifications.

Wells that induce flow from streams can result in dry streambeds, which is detrimental to aquatic species. These conditions have been noted in the Mahwah River and other streams by Heisig (2010). Methods for maintaining a flow that meets water needs downstream, yet also provides the highest ecological benefit have not been studied in either watershed.

Ecological needs for specific hydrologic conditions

Past research has shown that watersheds with more than 50 percent developed land and 10 percent impervious surfaces tended to have more impaired water quality than those with higher levels of unaltered land. Riparian buffers around lakes and streams and at least 70 percent contiguous forest cover within the watershed are correlated with quality habitat for sensitive aquatic plants, animals and ecosystems. (US Geological Survey, 2002). In a highly developed watershed, these parameters can appear daunting to even the most ardent environmentalist. Sustainability of water resources for ecological benefit is better understood through maintaining, restoring and connecting natural land cover of a sufficient size to support endangered, threatened or rare riparian or riverine species. (Van Abs, 2013). An understanding of the processes that create and disrupt the riverine and riparian ecosystems in each watershed can help to guide restoration efforts but still allow some historic human uses of the land. Watershed approaches to river and riparian management, like the 9 Element (9E) Watershed Plan in NYS, develop goals appropriate to local conditions, identify and implement best management practices (BMPs) and craft a plan for monitoring.

Recent research on the ecological effects of hydrologic alterations have resulted in new approaches to flow regulation, showing that a pattern of flows mimicking natural variability is important to stream ecosystems, not just maintaining a single low-flow threshold. The Ecological Limitations of Hydrological Alteration (ELOHA) approach has been developed by researchers from the Nature Conservancy and other institutions to provide estimates on the relevant flow needs. A USGS study for the NJ Department of Environmental Protection has resulted in a detailed methodology that is likely applicable to Rockland County watersheds, as both areas have Highlands and Newark Basin geology (Kennen, Henriksen, & Nieswand, 2007).

VIII. Water Infrastructure

Water supply infrastructure and inter-watershed transfer capabilities

Water sources: Wells, Reservoirs

Suez-New York, an investor owned public community water supply (PCWS) system, serves the majority of residents in Rockland County. Approximately 90% of the water supply in Rockland is provided by Suez. Other PCWS systems cater to 7% of the water supply and their customer base ranges from 50 to a couple of thousands. Based on the records of the Rockland County Health Department there are about 6,000 active domestic and commercial wells which make up for 3% of the water supply (Vanderhoef & Cornell, 2011). These wells are both within and outside of the PCWS service areas.

Suez-New York is the successor to the Spring Valley Waterworks and Supply Company, founded in 1893, and more recently was incorporated as United Water-NY until being rebranded Suez to reflect the parent company name. It provides water for drinking as well as for fire protection to the residents and businesses in Rockland County excluding villages of Suffern, and South Nyack, which have their own systems. Within the Suez-NY system, Lake DeForest reservoir provides approximately 32 percent of water supplied each year, the Ramapo Valley Well Field provides 25 percent and the remaining system wells (e.g., Mahwah River well field and Newark Basin wells) provide 43 percent (Haverstraw Water Supply Project DEIS report, 2010). The monthly water production record from each of the sources serving Suez over the past 10 years (2000-2010) but excluding the drought year of 2002 is shown in the Table VIII-1, it depicts the adjustments made over the years to provide enough water within the permit limits. Suez also serves a small portion of Orange County in portions of towns of Tuxedo, Warwick and Monroe.

The New York State Department of Environmental Conservation (NYSDEC) is mandated to conserve the state's public water supply program. NYSDEC and the New York State Department of Health (NYSDOH) administer different aspects of the state's public water supply program. The Department of Health is involved to oversee the delivery of drinking water to ensure that it is suitable for human consumption. NYSDEC is responsible for the allocation of water supplies.

Suez draws its water from both aquifers (the Newark sedimentary bedrock aquifer and the alluvial aquifers along the Ramapo and Mahwah rivers) and surface water from the Lake DeForest reservoir and Letchworth reservoir. Its total system capacity is shown in **Table VIII-1.**

Ramapo Valley Well Field:

The Ramapo river valley well field is located in the western part of the county and supplies about 3.73 billion gallons of water per year (31 percent) of the Suez public water supply (Vanderhoef & Cornell, 2011). The Village of Suffern also has a wellfield along the Ramapo, downstream of the Suez system. The Ramapo valley well field derives most of its water by inducing infiltration of the Ramapo River through the permeable sand and gravel to the supply wells. Restrictions on withdrawals have been imposed by the NYSDEC that require a minimum flow of 12.6 ft3/s (roughly 8 million gallons per day, MGD) in the Ramapo River so as to protect downstream water users. If the flows in the Ramapo River are greater than 10 MGD, the Ramapo Valley Well Fields can provide up to 14 MGD peak day and 10 MGD on monthly average.

Table 1-4
Average Monthly Water Production, 2000–2010, Excluding Drought Year (2002)

Month	Lake DeForest		Ramapo Valley Well Field		System Wells		Letchworth Reservoirs		Total	
	mgd	% of Total	mgd	% of Total	Mgd	% of Total	mgd	% of Total	mgd	% of Total
January	7.8	28.4	7.7	28.1	12.0	43.5	0.0	0.0	27.6	100.0
February	8.1	29.1	7.6	27.5	12.0	43.5	0.0	0.0	27.7	100.0
March	8.1	29.2	7.8	28.2	11.8	42.6	0.0	0.0	27.7	100.0
April	8.5	30.1	8.1	28.7	11.6	41.1	0.0	0.0	28.1	100.0
May	9.5	31.1	7.9	25.7	13.1	42.8	0.1	0.4	30.6	100.0
June	11.4	34.3	7.6	22.7	13.9	41.8	0.4	1.2	33.3	100.0
July	12.4	36.0	6.6	19.1	15.0	43.5	0.5	1.4	34.5	100.0
August	11.9	35.4	6.3	18.7	15.0	44.4	0.5	1.5	33.8	100.0
September	10.9	34.9	6.3	20.2	13.7	43.8	0.4	1.1	31.3	100.0
October	8.9	31.7	6.4	22.9	12.6	44.9	0.2	0.6	28.0	100.0
November	7.7	28.9	7.4	27.6	11.6	43.1	0.1	0.4	26.8	100.0
December	7.5	27.9	7.5	27.7	11.9	44.2	0.0	0.1	27.0	100.0
Annual Average	**9.4**	**31.7**	**7.3**	**24.5**	**12.9**	**43.3**	**0.2**	**0.6**	**29.7**	**100.0**

Note: United Water began operation of Letchworth Reservoirs in August 2006.

Table VIII-1: Average Monthly Water Production, 2000-2010 excluding drought year 2002
Source: Haverstraw Water Supply Project: Draft Environmental Impact Assessment (p. I-24)

When the flow in the river drops below 10 MGD but is higher than 8 MGD, the withdrawals are reduced, and when the withdrawal falls below 8 MGD the withdrawals are entirely eliminated. The water allocation permit WSA 6507 approved by the NYSDEC governs the water supply permit for the Ramapo Valley well field.

The Village of Suffern operates four production wells that provide water to about 12,000 people at a rate of 2 MGD.

The most recent aquifer model for the Ramapo valley aquifer dates back to 1982 when the NYSDEC permit was granted. According to CDM Smith, in a report for Suez-NY, the aquifer is fully allocated, and has no physical additional capacity except from improvements to management strategies that meet the existing regulations including the potential for the combined management of withdrawal between Suffern and Suez to maximize the yields. Suez has proposed the development for a new aquifer model that will allow Suez to test out alternative management strategies.

Potake Pond, located 1.3 miles from Sloatsburg, is used to augment river flow so that pumping can continue. However, total storage in Potake Pond is small, limiting the benefits. Until 2003, Suez had a lease agreement to take water from Potake Pond and another nearby water body, Cranberry Pond, to augment flow in the Ramapo River. But in 2003, Suez purchased Potake Pond and constructed a pipeline from the pond to Nakoma Brook, a tributary of the Ramapo River. Suez consolidated a water supply permit to withdraw 1900 million gallons from both the water bodies through Potake Pond for a total volume of approximately 700 million gallons. The practical result of these restrictions has been 7 MGD in annual average water withdrawals from Ramapo River Valley well field, and roughly 4 MGD during summer months which is the time of peak demand. On an average these rates meet 25 percent of the Suez needs, but less during the summer months. The Ramapo Valley well field has experienced contamination from industrial sources such as VOCs, and salt from winter road maintenance of the major highways traversing the valley, such as the New York State Thruway and Route 17.

Mahwah Valley Well Field and Bedrock Wells:

In addition to the Ramapo valley well field water supply, Suez operates 50 wells which are dispersed throughout Rockland, providing approximately 43 percent of Suez's water supply. The deep wells are primarily located in the bedrock of the southern half of the county, and shallow wells in the glacial and gravel part near Mahwah River, Minisceongo Creek, and Sparkill Creek. Similar to the Ramapo Valley well field, induced recharge and intercepted ground water flow are primary water sources for the Mahwah valley field. The Mahwah River drains into New Jersey, where it meets the Ramapo River; therefore, flow requirements are instituted to protect the downstream users. The aquifer is considered fully allocated and used, with no potential for additional yields.

Water is collected at storage tanks from system wells and is treated with chlorine before it is supplied to individual households. These wells are susceptible to contamination from surrounding development and a few wells are not in operation due to the low yield and contamination.

Safe yields of system wells:

The concept of safe yield proves to be difficult to apply to ground water resources, as the total capacity of wells is influenced by the capacity of their pumps and by the ground water condition at that specific well or well field. Some of the Suez system wells are located in close proximity to each other and cannot be operated without adversely affecting the surrounding wells. All the wells can operate simultaneously to meet the peak demands, but this proves to be unsustainable as it adversely affects ground water levels in the aquifer.

The firm capacity of a water supply system can be considered as the 'design maximum day demand with the largest producing well out of service." Dependable yield refers to the capacity of an aquifer or surface water system to meet a specific average demand during a repeat of the record drought. The Suez system wells have recorded a peak capacity of about 24.44 MGD and an average capacity of 15.9 MGD on a longer term (annual basis). But these values for Suez do not include consideration of capacity with the largest producing well out of service, so when this is taken into account, the average peak daily capacity of Suez wells reduces by approximately 1.5 MGD (Haverstraw Water Supply Project DEIS report, 2010).

Newark Basin Aquifer:

The Newark basin aquifer located in the central region of Rockland County supplies about 3.9 billion gallons of water per year to Suez based on an average calculated for the years from 1990 through 2006. Apart from Suez, other small public water supply entities also rely on the Newark basin aquifer as a source of water supply. Out of the 6000 private wells, around 2800 are located within the service area of the Suez service area based on the records of the Rockland County Health Department. About 1000 of these wells are connected to the Suez distribution system but are predicted to use the Suez connection only in situations when the private well cannot meet domestic needs. Such cases where homes with private wells are also connected to the Suez distribution system are located close to New Square and Monsey (Vanderhoef & Cornell, 2011, p. 263).

The average household size by census tracts is shown in **Figure VIII-1**. As per the Census 2010, the average household size in Rockland County was 3.07. The RCDOH indicated that approximately 80% of the private wells or 4,800 private wells are located in the Suez service area. It is assumed that most of the wells would be located in the less densely developed areas as the town centers or developed areas have long been served by public water supply. The probability that the private wells are located in suburban areas is much higher, even though those areas are now developed, as there would be pre-existing homes that were later surrounded by new development.

The census tracts whose densities were lower than 2500 persons per square mile were identified as suburban tracts. The weighted average of the household size of these suburban tracts was calculated to be 3.04. Thus, the total number of persons who use private wells is estimated at 18,240.

Surface Water

Lake DeForest: The reservoir provides approximately 32 percent of water supplied each year by Suez, and also guarantees flow down the Hackensack River for the use of Nyack Village and to meet passing flow requirements to New Jersey.

The passing flow requirements mandate 10 MGD of water from the Lake DeForest to be reserved for residents of Rockland County at all times of the year. Additionally, the water supply permit for Lake DeForest as governed by NYSDEC requires Suez to maintain a daily flow of at least 9.75 MGD in the Hackensack River. Of the 9.75 MGD, the Village of Nyack is permitted to withdraw 2 MGD, leaving the remaining water to flow to reservoirs downstream. During the summer months when the demand is typically higher, Suez draws larger volumes from Lake DeForest.

