Highlands Council
New Jersey

Water Resources Volume I
Watersheds and Water Quality

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Prepared by State of New Jersey Highlands Water Protection and Planning Council in Support of the Highlands Regional Master Plan

Technical Report

HIGHLANDS REGIONAL MASTER PLAN

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EXECUTIVE SUMMARY

The Watersheds and Water Quality Assessment element of the Water Resources Technical Report (Volume I) summarizes the existing environmental condition of the Highlands Region's critical water resources including watersheds, surface water, and ground water, in order to inform land use, preservation, management, and regulatory priorities for the Highlands Region. Its fundamental purpose is to identify the water resources in need of protection, the stresses on those resources, and the overall setting in which they exist.

Watershed Management Areas of the Highlands

NJDEP has grouped the watersheds of New Jersey into 20 Watershed Management Areas (WMAs), eight of which are located entirely or partially within the Highlands Region as follows:

- Upper Delaware River - WMA 1
- Wallkill River - WMA 2
- Pompton, Pequannock, Wanaque, Ramapo Rivers - WMA 3
- Lower Passaic and Saddle River - WMA 4
- Upper Passaic, Whippany and Rockaway Rivers - WMA 6
- North and South Branch Raritan River - WMA 8
- Main Stem (Lower) Raritan River - WMA 9
- Central Delaware Tributaries - WMA 11

This report summarizes the physical characteristics of the Highlands portions of the eight WMAs including a brief description of their drainage area, water bodies, topography and geology, soils, wildlife resources, water supply, and land use. The majority of the source information is derived from NJDEP Watershed Characterization and Assessment reports that were prepared for each WMA.

Water Quality of the Highlands

With the exception of the bacterial or sanitary parameter, surface water quality was generally found to be slightly higher in the Highlands compared to overall conditions statewide. Bacterial impairment was more extensive in the Highlands than observed statewide. As a result, the most common designated uses found to be impaired in the Highlands were primary contact recreation due to unacceptable bacterial quality, with 91% of assessed water body units not supporting primary contact use. Aquatic life support was also found to be impaired, with 65% of assessed water bodies not supporting the use. The most common water quality parameters in violation of surface water quality standards and with a TMDL established in the Highlands were bacteria, temperature and phosphorus.

Nine sites located within the Highlands Region were reviewed by NJDEP for water quality trends from 1984 to 2004. Of the constituents assessed, dissolved oxygen (DO), DO saturation, and nitrate (NO_3) showed stable conditions over time. Total dissolved solids (TDS) and specific conductance increased over time, and ammonia (NH_3) and total phosphorus (TP) decreased over time. Total nitrogen (TN) fluctuated over the time period, with four sites showing no measurable trend and four sites indicating decreased concentrations.

Total Maximum Daily Loads (TMDLs) have been adopted by NJDEP for many Highlands Region surface waters. These include TMDLs for fecal coliform bacteria and phosphorus loadings in various lakes and river segments, arsenic in the Wallkill River and Papakating Creek, and for temperature in the Pequannock River.

Based on available data, ground water quality is good in the deeper portion of the bedrock aquifers used for potable supplies. However, ground water may require treatment for various parameters (such as low or high pH) and certain contaminants (such as manganese or radionuclides) on a localized basis.

Of the 150 wells in NJDEP's statewide shallow ground water quality network, 23 are in the Highlands. These 23 wells are distributed among undeveloped, agricultural, and urban land use areas. Three of the eight wells in agricultural areas exceeded the drinking and ground water quality standards of 10 mg/L for nitrate plus nitrite. Pesticides were detected in seven of eight wells in agricultural areas and five of nine wells in urban areas. The concentration of individual pesticides was low in all land use categories.

Volatile organic compounds (VOCs) were detected in seven of nine wells in urban areas. Benzene, tetrachloroethylene, and trichloroethylene were the only compounds with concentrations exceeding drinking and ground water quality standards. There is evidence that shallow ground water quality is affected by land use activities in the Highlands Region. These contaminants in shallow ground water can migrate to and affect the deeper aquifer systems and receiving surface waters.

Nitrates Concentrations and Septic System Density of the Highlands Region

Nitrate concentrations are an indicator of overall ground water quality, and can serve as a surrogate for other pollutant parameters that are less frequently measured. Nitrate requires the greatest dilution of the constituents consistently found in septic effluent to attenuate the concentration in ground water. There is also a lower relative cost and greater laboratory availability to perform nitrate, versus many other constituent analyses.

The Highlands Council engaged the U.S. Geological Survey Water Science Center (USGS) to develop an analysis of background nitrate concentrations. The analyses determined that five factors are most correlated with nitrate concentrations. These are agricultural and urban land use, septic system density, length of streams and the presence of known contaminated sites within a HUC14. Based on these factors and water quality data from 352 wells in the Highlands Region, statistical models were developed to determine nitrate concentration estimates. Few well water samples exceeded 10 mg/L, the drinking and ground water quality standard, but many were higher than background levels, indicating water quality impairment from elevated nitrate concentrations.

Background nitrate concentrations were determined by HUC14 subwatershed, for the Highlands Region as a whole, and for undeveloped areas. Based on this analysis, median nitrate concentrations estimated for HUC14 subwatersheds range from 0.17 mg/L to 3.6 mg/L. These median concentrations reflect a broader range of likely concentrations within each HUC14 subwatershed, based on varying land use patterns. The median concentration for the Highlands Region overall is estimated as 0.83 mg/L and the median nitrate concentration in undeveloped areas was estimated to be 0.1 mg/L.

The median nitrate concentrations for the Protection and Conservation Zones within the planning areas of the Highlands Region were estimated to be 0.72 and 1.87 mg/L, respectively, and these concentrations were selected as the nitrate dilution targets for these two zones. By comparison, the median nitrate concentration estimated for the Existing Community Zone is 1.17 mg/L. For this zone, a nitrate target concentration of 2.0 mg/L, corresponding to NJDEP state-wide target, was selected for the regional build out analysis regarding the limited parts of this zone not served by public wastewater treatment systems. The selected target nitrate concentration of 2.0 mg/L reflects the protection and smart growth standards of the Existing Community Zone.

After the input values for the input variables were obtained, the Trela-Douglas model was used to calculate acceptable septic system densities for the three LUC zones in the Planning Area. For the 183 subwatersheds, the median septic system densities computed for the Existing Community, Conservation, and Protection Zones are 9.4, 10.0 and 26.1 acres per septic system, respectively. It should be noted that a number of these subwatershed are located exclusively in the Preservation Area, and would not be subject to these Planning Area densities.

Following computation of the appropriate densities with the Trela-Douglas model, septic system yields were computed within the three Planning Area zones for each municipality based upon developable land existing within each. Developable land was estimated from existing MODIV (tax assessment) data, and included both vacant and oversized lots, as defined by septic system densities, and excluded publicly owned lands. The septic system yield was then computed for each municipality by dividing calculated septic system density into the developable planning land area available for each zone. The total septic system yield in the Planning Area is shown below, by zone.

Additional Septic Systems For Each LUC Zone Within The Planning Area	
Land Use Capability Zone	**Number of Additional Septic Systems**
Conservation Zone	5,476
Protection Zone	1,068
Existing Community Zone	920

HYDROLOGIC UNITS OF THE HIGHLANDS

New Jersey uses a system developed by USGS consisting of Hydrologic Unit Codes (HUC), with a naming convention to identify these areas. Each HUC is delineated based on topography, so that a larger hydrologic unit (e.g., a river basin) is entirely comprised of a set of smaller hydrologic units (e.g., watersheds), each of which is comprised of a set of still smaller hydrologic units (e.g., subwatersheds).

The largest HUC type in New Jersey is the eight digit HUC (HUC8), which includes entire river basins such as the Passaic and Raritan River Basins. The Rockaway and Whippany River watersheds are both HUCs with eleven digit identifiers (or HUC11). They are both Passaic River tributaries; therefore, the first eight digits of their codes are the same as for the Passaic River Basin HUC8. HUC14 subwatersheds carry the first eleven digits of their "parent" HUC11 watershed and are nested within it, such as the Malapardis Brook subwatershed within the Whippany River watershed. The Highlands Region includes all or part of 183 HUC14 subwatersheds, as shown in the in the figure HUC14 Basins within the Highlands Region. The table HUC 14s and Associated Surface Water Bodies in the Highlands Region provides a listing of the HUC14s in the Region.

A watershed is an area of land that drains into a body of water such as a river, lake, stream or bay. It is separated from other systems by high points such as hills or slopes. It includes not only the waterway itself, but the entire land area that drains to it.

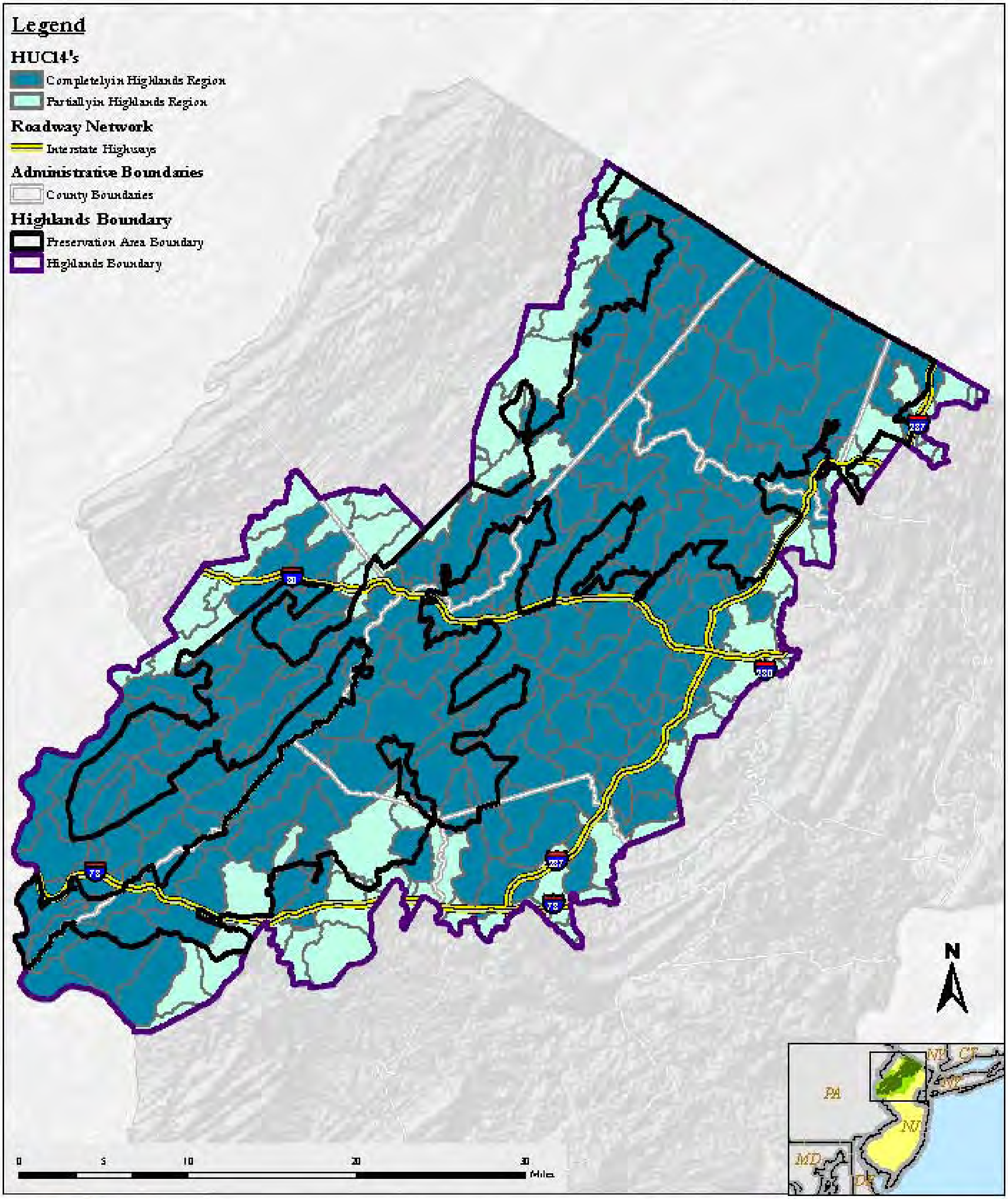
Ground water is the primary source of water for residents and businesses in the Highlands Region. More than 170 million gallons of water are withdrawn from Highlands aquifers daily. Aquifer characteristics and the function of the ground water flow system are both directly related to the underlying geology, which controls the ability to transmit significant quantities of water for various uses. In addition, the Highlands Region supports several potable water supply reservoir systems that can provide more than 500 million gallons of water per day during a repeat of the drought of record, mostly to urban areas in northern and central New Jersey outside the Highlands Region. These reservoir systems are addressed in detail in a later section of this Technical Report.

Five major aquifer types within the Highlands Region are classified by the bedrock or surficial materials that are exposed at or near the land surface. These include crystalline, carbonate and clastic rocks, typical geologic formations of the Highlands physiographic province. The Highlands Region also includes sedimentary and igneous rocks of the Newark Basin, along the eastern boundary, that are typical of the Piedmont physiographic province to the east. Locally, these bedrock units are overlain by surficial deposits of glacial origin.

DEFINING WATERSHEDS

Watersheds come in many sizes, from the drainage area of a local creek to the Mississippi River drainage area. Each larger watershed is comprised of two or more smaller watersheds. As stated above, HUC designations are used to identify these areas. All lands of the Highlands Region are contained within a HUC14 subwatershed, which is contained within a HUC11 watershed, which is contained within a HUC8 river basin. NJDEP has grouped HUC11 watersheds in New Jersey to identify twenty Watershed Management Areas, each of which is entirely contained within a HUC8 river basin. The Highlands Region includes part or all of eight Watershed Management Areas within the Upper Delaware River, Raritan River, Passaic River and Hudson River basins. The last, draining to the Hudson basin, is the Wallkill River Watershed Management Area.

HUC14 Basins within the Highlands Region



Regional Master Plan, July 2008

Highlands Council
New Jersey

Sources:
New Jersey Highlands Council, 2006
New Jersey Department of Environmental Protection, 2006

HUC 14s and Associated Surface Water Bodies in the Highlands Region

HUC14 number	Drainage area mi^2	WMA	WMA Name	Water Region	Water Region name	Surface water name
02040105040040	5.51	01	Upper Delaware	4	Northwest	Lafayette Swamp tribs
02040105040050	13.46	01	Upper Delaware	4	Northwest	Sparta Junction tribs
02040105040060	13.82	01	Upper Delaware	4	Northwest	Paulins Kill (above Rt 15)
02040105050010	18.95	01	Upper Delaware	4	Northwest	Paulins Kill (Blairstown to Stillwater)
02040105060020	12.28	01	Upper Delaware	4	Northwest	Delawanna Creek (incl UDRV)
02040105070010	5.37	01	Upper Delaware	4	Northwest	Lake Lenape trib
02040105070020	11.47	01	Upper Delaware	4	Northwest	New Wawayanda Lake/Andover Pond trib
02040105070030	13.45	01	Upper Delaware	4	Northwest	Pequest River (above Brighton)
02040105070040	8.63	01	Upper Delaware	4	Northwest	Pequest River (Trout Brook to Brighton)
02040105070050	9.42	01	Upper Delaware	4	Northwest	Trout Brook/Lake Tranquility
02040105070060	6.30	01	Upper Delaware	4	Northwest	Pequest R (below Bear Swamp to Trout Bk)
02040105080010	7.52	01	Upper Delaware	4	Northwest	Bear Brook (Sussex/Warren Co)
02040105080020	10.79	01	Upper Delaware	4	Northwest	Bear Creek
02040105090010	9.49	01	Upper Delaware	4	Northwest	Pequest R (Drag Strip--below Bear Swamp)
02040105090020	7.64	01	Upper Delaware	4	Northwest	Pequest R (Cemetary Road to Drag Strip)
02040105090030	8.23	01	Upper Delaware	4	Northwest	Pequest R (Furnace Bk to Cemetary Road)
02040105090040	6.05	01	Upper Delaware	4	Northwest	Mountain Lake Brook
02040105090050	7.71	01	Upper Delaware	4	Northwest	Furnace Brook
02040105090060	8.27	01	Upper Delaware	4	Northwest	Pequest R (below Furnace Brook)
02040105100010	8.32	01	Upper Delaware	4	Northwest	Union Church trib
02040105100020	10.31	01	Upper Delaware	4	Northwest	Honey Run
02040105100030	8.98	01	Upper Delaware	4	Northwest	Beaver Brook (above Hope Village)
02040105100040	9.06	01	Upper Delaware	4	Northwest	Beaver Brook (below Hope Village)
02040105110010	5.62	01	Upper Delaware	4	Northwest	Pophandusing Brook
02040105110020	14.72	01	Upper Delaware	4	Northwest	Buckhorn Creek (incl UDRV)
02040105110030	7.87	01	Upper Delaware	4	Northwest	UDRV tribs (Rt 22 to Buckhorn Ck)
02040105120010	7.75	01	Upper Delaware	4	Northwest	Lopatcong Creek (above Rt 57)
02040105120020	11.99	01	Upper Delaware	4	Northwest	Lopatcong Creek (below Rt 57) incl UDRV
02040105140010	10.08	01	Upper Delaware	4	Northwest	Pohatcong Creek (above Rt 31)
02040105140020	12.49	01	Upper Delaware	4	Northwest	Pohatcong Ck (Brass Castle Ck to Rt 31)
02040105140030	10.76	01	Upper Delaware	4	Northwest	Pohatcong Ck (Edison Rd-Brass Castle Ck)
02040105140040	5.63	01	Upper Delaware	4	Northwest	Merrill Creek
02040105140050	6.95	01	Upper Delaware	4	Northwest	Pohatcong Ck (Merrill Ck to Edison Rd)
02040105140060	6.33	01	Upper Delaware	4	Northwest	Pohatcong Ck (Springtown to Merrill Ck)
02040105140070	5.86	01	Upper Delaware	4	Northwest	Pohatcong Ck(below Springtown) incl UDRV
02040105150010	6.44	01	Upper Delaware	4	Northwest	Weldon Brook/Beaver Brook
02040105150020	18.88	01	Upper Delaware	4	Northwest	Lake Hopatcong
02040105150030	5.60	01	Upper Delaware	4	Northwest	Musconetcong R (Wills Bk to LkHopatcong)
02040105150040	8.00	01	Upper Delaware	4	Northwest	Lubbers Run (above/incl Dallis Pond)
02040105150050	10.07	01	Upper Delaware	4	Northwest	Lubbers Run (below Dallis Pond)
02040105150060	5.24	01	Upper Delaware	4	Northwest	Cranberry Lake / Jefferson Lake & tribs
02040105150070	6.95	01	Upper Delaware	4	Northwest	Musconetcong R(Waterloo to/incl WillsBk)
02040105150080	7.74	01	Upper Delaware	4	Northwest	Musconetcong R (SaxtonFalls to Waterloo)
02040105150090	4.95	01	Upper Delaware	4	Northwest	Mine Brook (Morris Co)
02040105150100	7.72	01	Upper Delaware	4	Northwest	Musconetcong R (Trout Bk to SaxtonFalls)
02040105160010	14.50	01	Upper Delaware	4	Northwest	Musconetcong R (Hances Bk thru Trout Bk)
02040105160020	17.77	01	Upper Delaware	4	Northwest	Musconetcong R (Changewater to HancesBk)
02040105160030	7.77	01	Upper Delaware	4	Northwest	Musconetcong R (Rt 31 to Changewater)
02040105160040	5.10	01	Upper Delaware	4	Northwest	Musconetcong R (75d 00m to Rt 31)
02040105160050	14.49	01	Upper Delaware	4	Northwest	Musconetcong R (I-78 to 75d 00m)
02040105160060	6.76	01	Upper Delaware	4	Northwest	Musconetcong R (Warren Glen to I-78)
02040105160070	7.48	01	Upper Delaware	4	Northwest	Musconetcong R (below Warren Glen)
02020007010010	11.46	02	Wallkill	4	Northwest	Wallkill R/Lake Mohawk(above Sparta Sta)
02020007010020	7.18	02	Wallkill	4	Northwest	Wallkill R (Ogdensburg to SpartaStation)
02020007010030	7.17	02	Wallkill	4	Northwest	Franklin Pond Creek
02020007010040	14.11	02	Wallkill	4	Northwest	Wallkill R(Hamburg SW Bdy to Ogdensburg)
02020007010050	5.47	02	Wallkill	4	Northwest	Hardistonville tribs
02020007010060	6.47	02	Wallkill	4	Northwest	Beaver Run
02020007010070	9.13	02	Wallkill	4	Northwest	Wallkill R(Martins Rd to Hamburg SW Bdy)
02020007020070	13.27	02	Wallkill	4	Northwest	Papakating Creek (below Pellettown)
02020007030010	9.15	02	Wallkill	4	Northwest	Wallkill R(41d13m30s to Martins Road)
02020007030030	5.19	02	Wallkill	4	Northwest	Wallkill River(Owens gage to 41d13m30s)
02020007030040	6.41	02	Wallkill	4	Northwest	Wallkill River(stateline to Owens gage)
02020007040010	5.41	02	Wallkill	4	Northwest	Black Ck(above/incl G.Gorge Resort trib)
02020007040020	14.95	02	Wallkill	4	Northwest	Black Creek (below G. Gorge Resort trib)
02020007040030	5.58	02	Wallkill	4	Northwest	Pochuck Ck/Glenwood Lk & northern trib
02020007040040	6.17	02	Wallkill	4	Northwest	Highland Lake/Wawayanda Lake
02020007040050	14.34	02	Wallkill	4	Northwest	Wawayanda Creek & tribs
02020007040060	7.85	02	Wallkill	4	Northwest	Long House Creek/Upper Greenwood Lake
02030103050010	5.41	03	Pompton, Wanaque, Ramapo	1	Northeast	Pequannock R (above Stockholm/Vernon Rd)
02030103050020	7.17	03	Pompton, Wanaque, Ramapo	1	Northeast	Pacock Brook
02030103050030	10.48	03	Pompton, Wanaque, Ramapo	1	Northeast	Pequannock R (above OakRidge Res outlet)

HUC14 number	Drainage area mi^2	WMA	WMA Name	Water Region	Water Region name	Surface water name
02030103050040	13.25	03	Pompton, Wanaque, Ramapo	1	Northeast	Clinton Reservior/Mossmans Brook
02030103050050	18.37	03	Pompton, Wanaque, Ramapo	1	Northeast	Pequannock R (Charlotteburg to OakRidge)
02030103050060	7.88	03	Pompton, Wanaque, Ramapo	1	Northeast	Pequannock R(Macopin gage to Charl'brg)
02030103050070	7.30	03	Pompton, Wanaque, Ramapo	1	Northeast	Stone House Brook
02030103050080	16.92	03	Pompton, Wanaque, Ramapo	1	Northeast	Pequannock R (below Macopin gage)
02030103070010	5.43	03	Pompton, Wanaque, Ramapo	1	Northeast	Belcher Creek (above Pinecliff Lake)
02030103070020	9.03	03	Pompton, Wanaque, Ramapo	1	Northeast	Belcher Creek (Pinecliff Lake & below)
02030103070030	14.62	03	Pompton, Wanaque, Ramapo	1	Northeast	Wanaque R/Greenwood Lk(aboveMonks gage)
02030103070040	11.82	03	Pompton, Wanaque, Ramapo	1	Northeast	West Brook/Burnt Meadow Brook
02030103070050	21.47	03	Pompton, Wanaque, Ramapo	1	Northeast	Wanaque Reservior (below Monks gage)
02030103070060	5.99	03	Pompton, Wanaque, Ramapo	1	Northeast	Meadow Brook/High Mountain Brook
02030103070070	10.80	03	Pompton, Wanaque, Ramapo	1	Northeast	Wanaque R/Posts Bk (below reservior)
02030103100010	5.81	03	Pompton, Wanaque, Ramapo	1	Northeast	Ramapo R (above 74d 11m 00s)
02030103100020	4.35	03	Pompton, Wanaque, Ramapo	1	Northeast	Masonicus Brook
02030103100030	6.72	03	Pompton, Wanaque, Ramapo	1	Northeast	Ramapo R (above Fyke Bk to 74d 11m 00s)
02030103100040	4.71	03	Pompton, Wanaque, Ramapo	1	Northeast	Ramapo R (Bear Swamp Bk thru Fyke Bk)
02030103100050	6.31	03	Pompton, Wanaque, Ramapo	1	Northeast	Ramapo R (Crystal Lk br to BearSwamp Bk)
02030103100060	8.60	03	Pompton, Wanaque, Ramapo	1	Northeast	Crystal Lake/Pond Brook
02030103100070	11.28	03	Pompton, Wanaque, Ramapo	1	Northeast	Ramapo R (below Crystal Lake bridge)
02030103110010	13.11	03	Pompton, Wanaque, Ramapo	1	Northeast	Lincoln Park tribs (Pompton River)
02030103110020	10.87	03	Pompton, Wanaque, Ramapo	1	Northeast	Pompton River
02030103140010	5.30	04	Lower Passaic and Saddle	1	Northeast	Hohokus Bk (above Godwin Ave)
02030103140020	9.37	04	Lower Passaic and Saddle	1	Northeast	Hohokus Bk(Pennington Ave to Godwin Ave)
02030103140040	13.63	04	Lower Passaic and Saddle	1	Northeast	Saddle River (above Rt 17)
02030103010010	10.13	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Passaic R Upr (above Osborn Mills)
02030103010020	5.24	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Primrose Brook
02030103010030	7.92	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Great Brook (above Green Village Rd)
02030103010040	5.06	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Loantaka Brook
02030103010050	5.15	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Great Brook (below Green Village Rd)
02030103010060	14.19	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Black Brook (Great Swamp NWR)
02030103010070	8.89	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Passaic R Upr (Dead R to Osborn Mills)
02030103010080	7.60	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Dead River (above Harrisons Brook)
02030103010090	5.44	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Harrisons Brook
02030103010100	7.73	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Dead River (below Harrisons Brook)
02030103010110	6.68	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Passaic R Upr (Plainfield Rd to Dead R)
02030103010180	5.34	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Passaic R Upr (Pine Bk br to Rockaway)
02030103020010	6.05	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Whippany R (above road at 74d 33m)
02030103020020	6.27	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Whippany R (Wash. Valley Rd to 74d 33m)
02030103020030	7.77	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Greystone / Watnong Mtn tribs
02030103020040	5.61	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Whippany R(Lk Pocahontas to Wash Val Rd)
02030103020050	6.72	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Whippany R (Malapardis to Lk Pocahontas)
02030103020060	5.09	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Malapardis Brook
02030103020070	10.38	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Black Brook (Hanover)
02030103020080	10.06	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Troy Brook (above Reynolds Ave)
02030103020090	6.04	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Troy Brook (below Reynolds Ave)
02030103020100	5.61	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Whippany R (Rockaway R to Malapardis Bk)
02030103030010	8.56	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Russia Brook (above Milton)
02030103030020	4.84	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Russia Brook (below Milton)
02030103030030	6.70	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Rockaway R (above Longwood Lake outlet)
02030103030040	7.97	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Rockaway R (Stephens Bk to Longwood Lk)
02030103030050	7.37	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Green Pond Brook (above Burnt Meadow Bk)
02030103030060	7.90	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Green Pond Brook (below Burnt Meadow Bk)
02030103030070	9.10	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Rockaway R (74d 33m 30s to Stephens Bk)
02030103030080	4.89	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Mill Brook (Morris Co)
02030103030090	7.33	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Rockaway R (BM 534 brdg to 74d 33m 30s)
02030103030100	7.92	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Hibernia Brook
02030103030110	14.76	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Beaver Brook (Morris County)
02030103030120	9.01	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Den Brook
02030103030130	12.28	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Stony Brook (Boonton)
02030103030140	5.28	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Rockaway R (Stony Brook to BM 534 brdg)
02030103030150	6.90	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Rockaway R (Boonton dam to Stony Brook)
02030103030160	7.91	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Montville tribs.
02030103030170	8.02	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Rockaway R (Passaic R to Boonton dam)
02030103040010	11.87	06	Upper Passaic, Whippany, and Rockav	1	Northeast	Passaic R Upr (Pompton R to Pine Bk)
02030105010010	9.27	08	North and South Branch Raritan	2	Raritan	Drakes Brook (above Eyland Ave)
02030105010020	7.31	08	North and South Branch Raritan	2	Raritan	Drakes Brook (below Eyland Ave)
02030105010030	5.03	08	North and South Branch Raritan	2	Raritan	Raritan River SB(above Rt 46)
02030105010040	6.66	08	North and South Branch Raritan	2	Raritan	Raritan River SB(74d 44m 15s to Rt 46)
02030105010050	15.25	08	North and South Branch Raritan	2	Raritan	Raritan R SB(LongValley br to 74d44m15s)
02030105010060	14.88	08	North and South Branch Raritan	2	Raritan	Raritan R SB(Califon br to Long Valley)
02030105010070	7.89	08	North and South Branch Raritan	2	Raritan	Raritan R SB(StoneMill gage to Califon)
02030105010080	4.62	08	North and South Branch Raritan	2	Raritan	Raritan R SB(Spruce Run-StoneMill gage)
02030105020010	12.29	08	North and South Branch Raritan	2	Raritan	Spruce Run (above Glen Gardner)

HUC14 number	Drainage area mi^2	WMA	WMA Name	Water Region	Water Region name	Surface water name
02030105020020	3.21	08	North and South Branch Raritan	2	Raritan	Spruce Run (Reservior to Glen Gardner)
02030105020030	14.70	08	North and South Branch Raritan	2	Raritan	Mulhockaway Creek
02030105020040	12.19	08	North and South Branch Raritan	2	Raritan	Spruce Run Reservior / Willoughby Brook
02030105020050	6.93	08	North and South Branch Raritan	2	Raritan	Beaver Brook (Clinton)
02030105020060	14.22	08	North and South Branch Raritan	2	Raritan	Cakepoulin Creek
02030105020070	8.22	08	North and South Branch Raritan	2	Raritan	Raritan R SB(River Rd to Spruce Run)
02030105020080	7.37	08	North and South Branch Raritan	2	Raritan	Raritan R SB(Prescott Bk to River Rd)
02030105020090	11.27	08	North and South Branch Raritan	2	Raritan	Prescott Brook / Round Valley Reservior
02030105040020	10.80	08	North and South Branch Raritan	2	Raritan	Pleasant Run
02030105040030	12.44	08	North and South Branch Raritan	2	Raritan	Holland Brook
02030105050010	6.27	08	North and South Branch Raritan	2	Raritan	Lamington R (above Rt 10)
02030105050020	11.03	08	North and South Branch Raritan	2	Raritan	Lamington R (Hillside Rd to Rt 10)
02030105050030	6.00	08	North and South Branch Raritan	2	Raritan	Lamington R (Furnace Rd to Hillside Rd)
02030105050040	8.90	08	North and South Branch Raritan	2	Raritan	Lamington R(Pottersville gage-FurnaceRd)
02030105050050	4.92	08	North and South Branch Raritan	2	Raritan	Pottersville trib (Lamington River)
02030105050060	6.23	08	North and South Branch Raritan	2	Raritan	Cold Brook
02030105050070	13.97	08	North and South Branch Raritan	2	Raritan	Lamington R(HallsBrRd-Pottersville gage)
02030105050080	16.93	08	North and South Branch Raritan	2	Raritan	Rockaway Ck (above McCrea Mills)
02030105050090	5.09	08	North and South Branch Raritan	2	Raritan	Rockaway Ck (RockawaySB to McCrea Mills)
02030105050100	12.35	08	North and South Branch Raritan	2	Raritan	Rockaway Ck SB
02030105050110	7.55	08	North and South Branch Raritan	2	Raritan	Lamington R (below Halls Bridge Rd)
02030105060010	6.69	08	North and South Branch Raritan	2	Raritan	Raritan R NB (above/incl India Bk)
02030105060020	6.64	08	North and South Branch Raritan	2	Raritan	Burnett Brook (above Old Mill Rd)
02030105060030	7.65	08	North and South Branch Raritan	2	Raritan	Raritan R NB(incl McVickers to India Bk)
02030105060040	7.50	08	North and South Branch Raritan	2	Raritan	Raritan R NB(Peapack Bk to McVickers Bk)
02030105060050	6.60	08	North and South Branch Raritan	2	Raritan	Peapack Brook (above/incl Gladstone Bk)
02030105060060	5.07	08	North and South Branch Raritan	2	Raritan	Peapack Brook (below Gladstone Brook)
02030105060070	8.40	08	North and South Branch Raritan	2	Raritan	Raritan R NB(incl Mine Bk to Peapack Bk)
02030105060080	6.68	08	North and South Branch Raritan	2	Raritan	Middle Brook (NB Raritan River)
02030105060090	8.69	08	North and South Branch Raritan	2	Raritan	Raritan R NB (Lamington R to Mine Bk)
02030105070010	9.32	08	North and South Branch Raritan	2	Raritan	Raritan R NB (Rt 28 to Lamington R)
02030105120050	9.57	09	Lower Raritan, South River, and Lawr	2	Raritan	Middle Brook EB
02030105120060	6.54	09	Lower Raritan, South River, and Lawr	2	Raritan	Middle Brook WB
02040105170010	6.03	11	Central Delaware	4	Northwest	Holland Twp (Hakihokake to Musconetcong)
02040105170020	17.54	11	Central Delaware	4	Northwest	Hakihokake Creek
02040105170030	11.83	11	Central Delaware	4	Northwest	Harihokake Creek (and to Hakihokake Ck)
02040105170040	6.73	11	Central Delaware	4	Northwest	Nishisakawick Creek (above 40d 33m)
02040105170050	8.49	11	Central Delaware	4	Northwest	Nishisakawick Creek (below 40d 33m)

WATERSHED MANAGEMENT AREAS OF THE HIGHLANDS

This section presents a general description of watershed features within the Highlands Region. NJDEP has divided the state into five major water regions containing a total of twenty delineated Watershed Management Areas (WMAs). Of these, eight are located wholly or partly within the Highlands Region, as shown in the figure *Highlands Watershed Management Areas.*

The eight WMAs located wholly or partly within the Highlands Region are:

- Upper Delaware River - WMA 1
- Wallkill River - WMA 2
- Pompton, Pequannock, Wanaque, Ramapo Rivers - WMA 3
- Lower Passaic and Saddle Rivers – WMA 4
- Upper Passaic, Whippany, and Rockaway Rivers - WMA 6
- North and South Branch (Upper) Raritan River - WMA 8
- Main Stem (Lower) Raritan River - WMA 9
- Central Delaware Tributaries - WMA 11

A brief description of the drainage area, water bodies, topography and geology, soils, wildlife resources, water supply, and land use of each WMA that is at least partially within the Highlands Region follows. The majority of the source information is derived from each WMA's respective *Watershed Characterization and Assessment* report.

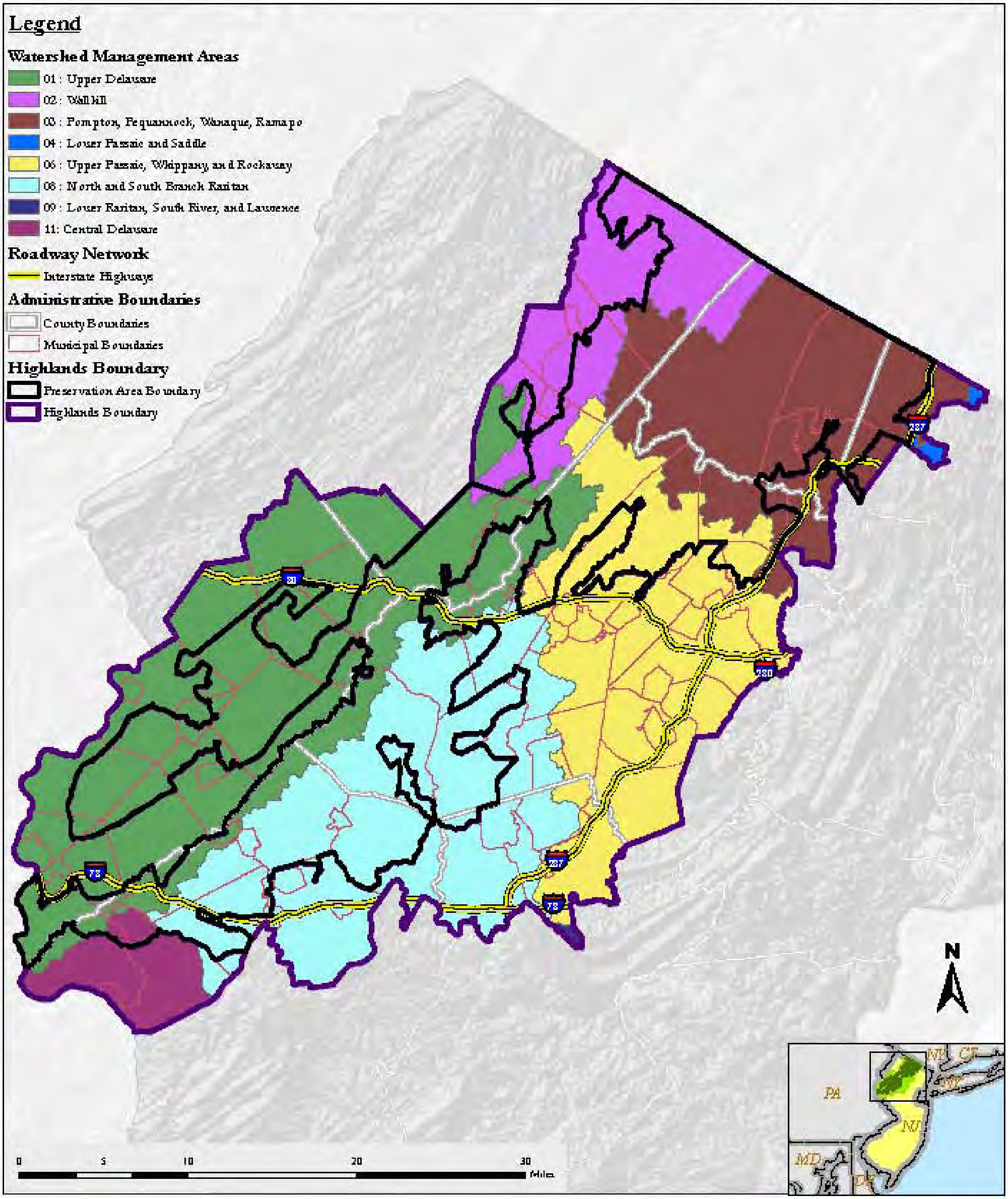
UPPER DELAWARE RIVER - WMA 1

The Upper Delaware Watershed encompasses 746 square miles in total area, 42% located within the Highlands Region. This watershed is located within both the Valley and Ridge and Highlands Physiographic Provinces, with well-defined mountain ridges running in a southwest to northeast direction. It includes portions of Sussex, Morris, Hunterdon, and all of Warren Counties. There are 54 municipalities within this watershed, including Phillipsburg, Washington, Hackettstown, Hopatcong, and Newton. The majority of these towns receive their drinking water from private and community wells.

Water Bodies

Major streams include the Paulins Kill, Pequest, Pohatcong and Lopatcong Rivers, and the Musconetcong River, recently designated as a federal Wild and Scenic River. This designation enhances standards for further development, placing the highest priority on preservation of the watershed's natural resources. This WMA provides extensive habitat for fish and wildlife. A total of 64% of New Jersey's FW-1 trout production stream miles are found here, and over 53% of the land area is forested. Agriculture, forest, and wetlands combine for 82% of the total land cover in the watershed.

Highlands Watershed Management Areas



The Highlands Council makes no representations of any kind, including, but not limited to, the warranties of merchantability or fitness for a particular use, nor are any such warranties to be implied with respect to the information contained on this map. The State of New Jersey shall not be liable for any actions taken or omissions made from reliance on any information contained herein from whatever source nor shall the State be liable for any other consequences from any such reliance.

Regional Master Plan, July 2008

Highlands Council
New Jersey

Sources:
New Jersey Highlands Council, 2006
New Jersey Department of Environmental Protection, 2006

The Upper Delaware Watershed is approximately 746 square miles in total area and includes many sub-watersheds. The subwatersheds have been grouped into five larger units, including:

- Paulins Kill: The Paulins Kill and its tributaries drain an area of 197 square miles. Major tributaries include Trout Brook, Delawanna Brook and Stony Brook. Numerous lakes and ponds are found throughout the subwatershed, the largest being Culvers Lake, Swartswood Lake, Lake Owassa, Paulins Kill Lake, and the Yards Creek Reservoir.
- Pequest River: The Pequest River and its tributaries drain an area of 157 square miles. Major tributaries include Beaver Brook, Trout Brook, Furnace Brook and Bear Creek. There are many small lakes and ponds within the subwatershed, mostly located in the Pequest River headwaters. The larger impoundments are Mountain Lake, Allamuchy Pond and Wawayanda Lake.
- Pohatcong and Lopatcong Rivers: The Pohatcong and Lopatcong River basins drain an area of 106 square miles. Major tributaries include Buckhorn Creek, Pophandusing Brook, Brass Castle Creek, Shabbecong Creek and Merrill Creek. Merrill Creek Reservoir is the largest impoundment in the subwatershed.
- Musconetcong River: The Musconetcong River and its tributaries drain an area of 156 square miles. Major tributaries include Lubbers Run, Mine Brook, Hances Brook, and several smaller streams. The major impoundments include Lake Hopatcong, Lake Musconetcong, Cranberry Lake and Lake Lackawanna.
- Flat Brook: Flat Brook and its tributaries drain an area of 130 square miles, all lying outside the Highlands Region. Major water features include Shimers Brook, Clove Brook, Van Campen's Brook, Dunnfield Creek, Stony Brook, Little Flat Brook, Parker Brook, Tilghman Brook and several small lakes and ponds.

Topography and Geology

WMA 1 is dominated by valleys and ridges oriented southwest to northeast. Generally, the drainage patterns follow the same orientation, flowing to the Delaware River. Elevations range from the highest spot in New Jersey, Sussex County's High Point at 1803 feet above sea level, to approximately 120 feet in the Delaware Valley of southern Warren County. The land is rolling to steeply sloped. The broad, flat-topped uplands are separated by deep narrow valleys lying 400 to 600 feet below the ridge tops. The ridges are underlain chiefly with Precambrian gneisses and schists, while the long, narrow valleys are underlain with Paleozoic Kittatinny Limestone and Martinsburg shale. Small outcrop belts of Precambrian Franklin Limestone and infolds of Devonian sandstone and shale occur in some of the valleys.

Although not as dramatic as that found in the Valley and Ridge Province, the topography of the Highlands region in WMA1 is one of considerable relief. The Musconetcong River and some smaller tributaries have carved deep valleys in the basins between the ranges. The limestone formations in several of the valleys are notable for the solution caverns that hold and transmit large quantities of water. The nature of these formations means that there are unique considerations relating to water resources due to the potential for sinkhole formation and contamination of the underlying aquifer.

Soils

The soil characteristics in a watershed have large bearing on all other resources, such as vegetation and land use. Dynamic hydrologic processes (e.g., infiltration and runoff) are also dictated largely by the characteristics of soils. The soils in this watershed are quite diverse, with varying geologic material, topography, and hydrology. Many have been formed from glacial processes. The United States Department of Agriculture (USDA) Cooperative Soil Survey Program maps and categorizes soils in a county according to the most important characteristics. From a watershed management perspective, these would include infiltration, permeability, depth to bedrock or other restrictive layer, depth to seasonal high water table, and slope. The USDA Soil Survey information for Warren counties is in the process of being updated. In the Upper Delaware Watershed, the following are examples of the revised soil series associations that have been mapped:

- Delaware-Unadilla-Colonie post-glacial alluvium soils
- Hazen-Hoosic-Otisville and Fredon-Halsey glacial outwash soils
- Carlisle-Adrian organic deposit soils
- Rockaway-Rock outcrop
- Rowland-Birdsboro-Raritan alluvial material soils

Wildlife Resources

The Upper Delaware Watershed is home to a diverse wildlife population. The tremendous variation in topography, soils and vegetation, combined with historically low human population have created optimal conditions for a number of wildlife species. More than 200 species of birds are known to winter, breed, or migrate through the watershed. Reptiles and amphibians flourish in the varied habitats found within the watershed. Over 30 species of mammals make their home here. Common species are whitetail deer, black bear, woodchuck, rabbit, opossum, skunk, raccoon, gray squirrel, and chipmunk. Almost fifty species of state threatened or endangered wildlife species can be found within the Upper Delaware Watershed.

Water features of the region are valuable in supporting habitat. The relatively clean, cold, swift streams of the Upper Delaware provide favorable conditions for aquatic species. Fish resources are important economically with shad, trout, bass, and other game fish sought nearly year-round. The majority (64% of stream miles) of New Jersey FW-1 trout production waters are found in WMA 1. Most of the numerous lakes also provide excellent aquatic habitat, hosting bass, sunfish, perch, and pickerel.

Critical habitats such as wetlands, grasslands, and unbroken tracts of mature forest are present in this region, but are being fragmented due to development.

Water Supply

The majority of drinking water used within the watershed is obtained from individual or community ground water wells. As the population of the Upper Delaware watershed grows, demands on the surface and ground water supplies of the region will increase. The NJDEP 1996 Water Supply Plan shows that the heaviest projected future demand in WMA 1 is in the Pequest and Paulins Kill basins.

Land Use

The land use in the study area is derived from a GIS coverage (NJDEP, 2000) using Anderson classifications (Anderson, et al., 1976). The digital land use data were generated from 1985 and 1995-97 NJDEP aerial photogrammetry, involving measuring and using aerial photography in the development of maps. Land uses were characterized based on percentages of urban, agriculture, forest, wetland, open water, and barren land for the study area and for each subwatershed. In 1995, undeveloped land comprised 67% of the land area in WMA1. Forested areas comprised 53.3%; reservoirs, lakes and ponds 3%; wetlands 10% and barren areas, 0.7% of the land area. Developed areas account for nearly 33% of the land area; with 19% used for agricultural purposes and 14% in residential, commercial and industrial uses.

The highest percentages of undeveloped land (84.6-99.9%) were located in the Dunnfield Creek, VanCampen's Brook, Flat Brook, and Shimers Brook basins. The largest areas of urban land use are in the vicinity of Lake Hopatcong and Hackettstown, both located in the upper portions of the Musconetcong River watershed, in Washington Borough in the headwaters of Pohatcong Creek, Newton Borough in the Paulins Kill watershed and in Phillipsburg, at the downstream end of Lopatcong Creek.

WALLKILL RIVER - WMA 2

The Wallkill watershed includes 133,120 acres of land, encompassing approximately 37% of Sussex County and a small portion of Passaic County. Approximately 96% of the watershed within New Jersey lies within Sussex County; with the remaining 4% in Passaic County. The eastern portion of WMA 2 falls within the New Jersey Highlands. The headwaters of the Wallkill River begin at Lake Mohawk in Sparta Township. The river then flows north into New York, eventually emptying into the Hudson River. Land use within the watershed is diverse, ranging from agricultural and forested land to extensive commercial and residential development. The watershed also provides extensive habitat for fish and wildlife.

Water Bodies

The Wallkill River WMA encompasses approximately 208 square miles of land in New Jersey, or 133,120 acres. In Orange County, the river drains 382 square miles. There are more than 80 dams and impoundments on the rivers and streams. There are five defined subwatershed areas within WMA 2, including:

- Wallkill River: The Wallkill bisects the WMA, eventually exiting into New York State. It drains approximately 90 square miles. Major lakes include Lake Mohawk, Newton Reservoir, Beaver Lake, Lake Grinnell and Wallkill Lake. The main stem of the river originates at Lake Mohawk and flows north through Sussex County until it crosses into New York State. It joins Rondout Creek and empties into the Hudson River near Kingston, New York. The majority of the Wallkill Basin (approximately 83% of the total land area) lies within New York State.
- Pochuck Creek: Pochuck Creek and its tributaries, including Black Creek, Wawayanda Brook and Lake Lookout Brook drain approximately 49 square miles. Major lakes include Upper Greenwood Lake, Lake Wawayanda, Pleasant Valley Lake and Highland Lake.
- Papakating Creek: Papakating Creek joins the Wallkill River just east of Sussex Borough. The creek and its tributaries, West Branch Papakating Creek, Clove Brook, and Neepaulakating Creek, drain an area of 61 square miles. Lake Neepaulin is located within the watershed.
- Rutgers Creek: The Rutgers Creek watershed is located at the northwestern corner of the WMA, outside the Highlands Region. It drains approximately three square miles.

Topography and Geology

The topography of WMA 2 is dominated by valleys and ridges. Most of the Wallkill River Basin lies within the Ridge and Valley Province. The eastern portion falls within the Highlands Region, where the mountains (elevations of 1,000 to 1,500 feet above sea level) are composed of granite and gneiss and form a portion of the most ancient rock formations in North America. The ridges are composed of resistant, crystalline, Precambrian igneous and metamorphic rocks.

Soils

The Natural Resources Conservation Service (NRCS) is in the process of updating soil surveys for Sussex County. The information being developed will include soil maps, a database defining each type of soil, and interpretations of the soil's characteristics, physical properties, and use limitations.

Wildlife Resources

The Wallkill River watershed is home to a diverse wildlife population. Supported by wetlands, marshes, lakes and uplands in the river valley, significant populations of migrating and nesting water fowl, nesting water birds and grassland birds, rare reptiles, calcareous communities, and plant species are prevalent.

Wallkill River National Wildlife Refuge is located in WMA 2, protecting over 7,500 acres of the sub-basin. The Refuge affords the opportunity to preserve and enhance its lands and waters in a manner that will conserve the natural diversity of fish, wildlife, plants and their habitats. Many opportunities are afforded for wildlife observation, hunting, fishing, nature photography and environmental education. It is one of the few remaining large areas of wetlands in the northeastern section of the watershed. These wetlands attract large numbers of waterfowl during migration, including the American black duck, mallard, green-winged teal, blue-winged teal, wood duck and Canada goose. Similar waterfowl habitat occurs in the wetlands along Papakating Creek, and, to a lesser extent, along other tributaries within the watershed. Barred owls are known to nest in the large forested swamp areas in the Wallkill River and Papakating Creek Basins.

Nearly 150 species of birds that are probable or confirmed breeders have been recorded for the upper Wallkill River Watershed, including numerous species of neotropical migrant land birds. Songbirds nesting in forest interior habitat include the wood thrush, scarlet tanager, and black-and-white warbler, while those using grassland and early successional habitat include the bobolink, grasshopper sparrow, and northern harrier.

Bog turtles have been reported in appropriate habitat throughout the watershed. Favorable habitats are calcareous wetlands; especially open fens (wet areas that are typically alkaline) dominated by sedges and other vegetation.

Game species include the white-tailed deer, wild turkey, river otter, beaver, mink, muskrat, raccoon, red fox, gray fox, coyote, cottontail rabbit, gray squirrel, and ruffed grouse. Small mammals such as voles, shrews, and mice are common in the fields and early successional habitats, and form an important forage base for resident and migrating raptors. Bobcat and black bear have populations within the northern and western regions of the watershed. Game fishing is also prevalent within the watershed. Where the Wallkill River runs through the Refuge, it supports largemouth bass, pickerel, yellow perch, sunfish, carp, and bullheads.

Water Supply

Most of the watershed relies upon public and private wells for potable water supply. Sussex Borough is dependent on a surface water supply, receiving water from Lake Rutherford, located within the eastern portion of High Point State Park. No municipalities are dependent upon waters from the Wallkill River or its major tributaries as a primary source of drinking water. The USEPA has designated the Northwest New Jersey 15 Basin Aquifer System as a Sole Source Aquifer. The portion of this WMA that is located in the Highlands Region lies entirely within the boundaries of this aquifer system.

Land Use

On the basis of the 1995/97 aerial data obtained by NJDEP, the land coverage for WMA 2 is approximately 19% agricultural, 49% forested, 15% urban, 3% surface waters, 14% wetlands and 1% classified as "other". Modest land use changes occurred from 1986 to 1995/1997. Urban lands increased approximately 2 % at the expense of agricultural lands within Sussex County and approximately 2.5% within the watershed overall. Since the 1995/1997 aerial survey, significant urban development at the expense of agricultural lands has taken place in many municipalities. Farmland acreage had decreased 3% from 75,531 acres in 1992 to 73,001 acres in 1997. Full time farms have decreased 6% from 296 farms in 1992 to 278 farms in 1997. Beyond adding to the area's quality of life, preservation of farmland within the watershed was considered vital to the region's agricultural industry, natural resources, water quality and quantity, and health of the area's ecosystems.

POMPTON, PEQUANNOCK, WANAQUE, AND RAMAPO RIVERS - WMA 3

WMA 3 includes 238 square miles in New Jersey, of which more than 58% is forested lands. Watersheds include the Pompton, Pequannock, Wanaque, and Ramapo Rivers. The drainage areas of the Wanaque and Ramapo Rivers extend north into New York to include an additional 140 square miles. These watersheds are located in portions of 21 municipalities in Passaic, Bergen, Morris and Sussex Counties in New Jersey, and portions of Orange and Rockland Counties in New York. More than half of WMA 3 remains as forest area and provides habitat to extensive wildlife and fish communities. WMA 3 contains numerous lakes that provide recreational opportunities for the populace, and several major reservoirs that provide a source of water supply to a large portion of the population in northeast New Jersey.

Water Bodies

The Pequannock, Wanaque, and Ramapo Rivers all flow into the Pompton River. The Pompton River is, in turn, a major tributary to the Passaic River. The major watercourses in each major drainage basin include:

- Pequannock River: The headwaters of the Pequannock River are in Sussex County. The river flows east, delineating the Morris/Passaic County boundary. It joins the Wanaque River and flows to the Pompton River in Wayne Township. Major impoundments within the watershed include Butler Reservoir, Lake Kinnelon, Clinton Reservoir, Oak Ridge Reservoir, Charlottesburg Reservoir, and Echo Lake.
- Ramapo and Pompton Rivers: The Ramapo River flows from New York into Bergen County and joins the Pequannock River to form the Pompton River in Wayne Township. Major impoundments in the Ramapo and Pompton River watersheds include Point View Reservoir #1, Pompton Lake, and Pines Lake.
- Wanaque River: The headwaters of the Wanaque River lie within New York State as a minor tributary to Greenwood Lake. The major impoundments include Wanaque Reservoir, Monksville Reservoir, Greenwood Lake, Arcadia Lake, and Lake Inez.

Topography and Geology

Approximately 80% of WMA 3 is in the Highlands Province. The remaining southeastern portion is in the Newark Basin of the Piedmont Province. The topography is hilly, with stream-dissected plateaus of crystalline rocks. Due to the rugged topography, the thickness of glacial deposits varies greatly over relatively short distances. Bedrock is usually not far from the surface, except in major stream valleys. Approximately 50% of the Highlands area in WMA 3 exhibits glacial till deposits greater than 25 feet in thickness. Elevations extend from approximately 160 feet above sea level at the confluence of the Passaic and Pompton Rivers, to a few ridges that reach above 1,350 feet.

The Newark Basin is primarily lowlands formed on inclined siltstone, shale, and sandstone strata, interrupted in places by long trap rock ridges and local hills formed of erosion-resistant diabase or conglomerate. The portion of WMA 3 that lies in the Newark Basin is generally lower, with the majority of the land between 200 and 400 feet, and ridges reaching 680 feet.

Glaciation caused the erosion of hills and the deposition of various stratified (layered) and unstratified deposits. Coarse-grained stratified deposits typically act as aquifers. Often the advance of ice would block a stream that drained the pre-glacial drainage basin and form a glacial lake. The largest and most prominent in northern New Jersey is Glacial Lake Passaic. Remnants extend from Kinnelon and Wayne Township in the north to Bemards Township in the south (within WMA 6). The Bog and Vly meadows in the Borough of Lincoln Park are a remnant of Glacial Lake Passaic in WMA 3. Surficial sand and gravel deposits from melt water from retreating glaciers form prolific aquifers along the Ramapo River. Due to their high permeability, these surficial deposits are vulnerable to contamination.

Soils

Soils in WMA 3 are predominantly in Hydrologic Soil Group C, except for river valleys where Group A and B soils are common. Soil Group C is characterized by slow infiltration rates when wetted and usually contain a layer that impedes downward movement. Group A soils are considered to have low runoff potential and are well drained; while Group B soils have a moderate infiltration rate and are moderately well drained.

Wildlife Resources

As of 1995, more than 58% of WMA 3 was forested, with about 16% consisting of water and wetlands. Approximately 24% was classified as urban. WMA 3 remains one of the most pristine areas of the Highlands region. It provides extensive habitat for wildlife and fish communities and provides recreational opportunities for the population in WMA 3 and surrounding areas.

Water Supply

Water supply reservoirs and intakes diverted approximately 89 billion gallons of water per year between 1990-2000, with more than 90% of that total being exported outside of WMA 3. The watershed provides surface water supply to over two million residents in other watersheds. Approximately 92% of the withdrawals from the WMA within New Jersey were from surface water sources, with 8% coming from ground water sources. The surface water withdrawals from within WMA 3 are primarily used for potable supply outside of WMA 3.

Approximately 95% of the local residents depend on ground water for their potable supply. The most prolific ground water resources in WMA 3 are located along the Ramapo River and some of its tributaries, and in the Pompton River basin. High yielding surficial aquifers are sparse and bedrock is low yielding in the remainder of WMA 3.

Land Use

Large land areas have been preserved as State and county parks, forests and wildlife management areas, with additional lands set aside as watershed for the major reservoirs located here. Fully 58% of the land was categorized as forested in 1995, 24% as urban, 10% as wetlands, and almost 7% as water bodies, with less than 1% agricultural or barren lands.

LOWER PASSAIC AND SADDLE RIVERS – WMA-4

The Lower Passaic and Saddle River watersheds, which comprise WMA 4, encompass 2,373 acres or approximately 2% of the Highlands Region. The New Jersey portion of WMA 4 (which includes lands within and outside the Highlands Region) totals 188 square miles and includes parts of Bergen, Essex, Passaic, Hudson and Morris Counties. The watershed is extensively developed, including older cities and industrial centers of Newark, Paterson, Clifton, and East Orange.

Water Bodies

This WMA consists of the Passaic River downstream of the confluence with the Pompton River, with Saddle River as one major tributary. Other tributaries to the Lower Passaic include Preakness, Deepavaal, Molly Ann and Goffle Brooks, and the Peckman, Third and Second Rivers. Tributaries to the Saddle River include Pine, Saddle, Hohokus, and Sprout Brooks.

Topography and Geology

WMA 4 is contained within the Newark Basin of the Piedmont Physiographic Province. It is formed of siltstone, sandstone and shale lowlands with long trap rock ridges and localized hills of diabase or conglomerate formations. The effects of glaciation can be seen in smaller scale topographic features such as eskers, drumlins, kettles and kames. The elevation of WMA 4 varies between sea level and 850 feet in the Watchung Mountains.

Bedrock geology consists of Brunswick siltstone and shale, Lockatong shale, and Stockton sandstone; these formations also form the major aquifers in the area. Crystalline rocks also occur between and within these formations. Surficial geology includes stratified glacial deposits that, in some areas form prolific aquifers.

Soils

Principal soils include those derived from glacial till (gravelly loams in Hydrologic Soil Group C and Group D loamy soils), outwash plains (sand and gravel in Hydrologic Group A and sandy loam, Group B), and lake bed sediments; and those from recent alluvium (also sand and gravel in Hydrologic Group A.)

Wildlife Resources

WMA 4 is home to trout fisheries, along with smallmouth bass, yellow perch, and largemouth bass. There are also many common species of mammals, reptiles and birds. The watershed includes 8.3 square miles of critical habitat and two Natural Heritage Sites. A total of 5,192 acres are set aside as open space and recreation areas.

Water Supply

Total water diversions for water supply, industrial, hydropower and other uses are estimated at over 114 billion gallons per year. It is estimated that 92% of that total is derived from surface water resources, 8% from ground water wells. One fourth of the total (29 billion gallons) is for potable use (with nine billion gallons derived from ground water). Water use by a hydroelectric power plant at the Great Falls in Paterson and industrial uses are also significant, at 78 and 6 billion gallons per year, respectively. Irrigation and commercial uses account for 296 and 25 million gallons of water use per year, respectively.

The Passaic Valley Water Commission (PVWC) is the primary public water user in WMA 4 and could divert a maximum of 2,325 million gallons a month from the Passaic River at Two Bridges or Little Falls, at a maximum daily rate of 75 MGD. PVWC supplies numerous municipalities and wholesale water customers. United Water diverts water from the Saddle River and exports it to Oradell Reservoir, in WMA 5.

Land Use

The eastern portions of this WMA are mostly urban, with small areas of forest and agriculture to the north and west. As in the rest of the State, the amount of land in urban use increased between 1986 and 1995, and this WMA was reported to be 83% urban, including residential, commercial, and industrial uses, with only 16% categorized as forest, wetlands and water bodies.

UPPER PASSAIC, WHIPPANY AND ROCKAWAY RIVERS - WMA 6

The Passaic River Basin covers 361 square miles of land area in New Jersey, mostly in Morris County. It also includes parts of western Essex and Union Counties, northern Somerset County, and eastern Sussex County, with an additional 575 square miles in New York. The Passaic Basin in New Jersey has been divided into three watershed management areas, identified as WMAs 3, 4 and 6. WMAs 3 and 4 were previously discussed. The subject of this section is WMA 6.

WMA 6 includes the area tributary to the Passaic River upstream of Two Bridges. Watersheds in WMA 6 include the Upper and Middle Passaic, Rockaway and Whippany Rivers. The watershed is home to approximately 540,000 residents, with 90% dependent on local ground water for their potable supply. More than 43% of the land area is developed, with approximately 34% in forest lands.

Water Bodies

Following is a list of the major water bodies in WMA 6:

- Upper Passaic River: The Upper Passaic River and its tributaries drain an area of 143 square miles. Major tributaries to the Upper Passaic include the Dead River, Rockaway River, Whippany River and Black Brook.
- Middle Passaic River: The Middle Passaic River and its tributaries drain an area of 11 square miles. A major tributary is Deepavaal Brook.
- Rockaway River: The Rockaway River and its tributaries drain an area of 137 square miles. Major tributaries include Stone Brook, Mill Brook, Beaver Brook and Den Brook.
- Whippany River: The Whippany River and its tributaries drain an area of 70 square miles. Two major tributaries are Black Brook and Troy Brook.

Topography and Geology

Approximately 50% of WMA 6 is in the Highlands Physiographic Province. The southeastern portion of the WMA is in the Newark Basin of the Piedmont Province. The topography is hilly, with stream-dissected plateaus of crystalline rocks. Due to the rugged topography, the thickness of glacial deposits varies greatly over relatively short distances. Bedrock in the Highlands is usually not far from the surface, except in major stream valleys. However, approximately 55% of the Highlands area in WMA 6, north of the Rockaway River, contains glacial till deposits greater than 25 feet in thickness. Elevations extend from approximately 300 feet above sea level near the point where the Passaic River emerges from the Highlands, to a few points in the extreme north of WMA 6 that reach above 1,350 feet.

The Newark Basin is primarily lowlands formed on inclined siltstone, shale, and sandstone strata, interrupted in places by long trap rock ridges and local hills formed of erosion-resistant diabase or conglomerate. The portion of WMA 6 that lies in the Newark Basin is generally at an elevation between 200 and 400 feet above sea level, with a few points along the crest of the Second Watchung Mountain reaching above 600 feet. The lowest point is at approximately 160 feet, where the Passaic River exits WMA 6 at the confluence with the Pompton River.

Glaciation caused the erosion of hills and the deposition of various stratified and unstratified deposits. As the ice sheet advanced across the Newark Basin portion of WMA 6, several lakes formed. The largest and most prominent in northern New Jersey was Glacial Lake Passaic. The Great Swamp, Troy Meadows, Lee Meadows, and Great Piece Meadows are remnants of Glacial Lake Passaic in WMA 6. Surficial sand and gravel deposits from melt water from retreating glaciers form prolific aquifers along the upper reaches of the Rockaway River. Deltaic deposits in former Lake Passaic also yield significant amounts of water. Due to their high permeability these surficial deposits are vulnerable to contamination. A number of pre-glacial stream valleys were filled with coarse sediments and subsequently deeply buried in till. These buried valley aquifers are significant sources of water for portions of WMA 6.

Soils

Soils in WMA 6 are predominantly in Hydrologic Soil Group C, except on the basalt ridges in the Newark Basin and the portion of the Highlands south of the Rockaway River, where Group B soils dominate. Soil Group C is characterized by slow infiltration rates, while infiltration rates of Group B soils are greater.

Wildlife Resources

The significant wetlands (62.5 square miles, or approximately 17% of WMA 6) include two critical areas: 1) Passaic Meadows (includes Troy Meadows and Great Piece Meadows) and 2) the Great Swamp. A third large critical area, Green Pond, is found in the upper reaches of the Rockaway River and is predominantly forest area. The City of East Orange has preserved a significant area for water reserve purposes in western Essex County. These three large areas, as well as several small critical areas and other natural areas, provide extensive habitat for wildlife and for fish communities, as well as protecting the quality and quantity of water in those areas.

Water Supply

Between 1990 and 2000, an average of approximately 42 billion gallons of water per year was reported as being diverted in WMA 6 for public water supply purposes. About 1.3 billion gallons per year is used for industrial purposes. Approximately half of this water was from surface supply, half from ground water. Approximately 19 billion gallons per year of the public water supply total, mostly from surface water sources, is exported out of WMA 6. This includes diversions to the Boonton Reservoir System, reported as providing Jersey City with approximately 50 MGD. In addition, stream flow through WMA 6 supports downstream passing flow and water supply allocation requirements.

The public water supply used within WMA 6 is approximately 90% from ground water. The ground water characterization and assessment for this watershed indicates a variety of ground water sources that vary from low producing to prolific. Based on data from 1990-2000, ground water use in WMA 6 averaged approximately 22 billion gallons per year. About 21 billion gallons was for public supply use, and 1.3 billion gallons for industrial, commercial and irrigation use. Comparing current and projected ground water withdrawals to estimated ground water availability, there is evidence to suggest a growing ground water deficit. The watershed characterization and assessment report indicated that surface water supplies have almost been maximized, and projected growth, both in and out of the basin would require additional infrastructure projects or alternative water sources.

Although there are a few surface water intakes and water supply reservoirs within this WMA, the major users relying on surface water supply diversions from within WMA 6 are located outside of the WMA. It was reported that approximately 8 MGD of the water diverted from downstream of WMA 6 is pumped back into WMA 6 after treatment.

In the eastern half of WMA 6, there is an extensive system of valley aquifers (the Buried Valley Aquifer System), which also have extensive surficial aquifers overlying them in most areas. In addition, there are surficial aquifers in the Great Swamp and in several of the river valleys, particularly in the Rockaway River watershed. If these aquifers were to become contaminated, it would have a dramatic effect on water supply within WMA 6.

Land Use

As of 1995, approximately 43% of WMA 6 was urban land, 34% forest, and 20% water or wetlands. Only about 2% of the area of WMA 6 was in agricultural use at that time. A comparison of land use data for 1986 and 1995 reveals that during that time there was a loss of approximately 9.4 square miles of forest area, 2.1 square miles of agricultural lands, and 1.3 square miles of wetlands, with an increase of approximately 12 square miles of urban area. The total change in land use in that period involved about 3.5% of the area of WMA 6.

NORTH AND SOUTH BRANCH RARITAN RIVER - WMA 8

The northern half of the Upper Raritan Watershed Management Area is located in the Highlands Region. WMA 8 includes the North and South Branches of the Raritan River and their tributaries, encompassing large portions of Somerset, Hunterdon, and Morris Counties, for a total of approximately 470 square miles. It is one of three watershed management areas that comprise the overall Raritan River Basin. The others are the Lower Raritan WMA and Millstone WMA. The entire Raritan River Basin covers 1,100 square miles of land drained by the Raritan River into Raritan Bay, making it the largest river basin located entirely within New Jersey.

Water Bodies

The South Branch of the Raritan River is 51 miles long from its source in Budd Lake to its confluence with the North Branch. The North Branch of the Raritan River originates as a spring-fed stream in Morris County and flows south for approximately 23 miles to its confluence with the South Branch. Major impoundments in the Raritan Basin include Spruce Run Reservoir, Budd Lake, and Round Valley Reservoir.

The water courses in each major drainage basin include:

- North Branch of the Raritan River: The North Branch of the Raritan River is 23 miles long and flows from northwestern Morris County through Somerset County, to the confluence with the South Branch near Branchburg and Raritan. Major tributaries include Peapack Brook, Rockaway Creek, and Lamington River. The only major impoundment is Ravine Lake.
- South Branch of the Raritan River: The South Branch of the Raritan River is 51 miles long and flows from western Morris County through central Hunterdon County, and into western Somerset County before joining the North Branch. Major tributaries include the Neshanic River, Spruce Run, Mulhockaway and Cakepoulin Creeks. Major impoundments include Spruce Run and Round Valley Reservoirs.

Topography and Geology

The Upper Raritan WMA ranges in elevation from less than 100 feet above sea level near streams, to more than 1,400 feet at its headwaters near Budd Lake in Morris County. The topography is generally steeply sloped with incised stream valleys. It is roughly divided into two physiographic provinces – the Highlands in the north and the Piedmont in the south. The Piedmont Province contains sedimentary rocks and is characterized by gently rolling terrain, dissected by broad winding river valleys.

The present surface features of northern New Jersey are due almost entirely to erosion of older and higher land masses and the effects of the Wisconsin glaciation. A small area of the terminal moraine intersects the very northern portion of WMA 8. The topography is a result of long continued weathering and erosion over hundreds of millions of years, on rocks of different degrees of resistance and arrangement. Highland valleys consist of much softer materials of limestone or shale, making them less resistant to erosion.

The Highlands contains geologic formations that are among the oldest in New Jersey. Bedrock in the Highlands consists of gneiss, igneous and sedimentary rock. Water movement in the Highlands occurs primarily through joints, fractures and bedding planes in the formations on a local scale. The gneissic aquifers do not generally produce large yields, except near streams or where wells intercept major fault zones. They can be hydraulically connected with surface waters, particularly in the limestone valleys that are very prolific aquifers. These areas have high water yield potentials and are found in several areas of the Raritan Basin, specifically Hunterdon and Morris Counties.

Soils

Highlands soils within this WMA are weathered from eroding bedrock and glacial deposits that are generally shallow and stony with frequent rock outcrops. The soils are generally well drained, with some poorly draining soils found in depressions and along streams. The dominant soils within the Highlands portion of the basin are Parker and Gladstone series, well-drained, gravelly sandy loams and loams. Annandale soils are also extensive on broad undulating ridge tops. These soils are well-drained but contain a water restrictive horizon (fragipan) in the subsoil. Bartley soils, which are moderately well-drained, are important in the limestone valleys. Poorly drained Cokesbury soils are found in depressions and waterways. Carlisle series are very poorly drained soils, formed in organic deposits.

Wildlife Resources

The Highlands Region contains numerous wetlands and mountain streams that flow down through rocky ravines south and east to the Piedmont, and comprise many of the headwaters for the Raritan Basin. These streams and wetlands provide important habitat for a broad array of animal and plant species and are critical for the survival of more than 23 species of threatened and endangered animals and 120 resident bird species. Wetlands, lakes and streams of the Highlands Region support Bog and Wood Turtle, as well as large populations of small mammals, butterflies, moths and dragonflies. Streams of the Highlands are well oxygenated and of high quality as indicated by high populations of aquatic insects and pollution-intolerant macroinvertebrates.

The forested ridges provide critical nesting habitat and migration corridors for migratory songbirds and other avian species. Large contiguous forests provide nesting and foraging opportunities for several species of hawks and owls. Other wildlife species of the Highlands include black bear, beaver, coyote, river otter, wild turkey, white-tailed deer and bobcat.

Due to the topographical relief, wetlands in the Highlands are not as extensive as the wetlands that exist in the lower elevations of the Piedmont and Coastal Plain. Limestone bedrock that lies close to the surface in the Highlands formed the calcareous fens of the region. Natural freshwater wetlands that have remained in the northern part of the Basin consist primarily of swamps, marshlands, bogs and fens; and floodplains located adjacent to streams and lakes.

Water Supply

The Raritan Basin has a number of important water supply sources. Ground water supplies range from limited to prolific, depending on local geology. Topographic relief in the northwestern part of the Basin also has allowed for the impoundment of important surface water supplies. The limestone aquifers can be very prolific, with water movement through solution channels in the rock. These aquifers are also very vulnerable to pollution from the land surface. The Spruce Run and Peapack-Gladstone valleys, part of the Highlands, are underlain by limestone. Water movement outside of the limestone areas is primarily through joints, fractures and bedding planes in the formations on a very local scale. The gneissic aquifers do not generally produce large yields, except near streams, or where wells intercept major fault zones and are hydraulically connected with surface water.

Glacial deposits consist of unconsolidated stratified (layered) and unstratified (mixed) deposits of gravel, sand, silt and clay. Only a small portion of the northern Raritan Basin has glacial deposits. Glacial aquifers supply important quantities of water in northern New Jersey. These buried valley aquifers are frequently the main local water supply sources. Many wells that draw from the underlying aquifer are extensively recharged by streams flowing over the glacial deposits.

Major potable water systems include Spruce Run and Round Valley Reservoirs and the Delaware and Raritan (D&R) Canal. The D&R Canal brings water from the Delaware River to the eastern part of the Basin. Collectively, they provide potable water to approximately 1.5 million people in central New Jersey. According to the 1996 New Jersey Statewide Water Supply Plan, the total water use in the Raritan Basin in 1990 was approximated at 202 MGD with 122 MGD (60%) of the total water use being supplied by surface water sources.

The Spruce Run and Round Valley Reservoirs are operated by the NJ Water Supply Authority. Spruce Run has a capacity of 11 billion gallons and is fed by natural stream flow. The two largest tributaries are Spruce Run and Mulhockaway Creek. Spruce Run Reservoir releases water as needed to the Spruce Run and South Branch of the Raritan River. Round Valley has a capacity of 55 billion gallons and is almost entirely reliant on water pumped from the South Branch. Water can be released as needed to either the Hamden Pumping Station or to the South Branch of Rockaway Creek. The water released from either reservoir travels downstream to maintain flow at the intake of Elizabethtown Water Company, located at the confluence of the Raritan and Millstone Rivers and other intakes.

Land Use

Urban land uses are significantly greater in the eastern portion of the Basin than to the north and west. Land use totals for the Raritan Basin for 1995 were approximately 19% agricultural land, 1.4% barren land, 27% forest, 36% urban, 2% open water, and 15% consisting of wetlands. Comparison of land use conditions in 1995 with those of 1986 reveal significant losses in agricultural land and increases in urban land use. Loss of forested land has been greatest in the Upper Raritan WMA 8, especially in Morris County.

MAIN STEM RARITAN RIVER - WMA 9

Only a very small portion of the Highlands Region extends into this WMA 9 (see figure Highlands Watershed Management Area), lying within the Piedmont Province.

The Main Stem or Lower Raritan River Watershed (WMA 9) encompasses approximately 350 square miles. WMA 9 is one of three watershed management areas that comprise the Raritan River Basin. The others are the Upper Raritan WMA and Millstone WMA. This WMA is roughly divided into two physiographic provinces – the Piedmont in the north and the Coastal Plain province to the south. Large portions of Middlesex, Somerset and Monmouth Counties are included in this land area.

The Lower Raritan WMA ranges in elevation from greater than 500 feet above sea level along its northern boundary, where the Watchung Mountains are located, to less than 100 feet above sea level near streams and associated riparian areas. With the exception of the Watchung Mountains, which have greater relief, the topography of WMA 9 is predominantly gently sloping.

The major water courses of the Lower Raritan WMA include the South River, Lawrence Brook, Green Brook and the main stem of the Raritan River all of which are entirely outside of the Highlands Region. The portion of the WMA is included in the Highlands Region includes branches of Middle Brook. The USEPA has designated the Buried Valley Aquifer System as a Sole Source Aquifer. The small area of this WMA that falls within the Highlands lies within the boundaries of this aquifer system.

CENTRAL DELAWARE TRIBUTARIES - WMA 11

The Central Delaware Tributaries run in a narrow band along the Delaware River from northern Hunterdon County, Holland Township to southwestern Monmouth County in Millstone Township. This WMA encompasses 24 municipalities and 272 square miles of land.

Water Bodies

Highlands Region subwatersheds are located in the most northern area of Hunterdon County in Holland and Alexandria Townships. These include the Hakihokake, Harihokake and Nishiskawick Creek subwatersheds, which drain approximately 63 square miles. There are three additional subwatersheds in WMA 11, all located outside the Highlands Region that include Lockatong/Wickecheoke Creek, Alexauken/Moore/Jacobs Creek, and Assunpink Creek.

Topography and Geology

Land elevations in the south begin near sea level in Trenton and develop into rolling hills of 300 to 400 feet in the center of this WMA. Elevations rise to over 800 feet in the Musconetcong Mountains, along the watershed's northern boundary within the Hakihokake, Harihokake, and Nishiskawick watersheds.

Highlands portions of the watersheds in the Musconetcong Mountains contain the oldest Precambrian rocks in New Jersey, formed 1.1 billion to 750 million years ago. Geology of the Highlands Region is generally characterized by granite and gneiss. The Precambrian rocks are considered to be unproductive aquifers. Slopes in the Highland Region watersheds of this WMA can be greater than 15% in grade.

Soils

Lakehurst-Lakewood-Atsion soils are found in the upper reaches of the watershed; Penn-Reaville-Kinesville from the red shale rocks in the middle reaches and Rowland-Pope-Birdsville in the lower reaches.

Wildlife Resources

There are seven natural resource priority habitat areas in Hunterdon County. They include Hunterdon Milford Bluffs, an important red shale community; the Jarves Road site; Devil's Tea Table; Byram; Treasure Island; Raven Rock; and Holocombe Island. The Sourland Mountain forest and Assunpink Wildlife Management Area are also within this WMA.

Water Supply

The Delaware River supplies water supply for most of the population in the entire WMA. With respect to the Highlands Region specifically, Holland and Alexandria Townships are totally reliant on ground water for their potable supplies.

Land Use

Land use around the Central Delaware Tributaries is largely evenly split evenly between agriculture, forest, and urban land. Hunterdon County has reportedly lost 71% of its wetlands to agriculture between the years 1940 to 1970. Urban lands in the Central Delaware Tributaries had increased by approximately 15% between 1986 and 1995.

SURFACE WATER QUALITY

This section provides a detailed description of current surface water quality conditions in the Highlands Region based upon assessments generated for the New Jersey 2006 Integrated Report, as compiled by the NJDEP.

Section 303(d) of the Federal Water Pollution Control Act (33 U.S.C. 1313(c)), commonly known as the Clean Water Act, requires states to identify "Impaired Waters" where specific designated uses are not fully supported. Known as the 303(d) list, this list identifies the name of the water body and the pollutant or pollutants causing the water body to be listed as impaired. Section 305(b) of the Clean Water Act also requires states to periodically assess and report on the overall quality of their waters. With guidance from USEPA, in 2002 the NJDEP integrated the 303(d) report with the 305(b) report into one report titled the New Jersey Water Quality Monitoring and Assessment Report (Integrated Report) (NJDEP, 2006af).

Based on information included in the 2006 Integrated Report, surface water quality overall was found to be moderately higher in the Highlands compared to conditions statewide. However, bacterial impairment was more extensive in the Highlands than elsewhere in the State. A full 91% of assessed water body units in the Highlands are not supporting primary contact recreation due to unacceptable sanitary quality and 65% are not supporting aquatic life support use. The most common water quality parameters in violation of surface water quality standards were bacteria, temperature and phosphorus, in that order. Water quality is presented both in overall terms and in detail at the water body level.

Nine sites located within the Highlands Region were reviewed for water quality trends covering the period from 1984 to 2004. Of the constituents assessed, dissolved oxygen (DO), DO saturation, and nitrate (NO3) levels indicated stable conditions over time. Total dissolved solids (TDS) and specific conductance (an indirect measure of chloride) displayed upward trends, indicating decreasing water quality. Ammonia and total phosphorus showed declining trends, or improving water quality. Total nitrogen displayed mixed results, with four sites indicating no measurable trend and four sites indicating improving conditions.

INTRODUCTION

This report provides a recent snapshot of the surface water quality within or directly bordering the Highlands Region. The information is taken from the December 2006 *New Jersey Integrated Water Quality Monitoring and Assessment Report*. Water quality information contained here is divided into two parts. The first is a Highlands-wide summary of the degree to which designated uses of the state's waters are supported or not, based on an assessment of the water quality for HUC14 subwatersheds contained either wholly or partially within the Highlands Region. It summarizes the overall use support status, if a water body does or does not support a designated use in the Highlands, and compares this to the use support status of New Jersey. The second part provides a detailed assessment of parameter-specific water quality, on a stream-based scale, using monitoring results from individual locations. This provides detailed water quality condition data which underlie the overall use attainment assessments, determining whether a use is supported or not.

Water quality assessments are completed based upon procedures outlined in the 2006 Integrated Water Quality Monitoring and Assessment Methods (Methods Document) that can be downloaded at http://www.state.nj.us/dep/wmm/sgwqt/wat/integratedlist/06MethodsDoc.pdf. In general, assessments of HUC14 subwatersheds are based upon water quality data taken from monitoring sites within the HUC14 in question. If data from within a HUC14 was insufficient or absent, data from neighboring HUC14 subwatersheds were extrapolated along contiguous waterways into HUC14s where the water quality assessments might apply. This was performed only in situations where land uses were consistent and no major tributaries or pollution sources appeared between neighboring HUC14 subwatersheds. In some cases, monitoring sites from one HUC14 formed the basis of assessments in two, three and in a few cases as many as four neighboring HUC14s. Monitoring stations that formed the basis of multiple HUC14 assessments are listed in Appendix A.

The assessment of aquatic life use support in New Jersey is based on a direct evaluation of instream biological communities, specifically fin-fish and benthic macroinvertebrate (insects, worms, clams etc.) communities, whenever possible. Such biological monitoring is based on the premise that biological communities are shaped by the long-term conditions of their environment and best reflect the health of an ecosystem. Benthic macroinvertebrate assemblages are generally reflective of short-term and localized impairment. Currently, the NJDEP monitors benthic macroinvertebrate assemblages at numerous stream stations in the Highlands Region. In order to assess environmental conditions on a larger spatial and temporal scale, in 2000 the NJDEP began to supplement benthic macroinvertebrate monitoring with an index of biotic integrity (IBI). IBI measures the health of a stream based on multiple attributes of the resident fish assemblage.

The assessment methodology applied to these data is explained in the NJDEP Methods Document cited previously. All fin-fish assessments in the Highlands Region were assessed in the 2006 Integrated Report as being Excellent, Good, or Fair, all categories representing full support of the Aquatic Life Use from a regulatory perspective. One exception was an IBI site in the Musconetcong River (site FIBI061) where the community was assessed as "poor." This result reflected sampling error and more recent sampling, using improved methods, has resulted in assessing the site as acceptable. Fish IBI monitoring and benthic macroinvertebrate sites located in the Highlands Region are illustrated in the NJDEP map for *Fish IBI Stations in the New Jersey Highlands*, and in the

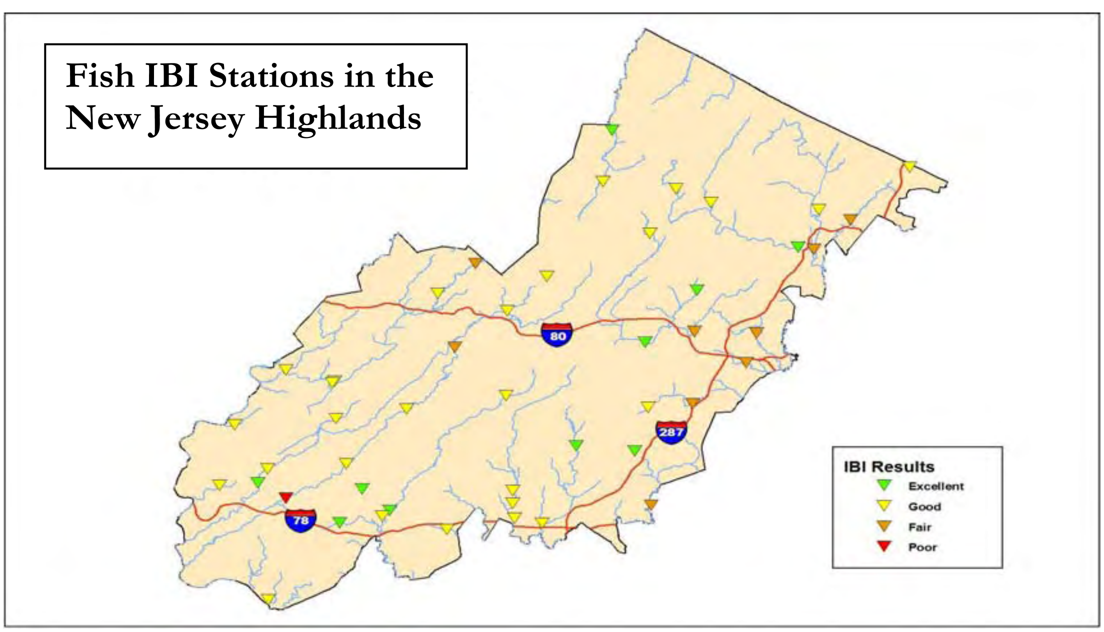
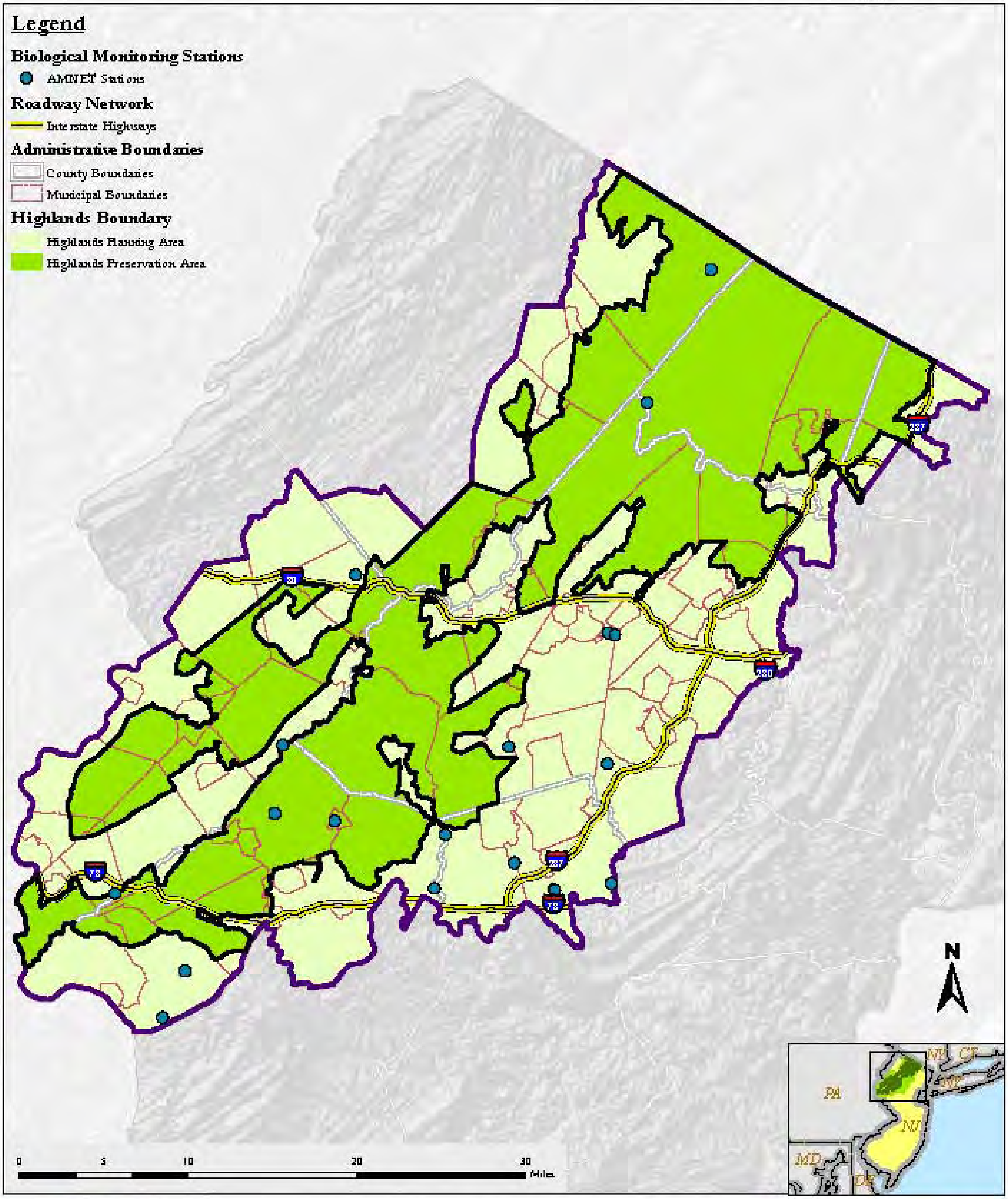


figure *AMNET Stations in the Highlands Region*, respectively.

AMNET Stations in the Highlands



The Highlands Council makes no representations
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from any such reliance.

Regional Master Plan, July 2008

Highlands Council
New Jersey

Sources:
New Jersey Highlands Council, 2006
New Jersey Department of Environmental Protection, 2006

In contrast to the fin-fish results, benthic macroinvertebrate communities exhibited both impaired as well as non-impaired biological conditions in the Highlands Region, reflecting both non-support and full support of Aquatic Life Use, respectively. For the purposes of this report, it is the benthic community assessment that will clarify the support status of Aquatic Life Use within the Highlands Region and will be the focus of the discussion of biological assessments in the water bodies included here.

Designated use support status by HUC14 subwatershed is listed in Appendix B. Statutory authority for the 305(b) and 303(d) reporting requirements, components of the Integrated Report, are included in Appendix C. Maps displaying designated use support status by assessment unit are contained in Appendix D. Similar maps showing the HUC14s where water quality standards are or are not met for a suite of water quality parameters are presented in Appendix E. 183 HUC14 subwatersheds are within or partially within the Highlands Region. On average, 68% of the Highlands HUC14 subwatersheds were assessed for one or more designated uses. The table *Use Support Summary per Assessed HUC14s* summarizes the use support status of the HUC14s assessed, both as number of HUC14s and as percentages of units assessed and supporting particular uses. The table *Use Support Summary per Assessed HUC14s Compared to Results for the State* compares use support by designated use for the Highlands to that of the State as a whole.

Use Support Summary per Assessed HUC14s

Use Support Status	Drinking Water		Primary Contact Recreation		Aquatic Life		Trout Use		Industrial		Agriculture	
Full Support:	90	(81%)	9	(8%)	56	(37%)	28	(27%)	107	(98%)	107	(98%)
Non Support:	21	(19%)	107	(92%)	102	(63%)	76	(73%)	2	(2%)	2	(2%)
Total HUC-14s Assessed	**111**		**116**		**150**		**104**		**109**		**109**	

Values represent number of HUCs and percent of HUCs assessed in the Highlands Region

Use Support Summary per Assessed HUC14s Compared to Results for the State

Use Support Status - %	Drinking Water - %		Primary Contact Recreation - %		Aquatic Life - %		Trout Use - %		Industrial - %		Agriculture - %	
	HL	**NJ**	**HL**	**NJ**	**HL**	**NJ**	**HL**	**NJ**	**HL**	**NJ**	**HL**	**NJ**
Full Support %	81	72	8	32	37	25	27	24	98	93	98	97
Non Support %	19	28	92	68	63	75	73	76	2	7	2	3

Values reflect percentage of total HUC14s assessed

As evident in the table *Use Support Summary per Assessed HUC14s Compared to Results for the State*, overall use support status is slightly better in the Highlands Region as compared to the State overall, with the exception of bacterial quality. For example, 37% of the Highlands aquatic life assessments fully supports the designated use; whereas only 25% of aquatic life designated use assessments statewide do so. . In contrast, bacterial quality in the Highlands (with only 8% fully supporting) was poorer than the degree of use support statewide (32% fully supporting). This difference largely reflects the favorable conditions in the Pinelands Region, where bacterial contamination is lower than in other portions of New Jersey. Sources of bacterial contamination within the Highlands Region HUC14 subwatersheds, based upon Total Maximum Daily Loads (TMDL) documents, are both anthropogenic (e.g., livestock, pet waste) and natural (e.g., wildlife).

TMDLs represent the carrying capacity of the receiving water and consider point and non-point sources of pollution, natural background concentrations and surface water withdrawals. TMDLs are required, as per Section 303(d) of the Clean Water Act, to be developed for water bodies that cannot meet surface water quality standards after the implementation of technology-based effluent limitations. TMDLs may also be established to help maintain or improve water quality in waters that are not impaired.

When use support in the Highlands Region was viewed per watershed, a few notable patterns were observed. One is the extensive degree of aquatic life use support within the Musconetcong and the Lamington/North Branch Raritan watersheds as compared to other areas. The Lamington/North Branch system displays the most extensive full support of trout use. An extensive degree of non-support of primary contact recreation due to unacceptable sanitary quality was also observed, a condition frequently found in waters of New Jersey.

Twelve HUC14 subwatersheds in the Highlands are listed in the 2006 Integrated Report for the instream presence of toxic organic substances, including cyanide, perchloroethylene, trichloroethane, or DDT. Other HUC14 subwatersheds are identified where benthic macroinvertebrate assessments have uncovered a significant percentage of larval flies whose head capsules had a disproportionate degree of physical deformities. These six HUC14 subwatersheds are considered impaired by an "unknown toxic substance(s)." .

Highlands Region HUC14s Listed as Impaired by an Organic Toxic or Unknown Toxic Substance

HUC14	SUBWATERSHED NAME	WMA	CONTAMINANT
02030103010070	Passaic R Upr (Dead R to Osborn Mills)	6	Cyanide
02030103010110	Passaic R Upr (Plainfield Rd to Dead R)	6	Cyanide
02030103010180	Passaic R Upr (Pine Bk br to Rockaway)	6	DDX
02030103040010	Passaic R Upr (Pompton R to Pine Bk)	6	DDX
02030103050080	Pequannock R (below Macopin gage)	3	DDX
02030103110020	Pompton River	3	DDX
	Boonton Reservoir	6	DDX
	Pompton Lake	3	DDX
02030105020060	Cakepoulin Creek	8	DDX
02030103030170	Rockaway R (Passaic R to Boonton dam)	6	PCE, TCE
02030103030140	Rockaway R (Stony Brook to BM 534 brdg)	6	PCE, TCE
02030103030150	Rockaway R (Boonton dam to Stony Brook)	6	PCE, TCE
02030103140020	Hohokus Bk(Pennington Ave to Godwin Ave)	4	Unknown Toxic Substance
02030103140040	Saddle River (above Rt 17)	4	Unknown Toxic Substance
02030103070070	Wanaque R/Posts Bk (below reservoir)	3	Unknown Toxic Substance
02030103110020	Pompton River	3	Unknown Toxic Substance
02030103140010	Hohokus Bk (above Godwin Ave)	4	Unknown Toxic Substance
02030103070030	Wanaque R/Greenwood Lk(aboveMonks gage)	3	Unknown Toxic Substance

Assessments of the pollution source are located in two areas in this report. Point and non-point sources, which have the potential to contribute to designated use impairment, were located using GIS data, by assessment unit. These data are current as of December 2006. Information was limited to point sources in the GIS coverage NJDEP submitted to the Highlands Council on August 29, 2006. These data are displayed in Appendix F.

Suspected or potential watershed specific sources of fecal coliform contamination were obtained from NJDEP TMDL Reports prepared by the Division of Watershed Management. These sources are based upon on-site observations by local stakeholders. This information is summarized below in the stream-specific descriptions of the respective watersheds (Section 4.3), where they apply.

WATER QUALITY TRENDS WITHIN THE HIGHLANDS REGION

An evaluation of water quality trends was conducted by NJDEP in cooperation with the USGS for selected physical and chemical constituents at 36 sampling stations located throughout the state using long-term data. Monitoring sites were limited to those with at least 20 years of continuous monitoring data and which contained flow recordings to correct for the possible impacts from flow variations on instream concentrations through time. The constituents evaluated include dissolved oxygen (DO), dissolved inorganic nitrogen (DIN), nitrate-nitrogen (NO3), total ammonia (NH3), total phosphorus (TP), specific conductance (SC) and total dissolved solids (TDS). The evaluation covered a time period from 1984 to 2004. Factors such as seasonality and variations in flow were taken into account and corrected for.

Results for nine sites located within the Highlands Region were reported (see Appendix G) and are summarized in the table *Water Quality Trend Results for the Highlands Region and the State*. They indicate mixed results for overall water quality based on the constituents examined. Of the eight constituents assessed, three (DO, DO saturation, and NO3), exhibited stable conditions over the twenty year time span. TDS and specific conductance had upward trends, indicating decreasing water quality. NH3 and TP had declining trends indicating improving water quality conditions. The eighth constituent, TN displayed mixed results, with four sites indicating no measurable trend and four with downward trends or improving conditions.

Water Quality Trend Results for the Highlands Region and the State

Parameter	DO		DO-SAT		TN		NH3		NO3		TP		TDS		SC	
Trend	**HL**	**NJ**	**HL**	**NJ**	**HL**	**NJ**	**HL**	**NJ**	**HL**	**NJ**	**HL**	**NJ**	**HL**	**NJ**	**HL**	**NJ**
NONE	9	28	9	23	4	10	2	16	8	24	2	19	2	9	2	11
DOWN	0	1	0	5	4	20	7	19	0	8	7	16	0	0	0	2
UP	0	6	0	7	0	2	0	0	1	2	0	0	7	24	7	22

Values reflect number monitoring sites assessed

In the table *Water Quality Trend Results for the Highlands Region and the State,* DO and DO saturation statewide showed some improvement, which were not observed in the Highlands Region. In contrast, NH_3 and TP each exhibited a greater percentage of sites with downward trends (improving water quality) in the Highlands Region than did statewide results. Trends for TN in the Highlands Region showed half the sites with no trend and half showing downward trends (increasing water quality). This is compared to statewide, where approximately two-thirds of sites assessed statewide exhibited downward trends, and one-third had stable conditions.

A greater proportion of Highlands Region to statewide sites displayed increases in TDS and SC. Seven of nine sites in the Highlands exhibited increasing trends versus 75% and 66% of the statewide sites showing increases for TDS and SC, respectively. This may reflect the greater degree of road salting necessary in northern New Jersey. NO3 trends were stable at a vast majority of Highlands Region sites. Statewide, NO3 was stable at 24 sites, with eight sites showing decreasing trends, a trend not observed in the Highlands Region.

DETAILED FINDINGS

This section provides a detailed assessment of current water quality, by parameter, on a stream-specific scale and based upon monitoring at individual locations. This provides detailed water quality condition data underlying the overall use attainment assessments for the HUC14 units. When available pollution source assessments were provided from NJDEP, TMDL data are included. As of July 2008, the majority of the TMDLs established focus on sources of bacterial, phosphorus, temperature, and arsenic contamination. Information in this section is organized by watershed and water body.

Each section begins with a narrative description of the water quality based upon the most current results of physical/chemical and biological monitoring. The narrative is followed by a series of tables displaying the data supporting the narrative. The first table for each displays conventional physical and chemical data. The second table shows the results of metals monitoring, which is limited to selected sites. The third table provides results of biological (benthic macroinvertebrate) monitoring in the watershed.

It should be noted that primary contact recreation is now being assessed in New Jersey using *Escherichia coli* (E. coli) concentrations. E. coli is a subset of the microbes included in fecal coliform analyses. Assessments performed previously, using the fecal coliform data are provided in the first table for informational purposes. TMDLs are based upon fecal coliform levels as it is the parameter listed on the relevant 303(d) Lists.

Tables are followed by a brief section summarizing the results of pollution source surveys taken from the NJDEP TMDL documents, when available. Information is limited to sources of fecal coliform bacteria, therefore, these are the only sources reported.

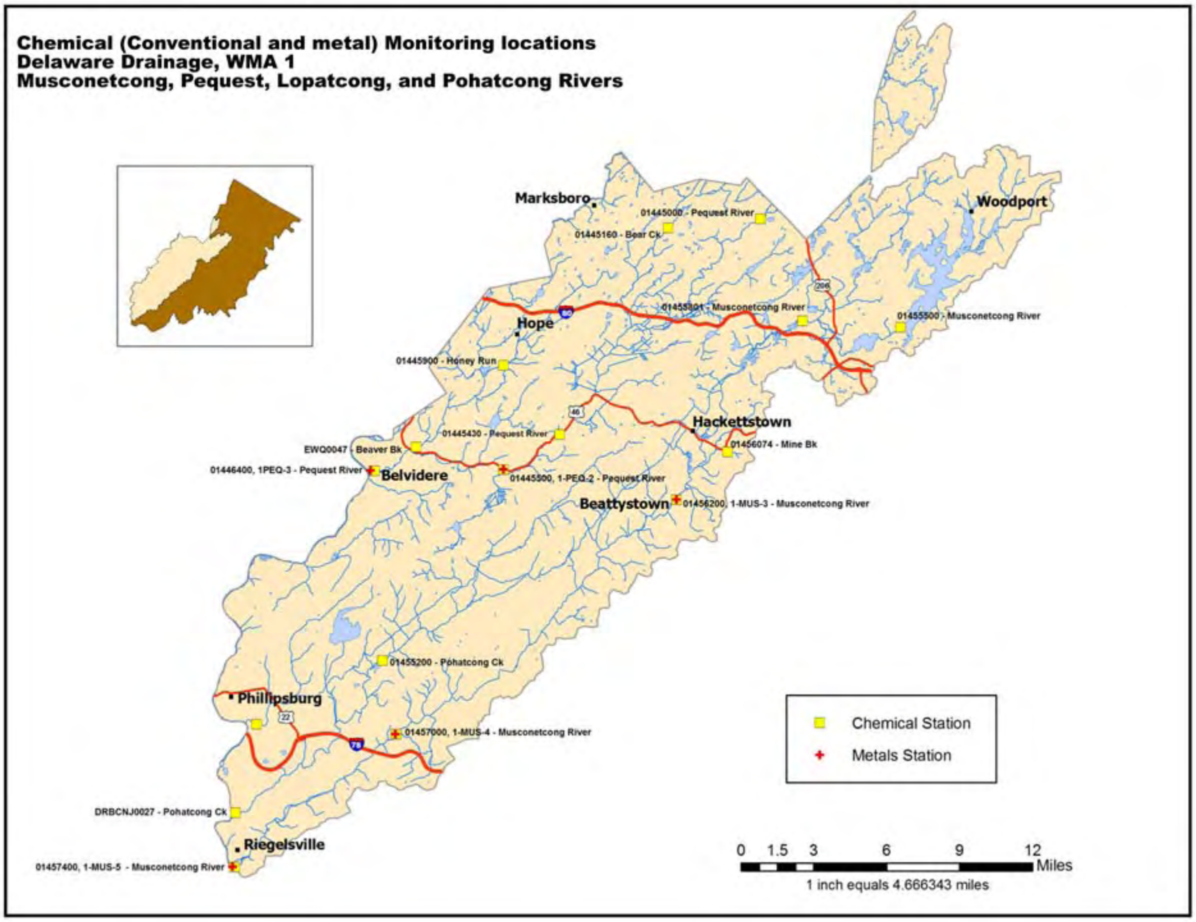
NJDEP watershed maps detailing the locations of all water quality monitoring sites are illustrated below. Each area is shown in a map pair; the first map for each area displays the physical, chemical and metal monitoring sites, while the second map for each area identifies the locations of biological assessment sites.

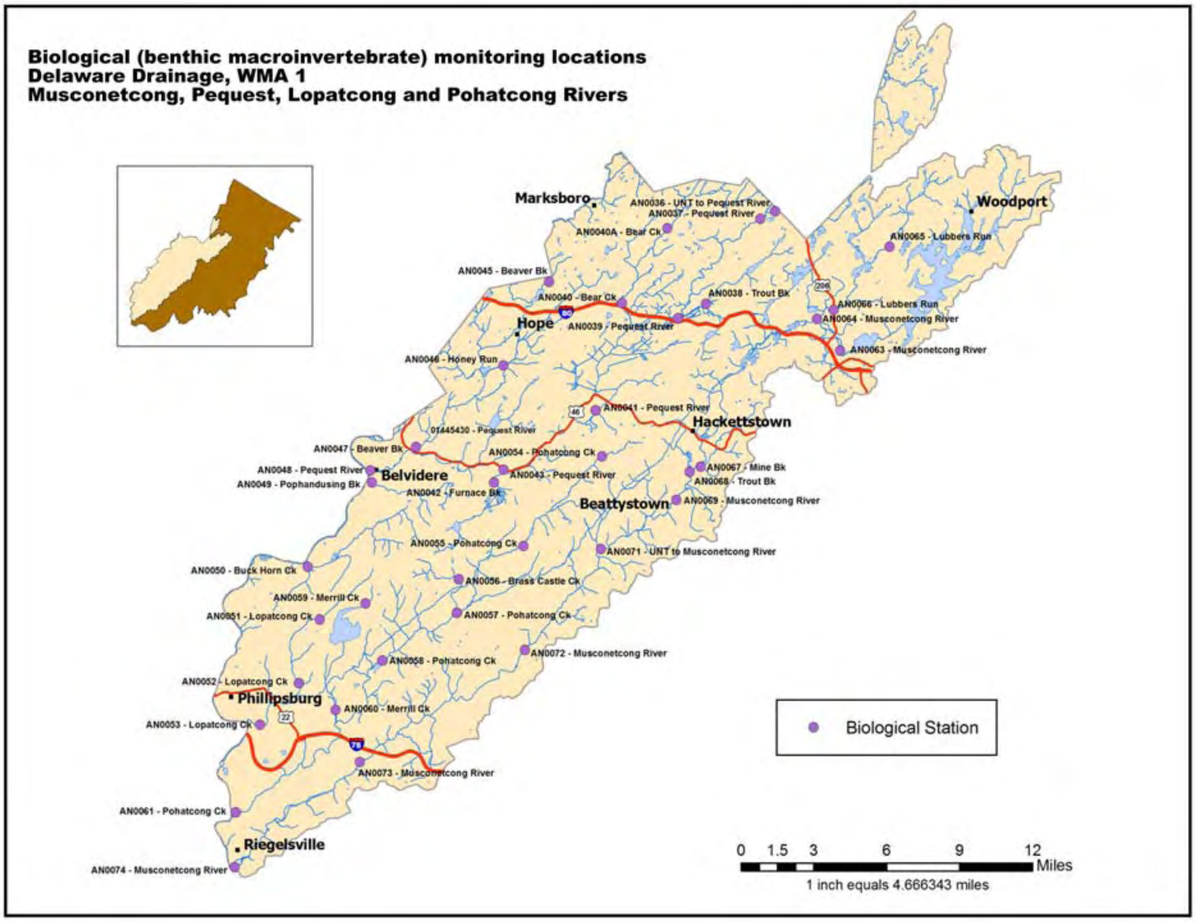
WATERSHED: DELAWARE DRAINAGE WMA 1:

Musconetcong River

These watersheds are depicted in the figures for the Delaware Drainage WMA 1 (see figures *Chemical [conventional and metal] Monitoring Locations Delaware Drainage WMA1*, and *Biological [benthic macroinvertebrate] monitoring locations Delaware Drainage WMA1*). Overall water quality in the main stem Musconetcong is good (see table *Musconetcong Water Quality Assessment for Conventional Parameters*) throughout its length, with some caveats. Sanitary quality throughout the main stem violates water quality standards, a situation common in New Jersey rivers is of concern. Due to these violations, the main stem Musconetcong fails to support primary contact recreation. Sources of bacterial contamination can be both anthropogenic and natural sources.

Also of concern to human health are arsenic violations in the vicinity of Beattystown (see table *Musconetcong Water Quality Assessment for Metals*). Though arsenic concentrations are below the Maximum Contaminant Level (MCL) for drinking water, this standard includes considerations such as analytical and treatment feasibility. Arsenic in this portion of the state may be from natural (i.e., erosion of bedrock material), as well as anthropogenic (e.g., hazardous waste disposal, pesticides) sources. One site on the Musconetcong at Lockwood exceeded standards for total phosphorus.


Chemical (Conventional and metal) Monitoring locations
Delaware Drainage, WMA 1
Musconetcong, Pequest, Lopatcong, and Pohatcong Rivers
Marksboro
Woodport
01445000 - Pequest River
01445160 - Bear Ck
01455500 - Musconetcong River
Hope
01445900 - Honey Run
Hackettstown
01445430 - Pequest River
EWQ0047 - Beaver Bk
01456074 - Mine Bk
01446400, 1PEQ-3 - Pequest River
Belvidere
01445500, 1-PEQ-2 - Pequest River
Beattystown
01456200, 1-MUS-3 - Musconetcong River
01455200 - Pohatcong Ck
Phillipsburg
01457000, 1-MUS-4 - Musconetcong River
DRBCNJ0027 - Pohatcong Ck
Riegelsville
01457400, 1-MUS-5 - Musconetcong River
Chemical Station
Metals Station
0 1.5 3 6 9 12
Miles
1 inch equals 4.666343 miles


Biological (benthic macroinvertebrate) monitoring locations
Delaware Drainage, WMA 1
Musconetcong, Pequest, Lopatcong and Pohatcong Rivers
Marksboro
Woodport
Hope
Hackettstown
Belvidere
Beattystown
Phillipsburg
Riegelsville
AN0036 - UNT to Pequest River
AN0037 - Pequest River
AN0040A - Bear Ck
AN0045 - Beaver Bk
AN0040 - Bear Ck
AN0038 - Trout Bk
AN0039 - Pequest River
AN0065 - Lubbers Run
AN0066 - Lubbers Run
AN0064 - Musconetcong River
AN0063 - Musconetcong River
AN0046 - Honey Run
AN0041 - Pequest River
01445430 - Pequest River
AN0047 - Beaver Bk
AN0054 - Pohatcong Ck
AN0048 - Pequest River
AN0049 - Pophandusing Bk
AN0043 - Pequest River
AN0042 - Furnace Bk
AN0067 - Mine Bk
AN0068 - Trout Bk
AN0069 - Musconetcong River
AN0055 - Pohatcong Ck
AN0071 - UNT to Musconetcong River
AN0050 - Buck Horn Ck
AN0056 - Brass Castle Ck
AN0059 - Merrill Ck
AN0051 - Lopatcong Ck
AN0057 - Pohatcong Ck
AN0072 - Musconetcong River
AN0058 - Pohatcong Ck
AN0052 - Lopatcong Ck
AN0060 - Merrill Ck
AN0053 - Lopatcong Ck
AN0073 - Musconetcong River
AN0061 - Pohatcong Ck
AN0074 - Musconetcong River
206
80
46
22
78
Biological Station
0 1.5 3 6 9 12
Miles
1 inch equals 4.666343 miles

Musconetcong Water Quality Assessment for Conventional Parameters

STATION	NAME	HUC14	E__COLI	TEMP	Dissolved oxygen	PH	Total Phosphorus	NITRATE	TSS	TDS	AMMONIA	CHLORIDE	TURBIDITY	SULFATE	FECAL_CO
1455500	Musc R. at Lake Hopatcong	02040105150030		5		5									4
1455801	Musc. R. at Lockwood	02040105150070	4	5			5								5
1457400	Musc R. at at Riegelsville	02040105160070	4	5	1	1	1	1	1	1	1	1	1	1	4
1456200	Musc R. at Kings Hwy in Beattystown	02040105160010	4	5	1	1	1	1	1	1	1	1			4
1457000	Musc. R near Bloomsbury	02040105160050	4	1	1	1	1	1	1	1	1	1			4
1457000	Musc. R. near Bloomsbury	02040105160060	4	1	1	1	1	1	1	1	1	1			4

1 denotes meeting standards

5 indicates not meeting standards.

4 is a subcategory of "not meeting standards" - denotes that a waterbody has undergone an EPA approved TMDL. Locations not meeting standards are shaded.

3 which occurs occasionally, denotes there was insufficient data to make an assessment.

Blank cells denote no data available for the constituent in question.

Musconetcong Water Quality Assessment for Metals

TYPE	STATION	NAME	WMA	ARSENIC	ARSENIC_1	CADMIUM	CHROMIUM	COPPER	LEAD	MERCURY	NICKEL	SELENIUM	SILVER	THALLIUM	ZINC
Metal Recon	1-MUS-3	Musc. R. on Kings Hwy in Beattystow	01	5		1	1	1	1	3	1				1
Metal Recon	1-MUS-4	Musc. R. on Person Rd. near Bloomsb	01	3		1	1	1	1	3	1				1
Metal Recon	1-MUS-5	Musc. R. on River Rd. at Riegelsvil	01	3		1	1	1	1	3	1				1

Based upon benthic macroinvertebrate data (see table *Musconetcong Water Quality Assessment for Aquatic Life Support*), the biological condition of the main stem is fair to excellent, with six sites on the main stem displaying unimpaired conditions. Four display the highest scores attainable. Although there are in-stream temperature violations in the upper reaches of the river at the outlet of Lake Hopatcong, Lockwood, and Riegelsville these violations do not seem to affect the quality of the benthic macroinvertebrate community. Violations of the pH standard were observed at the Lake Hopatcong outlet. However, this and the temperature recordings at this site may have more to do with the condition of the lake rather than of the river. Results of fecal coliform source surveys taken from the NJDEP TMDL documents are listed in the table *Suspected Pollution Sources of Fecal Coliform Bacteria Identified in the Musconetcong Watershed.*

Musconetcong Water Quality Assessment for Aquatic Life Support

Station	Location	HUC14	Subwatershed Name	Aquatic Life Support
AN0074	River Rd	02040105160070	Musconetcong R - (below Warren Glen)	Full Attain
AN0071	Unnamed trib to Musconetcong- Rt 57: in Mansfield Twp.	02040105160020	Musconetcong R (Changewater to Hances Bk)	Non Attain
AN0069	Kings Hwy	02040105160010	Musconetcong R (Hances Bk thru Trout Bk)	Full Attain
AN0072	New Hampton Rd	02040105160030	Musconetcong R (Rt 31 to Changewater)	Full Attain
AN0068	Rt 57	02040105150100	Musconetcong R- (Trout Bk to Saxton Falls)	Full Attain
AN0073	Rt 579	02040105160060	Musconetcong R (Warren Glen to I-78)	Full Attain
AN0063	blw Lk Musconetcong	02040105150030	Musconetcong R (Wills Bk to Lk Hopatcong)	Full Attain

Suspected Pollution Sources of Fecal Coliform Bacteria Identified in the Musconetcong Watershed

Stream Reach	Potential Sources
Musconetcong River at Riegelsville:	Livestock, manure application, older septic systems in the Warren Glen and Finesville area, geese and beaver in the river between Finesville and the Delaware River
Musconetcong River at Beattystown:	Wildlife, septic systems, local fish hatchery
Musconetcong River at Lockwood:	Wildlife, residential runoff

Pequest River

The upper most reaches of the Pequest River in Huntsville have excellent water quality with no observable exceedances of chemical water quality (see table *Pequest River Water Quality Assessment for Conventional Parameters*), as does Bear Creek at Dark Moon Road. Farther downstream on the Pequest at Townsbury, limited chemical monitoring indicates exceedances of total phosphorus. Still farther downstream at Oxford, the Pequest begins to exhibit additional water quality impairment with exceedances of the criterion for sanitary quality, impairing primary contact recreational use, as well as the criteria for TP and TSS.

At its downstream-most point in Belvidere, the Pequest exhibits violations of sanitary quality, temperature, pH, TP and TSS, as well as arsenic, cadmium, chromium, lead and mercury (see table *Pequest River Water Quality Assessment for Metals*).

Biological conditions in the Pequest system (see table *Pequest River Water Quality Assessment for Aquatic Life Support*) are mixed. In the upper watersheds, Bear Creek and Trout Brook both have impaired benthic macroinvertebrate communities. The upper most reaches of the Pequest (AN0039) show good biological conditions, but conditions degrade further downstream at Cemetery Road. Conditions recover still further downstream at the Pequest Road site (AN0043). The assessment at the downstream-most site near Belvidere indicates a non-impaired community. Near the lower end of the Pequest, at Pophandusing Brook, impaired biological conditions exist farthest downstream in the Pequest River.

Pohatcong and Lopatcong Creeks

Roughly midway in its watershed at New Village, Pohatcong Creek exhibits impaired conditions, exceeding sanitary quality, temperature, and TP. At the downstream-most site at River Road bridge, near the confluence with the Delaware River, only bacteria and TP show exceedances.

Biological monitoring in the Pohatcong indicates the upper reaches have healthy benthic macroinvertebrate communities. Further downstream, at the Edison Road site (AN0058) the benthic macroinvertebrate community reflects impaired conditions. The benthic community returns to non-impaired status further downstream and continues to reflect non-impaired conditions downstream to the confluence with the Delaware River. Merrill Creek, a tributary to the Pohatcong, exhibits good biological conditions at both its monitoring locations.

Results of limited physical chemical monitoring in the Lopatcong Creek, at its most downstream end in Philipsburg, exhibit exceedances of standards for bacteria. All other parameters monitored were at acceptable levels.

Pequest Water Quality Assessment for Conventional Parameters

STATION	NAME	HUC14	WMA	E__COLI	DO	TEMP	TMDL	PH	TP	NITRATE	TSS	TDS	AMMONIA	CHLORIDE	TURBIDITY	SULFATE	FECAL_CO
1445160	Bear Ck at Dark Moon Rd	02040105080010	01	1	1	1		1	1	1	1	1	1	1	1	1	1
1445900	Honey Run nr Hope	02040105100020	01	4	5	5	Yes	1	1	1	1	1	1	1	NA	1	5
DRBCNJ0028	Lopatcong Creek @ Main St, Phillipsburg	02040105120020	01		1	1	Yes	1	3	3	3	1	1				5
1446400	Pequest R at Belvidere	02040105090060	01	4	1	5	Yes	5	5	1	5	1	1	1	1	1	4
1445500	Pequest R at Pequest Furnace Rd off 625 in Oxford	02040105090060	01	4	1	1	Yes	1	5	1	5	1	1	1			4
1445000	Pequest R at Pequest Rd in Huntsville	02040105070040	01	1	1	1		1	1	1	1	1	1	1		NA	1
1445430	Pequest River	02040105090030	01		1	NA		1	5	1	NA	1	NA	1	NA		
1455200	Pohatcong Ck at Edison Rd in New Village	02040105140030	01	4	1	5	Yes	1	5	1	1	1	1	1			5
DRBCNJ0027	Pohatcong Creek @ River Road Bridge	02040105140070	01		1	1	Yes	1	5	1	1	1	1				5

1 denotes meeting standards

5 indicates not meeting standards.

4 is a subcategory of "not meeting standards" that denotes that a waterbody has undergone an EPA approved TMDL or some other enforceable management measure. Note that locations not meeting standards are shaded.

3 which occurs occasionally, denotes there was insufficient data to make an assessment.

Blank cells denote no data available for the constituent in question.

Pequest Water Quality Assessment for Metals

STATION	NAME	HUC14	WMA	ARSENIC	ARSENIC_1	CADMIUM	COPPER	LEAD	MERCURY	NICKEL	SELENIUM	SILVER	THALLIUM	ZINC
1-PEQ-2	Pequest River on Rte 625 in Pequest		01	3		1	1	1	3	1				1
1-PEQ-3	Pequest River on Water St in Belvidere		01	5		5	1	5	5	1		3		1

Pequest Water Quality Assessment for Aquatic Life Support

Station	Station Location	HUC14	WMA	Sub Watershed Name	Aquatic Life Support
AN0040A	Dark Moon Rd	02040105080010	01	Bear Brook (Sussex/Warren Co)	Non Attain
AN0040	near Alphano	02040105080020	01	Bear Creek	Non Attain
AN0045	above Silver Lake	02040105100030	01	Beaver Brook (above Hope Village)	Full Attain
AN0047	Sarepta Rd	02040105100040	01	Beaver Brook (below Hope Village)	Full Attain
AN0050	Hutchinson Sta Rd	02040105110020	01	Buckhorn Creek (incl UDRV)	Non Attain
AN0042	Pequest Rd	02040105090050	01	Furnace Brook	Non Attain
AN0046	Rt 519	02040105100020	01	Honey Run	Non Attain
AN0051	Montana Mt Rd	02040105120010	01	Lopatcong Creek (above Rt 57)	Full Attain
AN0052	Rt 57	02040105120010	01	Lopatcong Creek (above Rt 57)	Non Attain
AN0053	Old Rt 22	02040105120020	01	Lopatcong Creek (below Rt 57) incl UDRV	Non Attain
AN0059	Merrill Ck Rd r	02040105140040	01	Merrill Creek	Full Attain
AN0060	Farm Rd	02040105140040	01	Merrill Creek	Full Attain
AN0039	Rt 615	02040105070060	01	Pequest R (below Bear Swamp to Trout Bk)	Full Attain
AN0043	Pequest Rd	02040105090060	01	Pequest R (below Furnace Brook)	Full Attain
AN0048	Water St	02040105090060	01	Pequest R (below Furnace Brook)	Full Attain
AN0041	Cemetery Rd	02040105090030	01	Pequest R (Furnace Bk to Cemetary Road)	Non Attain
AN0036	Brighton Rd	02040105070040	01	Pequest River (Trout Brook to Brighton)	Non Attain
AN0037	Pequest Rd	02040105070040	01	Pequest River (Trout Brook to Brighton)	Full Attain
AN0056	Brass Castle Rd	02040105140020	01	Pohatcong Ck (Brass Castle Ck to Rt 31)	Full Attain
AN0057	Buttermilk Bridge Rd	02040105140030	01	Pohatcong Ck (Edison Rd-Brass Castle Ck)	Full Attain
AN0058	Edison Rd	02040105140030	01	Pohatcong Ck (Edison Rd-Brass Castle Ck)	Non Attain
AN0061	Carpentersville Rd	02040105140070	01	Pohatcong Ck(below Springtown) incl UDRV	Full Attain
AN0054	Janes Chapel Rd	02040105140010	01	Pohatcong Creek (above Rt 31)	Full Attain
AN0055	Tunnel Hill Rd	02040105140010	01	Pohatcong Creek (above Rt 31)	Full Attain
AN0049	off Rt 519	02040105110010	01	Pophandusing Brook	Non Attain
AN0038	Rt 612	02040105070050	01	Trout Brook/Lake Tranquility	Non Attain

Biological monitoring in the Lopatcong, at the upstream-most site in Harmony Township, exhibits good biological conditions. Further downstream in Lopatcong Township, the benthic macroinvertebrate communities are impaired, as is the case at the downstream-most site in Philipsburg near the Delaware River.

WATERSHED: WALLKILL RIVER DRAINAGE WMA 2:

Wallkill River, Black Creek, Wawayanda Creek

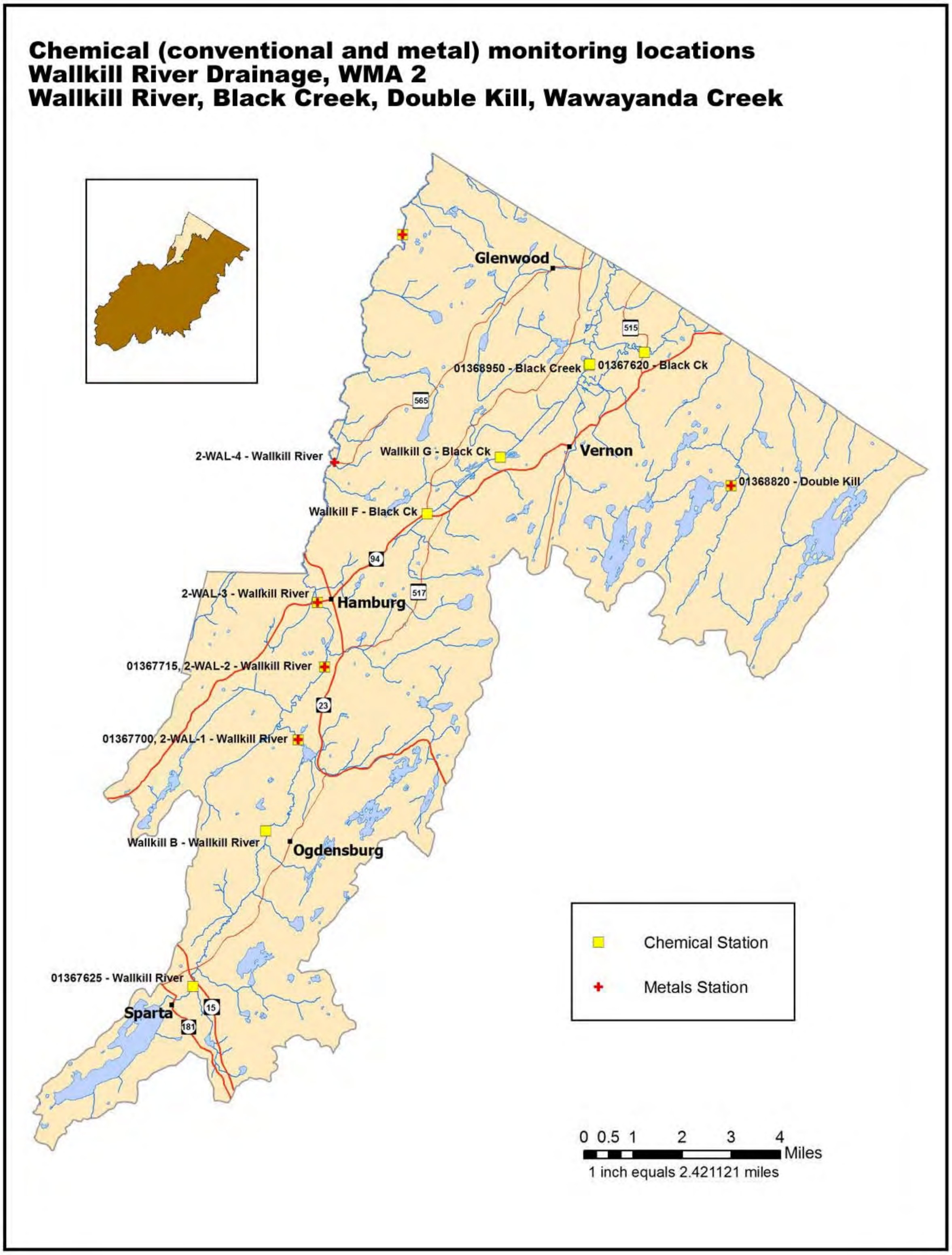
This watershed is depicted in the figures *Chemical [conventional and metal] Monitoring Locations Wallkill River Drainage, WMA 2,* and *Biological [benthic macroinvertebrate] Monitoring Locations Wallkill River Drainage, WMA 2*. With regards to conventional parameters (see table *Wallkill River Drainage, WMA 2 Water Quality Assessment for Conventional Parameters*), water quality problems in the Wallkill include temperature, TP, arsenic, and sanitary quality. Excess temperature levels were observed in the Wallkill River at Ogdensburg (Kennedy Ave.), the Black Creek in Vernon and Wawayanda/Pochuck Creek in Maple Grange. TP exceedances were recorded in the Wallkill River at Sparta, Franklin, and Unionville. TP was also found to exceed standards in the Black Creek site near Vernon, and in Wawayanda Creek in Maple Grange.

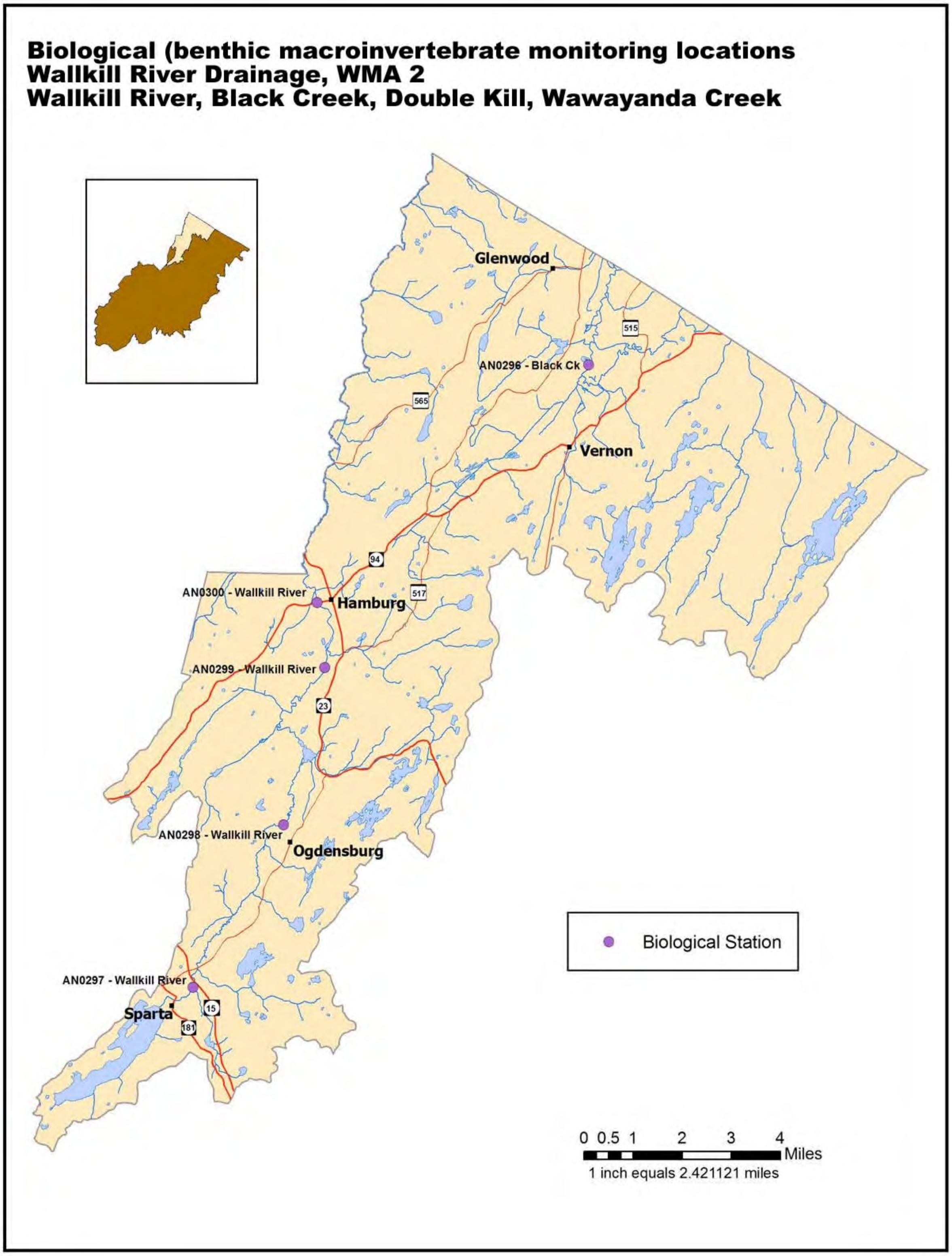
Arsenic (see table Wallkill River Drainage, WMA 2 Water Quality Assessment for Metals) was in violation of water quality standards at both of the Wallkill's Franklin sites, the Hamburg site, Unionville, Davis Road, and station 2-Wal-4 in Vernon and 2-Wal-1 in Franklin. The Wallkill site in Hamburg also exhibited water quality violations of cadmium, chromium, lead and mercury.

The results of a recent study by USGS indicate that Lake Mohawk may be the source of arsenic in the upper Wallkill (USGS, 2006). Prior use of arsenic-based herbicides is believed to be the source of arsenic buildup in lake sediments. Under anaerobic conditions, the arsenic is released into the water column and eventually exits into the stream channel. Farther downstream, the closed Franklin zinc mine is suspected to be leaching arsenic present in the geologic formations.

Biological sampling (see table *Wallkill River Drainage, WMA 2 Water Quality Assessment for Aquatic Life Support*) based upon benthic macroinvertebrates indicate two of the five sites on the Wallkill River to be impaired and in non-support of aquatic life use, specifically near Lake Mohawk and in Ogdensburg. An impaired biological site was also observed in the Black Creek below Great Gorge Resort in Vernon.

Results of fecal coliform source surveys taken from the NJDEP TMDL documents are listed in the table *Suspected Pollution Sources of Fecal Coliform Bacteria Identified in the Wallkill Watershed.*


Chemical (conventional and metal) monitoring locations
Wallkill River Drainage, WMA 2
Wallkill River, Black Creek, Double Kill, Wawayanda Creek
Glenwood
515
01368950 - Black Creek
01367620 - Black Ck
565
2-WAL-4 - Wallkill River
Wallkill G - Black Ck
Vernon
01368820 - Double Kill
Wallkill F - Black Ck
94
2-WAL-3 - Wallkill River
Hamburg
517
01367715, 2-WAL-2 - Wallkill River
23
01367700, 2-WAL-1 - Wallkill River
Wallkill B - Wallkill River
Ogdensburg
Chemical Station
Metals Station
01367625 - Wallkill River
Sparta
15
181
0 0.5 1 2 3 4
Miles
1 inch equals 2.421121 miles


Biological (benthic macroinvertebrate monitoring locations
Wallkill River Drainage, WMA 2
Wallkill River, Black Creek, Double Kill, Wawayanda Creek
Glenwood
515
AN0296 - Black Ck
565
Vernon
94
AN0300 - Wallkill River
Hamburg
517
AN0299 - Wallkill River
23
AN0298 - Wallkill River
Ogdensburg
Biological Station
AN0297 - Wallkill River
Sparta
15
181
0 0.5 1 2 3 4
Miles
1 inch equals 2.421121 miles

Wallkill River Drainage, WMA 2 Water Quality Assessment for Conventional Parameters

STATION	NAME	HUC14	WMA	E_COLI	DO	TEMP	PH_1	TP_1	NITRATE	TSS	TDS	AMONIA	CHLOR	TURBID	SULF	FECAL
1367625	at Sparta	02020007010010	02	4	1	1	1	5	1	1	1	1	1	1	1	4
1367700	at Franklin	02020007010040	02		NA	1	1	1	1	NA	1	1	NA		NA	4
Wallkill B	Kennedy Ave in Ogdensburg	02020007010040	02		1	5	1	1	1		1	1				
1367715	Scott Rd at Franklin	02020007010070	02	4	1	1	1	5	1	1	1	1	1	NA	1	4
2-WAL-3	Ames Blvd (Rte 94), Hamburg	02020007010070	02													
Wallkill E	at Unionville	02020007030040	02													
Wallkill F	Black Ck At Rt 94/517	02020007040010	02		1	5	1	5	1		1	1				
1368950	Black Creek Near Vernon	02020007040020	02	4	1	1	1	5	1	1	1	1	1			4
1367620	Black Ck at Grange Rd in Maple Grange	02020007040020	02		NA	NA	NA							NA		
Wallkill G	Black Ck At Sandhill Rd In Vernon	02020007040020	02		5	1	1	1	1		1	1				
1368820	Double Kill at Wawayanda	02020007040050	02	1	1	1	1	1	1	1	1	1	1	1	1	4
1368900	Wawayanda/Pochuck at Alt Rt 515	02020007040050	02		1	5	1	5	1	1	1	1	1			

1 denotes meeting standards

5 indicates not meeting standards.

4 is a subcategory of “not meeting standards” - denotes that a waterbody has undergone an EPA approved TMDL. Locations not meeting standards are shaded.

3 which occurs occasionally, denotes there was insufficient data to make an assessment.

Blank cells denote no data available for the constituent in question.

Wallkill River Drainage, WMA 2 Water Quality Assessment for Metals

STATION	NAME	HUC14	WMA	ARSENIC	CADMIUM	CHROMIUM	COPPER	LEAD	MERCURY	NICKEL	SELENIUM	SILVER	THALLIUM	ZINC
1367700	Wallkill River At Franklin	02020007010040	02											
1367715	Wallkill R at Scott Rd at Franklin	02020007010070	02											
2-WAL-3	Wallkill River on Ames Blvd (Rte 94), Hamburg	02020007010070	02	5	5	5	1	5	5	1	1	3		1
Wallkill E	Wallkill R At Unionville	02020007030040	02											
1368820	Double Kill at Wawayanda	02020007040050	02	3	1	1	1	1	3	1	1	1		1
2-WAL-2	Wallkill River on Davis Rd nr Scott Rd in Fr		02		3	1	1	1	3	1				1
2-WAL-4	Wallkill River on Glenwood		02		3	1	1	1	3	1				1
2-WAL-1	Wallkill River on Maple St nr Police Sta. Franklin Boro		02		3	1	1	1	3	1				1

Wallkill River Drainage, WMA 2 Water Quality Assessment for Aquatic Life Support

Station	Station Location	HUC14	WMA	Subwatershed	Aquatic Life Support
AN0297	Rt 15 –(nr municipal	02020007010010	02	Wallkill R/Lake Mohawk (Above Sparta)	Non Attain
AN0298	KennedyAve	02020007010040	02	Wallkill R (Hamburg SW Bdy to Ogdensburg)	Non Attain
AN0300	Rt 94	02020007010070	02	Wallkill R (Martins Rd to Hamburg SW Bdy)	Full Attain
AN0299	Scott Rd	02020007010070	02	Wallkill R (Martins Rd to Hamburg SW Bdy)	Full Attain
AN0296	Marker Rd	02020007040020	02	Black Creek (below G. Gorge Resort trib)	Non Attain

Suspected Pollution Sources of Fecal Coliform Bacteria Identified in the Wallkill Watershed

Stream Reach	Potential Sources
Wallkill River at Sparta	Pets, horses, wildlife
Wallkill River at Scott Road in Franklin	Geese and several small horse farms
Wallkill River near Sussex	Wildlife
Wallkill River near Unionville	Wildlife from a local wildlife refuge, cow pastures
Double Kill at Wawayanda	Wildlife
Black Creek near Vernon	Farms, goats, cows, wildlife

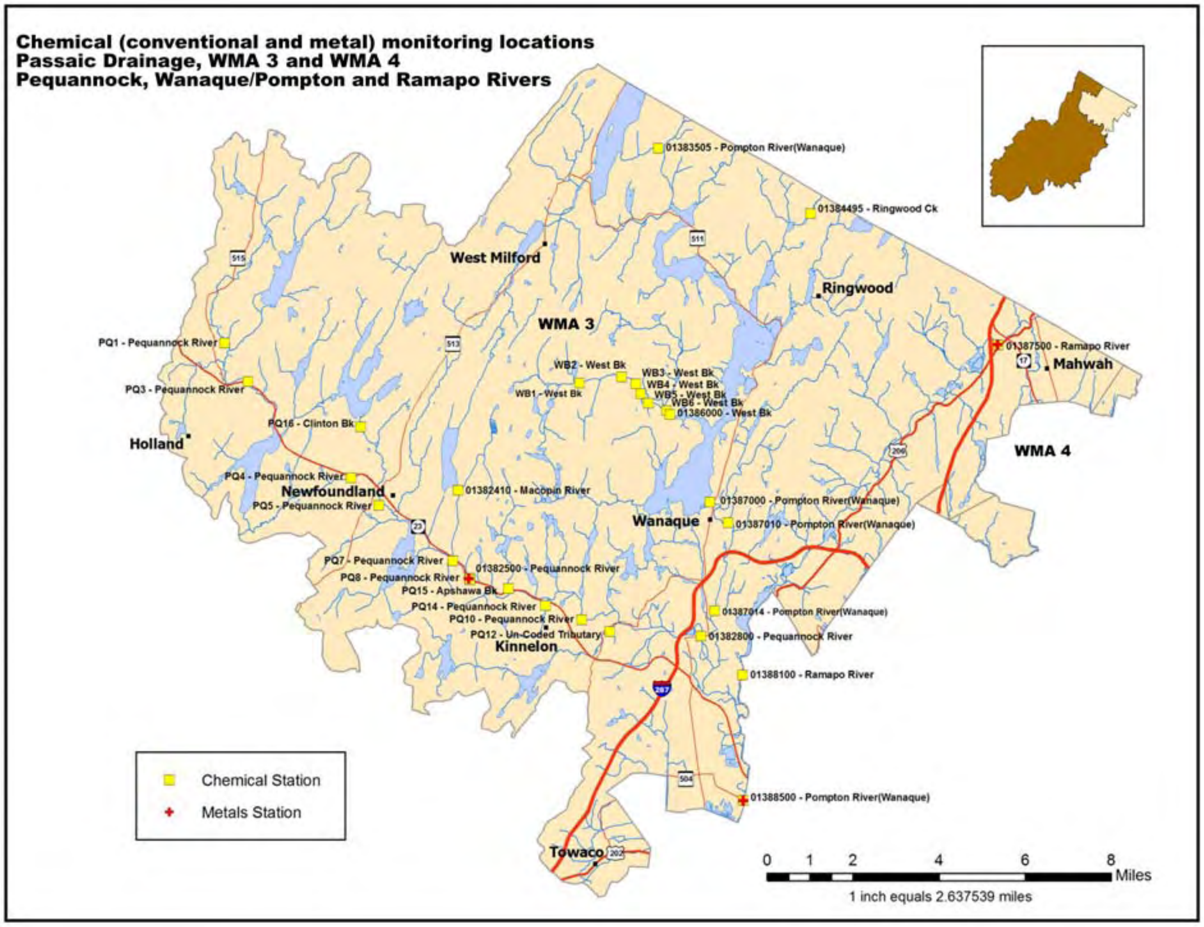
WATERSHED: PASSAIC DRAINAGE: WMA 3 AND WMA 4

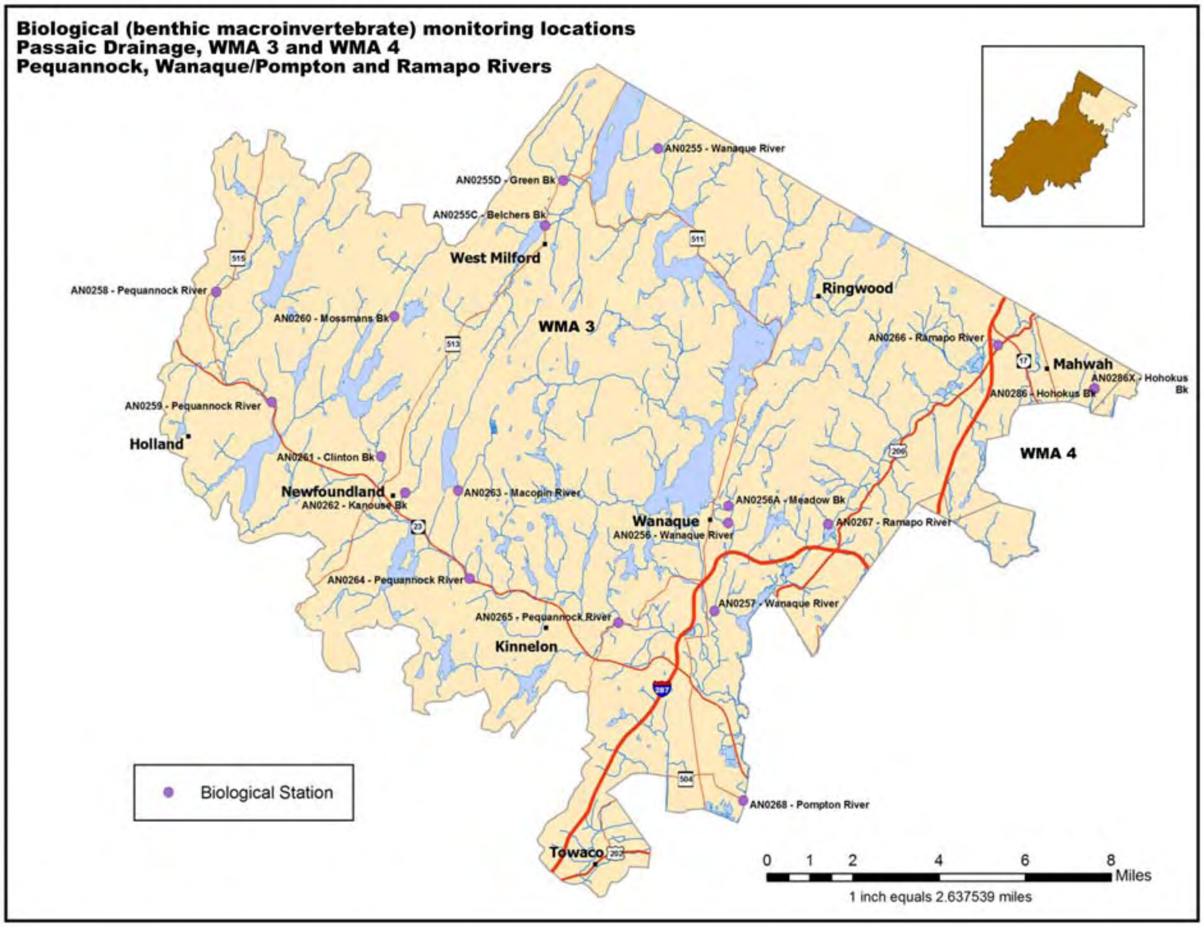
Pequannock River

These watersheds are depicted in the figures *Chemical [conventional and metal] Monitoring Locations Passaic Drainage: WMA 3 and WMA 4*, and *Biological [benthic macroinvertebrate] Monitoring Locations Passaic Drainage: WMA 3 and WMA 4*. As can be seen from the figures, WMA 4 comprises only a small portion of the Highlands Region (2%). Thus, the vast majority of the discussion in this section applies to WMA 3. Physical and chemical monitoring in the upper-most reaches of the Pequannock River (see table *Passaic Drainage: WMAs 3 and 4 Water Quality Assessment for Conventional Parameters*) is limited to in-stream temperature. This criterion is violated below the Canistear Reservoir, and continues downstream almost the end of the river. Only the most downstream site in Riverdale does not exceed the temperature criterion.

A full suite of chemical parameters is monitored at a site at the Macopin intake dam, just downstream of the confluence with the Macopin River. Here, exceedances were recorded for temperature and lead (see table *Passaic Drainage: WMAs 3 and 4 Water Quality Assessment for Metals*). Sanitary quality was within standards. Further downstream, the Riverdale site had no exceedances for a full suite of parameters, including temperature. Bacterial data was insufficient to assess sanitary quality at the Riverdale site.

Clinton Brook below Clinton Reservoir, and an unnamed tributary near the outlet of Maple Lake are monitored for stream temperature. There are in-stream temperature violations at these locations. A chemical monitoring site on the Macopin River near the outlet of Echo Lake had only DO exceedances. This may be related to the water exiting the lake. If water is released from the bottom of the lake (a "bottom release"), it is naturally depleted of oxygen, accounting for the low oxygen level recorded.




Biological (benthic macroinvertebrate) monitoring locations
Passaic Drainage, WMA 3 and WMA 4
Pequannock, Wanaque/Pompton and Ramapo Rivers
AN0255 - Wanaque River
AN0255D - Green Bk
AN0255C - Belchers Bk
West Milford
AN0258 - Pequannock River
AN0260 - Mossmans Bk
WMA 3
Ringwood
AN0266 - Ramapo River
Mahwah
AN0286X - Hohokus Bk
AN0286 - Hohokus Bk
AN0259 - Pequannock River
Holland
AN0261 - Clinton Bk
WMA 4
Newfoundland
AN0262 - Kanouse Bk
AN0263 - Macopin River
AN0256A - Meadow Bk
Wanaque
AN0256 - Wanaque River
AN0267 - Ramapo River
AN0264 - Pequannock River
AN0257 - Wanaque River
AN0265 - Pequannock River
Kinnelon
Biological Station
AN0268 - Pompton River
Towaco
0 1 2 4 6 8 Miles
1 inch equals 2.637539 miles

Passaic Drainage: WMAs 3 and 4 Water Quality Assessment for Conventional Parameters

STATION	NAME	HUC14	WMA	E COLI	DO	TEMP	PH	TP	NITRATE	TSS	TDS	AMMONIA	CHLORIDE	TURBID	SULFATE	FECAL_CO
PQ15	Apshawa Brook	02030103050080	03			4										
PQ16	Clinton Brook below Clinton Reservoir	02030103050050	03			4										
01382410	Macopin River At Echo Lake	02030103050060	03	1	5	1	1	1	1	1	1	1	1	NA	1	1
01382800	Pequannock R at Alt Rt 511 in Riverdale	02030103050080	03		1	1	1	1	1	1	1	1	1			3
01382500	Pequannock R at Macopin Intake Dam	02030103050060	03	1	1	5	1	1	1	1	1	1	1	1	1	1
PQ1	Pequannock River - Hardyston	02030103050030	03													
PQ3	Pequannock River - Hardyston	02030103050030	03			4										
PQ4	Pequannock River - Newfooundland	02030103050050	03			4										
PQ7	Pequannock River above Macopin	02030103050060	03			4										
PQ5	Pequannock River below Clinton	02030103050050	03			5										
PQ8	Pequannock River below Macopin	02030103050080	03													
PQ10	Pequannock River -Butler	02030103050080	03			5										
01388500	Pompton R at Pompton Plains	02030103110020	03	5	1	1	1	1	1	1	1	1	1	1	1	1

STATION	NAME	HUC14	WMA	E COLI	DO	TEMP	PH	TP	NITRATE	TSS	TDS	AMMONIA	CHLORIDE	TURBIDITY	SULFATE	FECAL_CO
01388100	Ramapo R at Dawes Hwy off Rt 202 in Pompton Plains	02030103100070	03		5	1	5	1	1	1	1	1	1			3
01387500	Ramapo R nr Mahwah	02030103100010	03	4	1	1	1	5	1	1	1	1	1	1	1	4
01384495	Ringwood Ck at Manor Rd in Ringwood St. Park	02030103070050	03		1	5	1	1	1	1	1	1	1			
PQ12	Stonehouse Brook	02030103050070	03			1										
PQ14	Trib Outlet of Maple Lake	02030103050080	03			5										
WB4	Unnamed Trib of West Brook	02030103070040	03			5										
WB5	Unnamed Trib of West Brook	02030103070040	03			5										
01387014	Wanaque R at Wanaque Ave at Pompton Lks	02030103070070	03	5	1	1	1	5	1	1	1	1	1	NA	1	4
01387010	Wanaque River At Highland Avenue At Wanaque	02030103070070	03	4	1	1	1	1	1	1	1	1	1			1
01387000	Wanaque River At Wanaque	02030103070050	03		5			5								5
01383505	Wanaque River Near Awosting	02030103070030	03		3	3	3	1	1	1	1	1				1
01386000	West Brook	02030103070040	03			1										
WB2	West Brook above West Brook Road	02030103070040	03			5										

STATION	NAME	HUC14	WMA	E COLI	DO	TEMP	PH	TP	NITRATE	TSS	TDS	AMMONIA	CHLORIDE	TURBIDITY	SULFATE	FECAL_CO
WB1	West Brook below Snake Den Road	02030103070040	03			5										
WB3	West Brook below West Brook Road	02030103070040	03			5										
WB6	West Brook on Windbeam Club Poperty	02030103070040	03			5										

1 denotes meeting standards

5 indicates not meeting standards.

4 is a subcategory of “not meeting standards” - denotes that a waterbody has undergone an EPA approved TMDL. Locations not meeting standards are shaded.

3 which occurs occasionally, denotes there was insufficient data to make an assessment.

Blank cells denote no data available for the constituent in question.

Passaic Drainage: WMA 3 and 4 Water Quality Assessment for Metals

STATION	NAME	HUC14	WMA	ARSENIC	ARSENIC_1	CADMIUM	CHROMIUM	COPPER	LEAD	MERCURY	NICKEL	SELENIUM	SILVER	THALLIUM	ZINC
3-PEQ-1, 3-SITE	Pequannock River at Macopin		03	3		3	1	1	**5**	3	1				1
3-SITE-7	Pompton River at Packanack		03	3		3	1	1	**5**	3	1				1
3-RAM-1, 3-SITE	Ramapo River nr Mahwah		04	3		3	1	1	1	3	1				1

The extensive impoundment system in the Pequannock watershed may contribute to the exceedances of in-stream temperatures frequently observed. The surface waters of the impoundments may warm, and when released into the river system, warm the rivers to a degree that violates water quality standards. It is also possible that lower flow releases may be insufficient to maintain the appropriate water temperatures. A temperature TMDL has been adopted by NJDEP for the Pequannock.

Biological monitoring (see table *Passaic Drainage: WMA 3 Water Quality Assessment for Aquatic Life Support*) is limited due to the extensive impoundment system. Two biological sites on the Pequannock main stem include one on the upper-most reach in Hardyston (AN0258), where the biological condition is impaired. The second is downstream in West Milford (AN0259), where the biological condition is good.

Mossmans Brook is monitored just above the Clinton Reservoir, and has a good benthic community. Monitoring farther downstream, in Clinton Brook below Clinton Reservoir, indicates an impaired biological condition. Both Kanouse Brook and the Macopin River, monitored just below Echo Lake, also have impaired biological conditions.

Wanaque River

Chemical and physical monitoring (see table *Passaic Drainage: WMA 3 Water Quality Assessment for Conventional Parameters*) in the upper-most Wanaque near Awosting showed no exceedances. Monitoring continues further downstream at the outlet of the Wanaque Reservoir, where data are limited to DO, TP and bacterial quality, all of which exceed standards. Somewhat further downstream at Highlands Avenue in Wanaque, analysis of a full parameter suite indicated no water quality violations.

Monitoring in West Brook, which enters Wanaque Reservoir from the west, is limited to in-stream temperature. The criterion was exceeded along the entire main stem, with the exception of the downstream-most site, just before the stream enters the reservoir. At Ringwood Creek in Ringwood State Park, only in-stream temperature exceeded its standard.

Biological monitoring (see table *Passaic Drainage: WMA 3 Water Quality Assessment for Aquatic Life Support*) exhibits impaired benthic macroinvertebrate communities throughout, except at Green Brook in West Milford (AN0255D).

Ramapo and Pompton Rivers

The physical and chemical quality of the Ramapo River is monitored at its most upstream point near Mahwah, where bacterial quality and TP criteria were exceeded. Much further downstream, on the Ramapo River at Dawes Highway in Pompton Plains, DO and pH exceeded standards.

The downstream-most site in the Highlands Region is the Pompton River site in Pompton Plains, below the confluence with the Wanaque and Pequannock Rivers. Bacterial quality and lead concentrations exceeded water quality criteria.

Passaic Drainage: WMA 3 Water Quality Assessment for Aquatic Life Support

Station	Station Location	HUC14	WMA	Sub Watershed Name	Watershed Name	Aquatic Life Support
AN0255C	Union Valley Rd	02030103070020	03	Belcher Creek (Pinecliff Lake & below)	Wanaque River	Non Attain
AN0255D	Union Valley Rd	02030103070020	03	Belcher Creek (Pinecliff Lake & below)	Wanaque River	Full Attain
AN0260	Clinton Rd (abv res)	02030103050040	03	Clinton Reservior/Mossmans Brook	Pequannock River	Full Attain
AN0256A	Highland Ave	02030103070060	03	Meadow Brook/High Mountain Brook	Wanaque River	Non Attain
AN0258	Rt 515	02030103050030	03	Pequannock R (above OakRidge Res outlet)	Pequannock River	Non Attain
AN0259	Rt 23 (abv res)	02030103050030	03	Pequannock R (above OakRidge Res outlet)	Pequannock River	Full Attain
AN0261	LaRue Rd	02030103050050	03	Pequannock R (Charlotteburg to OakRidge)	Pequannock River	Non Attain
AN0262	Rt 23	02030103050050	03	Pequannock R (Charlotteburg to OakRidge)	Pequannock River	Non Attain
AN0263	blw Echo Lk	02030103050060	03	Pequannock R(Macopin gage to Charl'brg)	Pequannock River	Non Attain
AN0264	Rt 23 (Macopin Intak	02030103050060	03	Pequannock R(Macopin gage to Charl'brg)	Pequannock River	Full Attain
AN0268	Newark Pompton Tnpk	02030103110020	03	Pompton River	Pompton River	Non Attain
AN0266	W Ramapo Ave	02030103100010	03	Ramapo R (above 74d 11m 00s)	Ramapo River	Full Attain
AN0267	Lenape Ln	02030103100070	03	Ramapo R (below Crystal Lake bridge)	Ramapo River	Full Attain

AN0265	Rt 511	02030103050070	03	Stone House Brook	Pequannock River	Full Attain
AN0255	E Shore Dr	02030103070030	03	Wanaque R/Greenwood Lk(aboveMonks gage)	Wanaque River	Full Attain
AN0256	Highland Ave (blw ST	02030103070070	03	Wanaque R/Posts Bk (below reservior)	Wanaque River	Non Attain
AN0257	Wanaque Ave	02030103070070	03	Wanaque R/Posts Bk (below reservior)	Wanaque River	Non Attain
AN0286	Masonicus Rd	02030103140020	04	Hohokus Bk(Pennington Ave to Godwin Ave)	Saddle River	Non Attain
AN0286X	Grenadier Dr W of Co	02030103140020	04	Hohokus Bk(Pennington Ave to Godwin Ave)	Saddle River	Non Attain

Biological monitoring in the Ramapo and Pompton Rivers watershed indicates good benthic communities in the upper reaches in Mahwah and Oakland. Conditions degrade downstream in the Pompton River in Pequannock Township (AN0268), where an impaired community was observed.

Results of fecal coliform source surveys taken from the NJDEP TMDL documents are listed in the table *Suspected Pollution Sources of Fecal Coliform Bacteria Identified in the Middle Passaic Watershed.*

Suspected Pollution Sources of Fecal Coliform Bacteria Identified in the Middle Passaic Watershed.

Stream Reach	Potential Sources
Macopin River at Macopin Reservoir	Detention basins at the upper end of Echo Lake, horse stables
Wanaque River at Highland Ave	Canada geese; storm water detention basins at Pompton Lakes, Lake Inez, Skyland Lake; failing septic systems, pet waste
Ramapo River near Mahwah	Failing septic systems in Oakland, Canada geese, horse farms

WATERSHED: RARITAN DRAINAGE WMA 8:

Spruce Run

These watersheds are depicted in the figures *Chemical [conventional and metal] Monitoring Locations Raritan Drainage: WMA 8*, and *Biological [benthic macroinvertebrate] Monitoring Locations Raritan Drainage: WMA 8*. With respect to physical and chemical monitoring (see table *Raritan Drainage: WMA 8 Water Quality Assessment for Conventional Parameters*), the upstream-most monitoring site on the Spruce Run at New Port exhibits relatively good water quality with the exception of sanitary quality and instream temperature. Farther downstream at Glen Gardner, exceedances are limited to sanitary quality. To the west, at Mulhockaway Creek at Van Syckel, bacterial quality and stream temperature violate water quality standards.

South Branch Raritan River

The South Branch Raritan River in its upper reaches at Middle Valley (see table *Raritan Drainage: WMA 8 Water Quality Assessment for Conventional Parameters*) exceeds sanitary quality, temperature, and TP limits. Farther downstream in High Bridge, just above the Spruce Run Reservoir, there are exceedances for bacteria and temperature. Stony Brook, a tributary to the upper end of the South Branch at Naughright, has unacceptable sanitary quality.

Biological monitoring results in the Spruce Run and the South Branch Raritan Rivers (see table *Raritan Drainage: WMA 8 Water Quality Assessment for Aquatic Life Support*), exhibit mostly non-impaired conditions overall, with some sites having impaired biological conditions.

Lamington River

The sanitary standard is exceeded at the upstream-most physical and chemical monitoring site on the Lamington River. Farther downstream at Pottersville, bacteria and total phosphorus criteria are violated. At the downstream-most chemical site, the Lamington exceeds standards for bacteria, pH and TP. Temperature does not exceed the criterion in the North Branch Rockaway River.

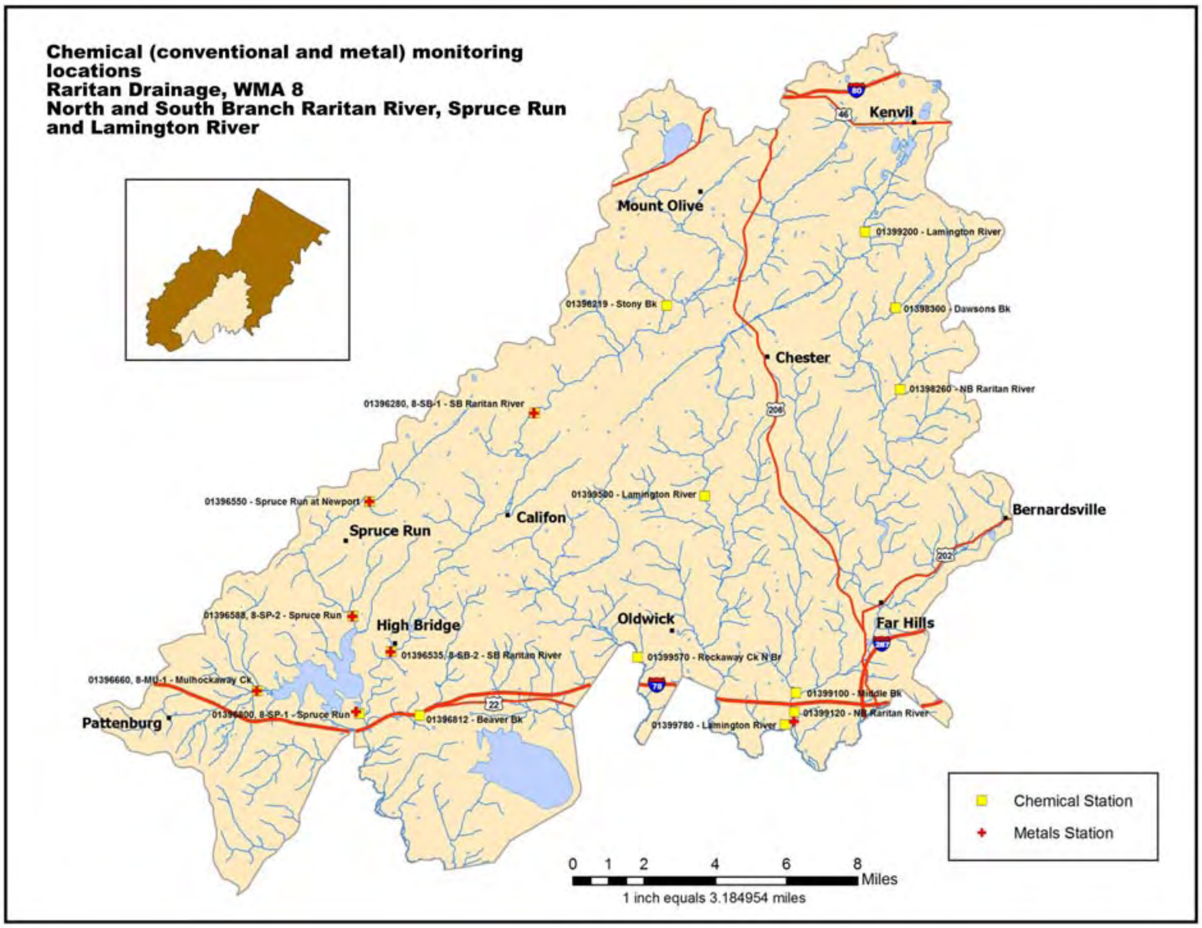
Biological monitoring on the Lamington River and its tributaries indicate overall good benthic macroinvertebrate communities. Impaired communities are limited to the two Lamington sites in Chester Township (AN0356 and AN0358). Only the upper South Branch Rockaway Creek, a tributary to the Lamington, showed impaired benthic macroinvertebrate communities.

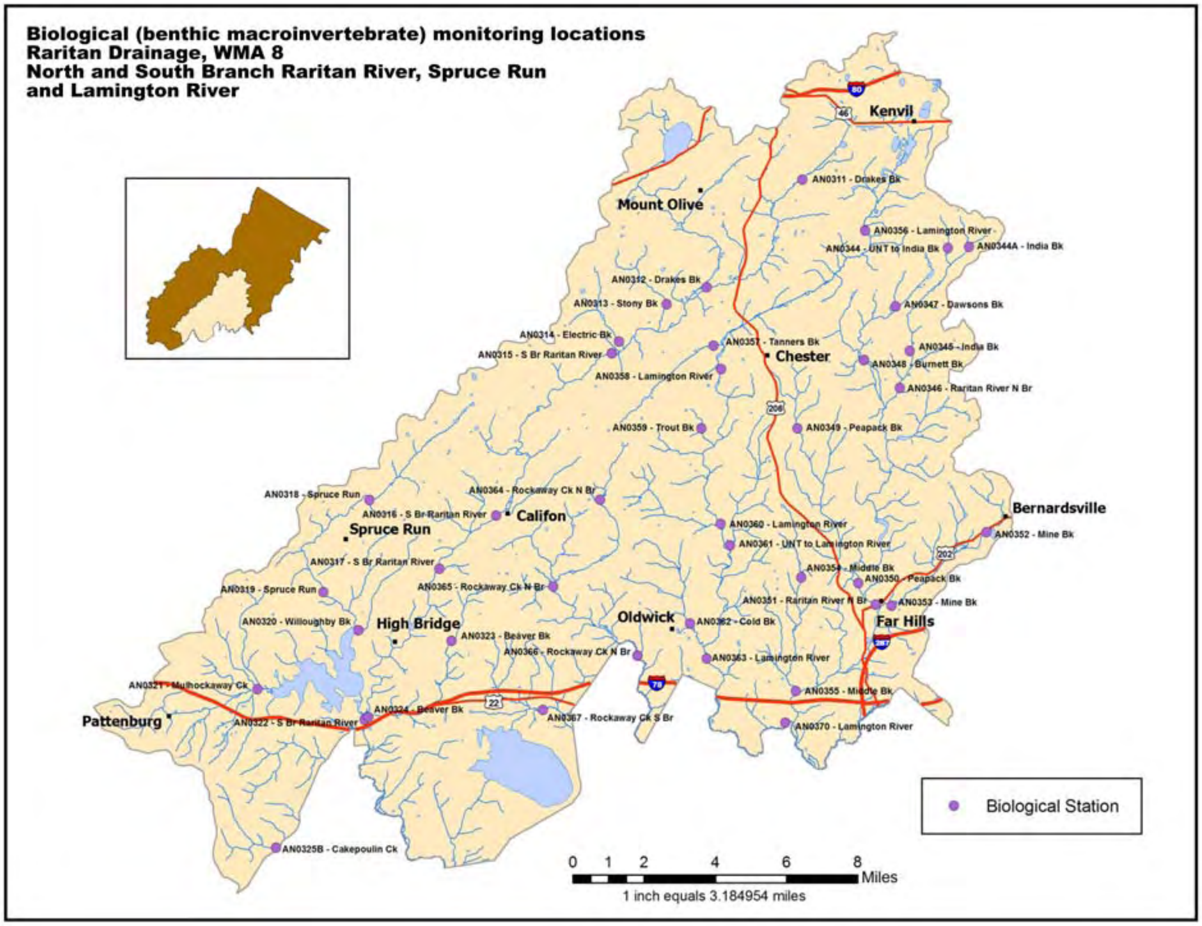
North Branch Raritan River

Physical and chemical monitoring in the North Branch Raritan River, near Chester and at Burnt Mills, indicates impaired sanitary quality. Metals monitoring (see table *Raritan Drainage: WMA 8 Water Quality Assessment for Metals*) at the Burnt Mills site indicates the copper criterion is exceeded. Chemical monitoring in the tributaries to the North Branch is limited. Dawsons Brook (a tributary in the upper North Branch) and Middle Brook (a tributary in the lower North Branch) do not display violations of a limited suite of parameters. Note that there was insufficient bacterial data for a sanitary assessment at both sites.

Biological monitoring of the North Branch Raritan River watershed indicates good biological communities throughout the watershed. The only exceptions are in the upper end of the Middle Brook and a site on an unnamed tributary to India Brook, a tributary to the North Branch Raritan River.

Results of fecal coliform source surveys taken from the NJDEP TMDL documents are listed in the table *Suspected Pollution Sources of Fecal Coliform Bacteria Identified in the Upper Raritan Watershed.*




Biological (benthic macroinvertebrate) monitoring locations
Raritan Drainage, WMA 8
North and South Branch Raritan River, Spruce Run
and Lamington River
Kenvil
Mount Olive
Chester
Califon
Spruce Run
High Bridge
Oldwick
Pattenburg
Bernardsville
Far Hills
AN0311 - Drakes Bk
AN0356 - Lamington River
AN0344 - UNT to India Bk
AN0344A - India Bk
AN0312 - Drakes Bk
AN0313 - Stony Bk
AN0347 - Dawsons Bk
AN0314 - Electric Bk
AN0315 - S Br Raritan River
AN0357 - Tanners Bk
AN0345 - India Bk
AN0348 - Burnett Bk
AN0358 - Lamington River
AN0346 - Raritan River N Br
AN0359 - Trout Bk
AN0349 - Peapack Bk
AN0318 - Spruce Run
AN0364 - Rockaway Ck N Br
AN0316 - S Br Raritan River
AN0360 - Lamington River
AN0352 - Mine Bk
AN0361 - UNT to Lamington River
AN0317 - S Br Raritan River
AN0350 - Peapack Bk
AN0365 - Rockaway Ck N Br
AN0319 - Spruce Run
AN0351 - Raritan River N Br
AN0353 - Mine Bk
AN0320 - Willoughby Bk
AN0362 - Cold Bk
AN0323 - Beaver Bk
AN0366 - Rockaway Ck N Br
AN0363 - Lamington River
AN0321 - Mulhockaway Ck
AN0355 - Middle Bk
AN0324 - Beaver Bk
AN0322 - S Br Raritan River
AN0367 - Rockaway Ck S Br
AN0370 - Lamington River
AN0325B - Cakepoulin Ck
80
46
206
202
287
78
22
Biological Station
0 1 2 4 6 8 Miles
1 inch equals 3.184954 miles

Raritan Drainage: WMA 8 Water Quality Assessment for Conventional Parameters

STATION	NAME	HUC14	WMA	E COLI	TEMP	TP	DO	PH	TP	NITRATE	TSS	TDS	AMMONIA	CHLORIDE	TURBIDITY	SULFATE	FECAL_CO
1396812	Beaver Brook	02030105020050	08		1		1	1	5	1	NA	1	NA	1	NA		
1398300	Dawsons Brook Near Ironia	02030105060020	08		3		3	1	1	1	1	1	1				3
1399780	Lamington R at Burnt Mills	02030105050110	08	4	1		1	5	5	1	1	1	1	1	1	1	4
1399500	Lamington Rifver Near Pottersville	02030105050040	08	4	1		1	1	5	1	1	1	1				4
1399200	Lamington River Near Ironia	'0203010505002 0	08	4	1		1	1	1	1	1		NA	1	1	1	4
1399100	Middle Brook At Burnt Mills	'0203010506008 0	08	3	1		1	3	3	1	3	1	1	NA		NA	3
1396660	Mulhockaway Ck at Van Syckel	'0203010502003 0	08	4	5		1	1	1	1	1	1	1	1	1	1	4
1399120	NB Raritan River At Burnt Mills	'0203010506009 0	08	4	1		1	1	1	1	1	1	1		NA		4
1398260	NB Raritan River Near Chester	'0203010506003 0	08	4	1		1	1	1	1	1	1	1		NA		4
1399570	Rockaway Ck N Br	'0203010505009 0	08		1												
1396535	SB Raritan River At Arch St At High Bridge	'0203010501008 0	08	4	5		1	1	1	1	1	1	1				4
1396280	SB Raritan River At Middle Valley	'0203010501006 0	08	4	5		1	1	5	1	1	1	1	1			4
1396800	Spruce Run At Clinton	'0203010502004 0	08		5			5	5								
1396550	Spruce Run at Newport	'0203010502001 0	08	4	5		1	1	1	1	1	1	1	1	1	1	1
1396588	Spruce Run Near Glen Gardner	'0203010502002 0	08	4	1		1	1	1	1	1	1	1	1	1	1	4
1396219	Stony Brook At Fairview Avenue At Naughright	'0203010501005 0	08	4	1		1	1	3	1	1	1	1				4

1 denotes meeting standards

5 indicates not meeting standards.

4 is a subcategory of “not meeting standards” - denotes that a waterbody has undergone an EPA approved TMDL. Locations not meeting standards are shaded.

3 which occurs occasionally, denotes there was insufficient data to make an assessment.

Blank cells denote no data available for the constituent in question.