Letchworth Reservoirs: The three Letchworth reservoirs are located in the Highlands, outside of the Ramapo and Hackensack watersheds; they a total capacity of 173 million gallons. They have been operated from 2007-2010 and provide less than 1 percent of the water supply. Suez started operating the Letchworth treatment plant in 2006 as an additional source for its distribution system and this reservoir is typically used during peak times to provide water during periods of high demand.

Suez meets the demand for water from various sources, and the amount of water provided from each source depends on the availability of water from that source and its permit conditions. The various water supply options available to Suez give it the flexibility to meet the annual average demand and to meet short term demands, which during peak periods can be as high as 50 to 60 percent higher than the average demand. The current production capacity of Suez's water supply system for average day and

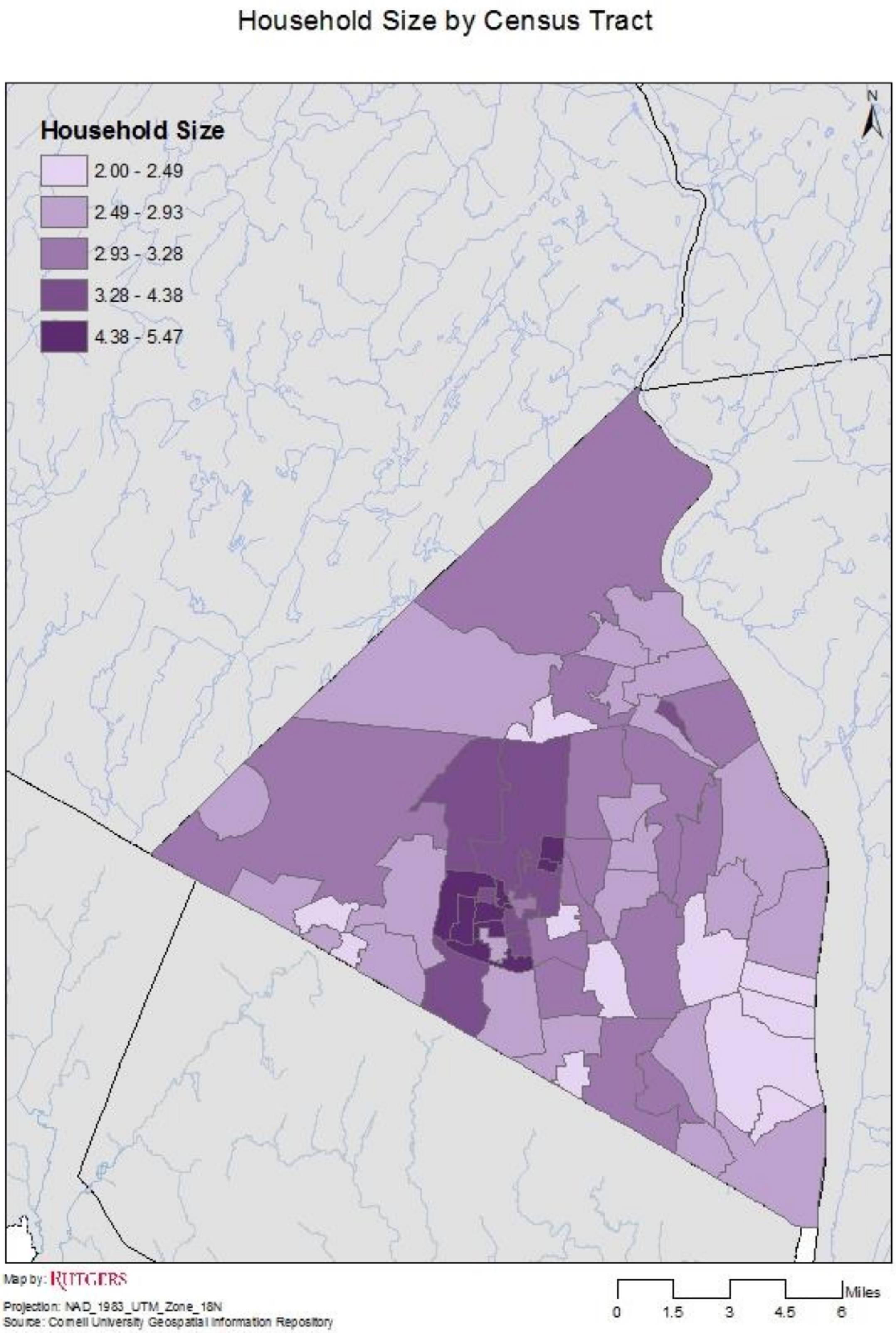


Figure VIII-1: Household Size by Census Tract
Source: Cornell University Geospatial Information Repository and American Fact Finder

peak day conditions is summarized in **Table VIII-2**. The total peak day supply for the June 2011 was 51.44 MGD while the daily average supply was a total of 33.9 MGD. **Table VIII-3** summarizes the conditions of water withdrawals from each of the water supply resources of Suez and the amount of water that must be released downstream to support stream flows so as to maintain ecological flows and preserve riparian rights.

Table 1-3
United Water Rockland County
Water Supply System Capacity (mgd)
(as of June 30, 2011)

Water Source	Average Day Supply (Safe Yield)	Peak Day Supply
Lake DeForest / Water Treatment Plant	10.00	20.00
Letchworth Reservoirs / Water Treatment Plant	1.00	3.00
Ramapo Valley Well Field	7.00	4.00
System Wells	15.90	24.44
Total	**33.90**	**51.44**

Table VIII-2: Suez Water Supply System Capacity for June 30, 2011
Source: Haverstraw Water Supply Project: Draft Environmental Impact Assessment (p. I-23)

Other Public Water Supplies:

There are 139 wells across Rockland County that serve about 7 percent of the County residents through smaller public water supplies as shown in **Figure VIII-2**. The Village of Suffern has an average demand of 1.3 MGD and a maximum day demand of 2 MGD from wells in the Ramapo aquifer. The village of Hillburn purchases water from Suez. The Village of Nyack withdraws water from the Hackensack River, supported by mandatory releases from Lake DeForest.

Water Supply Treatment plants

Rockland County has 6 public community water supply systems, 1 public non-transient non-community water system, 4 transient non-community water systems and a single surface water treatment plant (for Nyack) as indicated in **Figure VIII-3**. Suez operates five water treatment plants. The Lake DeForest treatment plant operated by Suez is located at the southern end of the reservoir. The operation of this treatment plant is subject to an approval by the NYSDOH which limits the daily intake of raw water to the treatment plant to 20.8 MGD, with a maximum daily production of 20 MGD, and the running annual average intake of raw water to 10 MGD. (Haverstraw Water Supply Project DEIS report, 2010)

The Village of Nyack water treatment plant has a capacity of 3.7 MGD; it draws water from the Hackensack River. There is a limit of 4.8 MGD at peak levels and an average limit of 3 MGD to the water supply allocation from Hackensack River. The treatment plant operated with an average monthly flow of 1.33 MGD and 1.27 MGD in the years of 2008 and 2009 respectively, the highest maximum day demand of 2.14 MGD observed through the year 2009. (Haverstraw Water Supply Project DEIS report, 2010)

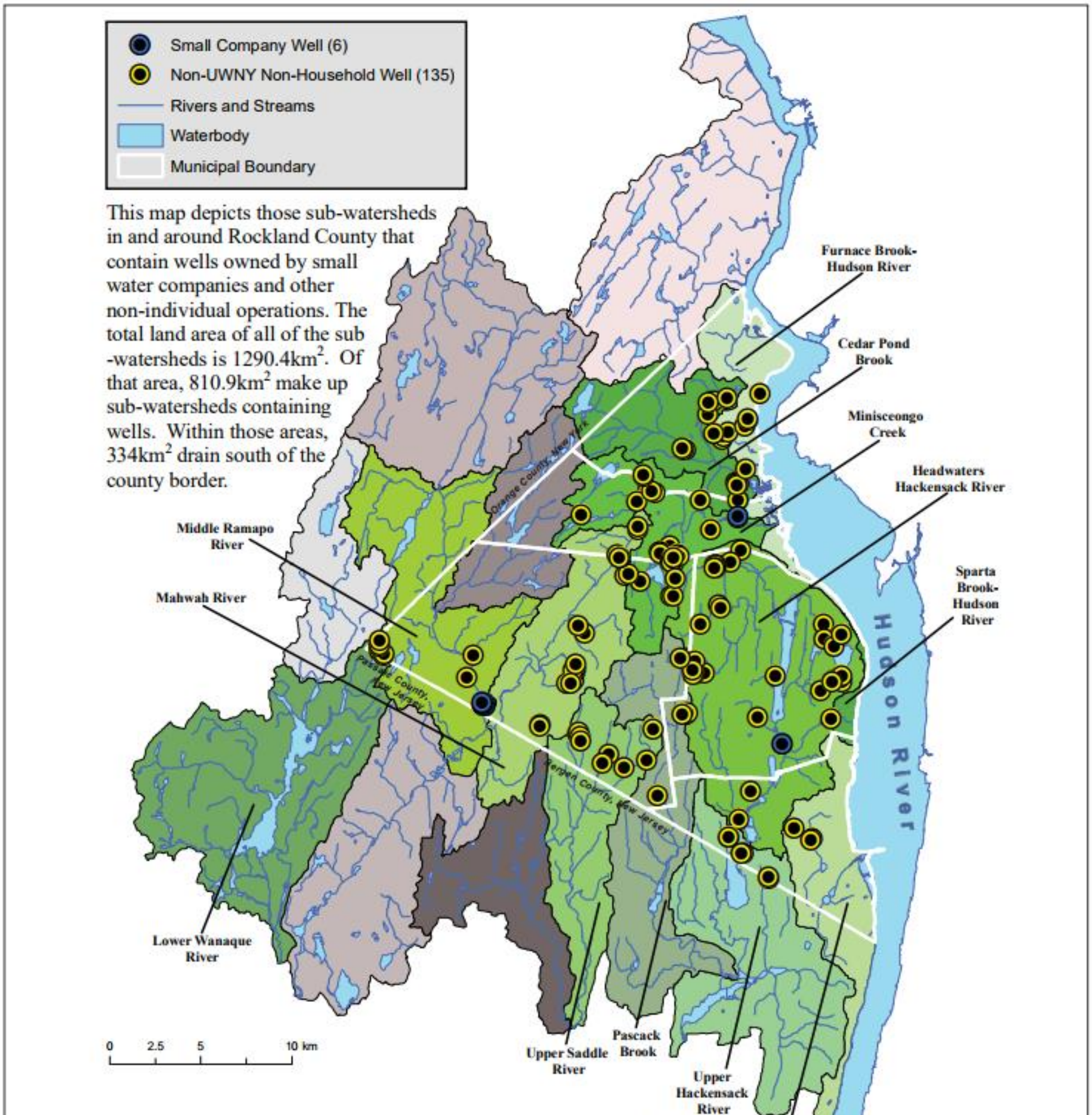
Permit Requirements for Existing Water Supply System Sources

Water Source	Identification	WSA #	Permitted Withdrawal	Permit Conditions: Obligations to Support Stream Flows	
				Water Body	Release Requirements
Lake DeForest	5.6 billion gallon reservoir	WSA 2189	10 mgd average 20 mgd peak	Hackensack River	Permit establishes Rule Curve to determine amount of water that must and may be released downstream to maintain riparian rights and downstream reservoirs. Permit requires United Water to maintain a daily average flow of 9.75 mgd or greater in the stream immediately above the intake works of the Village of Nyack.
Letchworth Reservoirs	Three reservoirs with total capacity of 173 million gallons	WSA 9947	1 mgd average 3 mgd peak	Horse Chock Brook	Permit regulates water releases between the three Letchworth Reservoirs to ensure none becomes too depleted. Permit does not require specific release to the stream downstream of third reservoir.
Ramapo Valley Well Field (RVWF)	10 shallow wells that draw groundwater from the Ramapo Aquifer near the Ramapo River	WSA 6507	Depends on flow in Ramapo River	Ramapo River	Permitted withdrawal depends on the amount of flow in the Ramapo River downstream of the wellfield. When the flow is greater than 10 mgd, maximum withdrawal is permitted. When the flow is between 8 and 10 mgd, less withdrawal is permitted and when the flow is at or below 8 mgd, no withdrawal is permitted.
	Potake and Cranberry Ponds used to augment Ramapo River to support RVWF	WSA 8620	10 mgd	—	Permit does not require a specific release to the stream downstream of Potake and Cranberry Ponds.
System Wells	50 wells throughout Rockland County	Multiple	15.9 mgd average 24.44 mgd peak	—	NYSDEC permits govern withdrawal rates at system wells based on results of aquifer testing at each well.