Raritan Drainage: WMA 8 Water Quality Assessment for Metals

STATION	NAME	HUC14	WMA	ARSENIC	ARSENIC_1	CADMIUM	CHROMIUM	COPPER	LEAD	MERCURY	NICKEL	SELENIUM	SILVER	THALLIUM	ZINC
1396550	Spruce Run at Newport	02030105020010	08		3	1	1	1	1	3	1	1	1		1
8-MU-1	Mulhockaway Cr on Rte 635 in Union Twp nr Van		08	3		3	1	1	1	3	1				1
8-NB-2	N Br Raritan River on Burnt Mills Rd. in Burn		08	3		3	3	5	3	3	3				3
8-SB-2	S Br Raritan River on Arch St in High Bridge		08	3		3	1	1	1	3	1				1
8-SB-1	S Br Raritan River on Middle Valley Rd, Middl		08	3		3	1	1	1	3	1				1
8-SP-1	Spruce Run in Spruce Run Reservoir at Spruce		08	3		5	3	3	3	3	3				3
8-SP-2	Spruce Run on Van Syckel Corner Rd nr High Br		08	3		3	1	1	1	3	1				1

Raritan Drainage: WMA 8 Water Quality Assessment for Aquatic Life Support

Station	Station Location	HUC14	WMA	Sub Watershed Name	Aquatic Life Support
AN0323	Herman Thau Rd	02030105020050	08	Beaver Brook (Clinton)	Full Attain
AN0324	Lehigh St	02030105020050	08	Beaver Brook (Clinton)	Non Attain
AN0347	S Rd & Ironia Rd	02030105060020	08	Burnett Brook (above Old Mill Rd)	Full Attain
AN0325B	Rt 513	02030105020060	08	Cakepoulin Creek	Full Attain
AN0362	Vliettown Rd	02030105050060	08	Cold Brook	Full Attain
AN0311	Emans Rd	02030105010010	08	Drakes Brook (above Eyland Ave)	Non Attain
AN0312	Bartley Long Valley	02030105010020	08	Drakes Brook (below Eyland Ave)	Non Attain
AN0370	Walsh Rd	02030105050110	08	Lamington R (below Halls Bridge Rd)	Full Attain
AN0357	Tanners Bk Rd	02030105050030	08	Lamington R (Furnace Rd to Hillside Rd)	Full Attain
AN0356	Ironia Rd	02030105050020	08	Lamington R (Hillside Rd to Rt 10)	Non Attain
AN0360	Rt 512	02030105050070	08	Lamington R(HallsBrRd-Pottersville gage)	Full Attain
AN0363	Rt 523	02030105050070	08	Lamington R(HallsBrRd-Pottersville gage)	Full Attain

AN0358	Rt 24	02030105050 040	08	Lamington R(Pottersville gage-FurnaceRd)	Non Attain
AN0359	Hacklebarney Rd	02030105050 040	08	Lamington R(Pottersville gage-FurnaceRd)	Full Attain
AN0354	Spook Hollow Rd	02030105060 080	08	Middle Brook (NB Raritan River)	Non Attain
AN0355	R Rd	02030105060 080	08	Middle Brook (NB Raritan River)	Full Attain
AN0321	Rt 635	02030105020 030	08	Mulhockaway Creek	Non Attain
AN0349	Fox Chase Rd	02030105060 050	08	Peapack Brook (above/incl Gladstone Bk)	Full Attain
AN0350	Old Dutch Rd	02030105060 060	08	Peapack Brook (below Gladstone Brook)	Full Attain
AN0361	Black R Rd	02030105050 050	08	Pottersville trib (Lamington River)	Full Attain
AN0344	Calais Rd	02030105060 010	08	Raritan R NB (above/incl India Bk)	Non Attain
AN0344A	Calais Rd BR#733	02030105060 010	08	Raritan R NB (above/incl India Bk)	Full Attain
AN0345	Mountainside Rd	02030105060 010	08	Raritan R NB (above/incl India Bk)	Full Attain
AN0346	Rt 24	02030105060 030	08	Raritan R NB(incl McVickers to India Bk)	Full Attain
AN0348	Old Mill Rd	02030105060 030	08	Raritan R NB(incl McVickers to India Bk)	Full Attain

AN0351	Rt 202	02030105060 070	08	Raritan R NB(incl Mine Bk to Peapack Bk)	Full Attain
AN0352	Bernardsville Rd	02030105060 070	08	Raritan R NB(incl Mine Bk to Peapack Bk)	Non Attain
AN0353	Far Hills Rd (Rt 512	02030105060 070	08	Raritan R NB(incl Mine Bk to Peapack Bk)	Full Attain
AN0313	Fairview Ave	02030105010 050	08	Raritan R SB(LongValley br to 74d44m15s)	Full Attain
AN0314	Fairview Ave	02030105010 050	08	Raritan R SB(LongValley br to 74d44m15s)	Non Attain
AN0315	Rt 517	02030105010 050	08	Raritan R SB(LongValley br to 74d44m15s)	Full Attain
AN0322	Rt 173 & Rt 513	02030105020 070	08	Raritan R SB(River Rd to Spruce Run)	Full Attain
AN0316	R Rd (dwnstr of Rt 5	02030105010 070	08	Raritan R SB(StoneMill gage to Califon)	Full Attain
AN0317	R Rd (Ken Lockwood G	02030105010 070	08	Raritan R SB(StoneMill gage to Califon)	Full Attain
AN0364	Rt 512	02030105050 080	08	Rockaway Ck (above McCrea Mills)	Full Attain
AN0365	Rockaway Rd	02030105050 080	08	Rockaway Ck (above McCrea Mills)	Full Attain

AN0366	Rockaway Rd	02030105050 090	08	Rockaway Ck (RockawaySB to McCrea Mills)	Full Attain
AN0367	Windy Acres Farm	02030105050 100	08	Rockaway Ck SB	Non Attain
AN0318	Newport Rd	02030105020 010	08	Spruce Run (above Glen Gardner)	Full Attain
AN0319	Rt 31	02030105020 020	08	Spruce Run (Reservior to Glen Gardner)	Non Attain
AN0320	Rt 31	02030105020 040	08	Spruce Run Reservior / Willoughby Brook	Full Attain

Suspected Pollution Sources of Fecal Coliform Bacteria Identified in the Upper Raritan Watershed

Stream Reach	Potential Sources
South Branch Raritan River at Stanton Station	Suburban development, wildlife, agricultural operations
South Branch Raritan River at High Bridge	Failing septic systems, horses, pet waste
South Branch Raritan River at Middle Valley	Suburban development, agriculture, horses, pet waste
North Branch Raritan River at Burnt Mills	Residential development, cattle, geese, deer, horse farms
North Branch Raritan River near Chester	Suburban development, geese and heavy deer populations. Livestock operations downstream of Rt. 24. Cattle and horses in the Pleasant Valley area.
Lamington River near Pottersville	Suburban development, wildlife, agriculture, pet waste
Lamington River near Ironia	Suburban development, geese
Lamington River at Burnt Mills	Suburban development, geese, pets, heavy deer populations, cattle and horse farms, manure spreading
Rockaway Creek at Whitehouse	Suburban development, cattle, horse and dairy farms
Spruce Run near Glen Gardner/ Newport	Suburban development, deer and geese, agriculture
Mulhockaway Creek at Van Syckel	Agriculture, deer, and heavy geese populations in local ponds
Stony Brook at Naughright	Agriculture and geese

The North and South Branch Raritan WMA has 36 permitted discharges into its surface waters. The effluent discharges range from 0.0003 to 3.9 cubic feet per second (cfs). Most of the seven constituents analyzed for source loading, including ammonia plus organic nitrogen, BOD, TDS, nitrate plus nitrite, TOC, TP, and TSS were attributed to non-permitted sources. However, permitted sources accounted for more than 50% of the load at some of the water quality sampling sites for ammonia plus organic nitrogen, nitrate plus nitrite, and total phosphorus, especially during low flow periods.

The point and non-point sources of pollutants in this watershed were assessed in the 1996 New Jersey State Water Quality Inventory Report. This report provides guidance in determining the possible causes of the water quality concerns described in the above sections. Facilities that discharge effluent into the surface waters of this watershed have the potential to be a significant point source because of their contribution of flow compared to base flow.

According to the 1996 report there were no active enforcement cases against any of those facilities. Past enforcement actions have been reconciled due to the facility upgrading or ceasing their discharge, and the facilities are no longer considered to be impairing the water quality. The surface waters of the North and South Branch Raritan Rivers also have pollutant loadings from non-point sources. In the South Branch Raritan River watershed, the 1996 report states that there is a "gradual" decline in agricultural non-point source pollution and a "rapid" increase in suburban non-point source pollution. Agricultural non-point source pollutants are suspected of contributing nutrient and sediment loads. The primary source of non-point pollutants for the North Branch Raritan watershed is from suburban landscape runoff and development. Non-point source pollutants from agriculture are a suspected, but unconfirmed, problem for this watershed.

WATERSHED: UPPER PASSAIC DRAINAGE: WMA 6

Upper Passaic, Dead River, Whippany Rivers

These watersheds are depicted in the figures Chemical [conventional and metal] Monitoring Locations Passaic Drainage: WMA 6, and Biological [benthic macroinvertebrate] Monitoring Locations Passaic Drainage: WMA 6. Physical and chemical water quality in the uppermost reaches of the Passaic River watershed is monitored at Tempe Wick Road in Mendham and in Primrose Brook in the Morristown National Park (see table Upper Passaic Drainage: WMA 6 Water Quality Assessment for Conventional Parameters). Both sites show overall good water quality. The Passaic River site exceeds the sanitary standard. Farther downstream, the Passaic River near Millington has good water quality, except for sanitary quality. In the same vicinity, the Dead River at Millington also exceeds sanitary quality, TP and TSS.

The Whippany River at Morristown, mid-point along the main stem, exceeds TP standards. Farther downstream in Pine Brook, DO, bacteria and TP criteria are exceeded. Biological monitoring data in the upper Passaic River and tributaries (see table *Upper Passaic Drainage: WMA 6 Water Quality Assessment for Aquatic Life Support*) indicate good conditions in the Mendham area, uppermost Primrose and Great Brook. The lower Primrose exhibits impaired benthic macroinvertebrates. The Dead River has impaired biological conditions at both its upper (AN0226) and lower (AN0227) ends. The upper Whippany River in Morris Township has good benthic macroinvertebrate communities, as does Watnong Brook. Approaching Morristown, biological impairment is evident and continues to the downstream-most site in Pine Brook.

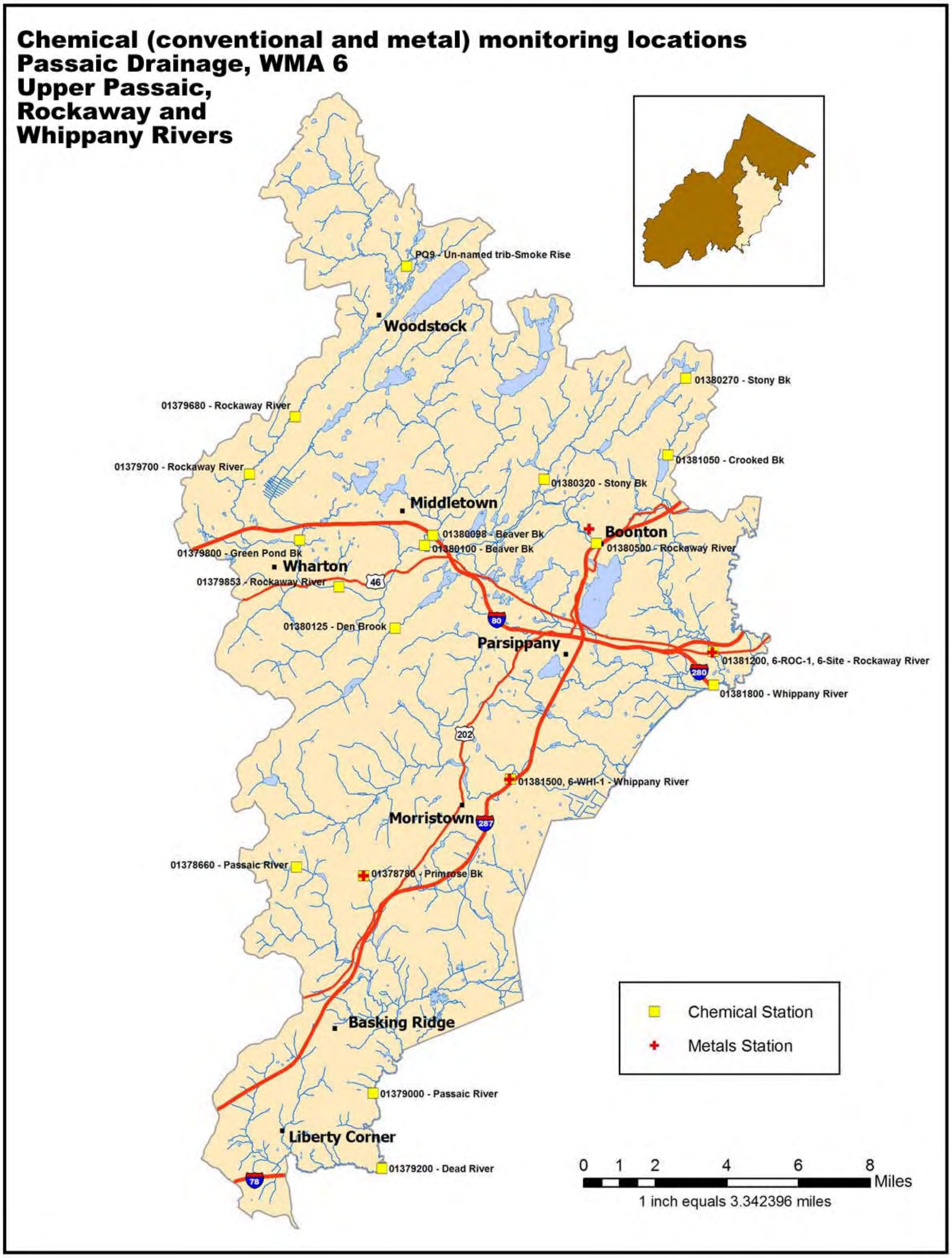
Results of fecal coliform source surveys taken from NJDEP TMDL documents are listed in the table *Suspected Pollution Sources of Fecal Coliform Bacteria Identified in the Upper Passaic Watershed.*

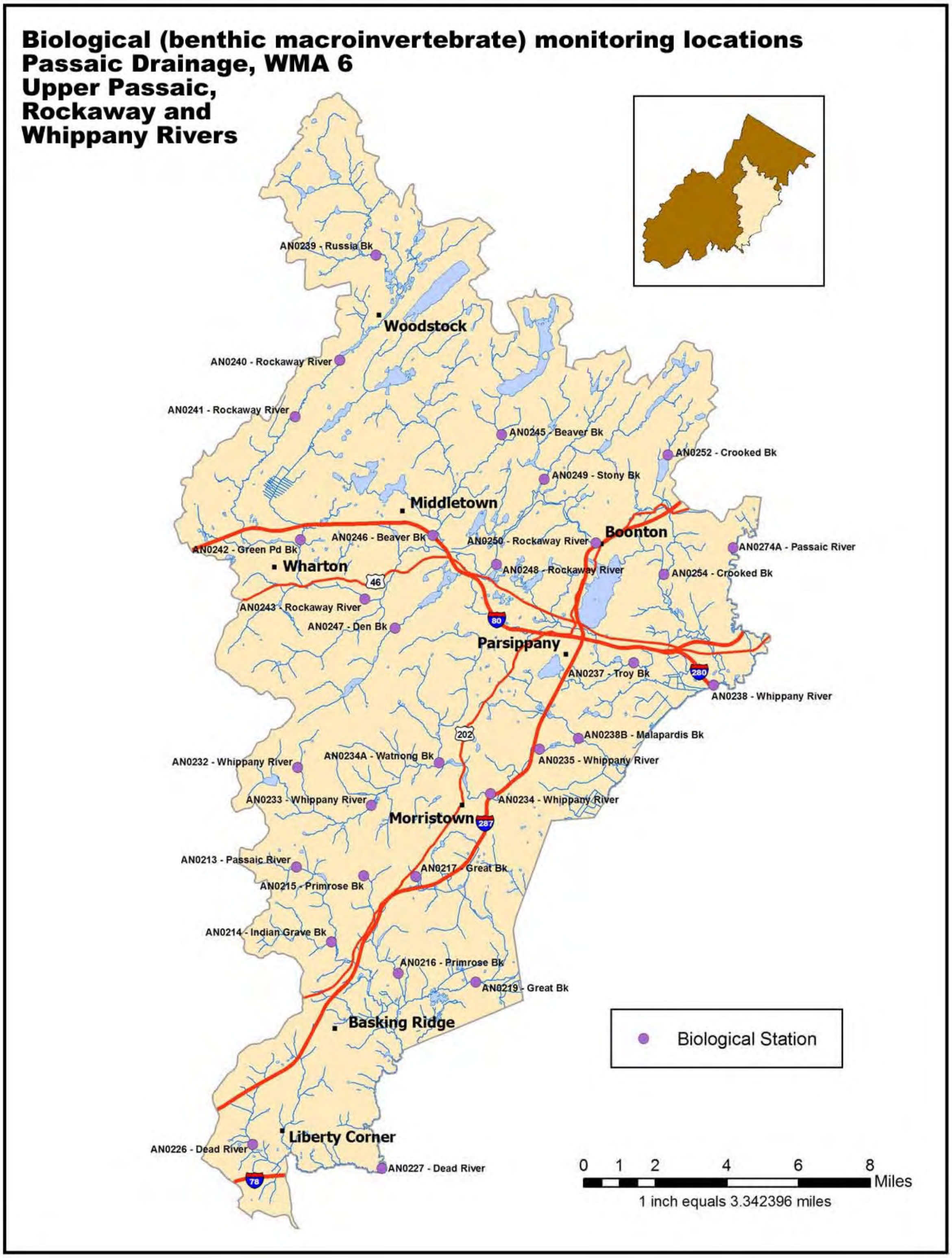
Rockaway River

Physical and chemical monitoring in the upper reaches of the Rockaway River occurs at Longwood Valley, see table *Upper Passaic Drainage: WMA 6 Water Quality Assessment for Conventional Parameters*) and farther downstream at Blackwell Street, sanitary quality exceeds standards. There were insufficient data to assess the other water quality parameters recorded. In Boonton, the Rockaway River exhibits good water quality; with even sanitary quality within standards. Metals monitoring (see table *Upper Passaic Drainage: WMA 6 Water Quality Assessment for Metals*), indicates that arsenic, cadmium, chromium, lead, zinc and mercury standards are exceeded. At the downstream-most station, at Old Bloomfield Road in Pine Brook, the Rockaway is impaired as a result of elevated bacteria and TP.

Water quality results for tributaries to the Rockaway were mixed. Lower Beaver Brook violates sanitary quality and pH. Water quality violations in the Stony Brook in Boonton were limited to bacteria. The Crooked Brook near Towaco has good water quality, including good sanitary quality.

Biological sampling results (see table *Upper Passaic Drainage: WMA 6 Water Quality Assessment for Aquatic Life Support*) in the upper reaches of the Rockaway River indicate good benthic macroinvertebrate communities, as is the case for Russian Brook, a tributary to the upper Rockaway. Biological conditions farther downstream, in the vicinity of the Longwood Valley chemical site are impaired, which continues through the remainder of the main stem of the Rockaway. Most tributaries to the middle and lower Rockaway exhibit impaired benthic communities, with the exception of the upper portions of Beaver Brook and Crooked Brook, both with good benthic macroinvertebrate communities.


Chemical (conventional and metal) monitoring locations
Passaic Drainage, WMA 6
Upper Passaic,
Rockaway and
Whippany Rivers
PQ9 - Un-named trib-Smoke Rise
Woodstock
01380270 - Stony Bk
01379680 - Rockaway River
01381050 - Crooked Bk
01379700 - Rockaway River
01380320 - Stony Bk
Middletown
01380098 - Beaver Bk
Boonton
01380100 - Beaver Bk
01380500 - Rockaway River
01379800 - Green Pond Bk
Wharton
01379853 - Rockaway River
46
80
01380125 - Den Brook
Parsippany
01381200, 6-ROC-1, 6-Site - Rockaway River
280
01381800 - Whippany River
202
01381500, 6-WHI-1 - Whippany River
Morristown
287
01378660 - Passaic River
01378780 - Primrose Bk
Chemical Station
Metals Station
Basking Ridge
01379000 - Passaic River
Liberty Corner
01379200 - Dead River
78
0 1 2 4 6 8
Miles
1 inch equals 3.342396 miles


Biological (benthic macroinvertebrate) monitoring locations
Passaic Drainage, WMA 6
Upper Passaic,
Rockaway and
Whippany Rivers
AN0239 - Russia Bk
Woodstock
AN0240 - Rockaway River
AN0241 - Rockaway River
AN0245 - Beaver Bk
AN0252 - Crooked Bk
AN0249 - Stony Bk
Middletown
Boonton
AN0242 - Green Pd Bk
AN0246 - Beaver Bk
AN0250 - Rockaway River
AN0274A - Passaic River
Wharton
AN0248 - Rockaway River
AN0254 - Crooked Bk
46
AN0243 - Rockaway River
AN0247 - Den Bk
80
Parsippany
AN0237 - Troy Bk
280
AN0238 - Whippany River
202
AN0238B - Malapardis Bk
AN0232 - Whippany River
AN0234A - Watnong Bk
AN0235 - Whippany River
AN0233 - Whippany River
AN0234 - Whippany River
Morristown
287
AN0213 - Passaic River
AN0217 - Great Bk
AN0215 - Primrose Bk
AN0214 - Indian Grave Bk
AN0216 - Primrose Bk
AN0219 - Great Bk
Basking Ridge
Biological Station
Liberty Corner
AN0226 - Dead River
AN0227 - Dead River
78
0 1 2 4 6 8
Miles
1 inch equals 3.342396 miles

Upper Passaic Drainage: WMA 6 Water Quality Assessment for Conventional Parameters

STATION	NAME	HUC14	WMA	E COLI	TP	DO	TEMP	PH	TP	NITRATE	TSS	TDS	AMMONIA	CHLORIDE	TURBIDITY	SULFATE	FECAL_CO
01380098	Beaver Bk at Morris Ave at Denville	02030103030110	06	5													
01380100	Beaver Bk at Rockaway	02030103030110	06	4		1	1	5	1	1	1	1	1	1	1	1	4
01381050	Crooked Brook Near Towaco	02030103030160	06	3		1	1	1	1	1	3	3	1	NA		NA	1
01379200	Dead River nr Millington	02030103010070	06	4		1	1	1	5	1	5	1	1	1	1	1	4
01380125	Den Brook	02030103030120	06				1										
01379800	Green Pond Brook At Dover	02030103030060	06			3	3	3	3	3	3	3	1				3
01378660	Passaic R at Tempewick Rd nr Mendham	02030103010010	06	4		1	1	1	1	1	1	1	1	1	NA	1	5
01379000	Passaic River Near Millington	02030103010070	06	4		1	1	1	1	1	1	1	1	1	NA		4
01378780	Primrose Bk at Morristown National Park	02030103010020	06	1		1	1	1	1	1	1	1	1	1	1	1	1
01381200	Rockaway R at Old Bloomfield Rd in Pine Brook	02030103030170	06	4		1	1	1	5	1	1	1	1	1			4
01379700	Rockaway River At Berkshire Valley	02030103030040	06				1						1	1	NA		4
01379853	Rockaway River At Blackwell St	02030103030090	06	4		3	3	3	3	3	3	3					
01380500	Rockaway River At Boonton	02030103030150	06			1	1	1	1	1	1	1	3				4
01379680	Rockaway River At Longwood Valley	02030103030040	06	4		1	1	1	1	1	1	1	1	1			4

STATION	NAME	HUC14	WMA	E COLI	TP	DO	TEMP	PH	TP	NITRATE	TSS	TDS	AMMONIA	CHLORIDE	TURBIDITY	SULFATE	FECAL_CO
01380270	Stony Brook	02030103030130	06				1										
01380320	Stony Brook At Boonton	02030103030130	06	4		1	1	1	1	1	3	3	1	NA		NA	4
PQ9	Un-named trib-Smoke Rise	02030103030030	06				1										
01381800	Whippany R nr Pine Bk	02030103020100	06	**5**		**5**	1	1	**5**	1	1	1	1	1	1	1	4
01381500	Whippany River At Morristown	02030103020050	06			1	1	1	**5**	1	1	1	1				4

1 denotes meeting standards

5 indicates not meeting standards.

4 is a subcategory of “not meeting standards” - denotes that a waterbody has undergone an EPA approved TMDL. Locations not meeting standards are shaded.

3 which occurs occasionally, denotes there was insufficient data to make an assessment.

Blank cells denote no data available for the constituent in question.

Upper Passaic Drainage: WMA 6 Water Quality Assessment for Metals

STATION	NAME	WMA	ARSENIC	ARSENIC_1	CADMIUM	CHROMIUM	COPPER	LEAD	MERCURY	NICKEL	SELENIUM	SILVER	THALLIUM	ZINC
01378780	Primrose Bk at Morristown National Park	06		3	1	1	1	1	3	1	1	1		1
6-SITE-11	Rockaway River at Boonton	06	5		5	5		5	5					5
6-ROC-1, 6-SITE	Rockaway River at Pine Brook	06	3		3	1	1	1	3	1				1
6-WHI-1	Whippany River at Morristown	06	3		3	1	1	1	3	1				1

Upper Passaic Drainage: WMA 6 Water Quality Assessment for Metals

STATION	NAME	WMA	ARSENIC	ARSENIC_1	CADMIUM	CHROMIUM	COPPER	LEAD	MERCURY	NICKEL	SELENIUM	SILVER	THALLIUM	ZINC
01378780	Primrose Bk at Morristown National Park	06		3	1	1	1	1	3	1	1	1		1
6-SITE-11	Rockaway River at Boonton	06	**5**		**5**	**5**		**5**	**5**					**5**
6-ROC-1, 6-SITE	Rockaway River at Pine Brook	06	3		3	1	1	1	3	1				1
6-WHI-1	Whippany River at Morristown	06	3		3	1	1	1	3	1				1

Upper Passaic Drainage: WMA 6 Water Quality Assessment for Aquatic Life Support

Station	Station Location	HUC14	WMA	Sub Watershed Name	Aquatic Life Support
AN0245	Lyonville Rd	02030103030110	6	Beaver Brook (Morris County)	Full Attain
AN0246	Morris Ave	02030103030110	6	Beaver Brook (Morris County)	Non Attain
AN0226	Somerville Rd (Liber	02030103010080	6	Dead River (above Harrisons Brook)	Non Attain
AN0247	Mt Pleasant Tnpk	02030103030120	6	Den Brook	Full Attain
AN0217	Blackwells Pl	02030103010030	6	Great Brook (above Green Village Rd)	Full Attain
AN0219	Woodland Rd (Gr Swam	02030103010050	6	Great Brook (below Green Village Rd)	Non Attain
AN0242	Mt Pleasant Tnpk	02030103030060	6	Green Pond Brook (below Burnt Meadow Bk)	Non Attain
AN0234A	Lake Rd	02030103020030	6	Greystone / Watnong Mtn tribs	Full Attain
AN0238B	Mt Pleasant Ave	02030103020060	6	Malapardis Brook	Full Attain
AN0252	Hemlock Rd	02030103030160	6	Montville tribs.	Full Attain
AN0254	River Rd	02030103030160	6	Montville tribs.	Full Attain
AN0213	Tempewick Rd	02030103010010	6	Passaic R Upr (above Osborn Mills)	Full Attain
AN0214	Hardscrabble Rd	02030103010010	6	Passaic R Upr (above Osborn Mills)	Full Attain

AN0227	King George Rd	02030103010070	6	Passaic R Upr (Dead R to Osborn Mills)	Non Attain
AN0274A	Willard St	02030103040010	6	Passaic R Upr (Pompton R to Pine Bk)	Non Attain
AN0215	Jockey Hollow Nat'l	'02030103010020	6	Primrose Brook	Full Attain
AN0216	Lees Mill Rd	02030103010020	6	Primrose Brook	Non Attain
AN0243	Blackwell St (Rt 513	02030103030090	6	Rockaway R (BM 534 brdg to 74d 33m 30s)	Non Attain
AN0250	Morris Ave	02030103030150	6	Rockaway R (Boonton dam to Stony Brook)	Non Attain
AN0240	blw Longwood Lk	02030103030040	6	Rockaway R (Stephens Bk to Longwood Lk)	Full Attain
AN0241	Berkshire Valley Rd	02030103030040	6	Rockaway R (Stephens Bk to Longwood Lk)	Non Attain
AN0248	Pocono Rd	02030103030140	6	Rockaway R (Stony Brook to BM 534 brdg)	Non Attain
AN0239	Milton - Dover Rd	02030103030020	6	Russia Brook (below Milton)	Full Attain
AN0249	Valley Rd	02030103030130	6	Stony Brook (Boonton)	Non Attain
AN0237	Beaverwyck Rd	02030103020090	6	Troy Brook (below Reynolds Ave)	Full Attain
AN0232	Mt Pleasant Rd	02030103020010	6	Whippany R (above road at 74d 33m)	Full Attain

AN0234	Ridgedale Ave	02030103020050	6	Whippany R (Malapardis to Lk Pocahontas)	Non Attain
AN0235	Jefferson Rd	02030103020050	6	Whippany R (Malapardis to Lk Pocahontas)	Non Attain
AN0238	Edwards Rd	02030103020100	6	Whippany R (Rockaway R to Malapardis Bk)	Non Attain
AN0233	Whitehead Rd	02030103020020	6	Whippany R (Wash. Valley Rd to 74d 33m)	Full Attain

Suspected Pollution Sources of Fecal Coliform Bacteria Identified in the Upper Passaic Watershed

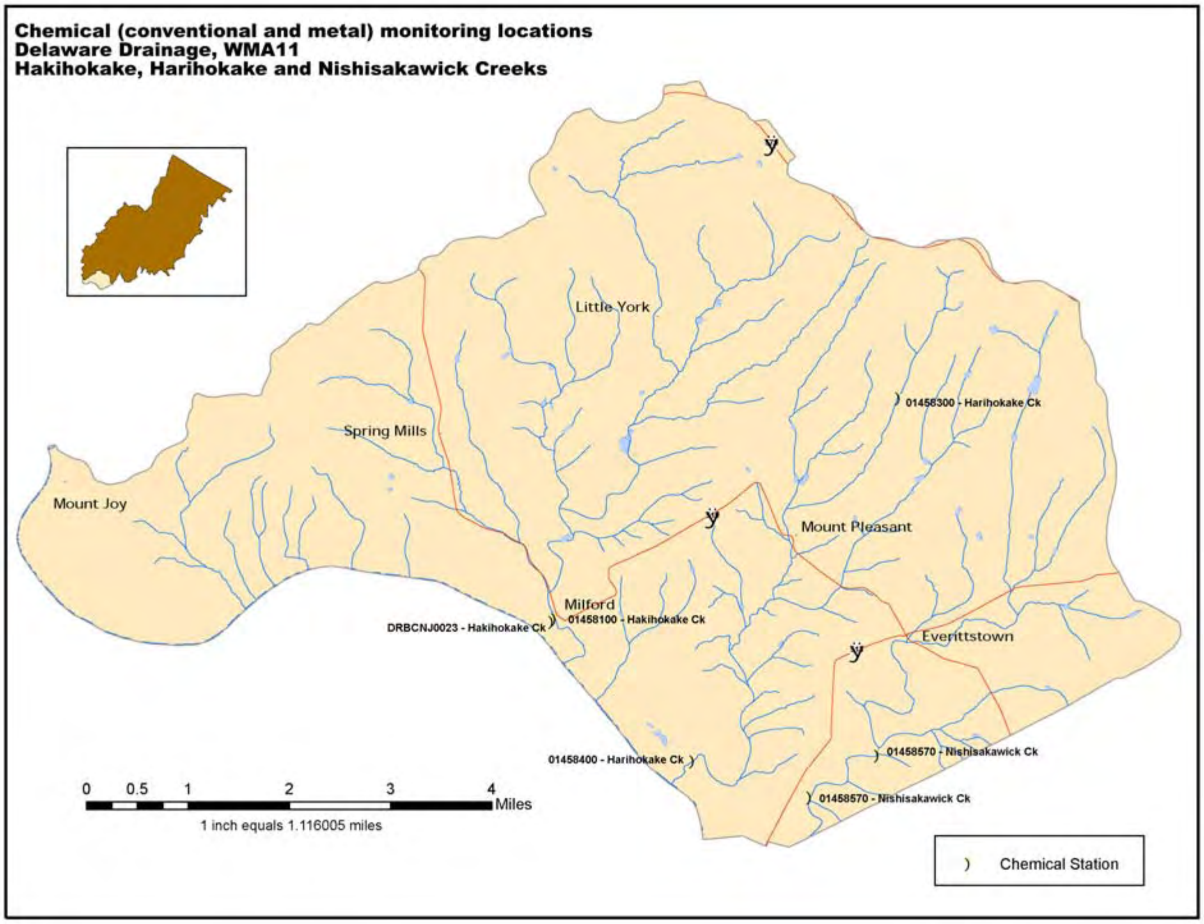
Stream Reach	Potential Sources
Black Brook in Madison	Geese and deer, kennel, Rolling Knolls landfill. Local complaints of trucks transporting animal waste, leaking fluids
Passaic River near Millington	Wildlife from the Great Swamp Refuge, geese, urban land use, pets, deer, horse stables and trails in Lord Sterling Park, livestock
Dead River near Millington	Geese, pets, livestock, pasture lands
Rockaway River at Longwood Valley	Wildlife, failing septic systems
Rockaway River at Pine Brook	Sharkey and Ecology Lake Club Sanitary Landfills, wildlife
Beaver Creek near Rockaway	Potential failing septic systems, wildlife
Stony Brook in Boonton	Canada geese, livestock

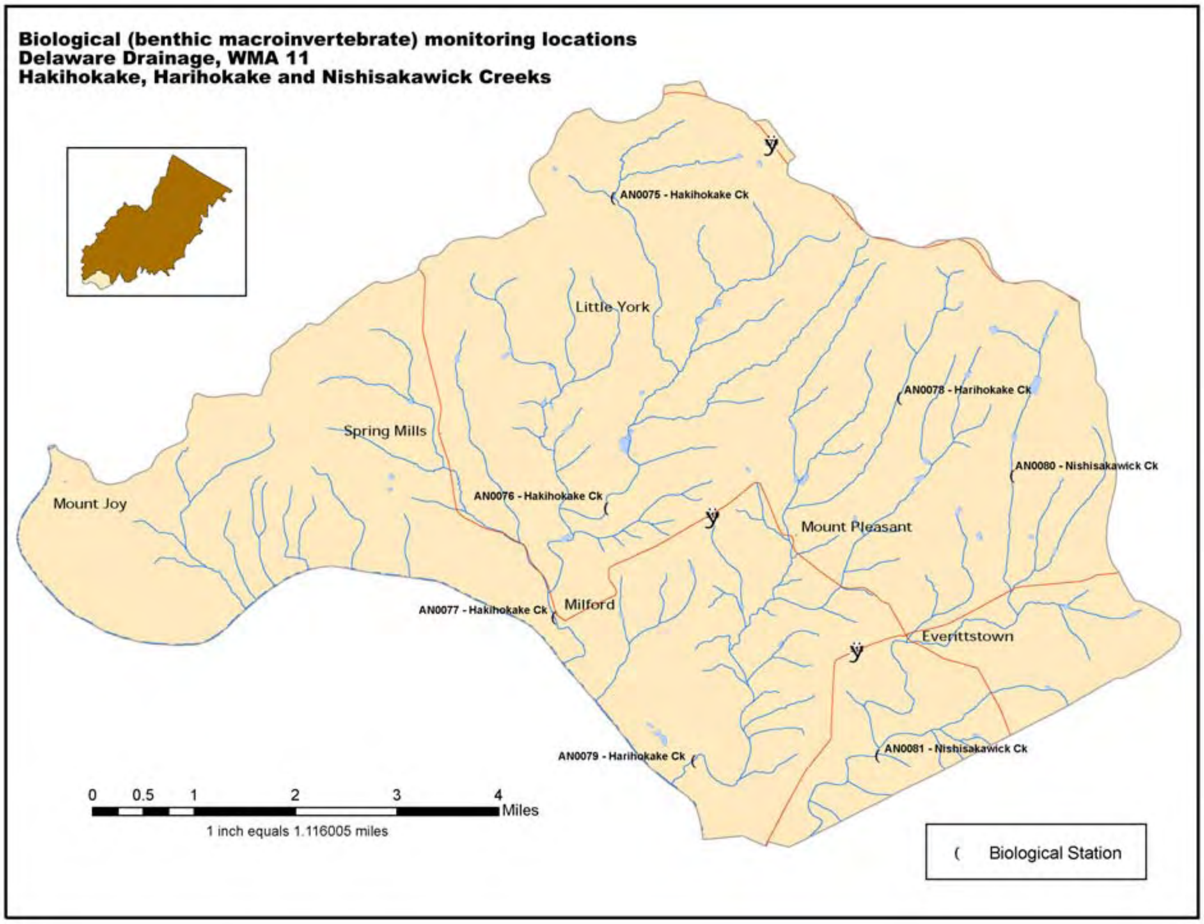
WATERSHED: DELAWARE DRAINAGE WMA 11:

This watershed is depicted in the figures *Chemical [conventional and metal] Monitoring Locations Delaware Drainage: WMA 11*, and *Biological [benthic macroinvertebrate] monitoring locations Delaware Drainage: WMA 11*. Physical and chemical water quality data (see table *Delaware Drainage: WMA 11 Water Quality Assessment for Conventional Parameters*) for Hakihokake Creek reflect relatively good quality. The Milford sites combined (sanitary and remaining conventional parameters) indicate violations of sanitary quality, leading to non-support of primary contact recreation. No other water quality problems were observed at this site. The biological monitoring (see table *Delaware Drainage: WMA 11 Water Quality Assessment for Aquatic Life Support*) also demonstrated good conditions at all three monitoring sites.

Conditions in Harihokake Creek, based on monitoring at two sites in Alexandra Township exceed sanitary quality and TP at the upstream site on Hartpence Road. Further downstream at River Road, no violations of conventional parameters were noted. However, sanitary data were not collected at this site. Biological conditions in the Harihokake were good at both monitoring sites.

Nishisakawick exceeded sanitary quality and pH standards at the site in Frenchtown. Biological conditions in the headwater reaches (Airport Rd., AN0080) were good. However, the more downstream site (AN0081) reflects impaired conditions. The pH violations are in rough proximity to the impaired biological site. A possible relationship could be investigated.


Chemical (conventional and metal) monitoring locations
Delaware Drainage, WMA11
Hakihokake, Harihokake and Nishisakawick Creeks
Little York
Spring Mills
Mount Joy
Mount Pleasant
Milford
Everittstown
01458300 - Harihokake Ck
DRBCNJ0023 - Hakihokake Ck
01458100 - Hakihokake Ck
01458400 - Harihokake Ck
01458570 - Nishisakawick Ck
01458570 - Nishisakawick Ck
0 0.5 1 2 3 4
Miles
1 inch equals 1.116005 miles
Chemical Station


Biological (benthic macroinvertebrate) monitoring locations
Delaware Drainage, WMA 11
Hakihokake, Harihokake and Nishisakawick Creeks
AN0075 - Hakihokake Ck
Little York
AN0078 - Harihokake Ck
Spring Mills
AN0080 - Nishisakawick Ck
AN0076 - Hakihokake Ck
Mount Joy
Mount Pleasant
AN0077 - Hakihokake Ck
Milford
Everittstown
AN0079 - Harihokake Ck
AN0081 - Nishisakawick Ck
0
0.5
1
2
3
4
Miles
1 inch equals 1.116005 miles
Biological Station

Delaware Drainage: WMA 11 Water Quality Assessment for Conventional Parameters

STATION	NAME	HUC14	WMA	E COLI	DO	TEMP	PH	TP	NITRATE	TSS	TDS	AMMONIA	CHLORIDE	TURBIDITY	SULFATE	FECAL_CO
DRBCNJ0023	Hakihokake Creek @ Bridge St Bridge, Milford	02040105170010	11													5
01458100	Hakihokake Creek on Bridge St, Milford	02040105170020	11		1	NA	1	1	1	NA	1	NA	1	NA		
01458300	Harihokake Creek on Hartpence Rd, Alexandra Twp	02040105170030	11	5	1	1	1	5	1	1	1	NA	1	1	1	
01458400	Harihokake Creek on Rt 619 (River Rd) Alexandra Twp	02040105170030	11		1	1	1	1	1	NA	1	NA	1	NA		
01458570	Nishisakawick Creek Near Frenchtown	02040105170050	11	4	1	1	5	1	1	1	1	1	1	1	1	4

1 denotes meeting standards

5 indicates not meeting standards.

4 is a subcategory of “not meeting standards” - denotes that a waterbody has undergone an EPA approved TMDL. Locations not meeting standards are shaded.

3 which occurs occasionally, denotes there was insufficient data to make an assessment.

Blank cells denote no data available for the constituent in question.

Delaware Drainage: WMA 11 Water Quality Assessment for Aquatic Life Support

Station	Station Location	HUC14	WMA	Subwatershed Name	Aquatic Life Support
AN0075	Myler Rd	02040105170020	11	Hakihokake Creek	Full Attain
AN0076	Miller Park Rd	02040105170020	11	Hakihokake Creek	Full Attain
AN0077	Bridge St	02040105170020	11	Hakihokake Creek	Full Attain
AN0078	Hartpence Rd	02040105170030	11	Harihokake Creek (and to Hakihokake Ck)	Full Attain
AN0079	River Rd	02040105170030	11	Harihokake Creek (and to Hakihokake Ck)	Full Attain
AN0080	Airport Rd	02040105170040	11	Nishisakawick Creek (above 40d 33m)	Full Attain
AN0081	off Creek Rd	02040105170050	11	Nishisakawick Creek (below 40d 33m)	Non Attain

TOTAL MAXIMUM DAILY LOADS

As stated earlier, TMDLs indicate the carrying capacity of the receiving water and are required for water bodies that cannot meet surface water quality standards after technology-based effluent limitations are imposed. They may be used to maintain or improve quality in waters that are not impaired. A TMDL is a mechanism for identifying all contributors to surface water quality impacts and setting pollutant load reduction goals to meet surface water quality standards. New Jersey's TMDL regulations are in N.J.A.C. 7:15-7 (Water Quality Management Planning rules).

A TMDL establishes wasteload allocations (WLAs) and load allocations (LAs) for point and non-point sources, respectively. They also will include a margin of safety (MOS) and may include a reserve capacity (RC) for future loadings. Where TMDLs are required to address documented surface water quality impairment, allocations are made to the varying sources contributing to the water quality problem in order to reduce the total pollutant load. Since NPS pollution does not come from discrete, identifiable sources, load allocations would consist of the identification of categories of non-point sources that contribute to the parameters of concern. Load allocations would also include specific load reduction measures for those categories of sources, to be implemented through BMPs, including local ordinances for storm water management and NPS pollution control, headwaters protection practices or other mechanisms for addressing the priority issues of concern.

All of the Watershed Management Areas (WMA) contained wholly or partly within the Highlands Region have TMDLs proposed or approved for certain river/creek stretches or lakes due to impairment from one or more contaminants. The water bodies and contaminant (parameter) of concern are listed in appendix H.. Additional details regarding TMDLs for each WMA follow.

Implementation Plans for Fecal Coliform TMDLs

Development of effective management measures depends on accurate source assessment. Fecal coliform is contributed to the environment from human and animal waste and agricultural practices. It can reach water bodies directly, through overland runoff, or through sewage or storm water conveyances. Each potential source can be managed. Various funding sources are available to assist in implementing the management strategies for fecal coliform and other pollutants. These strategies are summarized in the table Implementation Plan Concepts for Fecal Coliform TMDLs. Spatial data for streams for which fecal coliform TMDLs have been developed can be downloaded at http://www.nj.gov/dep/gis/stateshp.html#TMDLFS.

Implementation Plans for Phosphorus TMDLs

Phosphorus is contributed to the environment from fertilizer application, discharge from treatment plants, septic systems, lack of pump-out facilities for boats, and decomposition of plant and animal materials. Phosphorus from these sources can reach water bodies directly, through overland runoff, or through sewage or storm water conveyance facilities. Generic management strategies for various source categories and responses are summarized in the table *Implementation Plan Concepts for Phosphorus TMDLs*. Spatial data for lakes for which phosphorus TMDLs have been developed can be downloaded at http://www.nj.gov/dep/gis/stateshp.html#TMDLEL.

Implementation Plans for Arsenic TMDLs

Arsenic may come from natural sources such as leaching from rock formations, as well as historical mining activities. Historic pesticide uses are also suspected as sources that may be contributing to the elevated arsenic levels. A combination of best management practices (BMPs) and further investigation to pinpoint sources will be used to implement arsenic TMDLs. Because natural sources of arsenic are present, a possible outcome could be a finding that the SWQS cannot be achieved. In this case, a site specific criterion reflecting natural conditions will be defined with a loading capacity calculated relative to this criterion. Loading reductions attributed to anthropogenic sources may still be required.

Implementation Plans for Temperature TMDLs

Several key sources of temperature pollution have been identified. Point sources include stormwater outfalls, wastewater discharges and the level of reservoir discharges. Nonpoint sources include direct runoff from land uses that promote heating, such as asphalt; beaver activity resulting in the creation of wide, shallow ponds that absorb heat more than a free-moving stream would and beaver activity results in the loss of tree cover; and the lack of riparian buffer vegetation. Management strategies include stream bank restoration, water allocation permit requirements for reservoir releases to maintain a certain temperature, and a beaver management strategy.

Implementation Plan Concepts for Fecal Coliform TMDLs

Source Category	Responses	Potential Responsible Entity	Funding options
Human Sources			
Inadequate (per design, operation, maintenance, location, density) on-site disposal systems	Confirm inadequate condition; evaluate and select cost effective alternative, such as rehabilitation or replacement of systems, or connection to centralized treatment system	Municipality, MUA, RSA	CWA 604(b) for confirmation of inadequate condition; Environmental Infrastructure Financing Program for construction of selected option
Malfunctioning sewage conveyance facilities	Identify through source track-down	Owner of malfunctioning facility-compliance issue	User fees
Storm water Point Sources			
Inadequate or improperly maintained storm water facilities, illicit connections	Measures required under Municipal storm water permitting program including any additional measures determined in the future to be needed through TMDL process	Municipality, State and County regulated entities, storm water utilities	CWA 319(h), local sources
Agriculture/ Domestic/Confined animal sources			
Pets	Pet waste ordinances (MS4 requirement)	Municipalities for ordinance adoption and compliance	
Confined horses, livestock, zoos	Confirm through source track-down: SCD/NRCS develop conservation management plans	Property owner	EQIP, CRP, CREP
Manure application to crops/pasture	Confirm through source track-down; SCD/NRCS develop conservation management plans	Property owner	EQIP, CRP, CREP
Wildlife			
Nuisance concentrations, e.g. resident Canada geese	Feeding ordinances (MS4 requirement); Goose Management BMPs	Municipalities for ordinance; Community Plans for BMPs	CBT, CWA 319(h)
Indigenous wildlife	Confirm extent through track-down; consider revising designated uses if this source prevents attainment of standards	State	NA

Implementation Plan Concepts for Phosphorus TMDLs

Source Category	Responses	Potential Responsible Entity	Possible Funding options
Human Sources	Municipal Storm water permitting (MS4) requirements (NJAC 7:14), Statewide basic requirements and additional measures such as fertilizer management ordinances, NPS public education, septic tank management to address failing systems, sewering target areas	Municipalities, residents, watershed stewards	319(h), State sources
Non-Human Sources	Waterfowl ordinances, pet waste ordinances (MS4 requirement), goose management programs; riparian buffer restoration	Municipalities, residents, watershed stewards, property owner	319(h), State sources
Agricultural practices	Develop and implement conservation management plans or resource management plans	Property owner	EQIP, CRP, CREP

The following subsections provide a brief summary of the TMDLs that have been developed within each of the WMAs. More detailed information for each WMA is presented in Appendix H, as mentioned in the following subsections.

Upper Delaware and Wallkill - WMA 1 and 2 TMDLs

A total of 47 TMDLs have been developed within the Upper Delaware and Wallkill WMAs (1 and 2). TMDLs have been developed for fecal coliform, total phosphorus, and arsenic. Appendix H.1 presents tables that identify the water bodies in WMA 1 and WMA 2 for which TMDLs have been developed and the loading capacity and load allocations for each water body. It also presents figures that depict TMDL stream segments within the two WMAs. (appendix H.1)

Pompton Tributaries - WMA 3 TMDLs

A total of 36 TMDLs have been developed within the Highlands Region in the Pompton Tributaries - WMA 3. There are TMDLs for fecal coliform, total phosphorus, and temperature. Appendix H.2 presents tables that identify the water bodies in WMA 3 for which TMDLs have been developed and the loading capacity and load allocations for each water body. It also presents figures that depict TMDL stream segments within the WMA. (Appendix H.2)

Upper Passaic – WMA 6 TMDLs

A total of 39 TMDLs have been developed in the Upper Passaic - WMA 6. TMDLs address fecal coliform. Appendix H.3 presents tables that identify the water bodies in WMA 6 for which TMDLs have been developed. It also presents figures that depict TMDL stream segments within the WMA. Loading allocation for impaired segments are addressed in "New Jersey Department of Environmental Protection Report on the Establishment of a Total Maximum Daily Load for Fecal Coliform and an Interim Total Phosphorus Reduction Plan for the Whippany River Watershed." The Wanaque Reservoir and Pompton Lake phosphorus TMDLs is incorporated into a larger TMDL study addressing phosphorus impairments in the non-tidal Passaic River basin. This basin level TMDL employ a dynamic watershed model to determine phosphorus load reductions needed to meet environmental results-based endpoints at critical locations in the system. (Appendix H.3)

North and South Branch Raritan – WMA 8 TMDLs

Nineteen TMDLs have been developed in the North and South Branch - WMA 8. They address fecal coliform and total phosphorus (see Appendix H.4). A large scale TMDL study is underway to address nutrients, suspended solids, dissolved oxygen, temperature and pH impairments identified in WMAs 8, 9 and 10 within the Raritan River basin. This study will be identifying appropriate endpoints and critical locations that will drive pollutant load reductions from point and non-point sources within the basin. (Appendix H.4)

Lower Raritan, South River, Lawrence– WMA 9 TMDLs

One TMDL has been developed in WMA 9. It addresses fecal coliform. (Appendix H.5)

Central Delaware Tributaries – WMA 11 TMDLs

Two TMDLs have been developed within WMA 11. These TMDLs address fecal coliform (Appendix H.6).

GROUND WATER QUALITY

Ground water is a critical resource, as it provides potable water supplies and other uses for New Jersey citizens, and base flow for New Jersey surface water systems. This summary of ground water quality is based on data from New Jersey's Ambient Ground Water Quality Monitoring Network (AGWQMN). This 150-well network (see figure *Shallow Ambient Ground Water Quality Monitoring Network Wells in the Highlands Region*) is a NJDEP and USGS cooperative project providing information about land use related non-point source contaminant effects on shallow ground water quality (Serfes, 1998).

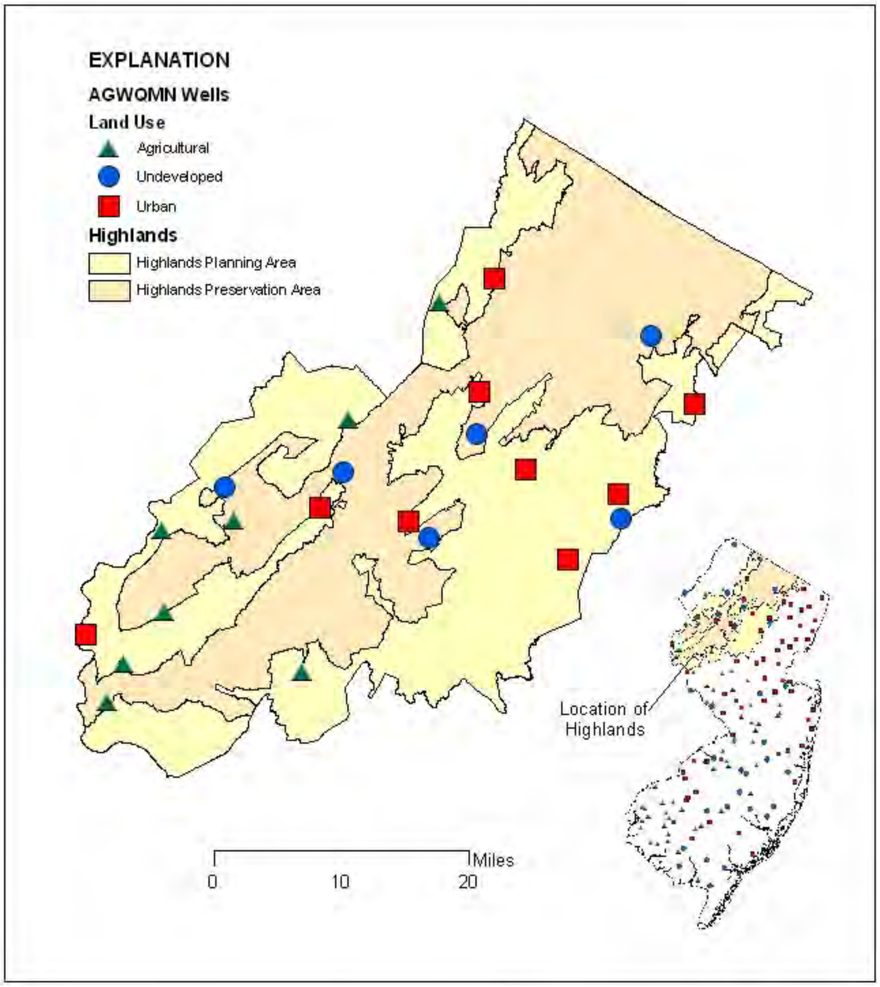
The distribution of wells relative to land use is 60 wells in agricultural areas, 60 in urban/suburban areas, and 30 in undeveloped areas. A total of 30 wells are sampled per year, on a five-year cycle. Chemical and physical characteristics for each well include the following parameters: pH, specific conductivity, DO, temperature, alkalinity; major ions, trace elements, gross alpha particle activity, volatile organic compounds and pesticides. Data from an original network are also used to characterize ground water quality as a function of bedrock aquifer geology in northern New Jersey (Serfes, 1994; Serfes, 2004). Well types sampled to meet this goal included public, observation, industrial, and private wells. Both of these networks include wells in the Highlands Province, which are used to provide an exploratory baseline and status assessment of older and deeper, as well as generally younger and shallow ground water quality.

A complete assessment of ground water quality in all the aquifers in the Highlands Region is not possible due to a lack of available data. There are ample data from wells in the used portion of the Precambrian crystalline rock aquifers in the upland areas. There is a lack of similar sample data from wells in the dolomites, slates, and other geologic units making up the valley floors. This is particularly true of data from wells in the Green Pond Mountain Region. Water quality data from glacial aquifers in the Highlands Region are not included here and would also need to be compiled and assessed for completeness.

Given those limitations, it can be concluded that based on the available data, ground water quality in the used deeper portion of the bedrock aquifers is good for most purposes. However, on a localized basis, ground water may require treatment for undesirable characteristics (e.g., low or high pH) and contaminants (e.g., manganese, radionuclides). Relatively low pH, alkalinity, and TDS concentrations in water from the Precambrian crystalline rock aquifers indicate that mineral water reactivity is minimal compared to the sedimentary rock aquifers in the valleys. Intrinsic resistance to weathering not only resulted in those metamorphic rock types being predominant in upland areas, but also yields a low buffering capacity, making water in and associated with these rock types particularly vulnerable to acid rain and some other forms of contamination.

Of the 150 wells in the shallow ground water quality network, only 23 are in the Highlands Region. Of these 23, six are in undeveloped areas, eight in agricultural areas and nine in urban land use areas. Three of eight wells (38%) in agricultural areas exceeded the nitrate plus nitrite drinking water standard of 10 mg/L. Pesticides were detected in seven out of eight wells (88%) in agricultural areas, and in five out of nine (56%) wells in urban areas. The concentration of individual pesticides is very low in all land use categories.

Shallow Ambient Ground Water Quality Monitoring Network Wells in the Highlands Region



The pesticide with the maximum concentration measured in a Highlands Region well was metolachlor, at 4.52 micrograms per liter (ug/L). Atrazine, deethylatrazine, metolachlor, prometon and simazine were the most frequently detected compounds. Volatile organic compounds (VOCs) were detected in seven out of nine (77%) wells in urban areas. Benzene, tetrachloroethylene and trichloroethylene are compounds found at concentrations exceeding drinking water and ground water quality standards. There is direct evidence that shallow ground water quality is being affected by land use activities in the Highlands Region. These contaminants will potentially affect the deeper used part of the aquifer systems and receiving surface waters.

HYDROGEOLOGY

The Highlands Province is characterized by mountainous ridges and valleys trending southwest to northeast. The terminal moraine of the Wisconsin glaciation extends from west to east approximately midway through the Highlands Province. North of the moraine, much of the bedrock is scoured and covered with thick, unconsolidated glacial sediments. South of the moraine, bedrock is deeply weathered and sporadically covered by pre-Wisconsin glacial sediment.

Ground water in the Highlands Region occurs under unconfined and confined conditions. The shallowest aquifer in an area is generally unconfined, and there is no impermeable rock or soil layer between the aquifer and the ground surface. An unconfined aquifer receives ground water recharge directly from rainfall or from a lake or stream with which it has a hydraulic connection. The upper boundary of an unconfined or water table aquifer is defined by the water table itself. However, the water table is not a stationary surface, as it rises and falls depending on the amount of rainfall.

Confined aquifers are located between or below confining rock or soil layers, and are usually found below unconfined aquifers. Confined aquifers are not directly recharged by precipitation, but receive recharge from an unconfined area with which it has a hydraulic connection. Confined aquifers are sometimes called artesian aquifers, as the ground water is under pressure and will flow without pumping if tapped by a well.

Ground water generally flows from the upland areas down into the valleys, where it eventually discharges to surface water. There is minimal transfer of ground water between the valleys, and ground water systems generally coincide with watershed boundaries (NJDEP, 1985). Geological controls on ground water flow include:

- The orientation, density, inter-connectiveness and openness of fractures, and layering of bedrock;
- The permeability and distribution of overlying glacial sediments; and
- Pumpage of ground water from production wells.

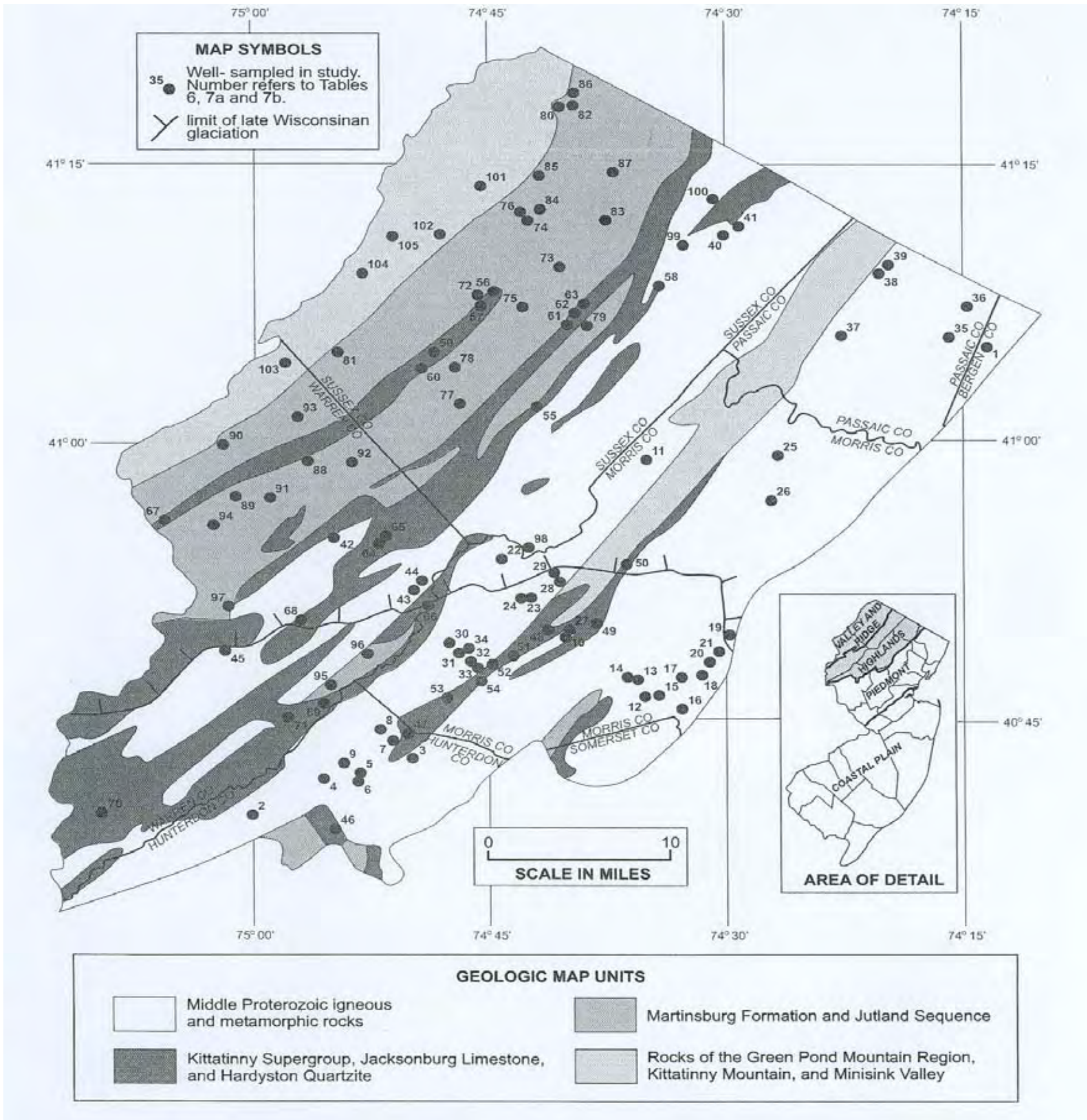
The mountainous ridges are mostly comprised of Middle Proterozoic (1600 to 900 million years old) metamorphic and igneous rocks. The valleys are mostly underlain by Paleozoic (570 to 360 million years old) sedimentary rocks that are more eroded (see figure *Generalized Geological Map of the Highlands and Valley and Ridge Provinces*). However, some mountainous ridges in the northeast part of the Highlands are underlain by Paleozoic conglomerate formations in the Green Pond Mountain region.

The Middle Proterozoic rocks are mostly composed of quartz- and feldspar-rich gneiss and granite with lesser amounts of marble. Aquifers composed of gneiss, granite, and marble are a major source of ground water for domestic, industrial and municipal needs. For example, about 16.4 billion gallons were reportedly withdrawn from these aquifers in 1996 (Hoffman, 2000). The marble aquifers locally provide significant quantities of water. Valleys are generally underlain by thick sequences of Lower Paleozoic carbonate and lesser volumes of sandstone, siltstone, shale and slate.

Aerially, the dominant geologic units are the Kittatinny Supergroup, some rocks of the Green Pond Mountain Region and the Martinsburg Slate as shown in *Generalized Geological Map of the Highlands and Valley and Ridge Provinces*.

Natural ground water quality is mainly a function of the composition and mineralogy of the aquifer matrix and the residence time of ground water in the aquifer. Therefore, the chemistry of ground water is characteristic of a particular aquifer and location along the ground water flow path. Other important factors include the composition of precipitation recharging the ground water system and the conditions that the precipitation encounters at the land surface and unsaturated zone before entering the ground water system. Non-point and point sources of pollution can affect ground water quality by contaminating ground water systems.

Generalized Geological Map of the Highlands and Valley and Ridge Provinces



DEEP GROUND WATER QUALITY IN THE HIGHLANDS

Assessment of Upland Bedrock Aquifers

The ridges in the Highlands consist of more resistant Middle Proterozoic metamorphosed igneous and sedimentary rocks. Ground water is unconfined unless overlain by low permeability glacial sediments. Characterization of ground water quality in these aquifers was conducted by collecting samples from 45 wells (Serfes, 2004). Ground water from the mostly non-carbonate gneissic aquifers in the Highlands is of a very good quality and unique among other bedrock aquifers in the State, because water-rock chemical reactivity is limited in these rock types. The major differences between the crystalline metamorphic bedrock aquifers in the Highlands Region and other bedrock aquifers in the northern part of the State are that they have a higher dissolved oxygen concentration; lower pH; lower alkalinity; lower TDS content; lower major ion concentration; and higher silica concentration.

Chemical parameters exceeding secondary drinking water standards are: hardness (4.5%), iron (6.7%), manganese (16.3%) and pH (30.2% with a pH less than 6.5). Minerals containing radioactive elements are found in a variety of crystalline rocks in the Highlands, and therefore the potential exists for radionuclide release to ground water (Volkert 1989). Nineteen percent of the wells exceeded the primary drinking water standard for gross alpha particle activity of 15 picocuries per liter (pCi/L), with a maximum of 85 pCi/L being detected in one of the wells. As with most unconfined aquifers, impacts from land use activities such as elevated sodium and chloride concentrations from road salting, and nitrate concentrations from fertilizer application are evident in some wells.

Radionuclides

Potassium-rich granite, granite pegmatite, alaskite and some quartzofeldspathic gneisses are associated with elevated radionuclides (Muessig et al., 1992). Gross alpha particle activity from radionuclides in a sample of water exceeded the drinking water standard of 15 pCi/L in two (10.5%) of the 19 water samples tested in 1990. Gross alpha particle activities of 18.6 and 27.5 pCi/L were measured in wells drawing water from hornblend-quartz-feldspar gneiss bedrock in Vernon, New Jersey. Samples collected in White Township (1992) and Frelinghuysen (1993) had gross alpha particle activities of 85.2 and 18 pCi/L, respectively.

In 1987, 154 wells in the crystalline rocks were sampled for radon 222 (Bell and others, 1992). Radon values in the sampling ranged from 36 to 24,000 pCi/L, with a median value of 1600 pCi/L. Of the wells sampled, 90% exceeded one of the USEPA proposed radon health risk mitigation options described at http://www.epa.gov/safewater/radon/proposal.html for reducing radon concentrations to below 300 pCi/L.

There is not enough data from geologic units in the Green Pond Mountain Region of the Highlands to characterize ground water quality in those units.

Assessment of Valley Bedrock Aquifers

The valley floors are mainly comprised of a thick sequence of Paleozoic sedimentary rocks in fault and unconformable (i.e., lying directly on a much older formation, indicating a period of erosion) contact with the older and more resistant upland crystalline rocks. Sedimentary rock types include dolomite, limestone, sandstone, shale (or slate) and siltstone. The major geologic units include the Kittatinny Supergroup, Martinsburg Formation, and Jutland Sequence, and other units of the Green Pond Mountain Region.

Many of the wells in this assessment are in similar geologic units but located in the Valley and Ridge Province just north and west of the Highlands. It is therefore assumed the ground water chemistry will be comparable between the two areas. However, ground water recharge from the upland crystalline rocks into the younger sedimentary aquifers in the Highlands Region valleys may have some effect on ground water quality. There is not enough data from the Green Pond Mountain Region in the Highlands to characterize ground water quality in those geologic units.

The percentage of samples exceeding the secondary drinking water standards in the Cambro-Ordovician sedimentary rocks of the Kittatinny Supergroup and the Martinsburg Formations are hardness (0% and 11.5% are less than 50 mg/L and 30.8% and 11.5% are greater than 250 mg/L), iron (3.8% and 0% are greater than 0.3 mg/L), manganese (7.7% and 23.1% are greater than 0.05 mg/L), pH (7.7% and 15.4% are greater than pH 8.5), sodium (0% and 15.4% are greater than 50 mg/L), respectively.

SHALLOW GROUND WATER QUALITY IN THE HIGHLANDS

The quality of shallow ground water is important, because it is this water that recharges deeper aquifers used for potable water supplies, and provides base flow to local streams and wetlands. Information presented here was compiled using analytical data associated with wells in the AGWQMN.

It must be noted that this well network was designed to assess the status and trends of shallow ground water quality as a function of land use for the entire state, not smaller sub-regions. Of the 150 wells, 23 are in the Highlands, with eight in agricultural, nine in urban and six in undeveloped land use areas (see figure *Shallow Ambient Ground Water Quality Monitoring Network Wells in the Highlands Region*). Therefore, the summary statistics presented for Highlands Region shallow ground water quality are not based on a large sample population, or a spatially representative distribution. Of the 23 wells, 14 are installed in glacial sediments and nine are in weathered or solid bedrock.

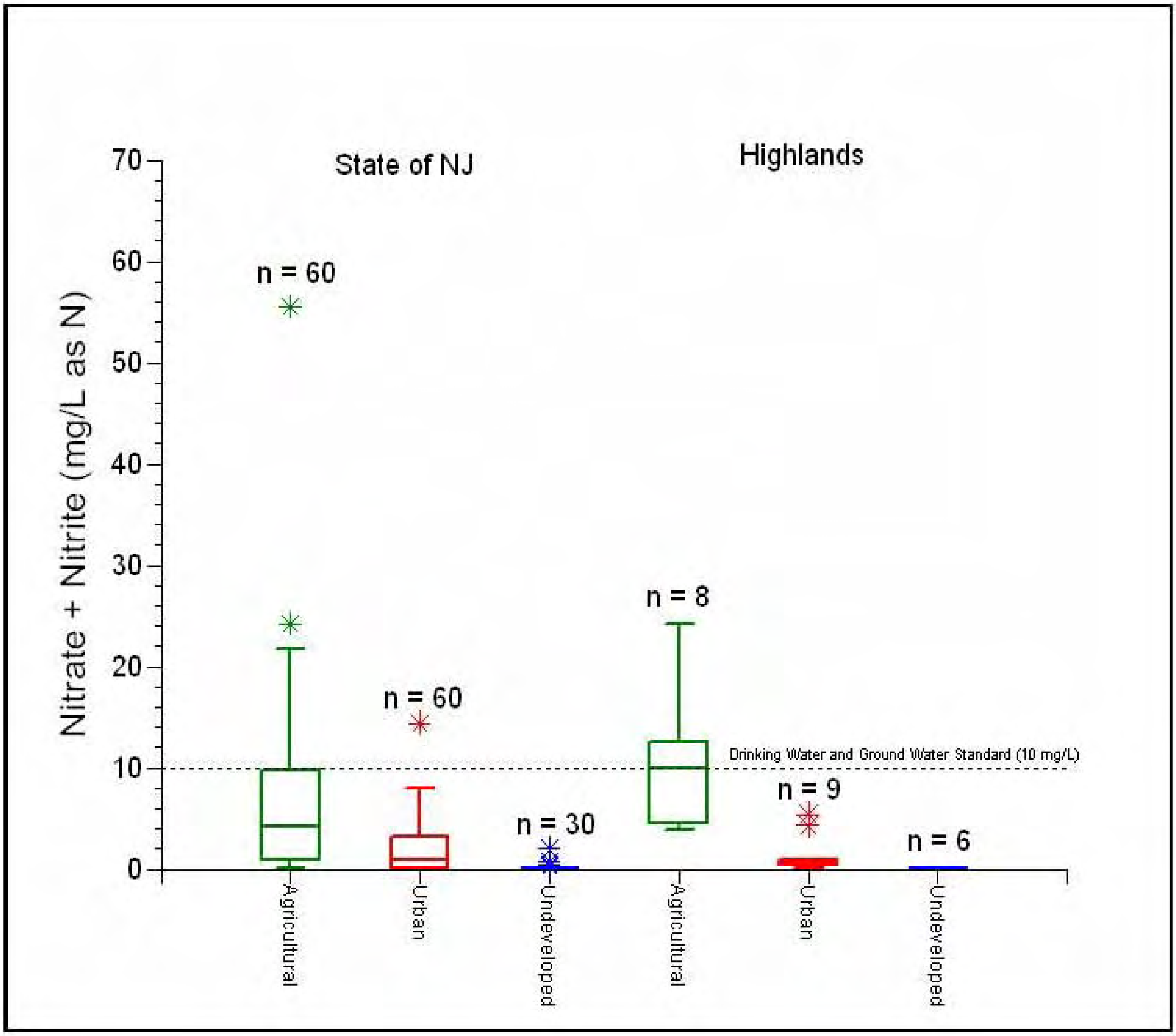
Nutrients

Nutrient concentrations are dominated by nitrate. The frequency and concentration by land use pattern in New Jersey are greatest in agricultural areas, followed by urban, then undeveloped land use areas (see figure *Nitrate plus Nitrite concentrations in shallow ground water in New Jersey and in the Highlands Region*). Based on samples from eight wells in Highlands Region agricultural areas, nitrate concentrations are greater here than those detected for the state as a whole. Three of eight (38%), exceeded the drinking and ground water standard of 10 mg/L. The use of nitrogen-based fertilizers in agricultural and urban areas, and possibly septic system and sewer system leakage in urban and suburban areas are considered the major sources. Phosphate was determined by measuring orthophosphate concentrations. Only two out of 23 wells (9%) had concentrations of orthophosphate above the reporting limit of < 0.02 mg/L. One of the wells was in an agricultural area (0.03 mg/L), the other in an undeveloped area (0.04 mg/L).

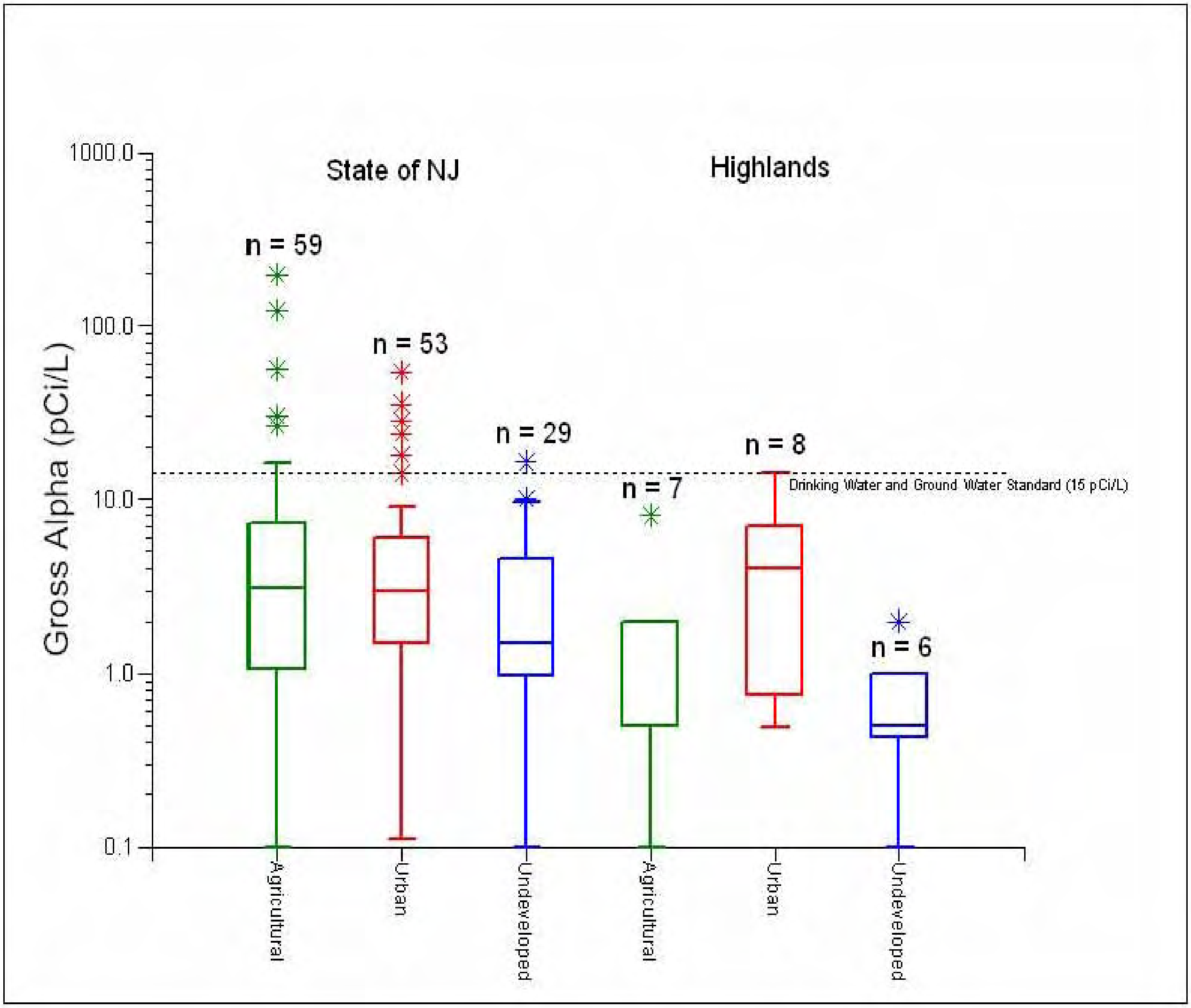
Radioactivity

Gross alpha particle activity was measured within 48 hours after sample collection to ensure that the radioactive decay of short-lived radium 224 (half-life of 3.64 days) is measured along with the other alpha emitters. The Federal and New Jersey drinking water standard of 15 pCi/L gross alpha particle activity still applies, even though the shorter holding time results in increased activity if substantial radium 224 is present. Activity is generally higher in southern than northern New Jersey in all land use settings, as radium 224 is more abundant in southern New Jersey and the pH of the ground water is lower, which increases radium's mobility (see figure *Gross Alpha Particle Activity in Shallow Ground Water in New Jersey and in the Highlands Region*). Shallow ground water in urban areas in the Highlands Region has higher gross-alpha particle activity than in agricultural and undeveloped areas. This observation may be preliminary because the sample population is low, or may reflect a causal, yet unidentified, land use activity. The maximum gross-alpha particle activity was 14 pCi/L, lower than the 15 pCi/L drinking and ground water quality standards.

Nitrate Plus Nitrite Concentrations in Shallow Ground Water in New Jersey and in the Highlands Region



Gross Alpha Particle Activity in Shallow Ground Water in New Jersey and in the Highlands Region



Pesticides

The percent of wells with detectable pesticides are very similar comparing the 150 wells in the statewide network and those in the Highlands Region (see figure Percent of Shallow AGWQMN Wells with Pesticide Detections in New Jersey and in the Highlands Region). In both, the concentration patterns are that agricultural lands have the highest concentrations of pesticides, then urban, then undeveloped land. In the Highlands Region, 88% of the agricultural, 56% of the urban and 17% of undeveloped areas wells had detectable pesticide levels. The concentration of individual pesticides is very low in all land use categories. The pesticide with the maximum concentration detected in a Highlands well was metolachlor at 4.52 ug/L (see table *Frequency of Pesticide Compound(s) Detection in Shallow Ground Water within the Highlands Region*). Atrazine, deethylatrazine, metolachlor, prometon and simazine were the most frequently detected compounds throughout the state and in the Highlands. They are all herbicides used to control grasses and broadleaf plants, except deethylatrazine, which is the major metabolite of atrazine. The degradation byproducts of these pesticides, except for deethylatrazine, are not measured and may be at much higher concentrations than the parent compounds (Roy Meyer, personal communication, NJDEP Pesticide Control Program, 2006).

Volatile Organic Compounds

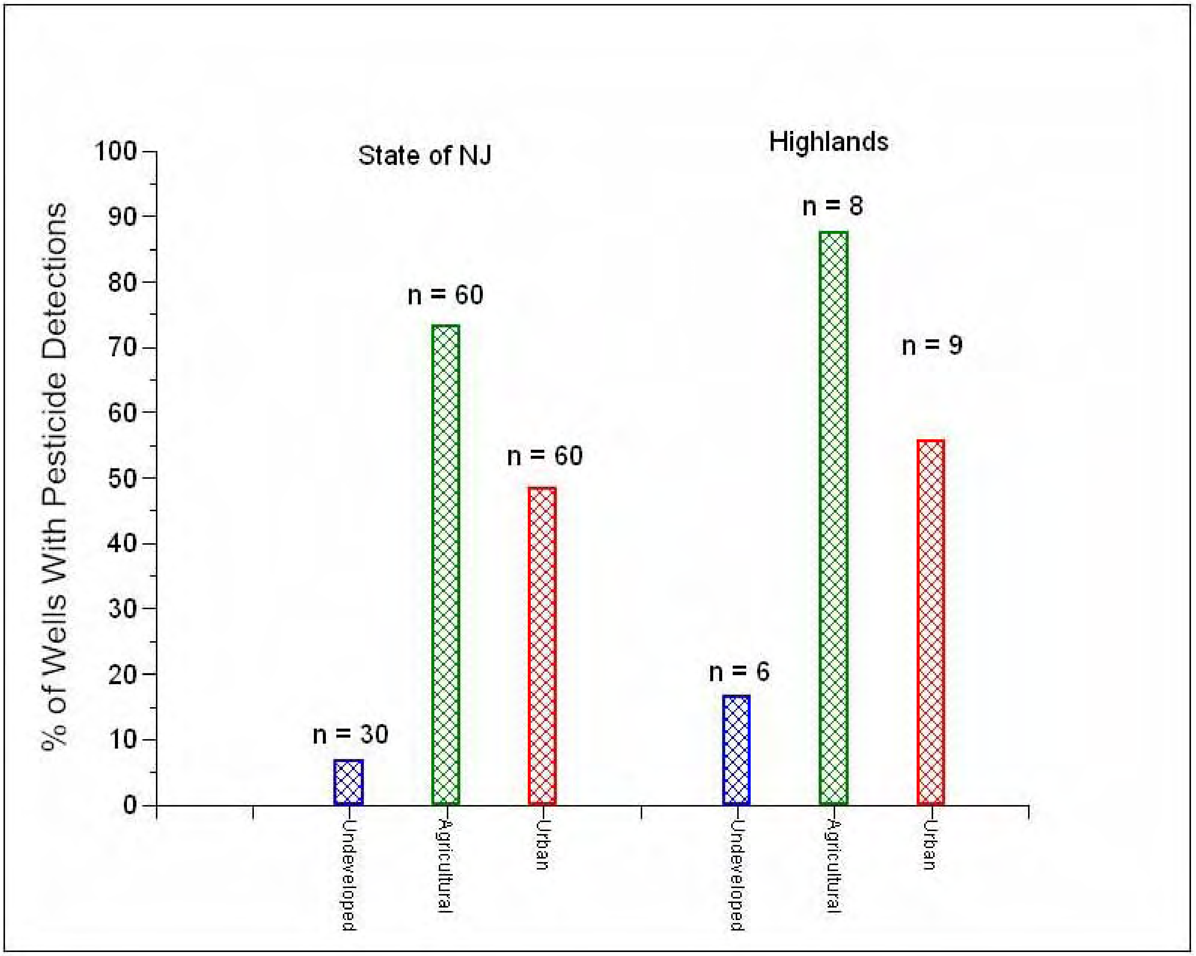
The percent of wells with detectable volatile organic compounds (VOC) are very similar comparing the 150 wells in the statewide network and those in the Highlands Region (see figure *Percent of Shallow AGWQMN Wells with VOC Detections in New Jersey and in the Highlands Region*). In both, the percent of wells with detectable VOCs is highest in urban areas, then in undeveloped, then agricultural areas. VOC concentrations in the Highlands Region wells ranged up to 38.3 ug/L. Of the wells sampled, 78% of urban, 33% of undeveloped and 25% of agricultural wells had detectable concentrations of VOCs (see table *Frequency of VOC Compound(s) Detection in Shallow Ground Water within the Highlands Region*). MTBE was the only compound found in wells in all three land use types in the Highlands, with concentrations all less than 1.0 ug/L. Benzene, tetrachloroethylene and trichloroethylene were the only compounds found at concentrations exceeding drinking and ground water quality standards. All three were detected in shallow network wells in urban land use areas.

LIMITATIONS

The summary above provides a preliminary assessment of the status of shallow and deep ground water quality in the Highlands. Some of the limitations of this assessment are:

- Deeper wells in geologic units in the valleys are not well represented;
- Deeper wells in the Green Pond Mountain Region are not represented;
- Water quality data from glacial wells are not represented; and
- There are too few shallow network wells in the Highlands Region to be statistically robust and spatially representative.

Percent of Shallow AGWQMN Wells with Pesticide Detections in New Jersey and in the Highlands Region



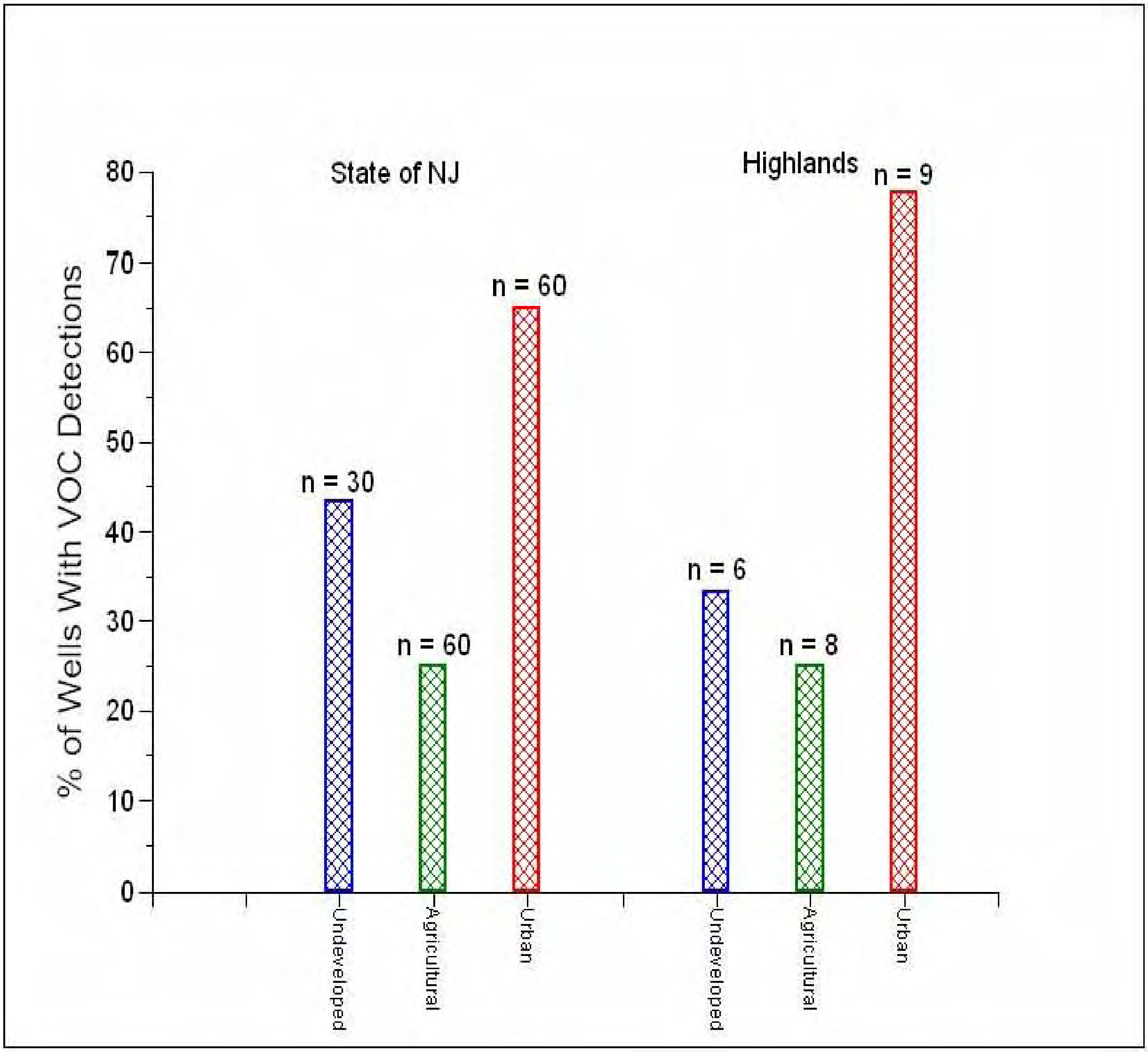
Frequency of Pesticide Compound(s) Detection by Land Use in Shallow Ground Water within the Highlands Region

		Number of Wells in which compound(s) detected by Land Use[1]			Maximum Value	NJ Drinking Water MCL	NJ Ground-Water Standards
Pesticide	N	Agricultural (N=8)	Urban (N=6)	Undeveloped (N=9)	Detected ug/L	ug/L Feb. 2005	ug/L 1993
Acetochlor	23	1	0	0	E0.005	NMCL	NGWS
Alachlor	23	1	0	0	0.27	2	0.43
Atrazine	23	7	3	0	2.5	3	3
Deethylatrazine	23	7	2	0	E0.946	NMCL	NGWS
Metolachlor	23	6	0	0	4.52	NMCL	NGWS
Prometon	23	1	3	0	0.06	NMCL	NGWS
Trifluralin	23	0	0	1	E0.0059	NMCL	NGWS
Simazine	23	4	2	0	0.051	4	1
Total number of detections		27	10	1			

Key: N, number of wells sampled; E, estimated value (number is crude); NMCL, no MCL; NGWS, no ground-water standard

[1] Land use assignment is based on 1986, 1995 and 1997 fly over derived land use coverages and field observations

Percent of Shallow AGWQMN Wells with VOC Detections in New Jersey and in the Highlands Region



Frequency of VOC Compound(s) Detection by Land Use in Shallow Ground Water within the Highlands Region

Compound	N	Frequency of Detection by Land Use[1]			Maximum Value Detected ug/L	NJ Drinking Water MCL ug/L Feb. 2005	NJ Ground-Water Standards ug/L 1993
		Agricultural (N=8)	Urban (N=9)	Undeveloped (N=6)			
MTBE	23	2	4	1	0.6	70	70(ism)
1,1,1-Trichloroethane	23	0	2	0	0.4	30	30
1,1,2-Trichloro-1,2,2-Trifluoroethane	23	0	1	0	0.2887	NMCL	NGWS
1,2,3,5-Tetramethylbenzene	1	0	1	0	35.2	NMCL	NGWS
1,2,3-Trimethylbenzene	1	0	1	0	3.8	NMCL	100(ignc)
1,2,4-Trimethylbenzene	1	0	1	0	32.3	NMCL	100(ignc)
2-Ethyltoluene	1	0	1	0	14.1	NMCL	NGWS
4-Isopropyltoluene	1	0	1	0	2.44	NMCL	100(ignc)
Benzene	23	0	1	0	1.4	1	0.2
Bromodichloromethane	23	0	1	0	0.2	NMCL	0.3
Cis-1,2-Dichloroethene	23	0	2	0	0.2414	70	10
Ethylbenzene	23	0	1	0	38.3	NMCL	NGWS
Isopropylbenzene	1	0	1	0	5.75	NMCL	NGWS
m-Xylene plus p-Xylene	23	0	1	1	22.2	1000*	40*[1000(ism)*]
Naphthalene	1	0	1	0	8	300	300(ism)
n-Butylbenzene	1	0	1	0	6.3	NMCL	NGWS
n-Propylbenzene	1	0	1	0	16.9	NMCL	NGWS
o-Xylene	23	0	1	0	1.06	1000*	40*[1000(ism)*]
sec-Butylbenzene	1	0	1	0	6.07	NMCL	NGWS
Tetrachloroethylene	23	0	2	0	13.85	1	0.4
Trichloroethylene	23	1	2	0	1.9	1	1
Trichloromethane (Chloroform)	23	0	2	1	0.7	80[2]	70
Total number of detections		3	30	3			

Key: N, number of wells sampled; E, estimated value (number is crude); NMCL, no MCL; NGWS, no ground-water standard.