Table VIII-3: Permit requirements for existing Water Supply System Sources
Source: Haverstraw Water Supply Project: Draft Environmental Impact Assessment (p. I-21)

Distribution systems and service areas

The Suez water distribution system in Rockland consists of more than 1,000 miles of water mains, 14 storage tanks, and 14 booster pump stations. The water distribution system is divided into 19 pressure districts, which are areas of similar ground elevation within which one common hydraulic gradient is maintained. Water is transmitted between the various pressure districts through the use of appropriately sized pipes and pumping stations that bring water to the correct pressure for the respective district. For emergency response, the Suez service area is broken down into two geographical



Sub-Watershed Name	Hydrologic Unit Code	State	Area km²	Area km² draining outside Rockland	Number of Wells
Cedar Pond Brook	20301010103	NY	46.0	0.0	13
Furnace Brook-Hudson River	20301010105	NY	33.3	0.0	9
Headwaters Hackensack River	20301030901	NY	119.1	0.0	32
Lower Wanaque River	20301030103	NJ,NY	121.2	120.3	5
Mahwah River	20301030203	NJ,NY	67.3	10.9	17
Middle Ramapo River	20301030204	NJ,NY	90.5	15.2	11
Minisceongo Creek	20301010104	NY	49.3	0.0	30
Pascack Brook	20301030902	NJ,NY	76.2	45.5	5
Sparkill Creek-Hudson River	20301010404	NJ,NY	47.3	16.6	3
Sparta Brook-Hudson River	20301010401	NY	4.8	0.0	1
Upper Hackensack River	20301030903	NJ,NY	97.3	86.9	6
Upper Saddle River	20301030702	NJ,NY	58.6	38.6	9
Total	N/A	NJ,NY	810.9	334.0	141

Figure VIII-2: Subwatersheds Containing Small Water Company and other Non- Household Wells
Source: Rockland Tomorrow: Rockland County Comprehensive Plan, (Vanderhoef & Cornell, 2011, p. 265)

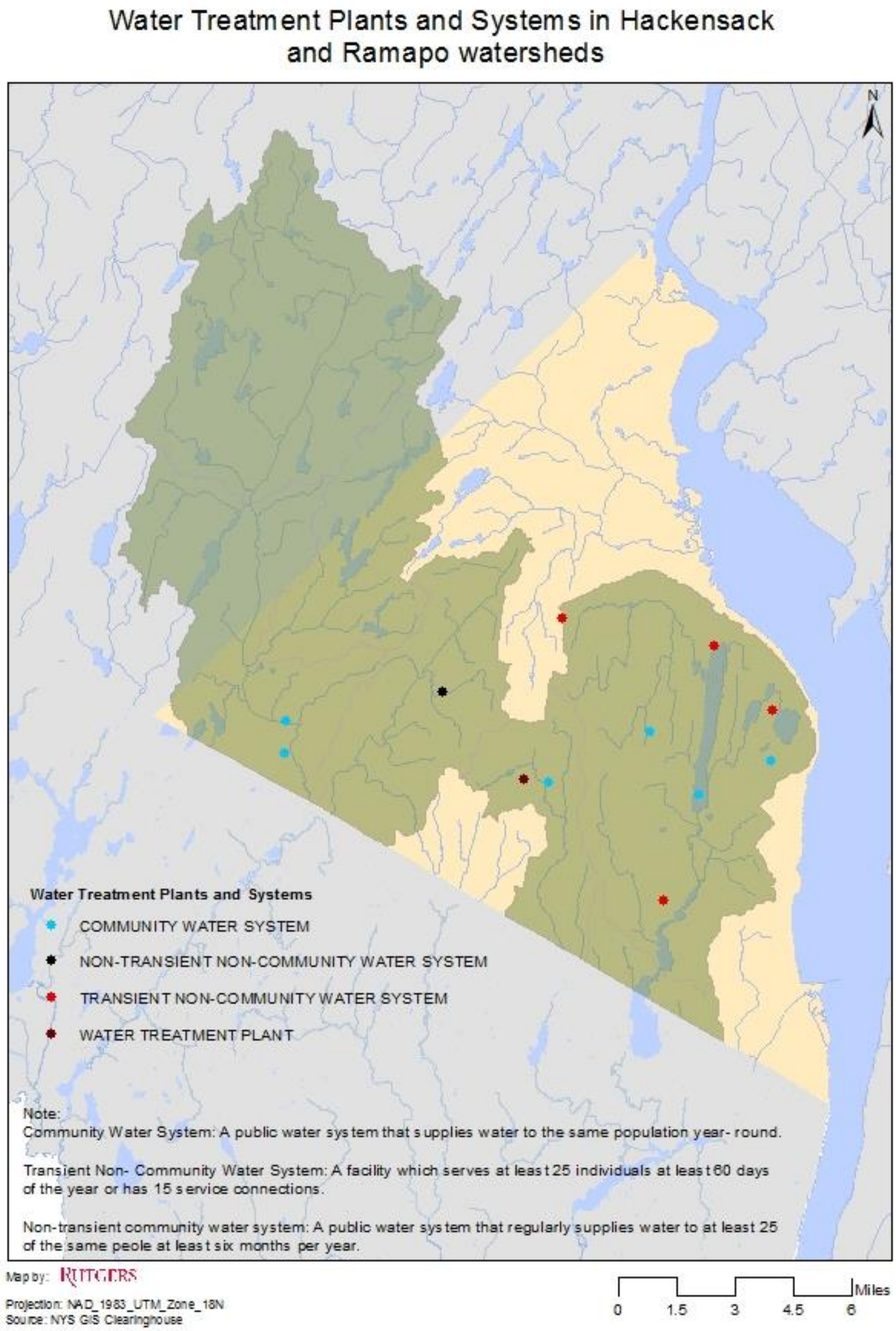


Figure VIII-3: Water Treatment Plants and Systems in Hackensack and Ramapo Water.
Source: NYS Clearinghouse

areas, namely East and West with the Palisades Interstate Parkway dividing the two regions. (Haverstraw Water Supply Project DEIS report, 2010) The relationship between the pressure districts, Suez service areas, and Suez water supply sources are shown in **Figure VIII-4**.

Sewerage infrastructure and inter-watershed transfer capabilities

Collection systems and service areas

The Rockland County Department of Health's Bureau of Water Pollution Control provides outreach and guidance in the promotion of public health and enforcement of the County's Public Health Law, as well as State and local Sanitary Codes relating to:

- Realty subdivisions (five or more residential lots and residential lots of five or less acres)
- Individual sewage disposal systems (review and approval of design plans for new systems, repair and replacement systems, site and construction inspection, complaint response)
- Sewage and industrial wastewater treatment plants (review and approval of design plans, reconnaissance and annual inspections, complaint response)
- Sewer main extensions
- All other phases of wastewater

The county's waste water (sewage) is currently being collected and treated by seven publicly owned wastewater collection systems, small private systems, and approximately 6000-8000 individual residential septic systems. (Haverstraw Water Supply Project DEIS report, 2010) The service areas of the seven municipal wastewater treatment plants are shown in **Figure VIII-5.**

The sewer collection systems in Rockland County are either owned by the sewer district, town or village. Due to the undulating topography of hills and valleys in the county, many of the collection systems require pump stations and force mains to convey the sewage flow to the treatment plants.

Treatment plants and affected receiving waters

In New York State, in order to maintain waters with reasonable levels of purity, Article 17 of the Environmental Conservation Law authorized the creation of a State Pollution Discharge Elimination System (SPDES). The SPDES program administered by the NYSDEC is broader in scope than the Clean Water Act as it controls point discharges to ground water as well as surface waters. The SPDES program has regulations for ground water and for surface water. As per the New York statute, for the ground water section of the program the permit is required for the construction of a disposal system such as a sewage treatment plant whose treatment system has a total flow of total discharges to ground water more than 1000 gallons per day and less than 10,000 gallons per day of sewage wastewater containing no industrial or other non-sewage wastes.

In accordance with the NYSDEC State Pollution Discharge Elimination System (SPDES) Permit List, there are 18 SPDES permits issued to private sewer facilities in Rockland County that discharge to ground water. Eleven of these facilities have permitted design flows with a total combined flow of 0.57 MGD, the largest of which are the New York State Thruway Sloatsburg/Ramapo Service Area, Bear Mountain

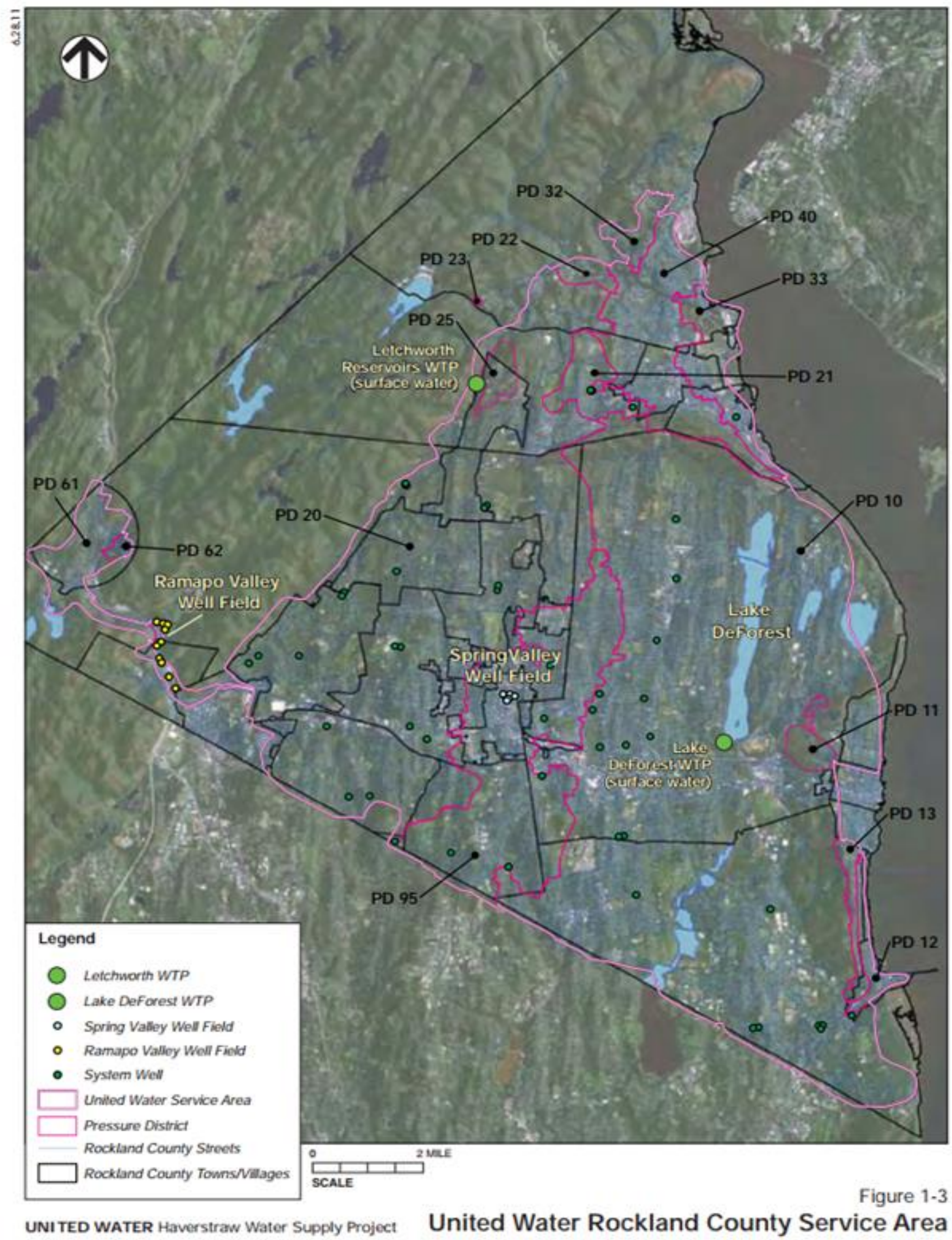


Figure VIII-4: Suez service areas

Source: Haverstraw Water Supply Project: Draft Environmental Impact Assessment (p. I-24)