[2] MCL is the running annual average Total of Dichlorobromomethane, Chlorodibromomethane, Bromoform and Chloroform.

* MCL and GWQS is for total Xylenes

(ism) = An interim specific criteria for GWQS, but expressly indicated to ensure consistency with SDWA MCL

(is) = Interim specific criteria form GWS based on the methodologies and risk assessment approach contained in the GWQS

(ignc) = Interim Generic Criteria for SOCs lacking evidence of carcinogenicity; 100 ppb

IDENTIFICATION AND ASSESSMENT OF NON-POINT SOURCE POLLUTION

INTRODUCTION

Understanding the potential impact of non-point source (NPS) pollution is useful in assessing overall water quality. The objective is to determine the types of sources of non-point pollution, and the relationships between land use patterns and of the quality of Highlands Region water resources. A main goal in preserving the critical natural resources of the Highlands is the Region's role in providing the vast majority of water supply for northern and central New Jersey, support of other human water uses and the integrity of aquatic ecosystems. Assessing the quality of surface and ground water is a critical first step in determining management strategies for water resource protection. An important element in assessing water quality is the examination of the potential sources and magnitude of NPS pollution.

NPS pollution is defined as any anthropogenic activity, factor, or condition (other than a point source discharge from a pipe or similar conveyance) from which pollutants are or may be discharged; or, that may temporarily or permanently change any chemical, physical, biological or radiological characteristic of waters of the State from what was or is the natural, pristine condition of such waters, or that may increase the degree of such change; or, that contributes or may contribute to water pollution.

SOURCES OF NON-POINT SOURCE POLLUTION

Primary sources of NPS pollution include urbanization, agricultural, institutional and industrial facility runoff. Unlike pollution that can be tracked back to an identifiable point source, NPS pollution comes from various diffuse sources and is transported via storm water runoff, ground water and atmospheric deposition.

Examples of NPS pollutants include:

- Excess nutrients, herbicides and insecticides;
- Oil, grease and chemicals from urban runoff;
- Sediment from construction sites, crop and forest lands and eroding stream banks;
- Bacteria and nutrients from livestock, domestic pet wastes, nuisance wildlife and faulty septic systems; and
- Acid mine drainage.

NPS pollutant loadings to surface or ground water can be both cumulative and compounding in nature. Cumulative effects occur not from the direct effects of a particular action, but from the combination of individual effects of multiple actions over time. A stream receiving surface runoff from both an adjacent agricultural field and an upstream construction site, with additional ground water discharge from a failing septic system, would be an example of a cumulative effect. Compounding effects occur when the interaction of two items is greater than the sum of individual effects. Water chemistry (e.g., pH, temperature) affects the bioavailability of various chemical constituents (e.g., ammonia, cyanide) and that interaction increases the impact on water resources in more than a simply additive way.

PERMITTED DISCHARGES OF NON-POINT SOURCE DERIVED POLLUTANTS

NJDEP regulates the discharge of storm water to surface water. The storm water permitting program is implemented primarily through the issuance of individual and general permits under the NJ Pollutant Discharge Elimination System (NJPDES) program. The industrial portion of the storm water permitting program emphasizes pollution prevention techniques and source control through development, implementation and maintenance of Storm water Pollution Prevention Plans (SPPP). A SPPP includes best management practices (BMPs) to prevent pollutants from coming in contact with and being transported in storm water.

The municipal portion of the storm water permitting program addresses pollutants entering waterways from municipal storm sewer systems. Municipalities are assigned to one of two categories. Tier A municipalities are in the more densely populated regions of the state, or along or near the coast, while Tier B municipalities are generally more rural and in non-coastal regions. There are four general permits administered by NJDEP to address storm water from municipalities and public entities. They are the Tier A Municipal Storm water General Permit, Tier B Municipal Storm water General Permit, Public Complex Storm water General Permit and Highway Agency Storm water General Permit. The Tier B Permit concentrates on new development and redevelopment projects. Tier A Permits include Tier B requirements, but also Best Management Practices (BMPs) aimed at controlling storm water pollutants from existing development. NJPDES storm water general permits are required for public complexes and highway systems.

In addition, any development project that proposes 0.25 acres or more of new impervious surface (or pre-existing impervious surface newly directed to storm sewers), or one acre or more of overall disturbance, is designated a "major development". This designation triggers the NJDEP Storm water Management Rules at N.J.A.C. 7:8. Once triggered, the development must meet standards for storm water quality, quantity and ground water recharge rates if they require a NJDEP permit. Storm water permit requirements are incorporated into NJDEP Stream Encroachment, Freshwater Wetlands, and Waterfront Development permits. As part of the municipal storm water management ordinances required by the Tier A and Tier B general permits, the same requirements apply to local development reviews.

WATER QUALITY AS A FUNCTION OF LAND USE

As part of a larger study of stream flow and water quality in the Raritan River Basin, the United States Geological Survey (USGS) reported on land uses and population densities as they relate to NPS pollution and water quality. The northern portion of the Raritan Basin is within the Highlands Region. (NJWSA, 2002; Reiser, 2003). Concentrations of nitrogen, total phosphorous, sulfate, TOC, TSS, water temperature and fecal coliform increased with increase in percent of developed land, while pH decreased. These results indicate a strong correlation between developed lands and lower water quality, and undeveloped lands and increased water quality.

Median concentrations of 17 constituents, water temperature, and pH were compared to the percentage of urban, urban/residential, agricultural, forested and wetland (including water) land uses; population density; total developed land uses and total undeveloped land uses. Median values of 15 of the 17 constituent concentrations were found to be significantly related to water quality and at least one land use category.

Forested Land Use

A strong correlation between the presence of forested lands and high water quality was evident. This land use had the most significant relation to median values of constituents. Alkalinity, dissolved oxygen (DO), hardness and pH increased with an increase in forested lands. Concentrations of nitrogen, total phosphorous, sulfate, total organic carbon (TOC), total suspended solids (TSS) and water temperature decreased with an increase in forested lands.

Forestry can cause significant water quality problems if improperly managed. The National Water Quality Inventory reports that forestry activities contribute to approximately nine percent of the water quality problems in surveyed rivers and streams nationally. While New Jersey has relatively limited forestry operations, but localized forestry activities can be of concern. Sources of NPS pollution include removal of streamside vegetation, road construction and use, timber harvesting and mechanical preparation for the planting of trees. Road construction and use are the primary sources of NPS pollution, contributing up to 90 percent of the total sediment from forestry operations.

Agricultural Land Use

Chloride decreased, while TSS and fecal coliform increased with an increase in agricultural lands. This data indicates that agricultural lands can have negative impacts on water quality related to the specific constituents used for agricultural purposes.

Soil runoff from agricultural areas can reach surface waters, where it contributes to excess sediment loads. Other pollutants such as fertilizers, pesticides and heavy metals are often attached to the soil particles and wash into the water bodies, potentially causing algal blooms, depleted oxygen and toxicity. Farmers apply nutrients such as phosphorus, nitrogen and potassium in the form of chemical fertilizers, manure and sludge. They may also grow legumes and leave crop residues to enhance production. When these sources exceed plant needs, or are applied just before it rains, nutrients can wash into aquatic ecosystems. This can result in impacts on recreation, create foul taste and odor in drinking water and kill fish by removing oxygen from the water. High concentrations of nitrate in drinking water can cause methemoglobinemia, commonly known as "blue baby syndrome", a potentially fatal condition in infants. Ground water can also be contaminated by agricultural waste seepage (e.g., animal waste).

Livestock overgrazing exposes soils, increases erosion, encourages invasion by undesirable plants, destroys fish habitat and may destroy stream banks and the floodplain vegetation necessary for habitat and water quality filtration. Insecticides, herbicides and fungicides can contaminate water through direct application, runoff and atmospheric deposition. They can poison fish and wildlife, contaminate food sources and destroy the habitat that animals use for protective cover.

Urban Land Use

Chloride, sulfate, nitrogen, sodium and TDS increased with an increase in urban land use. This data indicates that urban land areas can have a negative impact on water quality. The most recent USEPA National Water Quality Inventory reports that runoff from urban areas is the third largest source of water quality impairments to surveyed lakes. Roads, parking lots and buildings can prevent infiltration of precipitation into the ground underneath them. Water can then accumulate and run off to receiving waters. Although individual homes might contribute only minor amounts of NPS pollution the combined effect of an entire neighborhood can be serious, resulting in eutrophication, sedimentation and contamination of water resources. Increased population density is also correlated with increases in chloride, nitrogen, sodium and total dissolved solids (TDS), while DO decreased with increased population density.

Urbanization also increases the variety and amount of pollutants transported to receiving waters. Sediment, oil, grease, toxic chemicals, nutrients, pesticides, pathogens, road salts and heavy metals are examples of pollutants that can be generated in urban areas. Sediments and solids constitute the largest volume of pollutant loads to receiving waters in urban areas. Nutrient and pesticide use in residential, commercial and golf course lawns can be significantly higher per acre than agricultural loadings, though some landowners use minimal chemical additives. Excess application of such chemicals can have the same impacts on ground and surface water quality as excess agricultural applications.

Clearing of streamside vegetation for land development or agricultural activities can have negative impacts on water quality. The clearing of vegetation can result in increased water temperatures due to lack of shading, and stream bank erosion due to increased storm water runoff. In addition, land development may result in loss of water in the stream during dry periods due to loss of ground water recharge or increased water withdrawals within a watershed.

STORM WATER RUNOFF

The following is a brief discussion of the different storm water parameters of concern which can impair receiving water bodies. The most common pollutants associated with storm water runoff include:

- Sediment – Sediment derives from construction sites, crop and forest lands, roads and eroding stream banks. Sediment loading may result in increased turbidity, reduced light penetration, clogged fish gills and reduced prey capture for sight feeding predatory fish.
- Nutrients – Pollution from inorganic phosphorous and nitrogen used as fertilizers, and nitrates released by septic systems are of concern in New Jersey and can contribute to eutrophication and algal blooms.
- Pesticides – Numerous acute and chronic effects on humans and other organisms are associated with pesticide exposure. While many pesticides are highly soluble, those with low solubility accumulate in sediment by binding to particulate matter.
- Metals – Lead, arsenic, copper, cadmium, mercury and chromium are metals of concern. Elevated concentrations of these metals can cause health problems in humans and bioaccumulate in the food chain.
- Road Salt – Road salt has the potential to impair vegetation, ambient and drinking water quality and aquatic ecosystems, and contribute to other human health problems. Road salts have a long residence time, and can build up in ground water over time. In surface waters, it can contribute to decreased oxygen level, and cause high mortality rates among bottom dwelling organisms.
- Pathogens – Diseases which can be transmitted by runoff contaminated by pathogens include typhoid fever, dysentery, cholera and gastroenteritis. Deficient treatment of wastewater and ground water contamination is responsible for most of the outbreaks of these diseases. Ground water contamination is more likely to occur in areas with permeable soils, high water tables or fractured bedrock.
- Solids and Floatables – This includes such items as bottles, jars, cans, newspapers, plastic containers and wrappings -- litter. These can create odor and aesthetic problems, and can damage stream habitat.

SURFACE WATER PROTECTION STANDARDS

Surface water protection standards are promulgated in the New Jersey Surface Water Quality Standards (SWQS), N.J.A.C. 7:9B. The SWQS establish the designated uses to be achieved and specify the water quality criteria necessary to protect the state's waters. Designated uses are reflected in use classifications assigned to specific waters. Designated uses include potable water, propagation of fish and wildlife, recreation, agricultural and industrial supplies, and navigation. The criteria applicable to different use classifications are numerical estimates of constituent concentrations, including toxic pollutants that are protective of the uses. Narrative criteria describe instream conditions to be attained, maintained or avoided. Waters of the state include, but are not limited to, rivers, lakes, streams and wetlands. The SWQS also contain policies to ensure that the water quality necessary to allow designated uses is adequately protected.

GROUND WATER PROTECTION STANDARDS

Ground water protection standards are promulgated in the Ground Water Quality Standards (GWQS), N.J.A.C. 7:9C. Ground water is classified according to its hydrogeologic characteristics and designated uses. Ground water within watersheds of FW1 surface waters, State-owned Natural Areas, and the major aquifers of the Pinelands Area are designated Class I, with a designated use of maintenance of special ecological resources. Secondary uses include potable, agricultural and industrial water. Class II ground water is to provide potable water using conventional treatment. Both existing and potential potable water uses are included. Class II criteria specify the concentrations of constituents above which the water would pose an unacceptable risk for drinking water. Class III ground waters can be used for anything other than for potable water. The GWQS then specify the quality criteria, which are numerical values assigned to each constituent (pollutant) as necessary to protect specific designated uses.

LAKE MANAGEMENT

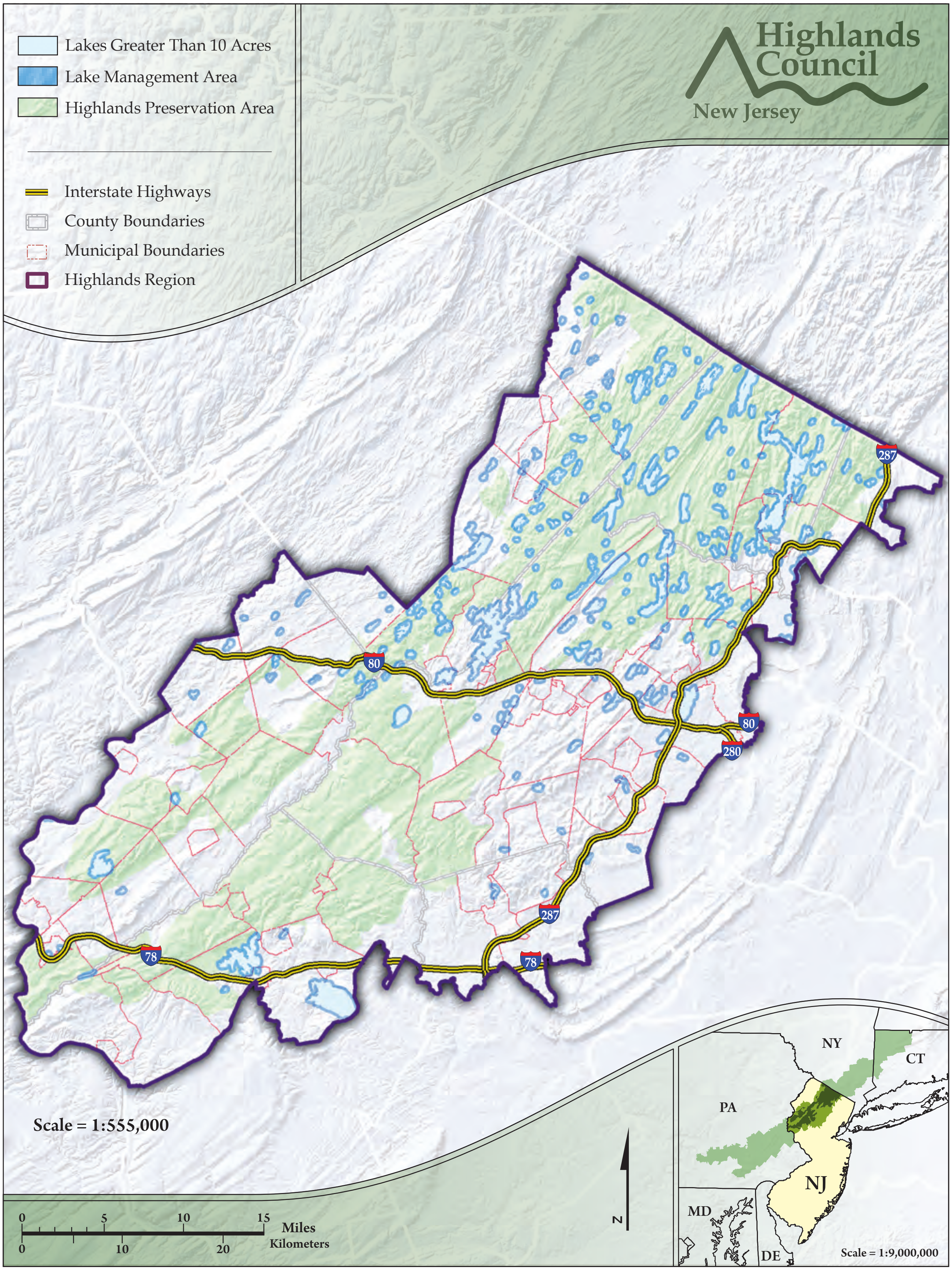
The Regional Master Plan (RMP) provides for the protection and enhancement of Highlands Lakes and their environs, including Highlands lake communities. The management of lands surrounding lakes is an important issue for the Highlands Region. Overdeveloped, damaged and poorly managed shoreland areas can result in the degradation of water quality, harm the lake ecosystem, decrease natural aesthetic values, and cause an overall loss of property values for lake communities. Lakes can be harmed by pollutant sources in the watershed area draining to them. Polluted lakes can, in turn, damage downstream streams and rivers. Most existing lake communities are fully built out, predate modern environmental protection requirements, and have limited potential for major land use changes. Some have sewer systems, but many rely on septic systems (or even cesspools) on inadequately sized lots, where direct contamination of the lakes is possible.

Past NJDEP studies indicate that nearly every public lake (privately-owned lakes were not evaluated) is experiencing unacceptable contamination, often including excessive bacteria and nutrients. In addition, many lake communities have been evolving from summer communities to year-round communities, and many are experiencing greatly intensified land uses as the original buildings are torn down and replaced by much larger structures. Addressing land uses within lake communities allows for potential opportunities to improve community value, to protect the cultural and historic resources often associated with lake communities, to protect natural resources and enhance and restore the quality of lake environments in the Region, and in some cases, to allow for in-fill development where appropriate.

The RMP seeks to protect, restore and enhance the water quality of Highlands lakes and to protect the unique character of Highlands lake communities through the delineation of Lake Management Areas that have several tiers:

- A Shoreland Protection Tier consisting of an area measured 300-foot or the first public road perpendicular to the shoreline of the lake;
- A Water Quality Management Tier consisting of an area measured 1,000-foot perpendicular from the shoreline of the lake, including the Shoreland Protection Tier;
- A Scenic Resources Tier consisting of an area measured 300 to 1,000-foot perpendicular from the shoreline of the lake, scaled based upon the view distance from the opposite shoreline, and determined through the size and layout of the lake and the topography of the land area, with wider portions of lakes and greater topographic relief having longer view distances; and
- A Lake Watershed Tier consisting of the entire land area draining to the lake.

LAKE MANAGEMENT AREAS



BASIS FOR 300-FT SHORELAND PROTECTION TIER

The 300-foot distance for this tier is based on the Highlands Open Water buffer requirement of 300 feet, and is intended to protect against physical intrusion and direct discharges to the lake or pond. Similar to the Highlands Open Water buffer, there is recognition of existing land uses and disturbances that would be addressed in a local development review or Highlands Project Review process.

BASIS FOR 300 TO 1,000-FT SCENIC RESOURCES TIER

This tier has a variable width based on lake size, dimensions and topographic variability. The minimum is set at 300 feet to conform to the Shoreline Protection Tier. The maximum is set to 1,000 feet to conform to the Water Quality Management Tier. The intermediate distances would be identified using the same "line of sight profile" concept used in the Highlands Council's Procedure for Nomination, Evaluation and Inventory of Highlands Regionally Significant Scenic Resources. A "line of sight profile" is a schematic that is a graphic depiction of the depression and elevations one would encounter walking along a straight path between two selected locations. A straight line depicting the path of light received by the eye of an imaginary viewer standing on the path and looking towards a predetermined location along the path constitutes a line of sight. The locations along the path where the viewer stands and looks are the control points of the line of sight profile. (NYSDEC, DEP-00-02 Article 8, 49 7/31/00) In small lakes or narrow portions of lakes, the line of sight profile will be relatively short, except in areas of significant topographic rise. In larger lakes, the line of sight profile will be relatively large, and therefore the Scenic Resources Tier will tend to be more toward the 1,000 foot maximum.

BASIS FOR 1,000-FT WATER QUALITY MANAGEMENT TIER

Precedence - Other Statewide Initiatives

The recommendation for 1,000-ft Water Quality Management Tier delineation is based upon other statewide initiatives aimed at protecting sensitive areas surrounding lakes, including: Minnesota's Shoreland Management Program (Minnesota Rules 6120.2500 - 3900) that uses a 1,000-ft shoreland management district; Wisconsin's Shoreland Management Program (Chapter NR 115) that uses a 1,000-ft shoreland zone; and Michigan's Great Lakes Shorelands Management Program (Part 323) that uses a minimum 500-ft shoreline protection overlay boundary. New Hampshire and Maine also have shoreland management and protection programs, but without establishment of a defined district. Staff research was undertaken to determine the basis and rational for establishment of a 1,000-ft district in the states of Minnesota and Wisconsin (and 500-ft in Michigan). In Wisconsin, the definition of the 1,000-ft district and the development of shoreland standards were based on recommendations from an interdisciplinary team of scientists from the University of Wisconsin and by scientists and engineers from several state and federal agencies. However, the available documents do not provide the scientific basis or rationale for establishment of the 1,000-ft district. One document indicated that 1,000 feet was intended to include three tiers of lots around lakes to "deal with backlots having access rights." The shoreland zoning program has taken root in Wisconsin, is generally supported, and has been around 34 years without judicial reversal.

Compared with Wisconsin, even less is known about the basis for the 1,000-ft shoreland district inMinnesota. In 1970, the Department of Natural Resources released *Minnesota Lakeshore – Resource,* *Development, and Policy Needs*. This documented presented considerable information and data about lakes and lakeshore communities that, presumably, served as the basis for subsequent decision-making. However, it did not mention a relevant shoreland district size. In 1971, the shoreland rules and regulations were issued that included the statutory definition of "shoreland" (i.e., includes lands within 1,000 feet of a lake). The State of Michigan recommends that when municipalities create a fixed-distance shoreline protection overlay boundary that "500 feet is generally recognized as a minimum distance to protect shoreline features."

Estimated Time of Travel Criterion in Ground Water

The staff also explored the potential for using ground water time of travel (TOT) for helping to establish upgradient limits of potential ground water contamination threats to the lake, thereby serving as a basis for delineating the Water Quality Management Tier. A cursory analysis was conducted using ground water data in the Highlands Region. The computed distances for five years TOT are approximately 1,000 feet for hard rock and unconsolidated aquifers and 1,600 feet for limestone, with an average distance of about 1,300 feet. Given the various hydrogeologic variables, the results are not inconsistent with a 1,000 foot distance for the Water Quality Management Tier.

IDENTIFICATION OF AMBIENT WATER QUALITY AND IMPACTS

SURFACE WATER

There are numerous USGS sources for surface water quality data in the Highlands Region. Such data is collected through national, state and local programs. National programs include the Hydrologic Benchmark Network, National Stream Quality Accounting Network and USGS National Water-Quality Assessment (NAWQA) Program. State and local programs include the Ambient Stream Monitoring Network (ASMN), which is a USGS/NJDEP cooperative venture, Delaware River Basin NAWQA, New Jersey Water Supply Authority monitoring sites, New Jersey Water Science Center Project Data and the New Jersey Ambient Biomonitoring Network (AMNET).

Surface water quality information from the Highlands Region includes a database of approximately 189 surface water sites; testing of 447 different constituents; 7,600 samples; and 208,000 analytical results.

GROUND WATER

The Ambient Ground Water Quality Monitoring Network (AGWQMN) is a cooperative project between the NJDEP and the U.S. Geological Survey (USGS). The purpose of the network is to determine the status and trends of shallow ground water quality as a function of land use related to NPS pollution in New Jersey. The statewide network consists of 150 monitoring wells that are sampled at a rate of 30 per year on a five year cycle. The second cycle began in 2004. Physical parameters measured at each well include pH, specific conductance, dissolved oxygen, water temperature and alkalinity. Chemical parameters measured at each well include major ions, metals, nutrients, pesticides, radionuclides and volatile organic hydrocarbons.

NJDEP also administers the New Jersey Ground Water Protection Program (GWPP). The GWPP relies on NJPDES-DGW discharge control permits to help prevent ground water and surface water quality degradation. Each permit includes requirements for a ground water monitoring well network, monitoring parameters, sampling and reporting schedule, discharge monitoring program and limitations, BMP and preventive measures.

WATER QUALITY IN THE LAKES OF THE HIGHLANDS REGION

NJDEP has recently renewed an ambient lake monitoring network designed to provide the water quality data necessary to assess the ecological health of the State's lakes. The program involves the testing of 200 lakes, each sampled once every five years. Each lake is sampled at least three times during the year, with a possible winter sample also collected. Depending on the lake size and characteristics, up to four sampling locations are monitored in each lake. The water quality measurements conducted at each lake include parameters such as dissolved oxygen, temperature, specific conductance, pH, nutrients, chlorophyll A and hardness. Qualitative evaluations of algal blooms and aquatic vegetation are also performed at each lake. Several of these parameters may be indicators of NPS pollution loadings in the Highlands Region.

Raw data results of the NJDEP ambient lake monitoring network are available at http://www.nj.gov/dep/wms/bfbm/lakes.html. Once available, such testing results will assist the Council in determining the status and trends for lake water quality in the Highlands Region.

The ambient lakes monitoring project is part of a larger NJDEP effort to develop current water quality information on the state's lakes. The NJDEP will also contract with the private sector to perform intensive surveys on lakes which are targeted for a *Lake Characterization and Restoration Plan* development as part of the establishing Total Maximum Daily Loads.

IMPACT OF IMPERVIOUS SURFACES ON HIGHLANDS RESOURCES

Impervious surfaces include roads, parking lots and buildings, as well as soil compaction which results from development, lawn maintenance and forest management. Impervious surfaces retard water infiltration into soil, potentially influencing natural hydrologic regimes, ground water recharge, stream flow, channelization and water quality. Increased impervious cover threatens immediate and downstream habitat. Primary and secondary impacts to wetlands, aquatic ecosystems and rare species are also of concern.

Data suggest that a strong relationship exists between percent impervious cover within a HUC14 subwatershed and overall water quality, including the ability of a water body to support biological diversity. The Center for Watershed Protection defines sensitive streams as typically having impervious surface cover from 0 to 10%, with higher quality water and aquatic habitat; impacted streams have a watershed impervious surface cover of 11 to 25% and show signs of degradation; and non-supporting streams have surrounding land use with greater than 25% impervious surface cover, with often severe degradation of water quality and limited ability to support an aquatic community.

NJDEP has estimated that statewide, approximately 68% of the HUC14 subwatersheds are below the 10% threshold, while 21% are considered impacted and 11% are considered non-supporting. NJDEP has demonstrated a relationship between storm water outfall into habitat for *Clemmys muhlenberg* (Bog Turtle) and habitat alteration, vegetative community shift, altered hydrologic regimes, loss of seeps and failure to confirm the presence of a previously known community of this endangered species. Similar effects on declining populations of the globally rare Helonais bullata (Swamp Pink) due to impervious surface impacts have also been documented in the state and can be expected in the Highlands Region. These results indicate that non-point source pollution and its effects on resources of the Highlands Region result, at least in part, from the presence of impervious surfaces.

On-site Wastewater Treatment

Septic systems are utilized for wastewater treatment throughout much of the Highlands Region. Even after treatment, septic effluent contains nitrates, phosphates and pathogens that may pollute nearby waterways and ground water, and contributing to NPS pollution. Therefore, the conventional septic system is responsible for a certain amount of water "pollution" that could be considered a non-point source, even when the system is working effectively.

The conventional septic system is still the most commonly used device to dispose of domestic sanitary wastewater. New and innovative means are becoming available that may perform better, provide more effective pollution control, or overcome site-specific constraints. Requiring setbacks from streams and potable wells provides another level of protection.

Nitrate concentration is one key characteristic of ground water quality. A detailed evaluation of Highlands ground water nitrate concentrations is discussed later in this Technical Report. The objectives of that effort were to determine the background concentrations of nitrates in ground water and the relationships between land use patterns and ground water nitrate concentrations. Statistical analyses were completed in order to identify a set of variables that could be used to predict nitrate concentrations in ground water. Land use variables such as type and density of land development, presence of specific contaminant sources and certain other features, including soil characteristics and surface hydrology, were considered as possible determinants of ground water quality. Analyses of nitrate concentrations as a function of individual land use and well construction variables were used to qualitatively assess the relations between these variables. Higher concentrations appear to be more prevalent in areas with substantial agricultural activities, in highly urbanized areas and where septic systems are in use.

BEST MANAGEMENT PRACTICES TO CONTROL NON-POINT SOURCE POLLUTION

New Jersey's Storm water Management Rules, N.J.A.C. 7:8, specify the storm water management standards that are mandatory for major new development, defined as the addition of 0.25 acres or more of additional impervious surface, or one acre or more of total land disturbance. The New Jersey Storm water Best Management Practices (BMP) Manual was developed to provide guidance to address the standards in the rules, and provides examples of ways to meet the standards. The guidance provided by the Storm water BMP Manual and USEPA BMPs can help maintain and restore surface and ground water integrity in the Highlands Region by minimizing NPS pollution. Examples of BMPs for different land use types include:

Agricultural Runoff

- Sedimentation occurs when wind or water runoff carries soil particles from a farm field and transports them to a water body, such as a stream or lake. Applying management measures to control the volume and flow rate of runoff water, keep the soil in place and reduce soil transport can reduce erosion and sedimentation by 20 to 90 percent.
- Fertilizers, manure, sludge, irrigation water, legumes and crop residues are applied to enhance agricultural production. Farmers can implement nutrient management plans which help maintain high yields and save money on the use of fertilizers.

- NPS pollution from irrigation can be reduced by improving water use efficiency, including Low Energy Precision Application (LEPA) sprinklers; surge flow furrow irrigation valves; drip irrigation; soil moisture measurement and irrigation scheduling; and the use of underground water distribution pipelines.
- Pesticides, herbicides, and fungicides can enter and contaminate water through direct application, runoff, wind transport and atmospheric deposition. To reduce NPS contamination from pesticides, Integrated Pest Management (IPM) techniques can be applied based on the specific soils, climate, pest history and crop for a particular field.

URBAN RUNOFF

Management plans for the runoff of sediment, toxics and nutrients can establish guidelines to help maintain the volume of runoff at pre-development levels. Controlling runoff from existing development can be targeted to make it more feasible. Runoff management plans can identify priority pollutant reduction opportunities, protect natural areas that help control runoff and begin the process of ecological restoration and retrofit activities to clean up degraded water bodies.

The control of nutrient and pathogen loadings includes use of proper design, installation, and operation of septic systems. These systems should be situated away from open waters, wetlands and floodplains. Also, septic systems should be located away from trees because tree roots can crack pipes or obstruct the flow of wastewater through drain lines. They should also be inspected, pumped out and repaired at regular time intervals. Maintaining water fixtures and purchasing efficient fixtures can limit wastewater volumes, reducing the likelihood of septic system overflow.

To limit NPS pollution from paved areas, alternatives to traditional impervious surfaces can be employed. Grasses and natural ground cover can be attractive and practical substitutes for asphalt driveways, walkways and patios.

Maintaining the natural land contours and using native plants that do not need fertilizer and water can decrease runoff volumes, erosion and pollution. Incorporating environmental factors such as soil type, practical turf areas, proper irrigation, mulches and appropriate maintenance schedules into landscape design can be very useful in controlling NPS pollution.

FORESTRY RUNOFF

Properly designed pre-harvest plans can result in logging activities that are protective of water quality. They should clearly identify the schedule and area to be harvested; locate special areas of protection, such as wetlands and streamside vegetation; plan for the proper timing of forestry activities; describe management measures for road layout, design, construction and maintenance, as well as for harvesting methods and forest regeneration.

BOATING AND MARINA RUNOFF

A significant amount of solvent, paint, oil and other pollutants can seep into the ground water or be washed directly into surface water through boat operation and maintenance. Selecting non-toxic cleaning products and maintaining boats away from the water; carefully fueling boat engines, recycling used oil, and discarding parts properly can prevent petroleum spills. Fecal contamination from the improper disposal of human waste during boating can make water unsuitable for recreation and cause human health problems.

Poorly planned marinas can disrupt natural water circulation, cause shoreline soil erosion and habitat destruction. Marinas should be located and designed so that natural flushing regularly renews adjacent waters. In addition, pre-development water quality and habitat assessments should be conducted to protect ecologically valuable areas. Marina fueling and sewage collection stations should be maintained and designed to avoid and make cleanup of spills easier.

MANAGING WETLANDS TO CONTROL NON-POINT SOURCE POLLUTION

Properly managed wetlands can intercept runoff, transform and store sediment, nutrients and certain heavy metals. In addition, wetland vegetation can keep stream channels intact by slowing runoff, evenly distributing the energy in runoff and regulating stream temperature. There are three primary management strategies to maintain the water quality benefits provided by wetlands:

- Wetlands Preservation: Preservation protects wetland functions by prohibiting development activity. This strategy encourages proper management of upstream watershed activities, including agriculture, forestry and urban development. Several government programs protect wetlands by either controlling development activities or providing financial assistance. In addition, non-governmental groups that purchase wetlands for conservation purposes are playing an increasingly important role in protecting water quality.
- Wetlands and Riparian Restoration: This strategy promotes restoration of degraded wetlands and riparian zones. Riparian areas characteristically have high water tables and are subject to periodic flooding from the adjacent water body. Restoration activities should recreate the full range of preexisting wetlands functions. That may require replanting degraded wetlands with native plant species and/or using structural devices to control water flows.
- Engineered Systems: The third strategy promotes the use of engineered vegetated treatment systems that are especially effective at removing suspended solids and sediment from NPS pollution before the runoff reaches natural wetlands. Vegetated filter strips can intercept sheet flows of runoff before the runoff reaches wetlands. These are effective at sediment removal, achieving greater than 70% removal. Constructed wetlands, complexes of water, plants and animal life that simulate naturally occurring wetlands can achieve sediment removal rates greater than 90%.

PROGRAMS AND RESOURCES TO REDUCE AND CONTROL NON-POINT SOURCE POLLUTION

Non-point source pollution is thought to be responsible for between 40 and 70 percent of pollutant loads, and therefore much of existing and threatened water quality impairments. To address these water quality problems, government agencies provide technical assistance and fund programs to implement NPS controls. Other sources of funding are also available from environmental and conservation organizations.

NJDEP administers the Statewide NPS Pollution Management Program, which is primarily responsible for developing and implementing the Statewide NPS Pollution Control Strategy for the State. This strategy is laid out in the December 2000 New Jersey Nonpoint Source and Storm water Management Program Plan. This Plan provides a detailed description of how the NJDEP will implement NPS and storm water management control strategies over the next 15 years.

Strategies identified in the plan include short-term preventive approaches to controlling priority NPS pollution, including minimum runoff control requirements for new development, land preservation, stewardship of existing forests and open space, education and outreach, innovative septic system management approaches, municipal storm water permits and stream corridor protection; and longer-term preventive approaches to be developed through Watershed Management Plans and Regional Storm water Management Plans. Preventive approaches can link NPS controls to the identified carrying capacity of waters, load allocations in TMDLs and local concerns.

In addition, the NPS Plan provides for a Watershed Restoration Action Strategy Process to include stakeholder involvement, watershed characterization and assessment, watershed problem identification and prioritization, goal setting, restoration strategy development, watershed restoration plan development, watershed restoration plan implementation and evaluation and refinement of the process.

Some of these strategies have already been realized through development of specified TMDLs as part of Water Quality Management Plans for certain impaired waters within Watershed Management Areas. Other ongoing strategies outlined in the Plan to control NPS pollution include open space preservation and the implementation of BMPs.

STATUTES, RULES AND PROGRAMS

Statutes, rules and programs highlighted in the NPS Plan, and/or in the State of New Jersey Nonpoint Source Report 2004-2006 related to the control and reduction of NPS pollution include:

- Highlands Water Protection and Planning Act, N.J.S.A. 13:20-1 et seq.
- Highlands Water Protection and Planning Act Rules, N.J.A.C. 7:38
- New Jersey Sewage Infrastructure Improvement Act, N.J.S.A. 58:25-23 et seq.
- Sewage Infrastructure Improvement Act Grant Rules, N.J.A.C. 7:22A
- Storm water Management Rules, N.J.A.C. 7:8
- New Jersey Water Quality Planning Act, N.J.S.A. 58:11A-1 et seq.
- Water Quality Management Planning Rules, N.J.A.C. 7:15
- Flood Hazard Area Control Act Rules, N.J.A.C. 7:13
- Freshwater Wetlands Protection Act Rules, N.J.A.C. 7:7A
- New Jersey Pollution and Discharge Elimination Rules, N.J.A.C. 7:14A
- Soil Erosion and Sediment Control Program, implemented through Soil Conservation Districts

FUNDING FOR NON-POINT SOURCE PROGRAMS

The NJDEP NPS Program administers the federal Section 319(h) and 604(b) grant programs. Federal 319(h) funds are granted to states and are used to implement programs and projects designed to reduce NPS pollution. New Jersey's NPS Program has targeted Section 319(h) grant funds to developing watershed restoration and protection plans. Section 604(b) grant funds are allocated to organizations for water quality planning activities. Other funds to assist with NPS impacts, at least in part, include the State Revolving Fund and Corporate Business Tax, as well as USEPA grants.

NON-POINT SOURCE REDUCTION IMPLEMENTATION PROGRAMS

One of several existing NPS partnerships between government agencies and the public is the Conservation Reserve Enhancement Program (CREP). This is a natural resource conservation program that addresses significant agricultural related environmental problems. Under CREP, program participants receive financial incentives from the United States Department of Agriculture Farm Service Agency to voluntarily enroll in the Conservation Reserve Program (CRP) in contracts of 10 to 15 year duration. Participants remove marginal pasture or crop lands from agricultural production and convert the land to native grasses, trees and other vegetation. The New Jersey CREP is designed to help farmers reduce impairment from agricultural water runoff sources in an effort to improve water quality along both impaired and unimpaired New Jersey streams.

The New Jersey Department of Agriculture (NJDA) Agricultural Conservation Planning Assistance program involves development of conservation management plans for farmers and landowners incorporating soil erosion and sediment control, animal waste nutrient management, water quality improvement, NPS pollution control and other natural resource management strategies. Technical assistance and cost-sharing grants are available to help eligible landowners.

Other programs to reduce and control NPS pollution, administered by NJDA, include the Environmental Quality Incentive Program, Conservation Cost Sharing Program, Wetlands Reserve Program, Agricultural Management Assistance, Conservation Security Program, Farm and Ranch Lands Protection Program, Wildlife Habitat Incentives Program, and Wetlands Reserve Program.

NON-POINT SOURCE EDUCATION PROGRAMS

Some activities of average citizens that add to NPS pollution include lawn fertilizing, throwing oil or litter down storm drains and not cleaning up pet wastes. Modification of people's daily activities can help reduce these types of NPS Pollution. Education is a key to making people aware of how they add to NPS pollution, and how they can make a difference. NPS education programs and materials in New Jersey include the New Jersey Watershed Ambassadors Program, Watershed Watch Volunteer Monitoring Program, Project WET (Water Education for Teachers), NJDEP Training Workshops on numerous NPS related topics, Harbor Watershed Urban Fishing Program, Clean Water Rangers Program, NJDEP, Division of Watershed Management publications.

LAKE HOPATCONG CASE STUDY FOR REDUCING NON-POINT SOURCE POLLUTION

Lake Hopatcong, located in Hopatcong and Mt. Arlington Boroughs (Sussex County), and Roxbury and Jefferson Townships (Morris County) is a working example of attempts by governmental agencies, local governments and the public to identify, control and reduce NPS pollution. In 2003 the NJDEP completed a total phosphorous TMDL for the lake. The TMDL identified storm water surface runoff and failing septic systems as the main contributors to the excess phosphorous. The following are identified as steps to reduce NPS phosphorous pollution within Lake Hopatcong: mapping of storm water outfalls around the lake, along with targeted monitoring of such outfalls; development of a municipal based Restoration Plans, outlining BMPs to reduce phosphorous loading; awarding 319(h) grants to address storm water "hot spots". These grants were used to implement BMPs and storm water retrofits; awarding USEPA grants to address storm water retrofits, BMP implementation, public education programs, training of Lake Hopatcong Commission staff and a pilot study of alternative on-site wastewater treatment systems; sewering of Hopatcong Borough, which is being completed in a three phase approach. Roxbury and Mt. Arlington are already sewered, and Jefferson Township has completed a Sewer Feasibility Study. These steps offer the means by which phosphorous TMDLs can be achieved and maintained to restore Lake Hopatcong to unimpaired status.

NITRATES CONCENTRATIONS AND SEPTIC SYSTEM DENSITY OF THE HIGHLANDS REGION

OVERVIEW

Studies of ground water quality have established a clear link between nitrate concentrations in ground water and land use. High nitrate concentrations are often associated with particular land use practices that can degrade water quality, such as septic system discharges and agricultural activities. Accordingly, nitrate is often used as an indicator of the risk of impairment to ground water quality related to land use and other activities, and is widely used as an indicator of overall water quality and the potential presence of biological (e.g., pathogenic) and chemical (e.g., pesticide, pharmaceuticals) contamination. High levels of nitrate in ground water can result in serious health impacts (e.g., methemoglobanemia, or "blue baby syndrome") and can have long lasting effects on the geochemistry and ecological functioning of soils and water resources. Elevated concentrations of nitrate in surface water can cause a loss of biodiversity and lead to eutrophication, algal blooms and oxygen depletion. Primary nonpoint sources for nitrate are agricultural runoff and soil contamination from the introduction of septic system effluent and other diffuse loading sources. Point source discharges, such as those from sewage treatment plants also contribute to nitrate loadings.

Understanding and managing the impact of nitrate loadings is critical to maintaining the ecological water resource quality in the Highlands Region. In order to understand the existing quality of the ground water resources, it is necessary to determine the background nitrate concentrations using available water quality data. Elevated nitrate concentrations may be the result of development activities (e.g., installation of septic systems) and other sources of nitrate loadings like fertilizer applications, although naturally-occurring characteristics (e.g., limestone geology) can also contribute to elevated concentrations of nitrate because they allow for rapid transport of contaminants with little attenuation. The concentrations of nitrate in ground water in the Highlands Region vary from high water quality areas, where the measured nitrate concentrations are likely to be representative of natural conditions, to areas where intensive land use activities have resulted in elevated levels of nitrate concentration.

A critical component for protecting ground water quality is limiting discharges of wastewater to ground water. Potential water quality degradation can be mitigated with proper location, design, construction, installation, repair and operation of individual septic systems. If managed properly, these systems can provide for some ground water recharge. These systems are subject to the NJDEP Standards for Individual Subsurface Sewage Disposal Systems (N.J.A.C. 7:9A) and are generally regulated at the county and municipal level. An important issue in the proper placement of septic systems is the suitability of the soils on a site to handle septic system effluent, as septic systems are designed to utilize the soils as a functioning part of the treatment process. Although the soil conditions and geological characteristics of the Highlands Region provide some areas where the soil characteristics are appropriate for the use of septic systems, much of the Region's soils are generally constrained for the use of conventional septic systems.

However, the Highlands Council recognizes that even with proper siting, design, operation and maintenance of septic systems, additional effluent discharges must be limited in order to prevent further degradation of water quality. This requires appropriate septic system density to ensure that future developed lots utilizing septic systems are appropriately zoned to provide for sufficient dilution of effluent discharges. It should be emphasized that though nitrate serves as the indicator contaminant for septic systems, it also serves as a surrogate for other contaminants of concern that may also be present in septic system effluent, and protecting ground water quality against elevated nitrate concentrations also provides protection against other contaminants. To this end, the Highlands Council has developed a methodology for computing appropriate septic system densities for municipalities within the Highlands Region, and, based upon the land area available for development, computed the total number of allowable septic systems (i.e. septic system yields) per municipality and Land Use Capability Zone.

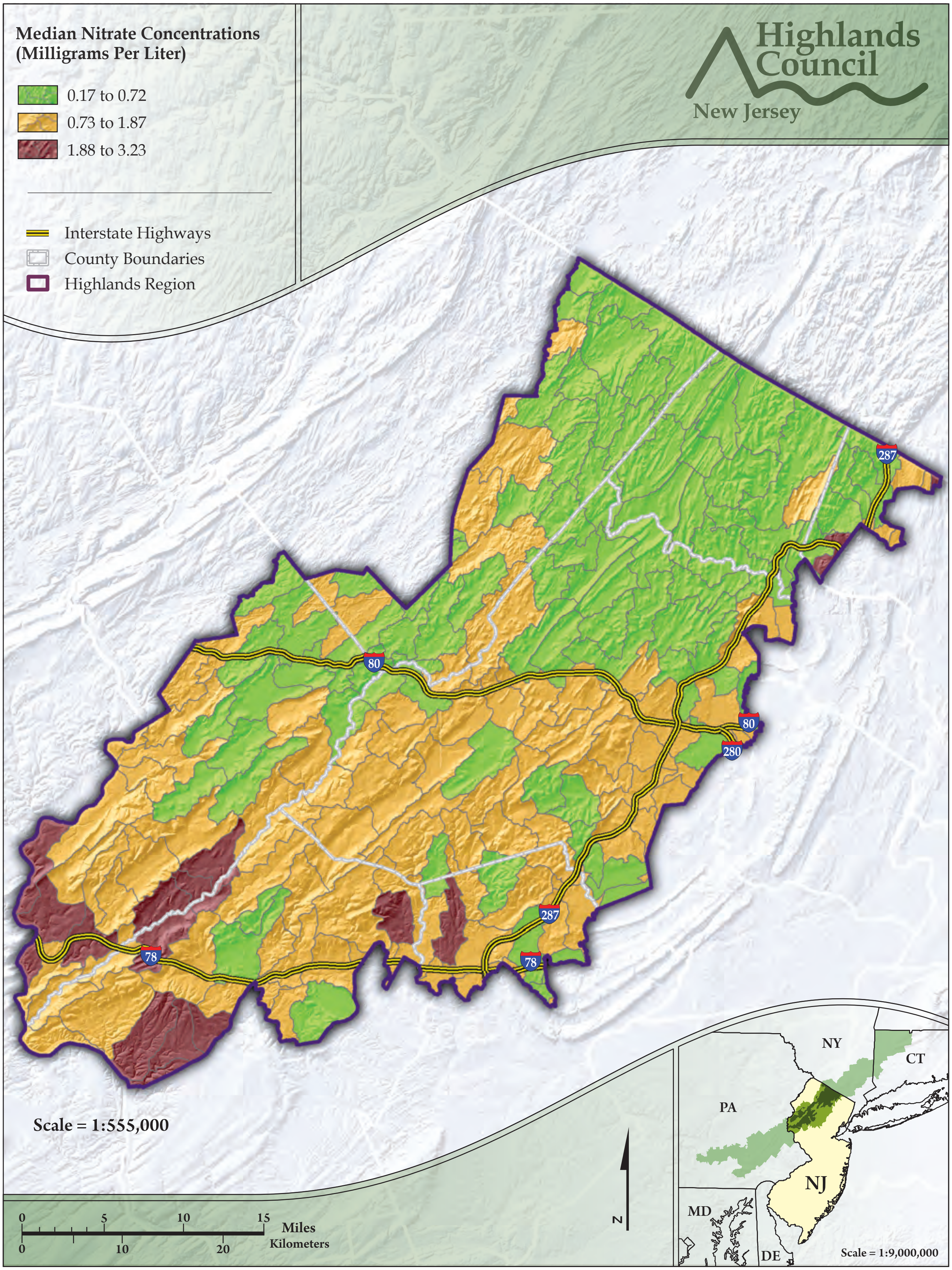
The Highlands Council's methodology for computing appropriate septic system yields for different Land Use Capability (LUC) Zones at the municipal scale relies upon a number of different modeling approaches and analytical techniques that estimate at the subwatershed scale: 1) median nitrate concentration; 2) annual drought ground water recharge rate; 3) septic system density required for sufficient septic system effluent dilution, and 4) an estimate of developable land within each zone by municipality. Computing appropriate septic system densities first required estimating median nitrate concentrations in ground water at the subwatershed scale using statistical models. Based upon these estimated median concentrations, "target" nitrate concentrations for the Protection and Conservation Zones were established by the Council. The Trela-Douglas nitrate dilution model was then used to compute appropriate densities for each LUC Zone at the subwatershed scale, based upon target nitrate concentrations, assumed annual septic system nitrate loadings, and estimated annual drought recharge rates. Following computation of an appropriate septic system density, the number of additional allowable septic systems per Protection and Conservation Zones within the Planning Area was calculated for each municipality. In addition, the Highlands Council is also providing potential septic system yields for non-sewered portions of the Existing Community Zone.

A necessary first step for computing appropriate septic system densities at the municipal scale is characterizing baseline conditions of nitrate concentrations throughout the Highlands Region. The Highlands Council analyzed nitrate concentrations in ground water measured in wells throughout the region, with consideration given to well location, construction, water use, land use, and available water quality data. An evaluation of specific well characteristics was performed to determine the data from wells that were representative of land use and water quality conditions in the Region. Based on analytical results from sampling of 352 wells selected for this analysis, the median of measured nitrate concentration for the entire Highlands Region is 1.1 milligrams/liter (mg/L).

This analysis, while useful, provides a large scale characterization of ground water quality throughout the Highlands Region, and is biased towards more developed areas where wells with water quality data primarily exist. In order to better estimate the nitrate concentrations for undeveloped areas of the Region, for each of the 183 HUC14 subwatersheds within the Region, and for the Region as a whole (beyond the calculated median value), the U.S. Geological Survey (USGS) Water Science Unit with the support of the Highlands Council developed empirical-based logistic regression water quality models. This modeling approach examined anthropogenic and naturally-occurring variables potentially related to water quality such as urban, agricultural and other types of land use, soil characteristics, geologic features, hydrology and other factors, including septic system density, that could be used in statistical models to most reliably predict nitrate concentrations. The models used inputs primarily indicative of land use activities for estimating the probability that a pre-specified target nitrate concentration is exceeded. Model development incorporated an analysis of the available water quality data from 352 wells located in the Highlands Region, as well as land use variables and specific features that are predictive of changes in nitrate concentrations in ground water. The optimal set of predictive variables, as determined by modeling objectives and performance, included: 1) the percentage of urban land use; 2) the percentage of agricultural land use; 3) the septic system density; 4) the length of streams; and 5) the number of known contaminated sites.

Based upon the median nitrate concentrations estimated with the logistic regression models for each of the 183 subwatersheds, the median concentration for the Highlands Region as a whole was determined to be 0.83 mg/L, slightly lower than the 1.1 mg/L value calculated directly from well sampling analytical results. The model-derived median is considered more accurate as it addresses limitations in the well monitoring network, related to the overall distribution of wells with a disproportionately small number located in undeveloped areas. The modeling analysis also provides an indication of general trends in water quality and magnitude of contamination in terms of both areal extent and actual concentrations that are related to nitrate loadings. Estimated median nitrate concentrations for each of the 183 subwatersheds range from 0.17 to 3.6 mg/L; just nine subwatersheds have an estimated median concentration greater than 2.0 mg/L. The median nitrate concentration in undeveloped areas was estimated to be 0.1 mg/L, with concentrations in subwatersheds with very limited development typically less than 1.0 mg/L. Highly urbanized areas are likely to have somewhat elevated concentrations, with intensely agricultural areas most likely to have the highest concentrations of nitrate. The results of the median nitrate concentration analysis, aggregated into representative values for the HUC14-specific results are illustrated in the map figure entitled *Median Nitrate Concentrations by HUC14*.

MEDIAN NITRATE CONCENTRATIONS BY HUC 14



The median nitrate concentrations for the Protection and Conservation Zones within the planning areas of the Highlands Region were estimated to be 0.72 and 1.87 mg/L, respectively, and these concentrations were selected as the nitrate dilution targets for these two zones. By comparison, the median nitrate concentration estimated for the Existing Community Zone is 1.17 mg/L. For this zone, a nitrate target concentration of 2.0 mg/L, corresponding to NJDEP statewide target, was selected for the regional build out analysis regarding the limited parts of this Zone not served by public wastewater treatment systems. The selected target nitrate concentration of 2.0 mg/L reflects the protection and smart growth standards of the Existing Community Zone.

In addition to target nitrate concentrations, another model input variable required for estimating appropriate septic system densities is the annual ground water recharge rate. Annual ground water recharge under drought conditions was estimated for each subwatershed using the GSR-32 recharge methodology, which was developed by the NJ Geological Survey (Charles and others, 1993). The methodology is a soil-water budget approach that accounts for local climatic, soil, and land use/land cover characteristics to estimate annual ground water recharge using monthly time steps. In order to be most protective of ground water quality, "worst case" drought recharge conditions were used, where the 1961-1966 New Jersey drought of record was used to calibrate the GSR-32 model to extreme climatic conditions.

The final variable required for computing septic system density with Trela-Douglas is the annual load of nitrate mass generated per septic system, which in this analysis was assumed to be 40 pounds per year. This value was estimated on the basis of demographics for the Highlands Region (assumed average of 4 persons residing per dwelling with septic systems), and studies that indicate that a person generates approximately 10 pounds of nitrate annually. The 4 person average exceeds the 2.8 estimated mean household size for the Region, but was used to account for other possible nitrate loading sources, such as fertilizer applications to lawns, and for possible variations in household size within the Region.

After the input values for the input variables were obtained, the Trela-Douglas model was used to calculate acceptable septic system densities for the three LUC Zones in the Planning Area. However, these densities are expressed as average lot sizes for ease of calculation, and should not be interpreted as minimum lot sizes in zoning. For the 183 subwatersheds, the median septic system densities computed for the Existing Community, Conservation, and Protection Zones are 9.4, 10.0 and 26.1 acres per septic system, respectively. It should be noted that a number of these subwatershed are located exclusively in the Preservation Area, and would not be subject to these Planning Area densities. The septic system densities in the Highland's Preservation Area, as computed by NJDEP using Trela-Douglas, are 25 and 88 acres in the non-forested and forested areas, respectively. These Preservation area densities were computed with target nitrate concentrations of 0.21 and 0.76 mg/L for the forested and non-forested areas, respectively.

Following computation of the appropriate densities with the Trela-Douglas model, septic system yields (i.e., a calculation of the additional allowable septic systems within a specific area) were computed within the three Planning Area Zones for each municipality based upon developable land existing within each. Developable land was estimated from existing MODIV (tax assessment) data, and included both vacant and oversized lots, as defined by septic system densities, and excluded publicly owned lands. The septic system yield was then computed for each municipality by dividing calculated septic system density into the developable planning land area available for each Zone.

The total combined number of additional allowable septic units within the Protection and Conservation Zones of the Planning Area is 6,544.

However, in the Preservation Area, septic system yield will be implemented by NJDEP based on individual projects. Many lots have a mix of forested and non-forested lands, and therefore the total calculated septic system yield for the Preservation Area will likely be somewhat smaller due to the need for development yields of individual parcels to be rounded down. Additionally, the existence of exempt lots makes a total calculation of septic system yield problematic. Therefore, septic yields for the Preservation Area are not included in this report.

This document is organized as follows: first, the general policy issues and background which served as the basis for developing the water quality targets for various areas within the Highlands Region, as well as a brief technical overview of the modeling methodology used for computing appropriate septic system densities and corresponding well yields, are presented. Second, the well data, methodology, and results for computing the baseline regional median nitrate concentration are presented. Third, the logistic regression modeling methodology and associated data used for computing median nitrate concentrations at the subwatershed scale and regional scale, as well as the possible utilization of these models for estimating appropriate septic system densities, are presented. Fourth, the Trela-Douglas nitrate dilution model for estimating appropriate septic system densities is presented, with some discussion given to logistic regression-based methods that were also considered, are presented and finally, the methodology for computing the number of additional allowable septic systems per municipality per zone with the results, are presented.

HIGHLANDS COUNCIL APPROACH TO NITRATE BACKGROUND CONCENTRATION AND SEPTIC SYSTEM YIELD

ESTABLISHING APPROPRIATE PROTECTION STANDARDS

The Highlands Act includes a goal for the protection, enhancement and restoration of water quality. It then establishes specific regulatory approaches for the Preservation Area, including an objective of non-degradation for ground water regarding new septic systems, using dilution associated with "deep aquifer recharge" and allowing only standard septic system designs. This standard resulted in the 88 and 25 acre septic system densities for forested and non-forested Preservation Area lands, respectively, within the Highlands Preservation Area rules at N.J.A.C. 7:38. The Act does not provide specific approaches for the Planning Area.

Therefore, the most appropriate source of guidance regarding the requirement to "protect, enhance and restore" water quality comes from the New Jersey Water Quality Planning Act, which authorizes NJDEP to establish water quality standards for both ground and surface waters. The meaning of the three terms is important to understanding how the regulations work.

"Restore" is the simplest – where waters violate water quality standards, their quality must be improved to the point where they at least meet the water quality criteria established to protect designated water uses such as drinking water, fishing, swimming and ecosystems. The Highlands Region includes areas of both localized and wider scale contamination where restoration would be appropriate, ranging from the effects of intensive agriculture, to the impacts of communities with many septic systems on small lots, to areas of industrial contamination.

"Enhance" is also fairly clear but less used for regulatory purposes – it means improving water quality even where the waters currently meet all standards. The laws do not provide a direct mechanism for doing so, but some regulatory programs (e.g., uniform requirements for secondary treatment of sanitary sewage, industrial treatment standards, municipal stormwater permits) enhance water quality. Voluntary efforts (e.g., agricultural improvement cost-share programs, public education) or indirect efforts (e.g., where efforts to control one contaminant achieve improvements for a non-targeted contaminant) also enhance water quality.

"Protect" is the most variable in meaning, but is a critical focus of water pollution control programs. Existing regulations, case law and legislative history at both the state and federal level make clear that "protect" covers a wide range of policies, from natural quality (no non-natural pollutant loadings of any type) to nondegradation (no reduction in water quality from a baseline condition) to various levels of antidegradation (allowing some level of reduction in water quality but never beyond the water quality criteria and always controlled to protect public interests). What becomes clear from historic use is that "protect" refers to the protection of water <u>uses</u> ranging from highly sensitive ecosystems that tolerate no degradation, to other water uses that will tolerate some limited degradation under some situations.

Given that the Highlands Act clearly calls for the RMP to identify areas appropriate for new development, redevelopment or sustainable agricultural uses, application of one or more "antidegradation" policies will be more appropriate for those areas of the Highlands. Conversely, areas where no existing or future development will exist are appropriate for "natural quality" policies. Areas where water quality already violates water quality standards should be targeted for restoration, not further degradation. This standard does not necessarily prohibit any new pollutant loads (though it can), but rather might require mitigation or offsets of existing pollutant loads. <u>All</u> areas are appropriate for water quality enhancement where feasible within the goals and objectives of the Highlands Act, such as improved management of existing land uses and stormwater systems.

GENERALIZED APPROACH

The goals and objectives of the Highlands Act require protection of designated water uses (including both human and ecological uses) in all areas of the Highlands Region. Protection can range from natural quality to strict nondegradation to a range of antidegradation approaches. Restoration is for areas that violate standards, and enhancement is appropriate for areas where waters currently meet standards but can be improved through better land use management or pollution control practices.

The Highlands Council approach for protecting ground water quality through a septic systems analysis is summarized below. Additional discussion that serves as the basis for each topic follows.

- **Using Septic System Density -** Septic system density controls are useful for regional planning purposes but <u>do not</u> address site-specific or even neighborhood water quality issues. The risk of localized impacts is reduced as septic system densities are reduced, but risks will still exist due to site layout, local geological conditions, well construction, etc. Guidance to municipalities on these issues would be valuable in reducing site-specific risks. Septic system density is a useful indicator for the water quality impacts of development in areas that lack community sewer systems.
- **Selection of Nitrate as an Indicator Contaminant** - Nitrate concentration is a useful surrogate for the many pollutants discharged by properly functioning septic systems. Therefore, establishing existing nitrate concentrations is a critical step. It is important critical to note that addressing nitrates alone will not necessarily address the other related contaminants, requiring the use of conservative assumptions.

- **Types of Nitrate Targets** - Target nitrate concentrations should be used as the basis for septic system yields and tailored to each LUC Zone. The target nitrate concentration must recognize the legislative distinction between the Preservation and Planning Areas, and the distinct policies and standards of each LUC Zone.
- **Nitrate Dilution Modeling and Variables -** Nitrate dilution models, using appropriately conservative factors for nitrate loads, is selected as the basis for computing septic system densities.
- **Policy Options for Nitrate Targets** - The nitrate target for the Existing Community Zone in the Planning Area should recognize that the zone is where new development is most appropriate. Accordingly, it should reflect the protection standards associated with the zone and the state-wide WQMP standard. Recognizing that new development will be primarily served by public sewer, septic system densities should not affect existing areas served by public sewer or the approved expansion of those facilities. In the limited instances where septic systems are used, it will be used for infill or possibly redevelopment. There is an opportunity for water quality restoration through techniques like those implemented in a municipal Stormwater Pollution Prevention Plan. The nitrate target for the Conservation Zone in the Planning Area should recognize that existing nitrate concentrations are elevated in significant part by agricultural practices. There is an opportunity for water quality enhancement through more thorough implementation of agricultural best management practices (BMPs). The nitrate target for the Protection Zone in the Planning Area should recognize that existing low nitrate concentrations reflect minimal agriculture and development land uses. The impacts of additional development will be more difficult to offset through improvements to existing land management practices.

Rationale for Using Septic System Density

Septic system density is commonly used in New Jersey and elsewhere as a method of minimizing the potential for contamination of ground water. Discharges of effluent to ground water have the potential to damage the quality of aquifers, reducing their utility as drinking water supplies. They also can damage surface water quality, through the flow of contaminated ground water to natural discharge points as springs, seeps or stream base flow.

It should be noted that septic system density is one indicator of the potential for such impacts, but is not the sole cause of aquifer or stream contamination from discharges to ground water. Lawn and home care create the potential for nutrients (fertilizer) and pesticides (herbicides, insecticides and fungicides) to reach ground water. Agricultural applications have a similar potential. Finally, commercial or industrial discharges to ground water can include contaminants of concern. However, the commercial and industrial discharges are directly regulated by NJDEP, while the discharges of septic systems, lawn care and agricultural applications are not.

Septic system density is closely associated with lawns and homes, and so septic system density is a good indicator of the impacts of non-sewered residential development. Agricultural and sewered development impacts are not closely associated with septic systems, and therefore must be addressed as separate policies.

Selection of Nitrate as an Indicator Contaminant

Septic systems can discharge a wide range of contaminants to ground water, including bacteria, viruses, organic materials, household chemicals, pharmaceutical products, and various nutrients. The septic systems are designed to treat organic matter and bacteria, but not other contaminants that are less easily treated. NJDEP's septic system design standards are primarily focused on ensuring that septic system effluent does not clog the distribution box or disposal field, does not migrate to the land surface and cause a direct public health threat, and has sufficient contact time within the soil media to reduce bacterial pathogens. The standards also ensure that septic system disposal fields are at least 100 feet from any neighboring well.

The question is what contaminant to use as an indicator. NJDEP has determined through a variety of rules and rule proposals (including the Highlands Preservation Area Rules at N.J.A.C. 7:38) that nitrates are the best indicator to use for septic system density. Nitrates are stable in ground water, can travel long distances within the septic system plume, are a commonly measured contaminant with inexpensive analytical methods, and have been shown to have a good association with other contaminants (i.e., where the other contaminants are found, nitrate levels tend to be elevated above natural levels). Further, nitrate modeling has been used for decades at the municipal, county, regional and State level both in New Jersey and elsewhere. The Highlands Council also uses nitrates in the Highlands Regional Master Plan. It is important, though, to recognize that nitrates are used as an indicator, and are not the only contaminant of concern.

TYPES OF NITRATE TARGETS

Four types of nitrate targets (i.e., the target concentration that nitrate in the ground water should not exceed) were investigated for use in the RMP. One of them is inappropriate for regional planning efforts – site-specific fate and transport modeling, which is used for industrial discharge analysis and major remedial efforts. Two others were investigated and have not been proven as useable concepts – defining an allowable incremental change in concentration, and defining an allowable statistical change in concentration. Accordingly, the Highlands Council determined to use target nitrate concentrations at this time, with variations based on the LUC Zone involved.

Utilizing a target concentration is common in regulations such as NJDEP's Ground Water Quality Standards (N.J.A.C. 7:9C) and Water Quality Management Planning rules (N.J.A.C. 7:15), where a specific concentration is established as the maximum permissible level. For septic systems, this approach relies on mass balance equations such as nitrate dilution models. This method is useful because it treats all similar waters alike. It also can be used to define a maximum tolerable concentration. Subwatersheds that exceed the threshold can be targeted for enhancement. Given that the standards will apply to developable parcels, it should be noted that the median HUC14 nitrate levels, even in build-out conditions, generally would be less than the allowable concentration because some lands (e.g., preserved open space) will not have septic systems. The exception to this generalization will occur where existing septic systems are at much higher densities than the RMP anticipates for new development. The nitrate targets can be established based on medians by HUC14 subwatershed, LUC Zone, Planning or Preservation Area, or the entire Highlands Region.

NITRATE DILUTION MODELING

Ground water contaminants tend to move in plumes from their source to their discharge point in surface waters or wells. Plumes tend to be more concentrated if the contaminant source is localized or concentrated, the movement of ground water is less dispersive (causing less spreading of the contaminants away from the center of the plume), or the distance from the source to the discharge point is shorter.

Natural soil and subsurface conditions will result in some attenuation or treatment of ground water contaminants. The contaminants may be broken down into other substances by bacteria or chemical action, they may be bound to soil particles (adsorption) or drawn into organic or other matter (absorption), or they may move into the atmosphere through plants (transpiration) or evaporation.

These processes of plume movement and attenuation address the "fate and transport" of the contaminants. For major ground water contamination cases, such as Superfund or Spill Fund sites, enormous and expensive efforts go into mapping and modeling these processes to help predict the plume's potential impacts and determine what remedial approach may be most appropriate. However, the cost of monitoring or modeling the actual movement of septic system plumes at any level, from local to regional, is far beyond available funds. Therefore, simplified models are routinely used that make assumptions appropriate for determining allowable septic system densities. These models are all variations on a theme, but basically compare nitrate loadings to available dilution over a large area. The variations relate to the loading assumptions, the available dilution and the size of the area in question. Dilution cannot be directly measured, and therefore is estimated through the use of recharge analyses. However, it must be noted that such models cannot predict the actual nitrate concentrations at any one point, such as a downgradient well that may or may not be within the actual plume of a septic system. The nitrate dilution model approach was selected for septic system density calculations, based on specific nitrate targets. The major variables that are selected as inputs in the models, nitrate loadings and available dilution must also be carefully selected.

The pollutant loadings that are modeled in a nitrate dilution modeled will vary based on housing occupancy, the type of treatment technology, and system maintenance. Other loadings associated with residences will also vary based on lawn size, condition and chemical applications.

Loading assumptions require consideration of three major factors:

<u>Concentration and loading of nitrates emanating from septic systems</u> – In general, the literature supports the use of 10 pounds of nitrate generated per person per year, which is consistent with what NJDEP assumed in their calculations for the Preservation Area.

<u>Household size</u> – Given that regional models cover households of many different sizes, a single value is usually selected to represent average household size, with some models rounding up to a somewhat higher level to ensure that the septic system density will still be valid even if household size increases marginally. In addition, the use of a higher household size offsets the potential for nitrate loadings from other sources, such as lawn fertilizers, that may exist in the same area. The latter approach, at four persons per household, was used as in the NJDEP Highlands Rules. This approach is supported by findings in the *Highlands Regional Build Out Report* that average per household population in rural areas, where septic systems are more likely to be used, are significantly higher than either the regional average or the average in more developed areas.

<u>Other nitrate sources associated with the household</u> – Some models include lawn care contributions to the nitrate loadings, but others do not because (unlike nitrates from human sewage) such nitrate loadings can be changed by management approaches. NJDEP did not include other contributions explicitly, but did include a number of conservative assumptions that reduced the need to include a new contribution to the model, including the use of four persons per household, as discussed above. Conservative factors in the model should be used to account for these loadings. Educational programs and other management approaches should be used to reduce such loadings over time.

The second major factor, dilution, is critical to the model. Several alternatives can be considered in determining dilution for the model:

Scale of impact – Some ground water systems are small in scale, providing mostly base flow to headwaters streams and little recharge to significant aquifers. Others are very large, providing both stream base flow and major aquifer recharge. Smaller systems are much more sensitive to periodic changes in loadings and dilution. Dilution is critical to the use of nitrate dilution models. The Council determined that dilution should be based upon ground water recharge by HUC14 subwatershed. This is appropriate and feasible given technical analyses performed for the RMP, and the fact that other aspects of the RMP (e.g., water availability) are also based on HUC14 analyses.

Dilution from properties not using septic systems – Where used on a broad scale, such as a municipality or watershed, some models incorporate dilution from properties that may be in public ownership, sewered development, or otherwise protected from later development with septic systems. The development yields for septic systems should be based on privately-owned, undeveloped, non-preserved lands in septic system areas of the HUC14 subwatershed, for three reasons:

1) Public lands are often purchased for the purpose of environmental protection, and downgradient private property owners should not receive an equity benefit from that public expenditure.
2) Sewered development will still contribute ground water contaminants, including from more concentrated lawn care activities, and it is impossible to accurately measure that impact; and
3) Where the protected lands are agricultural, there is a significant potential for ground water contaminant loads that are not associated with septic systems.

Climate factors – Climate, as seen in annual precipitation patterns, has a direct impact on recharge potential. In New Jersey, the two most commonly used factors for climate have been annual average rainfall (used in the original NJGS GSR-32 method) and drought rainfall from the 1961-1966 drought of record (used in the NJDEP Highlands Preservation Area Rules). Drought recharge is used to estimate actual aquifer recharge, which cannot be directly measured. Annual average recharge includes shallow recharge that moves more quickly to surface waters, and does not ever enter deeper ground water systems (aquifers). The recharge from the 1960's drought is estimated at approximately two-thirds of the annual average recharge. The drought period was determined by an analysis of precipitation records, and is regarded as beginning on May 1961 (Jeffrey Hoffman, personal communication, 26 October 2007). The choice between these two climate factors is closely related to the scale of impact issue described above. A multi-year drought is likely to result in more concentrated septic system plumes in small ground water systems, where there is less potential for ground water storage from pre-drought periods. The Highlands Region, with its many headwaters, subwatersheds and hard rock formations with limited ground water storage capacity, will be more prone to such effects than, say, New Jersey's Coastal Plain watersheds. Most of the larger aquifers and watersheds are in areas served by public sewerage. NJDEP's septic system basis and background document for the Highlands Rules demonstrated that the GSR-32 method, when modified to incorporate climate factors based on 1960's drought conditions, provided recharge estimates that corresponded very well to another method (the Posten method) of estimating long-term (deep) aquifer recharge. The use of 2002 land use/land cover data is appropriate, as it is the most recent available and is also close to the 2004 adoption date of the Highlands Act. The area weighted regional average for drought ground water recharge based on 2002 land use/land cover is 9.4 inches/year.

POLICY OPTIONS FOR NITRATE TARGETS

There are many options and considerations for selecting nitrate targets, which in turn will affect the allowable or recommended septic system densities. The targets discussed here are constrained by scientific information. For instance, it is not feasible to set a nitrate target for septic systems that is lower than natural levels. Further, if an area is to have agricultural or developed land uses, natural levels cannot be maintained and therefore are not a feasible target; any introduction of contaminants to natural quality waters will elevate the average concentration above natural levels. As another example, it is not possible to have a standard for septic system density where no ground water may have a site-specific concentration greater than 10 mg/L, as septic system plumes routinely have much higher concentrations. However, given the constraints imposed by science and logic, there were several considerations:

Applicability – Thresholds have different purposes. The NJDEP Highlands Preservation Area Rules address site-by-site regulation of development, where each development has to meet the standards. The WQMP Rules, on the other hand, are focused on septic system density at the watershed level, with variations allowed for clustering and for different zoned densities within the broader area, as long as the average allowable density is not exceeded. The Highlands RMP septic system densities are more analogous to the WQMP rules. The default standard will provide average septic system densities for privately-owned, undeveloped, non-preserved portions of HUC14 subwatersheds, which may be apportioned within the target area through the municipal Plan Conformance process.

Nitrate Targets – Targets of natural water quality (no anthropogenic contaminants at all), nondegradation (no increase in contaminant concentration) and antidegradation (controlled allowance for a limited increase in contaminant concentration but not beyond water quality criteria) all could be applicable to parts of the Highlands Region. Antidegradation policies at the State, regional and local levels include:

- the Highlands Rules (N.J.A.C. 7:38) apply the regional median nitrate quality for forested or non-forested lands, weighted as appropriate to the development site in question, as the nitrate target for individual projects;
- the Pinelands CMP uses 2 mg/L for the Protection Area (which correlates to an minimum lot size of 3.2 acres) and a target of 0.17 mg/L for the Preservation Area, which correlates to an average lot size of 23 acres;
- the earlier (1993) Ground Water Quality Standards (N.J.A.C. 7:9C) antidegradation policy generally resulted in a nitrate target of 5.2 to 5.4 mg/L using a method devised for regulated point sources but applied to septic systems; it is applied as a municipal or sub-municipal average through either NJDEP or municipal rules;
- the Reality Improvement Act certification by NJDEP (for developments of 50 units or more), requires that each development meet 5.2 mg/L as an average;
- the revised (2008) Ground Water Quality Standards (N.J.A.C. 7:9C) and Water Quality Management Planning Rules (N.J.A.C. 7:15) both include a nitrate threshold of 2 mg/L to be applied either by project (GWQS) or by watershed (WQMP);
- The Water Quality Management Planning Rules (N.J.A.C. 7:15) includes a nitrate threshold of 10 mg/L to be applied to the developed portion of proposed cluster developments. Note that rule proposal requires that the full area of the cluster development (both the developed and preserved

lands) meet the 2 mg/L nitrate target.

The Highlands RMP should not allow a nitrate target greater than 2 mg/L (other than for clusters), for consistency with the NJDEP GWQS & WQMP rules. It should be noted that any introduction of new nitrate loadings, such as septic systems, into any area will increase the average concentration of nitrates unless mitigation or enhancement occurs within the target area. NJDEP's Highlands Preservation Area Rules allow for very limited additional septic systems on the assumption, among other things, that nitrate loadings from existing and past land uses are declining over time, resulting in an offset to minor additional loadings. It should be noted that a policy requiring that "new development not increase average nitrate concentrations" is a nondegradation policy – no new loadings would be allowed unless full mitigation is provided.

<u>Areal Scale of Threshold</u> – The standards can be applied at different areal scales, including HUC11 watershed (as in the WQMP Rules), the HUC14 subwatershed (using the USGS analyses), LUC Zone or municipality. Any of the multi-municipality scales could be disaggregated to the affected municipalities or zones. Given that the Highlands Council has performed other resource analyses at the HUC14 level, this scale is most appropriate for septic system densities, with further disaggregation as necessary. The HUC14 subwatershed analysis can be disaggregated to LUC Zone and then to municipality as needed.

<u>Mitigation Requirements</u> – As alluded to above, it may be appropriate to require that additional loadings in some areas be offset by reduced loadings within the same site or target area. A major issue is whether mitigation credits should be allowed for reduction of loadings from an illegal source or one that is not using best management practices. For instance, should the development of a poorly managed farm provide mitigation for the septic systems of a new development? The Council determined not to use this approach due to excessive uncertainty and complexity.

<u>Restoration</u> – USGS modeling indicates that the higher nitrate concentrations of HUC14 subwatersheds in the Conservation Zone are primarily related to agricultural land uses. Cooperative efforts in such subwatersheds will be critical in offsetting any increased impacts of development on septic systems. Other restoration opportunities may exist in lake communities and other dense developments using septic systems, where transition to community wastewater systems (e.g., Hopatcong Borough) would reduce loadings. The RMP encourages restoration through improved management practices, and that retrofit or elimination of densely placed septic systems are explored and implemented as feasible.

Given these considerations, the table below entitled Nitrate Dilution Targets for Various Areas within the Highlands Region summarizes the nitrate targets for various areas within the Highlands Region. These specific nitrate targets were established on the basis of water quality data and logistical regression modeling, which is discussed in more detail later in the document. Note that the Highlands Act specifically treats the Preservation Area and the Planning Area distinctly. While the delineation of the various LUC Zones in the Regional Master Plan is "blind to the line," the policies for septic system density must recognize that the two areas have different legislative requirements.

Nitrate Dilution Targets for Various Areas within the Highlands Region

Highlands Area/Zone	Nitrate Dilution Target (mg/L)*
Preservation Forested Area (NJDEP)	0.21
Preservation Non-Forested Area (NJDEP)	0.76
Planning Area Protection Zone	0.72
Planning Area Conservation Zone	1.87
Planning Area Existing Community Zone	2.0

**mg/L is milligrams per liter*

CHARACTERIZING REGIONAL AND SUBWATERSHED BACKGROUND NITRATE CONCENTRATIONS

In order to help characterize nitrate concentrations in ground water across the Highlands Region, a statistical analysis of water quality data collected in wells across the region was performed. The background median concentration of nitrate in ground water was estimated using available data for the Highlands related to well location, construction, water use, site use and water quality that were obtained from quality assured USGS databases. This analysis was also compared to a significantly more limited statistical analysis performed by the NJDEP for the Highlands Preservation Area, discussed later in more detail, which was different from the empirical-based logistic regression modeling subsequently undertaken to further characterize median nitrate concentrations at both the regional and subwatershed scales.

WELL SELECTION

Data comprised of well location, construction, water use and site use were obtained for this regional analysis from the National Water Information System (NWIS). Maintained by the United States Geological Survey ("USGS"), the NWIS is a storage and retrieval system of water data collected through its activities at approximately 1.5 million sites around the country. NWIS is comprised of the Ground Water Site Inventory (GWSI), the Automated Data Processing System (ADAPS), the Water Quality System (QWDATA) and the Site Specific Water Use Data System (SWUDS). Data related to water quality were obtained from QWDATA. Only water quality data that have been subjected to thorough quality assurance and approval for archiving in QWDATA under strict USGS guidelines were used in this analysis.

Well selection involved choosing an initial, representative subset of the 782 wells located in the Highlands Region that are part of the USGS monitoring network and have available quantitative nitrate data. An evaluation of specific well characteristics was performed to determine the extent to which the data from these 782 wells were representative of land use and water quality conditions and therefore, appropriate for inclusion in the modeling. The evaluation was designed to identify well clusters, and the confined or unconfined nature of the wells from which samples were drawn. This was done to limit the number of wells with overlapping buffer zones, as well as those developed in confined aquifer units, as inclusion of data from either would not be representative of actual influences on water quality from nitrate loadings. For example, the use of data from one or more wells clustered around a known contaminated site would provide a false impression of overall ground water quality, potentially skewing the data in one direction. Use of data from confined wells (that are unlikely to be affected to the same extent as unconfined wells by introduction of contamination at the ground surface or shallow subsurface) could skew the data in another direction.

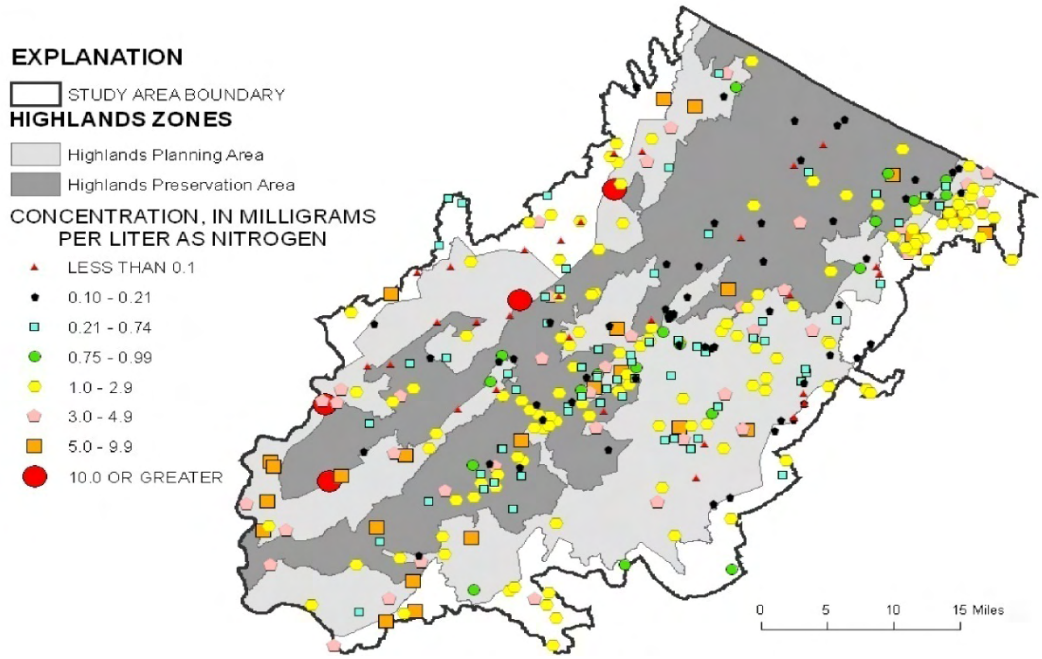
In addition, a homogeneous distribution of wells throughout the study area is desirable in order to avoid geographical bias and multiple counting of well recharge areas. Therefore, a subset of wells was created in which substantial overlap of 500-meter radius buffer areas surrounding each well was minimized. Following an analysis of the 782 wells, which was designed to limit the overlapping buffer zones and exclude wells developed in confined aquifer units and an evaluation of well characteristics and land use patterns; only data from a subset of 352 wells were considered appropriate for use and therefore were retained for the analysis.

WATER QUALITY DATA

Nitrate is analytically quantified as nitrate plus nitrite, in milligrams per liter nitrogen (mg/L NO_3+NO_2-N). Nitrite is quantified separately, and nitrate concentration is calculated as the difference between mg/L NO_3+NO_2-N and mg/L NO_2-N. Nitrite was detected in only 11 samples from the 352 well set, at a median concentration of less than 0.01 mg/L as nitrogen, and always constituted less than 10% of the NO_3+NO_2-N concentration. Therefore, in this report, "mg/L NO_3+NO_2-N" is essentially synonymous with "nitrate concentration" (mg/L NO_3-N).

A summary of the concentrations of nitrate detected in ground water samples is shown in the figure *Nitrite plus Nitrate in Highlands Region Ground Water (U.S.G.S).* The previously displayed figure *Median Nitrate Concentrations by HUC14* illustrates HUC14-specific nitrate concentration values across the Highlands Region. Few samples contained more than 10 mg/L NO_3+NO_2-N, which is the health effect based drinking water standard or maximum contaminant level (MCL). The analysis indicates that higher concentrations of nitrate appear to be more prevalent in areas with substantial agricultural activities, as well as in highly urbanized areas of the Highlands.

Nitrite plus Nitrate in Highlands Region Ground Water (U.S.G.S.)



Minimum concentration reporting limits for the data included in this analysis vary and depended upon the date of the analysis, with more recent analyses tending to have lower reporting or detection limits, as is generally the case due to continuing improvements in analytical techniques. The highest minimum reporting limit was 0.1 mg/L. Therefore, all reported nitrate concentration values that are less than 0.1 mg/L NO3+NO2-N (e.g., 0.05 mg/L) are assigned a value of "less than 0.1 mg/L" to account for this variation in reporting limits.