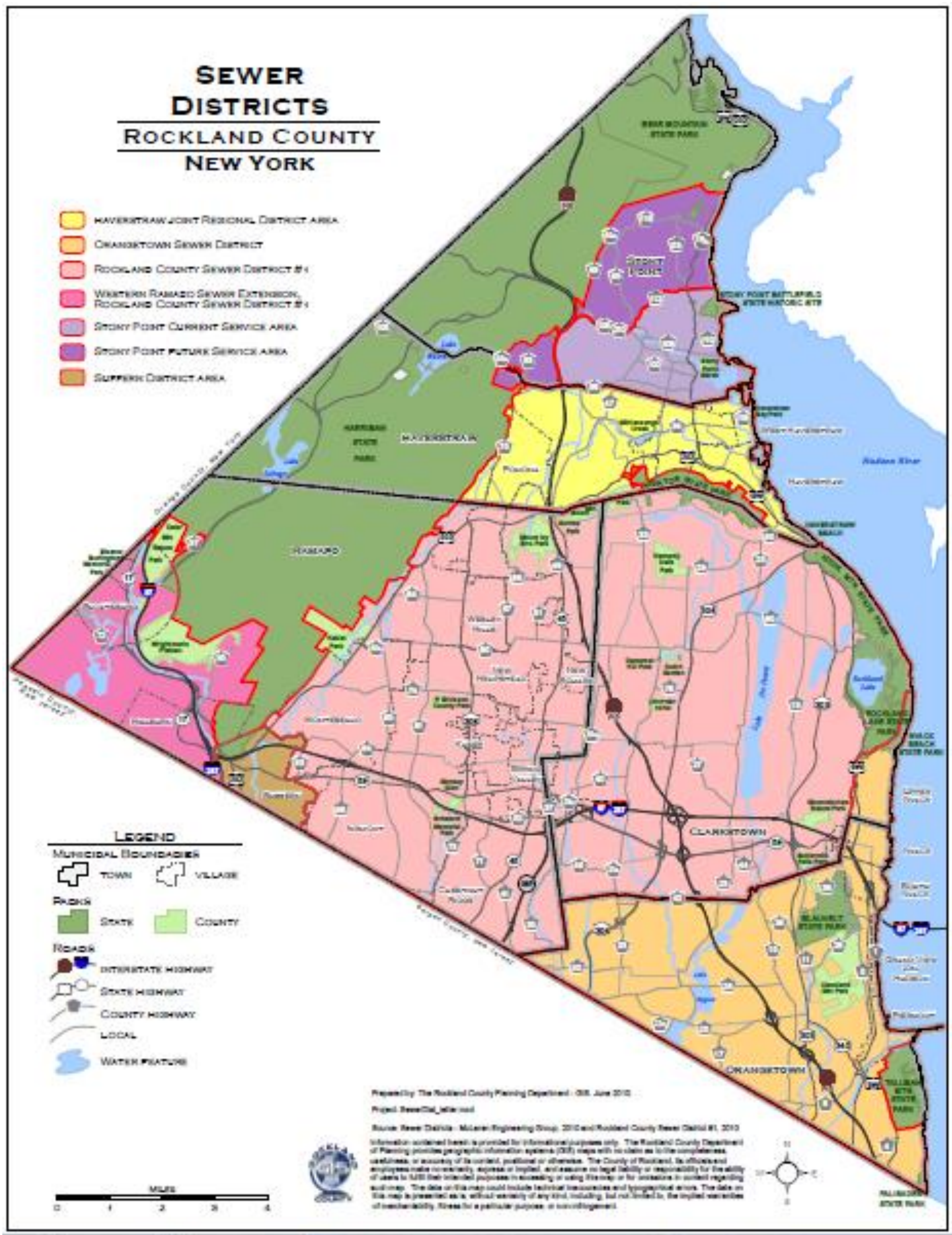


Figure VIII-5: Sewer Districts in Rockland County

Source: Haverstraw Water Supply Project: Rockland Tomorrow: Rockland County Comprehensive Plan, (Vanderhoef & Cornell, 2011)

State Park, and Lake Welch private sewage treatment facilities – all totaling 0.53 MGD. The remaining seven SPDES permits are for private subsurface treatment facilities. The details of the 18 privately owned sewer facilities in Rockland are presented in **Table VIII-4**.

Publicly owned sanitary sewers have been installed parallel to development in the county. The details of the publicly owned sewage treatment plants, as obtained from their DMR reports, are presented in **Table VIII-5**. Barring the Sloatsburg Wastewater Treatment Plant which had no records, the average flow of all the treatment plants were within the limits of the design flow except for the Western Ramapo Advanced Wastewater Treatment Plant which exceeded the design flow by 0.19 MGD. The Suffern Wastewater Treatment Plant and the Western Ramapo Advanced Wastewater treatment plant discharge to streams identified as impaired and in the need of a TMDL, per their DMR reports. The 'listed for impairment' category in the DMR's reports the impairment of the waterbody in which the facility is located. All these facilities discharge to streams that have been listed as water-quality impaired except for the Haverstraw Joint Regional Sewage Treatment Plant, which discharges to the Hudson River estuary.

Sanitary sewers have been critical in protecting the ground water quality in areas with thin soils that do not effectively treat domestic wastewater. However, one of the primary drawbacks of the implementation of the sewer network is that the net effect of the sewers has led to the export of water from the county. Out of the seven treatment plants in Rockland county that discharge to surface waters, four discharge their treated effluent into the brackish waters of the Hudson River; that water thus is unavailable for other purposes. In 2005, a total of 14.75 billion gallons (BG) was exported from the county, with a contribution of 0.54 MGD from the Ramapo River. Discharges from the five largest treatment plants are shown in **Table VIII-6**, for the year 2005. The highest amount of discharge of 8.492 (BG) in the year 2005 was released from the Sewer District 1 which serves the towns of Ramapo and Clarkstown, the most urbanized areas of the County. (Heisig, 2010)

Prior to suburban development most of the areas of the county were served by septic tanks which returned approximately 90 percent of the water back to the aquifer. Therefore, water use in the county had a minor impact on the ground water levels. However, with the implementation of sewer networks the amount of wastewater leaving the bounds of the county is as high as 14.75 MGD, a figure which is equivalent to approximately double the annual stream flow of Mahwah River recorded at Suffern. (Heisig, 2010)

The graph in **Figure VIII-6** illustrates that the highest wastewater treatment flows coincide with the wet periods during the year, which can be explained by the inflow of stormwater and infiltration of ground water into the sewer systems, a process that substantially increases the volume of wastewater before it reaches the treatment plants. Yearlong ground water infiltration is evident from the summer long recession of outflow. In 2005, about 14.1 BG of treated wastewater was discharged into the Hudson River. As seen in the graph the amount of wastewater discharged into the Hudson River exceeds the baseline water use by about 5 BG.

S.No	Facility Name:	Receiving Water	Listed for Impairment	Causes of Impairment	Facility Pollutants potentially contributing to Impairment	Impairment Class	2017 Avg. Flow accessed on 3 Sept (MGD)	NPDES ID
1	Lovett SWM Facility	Hudson River	Yes	Metals (Other Than Mercury), Nuisance Exotic Species, Other Cause, Pathogens, Polychlorinated Biphenyls (Pcbs), Temperature	Aluminum; Arsenic; Barium; Chromium; Coliform, fecal general; Copper; Iron; Lead; Manganese; Nickel; Vanadium; Zinc	Not Provided	0	NY0166456
2	Panco Petroleum Company	Cedar Pond Brook	Yes	Metals (Other Than Mercury), Nuisance Exotic Species, Other Cause, Pathogens, Polychlorinated Biphenyls (Pcbs), Temperature	None found	Not Provided	0	NY0235067
3	Bowline Generating Station	Hudson River	Yes	Metals (Other Than Mercury), Nuisance Exotic Species, Other Cause, Pathogens, Polychlorinated Biphenyls (Pcbs), Temperature	None found	Not Provided	516	NY0008010
4	Tilcon Quarries Haverstraw Plant	Hudson River	Yes	Nutrients, Organic Enrichment/Oxygen Depletion, Other Cause, Sediment, Total Toxics	Solids, total suspended	Not Provided	0.107	NY0005231
5	Tilcon - West Nyack Stone Processing	Hackensack River	Yes	Nutrients, Pathogens, Salinity/Total Dissolved Solids/Chlorides/Sulfates, Sediment	Solids, total suspended	Impaired by a pollutant and in need of a TMDL.	1.061	NY0110612
6	Lake DeForest Filtration Plant	Hackensack River	Yes	Nutrients, Organic Enrichment/Oxygen Depletion, Other Cause, Sediment, Total Toxics	Solids, total suspended	Not provided	0.15	NY0037265

S.No	Facility Name:	Receiving Water	Listed for Impairment	Causes of Impairment	Facility Pollutants potentially contributing to Impairment	Impairment Class	2017 Avg. Flow accessed on 3 Sept (MGD)	NPDES ID
7	U & A Construction Corp	Sparkill Creek	No	None		Not provided	0.072	NY0259993
8	Praxair - Mrc	Sparkill Creek	Yes	Nutrients, Salinity/Total Dissolved Solids/Chlorides/Sulfates	None found	Impaired by a pollutant and in need of a TMDL	0.18	NY0007579
9	Wyeth Pharmaceuticals	Muddy Brook	No	None	No info	Not provided	1.66	NY0004600
10	Woodbine Yard	Pascack Brook	No	None	No info	Not provided	0.0061	NY0264024
11	Ramapo Valley Well Field	Ramapo River	Yes	Metals (Other Than Mercury), Nutrients, Other Cause, Pathogens, Sediment	Aluminum; Copper; Lead; Zinc	Impaired by a pollutant and in need of a TMDL.	0	NY0248258
12	Breakneck Wtp	Beaver Pond Brook	No	None	No info	Not Provided	0	NY0215333
13	Exxon S/S #3-6584 / Kings Hywy/Old Lk Rd	No Information						NY0215066
14	Piermont Papermill Site							NY0234192
15	Sloatsburg Mountain Lake Manor Stp							NY0105198
16	Former Kay Fries Redevelopment							NY0006076
17	Gabriel Mfg Co Inc							NY0214591
18	Xerox Corp							NY0215147

Table VIII-4: Details of the privately-owned treatment plants.
Data gathered from NYSDEC DMR reports

S.No	Facility Name:	Owner	Year Built/ Upgraded	Receiving Water	Design Flow	Population Served	Listed for Impairment	Causes of Impairment	Facility Pollutant(s) potentially contributing to Impairment	Impairment Class	2017 Avg. Flow accessed on 3 Sept (MGD)	NPDES ID
1	Haverstraw Joint Regional Sewage Treatment Plant		1971/1977	Hudson River	8 MGD	40,000	No	None		Not Provided	4.48	NY0028533
2	Orangetown Wastewater Treatment Plant	Town of Orangetown	1959/1995	Hudson River	12.75 MGD	52,974	Yes	Metals (Other Than Mercury), Nuisance Exotic Species, Other Cause, Pathogens, Polychlorinated Biphenyls (Pcbs), Temperature	Coliform, fecal general; Copper	Not Provided	8.37	NY0026051
3	Rockland County Sewer District #1	Rockland County	1968/1988	Hudson River	28.9 MGD	173,504	Yes	Metals (Other Than Mercury), Nuisance Exotic Species, Other Cause, Pathogens, Polychlorinated Biphenyls (Pcbs), Temperature	Coliform, fecal general	Not Provided	15.6	NY0031895
4	Sloatsburg Wastewater Treatment Plant	Rockland County Sewer District #1	1973	Ramapo River	30,000 gpd	120						
5	Stony Point Wastewater Treatment Plant	Town of Stony Point	1969/1984	Hudson River	1 MGD	10,000	Yes	Metals (Other Than Mercury), Nuisance Exotic Species, Other Cause, Pathogens, Polychlorinated Biphenyls (Pcbs), Temperature	Coliform, fecal general	Not Provided	0.78	NY0028851
6	Suffern Wastewater Treatment Plant	Village of Suffern	1935/1983	Ramapo River	1.8 MGD	13,000	Yes	Metals (Other Than Mercury), Nutrients, Other Cause, Pathogens, Sediment	Ammonia as NH3; Coliform, fecal general; Phosphorus; Solids, total suspended; Total Kjeldahl Nitrogen	Impaired by a pollutant and in need of a TMDL	1.17	NY0022748

S.No	Facility Name:	Owner	Year Built/ Upgraded	Receiving Water	Design Flow	Population Served	Listed for Impairment	Causes of Impairment	Facility Pollutant(s) potentially contributing to Impairment	Impairment Class	2017 Avg. Flow accessed on 3 Sept (MGD)	NPDES ID
7	Western Ramapo Advanced Wastewater Treatment Plant	Rockland County Sewer District #1	2009	Ramapo River	1.5 MGD	NA	Yes	Nutrients, Organic Enrichment/Oxygen Depletion, Pathogens		Impairmed by a pollutant and in need of a TMDL	1 .69	NY0270598

Table VIII-5: Details of publicly owned sewer treatment plants.