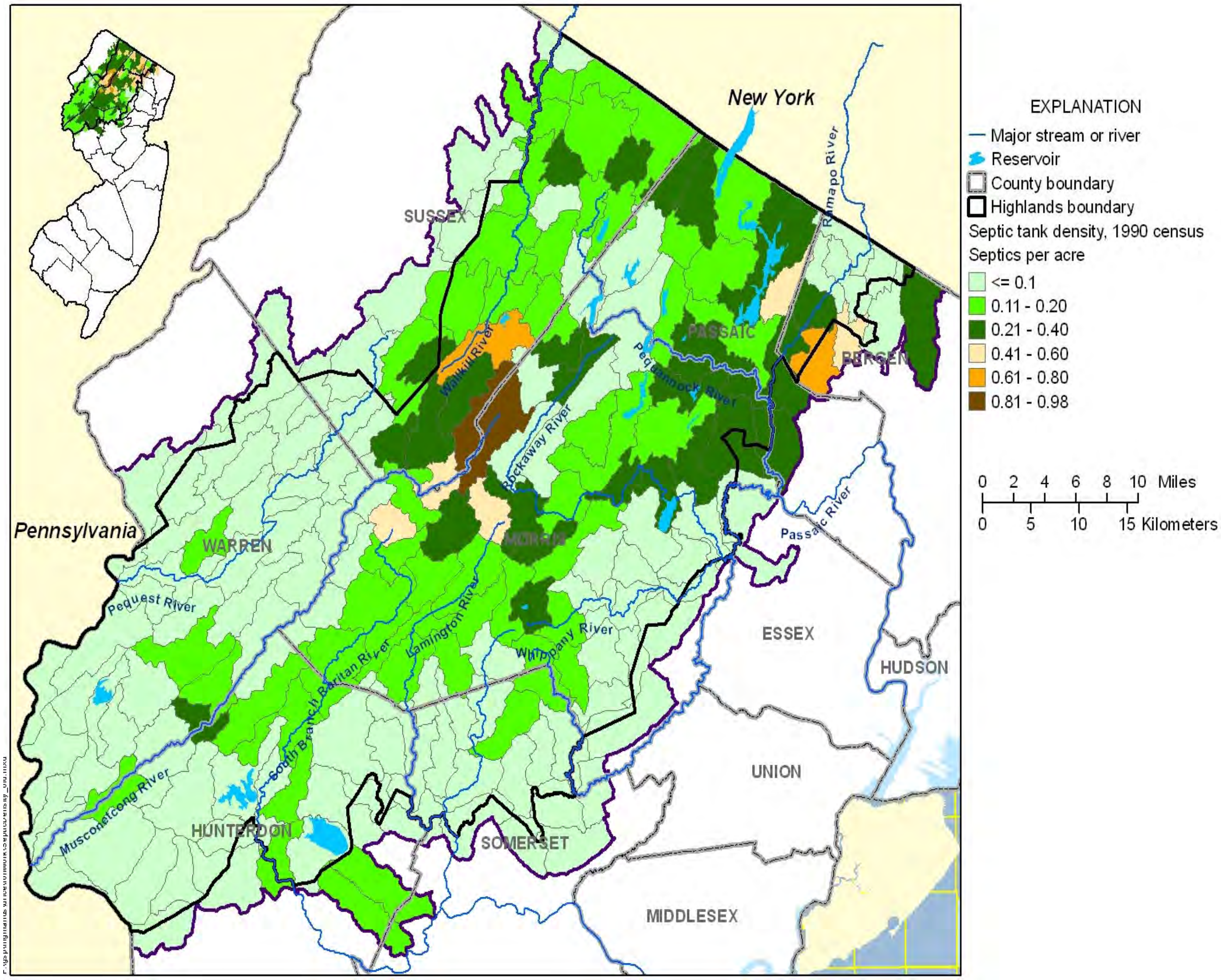
STATISTICAL ANALYTICAL RESULTS OF MEASURED NITRATE CONCENTRATION

The median concentration from measured analysis of water samples from 352 wells throughout the Highlands Region was 1.1 mg/L nitrate as nitrogen. This value is relatively consistent with a 0.76 mg/L median reported by the NJ Geological Survey, which they estimated with 45 water samples collected from non-carbonate bedrock of northern New Jersey, discussed later. By comparison, the logistic regression modeling, presented in more detail later, yielded a 0.83 mg/L median nitrate concentration for the entire Highlands Region. The 1.1 mg/L value is believed to be biased towards higher nitrate concentration areas, as wells tend to be located in or near urban, agricultural, and septic system land use areas, and not in the forested or otherwise undeveloped areas of the Highlands Region.

ANALYSIS OF EXISTING SEPTIC SYSTEM DENSITY

Because septic systems are significant contributors of nitrate in ground water, an analysis of the existing septic system density within the Highlands Region was performed. Septic system density as determined from 1990 census data, the last year that septic system information was reported in the United States census, is shown in the figure *Septic System Density in HUC14 Basins, from 1990 Census Data of the New Jersey Highlands.*

Septic System Density in HUC14 Basins, from 1990 Census Data of the New Jersey Highlands

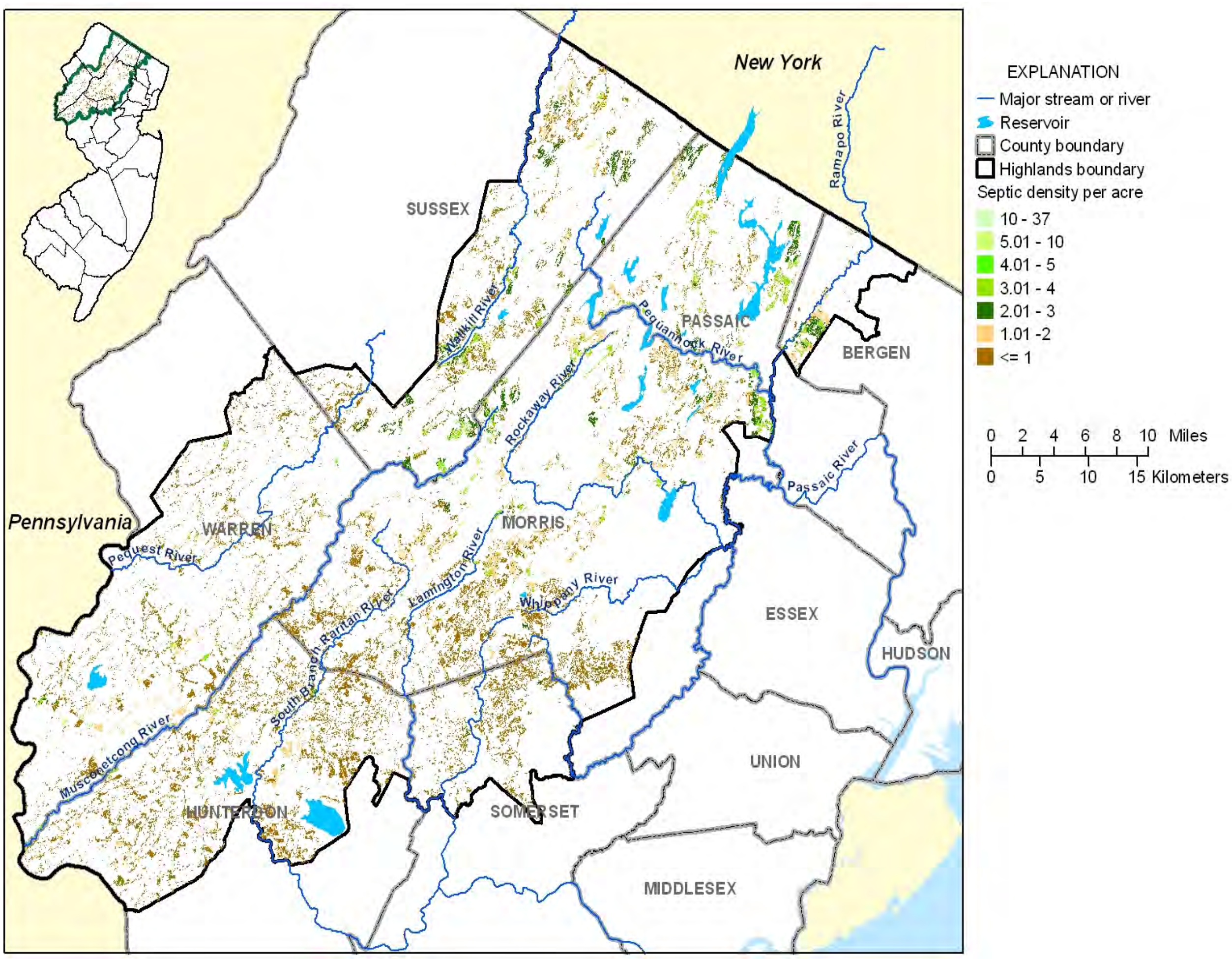


This figure shows that by 1990, the great majority of the Highlands Region had a density of less than one to one septic system per acre.

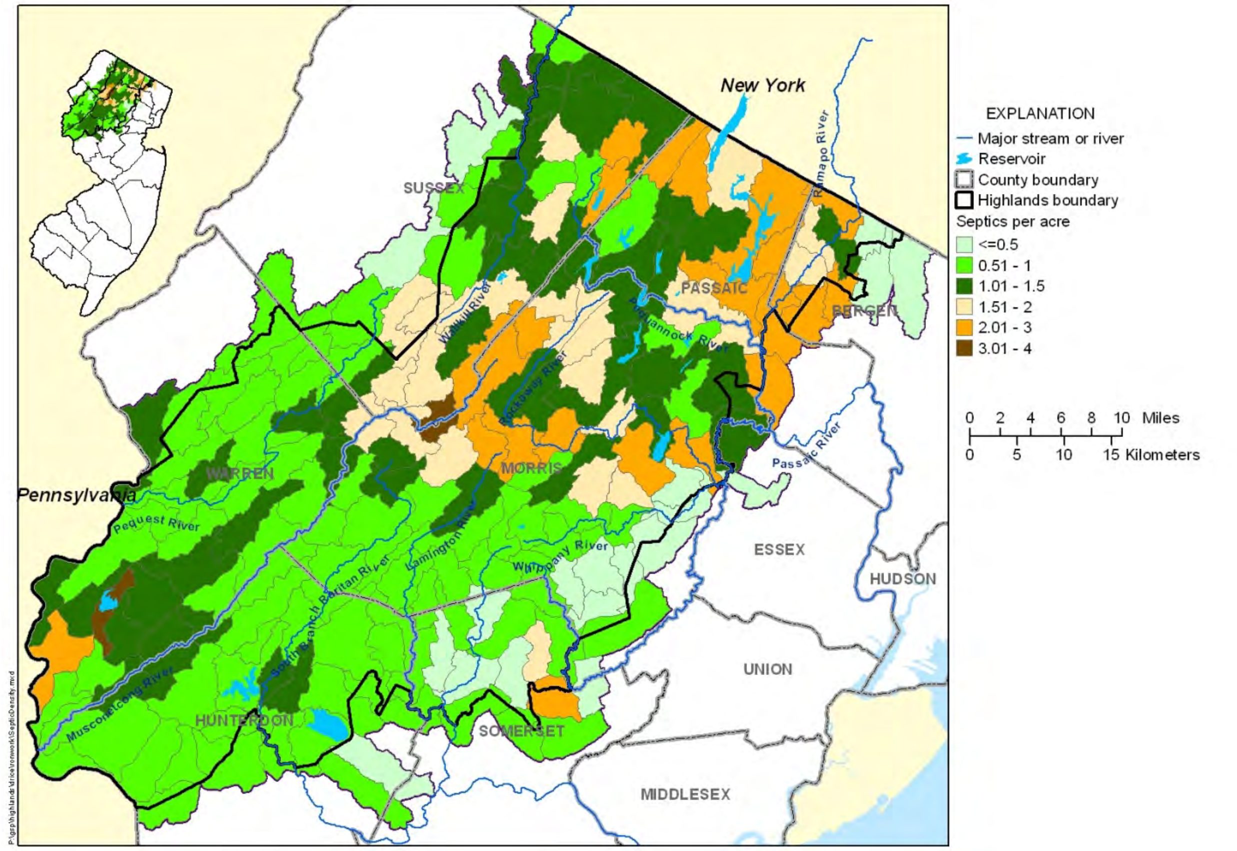
There were some areas with as few as 0.1 septic systems per acre, mostly in undeveloped areas, but this also occurred in areas of higher density development where it is likely that much of the census block was already served by public sewer. The highest septic system densities are in the central, eastern and northeastern areas that were more urbanized, yet had significant areas that had not yet been provided with sewer service in 1990. One exaggeration to this general pattern is the area surrounding Lake Hopatcong, where septic system systems were installed on small lots as the norm during the process of local residential development. Due to the deleterious impacts of this historic practice on lake water quality, this area is currently in the process of being sewered. Septic system density for non-sewered residential areas in the Highlands Region is shown in the figure. The 1990 census information was updated using 2000 census data and dasymetric mapping techniques that allow for the finer resolution in determining where septic systems may be in use, based on remote land use data indicating where residential land use occurs and information developed regarding the location of non-sewered areas. The assumption is that a house without sewer service indicates the location of a septic system to accommodate the need for wastewater treatment. This combination of data was used to refine the 1990 census block-based septic system density mapping.

Septic system density as determined using this method is shown in the figure *Septic System Density in Non-Sewered Residential Areas of the Highlands Region, from 2000 Census Data Dasymetric Mapping of the New Jersey Highlands* The related figure *Septic System Density in HUC14 Basins, from 2000 Census Data Dasymetric Mapping of the New Jersey Highlands*, also generated from *U.S. Census 2000 Data,* shows the number of septic systems per HUC14, but only accounts for the non-sewered areas and expresses that density as if it applied to the entire HUC14, which is not actually the case. The density shown in this figure does not normalize the data over the entire HUC14. It simply illustrates the data for the non-sewered areas. While this allows for analysis of the use of individual systems on a subwatershed scale, the difference between the dasymetric-derived data, which can be considered spatially "concentrated", versus expressing the data as an overall value for the entire HUC 14 must be clearly understood. The septic system density shown is not assumed to be evenly distributed over the entire land area of the subwatershed.

Septic System Density in Non-Sewered Residential Areas of the Highlands Region, from 2000 Census Data Dasymetric Mapping of the New Jersey Highlands



Septic System Density in HUC14 Basins, from 2000 Census Data Dasymetric Mapping of the New Jersey Highlands



Normalization of the data is an additional, necessary step for data analysis and modeling. Normalization techniques allow one to "compare apples and oranges" and adjust map values to express the data in a way that is useful for the analysis in question. While the descriptive statistics are different, the numeric and spatial relationships in the data are preserved during normalization.

Looking at the figure generated from the dasymetric mapping, it appears that in 2000, most of the Highlands Region had an increased septic system density compared to 1990, with values ranging from less than one to four septic systems per acre. This increase likely reflects a few factors, beyond the more accurate distribution allowed for by the dasymetric mapping and normalization issue discussed above. Among them are an overall increase in development across the Region and residences being built in less urbanized areas that are likely to be non-sewered. This pattern is a consequence of where available land was located and homebuyers' preferences. The net result is that while there was a demonstrated increase in septic system density, it is not likely to be as great in reality as a comparison of the data for 1990 and 2000 would initially indicate.

While these discrepancies due to the lag time in acquiring data and analytical techniques are acknowledged, the Highlands Council used the most recent and reliable data available to perform theses analyses. The Council also intends to refine the information as better information becomes available or can be developed, and to develop more refined logistic regression models.

DETERMINING SUB-WATERSHED NITRATE CONCENTRATIONS IN GROUND WATER WITH LOGISTIC REGRESSION MODELING

The statistical approach of calculating the median nitrate concentration from measured well data is an appropriate method for characterizing water quality at a regional scale. However, the median value calculated with the water quality data is biased by the well locations, which are disproportionately located in more developed areas subject to higher nitrate concentrations. Furthermore, this type of analysis, while important, is limited for estimating median nitrate concentrations at the smaller subwatershed scale, or for quantifying and understanding how concentrations change with different land use conditions.

In order to overcome these limitations, an empirical-based logistic regression modeling approach was used to estimate median nitrate concentrations at the subwatershed scale based upon measurable land use characteristics and conditions. In addition, the models were used to estimate the median nitrate concentration for the Highlands Region as a whole, as well as pristine conditions prior to land development. The models also helped identify land use variables that influence and/or are correlated with nitrate concentrations in ground water.

MULTIVARIATE LOGISTIC REGRESSION MODELS

Empirical-based models use a set of input or explanatory variables for estimating an output variable(s) of interest through a derived mathematical function. These models often provide insights into the inter-relationships between the input and output variables, increasing the conceptual understanding of the system of interest. Although parametric statistical methods such as Pearson's "r" correlation coefficient and analysis of variance (ANOVA) can be used to determine if significant relationships exist between variables, they are generally not appropriate for analyzing untransformed hydrologic and water quality data, as these data tend to be non-normally distributed and have large percentages of outliers (Helsel and Hirsch, 2002).

Therefore, more appropriate non-parametric statistical methods, including univariate and multivariate regression analytical methods, were used for modeling median nitrate concentrations in ground water. A step-wise logistic regression, multivariate statistical approach can help identify cause and effect relationships between the input or explanatory and output variable(s); in this case, variables that are correlated with and/or influence the occurrence of elevated nitrate concentrations in ground water. Logistic regression as a probabilistic technique may identify relations when other methods do not, because it answers a simpler question - namely if a particular well is likely to have a concentration greater than a specified target value - not what that value might be, as is the case in traditional regression analysis.

This logistic regression analysis is similar to methods performed in previous similar studies, where logistic models were used to relate land use and other explanatory variables to nitrate concentrations. See Eckhardt and Stackelberg, 1995; Tesoriero and Voss, 1997; Nolan, Greene and others, 2004. A comprehensive discussion of logistic regression can be found in Helsel & Hirsch, 2002.

MATHEMATICAL BASIS OF LOGISTIC REGRESSION

The logistic regression models, developed from water quality and land use/land cover data, use a set of input or explanatory variables to estimate the probability that a target nitrate concentration is exceeded. Mathematically, the logistic relation is:

$$ln\ (p/\ (1\text{-}p)) = a + bY + cZ\ldots \qquad (1)$$

where p is the probability of the event occurring, a, b, c… are empirically determined coefficients, and Y, Z… are values of the independent or explanatory variables.

For example, the probability of nitrate exceeding a target concentration of 10 mg/L, which is the health-based Maximum Contaminant Level (MCL) of nitrate allowed in drinking water, could be calculated as a function of the set of explanatory variables (e.g., septic system density, percent urban and agricultural land use).

The coefficient values are determined by applying a "best fit" optimization algorithm to existing data. Identifying the best fit model involves identifying the logistic regression model that is best able to estimate the probability of exceeding the target concentration as a function of the explanatory variables. The best fit model can then be used to predict the probability of exceeding the target nitrate concentration where values of the variables are known.

The logistic regression modeling approach is more comprehensive than simple parametric or non-parametric regression analysis, but is still merely an effort to correlate known values of a set of explanatory variables to known values of a dependent variable (nitrate concentration). This differs from a mechanistic model, where, for example, the effect of additional urban development on ground water recharge could be related to the vertical transport of nitrate. However, the availability of extensive and detailed land use and water quality data allows for logistic model development with powerful predictive capabilities, while the lack of sufficiently detailed hydrogeologic, soil, recharge and nitrate attenuation data are obstacles to the development of useful mechanistic models.

LAND USE DATA FOR LOGISTIC REGRESSION MODELS

A relational database was assembled containing 320 anthropogenic and naturally-occurring variables related to land use, population, septic system density, well construction, soil characteristics and water quality. The database was populated with the values of these variables within a 500-meter radius buffer surrounding wells included in a water quality monitoring network in the Highlands. Results of graphical and statistical analyses identified the variables related to nitrate concentration at a statistically significant level. The 352 wells used in the previously described statistical analysis provided the water quality data for the logistic regression models.

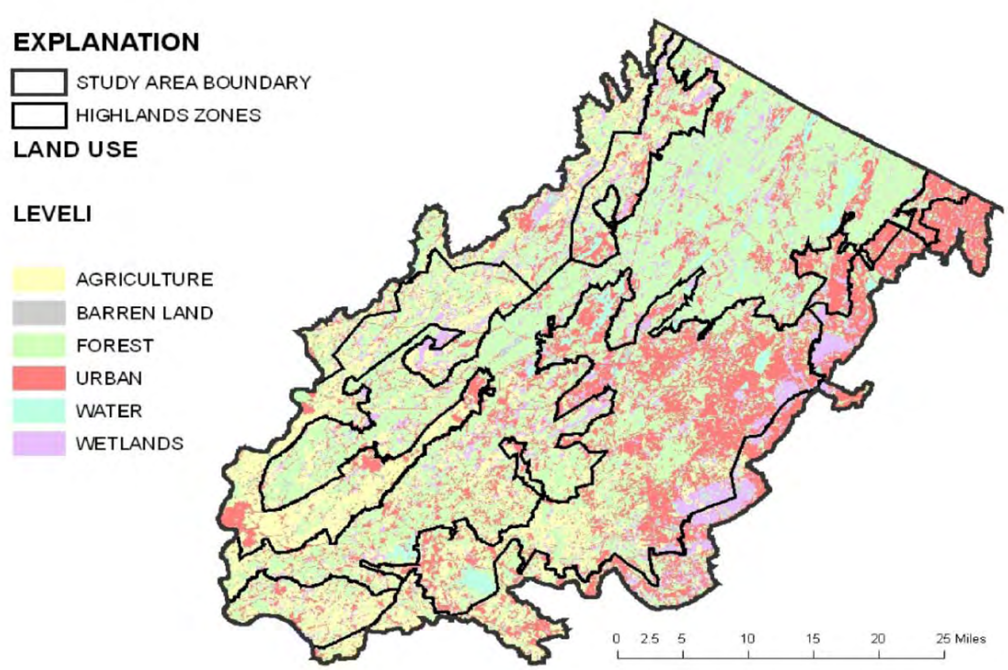
A geographic information system computer application (GIS) was used to associate land use patterns with specific well locations. Land use and other spatial data were obtained from USGS archives and from other government entities, including the New Jersey Departments of Environmental Protection (NJDEP) and Transportation (NJDOT). A statistical analysis application (S-Plus) was used to conduct regressions and hypothesis testing, discussed in more detail later.

Land use categories, as defined by the Anderson system (Anderson et al.) were obtained for three years, 1986, 1995 and 2002 for the Highlands Region using NJDEP data sets. The spatial distribution of land use data in the Highlands for 1986 and 2002 is shown in the figure *1986 Anderson Level 1 Land Use in the Highlands Region* and the figure *2002 Anderson Level 1 Land Use in the Highlands Region*, respectively). Explanatory land use variables and specific features were determined for 500-meter radius circular buffers around each well for undeveloped areas and for the Highlands Region as a whole using the actual data included in the GIS coverage, clipped to include only the data for the well buffer area being evaluated. Applying the explanatory variables determined using buffer areas, median concentrations were then calculated for the larger area of each HUC14 subwatershed in the Highlands.

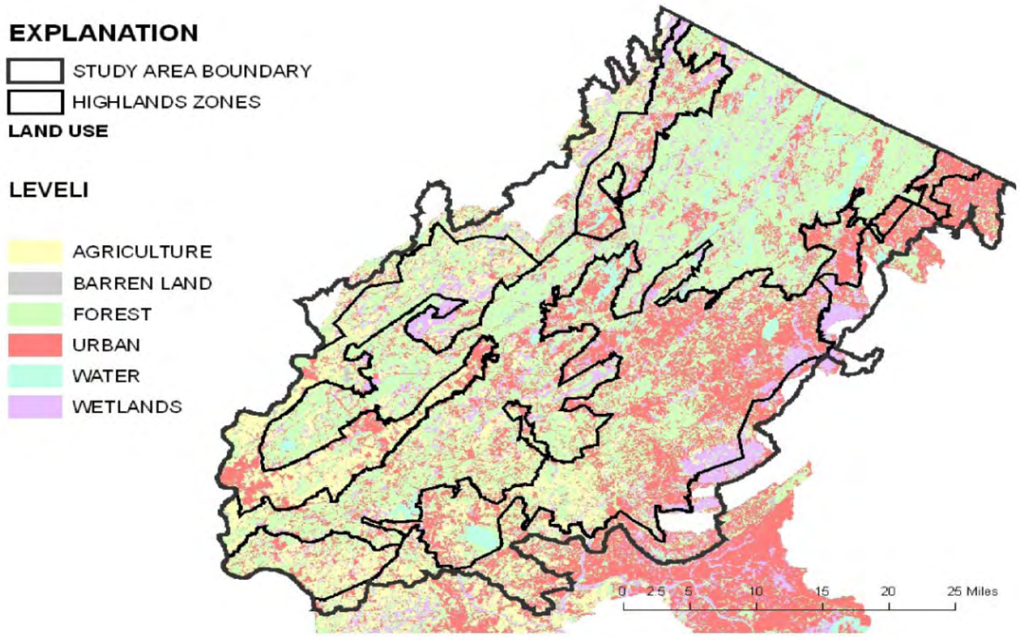
Percentage-based variables (i.e., percent of agricultural land use) were aggregated from land use polygons; distance variables were defined as the shortest distance from the well to a feature or land use type; and number variables were defined as the total number of a specific type of feature (e.g., sewage treatment plants) within the area of interest. Road length, surface hydrology, contaminant and discharge locations, soil characteristics, population and septic system density were also considered as possible variables to determine nitrate concentrations in ground water in the Highlands. The septic system density from 1990 census data was updated using 2000 census data and dasymetric mapping techniques that provides the spatial distribution of where septic systems are in use.

Circular well buffers are widely used in spatial ground water quality investigations. The 500-meter radius was selected based on an evaluation of previous studies by Koterba 1998, which suggested that the best compromise for defining land use characteristics around monitoring wells in a wide variety of hydrogeologic settings across the nation would be a circular buffer with a 500-meter radius from the well.

1986 Anderson Level 1 Land Use in the Highlands Region



2002 Anderson Level 1 Land Use in the Highlands Region



The alternative "sector method" uses potentiometric surface maps to estimate average flow direction, combined with a ground water flow model to estimate maximum length of the contributing area to the monitoring well within an upgradient sector. This may more accurately represent the contributing area around each well, largely by not including land area not contributing recharge to the well. Similarity between the two methods would be 70-80%, based on a comparison by Lorenz and others, 2003. However, contributing area models (i.e. wellhead protection area delineations) have been applied only to public water supply wells in New Jersey, and the wells in the data set do not all have such delineations. Consequently, the sector method was not a feasible alternative.

In completing the analysis, all percentage-based variables (i.e., percent of agricultural or other types of land use) were aggregated from land area polygons either within the well buffer or HUC14-based areas of interest. Distance variables were defined as the shortest distance from the well to a feature or land use type. Number variables were defined as the total number of a specific type of feature (e.g., sewage treatment plants) within the well buffer or individual HUC14 subwatersheds.

Other land use information and specific feature data were also obtained, providing additional factors to be considered regarding roads, railroads, recreational areas, surface hydrology, contaminant and discharge locations, soil characteristics, population and septic system density. As stated earlier, all of these spatially-defined data types were statistically evaluated as possible variables to help explain the variability of nitrate concentrations in ground water in the Highlands.

This 1990 information updated using 2000 census data and dasymetric mapping techniques that allow for the finer resolution of where septic systems are actually in use were used in the modeling. Use of the 2000 data and refined mapping technique allowed the Council to more accurately reflect septic system locations on the ground.

CORRELATION ANALYSIS WITH SPEARMAN'S RANK

In order to help identify potentially important explanatory variables for inclusion in the logistic regression models, a correlation analysis was first performed. This analysis is an efficient method for estimating the relative predictive powers of potential explanatory variables, as well as determining whether they are positively or negatively correlated with nitrate concentrations in ground water.

Spearman's rank correlation coefficient (rho or ϱ) is a commonly used statistic calculated from the ranks of data values (Zar, 1974) to assess whether there is a statistically significant relationship between two variables (e.g., nitrate concentration and urban land use). Each independent variable is evaluated separately by putting the values of the variables in order and ranking them.

The correlation coefficient or rho value will be between -1 and +1. A value near zero indicates no linear relationship between the ranks of data being analyzed. The one-tail probability value must be less than 0.05 to indicate a significant correlation between the data sets. It should be noted that correlation does not mean that there is necessarily a cause and effect relationship between correlated variables, but provides an indication of the likelihood that they are related.

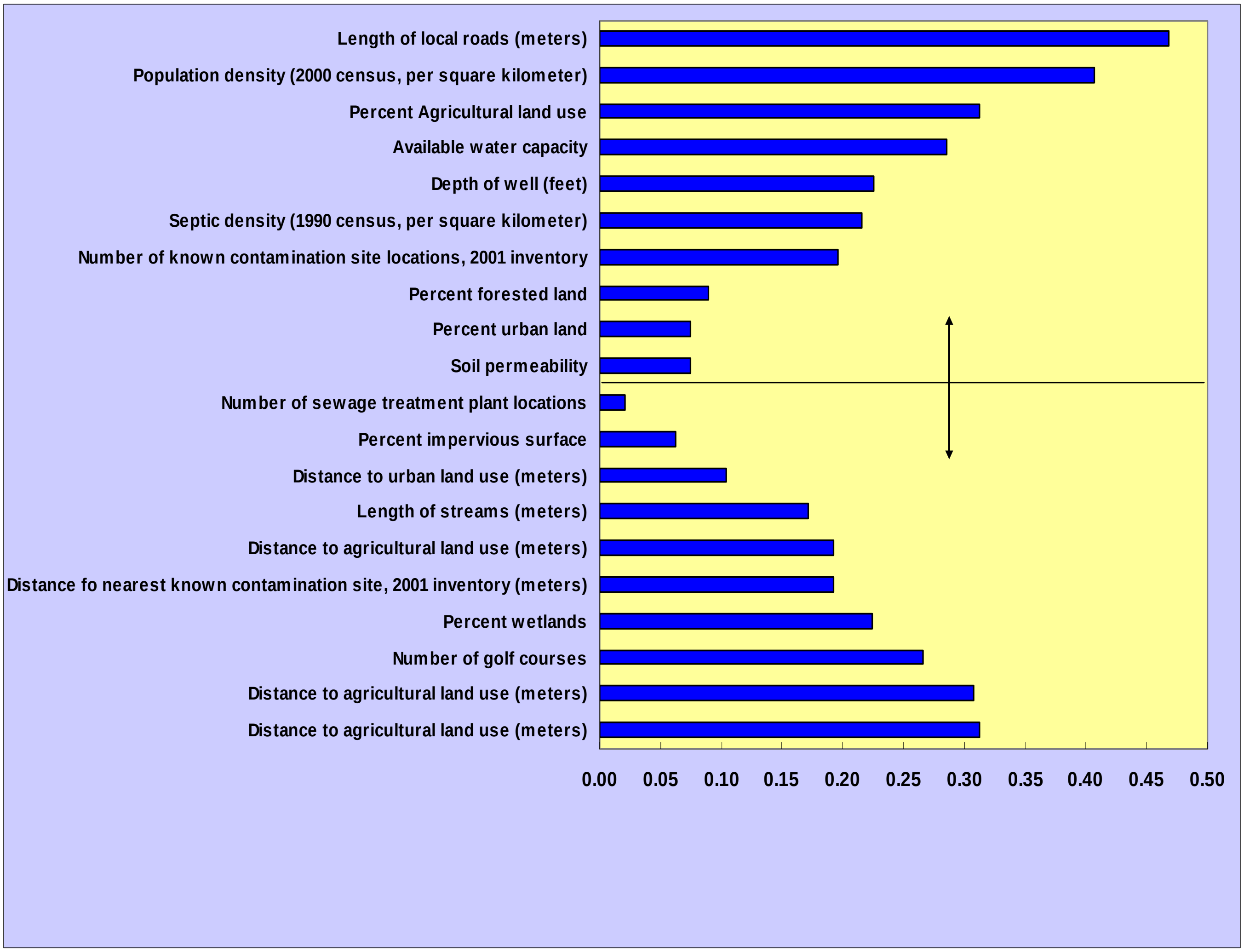
Spearman's rho was calculated between each of 320 assembled variables and nitrate concentrations for the 352 well set used in these analyses. This enabled the evaluation of each variable as a predictor of nitrate concentration in ground water.

No single variable was expected to, nor did one completely explain nitrate concentration variability, but the relative magnitude of the individual rho values provided guidance for the selection of variables appropriate for use in the subsequent multivariate models that were performed. This step-wise process did provide assurance that the relative importance of any of the variables examined in determining nitrate concentrations was understood.

The results of this analysis indicate that the variables related to urban development, such as proximity to and percent of residential, commercial and total urban land use, population and septic system density were all determined to be significantly and positively related to nitrate concentrations detected in ground water (i.e. an increase in one is related to an increase in nitrate). Variables related to agricultural land use are also significant and positively correlated with nitrate concentrations. Accordingly, an increase in distance from these land use features results in a decrease in nitrate concentrations. The rho values for land use variables for which data are available for multiple years are similar, indicating that the significance of these variables and their usefulness in multivariate models persists, influencing nitrate concentrations in the same manner over time.

The figure *Examples of Spearman's rho Values for Nitrate Concentration in Ground Water Samples and Potential Explanatory (Independent) Variables* illustrates the correlations found between several explanatory variables and nitrate concentrations.

Examples of Spearman's rho Values for Nitrate Concentration in Ground Water Samples and Potential Explanatory (Independent) Variables



In reviewing the figure, it should be noted that values of rho near zero are least predictive, while those closer to the ends of the range, either -1 or +1, are more predictive, being either negatively or positively correlated. In addition, the rho value is not an absolute measure of how predictive the variable may in a logistic regression model; some variables may have insignificant rho values, but can be significant in one or more multivariate models. Some of these variables were carried forward and used in the multivariate modeling because they are known to be related to nitrate concentrations in water. In proceeding to the next step, selecting sets of variables for use in the multivariate models, it was important to avoid using sets of variables that contain the same information, or co-vary, with respect to nitrate concentrations. For example, it would be redundant to include percent urban land use and population density in the same model, as they tend to increase in value together. Based on an evaluation of the co-variance, or collinearity of the variables and their statistical significance, as identified using Spearman's rho values in the univariate modeling, a subset of the 320 assembled variables was carried forward into the multivariate model described below.

LOGISTIC REGRESSION MODEL DEVELOPMENT

The relationships between land use, other anthropogenic and naturally-occurring variables and the occurrence of elevated nitrate concentrations were first examined using correlation analysis as discussed above, and then extended with logistic regression modeling. Correlation analysis helped identify potentially important explanatory variables for inclusion in different logistic regression models, and also provides a means of assessing the logistic modeling results. However, correlation analysis only considers a simple relation between a single potential explanatory variable with the prediction variable of interest (e.g. percentage of urban cover with nitrate concentrations), while multivariable logistic regression models consist of multiple explanatory variables, and hence, their combined predictive powers can only be assessed through development and validation of these models.

Logistic regression models provide a probability that a well will contain nitrate concentrations greater than a specific value, thereby identifying which areas have a higher probability of contamination. It also predicts how and if median nitrate concentrations change over time in response to changing land use conditions. The investigative method used does not directly consider known effects of changing land use, such as changes in dilution and recharge rates due to additional impervious surface contributed by urbanization, or plant uptake of nutrients. However, the effects of such changes are encompassed to some degree within the variables that are examined (e.g., ground water nitrate concentrations, land use percentages) and therefore these effects are indirectly taken into account.

Given that to test all potential variations of all 320 variables would have involved approximately three trillion combinations, the reduction in variables based on their relevance in predicting nitrate concentrations was both necessary and appropriate. Models were developed using 1, 2, 3, 4 and 5 variables. All 320 variables were tested in simple univariate modeling to directly assess their potential for accurately predicting nitrate concentrations in ground water. This step-wise logistic regression process was repeated to obtain the optimum three-, four- and five- explanatory variable set models. Selection of sets of explanatory variables for the final models is a partially subjective process, guided in part by a conceptual understanding of the physical system, partially enhanced by the correlation and regression analyses, as well as the overall ability of a model to fit the data and the significance of each variable in the model. The significance of these models was tested to determine how well the sets of explanatory variables correlate with increases in nitrate concentration.

"Reasonableness" of each variable must also be considered in model development. For example, length of roads emerged as a strong variable in many logistic models. Transportation variables are likely to be related to other characteristics of urbanization, such as population density, percent urban land use and features such as known contamination sites and sewage treatment plants. However, length of roads has no logical, direct link to nitrate contamination. Therefore, a variable more closely related to nitrate contamination, such as percent urban land, may be selected, even if its statistical significance is slightly lower. Inclusion of collinear variables should also be minimized. For example, length of roads and population density would not be used in the same model, because they are related to nitrate concentration for the same underlying reason, namely the extent of urban development.

In the logistic regression model development algorithm, the contributions of co-varying or collinear variables are "shared", not "double counted". This allows for the selection of variables with some collinearity, such as septic system density and percent urban land use, as not all urban use includes the installation and use of septic systems, and not all septic systems are installed in urban areas. Logistic models using only spatial (e.g., land use and septic system density) variables, and not incorporating variables such as length of streams and known contaminated sites, were also developed and are termed "land use models" in this analysis.

LOGISTIC REGRESSION MODEL VALIDATION

Model validation is necessary to test the robustness of the different models using different subsets of the data. The appropriateness of selected variables and the overall ability of the logistic regression models to correctly predict nitrate concentrations were assessed by using established statistical procedures, including the Wald statistic as presented by Greene and others, 2004, and the t statistic. These statistical analyses were also used to determine the significance of individual model parameters.

The Wald statistic is used to identify significant variables by comparing correlated proportions, allowing the step-wise elimination of variables until only statistically significant variables remain. It is defined as:

$$W = (\beta i / \text{ (standard error of } \beta i))^2 \qquad (2)$$

For i = 0, 1, 2…k where βi are the model parameters (intercept and coefficients), critical values of W are equivalent to chi square values with one degree of freedom (3.841 for $\alpha = 0.05$).

Rejection of a variable based on the Wald statistic value can occur if the parameter either is small or has little effect on model calculations. It can also occur if the standard error of the parameter is large and including the parameter is likely to have a detrimental effect on the model's predictive capability.

The t value is an accepted statistic used for evaluating the significance of each variable in a logistic regression model, and is calculated as the value of that variable's regression coefficient divided by its standard error. This is not to be confused with the t-test, a parametric test for comparing two populations of subsets or a single population. The t value is strictly based on the parameter's significance in the model, and generally for sample sizes like those used in this analysis, t values greater than 2.0 are significant at the $\alpha = 0.05$ level.

These criteria were used as guidelines for selecting model variables. Many models were developed and run on an iterative basis to address a full range of values from 0.1 to 5.0 mg/L nitrate, land use data from three time periods and several combinations of other variables. For example, a value of 0.1 mg/L may have been combined with land use data from 2002, a specific septic system density and percent impervious cover in one model run.

Values of t were calculated for each variable in each model. Models that included insignificant t values were rerun without those variables. Wald statistic values were less informative for rejecting variables; intercepts in some models had insignificant W values, but in all cases this occurred because the value (not the standard error) of the intercept was low.

Overall goodness-of-fit for each model was assessed by using a regression procedure developed by Nolan and others. Here, the probability of exceeding the target value is calculated for each well and sorted in ascending order. The sorted list is divided into as many as 10 segments, and the predicted probability of exceeding the target value is then compared to the observed fraction of wells where the nitrate concentration exceeded the target value. A high correlation coefficient indicates a good fit between the calculated (modeled) and observed values.

The PRESS statistic (SAS Institute, 1990) was adapted for use in logistic regression by Greene and others, and was used to assess the predictive abilities of the models. In this test, the fraction of outcomes that are correctly predicted is determined. The calculated probability of exceeding the target value is converted to 1 if greater than 0.5, and to 0 if less than 0.5. The fraction of outcomes that match the converted probability is the PRESS statistic value, which based on the conversion process, varies between 0 and 1. Values significantly greater than 0.5 indicate a good predictive ability of the model. Values near 0.5 indicate either poor predictive value or that a large fraction of the data sample has a near 50% probability of exceeding the target value.

In the models used in this analysis, PRESS statistic values were mostly greater than 0.7, with lower values observed for models where the target value was close to the median nitrate concentration. Models with target values that differed substantially from the median nitrate value had much higher PRESS values (often greater than 0.9), indicating an even better predictive ability. Therefore, the PRESS statistic results are consistent with a high level of predictive value in the logistic models used.

The effect of outliers in logistic regression is different for the dependent variable (nitrate concentration) than for the independent (explanatory) variables. The dependent variable is coded as a binary distribution, in this case greater than or less than a target concentration. Extremely high or non-detect values of nitrate would not receive more or less weight than other values. Therefore, outliers of nitrate concentration have no effect on the model. Conversely, outliers among the explanatory variables would affect the model in ways similar to the effect seen in other best-fit regression models. The distributions of each of the explanatory variables (e.g., urban and agricultural land use, number of known contamination sites, length of streams and septic system density) were examined and none of them has a substantial number of outliers. The large data sets used in all models would also reduce the effect of any outliers. Therefore, the effect of outliers appears to be minimal for all models developed here.

ESTIMATION OF MEDIAN NITRATE CONCENTRATIONS FROM LOGISTIC REGRESSION MODELS

Logistic regression models are used to predict a discrete outcome from a set of variables. Equation 1 expresses the odds ratio "ln (p/ (1-p))" as a linear function of the explanatory variables (e.g., percent of agricultural land use, septic system density). A value exceeding the median nitrate concentration from a set of samples has a 50% probability of occurring in a randomly selected sample (p=0.5). Therefore, the natural log of the odds ratio is equal to zero when the target value is equal to the median value of the dependent variable (i.e. nitrate concentration):

$$\ln (0.5/\ (1-0.5)) = \ln (1) = 0 \qquad (3)$$

The median nitrate concentration can be determined by identifying a model such that p=0.5 when known values of the explanatory variables are input. This was done by constructing logistic models for all possible target nitrate values between 0.1 and 5.0 mg/L NO3-N and the selected explanatory variables (percent agricultural and urban land use, septic system density, total length of streams and number of known contaminated sites). Models with probabilities close to 0.5 are based on target values close to the median nitrate concentration. The two models with probabilities just over and just under 0.5 (M1 and M2) are identified, and the median nitrate concentration is calculated as the linear interpolation between the target values of M1 and M2:

$$Median\ [NO_3\text{-}N] = (T_{M1})\ (p_{M2}\text{-}0.5) /\ (p_{M2}\text{-}\ p_{M1}) + (T_{M2})\ (0.5\text{-}p_{M1}) /\ (p_{M2}\text{-}\ p_{M1}) \qquad (4)$$

Where:

T_{M1} is the target nitrate concentration of model 1
T_{M2} is the target nitrate concentration of model 2
p_{M1} is the probability of a nitrate concentration exceeding the target value of Model 1
p_{M2} is the probability of a nitrate concentration exceeding the target value of Model 2

This procedure was done for each HUC14, providing a median nitrate concentration value for each. The median nitrate concentration for the Highlands as a whole is defined as the median of all median nitrate concentrations among HUC14s. The table HUC14 Specific Median Nitrate Concentration in Ground Water (2002) indicate median nitrate concentrations within the 183 HUC14s included in the Highlands ranged from 0.17 to 3.6 mg/L. This variability reflects the effects of varying amounts of developed lands and associated factors on nitrate concentration in ground water in the different HUC14 areas. The median value for the Highlands as a whole is 0.83 mg/L.

The median nitrate concentrations for undeveloped land were obtained by setting the urban and agricultural land use and septic system density to zero in the model and repeating the process described above. Median nitrate values for undeveloped land throughout the Highlands of 0.12 - 0.14 mg/L were obtained for the models. This method, which used data from 352 wells, provides a more representative median value than would be obtained from the nitrate concentration of the limited values available for undeveloped areas.

HUC14 Specific Median Nitrate Concentration in Ground Water (2002)

HUC14	Subwatershed Name	WMA	Septic Density	Urban Land-Use Percent	Ag Land-Use Percent	Streams	Known Contaminated Sites	Nitrate Concentration
02020007010010	Wallkill R/Lake Mohawk(above Sparta Sta)	02	151.70	30.48	0.98	2,226.69	0.50	0.84
02020007010020	Wallkill R (Ogdensburg to SpartaStation)	02	48.14	19.69	1.75	2,200.43	0.38	0.43
02020007010030	Franklin Pond Creek	02	25.63	10.99	0.08	3,280.39	0.34	0.25
02020007010040	Wallkill R(Hamburg SW Bdy to Ogdensburg)	02	24.78	24.02	12.03	2,055.85	0.41	0.70
02020007010050	Hardistonville tribs	02	12.52	15.30	4.14	2,688.29	0.11	0.34
02020007010060	Beaver Run	02	13.50	10.08	26.64	2,723.36	0.05	0.89
02020007010070	Wallkill R(Martins Rd to Hamburg SW Bdy)	02	34.82	25.72	10.42	2,491.19	0.40	0.70
02020007020070	Papakating Creek (below Pellettown)	02	20.64	13.54	24.83	3,099.94	0.02	0.91
02020007030010	Wallkill R(41d13m30s to Martins Road)	02	33.50	18.41	18.95	3,087.93	0.17	0.83
02020007030030	Wallkill River(Owens gage to 41d13m30s)	02	35.64	10.38	13.11	2,330.60	-	0.48
02020007030040	Wallkill River(stateline to Owens gage)	02	18.70	7.29	15.05	3,442.26	0.05	0.42
02020007040010	Black Ck(above/incl G.Gorge Resort trib)	02	50.58	27.00	3.82	2,991.07	0.17	0.56
02020007040020	Black Creek (below G. Gorge Resort trib)	02	46.05	22.34	7.79	3,201.29	0.26	0.57
02020007040030	Pochuck Ck/Glenwood Lk & northern trib	02	43.49	18.94	9.32	3,505.03	0.05	0.49
02020007040040	Highland Lake/Wawayanda Lake	02	57.48	23.92	-	2,007.65	0.59	0.48
02020007040050	Wawayanda Creek & tribs	02	29.19	6.75	5.76	2,631.61	0.15	0.30
02020007040060	Long House Creek/Upper Greenwood Lake	02	84.06	17.14	0.05	2,402.97	0.15	0.41
02030103010010	Passaic R Upr (above Osborn Mills)	06	25.16	39.39	7.53	3,247.57	0.15	0.83
02030103010020	Primrose Brook	06	28.72	29.59	6.51	3,334.19	0.12	0.62
02030103010030	Great Brook (above Green Village Rd)	06	21.22	47.57	12.69	2,959.04	0.23	1.29
02030103010040	Loantaka Brook	06	15.64	51.19	6.38	2,756.66	0.30	1.04
02030103010050	Great Brook (below Green Village Rd)	06	19.71	20.55	9.77	4,042.37	0.06	0.47
02030103010060	Black Brook (Great Swamp NWR)	06	13.53	26.11	2.66	3,097.22	0.21	0.44
02030103010070	Passaic R Upr (Dead R to Osborn Mills)	06	9.28	47.02	4.21	3,951.10	0.55	0.79
02030103010080	Dead River (above Harrisons Brook)	06	12.18	42.93	7.41	2,941.91	0.08	0.87
02030103010090	Harrisons Brook	06	9.79	72.02	1.48	3,067.28	0.72	1.42
02030103010100	Dead River (below Harrisons Brook)	06	19.65	41.72	1.87	3,090.82	0.43	0.69
02030103010110	Passaic R Upr (Plainfield Rd to Dead R)	06	15.09	37.09	3.77	3,759.13	0.73	0.65
02030103010180	Passaic R Upr (Pine Bk br to Rockaway)	06	2.13	63.25	0.17	3,514.32	0.97	0.98
02030103020010	Whippany R (above road at 74d 33m)	06	62.09	36.76	1.36	2,332.52	0.20	0.71
02030103020020	Whippany R (Wash. Valley Rd to 74d 33m)	06	34.47	29.31	3.12	3,014.44	0.05	0.52
02030103020030	Greystone / Watnong Mtn tribs	06	16.42	53.61	2.43	3,134.53	0.31	0.92
02030103020040	Whippany R(Lk Pocahontas to Wash Val Rd)	06	20.00	62.33	0.81	2,770.59	0.70	1.17
02030103020050	Whippany R (Malapardis to Lk Pocahontas)	06	12.91	70.62	1.19	2,132.54	2.53	1.40
02030103020060	Malapardis Brook	06	3.08	66.91	0.11	2,434.19	0.95	1.22
02030103020070	Black Brook (Hanover)	06	3.73	66.29	-	3,072.72	0.73	1.15
02030103020080	Troy Brook (above Reynolds Ave)	06	6.13	65.71	0.06	2,327.08	1.12	1.18
02030103020090	Troy Brook (below Reynolds Ave)	06	2.82	34.20	0.21	4,878.64	0.55	0.44
02030103020100	Whippany R (Rockaway R to Malapardis Bk)	06	1.73	66.05	-	2,753.14	1.46	1.10
02030103030010	Russia Brook (above Milton)	06	25.81	16.11	0.02	2,897.08	0.14	0.31
02030103030020	Russia Brook (below Milton)	06	80.88	28.13	1.79	3,338.03	0.25	0.60
02030103030030	Rockaway R (above Longwood Lake outlet)	06	62.18	25.78	0.48	3,158.54	0.23	0.47
02030103030040	Rockaway R (Stephens Bk to Longwood Lk)	06	21.94	9.35	0.26	2,303.86	0.08	0.26
02030103030050	Green Pond Brook (above Burnt Meadow Bk)	06	17.20	10.58	0.40	2,831.59	0.12	0.25
02030103030060	Green Pond Brook (below Burnt Meadow Bk)	06	20.02	27.59	0.03	3,706.13	0.31	0.40
02030103030070	Rockaway R (74d 33m 30s to Stephens Bk)	06	63.13	48.41	0.31	2,443.80	1.23	0.87
02030103030080	Mill Brook (Morris Co)	06	57.71	49.53	0.87	2,801.65	0.81	0.90
02030103030090	Rockaway R (BM 534 brdg to 74d 33m 30s)	06	27.11	68.52	0.11	1,613.30	2.57	1.38

HUC14 Specific Median Nitrate Concentration in Ground Water (2002)

HUC14	Subwatershed Name	WMA	Septic Density	Urban Land-Use Percent	Ag Land-Use Percent	Streams	Known Contaminated Sites	Nitrate Concentration
02020007010010	Wallkill R/Lake Mohawk(above Sparta Sta)	02	151.70	30.48	0.98	2,226.69	0.50	0.84
02030103030100	Hibernia Brook	06	35.74	13.86	0.14	3,115.15	0.38	0.30
02030103030110	Beaver Brook (Morris County)	06	35.59	19.30	0.25	2,915.97	0.43	0.37
02030103030120	Den Brook	06	33.31	51.63	1.41	2,583.58	0.74	0.89
02030103030130	Stony Brook (Boonton)	06	44.24	21.31	2.22	3,185.28	0.15	0.41
02030103030140	Rockaway R (Stony Brook to BM 534 brdg)	06	96.33	45.20	3.51	4,466.67	0.63	1.03
02030103030150	Rockaway R (Boonton dam to Stony Brook)	06	49.71	38.74	0.28	2,646.82	0.84	0.70
02030103030160	Montville tribs.	06	51.07	42.32	0.36	3,570.35	0.50	0.72
02030103030170	Rockaway R (Passaic R to Boonton dam)	06	18.45	65.06	1.40	3,657.62	1.59	1.19
02030103040010	Passaic R Upr (Pompton R to Pine Bk)	06	12.25	34.47	0.60	5,515.24	0.87	0.46
02030103050010	Pequannock R (above Stockholm/Vernon Rd)	03	35.45	2.69	0.09	2,056.65	-	0.24
02030103050020	Pacock Brook	03	34.80	2.03	-	2,484.63	0.04	0.22
02030103050030	Pequannock R (above OakRidge Res outlet)	03	22.34	6.19	0.09	2,520.17	0.09	0.23
02030103050040	Clinton Reservior/Mossmans Brook	03	13.79	1.80	0.11	2,616.40	-	0.17
02030103050050	Pequannock R (Charlotteburg to OakRidge)	03	17.29	11.73	1.10	2,507.37	0.20	0.28
02030103050060	Pequannock R(Macopin gage to Charl'brg)	03	42.35	14.71	0.74	3,386.38	0.19	0.32
02030103050070	Stone House Brook	03	58.34	35.97	0.11	2,645.54	0.79	0.68
02030103050080	Pequannock R (below Macopin gage)	03	72.59	35.80	0.28	3,666.26	0.75	0.68
02030103070010	Belcher Creek (above Pinecliff Lake)	03	37.41	22.48	0.63	2,677.73	0.22	0.41
02030103070020	Belcher Creek (Pinecliff Lake & below)	03	67.36	17.98	1.23	2,976.82	0.64	0.42
02030103070030	Wanaque R/Greenwood Lk(aboveMonks gage)	03	26.31	9.13	0.15	2,854.81	0.21	0.25
02030103070040	West Brook/Burnt Meadow Brook	03	34.05	17.17	0.51	3,133.89	0.15	0.33
02030103070050	Wanaque Reservior (below Monks gage)	03	55.11	11.22	0.06	3,350.04	0.23	0.30
02030103070060	Meadow Brook/High Mountain Brook	03	101.86	35.82	0.09	3,551.62	0.51	0.74
02030103070070	Wanaque R/Posts Bk (below reservior)	03	43.47	22.18	0.41	3,808.28	0.56	0.39
02030103100010	Ramapo R (above 74d 11m 00s)	03	8.82	23.18	0.70	1,989.56	0.42	0.41
02030103100020	Masonicus Brook	03	21.93	76.84	0.77	2,467.02	1.33	1.53
02030103100030	Ramapo R (above Fyke Bk to 74d 11m 00s)	03	13.48	31.34	0.02	3,944.06	0.18	0.42
02030103100040	Ramapo R (Bear Swamp Bk thru Fyke Bk)	03	11.13	8.54	1.16	3,135.17	-	0.21
02030103100050	Ramapo R (Crystal Lk br to BearSwamp Bk)	03	58.63	21.35	0.48	4,066.86	0.10	0.38
02030103100060	Crystal Lake/Pond Brook	03	173.53	67.54	0.27	2,877.71	0.63	2.35
02030103100070	Ramapo R (below Crystal Lake bridge)	03	51.03	42.91	0.69	3,724.54	0.54	0.74
02030103110010	Lincoln Park tribs (Pompton River)	03	63.70	44.83	2.72	3,315.45	0.32	0.89
02030103110020	Pompton River	03	78.18	69.42	0.08	3,453.15	1.09	1.59
02030103140010	Hohokus Bk (above Godwin Ave)	04	101.93	64.86	1.64	2,793.17	0.51	1.72
02030103140020	Hohokus Bk(Pennington Ave to Godwin Ave)	04	23.75	78.90	0.60	3,396.95	1.10	1.59
02030103140040	Saddle River (above Rt 17)	04	97.80	73.34	1.24	3,562.51	0.87	1.88
02030105010010	Drakes Brook (above Eyland Ave)	08	53.01	41.48	1.90	1,905.18	0.56	0.79
02030105010020	Drakes Brook (below Eyland Ave)	08	33.13	44.53	9.51	2,133.50	0.25	1.12
02030105010030	Raritan River SB(above Rt 46)	08	108.73	35.01	1.10	1,917.99	0.84	0.80
02030105010040	Raritan River SB(74d 44m 15s to Rt 46)	08	39.25	25.52	13.87	2,010.70	0.14	0.85
02030105010050	Raritan R SB(LongValley br to 74d44m15s)	08	31.23	30.35	12.06	2,191.94	0.10	0.85
02030105010060	Raritan R SB(Califon br to Long Valley)	08	30.59	19.84	25.86	1,662.45	0.08	1.17
02030105010070	Raritan R SB(StoneMill gage to Califon)	08	39.65	25.21	10.62	2,541.79	0.19	0.70
02030105010080	Raritan R SB(Spruce Run-StoneMill gage)	08	24.30	47.20	4.88	3,120.92	0.59	0.89
02030105020010	Spruce Run (above Glen Gardner)	08	33.71	21.11	19.96	1,938.17	0.07	0.95
02030105020020	Spruce Run (Reservior to Glen Gardner)	08	28.64	16.29	16.63	2,905.25	0.38	0.68
02030105020030	Mulhockaway Creek	08	23.09	23.60	17.11	3,385.58	0.19	0.83

HUC14 Specific Median Nitrate Concentration in Ground Water (2002)

HUC14	Subwatershed Name	WMA	Septic Density	Urban Land-Use Percent	Ag Land-Use Percent	Streams	Known Contaminated Sites	Nitrate Concentration
02020007010010	Wallkill R/Lake Mohawk(above Sparta Sta)	02	151.70	30.48	0.98	2,226.69	0.50	0.84
02030105020040	Spruce Run Reservior / Willoughby Brook	08	20.82	20.98	11.70	2,679.49	0.22	0.62
02030105020050	Beaver Brook (Clinton)	08	25.96	32.80	29.06	2,648.59	0.35	1.74
02030105020060	Cakepoulin Creek	08	17.93	20.62	48.90	2,842.32	0.15	2.74
02030105020070	Raritan R SB(River Rd to Spruce Run)	08	17.97	31.34	27.15	3,767.93	0.11	1.53
02030105020080	Raritan R SB(Prescott Bk to River Rd)	08	36.65	30.43	25.87	3,528.73	0.12	1.55
02030105020090	Prescott Brook / Round Valley Reservior	08	21.85	15.10	11.71	1,993.88	0.05	0.50
02030105040020	Pleasant Run	08	28.22	37.04	29.15	3,172.95	0.03	1.90
02030105040030	Holland Brook	08	31.82	43.99	21.02	3,125.40	0.15	1.72
02030105050010	Lamington R (above Rt 10)	08	106.34	35.73	1.35	1,394.26	1.06	0.82
02030105050020	Lamington R (Hillside Rd to Rt 10)	08	41.75	34.87	3.65	3,299.92	0.82	0.69
02030105050030	Lamington R (Furnace Rd to Hillside Rd)	08	39.21	31.55	13.24	2,266.08	0.40	0.94
02030105050040	Lamington R(Pottersville gage-FurnaceRd)	08	28.15	17.96	21.34	2,564.37	0.17	0.91
02030105050050	Pottersville trib (Lamington River)	08	20.67	10.78	20.67	3,429.14	0.06	0.63
02030105050060	Cold Brook	08	13.79	14.82	46.75	2,790.45	0.15	1.98
02030105050070	Lamington R(HallsBrRd-Pottersville gage)	08	15.25	16.50	32.67	3,146.06	0.09	1.24
02030105050080	Rockaway Ck (above McCrea Mills)	08	23.72	24.61	23.76	2,995.39	0.09	1.10
02030105050090	Rockaway Ck (RockawaySB to McCrea Mills)	08	16.70	30.98	14.82	3,544.10	0.12	0.89
02030105050100	Rockaway Ck SB	08	24.07	35.99	17.89	3,199.21	0.47	1.17
02030105050110	Lamington R (below Halls Bridge Rd)	08	12.32	18.34	30.27	2,907.49	0.04	1.20
02030105060010	Raritan R NB (above/incl India Bk)	08	47.26	42.48	4.22	2,511.21	0.36	0.86
02030105060020	Burnett Brook (above Old Mill Rd)	08	41.30	40.89	4.56	2,949.76	0.23	0.82
02030105060030	Raritan R NB(incl McVickers to India Bk)	08	19.22	32.09	11.56	3,128.44	0.08	0.81
02030105060040	Raritan R NB(Peapack Bk to McVickers Bk)	08	17.55	20.34	18.14	3,575.64	0.04	0.76
02030105060050	Peapack Brook (above/incl Gladstone Bk)	08	31.61	37.91	11.65	2,845.68	0.60	0.97
02030105060060	Peapack Brook (below Gladstone Brook)	08	12.24	33.40	20.40	3,250.61	0.36	1.15
02030105060070	Raritan R NB(incl Mine Bk to Peapack Bk)	08	24.93	41.39	11.16	3,327.46	0.54	1.00
02030105060080	Middle Brook (NB Raritan River)	08	10.86	15.54	47.56	3,495.74	0.09	2.03
02030105060090	Raritan R NB (Lamington R to Mine Bk)	08	11.16	28.89	29.79	2,875.31	0.17	1.57
02030105070010	Raritan R NB (Rt 28 to Lamington R)	08	8.96	44.88	15.84	3,160.63	0.13	1.29
02030105120050	Middle Brook EB	09	23.32	52.98	2.53	2,455.65	0.35	0.95
02030105120060	Middle Brook WB	09	8.65	40.20	5.43	2,373.83	0.19	0.74
02040105040040	Lafayette Swamp tribs	01	14.36	11.58	24.72	2,486.71	-	0.86
02040105040050	Sparta Junction tribs	01	28.31	20.69	16.55	2,058.09	0.23	0.79
02040105040060	Paulins Kill (above Rt 15)	01	21.49	31.27	14.98	3,386.22	0.77	0.90
02040105050010	Paulins Kill (Blairstown to Stillwater)	01	13.96	10.61	19.91	2,392.57	0.08	0.63
02040105060020	Delawanna Creek (incl UDRV)	01	16.16	13.34	30.50	2,482.07	0.07	1.08
02040105070010	Lake Lenape trib	01	65.08	24.75	1.42	2,811.26	0.23	0.48
02040105070020	New Wawayanda Lake/Andover Pond trib	01	41.63	18.34	8.82	2,591.10	0.21	0.52
02040105070030	Pequest River (above Brighton)	01	18.88	14.10	19.83	2,162.64	0.11	0.72
02040105070040	Pequest River (Trout Brook to Brighton)	01	15.41	16.26	33.97	2,332.04	0.04	1.36
02040105070050	Trout Brook/Lake Tranquility	01	21.11	10.99	14.38	3,226.11	0.06	0.46
02040105070060	Pequest R (below Bear Swamp to Trout Bk)	01	9.74	14.64	12.87	5,659.35	0.10	0.36
02040105080010	Bear Brook (Sussex/Warren Co)	01	15.86	13.31	28.71	2,334.44	-	1.02
02040105080020	Bear Creek	01	9.36	8.43	20.82	2,743.21	0.11	0.60
02040105090010	Pequest R (Drag Strip--below Bear Swamp)	01	17.28	8.79	9.52	2,608.40	0.06	0.36
02040105090020	Pequest R (Cemetary Road to Drag Strip)	01	18.52	16.85	20.30	1,374.25	0.08	0.84
02040105090030	Pequest R (Furnace Bk to Cemetary Road)	01	16.06	12.16	13.30	2,417.70	0.04	0.47

HUC14 Specific Median Nitrate Concentration in Ground Water (2002)								
HUC14	Subwatershed Name	WMA	Septic Density	Urban Land-Use Percent	Ag Land-Use Percent	Streams	Known Contaminated Sites	Nitrate Concentration
02020007010010	Wallkill R/Lake Mohawk(above Sparta Sta)	02	151.70	30.48	0.98	2,226.69	0.50	0.84
02040105090040	Mountain Lake Brook	01	38.82	15.46	6.56	2,338.77	-	0.43
02040105090050	Furnace Brook	01	15.02	16.10	8.90	2,772.99	0.24	0.44
02040105090060	Pequest R (below Furnace Brook)	01	18.52	21.23	23.18	2,109.01	0.40	1.00
02040105100010	Union Church trib	01	13.44	8.47	19.22	2,106.28	0.11	0.59
02040105100020	Honey Run	01	14.53	13.09	30.91	2,573.17	-	1.08
02040105100030	Beaver Brook (above Hope Village)	01	15.94	15.00	26.10	1,833.13	0.07	0.98
02040105100040	Beaver Brook (below Hope Village)	01	16.05	7.65	39.13	3,222.27	0.03	1.27
02040105110010	Pophandusing Brook	01	13.71	18.55	37.61	2,255.67	0.11	1.72
02040105110020	Buckhorn Creek (incl UDRV)	01	15.82	11.21	39.80	2,186.98	0.08	1.60
02040105110030	UDRV tribs (Rt 22 to Buckhorn Ck)	01	16.50	20.65	43.63	1,426.92	0.27	2.01
02040105120010	Lopatcong Creek (above Rt 57)	01	16.76	22.06	27.94	1,873.64	0.12	1.26
02040105120020	Lopatcong Creek (below Rt 57) incl UDRV	01	13.96	45.41	34.01	1,142.24	0.53	2.66
02040105140010	Pohatcong Creek (above Rt 31)	01	16.69	10.57	17.00	2,192.74	0.06	0.56
02040105140020	Pohatcong Ck (Brass Castle Ck to Rt 31)	01	29.34	29.83	15.16	2,987.22	0.41	0.92
02040105140030	Pohatcong Ck (Edison Rd-Brass Castle Ck)	01	17.70	13.03	38.91	2,971.37	0.08	1.60
02040105140040	Merrill Creek	01	19.02	11.64	22.29	3,161.11	-	0.71
02040105140050	Pohatcong Ck (Merrill Ck to Edison Rd)	01	17.24	10.15	45.84	2,806.94	0.04	1.87
02040105140060	Pohatcong Ck (Springtown to Merrill Ck)	01	20.30	23.08	53.48	2,214.20	0.05	3.08
02040105140070	Pohatcong Ck(below Springtown) incl UDRV	01	13.81	18.32	40.67	1,734.02	0.21	1.84
02040105150010	Weldon Brook/Beaver Brook	01	22.62	2.80	-	2,311.71	0.05	0.20
02040105150020	Lake Hopatcong	01	241.28	33.00	0.02	2,185.86	0.59	1.30
02040105150030	Musconetcong R (Wills Bk to LkHopatcong)	01	110.63	45.39	0.02	1,827.69	1.68	0.98
02040105150040	Lubbers Run (above/incl Dallis Pond)	01	56.16	22.23	1.52	2,266.88	0.11	0.46
02040105150050	Lubbers Run (below Dallis Pond)	01	66.91	14.19	0.57	2,358.46	0.21	0.38
02040105150060	Cranberry Lake / Jefferson Lake & tribs	01	51.61	10.54	0.04	3,037.66	0.23	0.30
02040105150070	Musconetcong R(Waterloo to/incl WillsBk)	01	43.60	31.09	0.83	2,835.92	1.09	0.61
02040105150080	Musconetcong R (SaxtonFalls to Waterloo)	01	17.07	3.82	0.03	3,248.21	-	0.17
02040105150090	Mine Brook (Morris Co)	01	23.78	33.48	14.71	2,549.48	0.18	0.98
02040105150100	Musconetcong R (Trout Bk to SaxtonFalls)	01	15.50	30.35	3.16	2,940.95	0.16	0.51
02040105160010	Musconetcong R (Hances Bk thru Trout Bk)	01	22.18	29.20	18.01	2,627.29	0.33	0.99
02040105160020	Musconetcong R (Changewater to HancesBk)	01	18.28	16.25	28.25	2,789.64	0.07	1.06
02040105160030	Musconetcong R (Rt 31 to Changewater)	01	32.30	27.90	37.66	1,655.25	0.16	2.03
02040105160040	Musconetcong R (75d 00m to Rt 31)	01	49.69	22.94	39.21	1,737.70	0.24	2.05
02040105160050	Musconetcong R (I-78 to 75d 00m)	01	14.38	13.16	46.32	2,368.87	0.04	1.95
02040105160060	Musconetcong R (Warren Glen to I-78)	01	31.98	18.34	32.42	2,128.06	0.18	1.51
02040105160070	Musconetcong R (below Warren Glen)	01	19.18	14.53	29.12	2,349.17	0.20	1.07
02040105170010	Holland Twp (Hakihokake to Musconetcong)	11	19.29	17.30	21.95	2,914.21	0.10	0.88
02040105170020	Hakihokake Creek	11	19.70	22.24	26.55	3,403.84	0.22	1.13
02040105170030	Harihokake Creek (and to Hakihokake Ck)	11	18.33	17.85	41.99	3,954.14	0.08	1.88
02040105170040	Nishisakawick Creek (above 40d 33m)	11	16.03	17.47	49.29	3,244.20	0.05	2.62
02040105170050	Nishisakawick Creek (below 40d 33m)	11	13.05	17.02	46.04	3,451.71	0.25	1.99

CONCLUSIONS RELATED TO MEDIAN NITRATE CONCENTRATIONS AND THEIR RELATIONSHIP TO LAND USE PATTERNS

The two objectives of the logistic regression analyses were to determine both background median nitrate concentrations in ground water for the Highlands Region, and more fully quantify the relationship of land use and related features and activities on nitrate concentrations, using available water quality data.

Background median values of nitrate in ground water were determined using statistical analyses for undeveloped areas; for the Highlands Region as a whole, regardless of land use; and for each of the 183 HUC14 subwatersheds in the Highlands. Median nitrate concentrations were determined in undeveloped areas and for the Highlands Region as a whole to be 0.1 mg/L and 0.83 mg/L, respectively. Results for the individual HUC14 subwatersheds range from 0.17 to 3.6 mg/L and are included in the tables *HUC14 Specific Median Nitrate Concentration in Ground Water* for 1986, 1995 and 2002 land use data. The relationships between nitrate concentrations in ground water and a large set of variables were also explored. Land use and other variables were then used to develop logistic regression models. Several statistical procedures were employed to evaluate the significance of each variable in each model, and to evaluate the predictive capability of the modeling effort overall.

Based on this multi-step analysis, it was determined that variables significantly and generally positively correlated (i.e., an increase in one is related to an increase in the other) to nitrate concentrations in ground water include percentage of urban development, percentage of agricultural land use, septic system density, and the number of known contaminated sites. It was also determined that variables associated with undeveloped land (e.g., percentage of forested lands and wetlands, length of streams within a subwatershed, etc.) are negatively correlated with nitrate concentrations.

These analyses provide the Highlands Council with important information related to its efforts to protect, enhance and restore the critical water and ecological resources of the Highlands. The statistical evaluation of background nitrate concentrations provides the scientific foundation for setting antidegradation thresholds, based on statistical analysis of actual water quality monitoring data.

In addition, the regression analyses have identified, specifically for the Highlands Region, those land uses, associated features and activities (e.g., septic system density, known contaminated sites) strongly correlated with an increase in the concentration of nitrate in ground water.

STRENGTHS AND LIMITATIONS OF THE AVAILABLE DATA

Water quality data from the several hundred wells included in the analysis were collected over more than twenty years, specifically between 1982 and 2004. The median date of data collection is September, 1989.

Three different land use time periods were also incorporated in the analysis, with a focus on 1990 land use as being the most closely matched and appropriate to be compared with the water quality data, with that median collection date in 1989. While 1990 septic system density data was used in calculating median concentrations of nitrate as being most appropriately matched to the median age of the water quality data, statistical tests were also performed to determine the consistency in nitrate concentration data using the 2002 dasymetric mapping versus the census block calculation methods.

The figure *Median Concentrations of Nitrate as Nitrogen in HUC14 Areas Calculated from Census-Block Septic Density and Non-sewered Area Population Data* indicates very high correlation (R^2 value of 0.9314) between these sets of HUC14-specific nitrate concentration values.

HUC14 Specific Median Nitrate Concentration in Ground Water

HUC14	Subwatershed Name	WMA	1986 Nitrate Concentration	1995 Nitrate Concentration	2002 Nitrate Concentration	Mean Nitrate Concentration
02020007010010	Wallkill R/Lake Mohawk(above Sparta Sta)	02	0.81	0.86	0.84	0.84
02020007010020	Wallkill R (Ogdensburg to SpartaStation)	02	0.43	0.42	0.43	0.43
02020007010030	Franklin Pond Creek	02	0.26	0.27	0.25	0.26
02020007010040	Wallkill R(Hamburg SW Bdy to Ogdensburg)	02	0.80	0.66	0.70	0.72
02020007010050	Hardistonville tribs	02	0.40	0.32	0.34	0.35
02020007010060	Beaver Run	02	0.90	0.87	0.89	0.89
02020007010070	Wallkill R(Martins Rd to Hamburg SW Bdy)	02	0.79	0.61	0.70	0.70
02020007020070	Papakating Creek (below Pellettown)	02	0.99	0.89	0.91	0.93
02020007030010	Wallkill R(41d13m30s to Martins Road)	02	0.95	0.82	0.83	0.87
02020007030030	Wallkill River(Owens gage to 41d13m30s)	02	0.81	0.48	0.48	0.59
02020007030040	Wallkill River(stateline to Owens gage)	02	0.82	0.43	0.42	0.55
02020007040010	Black Ck(above/incl G.Gorge Resort trib)	02	0.60	0.55	0.56	0.57
02020007040020	Black Creek (below G. Gorge Resort trib)	02	0.68	0.57	0.57	0.60
02020007040030	Pochuck Ck/Glenwood Lk & northern trib	02	0.60	0.49	0.49	0.53
02020007040040	Highland Lake/Wawayanda Lake	02	0.48	0.50	0.48	0.48
02020007040050	Wawayanda Creek & tribs	02	0.36	0.32	0.30	0.33
02020007040060	Long House Creek/Upper Greenwood Lake	02	0.41	0.43	0.41	0.42
02030103010010	Passaic R Upr (above Osborn Mills)	06	0.85	0.80	0.83	0.83
02030103010020	Primrose Brook	06	0.75	0.61	0.62	0.66
02030103010030	Great Brook (above Green Village Rd)	06	1.46	1.24	1.29	1.33
02030103010040	Loantaka Brook	06	1.26	1.00	1.04	1.10
02030103010050	Great Brook (below Green Village Rd)	06	0.55	0.48	0.47	0.50
02030103010060	Black Brook (Great Swamp NWR)	06	0.47	0.44	0.44	0.45
02030103010070	Passaic R Upr (Dead R to Osborn Mills)	06	0.78	0.77	0.79	0.78
02030103010080	Dead River (above Harrisons Brook)	06	0.69	0.57	0.87	0.71
02030103010090	Harrisons Brook	06	1.44	1.33	1.42	1.40
02030103010100	Dead River (below Harrisons Brook)	06	0.58	0.66	0.69	0.64
02030103010110	Passaic R Upr (Plainfield Rd to Dead R)	06	0.69	0.65	0.65	0.66
02030103010180	Passaic R Upr (Pine Bk br to Rockaway)	06	1.00	0.91	0.98	0.96
02030103020010	Whippany R (above road at 74d 33m)	06	0.66	0.68	0.71	0.68
02030103020020	Whippany R (Wash. Valley Rd to 74d 33m)	06	0.56	0.50	0.52	0.53
02030103020030	Greystone / Watnong Mtn tribs	06	0.92	0.87	0.92	0.90
02030103020040	Whippany R(Lk Pocahontas to Wash Val Rd)	06	1.25	1.06	1.17	1.16
02030103020050	Whippany R (Malapardis to Lk Pocahontas)	06	1.42	1.40	1.40	1.41
02030103020060	Malapardis Brook	06	1.21	1.12	1.22	1.18
02030103020070	Black Brook (Hanover)	06	1.19	1.07	1.15	1.14
02030103020080	Troy Brook (above Reynolds Ave)	06	1.33	0.99	1.18	1.17

HUC14 Specific Median Nitrate Concentration in Ground Water

HUC14	Subwatershed Name	WMA	1986 Nitrate Concentration	1995 Nitrate Concentration	2002 Nitrate Concentration	Mean Nitrate Concentration
02030103020090	Troy Brook (below Reynolds Ave)	06	0.42	0.42	0.44	0.43
02030103020100	Whippany R (Rockaway R to Malapardis Bk)	06	1.01	0.98	1.10	1.03
02030103030010	Russia Brook (above Milton)	06	0.25	0.30	0.31	0.29
02030103030020	Russia Brook (below Milton)	06	0.49	0.59	0.60	0.56
02030103030030	Rockaway R (above Longwood Lake outlet)	06	0.41	0.45	0.47	0.44
02030103030040	Rockaway R (Stephens Bk to Longwood Lk)	06	0.27	0.28	0.26	0.27
02030103030050	Green Pond Brook (above Burnt Meadow Bk)	06	0.24	0.26	0.25	0.25
02030103030060	Green Pond Brook (below Burnt Meadow Bk)	06	0.41	0.42	0.40	0.41
02030103030070	Rockaway R (74d 33m 30s to Stephens Bk)	06	0.79	0.84	0.87	0.83
02030103030080	Mill Brook (Morris Co)	06	0.76	0.83	0.90	0.83
02030103030090	Rockaway R (BM 534 brdg to 74d 33m 30s)	06	1.18	1.32	1.38	1.29
02030103030100	Hibernia Brook	06	0.29	0.32	0.30	0.31
02030103030110	Beaver Brook (Morris County)	06	0.35	0.38	0.37	0.37
02030103030120	Den Brook	06	0.83	0.84	0.89	0.85
02030103030130	Stony Brook (Boonton)	06	0.40	0.41	0.41	0.41
02030103030140	Rockaway R (Stony Brook to BM 534 brdg)	06	1.18	1.03	1.03	1.08
02030103030150	Rockaway R (Boonton dam to Stony Brook)	06	0.71	0.71	0.70	0.71
02030103030160	Montville tribs.	06	0.61	0.66	0.72	0.67
02030103030170	Rockaway R (Passaic R to Boonton dam)	06	1.25	1.14	1.19	1.19
02030103040010	Passaic R Upr (Pompton R to Pine Bk)	06	0.43	0.46	0.46	0.45
02030103050010	Pequannock R (above Stockholm/Vernon Rd)	03	0.23	0.25	0.24	0.24
02030103050020	Pacock Brook	03	0.22	0.24	0.22	0.22
02030103050030	Pequannock R (above OakRidge Res outlet)	03	0.22	0.24	0.23	0.23
02030103050040	Clinton Reservior/Mossmans Brook	03	0.16	0.18	0.17	0.17
02030103050050	Pequannock R (Charlotteburg to OakRidge)	03	0.27	0.29	0.28	0.28
02030103050060	Pequannock R(Macopin gage to Charl'brg)	03	0.32	0.33	0.32	0.32
02030103050070	Stone House Brook	03	0.65	0.66	0.68	0.66
02030103050080	Pequannock R (below Macopin gage)	03	0.65	0.68	0.68	0.67
02030103070010	Belcher Creek (above Pinecliff Lake)	03	0.37	0.40	0.41	0.40
02030103070020	Belcher Creek (Pinecliff Lake & below)	03	0.42	0.44	0.42	0.42
02030103070030	Wanaque R/Greenwood Lk(aboveMonks gage)	03	0.24	0.27	0.25	0.25
02030103070040	West Brook/Burnt Meadow Brook	03	0.33	0.34	0.33	0.34
02030103070050	Wanaque Reservior (below Monks gage)	03	0.31	0.32	0.30	0.31
02030103070060	Meadow Brook/High Mountain Brook	03	0.77	0.73	0.74	0.75
02030103070070	Wanaque R/Posts Bk (below reservior)	03	0.38	0.40	0.39	0.39
02030103100010	Ramapo R (above 74d 11m 00s)	03	0.37	0.41	0.41	0.40
02030103100020	Masonicus Brook	03	1.55	1.46	1.53	1.51
02030103100030	Ramapo R (above Fyke Bk to 74d 11m 00s)	03	0.35	0.41	0.42	0.39
02030103100040	Ramapo R (Bear Swamp Bk thru Fyke Bk)	03	0.17	0.19	0.21	0.19
02030103100050	Ramapo R (Crystal Lk br to BearSwamp Bk)	03	0.37	0.37	0.38	0.37
02030103100060	Crystal Lake/Pond Brook	03	2.40	2.33	2.35	2.36
02030103100070	Ramapo R (below Crystal Lake bridge)	03	0.69	0.73	0.74	0.72
02030103110010	Lincoln Park tribs (Pompton River)	03	0.82	0.86	0.89	0.86
02030103110020	Pompton River	03	1.59	1.55	1.59	1.58
02030103140010	Hohokus Bk (above Godwin Ave)	04	1.74	1.66	1.72	1.71
02030103140020	Hohokus Bk(Pennington Ave to Godwin Ave)	04	1.74	1.50	1.59	1.61
02030103140040	Saddle River (above Rt 17)	04	2.04	1.82	1.88	1.91
02030105010010	Drakes Brook (above Eyland Ave)	08	0.68	0.73	0.79	0.74
02030105010020	Drakes Brook (below Eyland Ave)	08	0.96	0.97	1.12	1.01
02030105010030	Raritan River SB(above Rt 46)	08	0.79	0.79	0.80	0.79
02030105010040	Raritan River SB(74d 44m 15s to Rt 46)	08	0.81	0.76	0.85	0.80
02030105010050	Raritan R SB(LongValley br to 74d44m15s)	08	0.79	0.78	0.85	0.81
02030105010060	Raritan R SB(Califon br to Long Valley)	08	1.11	1.09	1.17	1.12
02030105010070	Raritan R SB(StoneMill gage to Califon)	08	0.78	0.70	0.70	0.73
02030105010080	Raritan R SB(Spruce Run-StoneMill gage)	08	1.10	0.80	0.89	0.93
02030105020010	Spruce Run (above Glen Gardner)	08	0.92	0.90	0.95	0.92
02030105020020	Spruce Run (Reservior to Glen Gardner)	08	0.56	0.68	0.68	0.64
02030105020030	Mulhockaway Creek	08	0.85	0.78	0.83	0.82
02030105020040	Spruce Run Reservior / Willoughby Brook	08	0.57	0.60	0.62	0.60
02030105020050	Beaver Brook (Clinton)	08	1.85	1.65	1.74	1.75
02030105020060	Cakepoulin Creek	08	2.74	2.11	2.74	2.53
02030105020070	Raritan R SB(River Rd to Spruce Run)	08	1.84	1.22	1.53	1.53
02030105020080	Raritan R SB(Prescott Bk to River Rd)	08	1.73	1.33	1.55	1.53
02030105020090	Prescott Brook / Round Valley Reservior	08	0.47	0.51	0.50	0.49
02030105040020	Pleasant Run	08	2.08	1.80	1.90	1.93

HUC14 Specific Median Nitrate Concentration in Ground Water

HUC14	Subwatershed Name	WMA	1986 Nitrate Concentration	1995 Nitrate Concentration	2002 Nitrate Concentration	Mean Nitrate Concentration
02030105040030	Holland Brook	08	1.95	1.58	1.72	1.75
02030105050010	Lamington R (above Rt 10)	08	0.86	0.93	0.82	0.87
02030105050020	Lamington R (Hillside Rd to Rt 10)	08	0.71	0.69	0.69	0.69
02030105050030	Lamington R (Furnace Rd to Hillside Rd)	08	0.92	0.90	0.94	0.92
02030105050040	Lamington R(Pottersville gage-FurnaceRd)	08	0.91	0.87	0.91	0.90
02030105050050	Pottersville trib (Lamington River)	08	0.50	0.55	0.63	0.56
02030105050060	Cold Brook	08	1.90	1.96	1.98	1.95
02030105050070	Lamington R(HallsBrRd-Pottersville gage)	08	1.26	1.21	1.24	1.24
02030105050080	Rockaway Ck (above McCrea Mills)	08	1.22	1.00	1.10	1.11
02030105050090	Rockaway Ck (RockawaySB to McCrea Mills)	08	0.92	0.85	0.89	0.89
02030105050100	Rockaway Ck SB	08	1.18	1.07	1.17	1.14

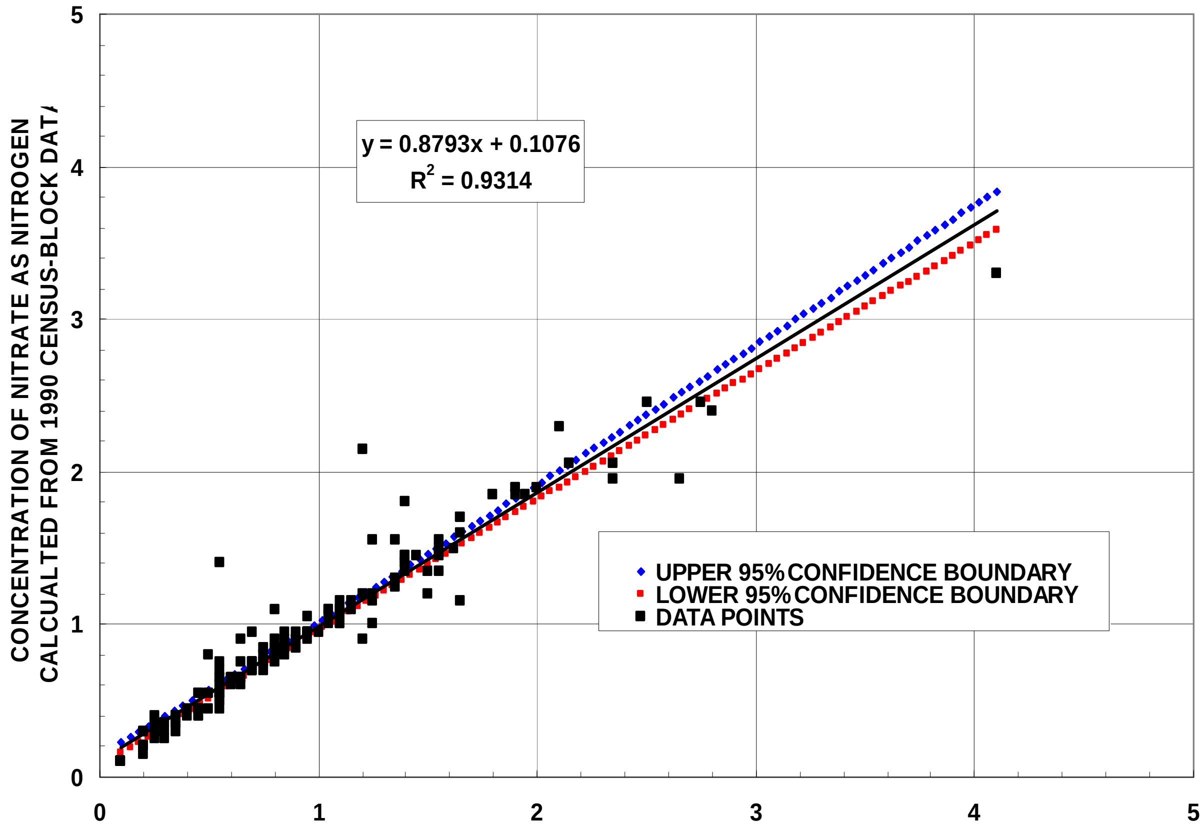
HUC14 Specific Median Nitrate Concentration in Ground Water

HUC14	Subwatershed Name	WMA	1986 Nitrate Concentration	1995 Nitrate Concentration	2002 Nitrate Concentration	Mean Nitrate Concentration
02030105050110	Lamington R (below Halls Bridge Rd)	08	1.31	1.19	1.20	1.23
02030105060010	Raritan R NB (above/incl India Bk)	08	0.80	0.80	0.86	0.82
02030105060020	Burnett Brook (above Old Mill Rd)	08	0.83	0.75	0.82	0.80
02030105060030	Raritan R NB(incl McVickers to India Bk)	08	0.74	0.69	0.81	0.75
02030105060040	Raritan R NB(Peapack Bk to McVickers Bk)	08	0.68	0.68	0.76	0.71
02030105060050	Peapack Brook (above/incl Gladstone Bk)	08	0.85	0.78	0.97	0.87
02030105060060	Peapack Brook (below Gladstone Brook)	08	1.05	1.03	1.15	1.08
02030105060070	Raritan R NB(incl Mine Bk to Peapack Bk)	08	0.96	0.91	1.00	0.95
02030105060080	Middle Brook (NB Raritan River)	08	1.86	1.89	2.03	1.92
02030105060090	Raritan R NB (Lamington R to Mine Bk)	08	1.26	1.27	1.57	1.37
02030105070010	Raritan R NB (Rt 28 to Lamington R)	08	1.43	1.20	1.29	1.30
02030105120050	Middle Brook EB	09	0.78	0.78	0.95	0.84
02030105120060	Middle Brook WB	09	0.69	0.71	0.74	0.71
02040105040040	Lafayette Swamp tribs	01	1.14	0.74	0.86	0.91
02040105040050	Sparta Junction tribs	01	0.84	0.70	0.79	0.78
02040105040060	Paulins Kill (above Rt 15)	01	0.97	0.83	0.90	0.90
02040105050010	Paulins Kill (Blairstown to Stillwater)	01	0.61	0.63	0.63	0.62
02040105060020	Delawanna Creek (incl UDRV)	01	1.01	1.09	1.08	1.06
02040105070010	Lake Lenape trib	01	0.42	0.46	0.48	0.45
02040105070020	New Wawayanda Lake/Andover Pond trib	01	0.50	0.52	0.52	0.51
02040105070030	Pequest River (above Brighton)	01	0.72	0.70	0.72	0.71
02040105070040	Pequest River (Trout Brook to Brighton)	01	1.79	1.22	1.36	1.46
02040105070050	Trout Brook/Lake Tranquility	01	0.57	0.47	0.46	0.50
02040105070060	Pequest R (below Bear Swamp to Trout Bk)	01	0.72	0.37	0.36	0.48
02040105080010	Bear Brook (Sussex/Warren Co)	01	1.14	0.97	1.02	1.04
02040105080020	Bear Creek	01	0.67	0.61	0.60	0.62
02040105090010	Pequest R (Drag Strip--below Bear Swamp)	01	0.84	0.37	0.36	0.53
02040105090020	Pequest R (Cemetary Road to Drag Strip)	01	0.88	0.78	0.84	0.83
02040105090030	Pequest R (Furnace Bk to Cemetary Road)	01	0.55	0.48	0.47	0.50
02040105090040	Mountain Lake Brook	01	0.43	0.43	0.43	0.43
02040105090050	Furnace Brook	01	0.46	0.43	0.44	0.44
02040105090060	Pequest R (below Furnace Brook)	01	1.05	0.98	1.00	1.01
02040105100010	Union Church trib	01	0.62	0.60	0.59	0.60
02040105100020	Honey Run	01	1.09	1.07	1.08	1.08
02040105100030	Beaver Brook (above Hope Village)	01	0.97	0.95	0.98	0.97
02040105100040	Beaver Brook (below Hope Village)	01	1.22	1.26	1.27	1.25
02040105110010	Pophandusing Brook	01	1.77	1.59	1.72	1.69

HUC14 Specific Median Nitrate Concentration in Ground Water

HUC14	Subwatershed Name	WMA	1986 Nitrate Concentration	1995 Nitrate Concentration	2002 Nitrate Concentration	Mean Nitrate Concentration
02040105110020	Buckhorn Creek (incl UDRV)	01	1.72	1.57	1.60	1.63
02040105110030	UDRV tribs (Rt 22 to Buckhorn Ck)	01	1.79	2.00	2.01	1.93
02040105120010	Lopatcong Creek (above Rt 57)	01	1.31	1.13	1.26	1.23
02040105120020	Lopatcong Creek (below Rt 57) incl UDRV	01	2.16	2.02	2.66	2.28
02040105140010	Pohatcong Creek (above Rt 31)	01	0.50	0.56	0.56	0.54
02040105140020	Pohatcong Ck (Brass Castle Ck to Rt 31)	01	0.92	0.90	0.92	0.91
02040105140030	Pohatcong Ck (Edison Rd-Brass Castle Ck)	01	1.65	1.55	1.60	1.60
02040105140040	Merrill Creek	01	0.81	0.72	0.71	0.75
02040105140050	Pohatcong Ck (Merrill Ck to Edison Rd)	01	1.89	1.83	1.87	1.86
02040105140060	Pohatcong Ck (Springtown to Merrill Ck)	01	3.69	2.90	3.08	3.23
02040105140070	Pohatcong Ck(below Springtown) incl UDRV	01	1.80	1.89	1.84	1.84
02040105150010	Weldon Brook/Beaver Brook	01	0.20	0.22	0.20	0.21
02040105150020	Lake Hopatcong	01	1.24	1.53	1.30	1.36
02040105150030	Musconetcong R (Wills Bk to LkHopatcong)	01	0.88	0.98	0.98	0.95
02040105150040	Lubbers Run (above/incl Dallis Pond)	01	0.38	0.43	0.46	0.42
02040105150050	Lubbers Run (below Dallis Pond)	01	0.36	0.39	0.38	0.38
02040105150060	Cranberry Lake / Jefferson Lake & tribs	01	0.31	0.32	0.30	0.31
02040105150070	Musconetcong R(Waterloo to/incl WillsBk)	01	0.45	0.54	0.61	0.53
02040105150080	Musconetcong R (SaxtonFalls to Waterloo)	01	0.17	0.18	0.17	0.17
02040105150090	Mine Brook (Morris Co)	01	0.87	0.86	0.98	0.90
02040105150100	Musconetcong R (Trout Bk to SaxtonFalls)	01	0.45	0.48	0.51	0.48
02040105160010	Musconetcong R (Hances Bk thru Trout Bk)	01	0.93	0.94	0.99	0.95
02040105160020	Musconetcong R (Changewater to HancesBk)	01	1.00	1.00	1.06	1.02
02040105160030	Musconetcong R (Rt 31 to Changewater)	01	2.77	1.91	2.03	2.24
02040105160040	Musconetcong R (75d 00m to Rt 31)	01	2.49	1.95	2.05	2.16
02040105160050	Musconetcong R (I-78 to 75d 00m)	01	1.98	1.92	1.95	1.95
02040105160060	Musconetcong R (Warren Glen to I-78)	01	1.58	1.45	1.51	1.51
02040105160070	Musconetcong R (below Warren Glen)	01	1.02	1.05	1.07	1.04
02040105170010	Holland Twp (Hakihokake to Musconetcong)	11	0.66	0.87	0.88	0.80
02040105170020	Hakihokake Creek	11	1.25	1.09	1.13	1.16
02040105170030	Harihokake Creek (and to Hakihokake Ck)	11	2.01	1.82	1.88	1.90
02040105170040	Nishisakawick Creek (above 40d 33m)	11	2.68	2.15	2.62	2.48
02040105170050	Nishisakawick Creek (below 40d 33m)	11	2.09	1.95	1.99	2.01

Median Concentrations of Nitrate as Nitrogen in HUC14 Areas Calculated from Census-Block Septic Density and Non-Sewered Area Population Data



The septic system density data largely reflect residential use only, as the data available for commercial, industrial and institutional land uses was felt to be inaccurate due to the variation in the quality and quantity the effluent being discharged to ground water. While one can identify that a school exists in a particular area, the Highlands Council did not have the data available to determine how many students were in attendance in order to calculate discharge volumes; multiplying the effort to make that one determination by the number of stores, manufacturing plants, hospitals and other facilities within the Region, it quickly becomes obvious that such a task is infeasible. In some HUC14 areas, this lack of data may affect the results of the analysis and will need to be evaluated and refined during conformance and implementation of the Regional Master Plan on a site-specific basis. In the regional analysis overall however, residential uses and their contribution to nitrate loadings predominate.

The large size of the data set, which incorporates information from 352 wells, use of data from a span of more than 20 years and the fact that the median date of the water quality data (1989) is matched with land use data from 1990, the closest timeframe for which such data is available, all help to offset both the types and magnitude of the data limitations acknowledged above. The close correlation between nitrate concentrations using both census-block and dasymetric mapping methods provides further confidence in the results of the analysis.

Therefore, this analysis is based on data from a large number of wells and the best water quality data available. It reflects changes in land use and other potentially relevant factors. This analysis allowed the Council to evaluate changes in nitrate concentration in ground water over time, taking changes in land use and other factors into account to the maximum extent feasible.

ESTIMATING SEPTIC SYSTEM DENSITY

Following an estimation of median nitrate concentrations at the subwatershed scale with the logistic regression models, a variety of methods were investigated for determining the appropriate septic system densities. Septic system density numbers are necessary for computing the total number of allowable new septic systems for each municipality based upon existing developable land area. From a water quality protection perspective, an appropriate septic system density is necessary for ensuring that over a regional planning area, septic system effluent does not produce median nitrate concentrations in ground water that exceed a specific target nitrate concentration.

The possibility of using the logistic regression models developed for each subwatershed for estimating appropriate septic system densities was investigated. Using these models, two approaches were investigated as a possible means for quantifying a measurably small change in nitrate concentrations as a function of septic system density (i.e. lot size).

In the first predictive approach, a logistic regression model was selected in which the median nitrate concentration is used as the model target value for the subwatershed under consideration. The method used for determining the predicted change, or probability of exceeding a specific nitrate concentration related to septic system density, does not directly consider known effects of changing land use (e.g., changes in impervious cover). In this approach, because the model target value equals the background median for the HUC14, the existing probability of exceeding the target is 0.5. The explanatory variables are set equal to their representative values for the area. The model (i.e. equation) was then solved to determine the septic system density increase at which the probability of exceeding the target (i.e. median) nitrate concentration increased from 0.50 to 0.51 (i.e. 1% probability increase).

A second method of quantifying the effect of increasing septic system density on nitrate concentrations was investigated to address the calculable change criterion. In this method, the median nitrate concentration within the subwatershed is first assumed to have increased some fixed amount, such as 0.1 mg/L. The logistic regression model corresponding to the new target value (i.e. original median value + 0.1 mg/L) is selected, with the explanatory variables set equal to their representative values for the subwatershed. The model was then used to compute the septic system density increase necessary for achieving a 0.50 probability of exceeding the new higher target nitrate concentration (i.e. the new median). The 0.1 mg/L median nitrate increase represents the lowest reliably measured incremental value of nitrate concentration in available water quality data.

LIMITATIONS OF LOGISTIC REGRESSION FOR ESTIMATING SEPTIC SYSTEM DENSITY TARGETS

However, densities computed by the two methods rely upon an assumption that is not consistent with the actual land use changes that would occur if new septic systems were allowed within the subwatershed.

For Method 1, because of the linear form of the logistic regression equation (i.e. models), and given that all other explanatory variables (e.g. percentage of agricultural land use) were held constant, the corresponding probabilistic change of exceeding the target nitrate concentration in response to septic system density increase is directly proportional to *f*, the model's septic system density coefficient. Consequently, all subwatersheds with the same median nitrate concentration share the same logistic regression model, and by extension, will exhibit the same unit response change (i.e. probability change) to septic system density change. This mathematically guarantees that subwatersheds sharing the same estimated median nitrate concentration will require an equivalent septic system density increase to attain the 1% probability increase, regardless of the values of the other four explanatory variables, which naturally differ between subwatersheds.

Accordingly, the five explanatory variables are not all independent of one another, as there is *compensation or interaction* between at least some. As one variable changes, namely septic system density, there will also be some relative change in at least percentages of agricultural land cover and/or urban cover, and it is these combined changes that would determine the probabilistic or median nitrate concentration changes within the subwatershed. The assumption of independence among all explanatory variables, then, where only septic system density changes as all other variables remain constant, in combination with the linear form of the logistic regression function, guarantees that the computed lot size is in direct proportion to the septic system density coefficient, which is not consistent with watershed dynamics. Although the direct relation between septic system density coefficient and computed densities is not as evident for Method 2, the same limitation of the assumption of variable independence applies.

The two methods would be valid if reasonable assumptions could be made regarding other relative land use changes as a function of septic system density changes, and explicitly accounted for in the models; for example, some percentage reductions in agricultural land use and urban development areas as septic system density increases. However, this would not only require a detailed land-use analysis at the subwatershed scale, but would also be fraught with inherent uncertainty difficult to quantify. Consequently, both methods as applied to this problem were determined to be infeasible, and a physical-based nitrate dilution model was selected for estimating appropriate densities.

ESTIMATING APPROPRIATE SEPTIC LOT SIZE WITH THE TRELA-DOUGLAS NITRATE DILUTION MODEL

Because of the aforementioned limitations of using logistic regression for computing appropriate septic densities, the more traditional recharge-based nitrate-dilution model (Hoffman and Canace, 2004) was investigated and ultimately selected by the Highlands Council for this task. This model involves coupling of a modified Trela-Douglas model (Trela and Douglas, 1978) with GSR-32 to estimate appropriate densities for not exceeding nitrate concentration targets. Utilization of this model for regional planning analysis has regulatory precedence in New Jersey, used by the NJDEP and the Pinelands Commission, as well as numerous municipalities. This recharge-based nitrate dilution model was also used by the NJDEP for computing the required densities for forested and non-forested area within the Preservation area of the Highlands.

PHYSICAL BASIS AND ASSUMPTIONS OF THE TRELA-DOUGLAS MODEL

Unlike logistic regression, which is an empirical-based method, Trela-Douglas is a physical-based nitrate dilution model based upon the mass balance principle. The Trela-Douglas model assumes that the nitrate mass generated by septic system effluent discharge is diluted by natural recharge, and this dilution determines the final nitrate concentration. The model ignores all other potential physical mechanisms that may further reduce nitrate concentrations in ground water, such as ground water mixing and molecular dispersion. In addition, Trela-Douglas ignores biological and chemical processes that may also reduce nitrate mass, such as plant uptake and denitrification. The model further assumes that the ground water recharge volume available for dilution is equal to the area of the septic system lot multiplied by the annual recharge rate used (i.e. inches/year). The model, then, calculates the required average lot size (or density) for diluting the septic system effluent to achieve the specified target nitrate concentration under assumed recharge and nitrate loading conditions.

The assumptions that are inherent to applying Trela-Douglas, as well as some of the implications, are:

There is a one-to-one correspondence between homes and disposal systems. Each home has only one disposal system and each disposal system serves only one home.

Complete and uniform mixing of wastewater and recharge takes place only at the water table. The actual behavior of ground water flow and contaminant plume suggests that the wastewater plume would move in a relatively concentrated mass, particularly near the septic, with higher concentrations at the center. However, on a regional basis, this assumption is justified.

The only water available to dilute wastewater is recharge. Only that recharge which falls directly over the lot will dilute the leachate plume. This assumption ignores mixing of the plume with ground water. On a regional scale, this assumption is reasonable as one cannot guarantee the quality of ground water.

The entire residential lot area provides recharge to dilute the effluent. No account is made for water diverted by roof tops and pave areas to storm drains. At the densities resulting from the selected nitrate targets for the Highlands Region, and with application of the Stormwater Management Rules at N.J.A.C. 7:8 which require maintenance of pre-construction ground water recharge, this issue is minimized.

Molecular dispersion and diffusion are not taken into account. Diffusion and dispersion are more active along the boundaries of the plume, and may not affect the interior significantly, particularly over short downgradient distances from the septic system where the plume is still concentrated.

Denitrification (i.e. chemical transformation of nitrate to nitrite) is absent, with no reduction in nitrate mass. Consequently, nitrate concentrations in ground water are reduced only by dilution from ground water recharge.

MATHEMATICAL BASIS OF THE TRELA-DOUGLAS MODEL

The Trela-Douglas dilution model is based upon the simple mass balance relationship between dissolved concentration, mass of the solute (i.e. nitrate), and volume of the solvent (i.e. water), formally expressed in Equation 6 below.

$$\textit{Concentration (mass per volume)} = (\textit{Mass of Solute}) \div (\textit{Volume of Solvent}) \qquad (6)$$

This general equation can be rewritten to express mass as the pounds of nitrate loading per person per year multiplied by the number of persons per septic system, and the volume of water available for nitrate dilution as the annual ground water recharge rate multiplied by the corresponding lot size area, yielding:

$$\textit{Target Nitrate Concentration} = [(\textit{Nitrate Load/Person/Year}) \times (\textit{Number of People/Septic System})] \div [(\textit{Annual Recharge Rate}) \times (\textit{Lot Size})] \qquad (7)$$

The target nitrate concentration is the maximum allowable concentration for nitrate at the site, which is prescribed. The unknown variable for which the equation is solved, lot size, can be computed by rearranging Equation 7, yielding:

Lot Size = [(Nitrate Load/Person/Year) × (Number of People/Septic)] ÷ [(Annual Recharge Rate) × (Target Nitrate Concentration)] (8)

To solve Equation 8 and directly compute the average lot size or density required to achieve the target nitrate concentration, values for the other variables in the equation must be estimated/assumed. This includes the nitrate mass generated annually by the septic system effluent, which is the product of the two terms in the numerator, and the annual recharge rate for the subwatershed, estimated with the soil-water budget-based GSR-32 methodology. Finally, the target nitrate concentration is required, and in this case, was established for the Protection and Conservation Zones within the Planning Area based upon statistical analyses of the median nitrate concentrations calculated with the logistic regression models. For the Existing Community Zone, the NJDEP state-wide target nitrate concentration of 2.0 mg/L was selected.

Nitrate Loading Input to the Trela-Douglas Model

In order to estimate the total nitrate mass generated by the septic effluent annually, it is necessary to assume some fixed mass (i.e. pounds) of nitrate waste generated per person per year, as well as the number of persons per septic, or household occupation rate. To establish a household occupation rate, the NJDEP examined the latest U.S. census data to determine a representative residential density (U.S. Census Bureau data can be accessed at www.census.gov). Based on the available data, the national average for household size is 2.7 people (U.S. Census Bureau, 2005). This value represents an average of all areas and housing types. Considering only those New Jersey counties relevant to the Highlands Region, e.g. Bergen, Hunterdon, Morris, Passaic, Somerset, Sussex, and Warren, the average household size is 2.8 people (U.S. Census Bureau, 2005).

None of these counties lie wholly within the Highlands Region, and some contain portions that are highly urbanized while others have large sections of agricultural and rural areas. Relying on county data alone may result in a skewed average household size; however, data for each individual municipality is not available. The municipal and Census Place Data (CDP) data was further analyzed to calculate the distribution of household size, e.g., 1-person, 2-person, up to 7 or more, relative to the total number of households per municipality and CDP. The percent of the residential population living in the households of 4 or more is as high as 40.1% within the municipalities and CDPs examined. The weighted average among total households is 30.6%. In addition, the majority of the households that contain 4 or more people are those that house 4 people. Therefore, a representative occupancy rate of 4 persons per household was used to establish a conservative loading per unit.

In terms of pounds of nitrate generated per person per year, there are several reported nitrate loading rates cited by the NJ Geological Survey (Hoffman and Canace, 2004) in their open-file report *A Recharge-Based Nitrate-Dilution Model for New Jersey*. As summarized in the table below entitled *Reported Nitrate Loading Rates*, the values reported for the five data sources range from 5.4 to 14.2 pounds per person per year, with an average value of 9.8 pounds per person per year.

Reported Nitrate Loading Rates

Data Source	Reported Parameter	Pounds/Person/Year
Laak, 1980	Total nitrogen	10.4
Ligman and others, 1974	Total nitrogen	14.2
Metcalf & Eddy, Inc., 1991	Total kejdahl nitrogen	9.9
Siegrist and others, 1976	Total nitrogen	5.4
U.S. EPA, 1980	Total kejdahl nitrogen	9.13

Accordingly, an average nitrate loading rate of 10 pounds/person/year was selected as a representative model input value. Combining this value with the 4 persons per septic, which exceeds the regional average of 2.8 persons per household, provides a conservative factor for total nitrate loading. This, coupled with the fact that any potential denitrification is assumed to be non-existent, further introduces a conservative factor into the total nitrate mass estimated for a representative septic system. This conservative factor helps address any additional nitrate loading sources that may include lawn fertilizers and animal waste. One important mitigating factor to consider of these additional nitrate sources is that, unlike septic system effluent, these sources must first travel downward through the root zone in order to enter ground water. Plant uptake may further decrease nitrate mass during this journey.

ANNUAL DROUGHT GROUND WATER RECHARGE RATE INPUT TO THE TRELA-DOUGLAS MODEL

The annual ground water recharge rate (i.e. inches/year) for the subwatershed is required for computing lot size with the Trela-Douglas model. As a component of the soil-water budget that is part of the hydrologic cycle, ground water recharge is the portion of precipitation that is not lost to other components, and may be expressed as:

Recharge = Precipitation - Surface Runoff - Evapotranspiration - Soil Moisture Deficit

Because the other soil-water budget components vary significantly over space and time, recharge similarly exhibits significant spatial and temporal variability. For example, surface water runoff is largely determined by land cover, which within the Highlands Region often changes significantly over relatively short distances; the asphalt paving of large parking area, which generates high surface runoff that may be diverted into a nearby stream, is in contrast to highly permeable soils characterizing a nearby forested area which minimize surface runoff loses. Similarly, other water budget components that influence recharge significantly vary over time (e.g. monthly and seasonal); for example, temperature and vegetation cover, both of which are highest in the summer season and increase evapotranspiration loses, and soil-moisture content, lowest in summer, which decreases the amount of precipitation that infiltrates downward past the root zone. Further complicating the process is that these temporally-varying variables also frequently exhibit high spatial variability; a forested area has much higher evapotranspiration potential than a nearby park with significantly less vegetation cover.

In order to account for these spatially and temporally variable conditions that determine annual ground water recharge, the NJ Geological Survey developed the GSR-32 (Charles and others, 1993) methodology. The methodology was designed to account for site-specific land use and land cover conditions as well as monthly climatic factors like temperature and precipitation to estimate annual volumetric ground water recharge using monthly time-steps for the study area of interest.

The original GSR-32 models were calibrated to thirty years of climate data measured at 32 climate stations in New Jersey. By using this relatively long historical period, the models captured average climatic conditions for New Jersey. However, to introduce an additional conservative factor into the septic system density modeling, the GSR-32 recharge method was re-calibrated using climatic data spanning the New Jersey drought of record, the years 1961 through 1966. This period is considered the drought of record as it exhibits the longest recorded period in New Jersey in which precipitation was lower than average. The justification for selecting an extreme period is to be consistent with the intent of the Highlands Act, which is to protect and restore ground water and surface water quality. During an extended dry period, recharge is reduced, and consequently, less water is available to dilute the effluent nitrate waste, resulting in higher nitrate concentrations.

It is important to emphasize that the drought of record, rather than a very short duration hydrologic event, such as the 7-day/10 year (7Q10) low-flow statistic frequently used in evaluating water extraction impacts, or the September median flow, was selected to compute "worst case" annual recharge values, as this is more consistent with recharge behavior observed during prolonged extreme drought conditions. Ground water recharge consistently exhibits temporal variability, with lowest recharge occurring during the summer season, and higher recharge occurring from October through April. A short duration extreme, such as the September median flow, represents just one (in this case the most extreme) of the 12 months, and fails to capture the natural intra-annual variability that occurs with recharge, even during prolonged drought periods.

The NJ Water Supply Authority used 2002 land use land cover data (the most recent available) to estimate an annual drought recharge volume for each of the 183 HUC14 subwatersheds with the revised GSR-32 model. Spatial variability in land use and land cover was accounted for to more accurately estimate total annual recharge volume within each subwatershed under drought conditions. This volume was converted to an annual drought recharge rate for the subwatershed (i.e. inches/year) by dividing its estimated annual drought recharge volume by its land surface area that permits recharge. Under the GSR-32 method, recharge is not calculated for areas comprised by wetlands, hydric soils and surface water bodies, not because it may not occur, but because the assumptions and complexity necessary to estimate recharge in these settings "is beyond the scope of the method." Consequently, the subwatershed area used to compute annual recharge rate was calculated as the difference between the total area of the subwatershed and its total area comprised by wetlands, hydric soils and surface water bodies.

The final equation used to compute annual recharge rate for each subwatershed is:

Recharge Rate (inches/year) = (GSR-32 computed annual volumetric recharge within subwatershed) ÷ (Recharge area within subwatershed) (9)

The table *Annual Drought Recharge Rate by HUC14 Subwatershed* lists the annual drought recharge rates computed for each of the 183 subwatersheds in the Highlands Region using this approach. Computed annual drought recharge rates for subwatersheds range between 2.3 and 12.8 inches per year, with an area weighted average value of 9.4 inches/year for the entire Highlands region.

The 9.4 inches/year value agrees closely with the area weighted average drought recharge value of 9.8 inches/year estimated for the Highlands Region by the NJ Geological Survey using GSR-32. This small discrepancy in estimated values (4%) is due to subjectivity in interpreting land use and land cover data from the Anderson maps and classifying soil type within the 13 different GSR-32 soil classifications, and provides confidence in the interpretation and recharge estimates. It should be noted that the NJDEP used the 9.8 inches/year recharge value for computing the required lot size for septic system units located within the Preservation Area of the Highlands Region.

To further assess the accuracy of the NJDEP estimated recharge values, the NJ Geological Survey performed a base flow or hydrograph separation analysis on flow data measured in the Highlands Region during the drought of record. Base flow is synonymous with the portion of stream flow that is sustained by ground water discharge into the stream channel. Base flow volumes change seasonally, but follow predictable trends that can be documented in a stream's annual hydrograph. Storm water runoff or overland flow, on the other hand, increases in flow rates after precipitation events that are assumed to end within hours to days after the storm peaks. Base flow is considered a possible surrogate for recharge in that it represents the long-term "steady-state" of a region's water resources. Still, it should be noted that separation techniques assume that all water that recharges the aquifer discharges into the stream as base flow, which is rarely the case. Some volume of recharge will never reach the stream, but will be "lost" to other water budget components, such as pumping extractions, evapotranspiration, and outward ground water fluxes. Consequently, due to their inability to account for these losses, base flow separation techniques have a tendency to under-estimate recharge volume.

Annual Drought Recharge Rate by HUC 14 Subwatershed		
HUC14 Name	**HUC14 Number**	**Drought Recharge Rate (inches/year)**
Wallkill R/Lake Mohawk(above Sparta Sta)	2020007010010	9.0
Wallkill R (Ogdensburg to SpartaStation)	2020007010020	9.4
Franklin Pond Creek	2020007010030	9.8
Wallkill R(Hamburg SW Bdy to Ogdensburg)	2020007010040	9.3
Hardistonville tribs	2020007010050	10.2
Beaver Run	2020007010060	9.2
Wallkill R(Martins Rd to Hamburg SW Bdy)	2020007010070	9.3
Papakating Creek (below Pellettown)	2020007020070	8.4
Wallkill R(41d13m30s to Martins Road)	2020007030010	9.2
Wallkill River(Owens gage to 41d13m30s)	2020007030030	9.3
Wallkill River(stateline to Owens gage)	2020007030040	9.5
Black Ck(above/incl G.Gorge Resort trib)	2020007040010	9.8
Black Creek (below G. Gorge Resort trib)	2020007040020	10.6
Pochuck Ck/Glenwood Lk & northern trib	2020007040030	10.7
Highland Lake/Wawayanda Lake	2020007040040	9.8
Wawayanda Creek & tribs	2020007040050	11.1
Long House Creek/Upper Greenwood Lake	2020007040060	11.9
Passaic R Upr (above Osborn Mills)	2030103010010	10.6
Primrose Brook	2030103010020	11.5
Great Brook (above Green Village Rd)	2030103010030	9.6
Loantaka Brook	2030103010040	8.6
Great Brook (below Green Village Rd)	2030103010050	10.9
Black Brook (Great Swamp NWR)	2030103010060	9.8
Passaic R Upr (Dead R to Osborn Mills)	2030103010070	8.6
Dead River (above Harrisons Brook)	2030103010080	8.0
Harrisons Brook	2030103010090	8.3
Dead River (below Harrisons Brook)	2030103010100	8.0
Passaic R Upr (Plainfield Rd to Dead R)	2030103010110	8.7
Passaic R Upr (Pine Bk br to Rockaway)	2030103010180	2.3
Whippany R (above road at 74d 33m)	2030103020010	11.2
Whippany R (Wash. Valley Rd to 74d 33m)	2030103020020	11.2
Greystone / Watnong Mtn tribs	2030103020030	9.0
Whippany R(Lk Pocahontas to Wash Val Rd)	2030103020040	9.3
Whippany R (Malapardis to Lk Pocahontas)	2030103020050	7.8
Malapardis Brook	2030103020060	6.9
Black Brook (Hanover)	2030103020070	6.7
Troy Brook (above Reynolds Ave)	2030103020080	7.5
Troy Brook (below Reynolds Ave)	2030103020090	7.8
Whippany R (Rockaway R to Malapardis Bk)	2030103020100	6.7
Russia Brook (above Milton)	2030103030010	10.5
Russia Brook (below Milton)	2030103030020	10.5

HUC14 Name	HUC14 Number	Drought Recharge Rate (inches/year)
Rockaway R (above Longwood Lake outlet)	2030103030030	10.3
Rockaway R (Stephens Bk to Longwood Lk)	2030103030040	10.2
Green Pond Brook (above Burnt Meadow Bk)	2030103030050	10.7
Green Pond Brook (below Burnt Meadow Bk)	2030103030060	9.1
Rockaway R (74d 33m 30s to Stephens Bk)	2030103030070	9.1
Mill Brook (Morris Co)	2030103030080	9.5
Rockaway R (BM 534 brdg to 74d 33m 30s)	2030103030090	8.2
Hibernia Brook	2030103030100	10.4
Beaver Brook (Morris County)	2030103030110	10.2
Den Brook	2030103030120	9.8
Stony Brook (Boonton)	2030103030130	10.1
Rockaway R (Stony Brook to BM 534 brdg)	2030103030140	9.0
Rockaway R (Boonton dam to Stony Brook)	2030103030150	8.9
Montville tribs.	2030103030160	8.9
Rockaway R (Passaic R to Boonton dam)	2030103030170	7.5
Passaic R Upr (Pompton R to Pine Bk)	2030103040010	7.9
Pequannock R (above Stockholm/Vernon Rd)	2030103050010	10.9
Pacock Brook	2030103050020	11.3
Pequannock R (above OakRidge Res outlet)	2030103050030	11.4
Clinton Reservior/Mossmans Brook	2030103050040	12.3
Pequannock R (Charlotteburg to OakRidge)	2030103050050	11.9
Pequannock R(Macopin gage to Charl'brg)	2030103050060	11.6
Stone House Brook	2030103050070	9.6
Pequannock R (below Macopin gage)	2030103050080	9.6
Belcher Creek (above Pinecliff Lake)	2030103070010	11.9
Belcher Creek (Pinecliff Lake & below)	2030103070020	11.7
Wanaque R/Greenwood Lk(aboveMonks gage)	2030103070030	12.8
West Brook/Burnt Meadow Brook	2030103070040	12.1
Wanaque Reservior (below Monks gage)	2030103070050	12.2
Meadow Brook/High Mountain Brook	2030103070060	10.6
Wanaque R/Posts Bk (below reservior)	2030103070070	10.4
Ramapo R (above 74d 11m 00s)	2030103100010	12.1
Masonicus Brook	2030103100020	7.7
Ramapo R (above Fyke Bk to 74d 11m 00s)	2030103100030	11.2
Ramapo R (Bear Swamp Bk thru Fyke Bk)	2030103100040	12.7
Ramapo R (Crystal Lk br to BearSwamp Bk)	2030103100050	11.7
Crystal Lake/Pond Brook	2030103100060	9.1
Ramapo R (below Crystal Lake bridge)	2030103100070	9.1
Lincoln Park tribs (Pompton River)	2030103110010	8.8
Pompton River	2030103110020	7.0
Hohokus Bk (above Godwin Ave)	2030103140010	9.4
Hohokus Bk(Pennington Ave to Godwin Ave)	2030103140020	8.2

HUC14 Name	HUC14 Number	Drought Recharge Rate (inches/year)
Saddle River (above Rt 17)	2030103140040	8.8
Drakes Brook (above Eyland Ave)	2030105010010	9.5
Drakes Brook (below Eyland Ave)	2030105010020	9.0
Raritan River SB(above Rt 46)	2030105010030	9.4
Raritan River SB(74d 44m 15s to Rt 46)	2030105010040	9.5
Raritan R SB(LongValley br to 74d44m15s)	2030105010050	10.4
Raritan R SB(Califon br to Long Valley)	2030105010060	10.9
Raritan R SB(StoneMill gage to Califon)	2030105010070	11.6
Raritan R SB(Spruce Run-StoneMill gage)	2030105010080	10.4
Spruce Run (above Glen Gardner)	2030105020010	11.0
Spruce Run (Reservior to Glen Gardner)	2030105020020	11.3
Mulhockaway Creek	2030105020030	9.5
Spruce Run Reservior / Willoughby Brook	2030105020040	10.5
Beaver Brook (Clinton)	2030105020050	9.5
Cakepoulin Creek	2030105020060	7.9
Raritan R SB(River Rd to Spruce Run)	2030105020070	9.0
Raritan R SB(Prescott Bk to River Rd)	2030105020080	10.0
Prescott Brook / Round Valley Reservior	2030105020090	10.2
Pleasant Run	2030105040020	8.4
Holland Brook	2030105040030	8.2
Lamington R (above Rt 10)	2030105050010	9.2
Lamington R (Hillside Rd to Rt 10)	2030105050020	10.5
Lamington R (Furnace Rd to Hillside Rd)	2030105050030	10.6
Lamington R(Pottersville gage-FurnaceRd)	2030105050040	11.0
Pottersville trib (Lamington River)	2030105050050	10.8
Cold Brook	2030105050060	9.6
Lamington R(HallsBrRd-Pottersville gage)	2030105050070	9.6
Rockaway Ck (above McCrea Mills)	2030105050080	10.9
Rockaway Ck (RockawaySB to McCrea Mills)	2030105050090	9.1
Rockaway Ck SB	2030105050100	9.3
Lamington R (below Halls Bridge Rd)	2030105050110	8.1
Raritan R NB (above/incl India Bk)	2030105060010	10.4
Burnett Brook (above Old Mill Rd)	2030105060020	11.0
Raritan R NB(incl McVickers to India Bk)	2030105060030	10.7
Raritan R NB(Peapack Bk to McVickers Bk)	2030105060040	10.4
Peapack Brook (above/incl Gladstone Bk)	2030105060050	10.2
Peapack Brook (below Gladstone Brook)	2030105060060	9.5
Raritan R NB(incl Mine Bk to Peapack Bk)	2030105060070	9.7
Middle Brook (NB Raritan River)	2030105060080	8.8
Raritan R NB (Lamington R to Mine Bk)	2030105060090	7.9
Raritan R NB (Rt 28 to Lamington R)	2030105070010	7.6
Middle Brook EB	2030105120050	8.4

HUC14 Name	HUC14 Number	Drought Recharge Rate (inches/year)
Middle Brook WB	2030105120060	7.8
Lafayette Swamp tribs	2040105040040	8.3
Sparta Junction tribs	2040105040050	8.4
Paulins Kill (above Rt 15)	2040105040060	6.9
Paulins Kill (Blairstown to Stillwater)	2040105050010	8.1
Delawanna Creek (incl UDRV)	2040105060020	8.5
Lake Lenape trib	2040105070010	8.9
New Wawayanda Lake/Andover Pond trib	2040105070020	8.6
Pequest River (above Brighton)	2040105070030	8.1
Pequest River (Trout Brook to Brighton)	2040105070040	8.5
Trout Brook/Lake Tranquility	2040105070050	9.1
Pequest R (below Bear Swamp to Trout Bk)	2040105070060	8.3
Bear Brook (Sussex/Warren Co)	2040105080010	7.9
Bear Creek	2040105080020	8.5
Pequest R (Drag Strip--below Bear Swamp)	2040105090010	9.0
Pequest R (Cemetary Road to Drag Strip)	2040105090020	9.3
Pequest R (Furnace Bk to Cemetary Road)	2040105090030	9.7
Mountain Lake Brook	2040105090040	9.2
Furnace Brook	2040105090050	9.0
Pequest R (below Furnace Brook)	2040105090060	8.3
Union Church trib	2040105100010	8.6
Honey Run	2040105100020	8.7
Beaver Brook (above Hope Village)	2040105100030	8.4
Beaver Brook (below Hope Village)	2040105100040	8.6
Pophandusing Brook	2040105110010	8.4
Buckhorn Creek (incl UDRV)	2040105110020	8.1
UDRV tribs (Rt 22 to Buckhorn Ck)	2040105110030	7.0
Lopatcong Creek (above Rt 57)	2040105120010	7.7
Lopatcong Creek (below Rt 57) incl UDRV	2040105120020	5.6
Pohatcong Creek (above Rt 31)	2040105140010	9.7
Pohatcong Ck (Brass Castle Ck to Rt 31)	2040105140020	8.5
Pohatcong Ck (Edison Rd-Brass Castle Ck)	2040105140030	8.1
Merrill Creek	2040105140040	8.1
Pohatcong Ck (Merrill Ck to Edison Rd)	2040105140050	8.0
Pohatcong Ck (Springtown to Merrill Ck)	2040105140060	6.9
Pohatcong Ck(below Springtown) incl UDRV	2040105140070	6.2
Weldon Brook/Beaver Brook	2040105150010	10.7
Lake Hopatcong	2040105150020	8.7
Musconetcong R (Wills Bk to LkHopatcong)	2040105150030	8.8
Lubbers Run (above/incl Dallis Pond)	2040105150040	9.3
Lubbers Run (below Dallis Pond)	2040105150050	9.4
Cranberry Lake / Jefferson Lake & tribs	2040105150060	8.8

HUC14 Name	HUC14 Number	Drought Recharge Rate (inches/year)
Musconetcong R(Waterloo to/incl WillsBk)	2040105150070	8.8
Musconetcong R (SaxtonFalls to Waterloo)	2040105150080	10.7
Mine Brook (Morris Co)	2040105150090	9.9
Musconetcong R (Trout Bk to SaxtonFalls)	2040105150100	9.3
Musconetcong R (Hances Bk thru Trout Bk)	2040105160010	9.6
Musconetcong R (Changewater to HancesBk)	2040105160020	10.5
Musconetcong R (Rt 31 to Changewater)	2040105160030	9.3
Musconetcong R (75d 00m to Rt 31)	2040105160040	9.4
Musconetcong R (I-78 to 75d 00m)	2040105160050	8.9
Musconetcong R (Warren Glen to I-78)	2040105160060	7.8
Musconetcong R (below Warren Glen)	2040105160070	6.8
Holland Twp (Hakihokake to Musconetcong)	2040105170010	7.1
Hakihokake Creek	2040105170020	7.6
Harihokake Creek (and to Hakihokake Ck)	2040105170030	8.2
Nishisakawick Creek (above 40d 33m)	2040105170040	8.2
Nishisakawick Creek (below 40d 33m)	2040105170050	7.5

Generally, base flow separation techniques attempt to separate the stream flow hydrograph into separate components, including surface runoff and "ground water runoff." This is done using graphical techniques, wherein the start of the ascending limb of the stream hydrograph is projected under the final peak in the stream flow curve for each precipitation event, based upon some time interval assumed to represent the duration of overland flow after each event. The sequence of connecting these lines produces a separate curve beneath the stream hydrograph, the base flow hydrograph. The area under the base flow hydrograph defines the base flow volume and rate. Numerous techniques have been developed e.g., fixed interval, sliding interval, local minimum, etc. USGS used a sliding-interval methodology for their input into the 1996 New Jersey Statewide Water Supply Plan, however, they have since abandoned that method. Prior to the development of GSR-32, the NJ Geological Survey utilized the Posten hydrograph separation method for their carrying capacity analyses. The Posten method was selected for this analysis because, like GSR-32, it is based upon conditions specific to New Jersey. Posten's analyses were focused in northern New Jersey geologic provinces, making it more appropriate for use in the Highlands and less likely to overestimate recharge. In addition, like GSR-32, the Posten Method has gone through an extensive peer-review process prior to publication.

In order to consider the drought of record, flow data from USGS gauging stations in the Highlands for this period were analyzed. The USGS gauging stations selected were based on the following criteria:

1) The majority of their watershed derives from the Highlands Preservation and Planning areas.
2) They generally lack significant control of their flow (e.g. manmade impoundments).
3) The hydrogeology of the watershed does not give rise to significant questions about the presence of ground water interflow (i.e. low permeability lenses above the water table that preclude recharge).

The result of the base flow separation analysis was an average annual recharge value of 10.2 inches/year for the drought of record. This value is highly supportive of the GSR-32 results obtained by both the NJ Geological Survey and the NJ Water Supply Authority.

ESTABLISHING TARGET NITRATE CONCENTRATIONS

Computing appropriate septic system density (i.e. lot size) requires input of a target nitrate concentration into the Trela-Douglas model. The target concentration represents the nitrate protection standard that the Highlands Council has established for the Protection and Conservation Zones within the Planning Area of the Region. A number of different options were investigated for establishing the nitrate standards for these two zones.

The NJDEP, in establishing target nitrate concentrations in forested and non-forested areas within the Highlands Preservation Area, considered a number of different peer-reviewed data sources. For determining the target nitrate concentration for non-forested areas (i.e. mixed land uses), they selected the NJ Geological Survey report aimed at establishing baseline water quality in the New Jersey Highlands (Serfes, 2004), which provided the most conservative (i.e. lowest) value. According to the study, based upon results from 45 water samples collected from noncarbonated bedrock of northern New Jersey, the median nitrate concentration was 0.76 mg/L. The median value, rather than the mean, was selected as representing the "central tendency" of the data, as it minimizes the effect of extreme outliers that skew the mean.

To assess nitrate levels under conditions that best represent *pristine* in contemporary terms, seven monitoring wells from the USGS QWDATA database that are located within the Highlands and surrounded by a 500-meter circular buffer that consists of at least 90% forest + wetlands + water, or conversely, less than 10% urban, agricultural, or barren land use, were identified. Although a low sample number, the 0.21 mg/L median nitrate concentration value for the seven monitoring wells is in close agreement with "background" surface water concentrations measured within the Highlands (a maximum nitrate concentration of 0.17 mg/L measured out of 20 samples collected from 1997-2002). The 0.21 mg/L is also in close agreement with the USEPA's Ambient Water Quality Criteria Recommendations (2001) manual for establishing a reference condition, which computed to 0.16 mg/L throughout sub-ecoregion 58, which consists of the Northern Highlands, including New Jersey/New York Highlands, as well as portions of Pennsylvania and states of the New England Highlands: Connecticut, Massachusetts, Vermont, New Hampshire, and Maine. In addition, the 0.17 mg/L value is in very close agreement with the 0.12 to 0.14 mg/L median nitrate concentration range estimated by USGS for undeveloped conditions using the logistic regression models.

In establishing the target nitrate concentrations for the Protection and Conservation Zones within the Planning Area, subwatershed median nitrate concentrations estimated with the logistic regression models calibrated to the 2002 water quality data were used. Several different approaches were investigated for establishing nitrate target concentrations with this data. As part of the process, it was recognized that the Conservation and Protection Zones should, by the nature of their markedly different land use characteristics, have different target nitrate concentrations. The data, when segregated by subwatershed, that are dominantly comprised of a particular zone clearly demonstrate statistical differences in median nitrate concentrations, as would be expected for different land use activities; for example, agricultural areas with high fertilizer loadings characteristic of the Conservation Zone generally have higher median nitrate concentrations than undeveloped areas characteristic of the Protection Zone.

Subwatersheds within the Protection and Conservation Zones that are primarily located within the Planning Area were identified, defined as any subwatershed that is more than 50% Planning Area (of the portion of its land located within the Highlands Region). Subwatersheds were identified as "dominantly" Protection or Conservation Zone if its total area within the Highlands Region was greater than 75% for the particular zone. For subwatersheds where no zone dominated, the Watershed Resource Value indicator was used (similar to the net water availability analysis, see Volume II of the Water Resources Technical Report), where "high" and "medium" values qualify the subwatersheds as Protection and Conservation Zones, respectively.

Because there is a fairly wide distribution of median nitrate concentrations even within a particular LUC Zone (for example, for the Conservation Zone median nitrate concentrations ranged from 0.44 to 3.08 mg/L), a bifurcation method was investigated. The method attempted to establish subwatershed specific target nitrate concentration that account for existing water quality conditions, as reflected by the median nitrate concentration estimated for each individual subwatersheds. The methodology would establish both a water quality goal concentration and a default target nitrate concentration value for each zone. A default value is necessary, given that the existing median nitrate concentration for some subwatersheds would invariably exceed any reasonable water quality goal. For example, the NJDEP has established a state-wide nitrate concentration target of 2.0 mg/L; accordingly, the water quality goals for the Protection and Conservation Zones could not exceed this value. However, there are a number of subwatersheds with median nitrate concentration estimates that already exceed the 2.0 mg/L state-wide target. The water quality goals and default values, then, are constrained by the need to be consistent with nitrate concentration targets and standards; they cannot be more stringent than the Preservation Area target concentrations or less stringent than the state-wide 2.0 mg/L target. At the same time, the water quality goal must be selected such that the default value is not excessively triggered, in effect becoming a de facto water quality goal, which would occur with lower water quality goals (i.e. the estimated median nitrate concentration of most subwatersheds would exceed the goal). After much analysis, a necessary balance between appropriate water quality goals and non-excessive triggering of an associated default value could not be achieved, and the method was rejected.

It was decided that the target nitrate concentrations for the Protection and Conservation Zones would be the estimated median nitrate concentration for the particular LUC Zone. This median-based target is consistent with how NJDEP established target nitrate concentrations for forested and non-forested areas within the Highlands Preservation area (0.21 and 0.76 mg/L, respectively), and how they developed the state-wide 2.0 mg/L target. Because the median nitrate concentrations were estimated only at the subwatershed scale, and not for specific zones (e.g. Protection), all subwatersheds primarily comprised of Planning Area and identified as dominantly one of the two Zones (i.e. Protection and Conservation) were included in the statistical sample for computing the median nitrate concentrations for the two Zones.

The tables *Median Nitrate Concentrations for HUC14 Subwatersheds that are Dominantly Protection Zone* and *Median Nitrate Concentrations for HUC14 Subwatersheds that are Dominantly Conservation Zone* list the different subwatersheds that apply for the Protection and Conservation Zones, respectively, along with their corresponding median nitrate concentrations estimated by logistic regression. Note that the Papakating Creek subwatershed was excluded, as only 2200 ft^2 of its area resides within the Highlands Region, and consequently, was not considered sufficient to justify its inclusion for characterizing water quality conditions within the Region. Based upon the data, the two median nitrate concentrations for the Protection and Conservation Zones is 0.72 and 1.87 mg/L, respectively, which were used as the target nitrate concentrations. This method was the basis for nitrate targets in the Protection and Conservation Zones of the Planning Area.

For the Existing Community Zone, the NJDEP 2.0 mg/L state-wide target was selected. Although this does not represent the median nitrate value of 1.17 mg/L of this LUC Zone, it is appropriate that the anti-degradation standard reflect both of the goals and standards associated with the Existing Community Zone, as well as the state-wide ground water quality standard. It would be inconsistent with the zone standards to have the Existing Community Zone standard more stringent than the Conservation Zone, where more environmentally

Median Nitrate Concentrations for HUC14 Subwatersheds that are Dominantly Protection Zone

Subwatershed Name	HUC14 Number	Median Nitrate Concentration (mg/L)
Pequest R (below Bear Swamp to Trout Bk)	02040105070060	0.36
Pequest R (Drag Strip--below Bear Swamp)	02040105090010	0.36
Green Pond Brook (below Burnt Meadow Bk)	02030103030060	0.40
Black Brook (Great Swamp NWR)	02030103010060	0.44
Passaic R Upr (Pompton R to Pine Bk)	02030103040010	0.46
Trout Brook/Lake Tranquility	02040105070050	0.46
Great Brook (below Green Village Rd)	02030103010050	0.47
Wallkill River(Owens gage to 41d13m30s)	02020007030030	0.48
Lake Lenape trib	02040105070010	0.48
Prescott Brook / Round Valley Reservior	02030105020090	0.50
Whippany R (Wash. Valley Rd to 74d 33m)	02030103020020	0.52
Black Ck(above/incl G.Gorge Resort trib)	02020007040010	0.56
Black Creek (below G. Gorge Resort trib)	02020007040020	0.57
Union Church trib	02040105100010	0.59
Bear Creek	02040105080020	0.60
Musconetcong R(Waterloo to/incl WillsBk)	02040105150070	0.61
Primrose Brook	02030103010020	0.62
Paulins Kill (Blairstown to Stillwater)	02040105050010	0.63
Passaic R Upr (Plainfield Rd to Dead R)	02030103010110	0.65
Dead River (below Harrisons Brook)	02030103010100	0.69
Wallkill R(Hamburg SW Bdy to Ogdensburg)	02020007010040	0.70
Wallkill R(Martins Rd to Hamburg SW Bdy)	02020007010070	0.70
Whippany R (above road at 74d 33m)	02030103020010	0.71
Montville tribs.	02030103030160	0.72
Pequest River (above Brighton)	02040105070030	0.72
Middle Brook WB	02030105120060	0.74
Raritan R NB(Peapack Bk to McVickers Bk)	02030105060040	0.76
Drakes Brook (above Eyland Ave)	02030105010010	0.79
Sparta Junction tribs	02040105040050	0.79
Raritan R NB(incl McVickers to India Bk)	02030105060030	0.81
Wallkill R(41d13m30s to Martins Road)	02020007030010	0.83
Passaic R Upr (above Osborn Mills)	02030103010010	0.83
Pequest R (Cemetary Road to Drag Strip)	02040105090020	0.84
Lafayette Swamp tribs	02040105040040	0.86
Holland Twp (Hakihokake to Musconetcong)	02040105170010	0.88
Beaver Run	02020007010060	0.89
Lincoln Park tribs (Pompton River)	02030103110010	0.89
Rockaway Ck (RockawaySB to McCrea Mills)	02030105050090	0.89
Beaver Brook (above Hope Village)	02040105100030	0.98
Pequest R (below Furnace Brook)	02040105090060	1.00
Delawanna Creek (incl UDRV)	02040105060020	1.08
Honey Run	02040105100020	1.08
Hakihokake Creek	02040105170020	1.13
Lamington R (below Halls Bridge Rd)	02030105050110	1.20
Beaver Brook (below Hope Village)	02040105100040	1.27
Holland Brook	02030105040030	1.72

Median Nitrate Concentrations for HUC14 Subwatersheds that are Dominantly Conservation Zone

Subwatershed Name	HUC14 Number	Median Nitrate Concentration (mg/L)
Troy Brook (below Reynolds Ave)	02030103020090	0.44
Burnett Brook (above Old Mill Rd)	02030105060020	0.82
Raritan R NB (above/incl India Bk)	02030105060010	0.86
Paulins Kill (above Rt 15)	02040105040060	0.90
Bear Brook (Sussex/Warren Co)	02040105080010	1.02
Peapack Brook (below Gladstone Brook)	02030105060060	1.15
Lamington R(HallsBrRd-Pottersville gage)	02030105050070	1.24
Raritan R NB (Rt 28 to Lamington R)	02030105070010	1.29
Pequest River (Trout Brook to Brighton)	02040105070040	1.36
Raritan R NB (Lamington R to Mine Bk)	02030105060090	1.57
Pophandusing Brook	02040105110010	1.72
Beaver Brook (Clinton)	02030105020050	1.74
Pohatcong Ck (Merrill Ck to Edison Rd)	02040105140050	1.87
Harihokake Creek (and to Hakihokake Ck)	02040105170030	1.88
Pleasant Run	02030105040020	1.90
Musconetcong R (I-78 to 75d 00m)	02040105160050	1.95
Cold Brook	02030105050060	1.98
Nishisakawick Creek (below 40d 33m)	02040105170050	1.99
UDRV tribs (Rt 22 to Buckhorn Ck)	02040105110030	2.01
Middle Brook (NB Raritan River)	02030105060080	2.03
Musconetcong R (Rt 31 to Changewater)	02040105160030	2.03
Musconetcong R (75d 00m to Rt 31)	02040105160040	2.05
Nishisakawick Creek (above 40d 33m)	02040105170040	2.62
Cakepoulin Creek	02030105020060	2.74
Pohatcong Ck (Springtown to Merrill Ck)	02040105140060	3.08

sensitive resources are located. Finally, the Existing Community Zone boundary was partly generated using utility infrastructure service areas such as public water and sewer. The use of new septic systems as a wastewater alternative will be limited to specific projects, such as in-fill, in this zone. The table Nitrate Dilution Targets for Various Areas within the Highlands Region is shown again displaying the nitrate targets for the different zone of the Highlands Region.

Nitrate Dilution Targets for Various Areas within the Highlands Region

Highlands Area/Zone	**Nitrate Dilution Target (mg/L)***
Preservation Forested Area	0.21
Preservation Non-Forested Area	0.76
Planning Area Protection Zone	0.72
Planning Area Conservation Zone	1.87
Planning Area Existing Community Zone	2.0

FINAL FORM OF TRELA-DOUGLAS NITRATE DILUTION MODEL

In accordance with the estimated nitrate loading per person, number of occupants per dwelling on septic, and the established target nitrate concentrations, the final form of the Trela-Douglas nitrate dilution model for the Protection, Conservation, and Existing Community Zones, respectively, are:

Septic System Density (acres) = [4.41 × (10 lbs nitrate/person/septic) × 4 persons/septic)] ÷ [(0.72 mg/L × HUC14 annual drought recharge rate in inches)] **(Protection Zone)** (12)

Septic System Density (acres) = [4.41 × (10 lbs nitrate/person/septic) × 4 persons/septic)] ÷ [(1.87 mg/L × HUC14 annual drought recharge rate in inches)] **(Conservation Zone)** (13)

Septic System Density (acres) = [4.41 × (10 lbs nitrate/person/septic) × 4 persons/septic)] ÷ [(2.0 mg/L × HUC14 annual drought recharge rate in inches)] **(Existing Community Zone)** (14)

The 4.41 constant is a conversion factor for the mixed units, and converts the computed septic system density into acres per septic system.

The estimated septic system densities were computed by LUC Zone for each subwatershed using the drought recharge values. The maximum septic system densities (minimum average lot sizes) calculated for the 183 subwatersheds for the Protection, Conservation, and Existing Community Zones are 19.1, 7.4, and 6.9 acres per septic system, respectively, while the maximum sized lots for these LUC Zones are 106.4, 41.0, and 38.3 acres, respectively. The median densities for the Protection, Conservation, and Existing Community Zones are 26.1, 10.0, and 9.4 acres per septic system, respectively. Note that these densities are not applicable to subwatershed areas located within the Preservation Area; these lands are subject to the 88 and 25 acre per septic system densities computed for the forested and non-forested areas, respectively.

In using the Trela-Douglas model for calculating septic system densities in the forested and non-forested areas of the Preservation area, the NJDEP also assumed the 40 pounds per year nitrate loading value. Rather than using subwatershed specific recharge values, they used the area weighted annual drought recharge rate of 9.8 inches/year for the entire Highlands region. They also assumed a 3% impervious cover for each lot, which slightly changes the 4.41 conversion factor (4.56). The nitrate dilution targets used by the NJDEP for the forested and non-forested areas, 0.21 and 0.76 mg/L respectively, yielded the densities of 88 and 25 acres per septic system, respectively.

CALCULATING MUNICIPAL SEPTIC SYSTEM YIELD

Following computation of the septic system densities for the Protection, Conservation, and Existing Community Zones within each subwatershed's Planning Area using the Trela-Douglas model, septic system yield was computed based upon the existing developable land area within each zone of the subwatershed.

The developable land area for septic system units within the Highlands consists of two general classes of land: undeveloped parcels and over-sized parcels (underdeveloped). Assuming they have sufficient land area, these parcels have the potential to accommodate an additional septic system(s) if subdivided.

<u>Developable acreage includes:</u>

Undeveloped lots
Oversized lots (residential lots greater in size than the calculated septic system density)

<u>Developable acreage excludes:</u>

Condos
Preserved open space (i.e. public lands)
Existing sewer areas/approved sewer service areas for Existing Community Zone.

Undeveloped lands were defined using the following MODIV property class combinations:

1 (vacant), including lots with any other property class
3B (Farm Qualified) only

Oversized lots were defined using the following MODIV property class combinations:

2 (Residential) only
2 (Residential) and 3B only
3A (Farm Regular) and 3B only

For computing the available area of over-sized lots, these lots were first identified within each subwatershed/zone as those parcels with acreage at least equal to the area of its corresponding septic system lot size, as computed by the Trela-Douglas model. Following identification of all oversized lots, their cumulative area in acres was summed for each zone and municipality. For each municipality and zone, the number of oversized lots was multiplied by its corresponding septic system lot size. This product was then subtracted from the cumulative area of oversized lots within the municipal zone to account for the assumed existing septic system area, yielding the net oversized developable land available for additional septic systems within each zone for each municipality. The undeveloped acreage was quantified for each zone and municipality with GIS analysis of the MODIV property class combinations, as specified above. The net developable land was then computed as the sum of the total undeveloped land and the net oversized developable land for each zone per municipality.

The number of additional allowable new septic systems for each zone per municipality was then computed from the corresponding net developable land with the following equation:

Number of Additional Allowable New Septic Systems = (Net Developable Land Area) ÷ (Septic System Density as computed by Trela-Douglas Nitrate Dilution Model) (15)

The computed number of allowable new septic systems will almost always have a fractional component (e.g. 23.4 septic systems). Because there can be no partial septic system unit, the computed number of allowable new septic systems was rounded down to the nearest whole number.

The total number of additional septic systems for each Land Use Capability zone within the Planning area is summarized on the table below;

Additional Septic Systems For Each LUC Zone Within The Planning Area

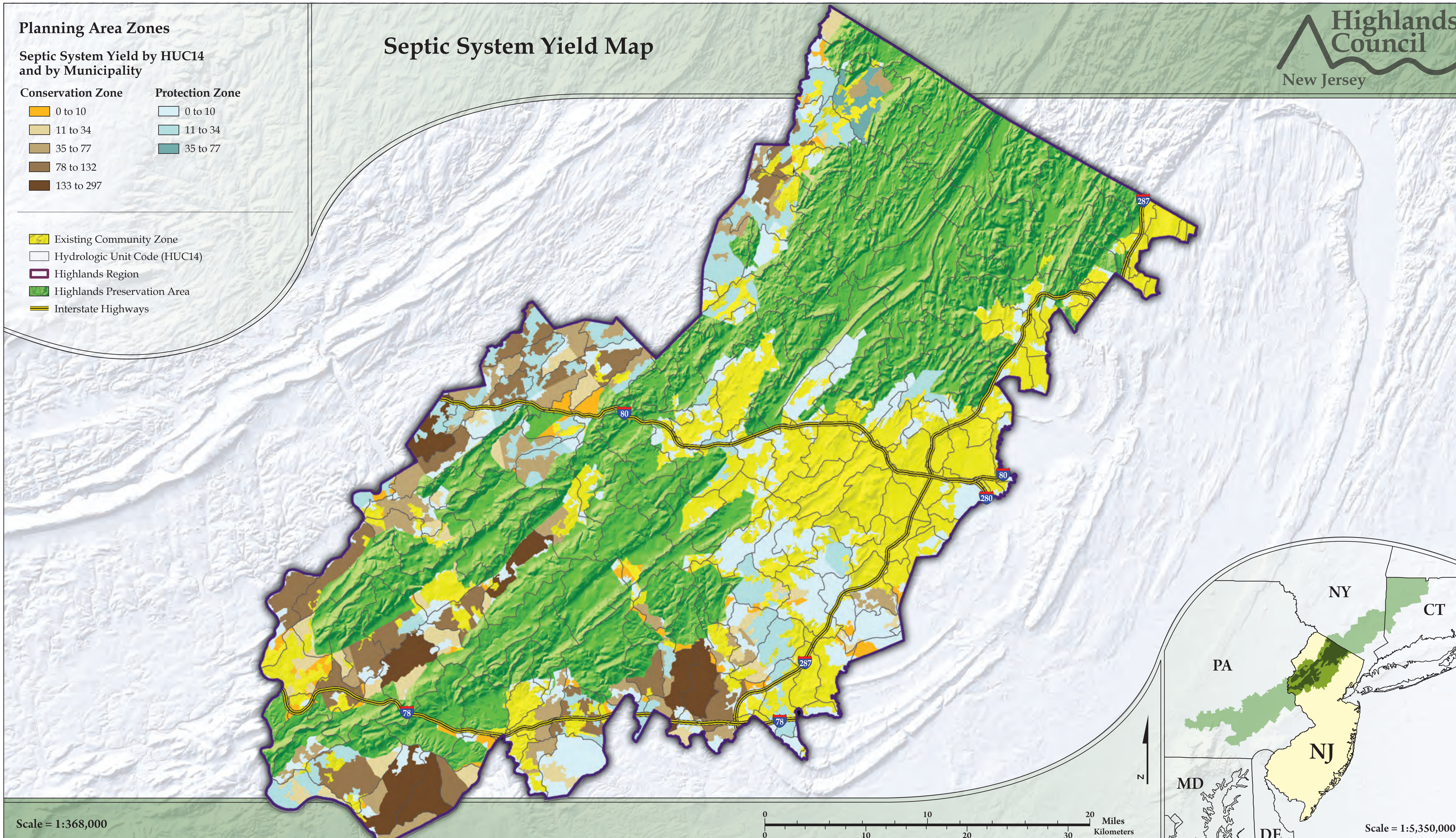
Land Use Capability Zone	Number of Additional Septic Systems
Conservation Zone	5,476
Protection Zone	1,068
Existing Community Zone	920

Breakdowns of septic system yields by municipality within the Planning Area are shown on the table *Septic System Yields by Municipality and Zone within the Planning Area.* The figure *Septic System Yield Map* displays the results for the Protection Zone and Conservation Zone. The total combined number of additional allowable septic system units within the Protection and Conservation Zones is 6,544. The septic system yield shown for the Existing Community Zone is based in part of the current mapping of areas served by wastewater. As municipalities and counties revise their Wastewater Management Plans and include areas into their sewer service areas, the area available for septic systems in the Existing Community Zone will likely be reduced. Hence, the septic system yield reported will also decrease. Because septic systems in the Existing Community Zone are approved on a project-by-project basis, they are reported only to give a relative comparison and should not be used for planning purposes.

Septic System Yields by Municipality and Zone within the Planning Area			
MUNICIPALITY	Conservation Zone	Protection Zone	Existing Community Zone (no EAS)
MAHWAH TOWNSHIP	0	0	35
OAKLAND BOROUGH	0	0	6
ALEXANDRIA TOWNSHIP	477	4	0
BETHLEHEM TOWNSHIP	14	0	0
CLINTON TOWN	0	2	6
CLINTON TOWNSHIP	262	24	31
HAMPTON BOROUGH	7	0	0
HIGH BRIDGE BOROUGH	0	0	14
HOLLAND TOWNSHIP	234	34	1
LEBANON BOROUGH	1	0	4
LEBANON TOWNSHIP	0	0	0
MILFORD BOROUGH	2	2	1
TEWKSBURY TOWNSHIP	238	36	0
UNION TOWNSHIP	26	3	3
BOONTON TOWN	0	0	1
BOONTON TOWNSHIP	0	34	15
BUTLER BOROUGH	0	0	8
CHESTER BOROUGH	0	0	1
CHESTER TOWNSHIP	0	8	1
DENVILLE TOWNSHIP	0	6	57
DOVER TOWN	0	0	0
HANOVER TOWNSHIP	0	8	54
HARDING TOWNSHIP	71	21	3
JEFFERSON TOWNSHIP	0	2	8
KINNELON BOROUGH	0	1	0
MENDHAM BOROUGH	34	12	10
MENDHAM TOWNSHIP	33	38	9
MINE HILL TOWNSHIP	0	12	17
MONTVILLE TOWNSHIP	0	10	51
MORRIS TOWNSHIP	0	21	16
MORRIS PLAINS BOROUGH	0	0	0
MORRISTOWN TOWN	0	0	1
MOUNTAIN LAKES BOROUGH	0	0	2
MOUNT ARLINGTON BOROUGH	0	7	4
MOUNT OLIVE TOWNSHIP	0	10	26
NETCONG BOROUGH	0	0	4
PARSIPPANY-TROY HILLS TOWN	0	7	62
PEQUANNOCK TOWNSHIP	0	2	14
RANDOLPH TOWNSHIP	0	16	54
RIVERDALE BOROUGH	0	5	11

MUNICIPALITY	Conservation Zone	Protection Zone	Existing Community Zone (no EAS)
ROCKAWAY BOROUGH	0	0	8
ROCKAWAY TOWNSHIP	0	14	72
ROXBURY TOWNSHIP	0	36	59
VICTORY GARDENS BOROUGH	0	0	0
WASHINGTON TOWNSHIP	48	5	3
WHARTON BOROUGH	0	0	12
BLOOMINGDALE BOROUGH	0	0	1
POMPTON LAKES BOROUGH	0	0	3
WANAQUE BOROUGH	0	3	2
BEDMINSTER TOWNSHIP	559	9	3
BERNARDS TOWNSHIP	0	23	35
BERNARDSVILLE BOROUGH	38	30	13
FAR HILLS BOROUGH	69	2	3
PEAPACK GLADSTONE BOROU	78	12	14
BYRAM TOWNSHIP	0	1	0
FRANKLIN BOROUGH	37	13	15
GREEN TOWNSHIP	238	40	9
HAMBURG BOROUGH	0	0	5
HARDYSTON TOWNSHIP	241	39	21
HOPATCONG BOROUGH	0	32	6
OGDENSBURG BOROUGH	0	7	0
SPARTA TOWNSHIP	81	89	23
STANHOPE BOROUGH	0	6	3
VERNON TOWNSHIP	98	80	8
ALLAMUCHY TOWNSHIP	94	18	1
ALPHA BOROUGH	10	1	1
BELVIDERE TOWN	0	0	1
FRANKLIN TOWNSHIP	423	39	0
FRELINGHUYSEN TOWNSHIP	377	67	0
GREENWICH TOWNSHIP	185	0	5
HACKETTSTOWN TOWN	0	6	8
HARMONY TOWNSHIP	219	5	0
HOPE TOWNSHIP	360	59	0
INDEPENDENCE TOWNSHIP	137	46	1
LIBERTY TOWNSHIP	13	0	0
LOPATCONG TOWNSHIP	32	0	1
MANSFIELD TOWNSHIP	187	4	9
OXFORD TOWNSHIP	42	7	4
PHILLIPSBURG TOWN	1	0	2
POHATCONG TOWNSHIP	20	0	1
WASHINGTON BOROUGH	0	2	5

MUNICIPALITY	Conservation Zone	Protection Zone	Existing Community Zone (no EAS)
WASHINGTON TOWNSHIP	185	20	31
WHITE TOWNSHIP	305	28	2
Totals	5476	1068	920



Septic System Yield Map
Planning Area Zones
Septic System Yield by HUC14 and by Municipality
Conservation Zone
0 to 10
11 to 34
35 to 77
78 to 132
133 to 297
Protection Zone
0 to 10
11 to 34
35 to 77
Existing Community Zone
Hydrologic Unit Code (HUC14)
Highlands Region
Highlands Preservation Area
Interstate Highways
Highlands Council
New Jersey
287
80
280
78
NY
CT
PA
NJ
MD
DE
N
Scale = 1:368,000
0
10
20
Miles
0
10
20
30
Kilometers
Scale = 1:5,350,000

SUPPORTING INFORMATION

Acknowledgements
Glossary
References
Appendices

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GLOSSARY

Benthic Macroinvertebrate – An animal lacking a backbone or internal skeleton which lives on or near the bottom of a body of water (for example, crayfish, mayflies, and nymphs). Because they spend their entire lifecycle in water, they are good indicators of the health of that water body.

Hydrologic Unit Code – Hydrologic Unit Code (HUC) means an area within which water drains to a particular receiving surface-water body, which is identified by a specific digit number, or "hydrologic unit code." The HUC codes were developed by the U.S. Geological Survey. *N.J.A.C. 7:38-1.4.*

HUC14 – An area within which water drains to a particular receiving surface-water body, which is identified by a fourteen-digit number, or "hydrologic unit code." In New Jersey, a HUC14 correlates to a subwatershed. *N.J.A.C. 7:38-1.4.*

Impaired Waters – Surface waters that are negatively impacted by pollution, resulting in decreased water quality. Under the Clean Water Act, this term refers to waters polluted to a level that no longer fully supports the uses (such as boating, swimming or drinking water) designated by a state for that particular body of water.

Multivariate – Term that describes statistical, mathematical, or graphical techniques that consider multiple variables simultaneously

Logistic Regression - a statistical technique that predicts the probability of a dichotomous dependent variable (e.g., dead or alive) using, typically, a combination of continuous and categorical independent variables.

Low Impact Development (LID) Best Management Practices – Low Impact Development is an environmentally sensitive approach to storm water management that emphasizes conservation and the use of existing natural site features integrated with distributed, small scale storm water controls to more closely mimic natural hydrologic patterns in residential, commercial and industrial settings. LID best management practices involve comprehensive land planning and engineering design to maintain and enhance the hydrologic regime of urban lands and development within watersheds. LID standards and best management practices are supported by the New Jersey Storm water Management Rules, N.J.A.C. 7:8 and the "New Jersey Storm water Best Management Practices Manual" developed by the New Jersey Department of Environmental Protection, in coordination with the New Jersey Department of Agriculture, the New Jersey Department of Community Affairs, the New Jersey Department of Transportation, municipal engineers, county engineers, consulting firms, contractors, and environmental organizations.

MOD-IV - a system used by the New Jersey Division of Taxation to provide for the uniform preparation, maintenance, presentation, and storage of property tax information

Non-Point Source Pollution – Pollution generated by diffuse land use activities rather than from an identifiable or discrete facility. It is conveyed to waterways through natural processes, such as rainfall, storm runoff, or groundwater seepage rather than by deliberate discharge. source pollution is not generally corrected by "end-of-pipe" treatment, but rather, by changes in land management practices.

Total Maximum Daily Load (TMDL) - A TMDL defines the pollutant load that a water body can assimilate without causing violations of water quality standards, and allocates the loading between contributing point sources and source categories.

Watershed - A watershed describes an area of land that drains downslope to the lowest point. Water moves through a network of drainage pathways, both underground and on the surface, and these pathways converge into streams and rivers, which become progressively larger (i.e., higher order) as the water moves downstream and the size of the contributing drainage area increases. Because water moves downstream, any activity that affects the water quality, quantity, or rate of movement at one location can affect locations downstream.

REFERENCES

Aitchison, J., 1986. The Statistical Analysis of Compositional Data, Chapman and Hall, NY, 416 pp.

Anderson, James R., Ernest E. Hardy, John T. Roach, and Richard E. Witmer, 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data. U.S. Geological Survey Professional Paper 964, Reston, VA.

Annear, T., et al (2004). Instream Flows for Riverine Resource Stewardship, revised edition. Instream Flow Council.

ArcGIS, ESRI, Redlands, CA, 2004. Geoprocessing in ArcGIS, 368 pp.

Ayers, Mark A., Wolock, David M., McCabe, Gregory J., Hay, Laurene E., and Tasker, Gary D. 1994. Sensitivity of Water Resources in the Delaware River Basin to Climate Variability and Change. USGS Water Supply Paper 2422.

Barbour, M.T., et al (1999). Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water.

Baron, J., et al (2002). Meeting Ecological and Societal Needs for Freshwater, Ecological Applications, 12(5), pp. 1247-1260, Ecological Society of America.

Bell, Christy, Litt, Barbara, Moser, Fredrika, and Uptegrove, Jane, 1992, Influence of geology on radon in ground-water supplies of New Jersey's Reading Prong: Research project summary, New Jersey Department of Environmental Protection and Energy.

Big Hole River Foundation (2005). Restoring Grayling: The Importance of the "Wetted P", Spring Newsletter at: http://www.bhrf.org/Spring%202005%20Newsletter.htm

Bisese, J.A., 1995, Methods for estimating the magnitude and frequency of peak discharges of rural, unregulated streams in Virginia: U.S. Geological Survey Water Resources Investigations, Report 94-4148, 70 p., 1 plate.

Brandes, David, Gregory J. Cavallo and Michael L. Nilson. 2005. Base Flow Trends in Urbanizing Watersheds of the Delaware River Basin. JAWRA 41(6):1377-1391.

Brown, K.W. and Associates, 1980. An Assessment of the Impact of Septic Leach Fields, Home Lawn Fertilization and Agricultural Activities on Groundwater Quality. Prepared for the NJ Pinelands Commission, College Station, TX.

Center for Watershed Protection. (2006). *Upper St. Mary's River Baseline Watershed Assessment.* Retrieved September 2, 2006 from http://www.cwp.org/st_marys_assessment.htm

Charles, Emmanuel G., Cyrus Behroozi, Jack Schooley and Jeffrey L. Hoffman. 1993. A Method for Evaluating Ground Water Recharge Areas in New Jersey. Geological Survey Report GSR-32. NJDEP-New Jersey Geological Survey, Trenton, NJ.

Choquette, A.F., 1988, Regionalization of peak discharges for streams in Kentucky: U.S. Geological Survey Water-Resources Investigations Report 88-4209, 105 p., 1 plate.

Commission on Geosciences, Environment and Resources (CGER), 1993. Ground Water Vulnerability Assessment: Predicting Relative Contamination Potential Under Conditions of Uncertainty.

Council on Environmental Quality (CEC). (1997). *Considering Cumulative Effects under the National Environmental Policy Act.* Retrieved September 6, 2006, from http://ceq.eh.doe.gov/nepa/ccenepa/ccenepa.htm

Dale, V.H., et al (2000). Ecological Principles and Guidelines for Managing the Use of Land, Ecological Applications, 10(3), pp. 639-670, Ecological Society of America.

Delaware River Basin Commission. 1999. Ground Water Protected Area Regulations: Southeastern Pennsylvania, Resolution No. 80-18 (as amended through 23 June 1999).

Domber, S.E. and Hoffman, J.L., 2004, New Jersey water withdrawals, transfers, and discharges by Watershed Management Area, 1990-1999: N.J. Geological Survey Digital Geodata Series DGS 04-9: computer workbook available on the Internet at www.njgeology.org

Dunbar, M.J., et al (1997). Environmental Agency Project W6B(96)4 Overseas approaches to setting river flow objectives, draft R&D Technical Report, Institute of Hydrology.

Eckhardt, D.A.V., and Stackelberg, P.E., 1995. Relation of ground-water quality to land use on Long Island, New York. Ground Water, v. 33, p. 1019-1033.

Ehlke, M. H., and Reed, L.A., 1999, Comparison of methods for computing streamflow statistics for Pennsylvania streams: U.S. Geological Survey Water Resources Investigations Report 99-4068, 80 p.

Ellis, W.H., and Price, C.V. (1995). Development of a 14-digit Hydrologic coding scheme and boundary data set for New Jersey, Water-Resources Investigations Report 95-4134.

Farm Service Agency (FSA). (2004). *The New Jersey State Conservation Reserve Enhancement Program.* Retrieved August 2006, from http://www.fsa.usda.gov/pas/FullStory.asp?StoryID=1552.

Flippo, H.N., Jr., 1982, Evaluation of the streamflow data program in Pennsylvania, U.S. Geological Survey Water Resources Investigations 82-21, 56 p.

Flynn. K.M., Hummel, P.R., Lumb, A.M., and Kittle, J.L., Jr. (1995). User's manual for ANNIE, version 2, a computer program for interactive hydrologic analysis and data management: U.S. Geological Survey Water-Resources Investigations Report 95-4085, 211p.

Flynn, R.H, 2003. A stream-gaging network analysis for the 7-day, 10-year low flow in New Hampshire streams: U.S. Geological Survey Water-Resources Investigations Report 03-4023, 31 p.

Flynn, R.H., 2003b. Development of regression equations to estimate flow durations and low-flow-frequency statistics in New Hampshire streams: U.S. Geological Survey Water-Resources Investigations Report 02-4298, 47 p.

Freund, R.J., and Littell, R.C., 1995, SAS system for regression (2nd edition): Cary, N.C., 210 p.

Gilliam, J. (1997). Selected Agricultural Best Management Practices to Control Nitrogen in the Neuse River Basin (North Carolina Agricultural Research Service Technical Bulletin No. 311). Raleigh, North Carolina State University.

Greene, E.A., LaMotte, A.E., and Cullinan, K., 2004. Ground-water vulnerability to nitrate contamination at multiple thresholds in the Mid-Atlantic Region using spatial probability methods. U.S. Geological Survey Scientific Investigation Report 2004-5118. 24 pp.

Groundwater Foundation. (2003). The Source Water Assessment and Protection Workshop Guide, 2nd Edition. Retrieved September 5, 2006 from http://www.groundwater.org/gi/swap/swap.html

Helsel, D.R. and Hirsch, R.M., 2002. Statistical Methods in Water Resources in: Techniques of Water-Resources Investigations of the United States Geological Survey, Book 4, Hydrologic Analysis and Interpretation, Chapter A3.

Henriksen, J.A, J. Heasley, J.G. Kennen, and S. Nieswand. 2006. Users' manual for the Hydroecological Integrity Assessment Process software (including the New Jersey Assessment Tools). Fort Collins, CO: U.S. Geological Survey, Fort Collins Science Center. Open-File Report 2006-1093. 71p. available at http://www.fort.usgs.gov/products/publications/21598/21598.pdf

Hirsch, R.M., 1982, A comparison of four streamflow record extension techniques: Water Resources Research, v.18, no.4, p. 1081-1088.

Hofer, Ernest W. No date. Setting of the Wallkill River Watershed Basin – WMA 02. The Wallkill River Watershed Management Project: A Technical Report. Prepared for the Sussex County Municipal Utilities Authority, Lafayette, New Jersey.

Hoffman, J. L., and Canace, R.J., 2004, A Recharge-Based Nitrate-Dilution Model for New Jersey. Open File Report OFR 04-1, 27 p.

Hoffman, J.L., Lieberman, S.E., 2000, New Jersey Water Withdrawals 1990-1996, New Jersey Geological Survey, Open-File Report OFM 00-1, 121 p.

Hutchinson, William. 23 March 2006. Personal communication. Executive Director, Southeast Morris County Municipal Utilities Authority.

Insightful Corporation, 2002. S-Plus Version 6.1 for Windows, Seattle, WA.

International Water Management Institute, viewed March 2006 at: http://www.lk.iwmi.org/ehdb/EFM/efm.asp

Kauffman, L.J., Baehr, A.L., Ayers, M.A., and Stackelberg, P.E., 2001. Effects of land use and travel time on the distribution of nitrate in the Kirkwood-Cohansey aquifer system in Southern New Jersey: U.S. Geological Survey Water-Resources Investigation Report 01-4117, 49 pp.

Kennen, J.G., and Ayers M.A., 2002, Relation of environmental characteristics to the composition of aquatic assemblages along a gradient of urban land use in New Jersey, 1996-98, Water Resources Investigations Report 02-4069, 77 p.

Knapp, G.N. 1904. Underground Waters of New Jersey. Wells Drilled in 1903. In: Annual Report of the State Geologist for 1903 New Jersey Geol. Survey, pp. 73-93; as cited in USEPA (1992), Ramapo Aquifer System Support Document. Bergen and Passaic Counties, New Jersey and Orange and Rockland Counties, New York. Available at http://www.epa.gov/region02/water/aquifer/ramapo/ramapo.htm.

Koltun, G.F., and Roberts, J.W., 1990, Techniques for estimating flood-peak discharges of rural, unregulated streams in Ohio: U.S. Geological Survey Water-Resources Investigations Report 89-4126, 68 p., 1 plate.

Koterba, M.T., 1998. Ground-water data-collection protocols and procedures for the National Water-Quality Assessment Program-Collection, documentation, and compilation of required site, well, subsurface, and landscape data for wells: U.S. Geological Survey Water-Resources Investigations Report 98-4107, 91 pp.

Lang, Vernon (1999). Questions and Answers on the New England Flow Policy, U.S. Fish and Wildlife Service.

Liu, X., 2004. Dasymetric mapping with image texture, ASPRS annual conference proceedings, Denver, CO, May 2004.

Lorenz, D.L., Goldstein, R.M., Cowdery, T.K. and Stoner, J.D., 2003. Comparison of Two Methods for Delineating Land Use Near Monitoring Wells Used for Assessing Quality of Shallow Ground Water. U.S. G. S. Water-Resources Investigations Report 03-4067.

Lowrance, R., R. Todd, J. Fair, Jr., O. Hendrickson, R. Leonard, and L. Asmussen. (1984). Riparian Forests as Nutrient Filters in Agricultural Watershed. *Bioscience, 34*: 374-377.

Lumb, A.M., Kittle, J.L., Jr., and Flynn, K.M., 1990, Users manual for ANNIE, a computer program for interactive hydrologic analysis and data management: U.S. Geological Survey Water-Resources Investigations Report 89-4080, 236 p.

Lumia, Richard, 1991, Regionalization of flood discharges for rural, unregulated streams in New York, excluding Long Island: U.S. Geological Survey Water-Resources investigations report 90-4197, 119 p., 2 plates.

Mace, R., et al. (2000). Estimating Ground Water Availability in Texas, Texas Water Resource Board.

Merriman, et al. (2001). Instream Flow Quantification Policy – Stream and Lake Protection – Instream Flow Appropriations, Colorado Water Conservation Board.

Montana Water Trust. 2006. Hydrological Assessment, at: http://www.montanawatertrust.org/projects/hydro.html.

Moore, M. (2003). Perceptions and Interpretations of Environmental Flows and Implications for Future Water Resource Management, Swedish Water House.

Muessig, K., Houghton, H., Monteverde, D., and Volkert, R., 1992, Field guide to the geology of radon hazard areas in New Jersey, New Jersey Geological Survey Open File Report 92-2, 17 p.

Natural Resources Conservation Service. 2004. Soil Survey Geographic (SSURGO) Database. National Soil Survey Cooperative – United States Department of Agriculture (USDA). Downloaded from USDA NRCS Soil Data Mart, http://soildatamart.nrcs.usda.gov/.

Nature Conservancy (2006). Sustainable Waters Program – Ecosystem Flow Prescription found on the World Wide Web at: http://www.freshwaters.org/flow

Nawyn, J. P., 2006, Quality Assurance and Quality Control Plan for Water use Data in the New Jersey District of the U.S. Geological Survey: U. S Geological Survey written communication, 64 p.

New Hampshire Department of Environmental Services. (2006*). Lake Eutrophication.* Retrieved August 21, 2006, from http://www.des.state.nh.us/factsheets/bb/bb-3.htm

New Jersey Department of Agriculture's (NJDA) Natural Resource Conservation (NRC) Division. (2006). *Non-Point Source Pollution.* Retrieved August 15, 2006, from http://www.state.nj.us/agriculture/rural/natrsrc.htm.

New Jersey Department of Environmental Protection (NJDEP), 1985. Sole Source Aquifer designation petition: Aquifer systems of the Coastal Plain, Piedmont, Highlands, and Valley and Ridge physiographic provinces. Submitted to Christopher Daggett, Regional Administrator, U.S. Environmental Protection Agency, 77 p.

NJDEP, 1994. Depletive Water Use Project for Regional Water Resource Planning Areas of New Jersey, July 1994.

NJDEP. 1995. DGS02-3 Ground-Water Recharge for New Jersey. Available from the New Jersey Geological Survey at http://www.nj.gov/dep/njgs/geodata/dgs02-3.htm

NJDEP. 1996a. New Jersey Statewide Water Supply Plan.

NJDEP. 1996b. Bureau of Geographic Information Systems (GIS). CD-ROM Series 1. January 1, 1996.

NJDEP. 1998. New Jersey Geologic Survey Digital Geodata Series DGS98-6: Sole-Source Aquifers of New Jersey GIS data and metadata available at http://www.state.nj.us/dep/njgs/geodata/dgs98-6.htm.

NJDEP, 2002a, NJPDES Ground Water Discharges in New Jersey, (1:12,000): digital GIS data downloaded 4/19/06 from http://www.state.nj.us/dep/gis/digidownload/zips/statewide/njpdesgwd.zip

NJDEP. 2002b. Draft NJDEP 2002 Land Use/Land Cover for New Jersey for WMA, Highlands Study Area.

NJDEP. (2003). Guidelines for Delineation of Well Head Protection Areas in New Jersey. Retrieved from New Jersey Geological Survey; http://www.state.nj.us/dep/njgs/enviroed/freedwn/whpaguide.pdf

NJDEP. 2004a. Total maximum daily load to address temperature in the Pequannock River northeast water region: digital report downloaded 2/14/06 from: http://www.state.nj.us/dep/watershedmgt/DOCS/pequannock_river_tmdl.pdf

NJDEP, 2004b. Basis and Background of the Septic Density Standard of the Highlands Water Protection and Planning Act Rule, N.J.A.C. 7:38-3.4.

NJDEP, 2005a. Ground Water Quality Standards, N.J.A.C. 7:9C.

NJDEP. 2005b. New Jersey Geologic Survey Digital Geodata Series DGS02-3: Ground water Recharge for New Jersey GIS data and metadata available at http://www.state.nj.us/dep/njgs/geodata/dgs02-3/dgs02-3.htm.

NJDEP. 2005c. Bureau of Geographic Information Systems (GIS). NJDEP 2002 Streams Update for New Jersey.

NJDEP. 2005d. Basis & Background of the Septic Density Standard of the Highlands Water Protection and Planning Act Rule at N.J.A.C. 7:38-3.4. Available at http://www.nj.gov/dep/highlands/docs/septicdensity.pdf

NJDEP. 2006a. Division of Watershed Management Basic Information – fact sheets describing each watershed management area at http://www.state.nj.us/dep/watershedmgt.

NJDEP, 2006b, NJPDES Database - Municipal Surface Water Discharger Flow Data: digital data downloaded 4/19/06 from: http://www.nj.gov/dep/dwq/database.htm#avgflow

NJDEP. 2006c. Potential Rate of Stream-Base-Flow Depletion from Ground-Water Use in the New Jersey Highlands. New Jersey Geological Survey, Draft, 1 September 2006.