Source: Data gathered from DMR reports.

Sewer district / treatment plant	Town(s) / area served	Water treated and discharged in 2005 in (billions of gallons)	Receiving water body
Sewer District 1	Ramapo, Clarkstown	8.492	Hudson River near Piermont
Sewer District 2	Orangetown	3.480	Hudson River near Piermont
Haverstraw Joint Regional Sewer Board	Haverstraw	1.678	Hudson River near Haverstraw
Stony Point Sewer District	Stony Point	0.378	Hudson River near Stony Point
Suffern Treatment Plant	Village of Suffern	0.540	Ramapo River

Table VIII-6: Discharges by Wastewater Treatment Plants in 2005

Source: Water Resources of Rockland County, New York, 2005- 07, with Emphasis on the Newark Basin Bedrock Aquifer (p. 112)

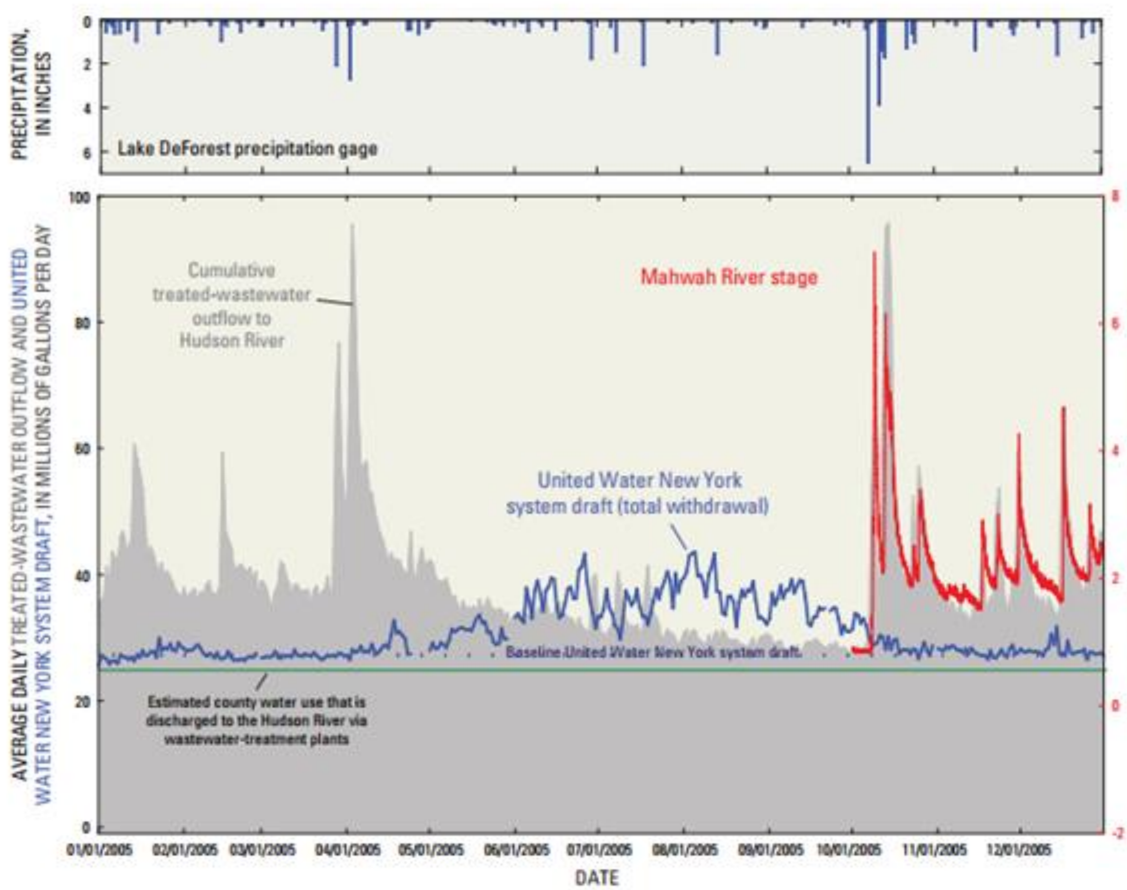


Figure 63. Comparison of 2005 total treated-wastewater outflow to the Hudson River, United Water New York system draft, Mahwah River stage, groundwater level at the U.S. Geological Survey Green Pond observation well (27–0028; http://nj.usgs.gov/gw-cgi/wldata.pl?UID=270028.rdb, accessed July 9, 2007); Morris County, New Jersey), and precipitation from the United Water New York precipitation station at Lake DeForest, Rockland County, New York.

Figure VIII-6: Comparison of 2005 total treated wastewater outflow to the Hudson River, Suez, Mahwah River stage, ground water level at the US. Geological Survey Green Pond observation well

Source: Water Resources of Rockland County, New York, 2005- 07, with Emphasis on the Newark Basin Bedrock Aquifer (p. 113)

Recycling of the water at high treatment levels and then pumping it back into either the Hackensack River or the Lake DeForest would create additional water supply availability for the residents of Rockland County. In order to reduce the wastage of water through inflow and infiltration in the sewer system the sewer districts have planned for expansion and upgrades. In the Rockland County Sewer District (RCSD) Number 1, the two objectives have been to minimize the flow and to optimize the system operation to reduce sanitary sewer overflow occurrences. Fixing leaky lines and manholes, and sealing illegal roof leader connections, are seen as methods to eliminate sanitary sewer overflows. The sewer district has already completed testing of 225,000 sewer joints, sealing 18,387 failed sewer joints and rehabilitating 2016 manholes during 1988 to 2006.

Another request of an upgrade by the Villages of Sloatsburg and Hillburn and the Town of Ramapo was generated from the failure of subsurface disposal systems and increased development pressures that petitioned the Rockland county legislature to extend the services of the RCSD No.1 to these areas. The initial plan required the out of basin diversion of the wastewater from the Ramapo river basin to the wastewater treatment plant in Orangeburg, which is located outside the Ramapo River basin. A new advanced wastewater treatment plant built in 2009 was constructed in the Ramapo basin in order to address this concern, thereby keeping all the flow within the Ramapo basin.

Beyond the limits of the County boundary, wastewater treatment plants located in Orange County that discharge into the Ramapo River or its tributaries affect the waters of the Ramapo as it flows into Rockland. The Harriman waste water treatment plant, located in Orange County, affects the water of Ramapo before it flows into Rockland County. This wastewater treatment plant serves the Orange County Sewer District No.1 that includes the villages of Kiryas Joel, Harriman and Monroe and a portion of the town of Monroe within the Ramapo basin.

The treatment plant was constructed in 1974 with a capacity of 2 MGD, but as the towns expanded and as more satellite towns entered into the inter-municipal agreement for wastewater treatment the facility expanded by 2 MGD at first and subsequently another 2 MGD in 2006, reaching its current capacity of 6 MGD. Currently, an additional 3 MGD of treatment capacity is proposed at Harriman due to continued residential and commercial growth within the service area. Constrained by the limited availability of land, instead of building a new wastewater treatment plant, plans for upgrading and improvising the Harriman waste water treatment plant have been proposed.

The Kiryas Joel treatment plant of 0.97 capacity that serves the residents of the Kiryas Joel village in Orange County discharges to a tributary of the Ramapo River. In 2010, the section of the Ramapo River into which the Harriman Wastewater treatment plant discharges was listed as threatened and was suspected of water quality impairment due to nutrient loading, dissolved oxygen and Biological Oxygen Demand from municipal effluent discharges and storm water run-off. The river reach with the Harriman Waste Treatment Plant doesn't have a Total Maximum Daily Load (TMDL) yet; adoption of a TMDL is likely necessary as the basis for permitting of this facility (Harriman Wastewater Treatment Plant Evaluation and Upgrade Options).

The impairment of the Ramapo in the Harriman region has a direct impact on the Rockland water supply source in the Ramapo valley well field located downstream. A representative from the Ramapo Health Department confirmed the need for a class A designation for Ramapo River as two wells in the Ramapo valley well field were recently classified as ground water under the direct influence of surface water, thereby requiring additional treatment by the customers. (Comprehensive Plan, 2011))

The Harriman Waste Water Treatment Plant (WWTP) and Kiryas Joel WWTP are currently not operating to their capacity. The use of Membrane technology in the upgradation of the Harriman WWTP is expected to enhance the water quality. This also results in the transfer of 3 MGD base flow to wastewater flow in the Ramapo Valley Well field with an associated pollutant load. If treated to the adequate levels, the water resources at the Ramapo aquifer will be augmented by this extra discharge of effluent from the Harriman WWTP. Effluent from the Kiryas Joel WWTP augments the ground water at the Ramapo river basin whereas the effluent from the Harriman augments ground water at the both Ramapo River basin as well as the Moodna Creek watershed. The proposed connection of Kiryas Joel Village to the New York City Catskill aqueduct is expected to provide the surface water from the Ashokan reservoir watershed to the Ramapo River watershed, through the Kiryas Joel WWTP. Rockland county legislators have supported this inter-basin transfer of water from the Catskill aqueduct for the augmentation of flow volume in the Ramapo basin.

The Sierra Club Lower Hudson group raised concerns about the water quality of the Ramapo River that was reportedly impaired due to the effluents from the Kiryas Joel WWTP in 2013 by specific conductance levels that significantly exceeded the NYSDEC effluent limits. Their other concern was the need for assessing the cost implication of the proposed Harriman expansion on the residents of the Rockland county as higher levels of treatment would be required at the Ramapo Valley Well field.

Stormwater systems (municipal and private)

The stormwater runoff along roads and streets is conveyed to the streams and drainage ways by open ditches or collected by inlets and catch basins. The stormwater catchbasins as of 2016 are depicted in **Figure VIII-7**. These outfalls are located in the residential areas and along transportation services of the county. Localized flooding during heavy rains is a regular occurrence throughout the county. One of the primary reasons for the local flooding is the fact that the drainage systems were installed in place much before the onset of development and hence the pipes, culverts or bridges do not have the capacity to pass the developed run off.

In order to improve water quality by reducing the amount of pollutants entering water bodies during stormwater events, the US EPA's Phase II stormwater rule regulates small municipal stormwater systems that are located within the boundaries of a Census Bureau defined as an 'urbanized area'. Rockland County has 5 towns and 19 villages, a total of 24 municipalities that are required to follow NYSDEC's SPDES General Permit for stormwater discharges from Municipal Separate Storm Sewer Systems (MS4). The MS4 municipalities are required to prepare a strategy for protecting the quality of water due to stormwater run-off. Currently, the county is engaged in a MS4 mapping project that digitizes stormwater outfalls and conveyance systems.

Infrastructure age and condition

Information was not available on the age and condition of water supply, sewer and stormwater infrastructure in the study area. One option is to use housing age as indicator of when original infrastructure development occurred, using American Community Survey data from the U.S. Bureau of the Census. As most underground water infrastructure has not been updated since construction, and likely all or nearly stormwater infrastructure has not been updated, housing age may serve as a good surrogate for infrastructure age until better information is available. However, age is not necessarily a good indicator of system integrity, as pipeline materials, construction, in-ground conditions and uses will vary within the study area.