NJDEP. 2006d. Source Water Assessment Program Web site, www.state.nj.us/dep/watersupply/swap.htm

NJDEP. (2006e). Safe Drinking Water Act Regulations (N.J.A.C. 7:10), adopted November 4, 2004. Retrieved August 24, 2006 from Bureau of Safe Drinking Water at http://www.nj.gov/dep/watersupply/sdwarule.pdf

NJDEP. (2006f). Digital Geodata Series DGS04-5 Well Head Protection Areas for Public Non-Community Water Supply Wells in New Jersey. Retrieved September 27, 2006 from New Jersey Geological Survey; http://www.nj.gov/dep/njgs/geodata/dgs04-5.htm

NJDEP. (2006g). *N.J. Digital Geodata Series: DGS05-2 New Jersey's Ambient Ground water Quality Network Data.* Retrieved September 6, 2006, from http://www.state.nj.us/dep/njgs/geodata/dgs05-2.htm

NJDEP. (2006h). Digital Geodata Series DGS02-2 Well Head Protection Areas for Public Community Water Supply Wells in New Jersey. Retrieved September 27, 2006 from New Jersey Geological Survey: http://www.state.nj.us/dep/njgs/geodata/dgs02-2.htm

NJDEP. (2006i). New Jersey Source Water Assessment Program Statewide Summary, December 2004. Retrieved August 24, 2006 from http://www.nj.gov/dep/swap/reports/swap_sum200412.pdf

NJDEP. (2006j). Site Remediation & Waste Management. Known Contaminated Sites in New Jersey. Retrieved September 27, 2006 from http://www.nj.gov/dep/srp/kc-nj/

NJDEP. (2006k). Source Water Assessment Program. Non-community Water System Source Water Assessment Reports. Retrieved August 24, 2006 from Division of Water Supply: http://www.nj.gov/dep/swap/noncreport.htm

NJDEP. (2006l). Source Water Assessment Program. Community Water System Source Water Assessment Reports and Summaries. Retrieved August 24, 2006 from Division of Water Supply; http://www.nj.gov/dep/swap/creport.htm

NJDEP. (2006m). Source Water Assessment Program. Frequently Asked Questions. Retrieved August 24, 2006 from Division of Water Supply; http://www.nj.gov/dep/swap/faq.htm

NJDEP. (2006n). Source Water Assessment Program. Source Water Protection. Retrieved August 24, 2006 from Division of Water Supply; http://www.nj.gov/dep/swap/source.htm

NJDEP. (2006o). Source Water Assessment Program. Retrieved August 24, 2006 from Division of Water Supply; http://www.nj.gov/dep/swap

NJDEP. (2006p). *Storm water Discharges.* Retrieved September 13, 2006, from Bureau of Nonpoint Pollution Control; http://www.state.nj.us/dep/dwq/stormw.htm

NJDEP. (2006q). *Final Report of the New Jersey Comparative Risk Project.* Retrieved August 21, 2006, from Division of Science, Research and Technology; http://www.state.nj.us/dep/dsr/njcrp/

NJDEP. (2006r). *Ground Water Protection Plans.* Retrieved August 16, 2006, from Division of Water Quality - Bureau of Non-Point Pollution Control; http://www.state.nj.us/dep/dwq/gwpp.htm

NJDEP. (2006s). *Storm Water Program and Ground Water Program.* Retrieved August 15, 2006, from Division of Water Quality – Bureau of Non-point Pollution Control; http://www.state.nj.us/dep/dwq/nonpoint.htm

NJDEP. (2006t). *Municipal Storm water Regulation Program.* Retrieved September 13, 2006, from Division of Water Quality; http://www.state.nj.us/dep/dwq/municstw.html

NJDEP. (2006u). *New Jersey Pollution Discharge Elimination System Rules, N.J.A.C. 7:14A.* Retrieved September 12, 2006, from Division of Water Quality; http://www.state.nj.us/dep/dwq/714a.htm

NJDEP. (2006v). *Storm water Discharges.* Retrieved September 13, 2006, from Division of Water Quality; http://www.state.nj.us/dep/dwq/stormw.htm

NJDEP. (2006w). *Non-point Source Pollution.* Retrieved August 15, 2006, from Division of Watershed Management – Bureau of Watershed Planning; http://www.state.nj.us/dep/watershedmgt/nps_program.htm

NJDEP. (2006x). *New Jersey Nonpoint Source Annual Report, 2001-2003.* Retrieved September 7, 2006, from Division of Watershed Management; http://www.state.nj.us/dep/watershedmgt/nps_program.htm

NJDEP. (2006y). *New Jersey Nonpoint Source and Storm water Management Program Plan*, *December 2000.* Retrieved September 7, 2006, Division of Watershed Management; from http://www.state.nj.us/dep/watershedmgt/nps_program.htm

NJDEP. (2006z). *Revised Manual for New Jersey: Best Management Practices for Control of Non-point Source Pollution from Storm water* Retrieved August 30, 2006, from Division of Watershed Management; http://www.state.nj.us/dep/watershedmgt/bmpmanual.htm

NJDEP. (2006aa). *State of New Jersey Nonpoint Source Report, 2004-2006, April 1, 2006.* Retrieved September 7, 2006, from Division of Watershed Management; http://www.state.nj.us/dep/watershedmgt/nps_program.htm

NJDEP. (2006ab) *Total Maximum Daily Loads*. Retrieved September 6, 2006, from Division of Watershed Management; http://www.state.nj.us/dep/watershedmgt/tmdl.htm

NJDEP. (2006ac). *New Jersey Storm water Best Management Practices Manual; Impacts of Development on Runoff.* Retrieved September 6, 2006 from Division of Watershed Management; http://www.state.nj.us/dep/watershedmgt/bmpmanualfeb2004.htm

NJDEP. (2006ad). *NJDEP Ambient Lake Monitoring Network*. Retrieved August 21, 2006 from Water Monitoring and Standards, Bureau of Freshwater and Biological Monitoring; http://www.state.nj.us/dep/wmm/bfbm/lakes.htm

NJDEP. (2006ae). *Interim Specific & Generic Ground Water Quality Criteria. Ground Water Quality Standards, N.J.A.C. 7:9C.* Retrieved September 2, 2006 from Water Monitoring & Standards; http://www.nj.gov/dep/wmm/sgwqt/is_text.html

NJDEP. (2006af). *New Jersey 2006 Integrated Water Quality Monitoring and Assessment Report.* Retrieved August 16, 2006, from Water Monitoring and Standards; http://www.state.nj.us/dep/wmm/sgwqt/wat/integratedlist/integratedlist2006.html

NJDEP. (2006ag). *Surface Water Quality Standards, N.J.A.C. 7:9B.* Retrieved September 18, 2006 from Water Monitoring and Standards; http://www.nj.gov/dep/wmm/sqwqt/sqwqt.htm

NJDEP. (2006ah). New Jersey Source Water Assessment Program Plan, approved by USEPA November 1999. Retrieved August 24, 2006 from http://www.state.nj.us/dep/watersupply/swap/.pdf

New Jersey Department of Environmental Protection and Energy. 1992. Task 2 Report: Water Supply Baseline Data Development and Analyses. Prepared for the New Jersey Statewide Water Supply Plan by CH2Mhill, Metcalf & Eddy and NJ First.

New Jersey Water Association (NJWA). (2006a). About NJ Water. Retrieved September 27, 2006 from http://www.njwater.org/about_us.aspx

NJWA. (2006b). Wellhead Protection. Retrieved September 27, 2006 from http://www.njwater.org/wellhead_protection. aspx

New Jersey Water Supply Authority (NJWSA). 2000a. Water Supply Availability in the Raritan River Basin: A technical report for the Raritan Basin Watershed Management Project, 23 p.

NJWSA. 2000b. Water Budget in the Raritan River Basin: A technical report for the Raritan Basin Watershed Management Project, 24 p.

NJWSA. 2000c. Settings of the Raritan River Basin. A technical report for the Raritan Basin Watershed Management Project

NJWSA. 2002a. Raritan Basin, Portrait of a Watershed. Raritan Basin Watershed Management Project, Watershed Management Programs.

NJWSA. 2002b. Surface Water Quality and Pollutant Loadings: A technical report for the Raritan Basin Watershed Management Project, 67 p.

NJWSA. 2004. Water Resource Protection Critical Areas of the Raritan River Basin. Available at www.raritanbasin.org.

Newman, M.C. and M.A. Unger. (2003). *Fundamentals of Ecotoxicology* page 21.

Nolan, B.T., 2001. Relating nitrogen sources and aquifer susceptibility to nitrate in shallow ground waters of the United States: Ground Water, v. 39, no. 2, p. 290-299.

North Jersey Resource Conservation and Development. 2001. Setting of the Upper Delaware Watershed – A Technical Report for the Upper Delaware Watershed Management Project. North Jersey Resource. Annandale, New Jersey. Available at http://www.upperdelaware.org/Documents/tech_rep/index.htm.

Olden, J. D., and Poff, N.L., 2003, Redundancy and the choice of hydrologic indices for characterizing streamflow regimes: River Research and Applications, v. 19, p. 101-121. Published online January 13, 2003, Wiley InterScience

Parker, Gene W., et al (2004). Comparison of Methods for Determining Stream flow Requirements for Aquatic Habitat Protection at Selected Sites on the Assabet and Charles Rivers, Eastern Massachusetts, 2000-02: U.S. Geological Survey Scientific Investigations Report 2004-5092.

Passaic River Basin Watershed Management Project. 2002a. Watershed Characterization and Assessment - A Technical Report for the Passaic River Basin Watershed Management Project, Watershed Management Area 3, Pompton, Pequannock, Wanaque & Ramapo River Watersheds, available at http://www.njdwsc.com/prbwmp/index.htm.

Passaic River Basin Watershed Management Project. 2002b. Watershed Characterization and Assessment - A Technical Report for the Passaic River Basin Watershed Management Project, Watershed Management Area 6, Upper Passaic, Whippany, and Rockaway River Watersheds, available at http://www.njdwsc.com/prbwmp/index.htm.

Poff, N. L., and Ward, J.V., 1989, Implication of streamflow variability and predictability for lotic community structure: A regional analysis of streamflow patterns: Canadian Journal of Fisheries and Aquatic Sciences, v. 46, p. 1805-1818.

Poff, N. L, Allan, J. D., Bain, M. B., Karr, J. R., Prestegaard, K. L., Richter, B. D., Sparks, R. E., and Stromberg, J.C.. 1997. The natural flow regime: A paradigm for river conservation and restoration. BioScience v. 47, p. 769-784.

Posten, S.E. 1984. Estimation of Mean Groundwater Runoff in Hard-Rock Aquifers of New Jersey, Columbia University Seminar Series on Pollution and Resources, Volume 16, Halais Kun, G. J. (ed.), Pergamon, NY.

Regional Planning Partnership. 2001. Settings Report for the Central Delaware Tributaries - Watershed Management Area 11. Prepared for the NJDEP.

Reiser, R.G. 2003. Evaluation of streamflow, water quality, and permitted and nonpermitted loads and yields in the Raritan River basin, New Jersey, water years 1991-98. Water Resources Investigation Report WRI no.2003-4207, 210 p.

Reiser, R. G. (2004). United States Geological Survey *(Report 03-4207)* West Trenton

Rice, Donald. 2006. Personal communication. U.S. Geological Survey.

Richter, B.D., Baumgartner, J.V., Powell, J., and Braun, D.B., 1996, A method for assessing hydrologic alteration within ecosystems: Conservation Biology, v. 10, p. 1163-1174.

Riggs, H.C., 1972, Low-flow investigations: U.S. Geological Survey Techniques of Water Resources Investigations, Book 4, Chap. B1, 18 p.

Ries, K.G., and Freisz, P.J., 2000, Methods for estimating low flow statistics for Massachusetts streams: U.S. Geological Survey Water Resources Investigations Report 00-4135, 81 p.

Rutledge, A.T., 1998, Computer programs for describing the recession of ground water discharge and for estimating mean ground water recharge and discharge from streamflow records—Update: U.S. Geological Survey Water Resources Investigations Report 98-4148, 43 p.

Saarela, H., 1992, 1988 New Jersey water withdrawal report: N.J. Department of Environmental Protection, Bureau of Water Allocation, Trenton, NJ, 41 p.

San Marcos River Foundation, (2006). Instream Flow Water Rights Project, at http://www.sanmarcosriver.org/WaterRight.htm.

SAS Institute Inc., 1989, SAS/STAT User's Guide, version 6, 4th ed., v. 2, Cary, North Carolina, 943 p.

SAS Institute, Inc., 1990. SAS User's Guide, Statistics, 6th ed., Cary, N.C., 1,686 pp.

Serfes, M.E., 1994, Natural ground-water quality in bedrock of the Newark Basin, New Jersey: New Jersey Geological Survey Report no. 35, 29p.

Serfes, M.E., 1998, History, Goals and Redesign of New Jersey's Ambient Ground Water Quality Network: Proceedings paper and presentation given at the National Water-Quality Monitoring Councils Conference; Monitoring: Critical Foundations to Protect our waters, held in Reno, Nevada in July 1998.

Serfes, M.E., 2004, Ground Water Quality in the Bedrock Aquifers of the Highlands and Valley and Ridge Physiographic Provinces of New Jersey: New Jersey Geological Survey Report.

Shallcross, Amy L. 2005. Safe Yield Model for the Raritan Basin System, New Jersey Water Supply Authority.

Shallcross, A.L., 2006, Written communication from New Jersey Water Supply Authority.

Sim, S., 2005. Dasymetric Mapping with Object-oriented Classification and GIS. Proceedings of the IGARSS 2005 Symposium. Seoul, Korea. July 25-29, 2005.

Solley, W., Merk, C., and Pierce, R., Estimated Water Use in the United States in 1985, US Geological Survey Circular 1004, 1988.

Tao, Pen. 17 May 2006. Personal communication. North Jersey District Water Supply Commission.

Tesoriero, A.J., Inkpen, E.L., and Voss, F.D., 1998. Assessing ground-water vulnerability using logistic regression, in Proceedings of the Source Water Assessment and Protection Conference 98, Dallas, TX, April 28-30, 1998, p. 157-165.

Texas Water Development Board. (2006). *Agricultural Water Conservation.* Retrieved September 14, 2006, from http://www.twdb.state.tx.us/assistance/conservation/agricons.asp

TRC Omni Environmental Corporation. 2004. Raritan River Basin Nutrient TMDL Study (slide presentation). Prepared for the NJDEP Division of Watershed Management.

Trela, J.J. and Douglas, L.A., 1978. Soils, septic systems and carrying capacity in the New Jersey Pine Barrens: paper presented at the First Annual Pine Barrens Research Conference, Atlantic City, N.J., May 22, 1978, 34 p.

URS. 1984. Feasibility Study: Additional Water for Northeast New Jersey. Prepared for the NJ Department of Environmental Protection.

U.S. Department of Agriculture, Shaffer, M. and Delgado, J., 2002. Essentials of a national nitrate leaching index assessment tool, Journal of Soil and Water Conservation, v. 57, no. 6.

U.S. Environmental Protection (USEPA). 1980. Buried Valley Aquifer System - Support Document. Western Essex and Southeastern Morris Counties, New Jersey available at http://www.epa.gov/region02/water/aquifer/burval/buryval.htm.

USEPA. 2000. Ambient Water Quality Criteria Recommendations – Rivers and Streams in Ecoregion XIV. EPA 822-B-00-022. available at http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_14.pdf

USEPA. 1983. Rockaway River Area Aquifer System (Unconsolidated Quaternary) - Support Document. Morris County, New Jersey available at http://www.epa.gov/region02/water/aquifer/rock/rockaway.htm.

USEPA. 1987. Highlands Basin Aquifer System - Support Document. Morris, Passaic and Sussex Counties, New Jersey available at http://www.epa.gov/region02/water/aquifer/high/highland.htm.

USEPA. 1988. Northwest New Jersey 15 Basin Aquifer; Support Document, Hunterdon, Mercer, Middlesex, Morris, Passaic, Somerset, Sussex, and Warren Counties New Jersey and Orange County, New York available at http://www.epa.gov/region02/water/aquifer/basin/15basin.htm.

USEPA. 1992. Ramapo Aquifer System Support Document. Bergen and Passaic Counties, New Jersey and Orange and Rockland Counties, New York available at http://www.epa.gov/region02/water/aquifer/ramapo/ramapo.htm.

USEPA. (1997). Ground Water & Drinking Water – New Federal Funding for Land Acquisition and Conservation Easements. Retrieved October 5, 2006 from http://www.epa.gov/safewater/dwsrf/ffland.html

USEPA. September 1997. Climate Change and New Jersey. EPA 230-F-97-008dd. http://yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BVJH3/$File/nj_impct.pdf

USEPA, 2000. Establishing Treatment System Performance Requirements, EPA 625/R-00/008 – Chapter 3. National Risk Management Research Laboratory, Cincinnati, Ohio.

USEPA, 2002. Hydrogeologic Framework, Ground-Water Geochemistry, and Assessment of Nitrogen Yield from Base Flow in Two Agricultural Watersheds, Kent County, MD, EPA 600/R-02/008. National Risk Management Research Laboratory, Subsurface Protection and Remediation Division, Ada, Oklahoma.

USEPA, 2003. Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems, EPA-832-B-03-001, Office of Water, Washington, DC.

USEPA, 2005a. Ecosystem Stress from Chronic Exposure to Low-levels of Nitrate, EPA/600/R-05/087. National Risk Management Research Laboratory, Ground Water and Ecosystems Restoration Division, Ada, Oklahoma.

USEPA, 2005b. Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations, EPA/600/R-05/118. National Risk Management Research Laboratory, Ground Water and Ecosystems Restoration Division, Ada, Oklahoma

USEPA. (2005c). *Protecting Water Quality from Agricultural Runoff.* Retrieved August 15, 2006, from http://www.epa.gov/owow/nps/Ag_Runoff_Fact_Sheet.pdf

USEPA. 2006a. Protecting Instream Flows: How Much Water Does a River Need? Presentation by Brian Richter on the Nature Conservancy's Freshwater Initiative, at: http://www.epa.gov/watertrain.

USEPA. (2006c). Drinking Water State Revolving Fund. Retrieved on October 5, 2006 from http://www.epa.gov/safewater/dwsrf/index.html

USEPA. (2006e). *Managing Non-point Source Pollution from Agriculture. Polluted Runoff (Non-point Source Pollution).* Retrieved August 15, 2006, from http://www.epa.gov/owow/nps/facts/point6.htm

USEPA. (2006f). Managing Non-point Source Pollution from Households. Polluted Runoff (Non-point Source Pollution). Retrieved August 15, 2006, from http://www.epa.gov/owow/nps/facts/point10.htm

USEPA. (2006g). Managing Non-point Source Pollution from Boating and Marinas. Polluted Runoff (Non-point Source Pollution). Retrieved August 15, 2006, from http://www.epa.gov/owow/nps/facts/point9.htm

USEPA. (2006h*). Managing Non-point Source Pollution from Forestry. Polluted Runoff (Non-point Source Pollution).* Retrieved August 15, 2006, from http://www.epa.gov/owow/nps/facts/point8.htm

USEPA. (2006i). Managing Wetlands to Control Non-point Source Pollution. Polluted Runoff (Non-point Source Pollution). Retrieved August 15, 2006, from http://www.epa.gov/owow/nps/facts/point11.htm

USEPA. (2006j). *Programs for Non-point Source Control. Polluted Runoff (Non-point Source Pollution)*. Retrieved August 15, 2006, from http://www.epa.gov/owow/nps/facts/point3.htm

USEPA. (2006k). *Total Maximum Daily Loads, Detailed TMDL Report, Pequannock River Watershed Temperature TMDL*. Retrieved September 18, 2006, from http://oaspub.epa.gov/tmdl/waters_list.tmdl_report?p_tmdl_id=11105

USEPA. (2006l). What is Nonpoint Source Pollution? Questions and Answers. Polluted Runoff (Nonpoint Source Pollution). Retrieved October 2, 2006 from http://www.epa.gov/owow/nps/qa.html

USEPA. (2006m). Safe Drinking Water Act (SDWA) Basic Information. Retrieved September 25, 2006 from http://www.epa.gov/safewater/sdwa/basicinformation.html

USEPA. (2006n). Safe Drinking Water Act 30th Anniversary Protecting Drinking Water Sources. (EPA 816-F-04-032). Retrieved September 25, 2006 from http://www.epa.gov/safewater/sdwa/30th/factsheets/sourceprotect.html

USEPA. (2006o). Source Water Protection Efforts. Retrieved September 5, 2006 from http://www.epa.gov/safewater/protect/protect.html

USEPA. (2006p). Source Water Protection Practices Bulletin – Managing Large-Scale Application of Pesticides to Prevent Contamination of Drinking Water. (EPA 916-F-01-030) July 2001. Washington, DC. Retrieved August 24, 2006 from http://www.epa.gov/safewater/protect/swpbull.html

USEPA. (2006q). Source Water Protection Practices Bulletin – Managing Turfgrass and Garden Fertilizer Application to Prevent Contamination of Drinking Water. (EPA 816-F-01-029) July 2001. Retrieved August 24, 2006 from http://www.epa.gov/safewater/protect/swpbull.html

USEPA. (2006r). Source Water Protection Practices Bulletin – Managing Agricultural Fertilizer Application to Prevent Contamination of Drinking Water. (EPA 916-F-01-028) July 2001. Washington, DC. Retrieved August 24, 2006 from http://www.epa.gov/safewater/protect/swpbull.html

USEPA. (2006s). Source Water Protection Practices Bulletin – Managing Pet and Wildlife Waste to Prevent Contamination of Drinking Water. (EPA 916-F-01-027) July 2001. Washington, DC. Retrieved August 24, 2006 from http://www.epa.gov/safewater/protect/swpbull.html

USEPA. (2006t). Source Water Protection Practices Bulletin – Managing Above Ground Storage Tanks to Prevent Contamination of Drinking Water. (EPA 916-F-01-022) July 2001. Washington, DC. Retrieved August 24, 2006 from http://www.epa.gov/safewater/protect/swpbull.html

USEPA. (2006u). Source Water Protection Practices Bulletin – Managing Underground Storage Tanks to Prevent Contamination of Drinking Water. (EPA 816-F-01-023) July 2001. Washington, DC. Retrieved August 24, 2006 from http://www.epa.gov/safewater/protect/swpbull.html

USEPA. (2006v). Source Water Protection Practices Bulletin – Managing Vehicle Washing to Prevent Contamination of Drinking Water. (EPA 816-F-01-024) July 2001. Washington, DC. Retrieved August 24, 2006 from http://www.epa.gov/safewater/protect/swpbull.html

USEPA. (2006w). Source Water Protection Practices Bulletin – Managing Livestock, Poultry, and Horse Waste to Prevent Contamination of Drinking Water. (EPA 816-F-01-026) July 2001. Washington, DC. Retrieved August 24, 2006 from http://www.epa.gov/safewater/protect/swpbull.html

USEPA. (2006x). Source Water Protection Practices Bulletin – Managing Small Quantity Chemical Use to Prevent Contamination of Drinking Water. (EPA 816-F-01-025) July 2001. Washington, DC. Retrieved August 24, 2006 from http:// www.epa.gov/safewater/protect/swpbull.html

USEPA. (2006y). Source Water Protection Practices Bulletin – Managing Storm Water Runoff to Prevent Contamination of Drinking Water. (EPA 816-F-01-020) July 2001. Washington, DC. Retrieved August 24, 2006 from http://www.epa.gov/safewater/protect/swpbull.html

USEPA. (2006z). Source Water Protection Practices Bulletin – Managing Septic Systems to Prevent Contamination of Drinking Water. (EPA 816-F-01-021) July 2001. Washington, DC. Retrieved August 24, 2006 from http://www.epa.gov/safewater/protect/swpbull.html

United States Fish and Wildlife Service. 1997. Significant Habitats and Habitat Complexes of the New York Bight Watershed. Southern New England – New York Bight Coastal Ecosystems Program. Charleston, Rhode Island.

United States Fish and Wildlife Service. 1999. Questions and Answers on the New England Flow Policy. Fourth printing with minor revisions 12 November 2002. New England Field Office, Concord, New Hampshire.

U.S. Geological Survey (USGS), 1990. USGeoData 1:250,000 and 1:100,000 Scale Land Use and Land cover and Associated Maps Digital Data. Reston, Virginia.

USGS. 1997. Simulation of Ground Water Flow Patterns and Areas Contributing Recharge to Streams and Water Supply Wells in a Valley Fill and Carbonate Rock Aquifer System, Southwestern Morris County, New Jersey. Water Resource Investigations Report 97-4216.

USGS. 2003a. Water Resource Data – New Jersey Water Year 2002. Volume 3. Water Quality Data. Water Data Report NJ-02-3. Prepared in cooperation with the NJDEP.

USGS. 2003b. Estimated Water Use and Availability in the Lower Blackstone River Basin, Northern Rhode Island and South-Central Massachusetts, 1995-99. Water Resources Investigations Report 03-4190.

USGS. 2006. Sources and Mobility of Arsenic and Metals in Water and Sediments of a Shallow Aerated and Alum-Dosed Lake, Northwestern New Jersey, USA, Julia L. Barringer, et al. Presented at 2006 GSA Annual Meeting, October 22-25, 2006.

Vogel R.M., and Kroll, C.N, 1990, Generalized low flow frequency relationships for ungaged sites in Massachusetts: Water Resources Bulletin

Volkert, R.A., 1989, Geology, ground-water occurrence, and ground-water quality in the middle Proterozoic rocks of the New Jersey Highlands: Proceedings, Geology and Hydrology of New Jersey - A two day field course presented by Rutgers University, Department of Geological Sciences in cooperation with Cook College, New Brunswick, New Jersey, p. B1-B35.

Watson, K.M., Reiser, R.G., Nieswand, S.P., and Schopp, R.D. 2005. Streamflow characteristics and trends in New Jersey, water years 1897-2003. U.S. Geological Survey Scientific Investigations Report 2005-5105.

Wildlife Waste is Major Water Polluter, Studies Say. (2006, September 29). *The Washington Post,* p. A01.

Wyoming Department of Environmental Quality. Water Quality Division. (1997). Guidance Document, Early Wellhead Protection. Retrieved October 5, 2006 from http://www.wrds.uwyo.edu/wrds/deq/whp/Zar, J.H., 1974. Biostatistical Analysis. Prentice-Hall, Englewood Cliffs, NJ, 620 pp.

APPENDICES

Appendix A

Monitoring Sites which Form the Basis of Assessments in Multiple Waterbodies

Assessments of HUC-14s are based in most cases upon water quality data taken from monitoring sites within the HUC in question. There were situations, however, where in-HUC-14 data were judged to be insufficient or absent and data from neighboring HUC-14s were used to assess these HUCs provided that the neighboring HUCs represented contiguous waterways. Thus, in some cases, monitoring sites from one HUC-14 would form the basis of assessments in 2, 3 and in a few cases as many as four neighboring HUC-14s. Monitoring stations that formed the basis of multiple HUC-14 assessments are listed in this Appendix.

Appendix A: Monitoring sites that form the basis of assessments in multiple waterbodies (HUC-14s).

Number	Name	Alias	Waterbody Name	Waterbody 1	Waterbody 2	Waterbody 3	Waterbody 4	Station Type
01367625	Wallkill R at Sparta		Wallkill R	02020007010010-01	02020007010020-01			LUI
01367715	Wallkill R at Scott Rd at Franklin	EWQ0299	Wallkill R	02020007010070-01	02020007010040-01			SS, EWQ
01367770	Wallkill R near Sussex		Wallkill R	02020007010070-01	02020007030010-01			WSI
01368000	Wallkill R at Unionville		Wallkill R	02020007030040-01	02020007030030-01			WSI
01379200	Dead R near Millington		Dead R	02030103010100-01	02030103010080-01			LUI
01379680	Rockaway R at Longwood Valley	EWQ0241	Rockaway R	02030103030040-01	02030103030030-01	02030103030070-01		SS, EWQ
01379700	Rockaway R at Berkshire Valley		Rockaway R	02030103030040-01	02030103030070-01	02030103030030-01		recon
01379853	Rockaway R at Blackwell St		Rockaway R	02030103030090-01	02030103030070-01			recon
01380450	Rockaway R at W Main St in Boonton		Rockaway R	02030103030150-01	02030103030140-01			EWQ, Historical ASMN
01381330	Whippany R at Whitehead Rd in Morris Twp	EWQ0233	Whippany R	02030103020020-01	02030103020010-01			EWQ
01381498	Whippany River at Ridgedale Ave at Morristown		Whippany R	02030103020050-01	02030103020040-01			SS
01381500	Whippany R at Morristown		Whippany R	02030103020050-01	02030103020040-01			Historical ASMN

Number	Name	Alias	Waterbody Name	Waterbody 1	Waterbody 2	Waterbody 3	Waterbody 4	Station Type
01382500	Pequannock R at Macopin Intake Dam		Pequannock R	02030103050080-01	02030103050060-01			WSI
01396280	Raritan R S Br at Middle Valley		Raritan R S Br	02030105010060-01	02030105010050-01	02030105010070-01		Historical ASMN
01396350	Raritan R S Br at Raritan R Rd in Califon	EWQ0316	Raritan R S Br	02030105010070-01	02030105010060-01	02030105010050-01		EWQ
01397000	Raritan R S Br at Stanton Station		Raritan R S Br	02030105020100-01	02030105020080-01			Historical ASMN
01398260	Raritan R N Br near Chester		Burnett Bk	02030105060030-01	02030105060010-01			Historical ASMN
01398900	Raritan R N Br at Rt 202 in Far Hills	EWQ0351	Raritan R N Br	02030105060070-01	02030105060060-01	02030105060050-01	02030105060040-01	EWQ
01399500	Lamington River near Pottersville		Lamington R	02030105050070-01	02030105050040-01			Historical ASMN
01399570	Rockaway Ck N Br on Rockaway Rd in McCrea's Mill		Lamington River	02030105050090-01	02030105050080-01			ASMN
01403075	Middle Bk E Br on Green Valley Rd in Warren Twp		Raritan R Lower (Lawrence to Millstone)	02030105120050-01	02030105120030-01			ASMN
01445430	Pequest River		Pequest R	02040105090030-01	02040105090020-01			ASMN/EWP
01445500	Pequest R at Pequest Furnace Rd off 625 in Oxford	EWQ0043	Pequest R	02040105090060-01	02040105090030-01			EWQ, Historical ASMN
01455135	Pohatcong Ck at Tunnel Hill Rd in Washington	EWQ0055	Pohatcong R	02040105140010-01	02040105140020-01			EWQ
01455200	Pohatcong Ck at Edison Rd in New Village	EWQ0058	Pohatcong R	02040105140050-01	02040105140030-01	02040105140020-01		EWQ, Historical ASMN

Number	Name	Alias	Waterbody Name	Waterbody 1	Waterbody 2	Waterbody 3	Waterbody 4	Station Type
01456200	Musconetcong R at Kings Hwy in Beattystown	EWQ0069	Musconetcong R	02040105160010-01	02040105160020-01			EWQ, Historical ASMN
01456590	Musconetcong R at Springtown/New Hampton Rd in Ne	EWQ0072	Musconetcong R	02040105160030-01	02040105160040-01			EWQ
01457000	Musconetcong R near Bloomsbury		Musconetcong R	02040105160050-01	02040105160060-01	02040105160040-01	02040105160030-01	Historical ASMN
1-MUS-3	Musconetcong R on Kings Hwy in Beattystown		Musconetcong R	02040105160010-01	02040105160020-01	02040105150100-01	02040105150080-01	Metal
1-MUS-4	Musconetcong R on Person Rd near Bloomsberg		Musconetcong R	02040105160060-01	02040105160050-01	02040105160040-01	02040105160030-01	Metal
1-PEQ-2	Pequest R on Rt 625 in Pequest		Pequest R	02040105090060-01	02040105090030-01			Metal
2-WAL-2	Wallkill R on Davis Rd near Scott Rd in Franklin		Wallkill R	02020007010070-01	02020007010040-01			Metal
2-WAL-4	Wallkill R on Glenwood Rd off Rt 23 near Sussex		Wallkill R	02020007030010-01	02020007030070-01			Metal
3-PEQ-1, 3-SITE-8	Pequannock R at Macopin		Pequannock R	02030103050060-01	02030103050080-01			Metal
6-PAS-2, 6-SITE-1	Passaic R near Chatham		Passaic R	02030103010130-01	02030103010120-01	02030103010110-01	02030103010150-01	Metal
6-SITE-11	Rockaway R at Boonton		Rockaway R	02030103030150-01	02030103030140-01			Metal
6-WHI-1	Whippany R at Morristown		Whippany R	02030103020050-01	02030103020040-01			Metal
8-SB-3	Raritan R S Br on Stanton Station Rd at Stanton Station		Raritan R S Br	02030105020080-01	02030105020100-01			Metal

Number	Name	Alias	Waterbody Name	Waterbody 1	Waterbody 2	Waterbody 3	Waterbody 4	Station Type
AN0039	Pequest R at Rt 615 in Allamuchy		Pequest R	02040105070060-01	02040105070050-01			Aquatic Life
AN0041	Pequest R at Cemetery Rd in Independence		Pequest R	02040105090030-01	02040105090020-01			Aquatic Life
AN0043	Pequest R at Pequest Rd in White		Pequest R	02040105090060-01	02040105090030-01			Aquatic Life
AN0057	Pohatcong Ck at Buttermilk Bridge Rd in Washington		Pohatcong Ck	02040105140030-01	02040105140020-01			Aquatic Life
AN0058	Pohatcong Ck at Edison Rd in Franklin		Pohatcong Ck	02040105140030-01	02040105140050-01			Aquatic Life
AN0064	Musconetcong R off Rt 604 (abv Lubbers Run) in Byram		Musconetcong R	02040105150050-01	02040105150080-01			Aquatic Life
AN0072	Musconetcong R at New Hampton Rd in Lebanon		Musconetcong R	02040105160030-01	02040105160040-01			Aquatic Life
AN0141B				02040201100010-01	02040201100040-01			Aquatic Life
AN0240	Rockaway R at blw Longwood Lk in Jefferson		Rockaway R	02030103030040-01	02030103030030-01			Aquatic Life
AN0258	Pequannock R at Rt 515 in Hardyston		Pequannock R	02030103050030-01	02030103050010-01			Aquatic Life
AN0264	Pequannock R at Rt 23 (Macopin Intake) in W Milford		Pequannock R	02030103050060-01	02030103050080-01			Aquatic Life
AN0267	Ramapo R at Lenape Ln in Oakland		Ramapo R	02030103100070-01	02030103100050-01			Aquatic Life
AN0297	Wallkill R at Rt 15 (nr municipal bldg) in Sparta		Wallkill R	02020007010010-01	02020007010020-01			Aquatic Life
AN0299	Wallkill R at Scott Rd in Franklin		Wallkill R	02020007010070-01	02020007010040-01			Aquatic Life

Number	Name	Alias	Waterbody Name	Waterbody 1	Waterbody 2	Waterbody 3	Waterbody 4	Station Type
AN0302	Wallkill R at Rt 565 in Wantage		Wallkill R	02020007030010-01	02020007010070-01			Aquatic Life
AN0310	Raritan R S Br at Smithtown Rd in Mount Olive		Raritan R S Br	02030105010040-01	02030105010030-01			Aquatic Life
AN0315	Raritan R S Br at Rt 517 in Washington		Raritan R S Br	02030105010050-01	02030105010060-01			Aquatic Life
AN0348	Burnett Bk at Old Mill Rd in Mendham		Burnett Bk	02030105060030-01	02030105060020-01			Aquatic Life
AN0366	Rockaway Ck N Br at Rockaway Rd in Tewksbury		Rockaway Ck N Br	02030105050090-01	02030105050080-01			Aquatic Life
AN0535	Toms R at Oakridge Pkwy in Dover		Toms R	02040301080060-01	02040301060080-01			Aquatic Life
Arthur Kill	Arthur Kill		Arthur Kill	02030104030010-01	02030104020030-01	02030104050120-01		
Delaware Bay-11	Delaware Bay		Delaware Bay	02040204910020-01	02040206200050-01			Historical Estuary-Ocean
Delaware Bay-12	Delaware Bay		Delaware Bay	02040204910010-01	02040204910020-01			Historical Estuary-Ocean
Delaware Bay-13	Delaware Bay		Delaware Bay	02040204910010-02	02040204910020-02	02040204910030-02		Historical Estuary-Ocean
Delaware Bay-16	Delaware Bay		Delaware Bay	02040204910010-01	02040204910020-01			Historical Estuary-Ocean
Delaware Bay-17	Delaware Bay		Delaware Bay	02040204910010-01	02040204910010-02			Historical Estuary-Ocean

Number	Name	Alias	Waterbody Name	Waterbody 1	Waterbody 2	Waterbody 3	Waterbody 4	Station Type
Delaware Bay-19	Delaware Bay		Delaware Bay	02040204910030-01	02040204910030-02	02040204910040-01		Historical Estuary-Ocean
Delaware Bay-21	Delaware Bay		Delaware Bay	02040204910010-02	02040204910020-02			Historical Estuary-Ocean
Delaware Bay-5	Delaware Bay		Delaware Bay	02040204910020-01	02040204910030-01	02040204910030-02		Historical Estuary-Ocean
DRBCNJ 0023	Hakihokake Ck at Bridge St Bridge in Milford		Hakihokake Ck	02040105170020-01	02040105170020-01			DRBC
DRBCNJ 0027	Pohatcong Ck at River Road Bridge		Pohatcong R	02040105140070-01	02040105140060-01			DRBC
Passaic River - Tidal	Passaic River - Tidal		Passaic River - Tidal	02030103150050-01	02030103150040-01	02030103150030-01	02030103120090-01	
Passaic-2	Passaic R at Jackson St in Harris		Passaic R-Tidal	02030103150040-01	02030103150050-01			PVSC
Pequest-4	Pequest River		Pequest River (below Bear Swamp)	02040105090020-01	02040105090010-01			Warren MUA
PQ1	Pequannock R above Pacock		Pequannock R	02030103050030-01	02030103050010-01			Pequannock-Temp
PQ20	Pequannock River - Kinnelon	Pq04blmrs	Pequannock River	02030103050060-01	02030103050080-01			Pequannock-Temp
PQ8	Pequannock R below Macopin		Pequannock R	02030103050060-01	02030103050080-01			Pequannock-Temp
Raritan Bay-1 thru 7	Raritan Bay		Raritan Bay	02030104910020-01	02030104920010-01	02030104910020-01		Historical Estuary-Ocean
Raritan River	Raritan River Estuary		Raritan R Estuary	02030105160090-01	02030105120170-01	02030105160100-01		

Number	Name	Alias	Waterbody Name	Waterbody 1	Waterbody 2	Waterbody 3	Waterbody 4	Station Type
Estuary								
SBWA01	Raritan River SB		Raritan River SB (above Spruce Run)	02030105010040-01	02030105010030-01			South Branch
SBWA04	Raritan River SB		Raritan River SB (3 Brdgs to Spruce Run)	02030105020080-01	02030105020070-01			South Branch
SBWA13	Raritan River SB		Raritan River SB (above Spruce Run)	02030105010060-01	02030105010050-01			South Branch
STA-5	Outlet of Lake Hopatcong		Musconetcong River (above Trout Brook)	02040105150030-01	02040105150020-01			Princeton Hydro
Wallkill B	Wallkill R at Kennedy Av in Ogdensburg	B	Wallkill R	02020007010040-01	02020007010020-01			Wallkill R Study

Appendix B

Designated Use Support Status by Assessment Unit (HUC-14)

Abbreviations are as follows:

Drinking:	Drinking Water Use
Primary Rec:	Primary Contact Recreation
Aquatic Life:	Aquatic Life Support
Trout Support:	Trout Support Use
Indus:	Industrial Use
Agri:	Agricultural Use
Fish Consu:	Fish Consumption
Second Rec:	Secondary Contact Recreation

Appendix B: Designated Use Support status by HUC-14 waterbody. "1" denotes fully supporting the use, "5" indicates not supporting the use. "4" is a subcategory of "not supporting" that denotes that a waterbody has undergone an EPA approved TMDL or some other enforceable management measure. Note that waterbodies not supporting uses (with exception of overall) are highlighted in yellow. "3" denotes there was insufficient data to make an assessment. Overall use support is assessed both with and without the Fish Consumption use. This is because the ubiquitous nature of fish advisories tends to dominate the overall use assessment. Table is sorted by HUC-14

Upper Delaware Watershed

HUC14	SW_NAME	WATERBODY	WMA	DRINKING	PRIMARY REC	AQUATIC LIFE	TROUT SUPPORT	INDUS	AGRI	FISH CONSU	SECON D REC	OVERALL WITHOUT FISH TISSUE	OVERALL INCLUDING FISH TISSUE
02040105040040	Lafayette Swamp tribs	02040105040040-01	01	3	4 A	3	3	3	3	3	3	3	3
02040105040050	Sparta Junction tribs	02040105040050-01	01	3	4 A	5	5	3	3	3	3	5	5
02040105040060	Paulins Kill (above Rt 15)	02040105040060-01	01	2	4 A	5	5	2	2	3	4 A	5	5
02040105050010	Paulins Kill (Blairstown to Stillwater)	02040105050010-01	01	2	4 A	5	5	2	2	3	3	5	5
02040105060020	Delawanna Creek (incl UDRV)	02040105060020-01	01	3	3	2	2	3	3	3	3	1	1
02040105070010	Lake Lenape trib	02040105070010-01	01	3	3	3	3	3	3	3	3	3	3
02040105070020	New Wawayanda Lake/Andover Pond trib	02040105070020-01	01	3	3	3	3	3	3	3	3	3	3
02040105070030	Pequest River (above Brighton)	02040105070030-01	01	2	4 A	5	5	2	2	3	3	5	5
02040105070040	Pequest River (Trout Brook to Brighton)	02040105070040-01	01	2	2	5	5	2	2	3	2	5	5
02040105070050	Trout Brook/Lake Tranquility	02040105070050-01	01	3	3	5	5	3	3	3	3	5	5
02040105070060	Pequest R (below Bear Swamp to Trout Bk)	02040105070060-01	01	3	4 A	2	3	3	3	3	3	1	1
02040105080010	Bear Brook (Sussex/Warren Co)	02040105080010-01	01	2	2	5	5	2	2	3	2	5	5
02040105080020	Bear Creek	02040105080020-01	01	3	3	5	5	3	3	3	3	5	5
02040105090010	Pequest R (Drag Strip--below Bear Swamp)	02040105090010-01	01	3	4 A	3	N/A	3	3	3	3	3	3
02040105090020	Pequest R (Cemetary Road to Drag Strip)	02040105090020-01	01	2	4 A	5	5	2	2	3	3	5	5
02040105090030	Pequest R (Furnace Bk to Cemetary Road)	02040105090030-01	01	2	4 A	5	5	2	2	3	3	5	5
02040105090040	Mountain Lake Brook	02040105090040-01	01	3	4 A	3	3	3	3	3	3	3	3
02040105090050	Furnace Brook	02040105090050-01	01	3	4 A	5	5	3	3	3	3	5	5
02040105090060	Pequest R (below Furnace Brook)	02040105090060-01	01	5	4 A	5	5	5	2	3	4 A	5	5
02040105100010	Union Church trib	02040105100010-01	01	3	3	3	3	3	3	3	3	3	3

Appendix B, continued:

HUC14	SW_NAME	WATERBODY	WMA	DRINK	PRIMARY REC	AQUATIC LIFE	TROUT	INDUS	AGRI	FISH CONSU	SECOND REC	OVERALL WITHOUT FISH TISSUE	OVERALL INCLUDING FISH TISSUE
02040105100020	Honey Run	02040105100020-01	01	2	4 A	5	5	2	2	3	3	5	5
02040105100030	Beaver Brook (above Hope Village)	02040105100030-01	01	3	3	2	3	3	3	3	3	1	1
02040105100040	Beaver Brook (below Hope Village)	02040105100040-01	01	2	3	2	N/A	2	2	3	3	1	1
02040105110010	Pophandusing Brook	02040105110010-01	01	3	3	3	3	3	3	3	3	3	3
02040105110020	Buckhorn Creek (incl UDRV)	02040105110020-01	01	2	3	5	5	2	2	3	3	5	5
02040105110030	UDRV tribs (Rt 22 to Buckhorn Ck)	02040105110030-01	01	3	3	3	N/A	3	3	3	3	3	3
02040105120010	Lopatcong Creek (above Rt 57)	02040105120010-01	01	2	4 A	5	5	2	2	3	3	5	5
02040105120020	Lopatcong Creek (below Rt 57) incl UDRV	02040105120020-01	01	2	4 A	5	5	2	2	3	3	5	5
02040105140010	Pohatcong Creek (above Rt 31)	02040105140010-01	01	2	4 A	2	5	2	2	3	3	5	5
02040105140020	Pohatcong Ck (Brass Castle Ck to Rt 31)	02040105140020-01	01	2	4 A	5	5	2	2	3	3	5	5
02040105140030	Pohatcong Ck (Edison Rd-Brass Castle Ck)	02040105140030-01	01	2	4 A	5	5	2	2	3	3	5	5
02040105140040	Merrill Creek	02040105140040-01	01	3	4 A	2	2	3	3	3	3	1	1
02040105140050	Pohatcong Ck (Merrill Ck to Edison Rd)	02040105140050-01	01	2	4 A	5	5	2	2	3	3	5	5
02040105140060	Pohatcong Ck (Springtown to Merrill Ck)	02040105140060-01	01	2	4 A	5	5	2	2	3	3	5	5
02040105140070	Pohatcong Ck(below Springtown) incl UDRV	02040105140070-01	01	2	4 A	5	5	2	2	3	3	5	5
02040105150010	Weldon Brook/Beaver Brook	02040105150010-01	01	3	3	3	3	3	3	3	3	3	3
02040105150020	Lake Hopatcong	02040105150020-01	01	3	3	3	3	3	3	3	3	3	3
02040105150030	Musconetcong R (Wills Bk to LkHopatcong)	02040105150030-01	01	3	4 A	5	5	3	3	3	3	5	5
02040105150040	Lubbers Run (above/incl Dallis Pond)	02040105150040-01	01	3	3	5	5	3	3	3	3	5	5
02040105150050	Lubbers Run (below Dallis Pond)	02040105150050-01	01	2	3	2	2	2	2	3	3	1	1
02040105150060	Cranberry Lake / Jefferson Lake & tribs	02040105150060-01	01	3	3	3	3	3	3	3	3	3	3
02040105150070	Musconetcong R(Waterloo to/incl WillsBk)	02040105150070-01	01	3	4 A	2	5	3	3	3	3	5	5

Appendix B, continued:

HUC14	SW_NAME	WATERBODY	WMA	DRINK	PRIMARY RECREATION	AQUATIC LIFE	TROUT	INDUS	AGRI	FISH CONSU	SECOND REC	OVERALL WITHOUT FISH TISSUE	OVERALL INCLUDING FISH TISSUE
02040105150080	Musconetcong R (SaxtonFalls to Waterloo)	02040105150080-01	01	5	4 A	2	2	3	3	3	3	5	5
02040105150090	Mine Brook (Morris Co)	02040105150090-01	01	3	4 A	3	3	3	3	3	3	3	3
02040105150100	Musconetcong R (Trout Bk to SaxtonFalls)	02040105150100-01	01	5	4 A	2	2	3	3	3	3	5	5
02040105160010	Musconetcong R (Hances Bk thru Trout Bk)	02040105160010-01	01	5	4 A	2	5	2	2	3	3	5	5
02040105160020	Musconetcong R (Changewater to HancesBk)	02040105160020-01	01	5	4 A	2	5	2	2	3	3	5	5
02040105160030	Musconetcong R (Rt 31 to Changewater)	02040105160030-01	01	2	4 A	2	2	2	2	3	3	4	4
02040105160040	Musconetcong R (75d 00m to Rt 31)	02040105160040-01	01	2	4 A	2	2	2	2	3	3	4	4
02040105160050	Musconetcong R (I-78 to 75d 00m)	02040105160050-01	01	2	4 A	2	2	2	2	3	3	4	4
02040105160060	Musconetcong R (Warren Glen to I-78)	02040105160060-01	01	2	4 A	2	2	2	2	3	3	4	4
02040105160070	Musconetcong R (below Warren Glen)	02040105160070-01	01	2	4 A	2	5	2	2	3	3	5	5
	Wallkill River Watershed												
02020007010010	Wallkill R/Lake Mohawk(above Sparta Sta)	02020007010010-01	02	2	4 A	5	5	2	2	3	3	5	5
02020007010020	Wallkill R (Ogdensburg to SpartaStation)	02020007010020-01	02	2	4 A	5	5	2	2	3	3	5	5
02020007010030	Franklin Pond Creek	02020007010030-01	02	3	3	3	3	3	3	3	3	3	3
02020007010040	Wallkill R(Hamburg SW Bdy to Ogdensburg)	02020007010040-01	02	4 A	4 A	5	5	2	2	3	3	5	5
02020007010050	Hardistonville tribs	02020007010050-01	02	3	3	3	3	3	3	3	3	3	3
02020007010060	Beaver Run	02020007010060-01	02	3	4 A	5	N/A	3	3	3	3	5	5
02020007010070	Wallkill R(Martins Rd to Hamburg SW Bdy)	02020007010070-01	02	5	4 A	5	N/A	2	5	3	3	5	5
02020007020070	Papakating Creek (below Pellettown)	02020007020070-01	02	5	4 A	5	N/A	2	2	3	3	5	5
02020007030010	Wallkill R(41d13m30s to Martins Road)	02020007030010-01	02	3	3	5	N/A	2	2	3	3	5	5
02020007030030	Wallkill River(Owens gage to 41d13m30s)	02020007030030-01	02	4 A	4 A	5	N/A	2	2	3	3	5	5
02020007030040	Wallkill River(stateline to Owens gage)	02020007030040-01	02	4 A	4 A	5	5	2	2	3	3	5	5
02020007040010	Black Ck(above/incl G.Gorge Resort trib)	02020007040010-01	02	2	3	4 A	5	2	2	3	3	5	5

Appendix B, continued:

HUC14	SW_NAME	WATERBODY	WMA	DRINK	PRIMARY REC	AQUATIC LIFE	TROUT	INDUS	AGRI	FISH CONSU	SECOND REC	OVERALL WITHOUT FISH TISSUE	OVERALL INCLUDING FISH TISSUE
02020007040020	Black Creek (below G. Gorge Resort trib)	02020007040020-01	02	2	4 A	5	5	2	2	3	3	5	5
02020007040030	Pochuck Ck/Glenwood Lk & northern trib	02020007040030-01	02	3	4 A	3	3	3	3	3	3	3	3
02020007040040	Highland Lake/Wawayanda Lake	02020007040040-01	02	3	3	3	3	3	3	3	3	3	3
02020007040050	Wawayanda Creek & tribs	02020007040050-01	02	2	4 A	4 A	5	2	2	3	2	5	5
02020007040060	Long House Creek/Upper Greenwood Lake	02020007040060-01	02	3	3	3	N/A	3	3	3	3	3	3
	Pequannock/ Wanaque	**Watershed**											
02030103050010	Pequannock R (above Stockholm/Vernon Rd)	02030103050010-01	03	3	3	4 A	4 A	3	3	3	3	5	5
02030103050020	Pacock Brook	02030103050020-01	03	3	3	3	3	3	3	3	3	3	3
02030103050030	Pequannock R (above OakRidge Res outlet)	02030103050030-01	03	2	3	5	5	2	2	3	3	5	5
02030103050040	Clinton Reservior/Mossmans Brook	02030103050040-01	03	3	3	2	2	3	3	3	3	1	1
02030103050050	Pequannock R (Charlotteburg to OakRidge)	02030103050050-01	03	3	3	5	5	3	3	3	3	5	5
02030103050060	Pequannock R(Macopin gage to Charl'brg)	02030103050060-01	03	2	4 A	5	4 A	2	2	3	2	4	4
02030103050070	Stone House Brook	02030103050070-01	03	3	3	2	N/A	3	3	3	3	1	1
02030103050080	Pequannock R (below Macopin gage)	02030103050080-01	03	2	2	5	5	2	2	5	2	4	5
02030103070010	Belcher Creek (above Pinecliff Lake)	02030103070010-01	03	3	3	3	N/A	3	3	3	3	3	3
02030103070020	Belcher Creek (Pinecliff Lake & below)	02030103070020-01	03	2	3	5	5	2	2	3	2	5	5
02030103070030	Wanaque R/Greenwood Lk(aboveMonks gage)	02030103070030-01	03	2	2	5	5	2	2	3	2	5	5
02030103070040	West Brook/Burnt Meadow Brook	02030103070040-01	03	3	3	3	5	3	3	3	3	5	5
02030103070050	Wanaque Reservior (below Monks gage)	02030103070050-01	03	2	5	5	5	2	2	3	3	5	5
02030103070060	Meadow Brook/High Mountain Brook	02030103070060-01	03	3	3	5	5	3	3	3	3	5	5
02030103070070	Wanaque R/Posts Bk (below reservior)	02030103070070-01	03	2	4 A	5	5	2	2	3	4 A	5	5
02030103100010	Ramapo R (above 74d 11m 00s)	02030103100010-01	03	2	4 A	4A	4A	2	2	3	4 A	5	5
02030103100020	Masonicus Brook	02030103100020-01	03	3	4 A	3	N/A	3	3	3	3	3	3

Appendix B, continued:

HUC14	SW_NAME	WATERBODY	WMA	DRINK	PRIMARY REC	AQUATIC LIFE	TROUT SUPPORT	INDUS	AGRI	FISH CONSU	SECOND REC	OVERALL WITHOUT FISH TISSUE	OVERALL INCLUDING FISH TISSUE
02030103100030	Ramapo R (above Fyke Bk to 74d 11m 00s)	02030103100030-01	03	3	4 A	3	3	3	3	3	3	3	3
02030103100040	Ramapo R (Bear Swamp Bk thru Fyke Bk)	02030103100040-01	03	3	4 A	3	3	3	3	3	3	3	3
02030103100050	Ramapo R (Crystal Lk br to BearSwamp Bk)	02030103100050-01	03	3	4 A	4 A	4 A	3	3	3	3	5	5
02030103100060	Crystal Lake/Pond Brook	02030103100060-01	03	3	4 A	3	3	3	3	3	3	3	3
02030103100070	Ramapo R (below Crystal Lake bridge)	02030103100070-01	03	2	4 A	5	5	2	2	3	3	5	5
02030103110010	Lincoln Park tribs (Pompton River)	02030103110010-01	03	2	4 A	5	N/A	2	2	3	4 A	5	5
02030103110020	Pompton River	02030103110020-01	03	5	2	5	N/A	2	2	5	2	5	5
	Hohokus/ Saddle River	**Watershed**											
02030103140010	Hohokus Bk (above Godwin Ave)	02030103140010-01	04	5	4 A	5	N/A	2	5	3	3	5	5
02030103140020	Hohokus Bk(Pennington Ave to Godwin Ave)	02030103140020-01	04	2	4 A	5	N/A	2	2	3	4A	5	5
02030103140040	Saddle River (above Rt 17)	02030103140040-01	04	2	4 A	5	5	2	2	3	3	5	5
	Passaic River Watershed												
02030103010010	Passaic R Upr (above Osborn Mills)	02030103010010-01	06	2	4A	2	2	2	2	3	3	4	4
02030103010020	Primrose Brook	02030103010020-01	06	1	1	1	1	1	1	3	1	1	1
02030103010030	Great Brook (above Green Village Rd)	02030103010030-01	06	3	3	2	N/A	3	3	3	3	1	1
02030103010040	Loantaka Brook	02030103010040-01	06	3	3	3	N/A	3	3	3	3	3	3
02030103010050	Great Brook (below Green Village Rd)	02030103010050-01	06	3	3	5	N/A	3	3	3	3	5	5
02030103010060	Black Brook (Great Swamp NWR)	02030103010060-01	06	5	4 A	5	N/A	2	2	3	3	5	5
02030103010070	Passaic R Upr (Dead R to Osborn Mills)	02030103010070-01	06	5	4 A	5	N/A	2	2	3	3	5	5
02030103010080	Dead River (above Harrisons Brook)	02030103010080-01	06	2	4 A	5	N/A	2	2	3	4 A	5	5
02030103010090	Harrisons Brook	02030103010090-01	06	3	4 A	3	N/A	3	3	3	3	3	3
02030103010100	Dead River (below Harrisons Brook)	02030103010100-01	06	2	4 A	5	N/A	2	2	3	4 A	5	5
02030103010110	Passaic R Upr (Plainfield Rd to Dead R)	02030103010110-01	06	5	4 A	5	N/A	5	2	3	3	5	5
02030103010180	Passaic R Upr (Pine Bk br to Rockaway)	02030103010180-01	06	5	4 A	5	N/A	2	2	5	3	5	5

Appendix B, continued:

HUC14	SW_NAME	WATERBODY	WMA	DRINK	PRIMARY REC	AQUATIC LIFE	TROUT SUPPORT	INDUS	AGRI	FISH CONSU	SECOND REC	OVERALL WITHOUT FISH TISSUE	OVERALL INCLUDING FISH TISSUE
02030103020010	Whippany R (above road at 74d 33m)	02030103020010-01	06	2	3	2	5	2	2	3	3	5	5
02030103020020	Whippany R (Wash. Valley Rd to 74d 33m)	02030103020020-01	06	2	3	2	5	2	2	3	3	5	5
02030103020030	Greystone / Watnong Mtn tribs	02030103020030-01	06	3	3	2	N/A	3	3	3	3	1	1
02030103020040	Whippany R(Lk Pocahontas to Wash Val Rd)	02030103020040-01	06	2	4 A	5	5	2	2	3	4A	5	5
02030103020050	Whippany R (Malapardis to Lk Pocahontas)	02030103020050-01	06	2	4 A	5	5	2	2	3	4A	5	5
02030103020060	Malapardis Brook	02030103020060-01	06	3	3	2	N/A	3	3	3	3	1	1
02030103020070	Black Brook (Hanover)	02030103020070-01	06	3	3	3	N/A	3	3	3	3	3	3
02030103020080	Troy Brook (above Reynolds Ave)	02030103020080-01	06	3	3	3	N/A	3	3	3	3	3	3
02030103020090	Troy Brook (below Reynolds Ave)	02030103020090-01	06	3	3	2	N/A	3	3	3	3	1	1
02030103020100	Whippany R (Rockaway R to Malapardis Bk)	02030103020100-01	06	5	4 A	5	N/A	2	2	3	4 A	5	5
02030103030010	Russia Brook (above Milton)	02030103030010-01	06	3	4 A	3	3	3	3	3	3	3	3
02030103030020	Russia Brook (below Milton)	02030103030020-01	06	3	4 A	2	2	3	3	3	3	1	1
02030103030030	Rockaway R (above Longwood Lake outlet)	02030103030030-01	06	2	4 A	2	N/A	2	2	5	3	4	5
02030103030040	Rockaway R (Stephens Bk to Longwood Lk)	02030103030040-01	06	2	4 A	5	N/A	2	2	5	3	5	5
02030103030050	Green Pond Brook (above Burnt Meadow Bk)	02030103030050-01	06	3	4 A	3	3	3	3	3	3	3	3
02030103030060	Green Pond Brook (below Burnt Meadow Bk)	02030103030060-01	06	3	4 A	5	N/A	3	3	3	3	5	5
02030103030070	Rockaway R (74d 33m 30s to Stephens Bk)	02030103030070-01	06	2	4 A	2	3	2	2	5	3	4	5
02030103030080	Mill Brook (Morris Co)	02030103030080-01	06	2	4 A	2	2	2	2	3	4A	5	5
02030103030090	Rockaway R (BM 534 brdg to 74d 33m 30s)	02030103030090-01	06	3	4 A	5	N/A	3	3	5	3	5	5
02030103030100	Hibernia Brook	02030103030100-01	06	3	4 A	3	3	3	3	3	3	3	3
02030103030110	Beaver Brook (Morris County)	02030103030110-01	06	2	4 A	5	5	2	2	5	3	5	5
02030103030120	Den Brook	02030103030120-01	06	3	3	2	3	3	3	3	3	1	1

Appendix B, continued:

HUC14	SW_NAME	WATERBODY	WMA	DRINK	PRIMARY REC	AQUATIC LIFE	TROUT SUPPORT	INDUS	AGRI	FISH CONSU	SECOND REC	OVERALL WITHOUT FISH TISSUE	OVERALL INCLUDING FISH TISSUE
02030103030130	Stony Brook (Boonton)	02030103030130-01	06	2	4 A	5	N/A	2	2	3	3	5	5
02030103030140	Rockaway R (Stony Brook to BM 534 brdg)	02030103030140-01	06	5	3	5	N/A	3	3	5	3	5	5
02030103030150	Rockaway R (Boonton dam to Stony Brook)	02030103030150-01	06	5	2	5	5	2	2	5	2	5	5
02030103030160	Montville tribs.	02030103030160-01	06	2	2	2	3	2	2	3	2	1	1
02030103030170	Rockaway R (Passaic R to Boonton dam)	02030103030170-01	06	2	4 A	5	N/A	2	2	5	3	5	5
02030103040010	Passaic R Upr (Pompton R to Pine Bk)	02030103040010-01	06	5	4 A	5	N/A	2	2	5	3	5	5
	Raritan River Watershed												
02030105010010	Drakes Brook (above Eyland Ave)	02030105010010-01	08	3	3	5	5	3	3	3	3	5	5
02030105010020	Drakes Brook (below Eyland Ave)	02030105010020-01	08	3	3	5	5	3	3	3	3	5	5
02030105010030	Raritan River SB(above Rt 46)	02030105010030-01	08	3	3	2	2	3	3	3	3	1	1
02030105010040	Raritan River SB(74d 44m 15s to Rt 46)	02030105010040-01	08	3	3	2	2	3	3	3	3	1	1
02030105010050	Raritan R SB(LongValley br to 74d44m15s)	02030105010050-01	08	2	4 A	5	5	2	2	3	3	5	5
02030105010060	Raritan R SB(Califon br to Long Valley)	02030105010060-01	08	2	4 A	5	5	2	2	3	3	5	5
02030105010070	Raritan R SB(StoneMill gage to Califon)	02030105010070-01	08	2	4 A	5	5	2	2	3	3	5	5
02030105010080	Raritan R SB(Spruce Run-StoneMill gage)	02030105010080-01	08	2	4 A	2	5	2	2	3	3	5	5
02030105020010	Spruce Run (above Glen Gardner)	02030105020010-01	08	2	2	2	5	2	2	3	2	5	5
02030105020020	Spruce Run (Reservior to Glen Gardner)	02030105020020-01	08	2	4 A	5	5	2	2	3	3	5	5
02030105020030	Mulhockaway Creek	02030105020030-01	08	2	4 A	5	5	2	2	3	3	5	5
02030105020040	Spruce Run Reservior / Willoughby Brook	02030105020040-01	08	3	3	5	5	3	3	3	3	5	5
02030105020050	Beaver Brook (Clinton)	02030105020050-01	08	2	3	5	5	2	2	3	3	5	5
02030105020060	Cakepoulin Creek	02030105020060-01	08	2	3	5	5	2	2	3	2	5	5
02030105020070	Raritan R SB(River Rd to Spruce Run)	02030105020070-01	08	2	3	2	2	2	2	3	3	1	1
02030105020080	Raritan R SB(Prescott Bk to River Rd)	02030105020080-01	08	5	4 A	5	5	2	2	3	3	5	5

Appendix B, continued:

HUC14	SW_NAME	WATERBODY	WMA	DRINK	PRIMARY REC	AQUATIC LIFE	TROUT SUPPORT	INDUS	AGRI	FISH CONSU	SECOND REC	OVERALL WITHOUT FISH TISSUE	OVERALL INCLUDING FISH TISSUE
02030105020090	Prescott Brook / Round Valley Reservior	02030105020090-01	08	3	3	2	2	3	3	3	3	1	1
02030105040020	Pleasant Run	02030105040020-01	08	2	5	5	N/A	2	2	3	5	5	5
02030105040030	Holland Brook	02030105040030-01	08	2	3	5	N/A	2	2	3	3	5	5
02030105050010	Lamington R (above Rt 10)	02030105050010-01	08	3	3	3	N/A	3	3	3	3	3	3
02030105050020	Lamington R (Hillside Rd to Rt 10)	02030105050020-01	08	2	4 A	5	5	2	2	3	3	5	5
02030105050030	Lamington R (Furnace Rd to Hillside Rd)	02030105050030-01	08	2	4 A	2	5	2	2	3	3	5	5
02030105050040	Lamington R(Pottersville gage-FurnaceRd)	02030105050040-01	08	2	4 A	5	5	2	2	3	3	5	5
02030105050050	Pottersville trib (Lamington River)	02030105050050-01	08	3	4 A	2	2	3	3	3	3	1	1
02030105050060	Cold Brook	02030105050060-01	08	3	4 A	2	2	3	3	3	3	1	1
02030105050070	Lamington R(HallsBrRd-Pottersville gage)	02030105050070-01	08	2	4 A	5	5	2	2	3	3	5	5
02030105050080	Rockaway Ck (above McCrea Mills)	02030105050080-01	08	3	3	2	2	3	3	3	3	1	1
02030105050090	Rockaway Ck (RockawaySB to McCrea Mills)	02030105050090-01	08	3	3	2	2	3	3	3	3	1	1
02030105050100	Rockaway Ck SB	02030105050100-01	08	2	3	5	5	2	2	3	3	5	5
02030105050110	Lamington R (below Halls Bridge Rd)	02030105050110-01	08	2	4 A	5	N/A	2	2	3	3	5	5
02030105060010	Raritan R NB (above/incl India Bk)	02030105060010-01	08	2	4 A	2	2	2	2	3	3	4	4
02030105060020	Burnett Brook (above Old Mill Rd)	02030105060020-01	08	2	3	2	2	2	2	3	3	1	1
02030105060030	Raritan R NB(incl McVickers to India Bk)	02030105060030-01	08	2	4 A	2	2	2	2	3	3	4	4
02030105060040	Raritan R NB(Peapack Bk to McVickers Bk)	02030105060040-01	08	2	3	2	3	2	2	3	3	1	1
02030105060050	Peapack Brook (above/incl Gladstone Bk)	02030105060050-01	08	2	3	2	2	2	2	3	3	1	1
02030105060060	Peapack Brook (below Gladstone Brook)	02030105060060-01	08	2	3	2	2	2	2	3	3	1	1
02030105060070	Raritan R NB(incl Mine Bk to Peapack Bk)	02030105060070-01	08	2	3	2	3	2	2	3	3	1	1

Appendix B, continued:

HUC14	SW_NAME	WATERBODY	WMA	DRINK	PRIMARY REC	AQUATIC LIFE	TROUT SUPPORT	INDUS	AGRI	FISH CONSU	SECOND REC	OVERALL WITHOUT FISH TISSUE	OVERALL INCLUDING FISH TISSUE
02030105060080	Middle Brook (NB Raritan River)	02030105060080-01	08	2	3	2	N/A	2	2	3	3	1	1
02030105060090	Raritan R NB (Lamington R to Mine Bk)	02030105060090-01	08	2	4 A	2	N/A	2	2	3	3	4	4
02030105070010	Raritan R NB (Rt 28 to Lamington R)	02030105070010-01	08	2	4 A	5	N/A	2	2	3	3	5	5
	Hakihokake/ Nishisakawick	**Watershed**											
02030105120050	Middle Brook EB	02030105120050-01	09	3	3	5	5	3	3	3	3	5	5
02030105120060	Middle Brook WB	02030105120060-01	09	2	4 A	2	N/A	2	2	3	3	4	4
02040105170010	Holland Twp (Hakihokake to Musconetcong)	02040105170010-01	11	3	3	3	3	3	3	3	3	3	3
02040105170020	Hakihokake Creek	02040105170020-01	11	2	4 A	2	2	2	2	3	3	5	5
02040105170030	Harihokake Creek (and to Hakihokake Ck)	02040105170030-01	11	2	3	5	5	2	2	3	3	5	5
02040105170040	Nishisakawick Creek (above 40d 33m)	02040105170040-01	11	2	4 A	5	N/A	2	2	3	3	5	5
02040105170050	Nishisakawick Creek (below 40d 33m)	02040105170050-01	11	2	4 A	5	N/A	2	2	3	3	5	5
	Delaware River												
	Delaware River 1D3	Delaware River 6	Zone 1	5	5	5	N/A	3	N/A	5	3	5	5
	Delaware River 1D4	Delaware River 7	Zone 1	5	2	5	N/A	3	N/A	5	2	5	5
	Delaware River 1D5	Delaware River 8	Zone 1	5	3	5	N/A	3	N/A	5	3	5	5
	Delaware River 1D6	Delaware River 9	Zone 1	5	5	5	N/A	3	N/A	5	5	5	5
	Delaware River 1E1	Delaware River 10	Zone 1	5	2	5	N/A	3	3	5	2	5	5
	Delaware River 1E2	Delaware River 11	Zone 1	5	5	5	N/A	3	3	5	5	5	5
	Delaware River 1E3	Delaware River 12	Zone 1	5	5	5	N/A	3	3	5	3	5	5
	Delaware River 1E4	Delaware River 13	Zone 1	5	5	5	N/A	3	3	5	3	5	5

Appendix C

Statutory Authority

The following is taken from the *2006 Integrated Water Quality Monitoring and Assessment Methods*, Chapter 2. The complete document is available at (http://www.state.nj.us/dep/wmm/sgwqt/wat/integratedlist/06MethodsDoc.pdf).

The rules and regulations that are relevant to the development of the Integrated Report are presented below.

The Federal Water Pollution Control Act and its subsequent amendments are collectively known as the Clean Water Act (CWA). The CWA provides the statutory requirements for numerous water programs including Surface Water Quality Standards, Water Quality Inventory Report, Impaired Waterbodies List and Total Maximum Daily Loads.

Surface Water Quality Standards (SWQS) include water quality goals, policies, numeric and narrative criteria (including design flows) and waterbody classifications. The terms "applicable SWQS" and "applicable criteria" refer to the legally binding SWQS and criteria for the waterbody depending on jurisdiction and waterbody classification. Federal SWQS are promulgated by USEPA. As required, New Jersey has adopted SWQS that are at least as stringent as the federal standards. The latest revisions to the New Jersey SWQS were adopted at N.J.A.C. 7:9B on June 20, 2005. The numerical criteria for some toxic parameters are found in USEPA's National Toxics Rule (CFR, 1989). The Delaware River Basin Commission establishes standards for the Delaware River, estuary and tributaries to the head of tide. The most recent standards for the Delaware River were promulgated on October 23, 1996. The New Jersey Department of Health and Senior Services (NJDHSS) establishes sanitary quality standards and beach closure procedures for ocean, bay, and lake bathing beaches. Sanitary criteria for shellfish harvesting in coastal waters are set by the federal Food and Drug Administration (FDA) through the National Shellfish Sanitation Program.

Water Quality Inventory Reports (305(b)) are prepared every two years by states and submitted to USEPA as required under Section 305(b) of the CWA. Water Quality Inventory Reports contain assessments of water quality for waters of the state as well as descriptions of applicable water resources management programs. These reports are used by Congress and USEPA to establish program priorities and funding for federal and state water resources management programs. USEPA issues guidance as needed regarding the preparation of water quality inventory reports.

Impaired Waterbodies Lists (303(d)) are required under Section 303(d) of the CWA. Federal regulations on implementation of the CWA can be found at 40 CFR 130.7. New Jersey regulations regarding Impaired Waterbodies Lists are found at N.J.A.C. 7:15-6. These regulations require identification of impaired waterbodies, i.e., waters for which required pollution controls were not stringent enough to achieve the state surface water quality standards. Impaired Waterbodies Lists are required every two years and must be developed based on a documented methodology that includes an evaluation of existing and readily available data. Once identified as impaired, waterbodies continue to be included on subsequent Impaired Waterbodies Lists until either: 1) TMDLs are adopted, 2) applicable criteria are met, or 3) the original basis for the listing is shown to be flawed. Public participation in the development of Impaired Waterbodies Lists is required. USEPA is required to review and approve each state's 303(d) List. In New Jersey, the final 303(d) List (Sublist 5B of the Integrated Report) is adopted as an amendment to the Statewide Water Quality Management Plan pursuant to N.J.A.C. 7:15-6.

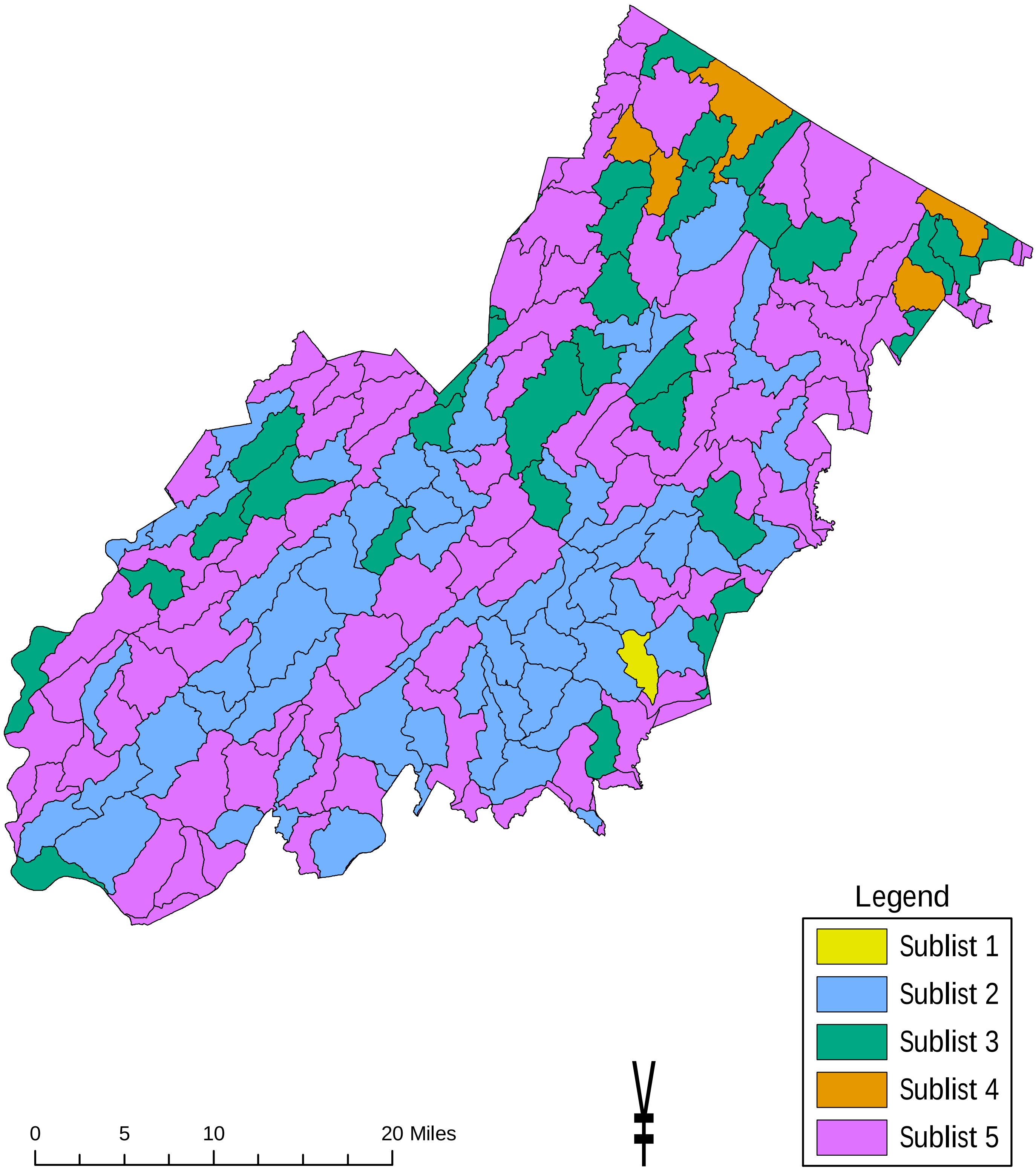
The state is required to establish TMDLs for those waters identified on the Impaired Waterbodies List. The schedule for TMDL development is developed based on a priority ranking and is included with the Impaired Waterbodies List. A TMDL specifies the maximum amount of a pollutant that a waterbody can receive on a daily basis and still meet water quality standards. A TMDL also allocates pollutant loadings for a given receiving water among point and nonpoint pollutant source discharges. TMDL implementation may result in more stringent discharge permit limits and/or nonpoint source pollution control measures.

Appendix D

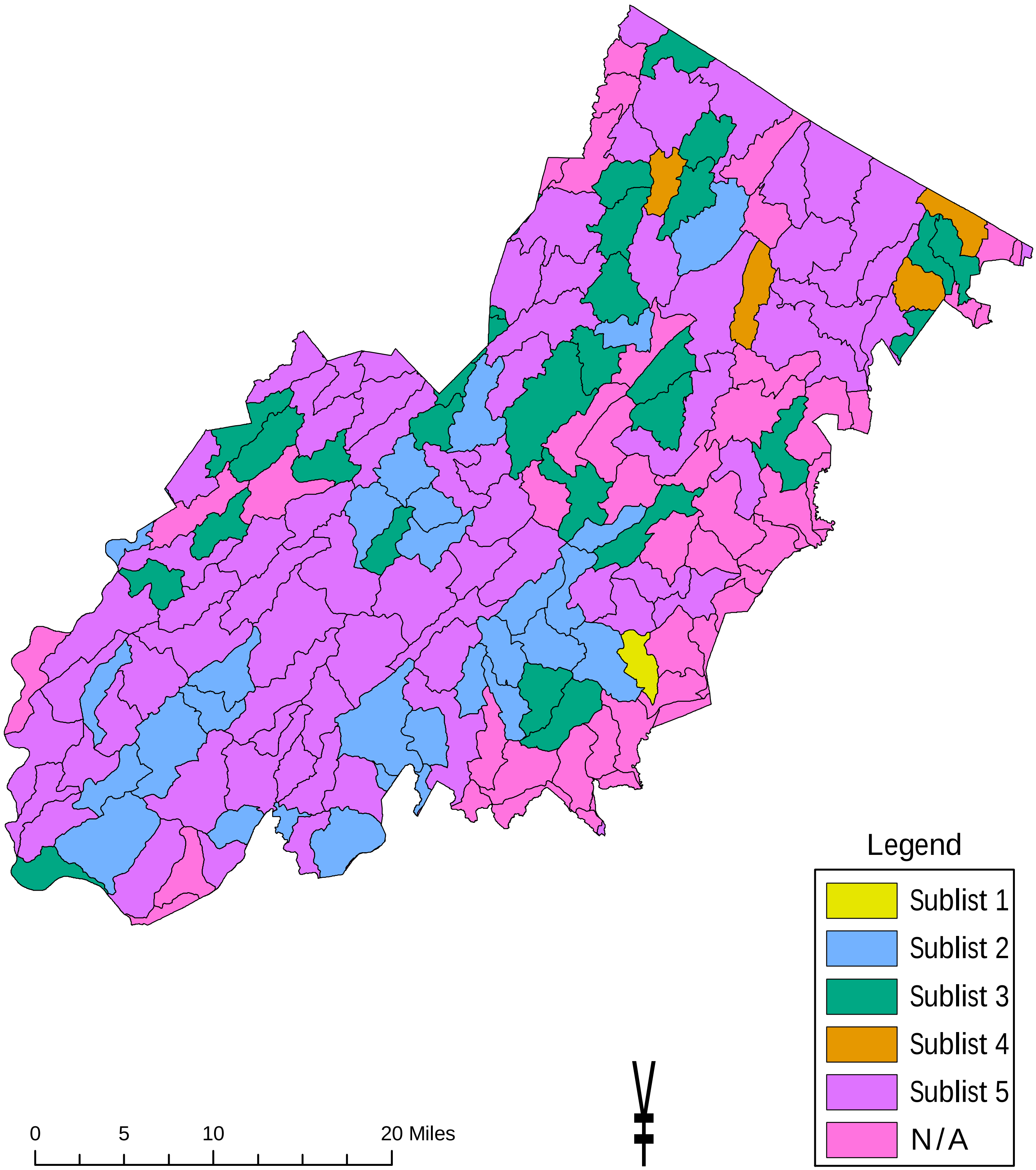
Spatial representations of designated use support of assessment units (HUC-14) within the Highlands area. Use attainment status is defined in one of six categories as follows:

Sublist 1: **A waterbody is attaining the designated use and the use not threatened.**
Sublist 2: **A waterbody is attaining the designated use.**
Sublist 3: **Insufficient or no data are available to determine if the designated use is attained.**
Sublist 4: **The waterbody is impaired or threatened for the designated use and an EPA approved TMDL has been developed.**
Sublist 5: **The designated use is not attained. The waterbody is impaired or threatened for the designated use by a pollutant(s), and requires a TMDL.**
N/A: **Designated use does not apply**