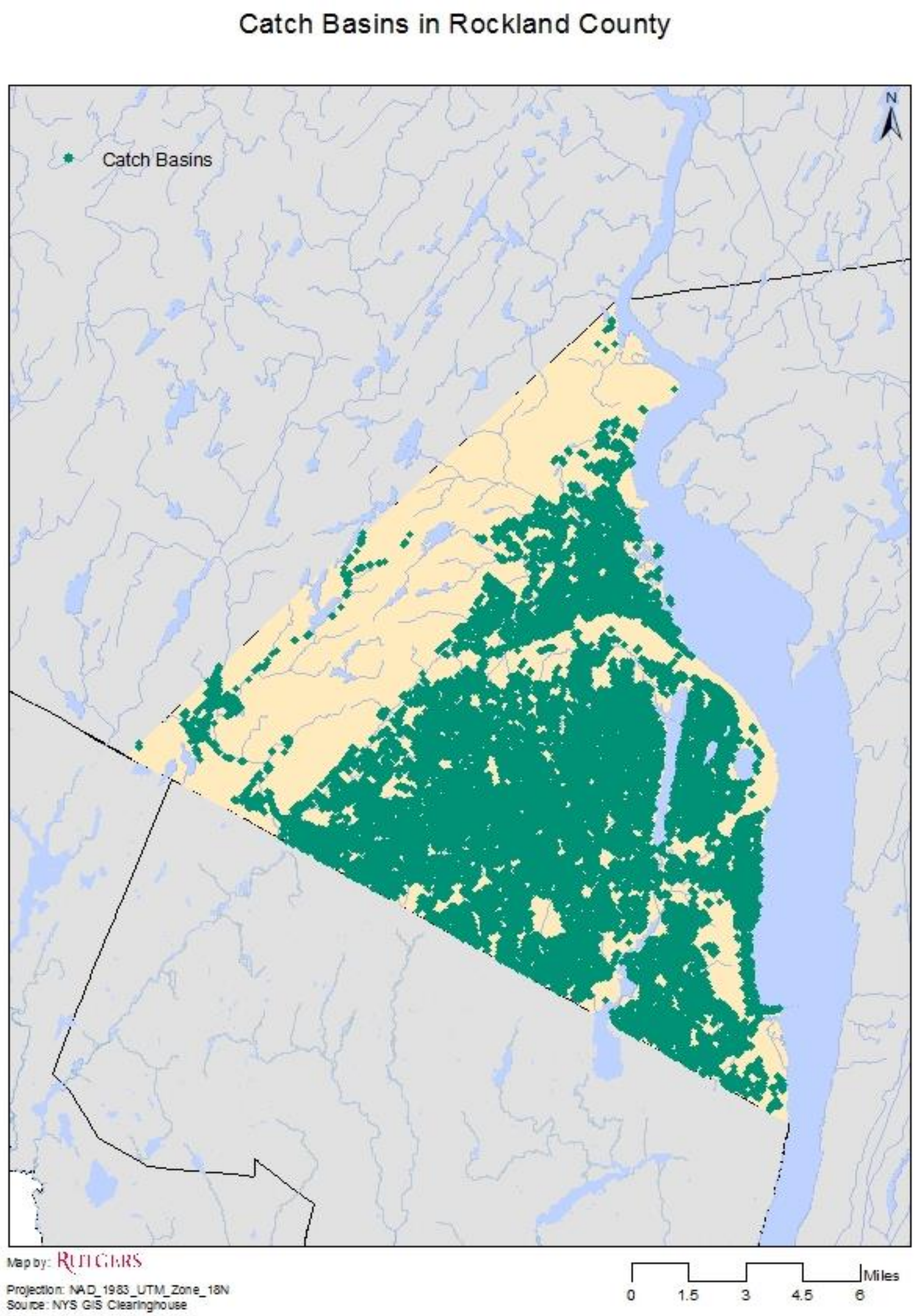


Figure VIII-7: Catch Basins in Rockland County.
Source: NYS GIS Clearing House

Implications of water infrastructure for hydrologic modifications and water quality

An increase in stormwater flows has the potential to increase the wet-weather streamflows unless a strategy for recharge augmentation is implemented. The increase in wet-weather streamflows reduces the amount of water for recharge, thereby leading to a reduction in base flow that supports stream ecosystems and water supply withdrawals. In essence, with the absence of storm water regulations and the increase in the impervious cover, the volume and velocity of stormwater discharges generated is on the rise. In addition, polluted stormwater is a potential cause for degradation of water bodies.

Sewage if not treated properly can be a major cause of pollution to the water bodies where it is typically discharged. Nutrients are an ongoing concern for further regulation of existing facilities. In addition, the inflow and infiltration of water into sewer systems can create flows that exceed the designed capacity of the wastewater treatment plants.

The amount of water pumped from a water supply source has an impact on the water levels in the entire aquifer, and also affects stream flows. Significant research on some aquifers has improved the potential for appropriate regulation of withdrawals, but additional modelling would be beneficial, and is in progress for the Ramapo River valley aquifers through Suez.

In order to clean and improve the surface waters and ground water and prevent them from getting polluted, regulations at the federal, state and county level have been instituted.

Regulatory requirements for new and upgraded infrastructure

The Rockland County Department of Public Health is responsible for ensuring the adequate supply of water for domestic, commercial and fire protection purposes and that the quality of water is safe for its intended use. New York State facilitates the protection of the fundamental water resources such as lakes and ground water resources and the sanitary code of Rockland County complements these regulations. The purview of the Department of Health extends to the regulation of well construction and well testing, as the entire hydrologic system is naturally interconnected, and ground water reserves are closely linked with surface water in lakes thereby demanding a multi-pronged approach.

Permits for wells:

Development of new wells requires permits and approvals from local and state agencies. All the wells require permits from NYSDEC and NYSDOH (e.g., allocation, well construction and testing, operation) in addition to the local site plan approvals and building department approvals from local municipalities where the well is proposed.

NYSDEC regulates the permit for any ground water withdrawal of 100,000 gallons per day or greater. The facilities in Ramapo and Hackensack watershed that have withdrawals greater than 100,000 gallons per day are shown in **Figure VIII-8**. The procedure for this permit requires a 3 to 5 day pumping test, nearby well interference testing, analysis of well and aquifer yield and consideration of potential surface water impacts. The entity that is constructing the well has to complete rigorous pumping tests required by NYSDEC to determine the sustainable yield of the well under drought and average capacity

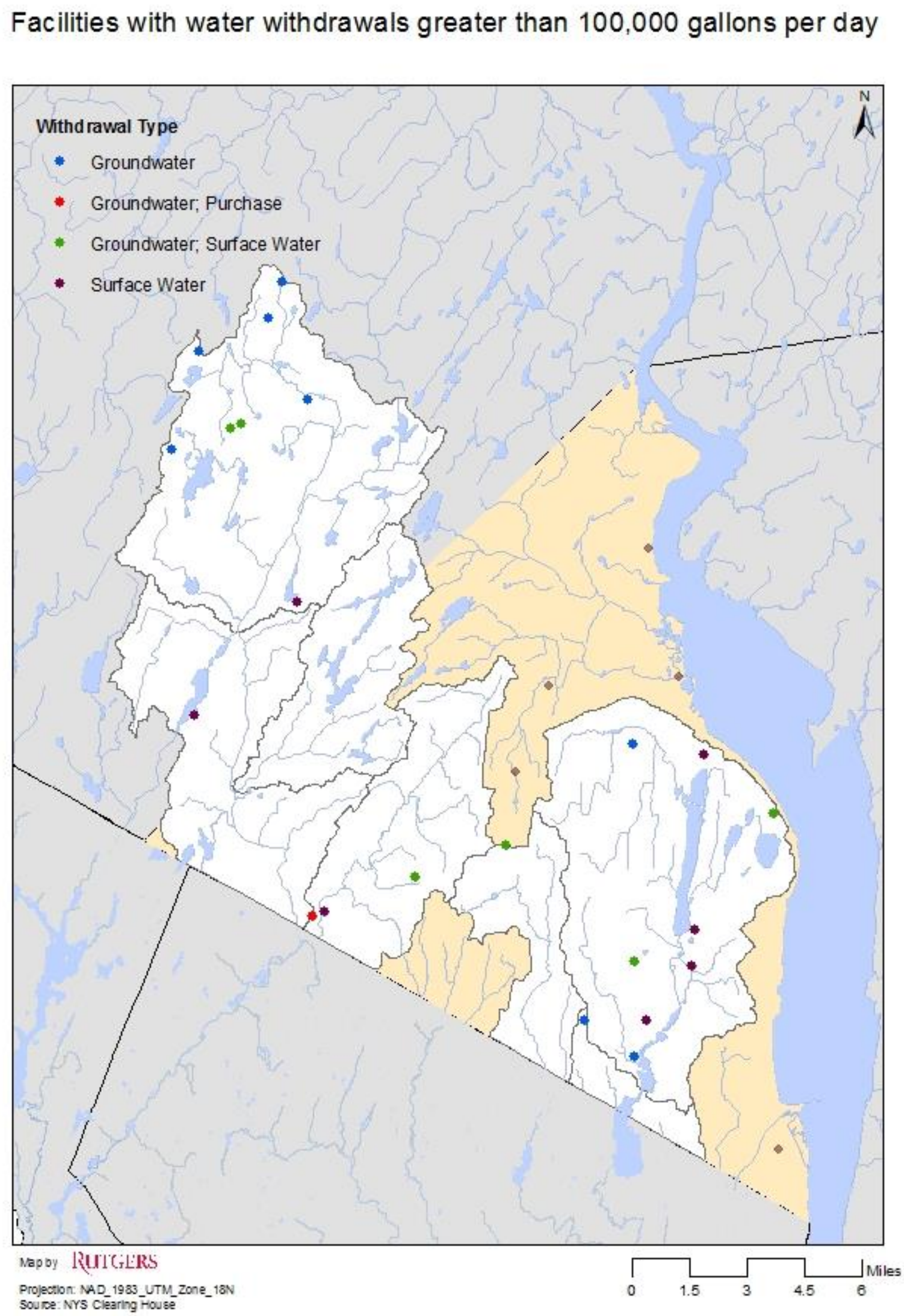


Figure VIII-8: Facilities with water withdrawals greater than 100,000 gallons per day.
Source: NYS GIS Clearinghouse

withdrawal rates, determine potential impacts on nearby ground water users and also potential effects on surface water resources (e.g. wetlands and streams).

Application to construct a well:

For anyone planning to construct a well, irrespective of its capacity, the RCDOH Application for Permit to construct a water supply well has to be completed by the property owner as well as the contractor who is engaged in the well construction. Along with the form, the additional documents to be submitted to the commissioner are a site plan depicting the topography, indicating the 100-year flood plain, all the natural features and infrastructure elements on the site which are at a distance of 250 feet from the proposed well location. A written statement must be submitted to the commissioner describing suspected contaminants that could potentially impair the ground water, surface water, and bedrock within 250 feet of the proposed well. (Article II, Rockland County Sanitary Code)

The Rockland County Department of Health is mandated to provide technical assistance to residents regarding their drinking water wells. **Table VIII-7** represents the required minimum separation distances to protect water wells from contamination.

Residential Well Testing:

The Rockland County Legislature recognizes that many of the Rockland County residents are dependent on private water systems as their source of drinking water. Additionally, disclosures regarding the contamination of well water as a result of ground water contamination by industrial, commercial and pesticide discharges have initiated calls for testing of private wells to test for ground water contamination. Well testing is required to be conducted by the property owners prior to the sale of residential homes or on an on-going basis for rental properties. Not only does this regulation protect the residents from contaminated water but it also helps in keeping a record of all the private well systems within the county.

When any resident intends to sell his or her property, upon the signing of a contract of sale for any property served by a private water system, the seller is required to obtain a written certificate from a New York State-approved laboratory that tests the untreated or raw water and conforms to the Rockland County water standards for such residences.

When a landlord offers the public with a rental property, the private water system must be tested every five years before it is rented and the tenants shall be handed a copy of the test results. Additionally, a copy of the test results should also be submitted to the Rockland County department of Health (Article II, Rockland County Sanitary Code).

Land requirement for public wells:

The public community wells in Rockland are regulated by NYSDOH to ensure the quality of water supplied to consumers meets applicable health standards. The NYSDOH requires the ownership of a 100-foot radius around a public community supply well, and a pollution easement of the area extending 200 feet from the well. In effect, the radius of 200 feet from a well occupies 2.9 acres of land; finding such a stretch of undeveloped area is a challenge in Rockland County, given the existing development

Contaminant Source	Distance (Feet)[1]
Chemical storage sites not protected from the elements (e.g., salt and sand/salt storage)[2]	300
Landfill waste disposal area, or hazardous or radiological waste disposal area[2]	300
Land surface application or subsurface injection of effluent or digested sludge from a Municipal or public wastewater treatment facility	200
Land surface application or subsurface injection of septage waste	200
Land surface spreading or subsurface injection of liquid or solid manure [3]	200
Storage Areas for Manure piles [4]	200
Barnyard, silo, barn gutters and animal pens [5, 6]	100
Cesspools (i.e. pits with no septic tank pretreatment)	200
Wastewater treatment absorption systems located in coarse gravel or in the Direct path of drainage to a well	200
Fertilizer and/or pesticide mixing and/or clean up areas	150
Seepage pit (following septic tank) [5]	150
Underground single walled chemical or petroleum storage vessels	150
Absorption field or bed [5]	100
Contained chemical storage sites protected from the elements (e.g. salt and sand/salt storage within covered structures) [7]	100
Septic system components (non-watertight) [5]	100
Intermittent sand filter without a watertight liner [5]	100
Sanitary Privy pit [5]	100
Surface wastewater recharge absorption system constructed to discharge storm water from parking lots, roadways or driveways [5]	100
Cemeteries	100
Sanitary privy with a watertight vault	50
Septic tank, aerobic unit, watertight effluent line to distribution box	50
Sanitary sewer or combined sewer	50
Surface water recharge absorption system with no automotive-related Wastes (e.g., clear-water basin, clear-water dry well)	50
Stream, lake, watercourse, drainage ditch, or wetland	25
All known sources of contamination otherwise not shown above	100

Table VIII-7: Minimum separation distances to protect water wells from contamination.
Source: From the Rockland County Website

pattern and the undulating topography of the county. Not only is securing an undeveloped land occupying approximately 3 acres a significant hurdle but also getting the owner to sell the property proves to be an additional task.

Regulatory requirements for existing infrastructure:

In order to regulate whether the existing infrastructure is performing up to the mark, the RCDOH regulates the repair, cleaning or other modifications that involve well drilling operations. These activities require a Permit to perform maintenance on a well from the RCDOH. Deepening an existing well does not fall into the permission required for maintenance category and requires a Permit to Construct a Water Supply Well instead. The decommissioning of a well also requires permission from the commissioner by the property owner.

Connections and Interconnections:

The commissioner has the full discretion to decommission, or impose restrictions on any water system or of any bottled or tanked water not meeting the requirements of the Rockland County Sanitary code or the New York State Sanitary code. The commissioner has the authority to permit additional connections to existing water systems or permit a change of use for the existing system whether potable or non-potable. Permission from the commissioner for a cross connection control device is mandatory to establish a connection between any water system or water system with any facility, piping, structure or vehicle containing sewage (Article II, Rockland County Sanitary Code).

Stormwater Regulatory Requirements:

The MS4 regulated areas are required to prepare a strategy for protecting water quality due to storm water run-off. Permits are required by municipalities for the stormwater discharges from Municipal Storm Sewer Systems (MS4s) in an urbanized area. Owners of these facilities are expected to comply with the SPDES General permit for stormwater discharges.

The six mandatory program components to be included in the stormwater management plan are as follows:

1. **Public Education and Outreach**: This involves activities such as the distribution of educational material to inform the public about the impacts of pollution from stormwater runoff.

2. **Public Involvement**: This involves engaging the public in the public hearings to participate in the stormwater management program process.

3. **Illicit Discharge Detection and Elimination**: The MS4 municipalities are required to map stormwater outfall locations and the receiving water bodies, mapping of the storm water sewer shed, and prohibit the illegal discharges through laws and ordinances.

4. **Construction Site Runoff Control**: Any construction activity that disturbs than or equal to one acre of land must demonstrate an erosion and sediment control program. The incorporation of Erosion and Sediment controls is detailed in the New York State Standards and Specifications for Erosion and Sediment Control or the Blue Book.

5. **Post-construction Runoff Control**: For new development a plan has to be enforced that addresses stormwater runoff. This could include preventive actions such as the protection of sensitive areas or the use of structural controls such as the incorporation of porous pavements.

6. **Pollution Prevention**: This requires the development of a plan that either prevents or reduces pollutant runoff from municipal operations. A number of activities such as regular street sweeping, reduction in the use of pesticide or street salt, or frequent cleaning of catch basins are examples of ways to reduce pollutant runoff from municipal operations.

Areas served by private wells and septic systems; implications for water resources

According to available information, roughly 6,000 domestic wells exist in Rockland County, some of which are for homes that may also have public water supply connections. Septic systems will exist in a few areas not served by public sewer systems, especially in the western part of the county that has some more rural area.

IX. Draft Scopes of Work for Watershed Projects

Project 1: Road Salt Management

The evidence is clear that surface and ground water salinity levels have doubled, tripled or more since the 1960s, and that road salt is the culprit. This project would document the trends over time in road/lane miles, winter road salt applications, road salt applications per lane mile, and salinity levels, all using existing information and salt application data compiled from road maintenance departments. Areas with elevated salinity levels are priorities, especially where well fields are affected. The project would recommend and educate public elected officials and public works departments on specific practices that would reduce road salt levels without materially harming public safety. Such practices exist and are well known and applied in other areas. This project can be a county-wide effort, as salinity is increasing in all developed areas.

Project Steps

1. Compile and evaluate ground and surface water salinity data, including available historic data.
2. For surface water data, map contributing watersheds and identify road miles (current and trend) within those areas.
3. For ground water data, map location of wells under the influence of surface water (e.g., Ramapo Valley well fields) and well head protection areas (WHPAs, using simple models such as for the New York State Source Water Assessment Program Plan, 1999, see page 18), and identify road miles (current and trend) within those areas.
4. Compile salt application information from all public agencies responsible for winter road safety within the areas identified in Steps 2 and 3. Determine salt application density (pounds per lane mile per season).
5. Compare salt application density to water salinity levels compiled in Step 1. Determine the extent to which the application density correlates with salinity levels. Note that some waters may be more or less susceptible to elevated salinity levels.
6. Through discussions with road departments, the Salt Institute (http://www.saltinstitute.org/) and other experts, identify methods to reduce overall salt use and water salinity levels such as brine applications, alternative chemicals in water supply areas, etc. Establish feasible targets for salinity decreases.
7. Implement educational programs for the public, public officials and especially public works officials and staff regarding the salt reduction techniques.

Recommended Qualifications for Project Team:

The project can be conducted by existing county personnel if available, by college project studios or interns, or by part-time professional assistance. It also would be possible for a qualified non-governmental organization to undertake this project with a foundation or government grant, with county cooperation. An advisory committee of road maintenance agencies, experts and water utilities would be beneficial.

Preliminary Estimate of Cost Range:

Minimal (likely less than $2000-$3000).

Project 2: Assessment of Stream and Riparian Area Integrity

This project will use a combination of GIS data, remote sensing information (e.g., aerial photography) and field surveys to assess the integrity of stream channels and their associated riparian areas. Specific issues will be areas of stream channel disruption (e.g., scour, channelization), stream blockages (e.g., culverts, bridges, sediment areas), and riparian area losses and damages. Assessment methods similar to the "Stream Visual Assessment Protocol" (Natural Resources Conservation Service, 1998) or "Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State" (NYSDEC, 2014) can be used. The purpose of this project is to identify areas for protection, for site-specific restoration (e.g., through control of stormwater outfalls that are scouring a stream), for bridge culvert modifications as a co-benefit of bridge reconstruction projects, for reach- or subwatershed-level control of stormwater inputs to reduce channel erosion, and for large-scale restoration projects including dam removals. This project can be conducted in multiple phases, starting with county-wide GIS-based analyses and then watershed or subwatershed field investigations. The purpose of this project is development of plans that will lead to improved stream ecosystems and that are eligible for state and federal implementation funding.

Project Steps

1. Using GIS, identify all stream channels and locate road crossings, stormwater outfalls, channelized segments, and adjacent land uses.
2. Using GIS, identify riparian areas based on hydrologic and ecologic features (i.e., not a uniform distance from the stream bank) so that the relevant functions of the riparian areas are captured. Example methods can be found from two nearby New Jersey programs: the Sussex County Open Space Plan: Technical Report 1: Land Preservation (2016) and the Highlands Council's Ecosystem Management Technical Report (2008). Identify riparian areas that have been developed or modified.
3. Identify prior subwatershed for field evaluation of stream and riparian area integrity.
4. Select a stream integrity evaluation method and train staff or consultants in its use.
5. Evaluate stream and riparian area integrity in the high priority subwatersheds, including physical, chemical (basic parameters) and biological impacts, and identify specific issues of physical intrusion into the riparian area or stream channel that appear to be damaging hydrologic or ecologic function, including stormwater outfalls, bridge culverts, and channelization.
6. Create a triage protocol to identify:
    a. Simple, low-cost projects that can be implemented quickly or by volunteers
    b. High priority, focused restoration projects that can create major benefits quickly
    c. High priority projects that will require modification of transportation structures, and should be addressed either immediately (i.e., imminent danger to public safety) or when the structures will be rehabilitated through ongoing transportation priority systems.
    d. High priority, large-scale issues that will require more detailed modeling, planning and design through future projects
7. For each subwatershed, implement the triage process and develop an implementation plan.

Recommended Qualifications for Project Team:

The initial GIS phase could readily be accomplished by county GIS staff if available, or by GIS consultants or qualified GIS students with assistance from Cornell Cooperative Extension (Soil and Water Conservation Districts). Field evaluations should be performed by professionals with extensive understanding of stream and riparian area stresses. The results must be analyzed by professionals with expertise in stream ecology and engineering

Preliminary Estimate of Cost Range:

The GIS phase likely requires between two and three weeks of work. The field analyses require professional assistance, with costs dependent on whether done in-house (up to two weeks per HUC12 subwatershed) or using consultants (perhaps $5,000 per subwatershed). Costs might be reduced through the involvement of trained volunteers, a "citizen science" approach. Analysis of the results will require on the order of two weeks of professional time (60-80 hours) at in-house or consultant rates.

Project 3: Recharge Loss Evaluation

This project will provide a preliminary analysis of recharge losses due to development at the subwatershed level, using a combination of GIS analysis of impervious cover, county surveys of stormwater outfalls, GIS analysis of likely storm sewer networks based on topographic evaluations (especially if LiDAR mapping is available), and simple ground water models. The project purpose is to identify the general extent of recharge losses by subwatershed, as a basis for regulation of future development (e.g., requiring that post-construction recharge equal pre-construction recharge) and redevelopment (e.g., requiring restoration of some portion of lost recharge from the initial development). This project will also be useful in identifying stormwater basins that could be retrofit to provide recharge in addition to detention or retention.

A better approach requiring considerable additional work is the development of a ground water infiltration model. No method currently exists for identifying the location and relative rate of ground water infiltration and recharge in this region. A method was developed for similar soils and geology in New Jersey (Charles et al., 1993) that may be relevant and perhaps transferable to the Ramapo and Hackensack watersheds. The method uses precipitation information, soil classifications, land use/land cover, and stream baseflow information. This method has been updated to be used on GIS. Further analysis would be needed by a qualified hydrogeologist to determine whether the method is readily transferable to this region.

Project Steps

1. Identify available methods (if any) for estimating ground water infiltration or recharge based on land cover, precipitation and other factors and determine whether the method is applicable or transferable to the region.
2. If a method is available and applicable, apply it to the target watersheds using available GIS information.
2. If no method is available and applicable, map impervious surfaces and stormwater outfalls.
3. If LiDAR data are available, use GIS to identify the land areas that are upgradient of the stormwater outfalls and within areas that have impervious surfaces (stormwater catchment

areas). Otherwise, the same exercise can be attempted using other digital topographic information.

4. For each subwatershed, determine the relative acreage of impervious area within likely stormwater catchment areas.
5. Compile subwatersheds upstream of each stream flow gauging station. Compare the relative level of impervious areas within stormwater catchment areas to stream flashiness and low flow metrics. Estimate the correlation between impervious surfaces and stream flow characteristics.
6. Identify priority subwatersheds where stormwater systems retrofits could allow for artificial recharge of stormwater, and where additional stormwater requirements for new development and redevelopment are high priority to protect remaining recharge rates.

Recommended Qualifications for Project Team:

The GIS work involved in this project can readily be accomplished with county GIS staff if available, or a graduate student with GIS expertise. A hydrologist is needed to assess base flow and peak flow information available from USGS and other gauging station data, using available base flow and stream flow analysis models, and to interpret the results. The project could rely on existing GIS data, reflecting development to a point in time, but would benefit by updated mapping of impervious surfaces at an additional cost. Another option is to engage a graduate student to undertake this project as the basis for a master's thesis in hydrogeology, including development or modification of a recharge model.

Preliminary Estimate of Cost Range:

If an existing model is available for use in GIS, the costs of this project would be minimal, requiring perhaps three to four weeks of effort between the hydrologist and GIS staff. If an existing model is transferable to the area with modifications, a qualified hydrologist would need to prepare the revised model, increasing the costs considerably but at probably less than $50,000.

Project 4: Subwatershed Water Quality Plans for Nonpoint Source Pollution

This project would focus on specific subwatersheds to identify the primary sources of pollutants identified through NYSDEC and county stream monitoring programs. Initially, we recommend a focus on two subwatersheds. One would be a Ramapo River subwatershed that is currently facing significant development pressures, as a method of improving land preservation, zoning and site design requirements for protection of the subwatershed. The other would be a Hackensack River subwatershed upstream of either Lake DeForest (for improvement of reservoir quality) or the Nyack water supply intake (for improvement of intake water quality). For each subwatershed, this project requires field monitoring of water quality during low flow and higher flow periods. Robust nonpoint source modeling will be developed, but not as sophisticated as a TMDL model for point source loadings. The plan would identify the major categories and locations of pollutant sources, and then recommend a combination of education, incentives, capital projects (e.g., stormwater system modifications), and regulatory requirements that will improve water quality. Runoff and stormwater pollutant reductions, reductions in pollutant generation from stream erosion (through stream restoration and the reduction of stormwater peak flows that cause scour) and base-flow augmentation (through increased stream base flows, not reservoir releases) can all be considered. The purpose of this project is development of plans that will reduce pollutant and flow stresses on water supply streams and that are eligible for state and federal implementation funding.

Project Steps

1. Create a project team and an advisory committee for the project. The advisory committee should be representative of major interests and agencies associated with water quality issues in the area. In addition, the advisory committee should engage in and be part of broader public outreach efforts to ensure that the resulting Clean Water Plan reflects and addresses the critical issues and has the greatest potential for success.
2. Identify target subwatersheds where point source pollution is not a dominant cause of water quality problems. At least one subwatershed should be at risk of additional pollution due to future development, and at least one subwatershed should be a developed area that contributes flow to a surface water supply resource.
3. Based on the specific needs of each subwatershed, create a detailed scope of work for the development of a Nine Element (9E) Clean Water Plan (see the NYSDEC general web site at http://www.dec.ny.gov/chemical/103264.html and the NYSDEC guidance document at http://www.dec.ny.gov/docs/water_pdf/9elements.pdf). The following components should be addressed in the plan, and can be used in developing a request for proposals to engage a qualified consultant.
    A. Identify and quantify sources of pollution in subwatershed
    - Identify an appropriate modeling software package for use in assessing relative nonpoint source loadings from land uses and land cover types. Models frequently used for this purpose include SWMM (Storm Water Management Model, see https://www.epa.gov/water-research/storm-water-management-model-swmm) and BASINS (Better Assessment Science Integrating point & Non-point Sources; see https://www.epa.gov/exposure-assessment-models/basins) from US EPA. The complexity of the modeling process should be the minimum necessary to effectively represent the nonpoint source pollution issues. Modeling of highly developed subwatersheds may require a more sophisticated model, as the effects of stormwater flows in streams will be an important factor in stream water quality. Public or open source model software should be used to ensure that the model can be modified over time regardless of selected consultant.
    - Identify land uses and land cover
    - Identify appropriate nonpoint source loading rates per acre (Event Mean Concentrations or similar concepts) for each land use/land cover type
    - Develop a subwatershed-specific model using the nonpoint source loadings along with available flow and water quality data.
    - Using the results of the initial modeling, develop a water quality and stream flow monitoring plan to address data needs for model calibration and verification, especially for any subwatershed stream reaches with major existing or future nonpoint source pollutant loadings that lack recent monitoring data. Create and receive NYSDEC approval of a Quality Assurance Project Plan (QAPP).
    - Implement the monitoring program, compile and quality check the data, and develop an assessment of the results.

- Modify, calibrate and verify the subwatershed-specific model using the compiled flow and water quality data.
- Develop a technical modeling report with a public version that can be understood by key interest groups and agencies, and engage in public participation regarding the results of the modeling process.

B. Identify water quality target or goal and pollutant reductions needed to achieve goal

- Assess the difference between water quality standards and both current and future water quality and provide this information to the advisory committee and public.
- Through a public process, identify any additional objectives beyond compliance with water quality standards, such as antidegradation policies, achievement of better quality than standards, etc.
- Through a public process, evaluate options for allocation of nonpoint source pollution loadings to achieve the water quality objectives. Options may include even distribution of pollutant reductions, cost optimization, consideration of technological feasibility, consideration of equity issues, etc.
- Through a public process, select nonpoint source load allocations for use in the plan.

C. Identify the best management practices (BMPs) that will help to achieve reductions needed to meet water quality goal/target

- For each nonpoint source pollutant category, identify and discuss the BMPs available and applicable for pollutant load reductions.
- Select the most viable BMPs and implementation methods, including education, training, in-field technical assistance, incentives, financial assistance and regulation. Note that for any one pollutant source, more than one BMP may be viable.

D. Describe the financial and technical assistance needed to implement BMPs identified in Element C

- Develop a program of financial and technical assistance for BMP implementation.
- Secure commitments of resources for initial phases of implementation.
- Secure commitments of intent for future phases of implementation.

E. Describe the outreach to stakeholders and how their input was incorporated and the role of stakeholders to implement the plan

- The stakeholder process should be robust enough to ensure that all major points of view are heard and recognized, that equitable treatment is ensured of those who may be required to reduce nonpoint source pollution and those who will be affected by the costs of such actions, and that no interest is able to dominate the process to the exclusion or diminishment of other interests. The process also should be cost-effective and focused on actions that secure the best plan for the least procedural cost.
- The plan should thoroughly document the stakeholder process.

F. Estimate a schedule to implement BMPs identified in plan

- Create a priority-based schedule for short-term, medium-term and long-term actions, with information on relative costs and priorities.
- Emphasis should be placed on achieving results in the short term using low-cost, higher impact BMPs wherever possible, followed by longer-term, cost-effective BMPs.

G. **Describe the milestones and estimated time frames for the implementation of BMPs**
   - Create a program tracking system that combines procedural steps and project completion milestones.
   - Create a listing of time frames for phased achievement of the procedural steps, project completion milestones, and environmental improvement milestones.
   - Create a process for public acknowledgement of process to help foster continued public support for plan implementation.

H. **Identify the criteria that will be used to assess water quality improvement as the plan is implemented**
   - Identify the critical water quality, stream flow and ecological parameters to be used in assessing progress toward the environmental goals.
   - Identify phased trends and thresholds of success for each parameter.

I. **Describe the monitoring plan that will collect water quality data need to measure water quality improvement (criteria identified in Element H)**
   - Create a monitoring system that tracks (assumed) nonpoint source reductions from BMP implementation, plus environmental improvement milestones (e.g., water quality, base flow, stream ecology)
   - The system should recognize that environmental improvements will become apparent only after enough projects have been completed to measurably change nonpoint source inputs and enough time has passed for the stream system to reflect those changes.
   - Develop and receive NYSDEC approval of a Quality Assurance Project Plan (QAPP) for field monitoring components of the monitoring system.

4. Secure local approval of the Clean Water Plan for each subwatershed.
5. Secure NYSDEC approval of the Clean Water Plan for each subwatershed.

Recommended Qualifications for Project Team:

The project team will require water flow and quality monitoring and modeling skills (e.g., for SWMM, BASINS and similar public models), with extensive expertise and experience in the development of watershed management plans for nonpoint source pollution. This project is not suitable for student projects or professionals without experience in these activities.

Preliminary Estimate of Cost Range:

Each subwatershed plan is likely to cost $150,000 to $300,000 depending on the level of water quality and flow monitoring costs involved to generate the model. The project can be implemented in phases, such as with development of a conceptual model, monitoring plan and monitoring implementation, and technical report as the first phase, and development of the management plan as the second phase. Another phasing approach would be to develop the modeling at the watershed scale first, and then development management plans at the subwatershed scale. However, this approach might result in a more complex modeling and monitoring process than is truly needed based on the known issues, as some subwatersheds may pose few or no issues and therefore not require modeling. Public participation would occur throughout. For best results, updates to GIS information on land use/land cover, impervious surfaces, etc., would be developed as an additional cost.

Project 5: Stormwater Infrastructure Asset Management Evaluation

Stormwater systems are shifting in function, from quick removal and discharge (regardless of stream damages) to a more integrated approach. No fee-based stormwater utilities exist in this region. Stormwater management functions are distributed among state agencies (e.g., NYSDEC and the Thruway Authority), counties (e.g., county-regulated streams and stormwater systems for county roads and facilities), municipalities (e.g., land development review and stormwater systems for municipal roads and facilities) and property owners for on-site systems. This project will identify the location, design, current condition and functionality of stormwater infrastructure, and its impact on water resources. The purpose is to identify infrastructure components that are inadequate for modern functions (e.g., insufficient design capacity, excessive discharge rates), degraded, or causing environmental harm. The purpose of this project is development of plans that will reduce pollutant and flow stresses on streams and that are eligible for property owner, municipal, county, state and federal implementation funding. Given the complexity of this analysis, we recommend focusing on specific subwatersheds where problems have been identified under Project 2, or on the priority subwatersheds under Project 4.

Project Steps

1. Create a multi-agency project team and identify a project leader to coordinate activities.
2. Identify all available information (GIS and paper) of existing stormwater infrastructure. This process may be implemented in phases, such as for priority subwatersheds, as stormwater systems will almost entirely be contained within subwatershed boundaries.
3. Create a GIS database of stormwater infrastructure with attribution information on the source and quality of the information.
4. Develop a process for collecting additional component location information and updating the GIS database.
5. Develop a protocol for assessing the integrity of various stormwater infrastructure components. The assessment should confirm or provide new information on the location, design, current condition and functionality of stormwater infrastructure, and its impact on water resources.
6. Implement the assessment protocol in high priority subwatersheds and then extend to other subwatersheds as resources permit.
7. Identify stormwater infrastructure maintenance, rehabilitation or upgrade/retrofit projects that will provide optimum environmental and public safety benefits in a cost-effective manner, by subwatershed.
8. Identify responsible parties and potential funding sources for all priority projects.

Recommended Qualifications for Project Team:

The project team will require the involvement of all governmental entities with responsibility for the management and regulation of stormwater infrastructure. Some portions of the work can be outsourced to consultants, particularly field inspections of infrastructure integrity, which requires engineering expertise.

Preliminary Estimate of Cost Range:

Total effort for this project in the two watersheds is likely to require up to two work-years of professional effort spread across multiple governmental entities, with county GIS staff involvement and a county coordinator. We recognize that additional staffing may be required to implement this project at the county level. Some portions of the work can be outsourced to consultants, particularly field inspections of infrastructure integrity, but most of the information that needs to be compiled will be in county and municipal government files, such as system designs.

Project 6: Sewer Infrastructure Asset Management Evaluation

The USGS estimates that 0.8 MGD of ground water is moving into sewers, diluting wastewater, increasing treatment costs, and reducing stream flows. Given that aging infrastructure will cause these problems to increase over time, implementation of an ongoing asset management program will help reduce (though not eliminate) infiltration and inflow, minimize the potential for sewer line failure, etc. This work involves an inventory of all wastewater utility assets, assessment of asset integrity, and a planned program of rehabilitation using cost-effective techniques.

Project Steps

1. Identify all available information (GIS and paper) of existing sewer system infrastructure. This process may be implemented in phases, such as for priority subwatersheds where evidence exists of sewer exfiltration (causing water quality problems) or inflow/infiltration, causing interbasin water transfers and excess treatment costs.
2. Create a GIS database of sewer infrastructure with attribution information on the source and quality of the information.
3. Develop a process for collecting additional component location information and updating the GIS database.
4. Develop a protocol for assessing the integrity of various sewer infrastructure components. The assessment should confirm or provide new information on the location, design, current condition and functionality of sewer infrastructure, and its impact on water resources.
5. Implement the assessment protocol in high priority subwatersheds and then extend to other subwatersheds as resources permit.
6. Identify sewer infrastructure maintenance, rehabilitation or upgrade/retrofit projects that will provide optimum environmental and public safety benefits in a cost-effective manner, by subwatershed.

Recommended Qualifications for Project Team:

Wastewater utilities will likely need to use a combination of staff and consulting engineers for this project.

Preliminary Estimate of Cost Range:

As this should be a normal function of wastewater utilities, this work is viewed a responsibility of the utilities and not an appropriate use of watershed management planning funds.

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