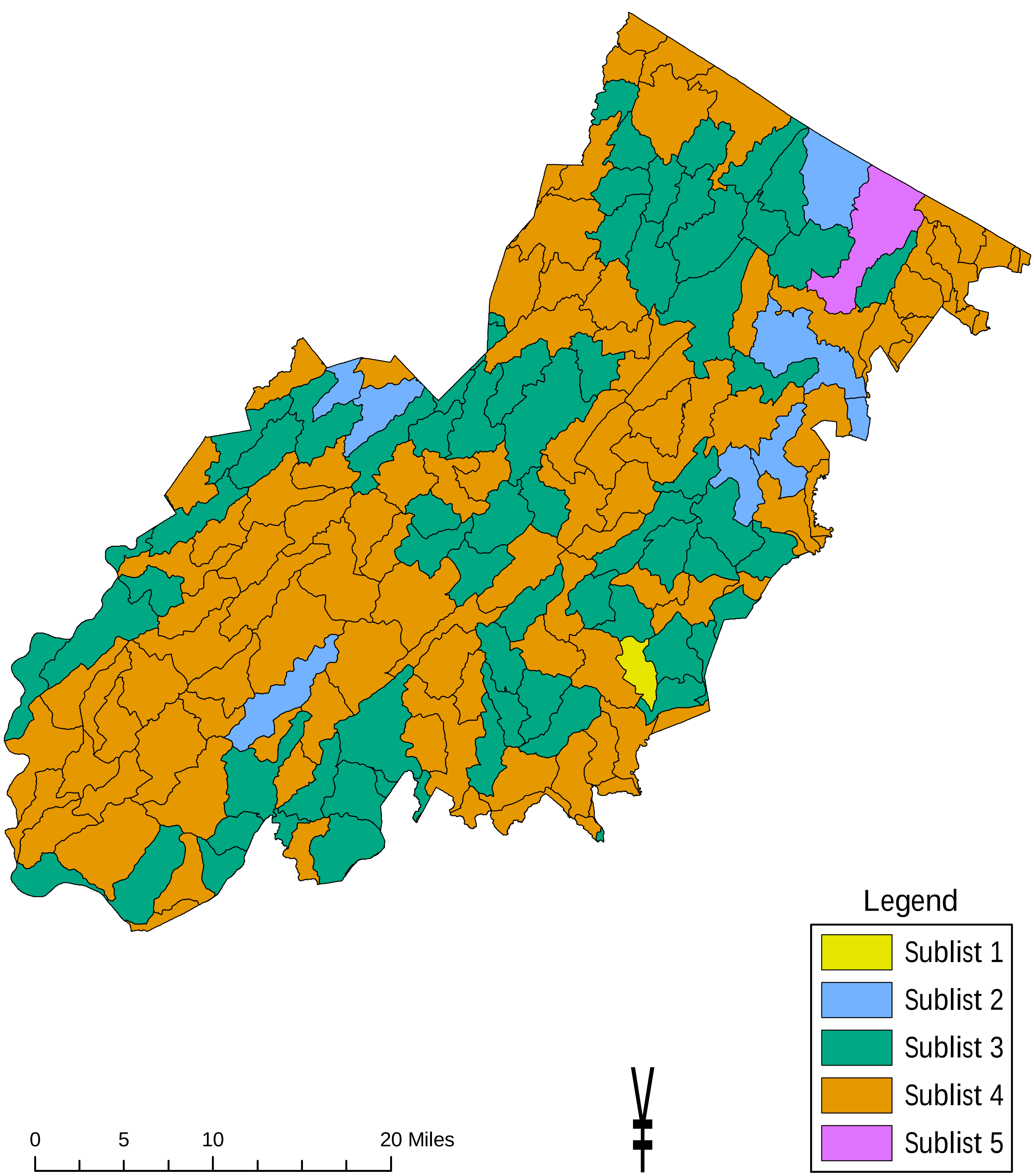
Aquatic Life



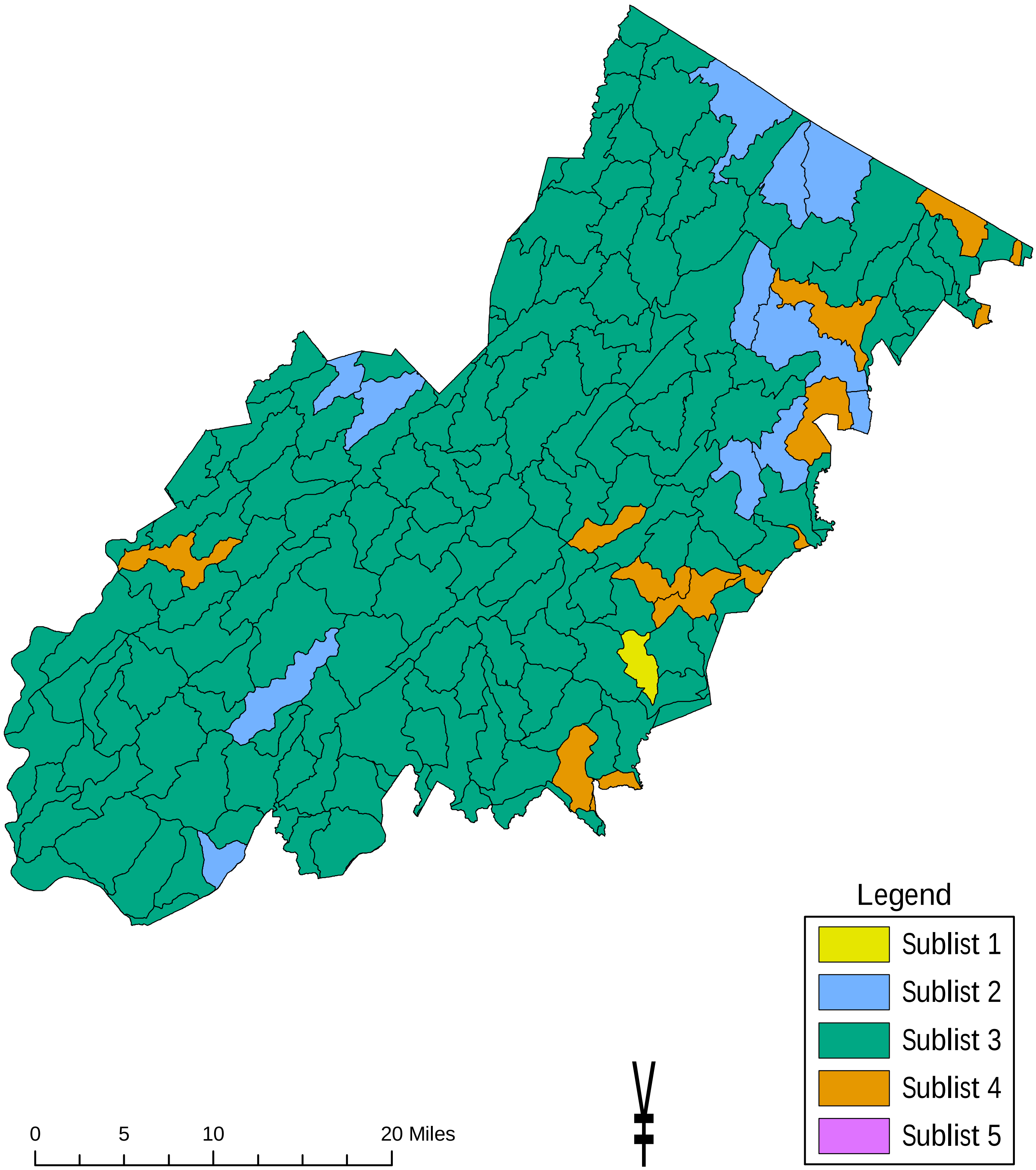
Aquatic Life Trout



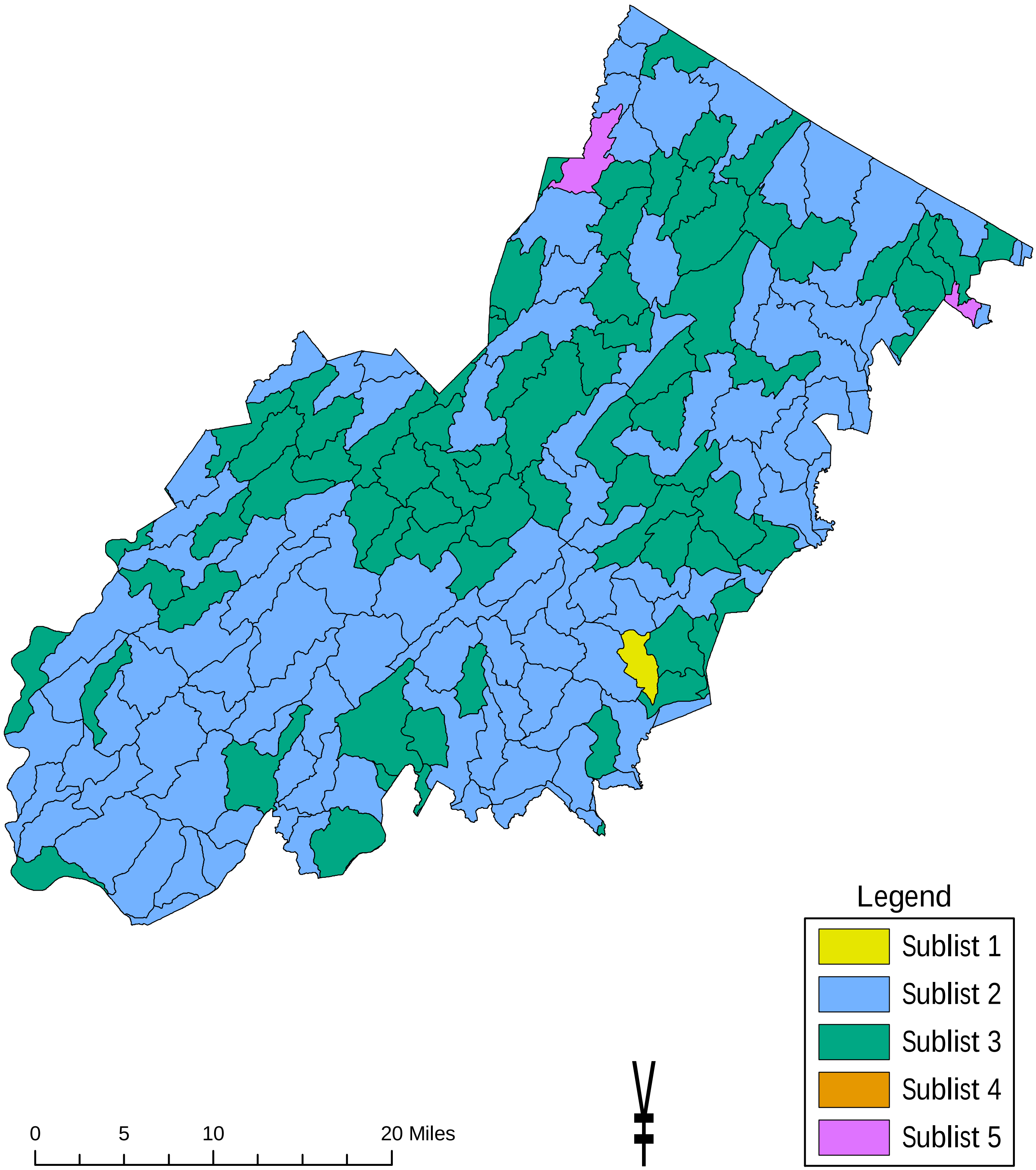
Primary Contact



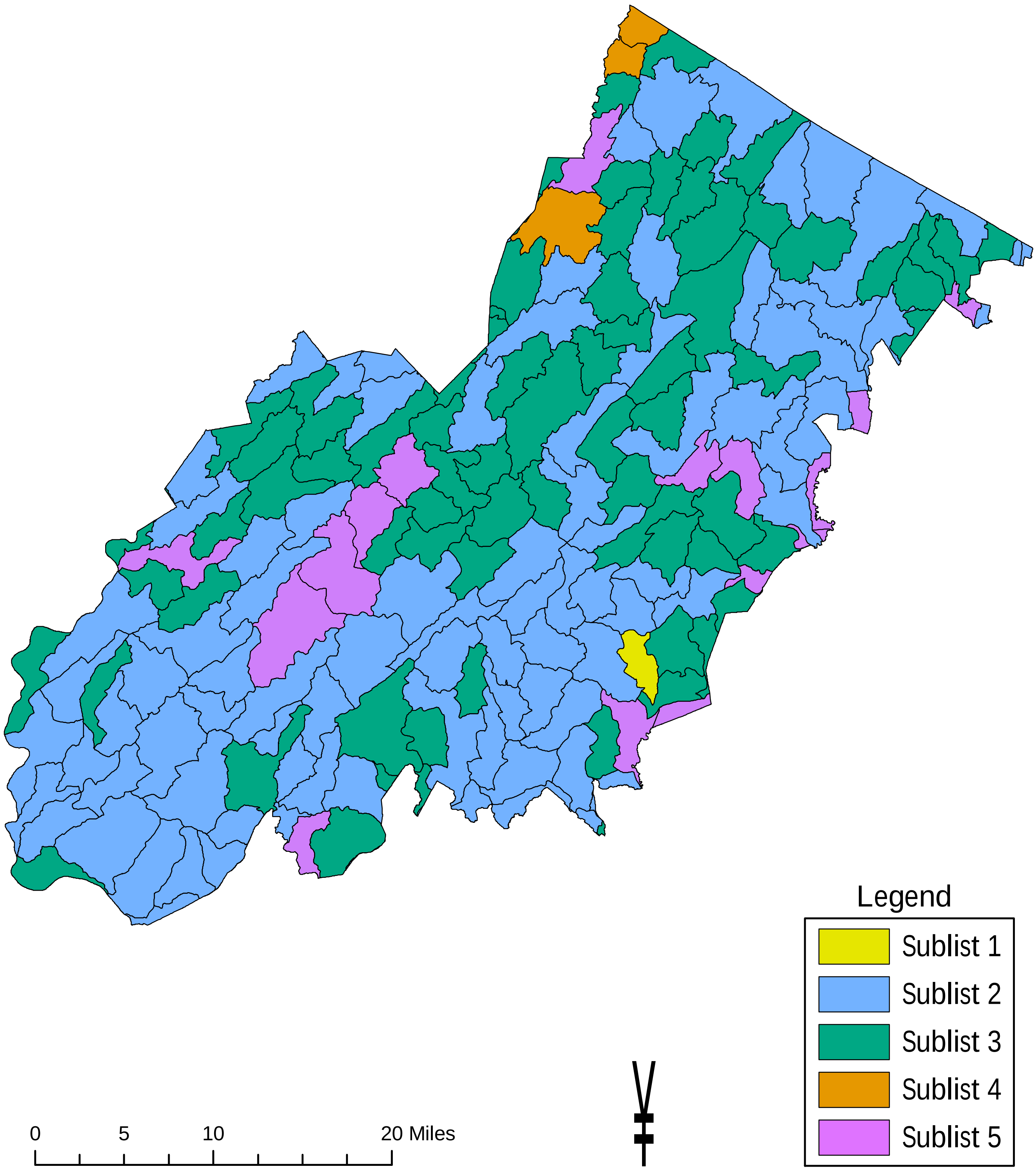
Secondary Contact



Agriculture



Drinking Water



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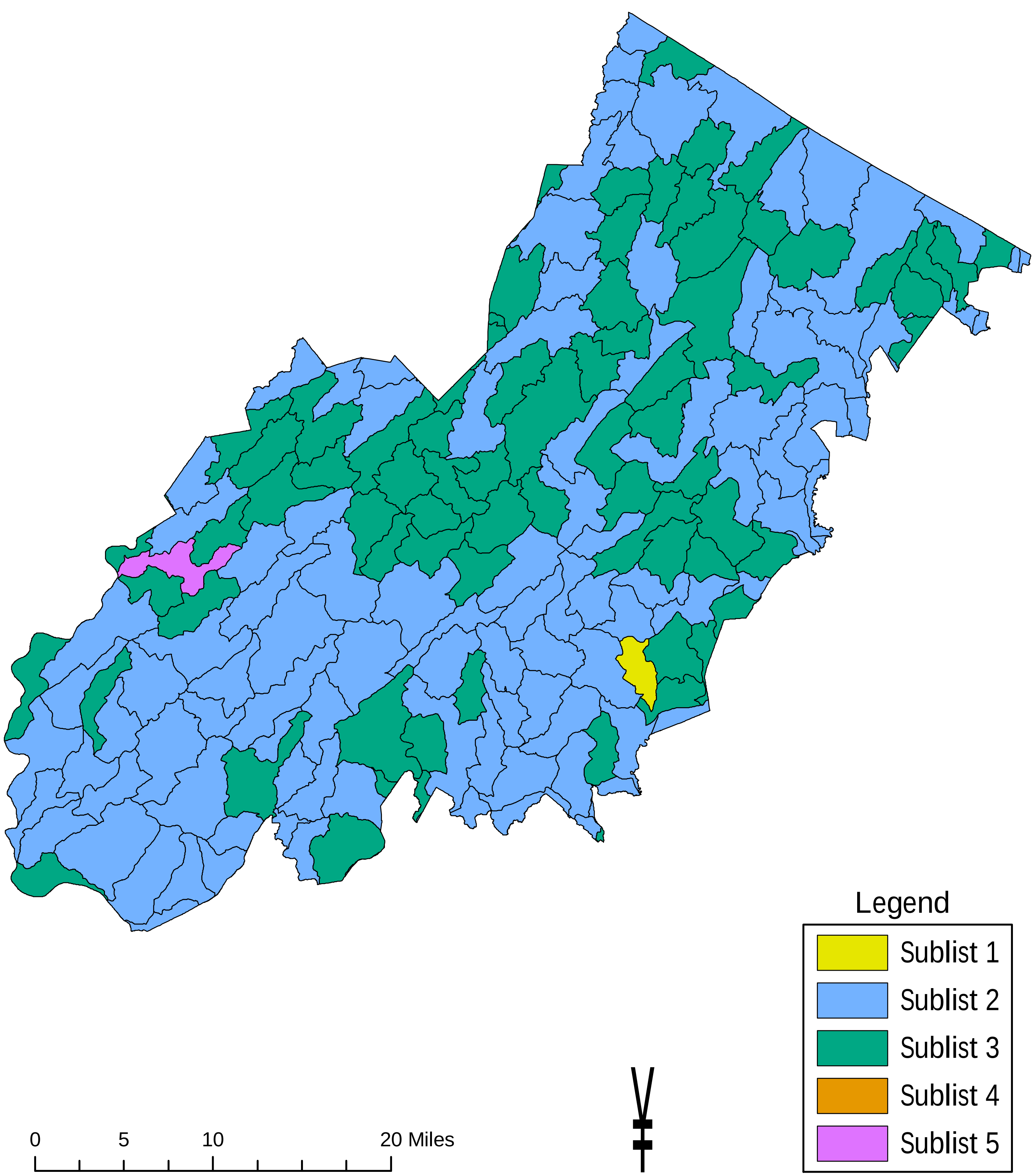
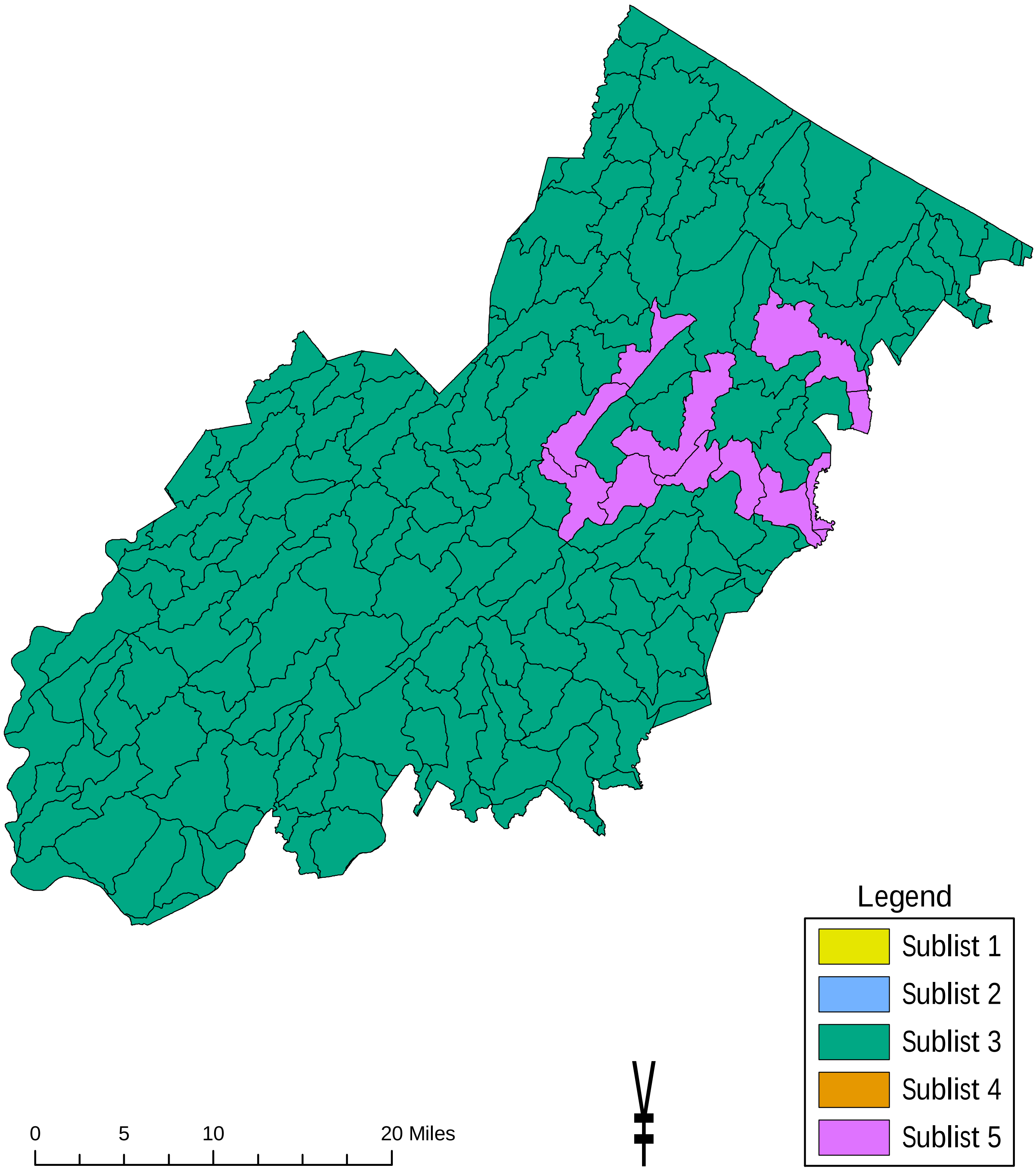
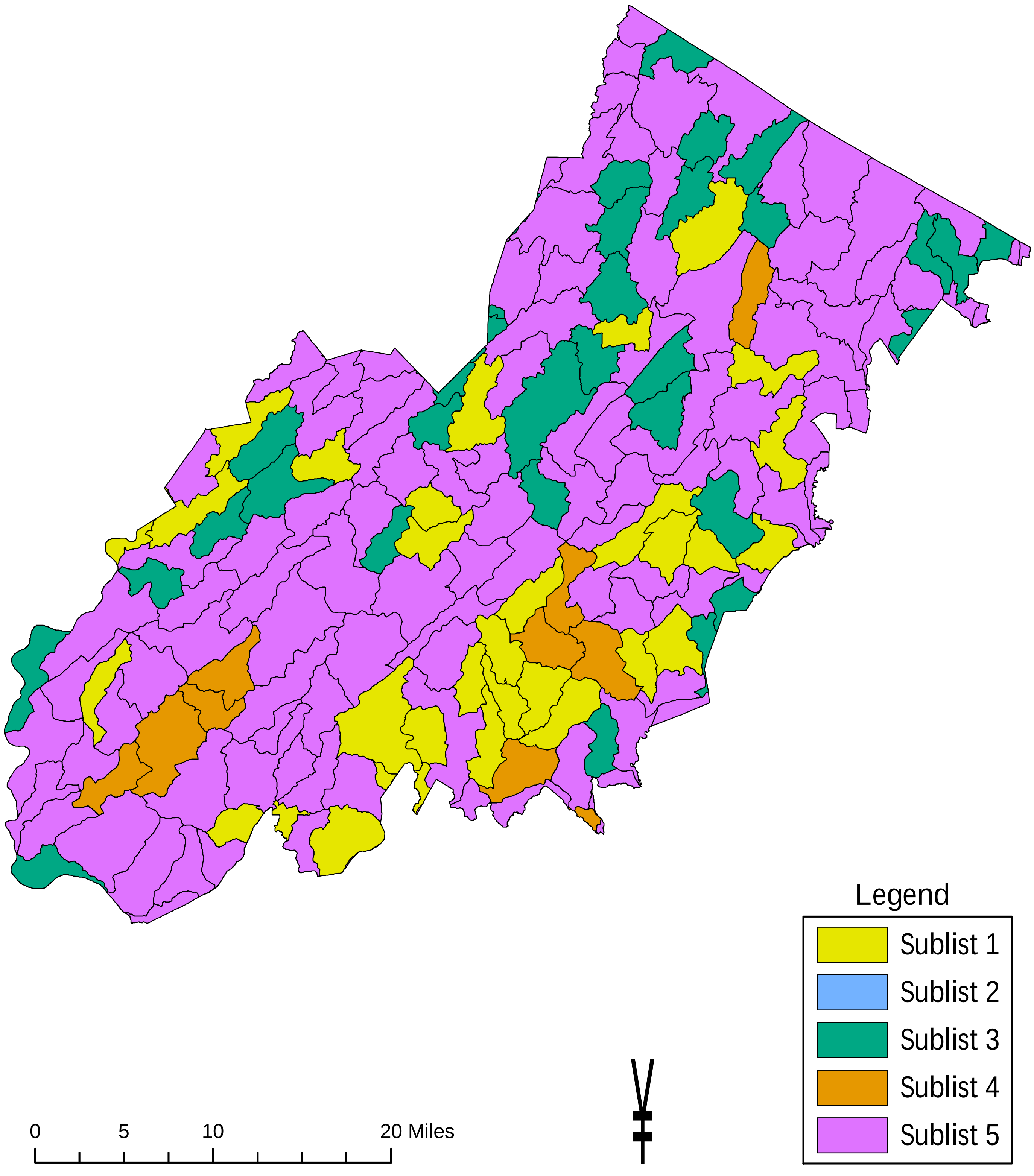


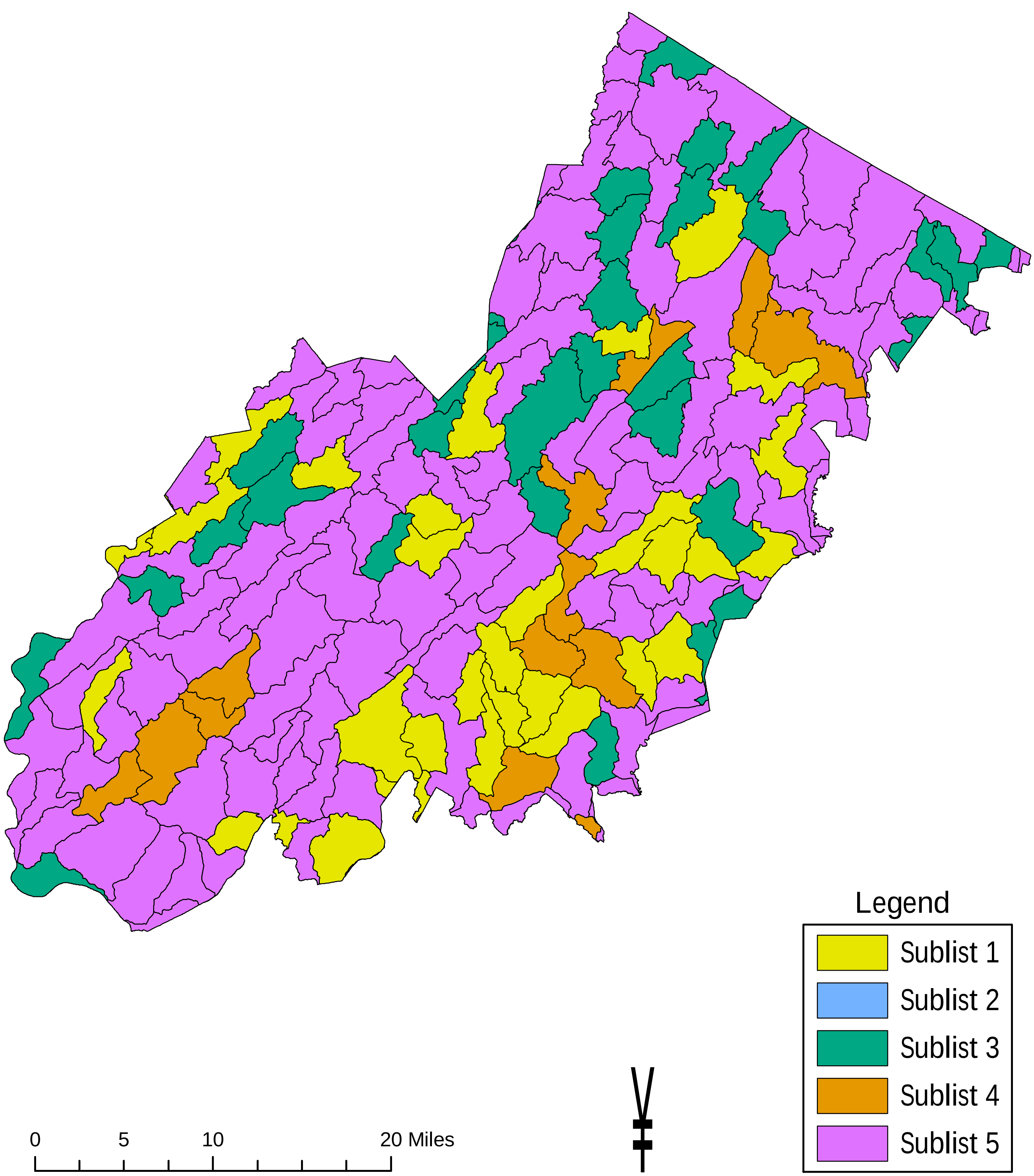
Fish Consumption



Overall Assessment
Including Fish Consumption



Overall Assessment Without Fish Consumption

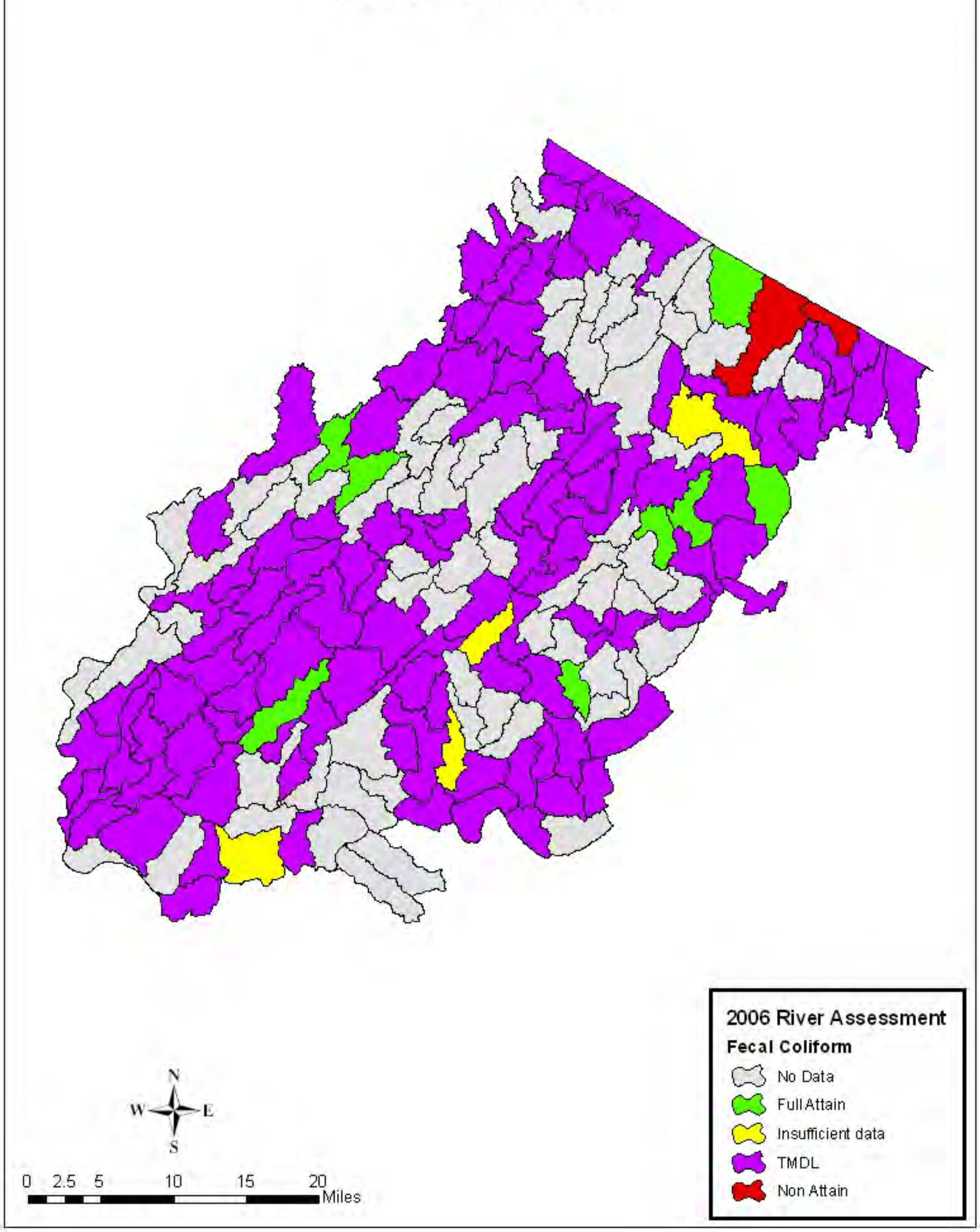


Appendix E

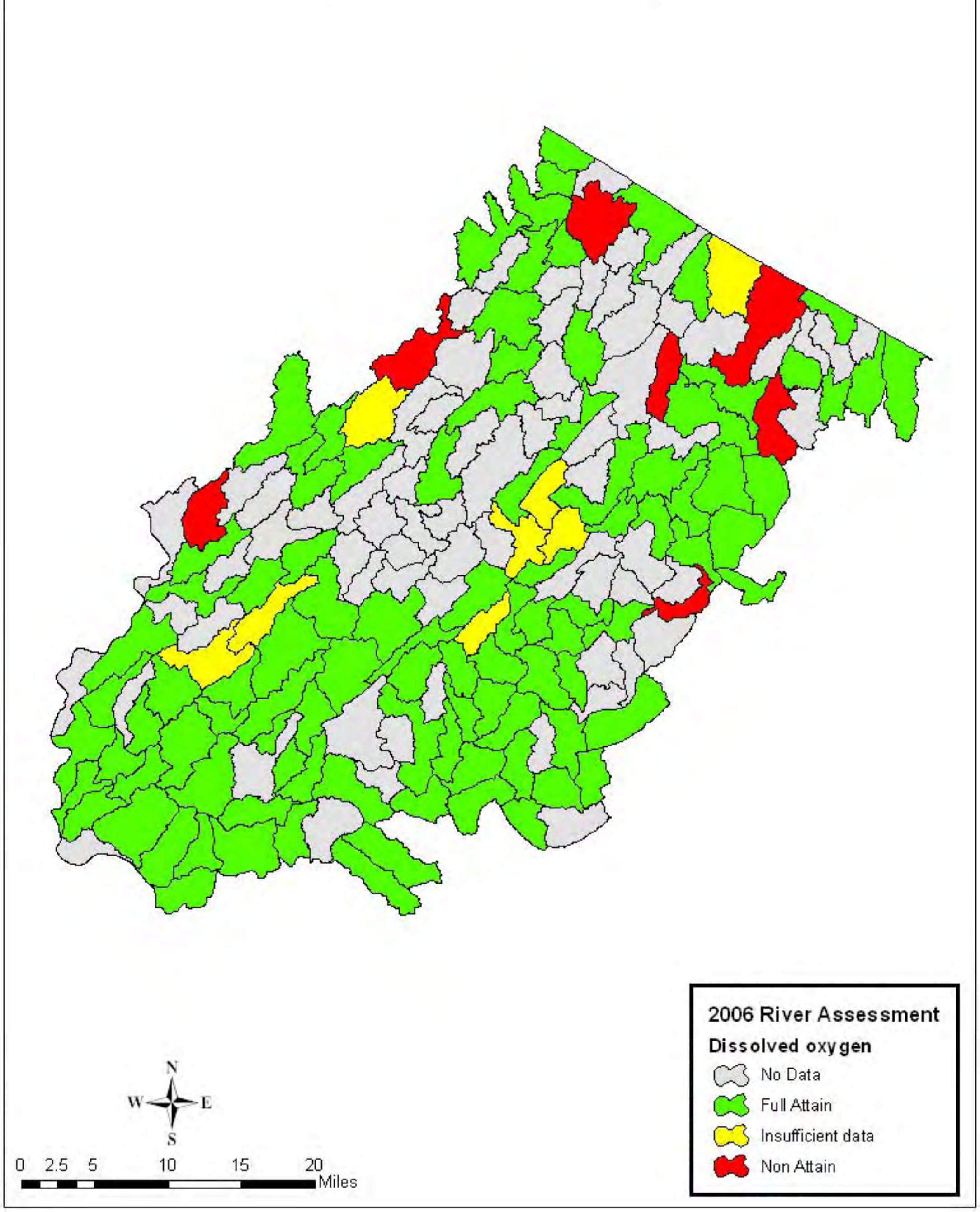
Spatial representation of assessment units (HUC-14) within the Highlands area with respect to meeting water quality standards for a suite of water quality parameters as per the draft New Jersey 2006 Integrated List.

Note, the data discussed and tabled in Part II of this report reflect current water quality conditions based upon current data. Maps in this appendix reflect assessments created for the purposes of fulfilling section 303(d) requirements and in doing so also include older historical data and assessments which must be carried over to the new assessment cycle unless there are newer data to reassess the waterbody. This means that maps in this appendix may display impairments that may or may not be supported by the information in Part II which is based upon current data only.

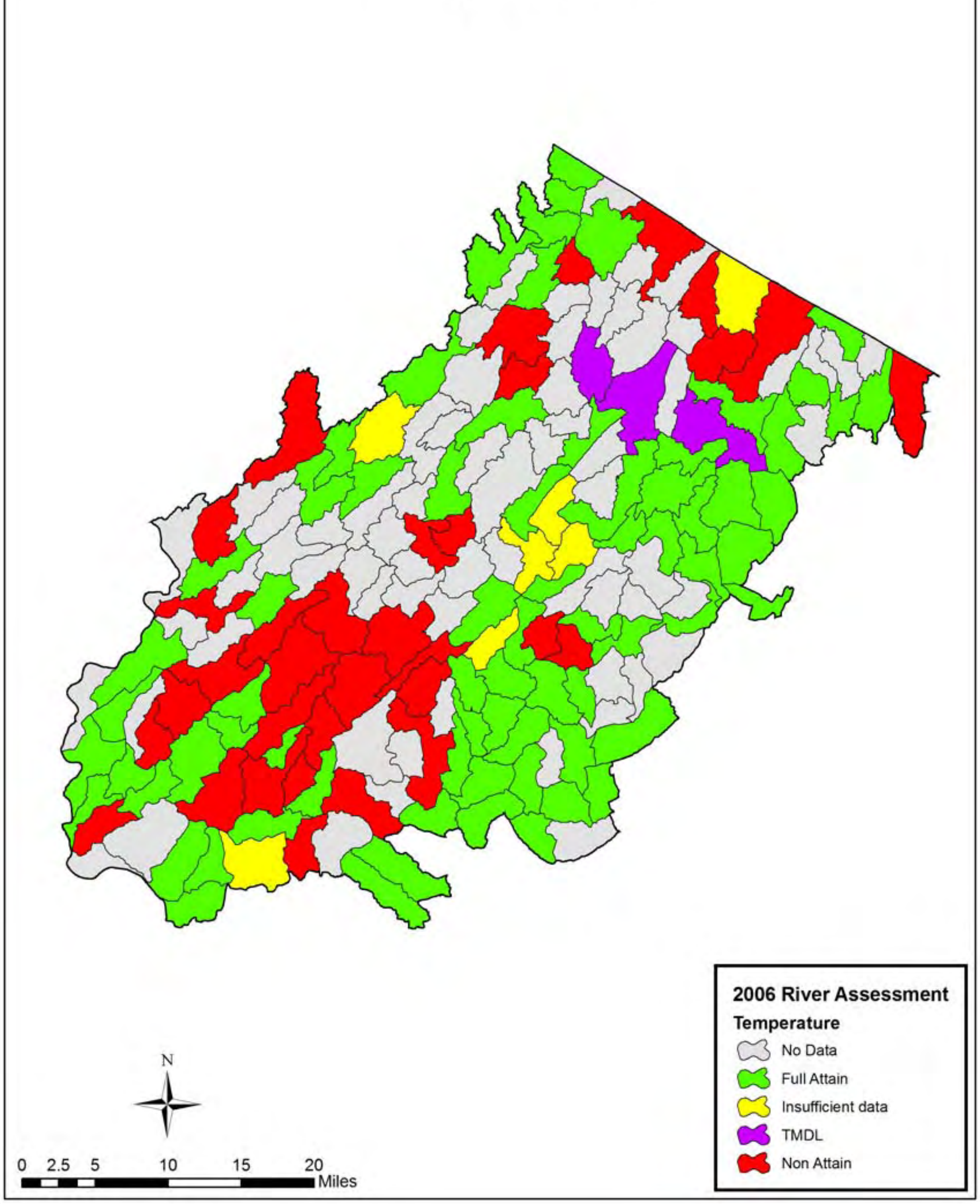
Fecal Coliform

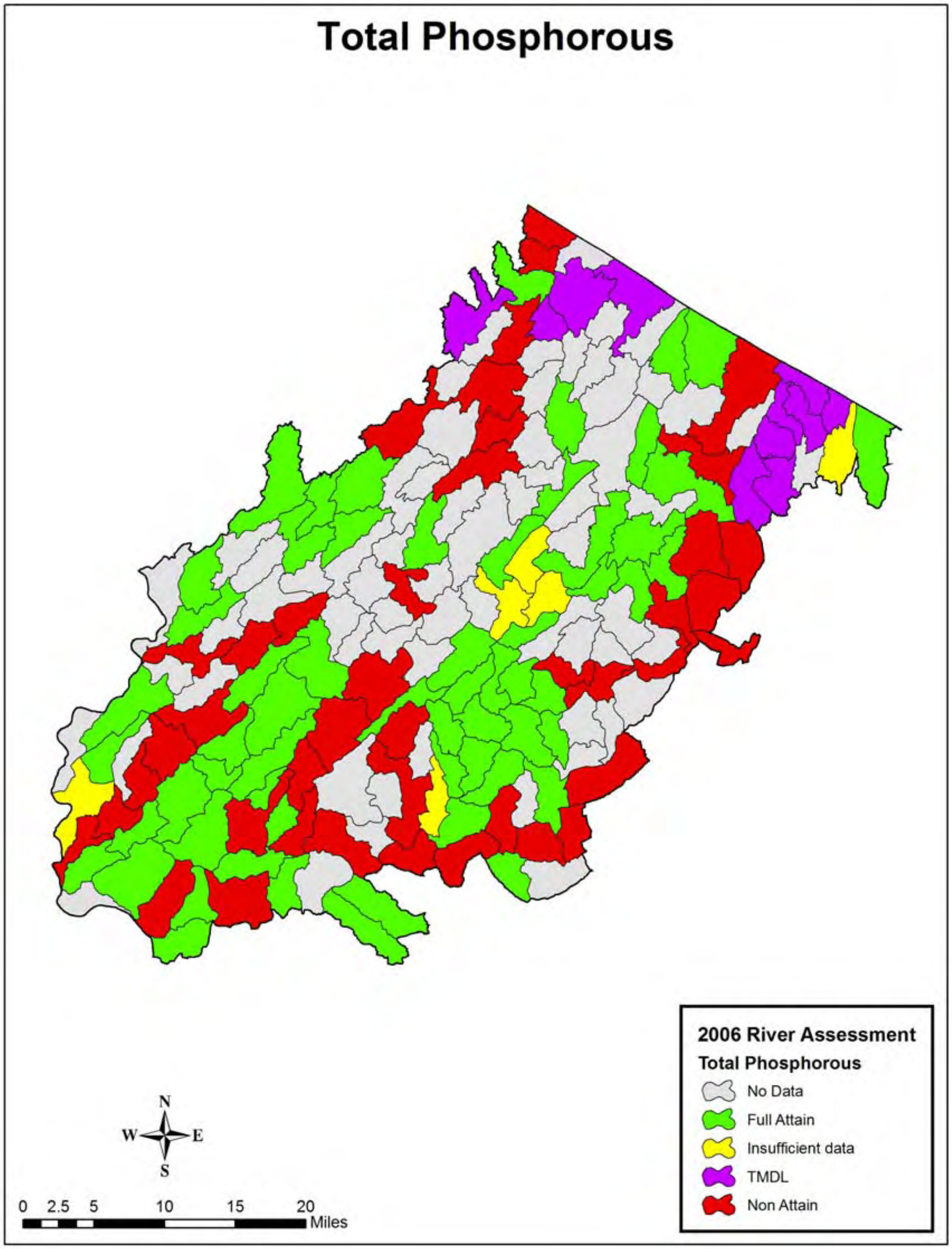


Dissolved oxygen

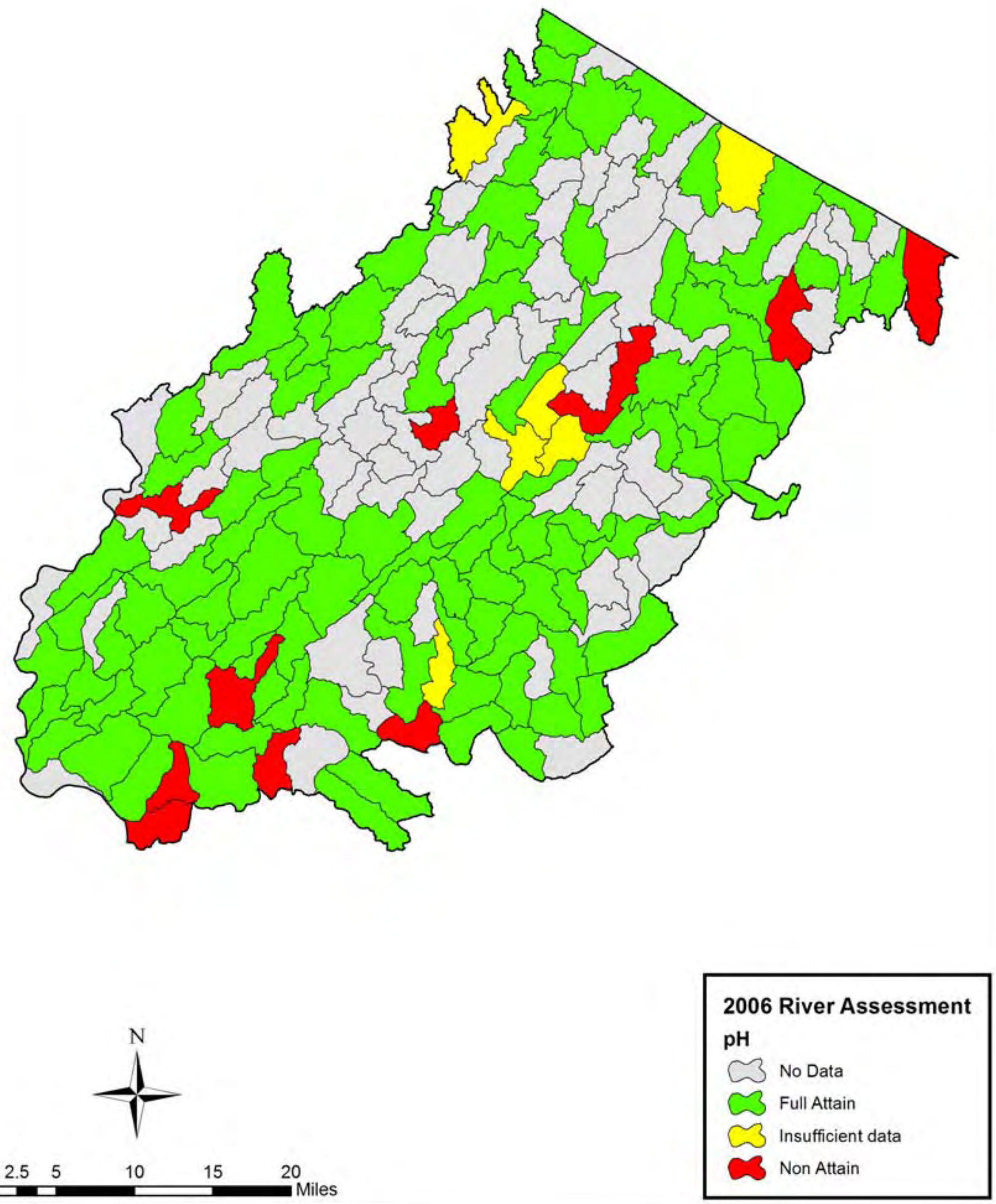


Temperature

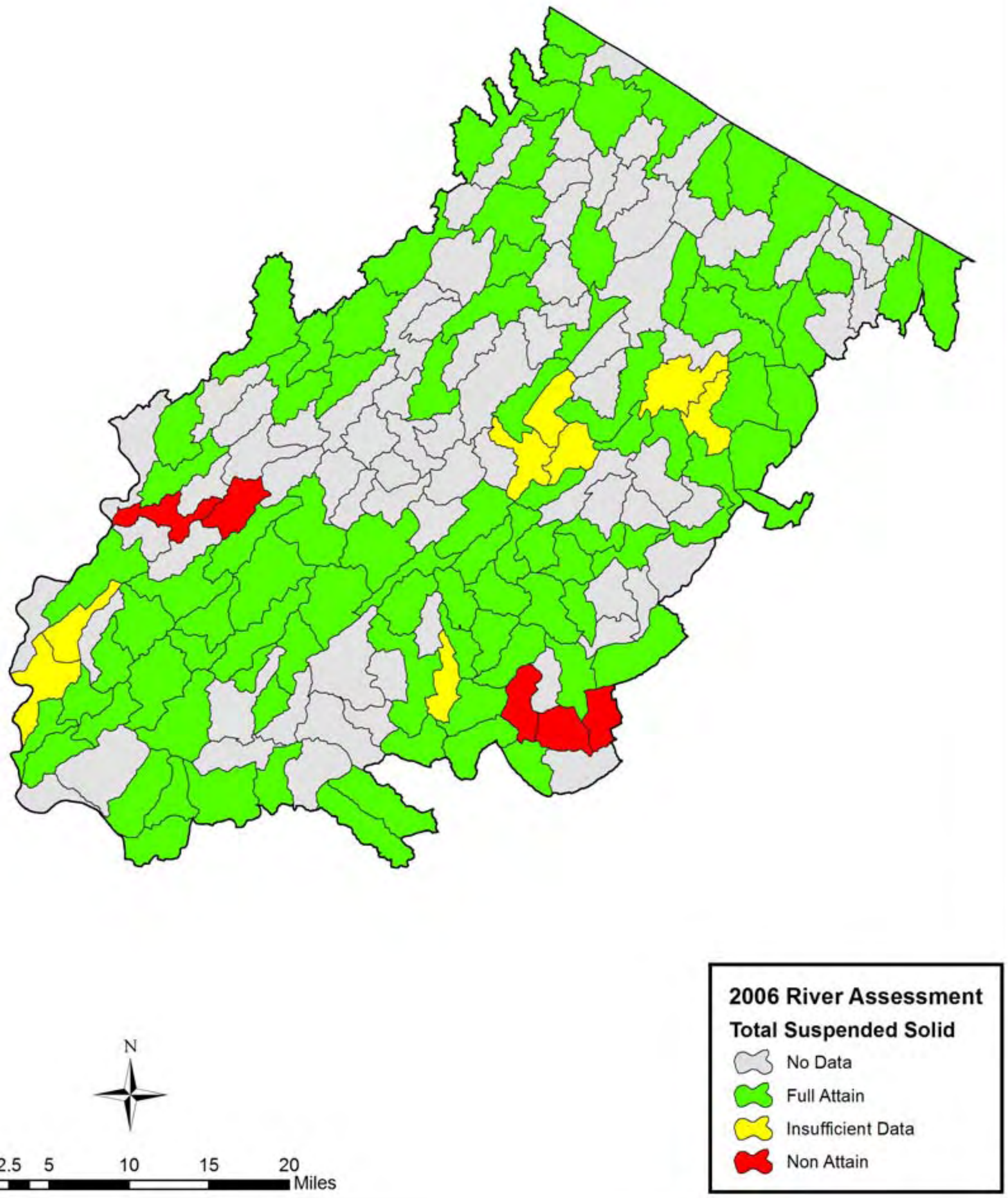



Total Phosphorous
2006 River Assessment
Total Phosphorous
No Data
Full Attain
Insufficient data
TMDL
Non Attain
N
W
E
S
0 2.5 5 10 15 20
Miles

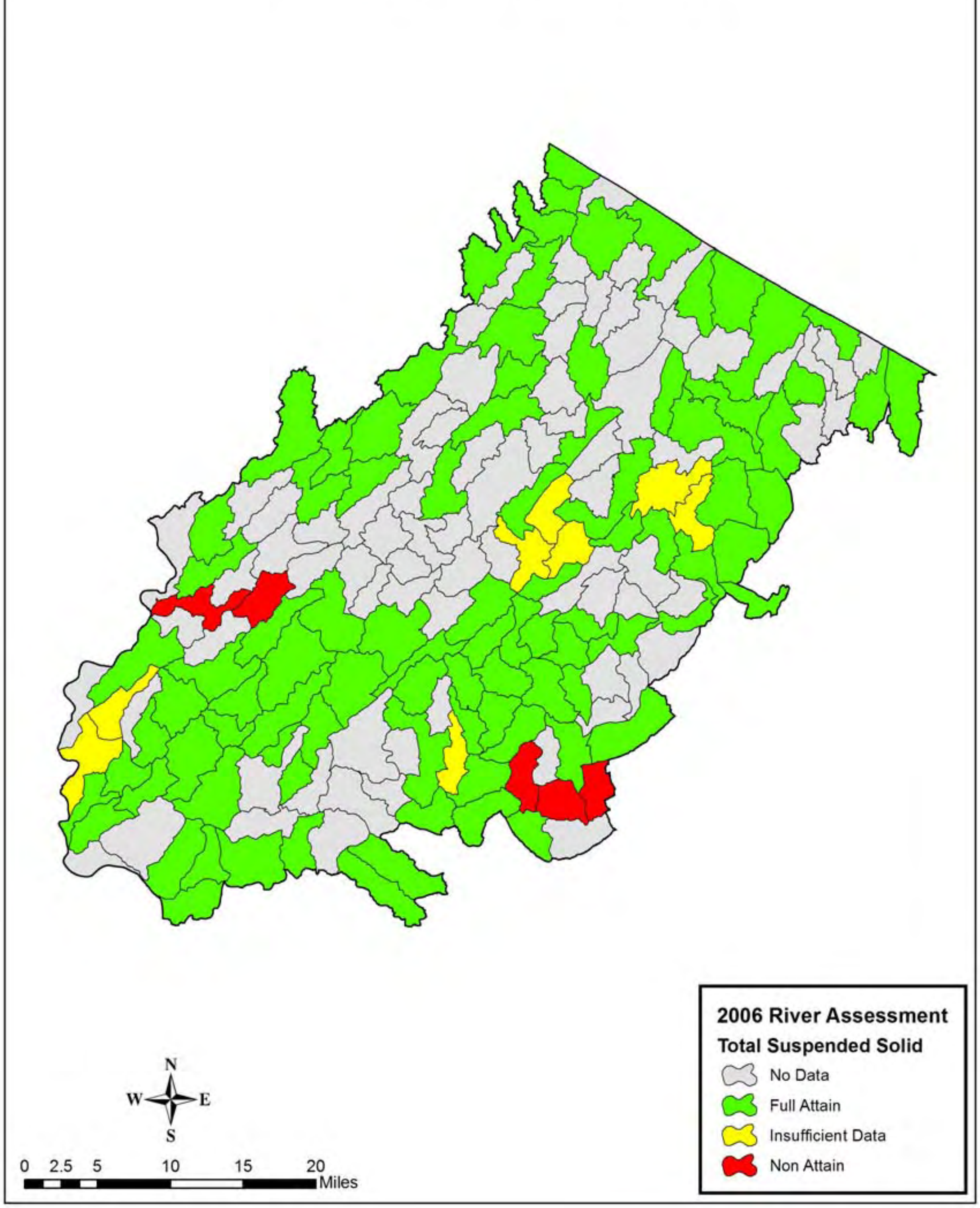
pH

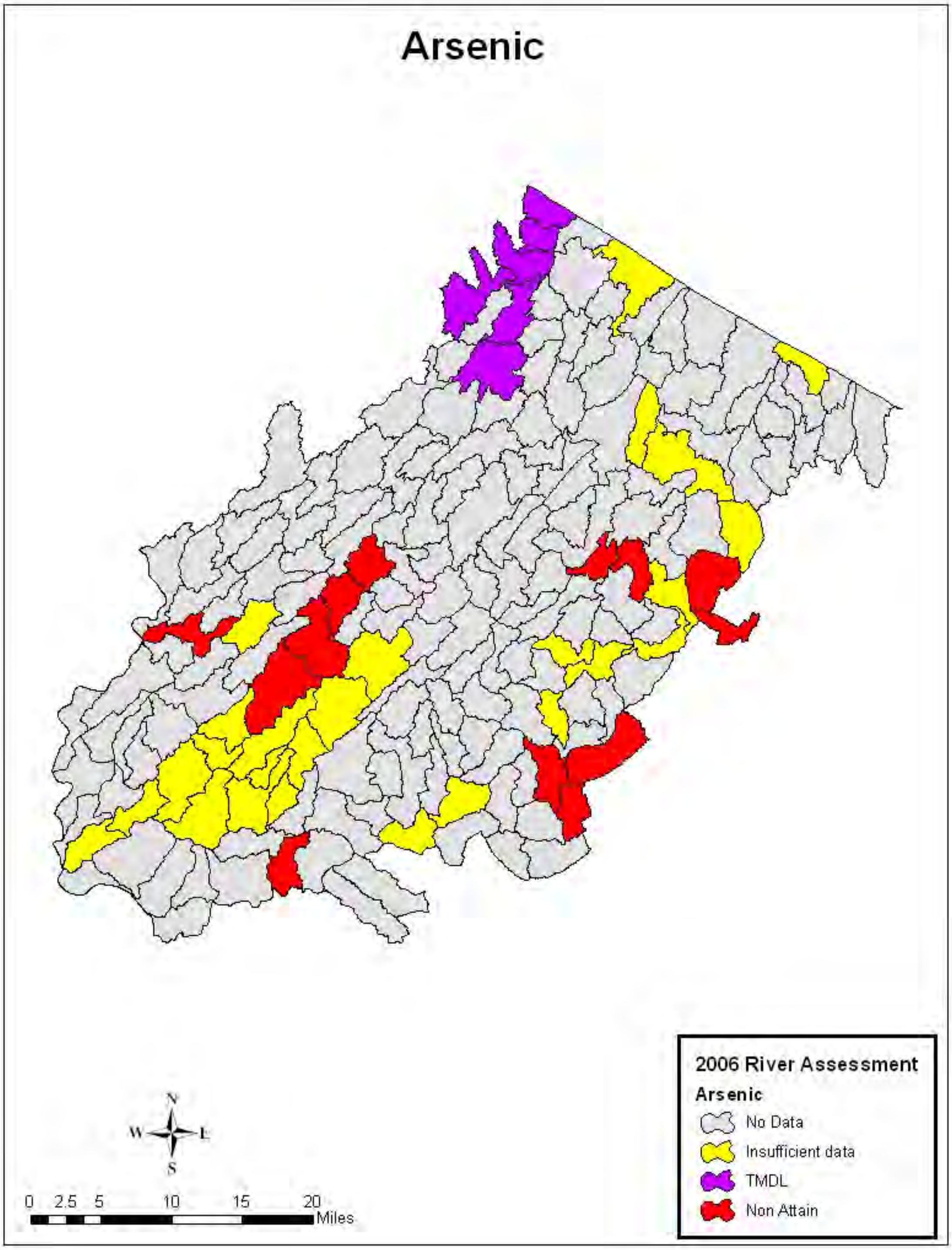

2006 River Assessment
pH
No Data
Full Attain
Insufficient data
Non Attain
N
0 2.5 5 10 15 20
Miles

Total Dissolved Solid



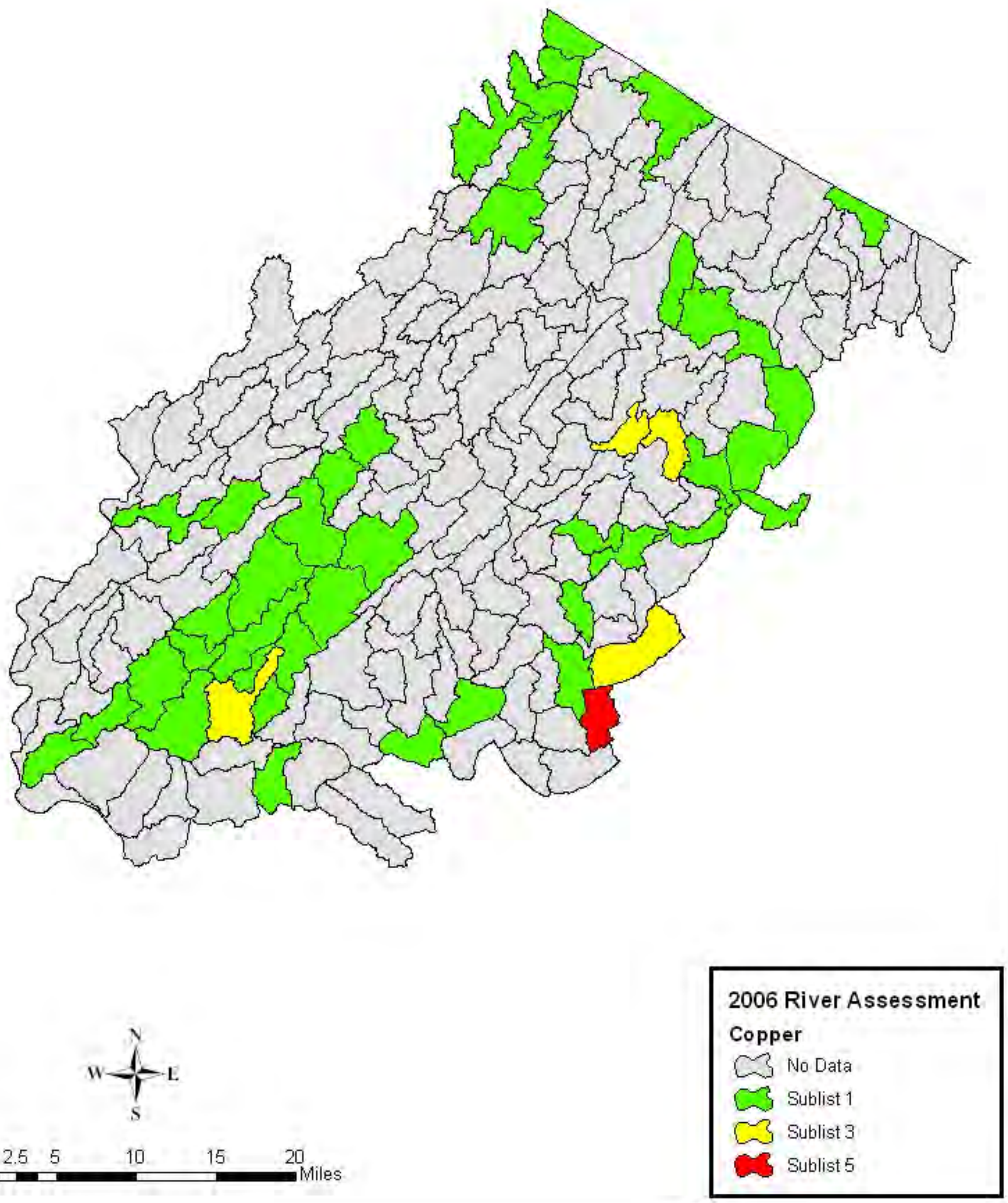
Total Suspended Solid





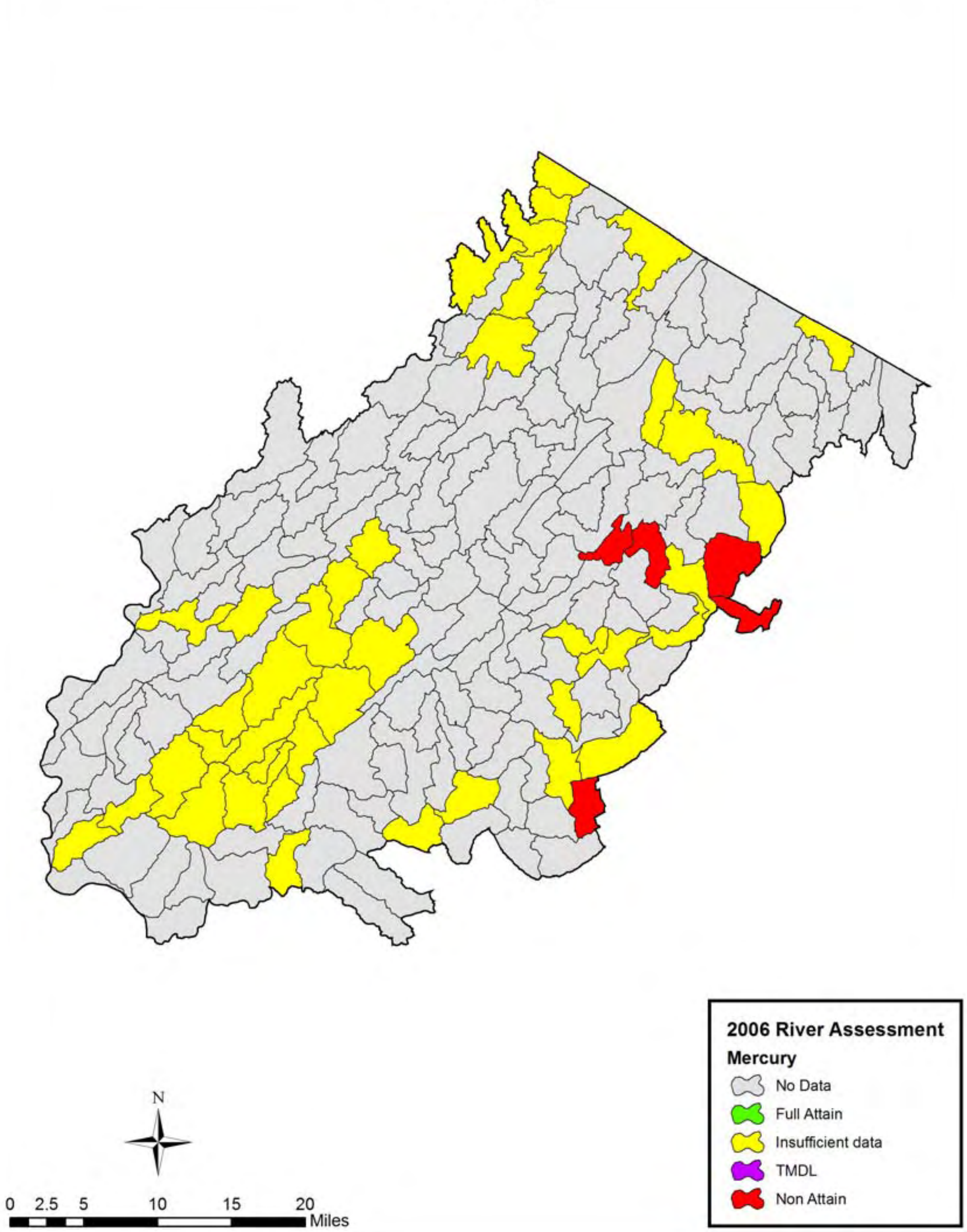
Arsenic
N
W
E
S
0 2.5 5 10 15 20
Miles
2006 River Assessment
Arsenic
No Data
Insufficient data
TMDL
Non Attain

Copper



2006 River Assessment
Copper
No Data
Sublist 1
Sublist 3
Sublist 5
N
W
E
S
0 2.5 5 10 15 20
Miles

Mercury



2006 River Assessment
Mercury
No Data
Full Attain
Insufficient data
TMDL
Non Attain
N
0 2.5 5 10 15 20
Miles

Appendix F

Point and nonpoint source categories which have the potential to contribute to designated use impairment were located using GIS data, assessment unit by assessment unit. These are displayed in this Appendix. HUC units displayed are impaired for the designated use indicated in the table legend and for the sake of brevity, only HUCs with identified sources are displayed. There are numerous HUCs for which there are no pollution source information; these are listed in the Integrated List as "pollutant unknown."

Note that watershed specific sources of fecal coliform obtained from Department TMDL Reports are contained in Part II of this report, in the waterbody specific descriptions.

Legend:

Abbreviation	Definition
MPS	Municipal Point Source
PP	Package Plant
OSW	On Site Wastewater Treatment
AG	Agricultural Land Use
UR	Urban Land Use
UI	Upstream Impoundment
NAT	Natural Sources
AIR	Air Deposition

Suspected Sources To Aquatic Life Use Impairment

HUC14	SW_NAME	WMA	MPS	PP	OSW	AG	UR	UI
02030103070060	Meadow Brook/High Mountain Brook	03		YES		YES	YES	
02030103140020	Hohokus Bk(Pennington Ave to Godwin Ave)	04				YES	YES	
02030105010010	Drakes Brook (above Eyland Ave)	08		YES	YES	YES	YES	
02040105120020	Lopatcong Creek (below Rt 57) incl UDRV	01	YES			YES	YES	
02040105170040	Nishisakawick Creek (above 40d 33m)	11				YES	YES	
02040105080010	Bear Brook (Sussex/Warren Co)	01				YES	YES	
02030103020100	Whippany R (Rockaway R to Malapardis Bk)	06	YES				YES	
02030105010020	Drakes Brook (below Eyland Ave)	08		YES		YES	YES	
02030105010050	Raritan R SB(LongValley br to 74d44m15s)	08		YES		YES	YES	YES
02030103020040	Whippany R(Lk Pocahontas to Wash Val Rd)	06	YES			YES	YES	
02030103010070	Passaic R Upr (Dead R to Osborn Mills)	06				YES	YES	
02030105020040	Spruce Run Reservior / Willoughby Brook	08				YES	YES	YES
02040105140060	Pohatcong Ck (Springtown to Merrill Ck)	01				YES	YES	
02030105050110	Lamington R (below Halls Bridge Rd)	08		YES		YES	YES	
02040105170030	Harihokake Creek (and to Hakihokake Ck)	11				YES	YES	
02030105040030	Holland Brook	08		YES		YES	YES	
02020007030010	Wallkill R(41d13m30s to Martins Road)	02		YES		YES	YES	
02030103070050	Wanaque Reservior (below Monks gage)	03		YES	YES	YES	YES	YES
02030103140040	Saddle River (above Rt 17)	04				YES	YES	YES
02030103070070	Wanaque R/Posts Bk (below reservior)	03	YES			YES	YES	
02040105070040	Pequest River (Trout Brook to Brighton)	01				YES	YES	
02030103110020	Pompton River	03	YES	YES		YES	YES	
02030105050020	Lamington R (Hillside Rd to Rt 10)	08	YES			YES	YES	
02030105020030	Mulhockaway Creek	08		YES		YES	YES	YES
02020007010060	Beaver Run	02				YES	YES	
02020007010040	Wallkill R(Hamburg SW Bdy to Ogdensburg)	02			YES	YES	YES	YES
02030103100010	Ramapo R (above 74d 11m 00s)	03				YES	YES	
02030103030110	Beaver Brook (Morris County)	06				YES	YES	
02040105070050	Trout Brook/Lake Tranquility	01			YES	YES	YES	
02040105140020	Pohatcong Ck (Brass Castle Ck to Rt 31)	01		YES	YES	YES	YES	YES
02030105010070	Raritan R SB(StoneMill gage to Califon)	08				YES	YES	YES
02030105020050	Beaver Brook (Clinton)	08	YES	YES		YES	YES	
02040105140070	Pohatcong Ck(below Springtown) incl UDRV	01				YES	YES	
02020007030040	Wallkill River(stateline to Owens gage)	02				YES	YES	
02020007010070	Wallkill R(Martins Rd to Hamburg SW Bdy)	02	YES			YES	YES	
02020007010020	Wallkill R (Ogdensburg to SpartaStation)	02		YES		YES	YES	YES
02040105150030	Musconetcong R (Wills Bk to LkHopatcong)	01	YES		YES	YES	YES	YES
02040105090020	Pequest R (Cemetary Road to Drag Strip)	01			YES	YES	YES	
02030105010060	Raritan R SB(Califon br to Long Valley)	08				YES	YES	YES
02040105120010	Lopatcong Creek (above Rt 57)	01				YES	YES	
02030103010080	Dead River (above Harrisons Brook)	06				YES	YES	
02030105020080	Raritan R SB(Prescott Bk to River Rd)	08		YES	YES	YES	YES	YES
02030105020060	Cakepoulin Creek	08				YES	YES	
02030105040020	Pleasant Run	08				YES	YES	
02030103050030	Pequannock R (above OakRidge Res outlet)	03				YES	YES	
02030103050050	Pequannock R (Charlotteburg to OakRidge)	03			YES	YES	YES	

Suspected Sources To Aquatic Life Use Impairment, continued

HUC14	SW_NAME	WMA	MPS	PP	OSW	AG	UR	UI
02030103140010	Hohokus Bk (above Godwin Ave)	04			YES	YES	YES	
02030103040010	Passaic R Upr (Pompton R to Pine Bk)	06				YES	YES	
02030103030170	Rockaway R (Passaic R to Boonton dam)	06	YES			YES	YES	
02030103010180	Passaic R Upr (Pine Bk br to Rockaway)	06				YES	YES	
02040105090060	Pequest R (below Furnace Brook)	01			YES	YES	YES	YES
02040105140030	Pohatcong Ck (Edison Rd-Brass Castle Ck)	01		YES		YES	YES	YES
02030105050070	Lamington R(HallsBrRd-Pottersville gage)	08		YES		YES	YES	YES
02030103010110	Passaic R Upr (Plainfield Rd to Dead R)	06		YES		YES	YES	
02030105050100	Rockaway Ck SB	08		YES		YES	YES	YES
02030103070020	Belcher Creek (Pinecliff Lake & below)	03		YES	YES	YES	YES	YES
02030103070030	Wanaque R/Greenwood Lk(aboveMonks gage)	03		YES		YES	YES	
02040105040060	Paulins Kill (above Rt 15)	01	YES	YES	YES	YES	YES	
02040105050010	Paulins Kill (Blairstown to Stillwater)	01				YES	YES	YES
02030103100070	Ramapo R (below Crystal Lake bridge)	03	YES	YES		YES	YES	
02020007010010	Wallkill R/Lake Mohawk(above Sparta Sta)	02		YES		YES	YES	
02040105150040	Lubbers Run (above/incl Dallis Pond)	01				YES	YES	
02030103030040	Rockaway R (Stephens Bk to Longwood Lk)	06				YES	YES	
02030103030060	Green Pond Brook (below Burnt Meadow Bk)	06					YES	
02030103030140	Rockaway R (Stony Brook to BM 534 brdg)	06				YES	YES	
02030103030090	Rockaway R (BM 534 brdg to 74d 33m 30s)	06					YES	
02030103020050	Whippany R (Malapardis to Lk Pocahontas)	06	YES			YES	YES	
02030105050040	Lamington R(Pottersville gage-FurnaceRd)	08		YES		YES	YES	YES
02030103010060	Black Brook (Great Swamp NWR)	06		YES	YES	YES	YES	
02040105170050	Nishisakawick Creek (below 40d 33m)	11				YES	YES	
02020007020070	Papakating Creek (below Pellettown)	02				YES	YES	
02040105040050	Sparta Junction tribs	01		YES	YES	YES	YES	
02030103050060	Pequannock R(Macopin gage to Charl'brg)	03				YES	YES	
02040105070030	Pequest River (above Brighton)	01			YES	YES	YES	
02040105080020	Bear Creek	01				YES	YES	
02030103030130	Stony Brook (Boonton)	06		YES		YES	YES	
02030103110010	Lincoln Park tribs (Pompton River)	03				YES	YES	
02040105100020	Honey Run	01				YES	YES	YES
02030103030150	Rockaway R (Boonton dam to Stony Brook)	06				YES	YES	
02040105090030	Pequest R (Furnace Bk to Cemetary Road)	01		YES		YES	YES	
02040105090050	Furnace Brook	01				YES	YES	
02040105110020	Buckhorn Creek (incl UDRV)	01		YES	YES	YES	YES	
02030103010050	Great Brook (below Green Village Rd)	06				YES	YES	
02040105140050	Pohatcong Ck (Merrill Ck to Edison Rd)	01				YES	YES	YES
02030105020020	Spruce Run (Reservior to Glen Gardner)	08		YES		YES	YES	
02030103010100	Dead River (below Harrisons Brook)	06	YES	YES		YES	YES	
02030105120050	Middle Brook EB	09				YES	YES	
02030105070010	Raritan R NB (Rt 28 to Lamington R)	08				YES	YES	
02020007030030	Wallkill River(Owens gage to 41d13m30s)	02				YES	YES	
02020007040020	Black Creek (below G. Gorge Resort trib)	02		YES		YES	YES	

Suspected Sources To Aquatic Life Trout Use Impairment

HUC14	SW_NAME	WMA	MPS	PP	OSW	AG	UR	UI
02030103070060	Meadow Brook/High Mountain Brook	03		YES		YES	YES	
02030103140020	Hohokus Bk(Pennington Ave to Godwin Ave)	04				YES	YES	
02030105010010	Drakes Brook (above Eyland Ave)	08		YES	YES	YES	YES	
02040105120020	Lopatcong Creek (below Rt 57) incl UDRV	01	YES			YES	YES	
02040105170040	Nishisakawick Creek (above 40d 33m)	11				YES	YES	
02040105080010	Bear Brook (Sussex/Warren Co)	01				YES	YES	
02030103020100	Whippany R (Rockaway R to Malapardis Bk)	06	YES				YES	
02030105010020	Drakes Brook (below Eyland Ave)	08		YES		YES	YES	
02030105010050	Raritan R SB(LongValley br to 74d44m15s)	08		YES		YES	YES	YES
02030103020040	Whippany R(Lk Pocahontas to Wash Val Rd)	06	YES			YES	YES	
02030103010070	Passaic R Upr (Dead R to Osborn Mills)	06				YES	YES	
02030105020040	Spruce Run Reservior / Willoughby Brook	08				YES	YES	YES
02040105140060	Pohatcong Ck (Springtown to Merrill Ck)	01				YES	YES	
02030105050110	Lamington R (below Halls Bridge Rd)	08		YES		YES	YES	
02040105170030	Harihokake Creek (and to Hakihokake Ck)	11				YES	YES	
02030105040030	Holland Brook	08		YES		YES	YES	
02020007030010	Wallkill R(41d13m30s to Martins Road)	02		YES		YES	YES	
02030103070050	Wanaque Reservior (below Monks gage)	03		YES	YES	YES	YES	YES
02030103140040	Saddle River (above Rt 17)	04				YES	YES	YES
02030103070070	Wanaque R/Posts Bk (below reservior)	03	YES			YES	YES	
02040105070040	Pequest River (Trout Brook to Brighton)	01				YES	YES	
02030103110020	Pompton River	03	YES	YES		YES	YES	
02030105050020	Lamington R (Hillside Rd to Rt 10)	08	YES			YES	YES	
02030105020030	Mulhockaway Creek	08		YES		YES	YES	YES
02020007010060	Beaver Run	02				YES	YES	
02020007010040	Wallkill R(Hamburg SW Bdy to Ogdensburg)	02			YES	YES	YES	YES
02030103100010	Ramapo R (above 74d 11m 00s)	03				YES	YES	
02030103030110	Beaver Brook (Morris County)	06				YES	YES	
02040105070050	Trout Brook/Lake Tranquility	01			YES	YES	YES	
02040105140020	Pohatcong Ck (Brass Castle Ck to Rt 31)	01		YES	YES	YES	YES	YES
02030105010070	Raritan R SB(StoneMill gage to Califon)	08				YES	YES	YES
02030105020050	Beaver Brook (Clinton)	08	YES	YES		YES	YES	
02040105140070	Pohatcong Ck(below Springtown) incl UDRV	01				YES	YES	
02020007030040	Wallkill River(stateline to Owens gage)	02				YES	YES	
02020007010070	Wallkill R(Martins Rd to Hamburg SW Bdy)	02	YES			YES	YES	
02020007010020	Wallkill R (Ogdensburg to SpartaStation)	02		YES		YES	YES	YES
02040105150030	Musconetcong R (Wills Bk to LkHopatcong)	01	YES		YES	YES	YES	YES
02040105090020	Pequest R (Cemetary Road to Drag Strip)	01			YES	YES	YES	
02030105010060	Raritan R SB(Califon br to Long Valley)	08				YES	YES	YES
02040105120010	Lopatcong Creek (above Rt 57)	01				YES	YES	
02030103010080	Dead River (above Harrisons Brook)	06				YES	YES	
02030105020080	Raritan R SB(Prescott Bk to River Rd)	08		YES	YES	YES	YES	YES
02030105020060	Cakepoulin Creek	08				YES	YES	
02030105040020	Pleasant Run	08				YES	YES	
02030103050030	Pequannock R (above OakRidge Res outlet)	03				YES	YES	
02030103050050	Pequannock R (Charlotteburg to OakRidge)	03			YES	YES	YES	
02030103140010	Hohokus Bk (above Godwin Ave)	04			YES	YES	YES	

Suspected Sources To Aquatic Life Trout Use Impairment, continued

HUC14	SW_NAME	WMA	MPS	PP	OSW	AG	UR	UI
02030103040010	Passaic R Upr (Pompton R to Pine Bk)	06				YES	YES	
02030103030170	Rockaway R (Passaic R to Boonton dam)	06	YES			YES	YES	
02030103010180	Passaic R Upr (Pine Bk br to Rockaway)	06				YES	YES	
02040105090060	Pequest R (below Furnace Brook)	01			YES	YES	YES	YES
02040105140030	Pohatcong Ck (Edison Rd-Brass Castle Ck)	01		YES		YES	YES	YES
02030105050070	Lamington R(HallsBrRd-Pottersville gage)	08		YES		YES	YES	YES
02030103010110	Passaic R Upr (Plainfield Rd to Dead R)	06		YES		YES	YES	
02030105050100	Rockaway Ck SB	08		YES		YES	YES	YES
02030103070020	Belcher Creek (Pinecliff Lake & below)	03		YES	YES	YES	YES	YES
02030103070030	Wanaque R/Greenwood Lk(aboveMonks gage)	03		YES		YES	YES	
02040105040060	Paulins Kill (above Rt 15)	01	YES	YES	YES	YES	YES	
02040105050010	Paulins Kill (Blairstown to Stillwater)	01				YES	YES	YES
02030103100070	Ramapo R (below Crystal Lake bridge)	03	YES	YES		YES	YES	
02020007010010	Wallkill R/Lake Mohawk(above Sparta Sta)	02		YES		YES	YES	
02040105150040	Lubbers Run (above/incl Dallis Pond)	01				YES	YES	
02030103030040	Rockaway R (Stephens Bk to Longwood Lk)	06				YES	YES	
02030103030060	Green Pond Brook (below Burnt Meadow Bk)	06					YES	
02030103030140	Rockaway R (Stony Brook to BM 534 brdg)	06				YES	YES	
02030103030090	Rockaway R (BM 534 brdg to 74d 33m 30s)	06					YES	
02030103020050	Whippany R (Malapardis to Lk Pocahontas)	06	YES			YES	YES	
02030105050040	Lamington R(Pottersville gage-FurnaceRd)	08		YES		YES	YES	YES
02030103010060	Black Brook (Great Swamp NWR)	06		YES	YES	YES	YES	
02040105170050	Nishisakawick Creek (below 40d 33m)	11				YES	YES	
02020007020070	Papakating Creek (below Pellettown)	02				YES	YES	
02040105040050	Sparta Junction tribs	01		YES	YES	YES	YES	
02030103050060	Pequannock R(Macopin gage to Charl'brg)	03				YES	YES	
02040105070030	Pequest River (above Brighton)	01			YES	YES	YES	
02040105080020	Bear Creek	01				YES	YES	
02030103030130	Stony Brook (Boonton)	06		YES		YES	YES	
02030103110010	Lincoln Park tribs (Pompton River)	03				YES	YES	
02040105100020	Honey Run	01				YES	YES	YES
02030103030150	Rockaway R (Boonton dam to Stony Brook)	06				YES	YES	
02040105090030	Pequest R (Furnace Bk to Cemetary Road)	01		YES		YES	YES	
02040105090050	Furnace Brook	01				YES	YES	
02040105110020	Buckhorn Creek (incl UDRV)	01		YES	YES	YES	YES	
02030103010050	Great Brook (below Green Village Rd)	06				YES	YES	
02040105140050	Pohatcong Ck (Merrill Ck to Edison Rd)	01				YES	YES	YES
02030105020020	Spruce Run (Reservior to Glen Gardner)	08		YES		YES	YES	
02030103010100	Dead River (below Harrisons Brook)	06	YES	YES		YES	YES	

Suspected Sources To Aquatic Life Trout Use Impairment, continued

HUC14	SW_NAME	WMA	MPS	PP	OSW	AG	UR	UI
02030105120050	Middle Brook EB	09				YES	YES	
02030105070010	Raritan R NB (Rt 28 to Lamington R)	08				YES	YES	
02020007030030	Wallkill River(Owens gage to 41d13m30s)	02				YES	YES	
02020007040020	Black Creek (below G. Gorge Resort trib)	02		YES		YES	YES	

Suspected Sources For Primary Contact Use Impairment

HUC14	SW_NAME	WMA	AG	UR
02030103070050	Wanaque Reservior (below Monks gage)	03	YES	YES
02030105040020	Pleasant Run	08	YES	YES

Suspected Sources For Secondary Contact Use Impairment

HUC14	SW_NAME	WMA	AG	UR
02030105040020	Pleasant Run	08	YES	YES

Suspected Sources For Drinking Water Use Impairment

HUC14	SW_NAME	WMA	MPS	AG	UR	NAT
02030103020100	Whippany R (Rockaway R to Malapardis Bk)	06	YES		YES	
02030103010070	Passaic R Upr (Dead R to Osborn Mills)	06		YES	YES	YES
02030103110020	Pompton River	03	YES	YES	YES	
02040105160020	Musconetcong R (Changewater to HancesBk)	01		YES	YES	YES
02020007010070	Wallkill R(Martins Rd to Hamburg SW Bdy)	02	YES	YES	YES	
02040105160010	Musconetcong R (Hances Bk thru Trout Bk)	01	YES	YES	YES	YES
02030105020080	Raritan R SB(Prescott Bk to River Rd)	08		YES	YES	YES
02030103140010	Hohokus Bk (above Godwin Ave)	04		YES	YES	
02030103040010	Passaic R Upr (Pompton R to Pine Bk)	06		YES	YES	YES
02030103010180	Passaic R Upr (Pine Bk br to Rockaway)	06		YES	YES	YES
02040105090060	Pequest R (below Furnace Brook)	01		YES	YES	YES
02030103010110	Passaic R Upr (Plainfield Rd to Dead R)	06		YES	YES	YES
02030103030140	Rockaway R (Stony Brook to BM 534 brdg)	06		YES	YES	YES
02040105150080	Musconetcong R (SaxtonFalls to Waterloo)	01		YES	YES	YES
02030103010060	Black Brook (Great Swamp NWR)	06		YES	YES	YES
02020007020070	Papakating Creek (below Pellettown)	02		YES	YES	
02030103030150	Rockaway R (Boonton dam to Stony Brook)	06		YES	YES	YES
02040105150100	Musconetcong R (Trout Bk to SaxtonFalls)	01		YES	YES	YES

Suspected Sources For Agricultural Use (AG) And Industrial Use (IND) Impairment

HUC14	SW_NAME	WMA	AG_MPS	AG_AG	AG_UR	IND_AG	IND_UR	IND_NAT
02020007010070	Wallkill R(Martins Rd to Hamburg SW Bdy)	02	YES	YES	YES			
02030103140010	Hohokus Bk (above Godwin Ave)	04		YES	YES			
02040105090060	Pequest R (below Furnace Brook)	01				YES	YES	YES
02030103010110	Passaic R Upr (Plainfield Rd to Dead R)	06				YES	YES	YES

Suspected Sources For Fish Consumption Use Impairment

HUC14	SW_NAME	WMA	MPS	PP	AG	UR	AIR
02030103030030	Rockaway R (above Longwood Lake outlet)	06			YES	YES	YES
02030103110020	Pompton River	03	YES	YES	YES	YES	YES
02030103030070	Rockaway R (74d 33m 30s to Stephens Bk)	06			YES	YES	YES
02030103030110	Beaver Brook (Morris County)	06			YES	YES	YES
02030103050080	Pequannock R (below Macopin gage)	03		YES	YES	YES	YES
02030103040010	Passaic R Upr (Pompton R to Pine Bk)	06			YES	YES	YES
02030103030170	Rockaway R (Passaic R to Boonton dam)	06	YES		YES	YES	YES
02030103010180	Passaic R Upr (Pine Bk br to Rockaway)	06			YES	YES	YES
02030103030040	Rockaway R (Stephens Bk to Longwood Lk)	06			YES	YES	YES
02030103030140	Rockaway R (Stony Brook to BM 534 brdg)	06			YES	YES	YES
02030103030090	Rockaway R (BM 534 brdg to 74d 33m 30s)	06				YES	YES
02030103030150	Rockaway R (Boonton dam to Stony Brook)	06			YES	YES	YES
	Delaware River 1D3	Zone 1					YES
	Delaware River 1D4	Zone 1					YES
	Delaware River 1D5	Zone 1					YES
	Delaware River 1D6	Zone 1					YES
	Delaware River 1E1	Zone 1					YES
	Delaware River 1E2	Zone 1					YES
	Delaware River 1E3	Zone 1					YES
	Delaware River 1E4	Zone 1					YES

Appendix G

Water Quality Trends (1984 to 2004) for Seven Water Quality Monitoring Locations within the Highlands Region of New Jersey

Introduction and Summary of Results

An evaluation of water quality trends was conducted in cooperation with the USGS for selected physical and chemical constituents at 36 sampling stations located throughout the state using long-term data. Monitoring sites were limited to those which contained flow recordings in order to correct for the possible impacts from flow variations on instream concentrations through time. The constituents evaluated include dissolved oxygen, total nitrogen, nitrate, total ammonia, total phosphorus, specific conductance, and dissolved solids. The evaluation covered a time period between 1984 to 2004. The sites were located throughout the state covering all physiographic regions and land uses. Factors such as seasonality and variations in flow were taken into account and corrected for.

The upgrades and regionalization to sewage treatment plants in the 1980's and early 1990's has played an important role in the improving water quality for nutrients and dissolved oxygen, but the upgrades to STP's would not result in a reduction of the concentration of major dissolved constituents in the treated wastewater discharged to the streams.

In response to a request from the Highlands Commission, results for nine sites located within the Highlands Region were isolated and are displayed on Table A and discussed here. Results indicate that overall water quality within the Highlands displayed mixed results based upon the constituents examined. Of the 8 constituents assessed, 3 (DO, DO Saturation, NO3) showed stable conditions suggesting no trend could be detected. Two constituents (Total Dissolved Solids and Specific Conductance) displayed upward trends indicating decreasing water quality while 2 others (Ammonia and Total Phosphorus) showed declining trends indicating improving water quality conditions. The eighth constituent (Total Nitrogen) displayed mixed results with 4 sites showing no measurable trend and 4 sites indicating downward trends (improving conditions).

Results in the Highland Region by Constituent

Total nitrogen levels showed mixed results with 4 stations showing declining trends and 4 showing no statistically significant trends. Total nitrogen has no Surface Water Quality Standard but indicates overall nutrient levels in the water column from which excessive levels could cause eutrophic conditions.

For total ammonia, 7 of the 9 stations showed improving conditions while the remaining 2 sites had stable conditions. The primary source for the improvements has been the upgrades of STP's that oxidizes ammonia to nitrate during the treatment process.

Nitrate (NO3) concentrations remained stable at the majority of sites (8) in the Highlands. One site displayed increasing trends. It is interesting that more sites did not display increasing nitrate trends as STP's processes convert ammonia to nitrate, thereby increasing the concentrations of nitrate in treated wastewater discharged to the streams.

Total phosphorus showed downward trends in 7of the 9 stations assessed, and no increasing trends. One site displayed no detectable trend.

Dissolved oxygen trends showed stable conditions for all 9 sites in the Highlands. While DO simply measures the total quantity of oxygen dissolved in a water sample, dissolved oxygen saturation takes into consideration temperature to calculate the amount of dissolved oxygen that is required for the water column to be saturated (100%). Values under 100% indicate a shortfall of DO levels in the water column while values over 100% show oversaturation caused by an overproduction of oxygen possibly caused by photosynthesis by algae. Even though oversaturation may not normally stress biota, it is an indicator of eutrophication in the waterbody. DO saturation is considered a more reliable indicator of dissolved oxygen conditions since it indicates the amount of dissolved oxygen that should be in the water column and shows deficits or surplus of DO levels. All of Highland sites showed stable conditions for DO saturation.

Total dissolved solids and specific conductance both showed declining water quality. Both had increasing trends in 7 of the 9 sites. TDS is an indicator of possible increases of pollutants in the water column. Specific conductance had identical results to TDS since the two characteristics are correlated. TDS exceedances have been associated with runoff from urban and agricultural areas, including runoff of salt used to control ice on roadways. Wastewater treatment discharges and discharges from septic systems can also contribute to increased TDS loadings. The TDS and SC trends were found in all types of land uses (urban, agriculture, mixed, and undeveloped) and physiographic regions.

Table A. Summary of Water Quality Trends for Sites Located in the New Jersey Highlands Region.

Station	Station Name	DO	DO_SAT	TN	NH3	NO3	TP	TDS	SC
01367770	Wallkill River near Sussex	none	none	none	down	none	none	up	up
01443500	Paulins Kill at Blairstown	none	none	down	down	none	down	up	up
01381800	Whippany River near Pine Brook	none	none	down	down	none	down	up	up
01382500	Pequannock River at Macopin Intake Dam	none	none	none	none	none	down	none	none
01457400	Musconetcong River at Riegelsville	none	none	none	down	up	down	up	up
01387500	Ramapo River near Mahwah	none	none	down	down	none	down	up	up
01396660	Muhockaway Creek at Van Syckel	none	none	NA	down	none	none	up	up
01399780	Lamington River at Burnt Mills	none	none	down	down	none	down	up	up
01457500	Delaware River at Riegelsville	none	none	none	none	none	down	none	none
	TRENDS:								
	NONE	**9**	**9**	**4**	**2**	**8**	**2**	**2**	**2**
	DOWN	**0**	**0**	**4**	**7**	**0**	**7**	**0**	**0**
	UP	**0**	**0**	**0**	**0**	**1**	**0**	**7**	**7**
	OVERALL TREND	**Stable**	**Stable**	**Stable/ Down**	**Down**	**Stable**	**Down**	**Up**	**Up**

Appendix H

TMDL Data for Watershed Management Areas in the Highlands Region

APPENDIX H.1

WMA 1 and 2 – TMDL DATA

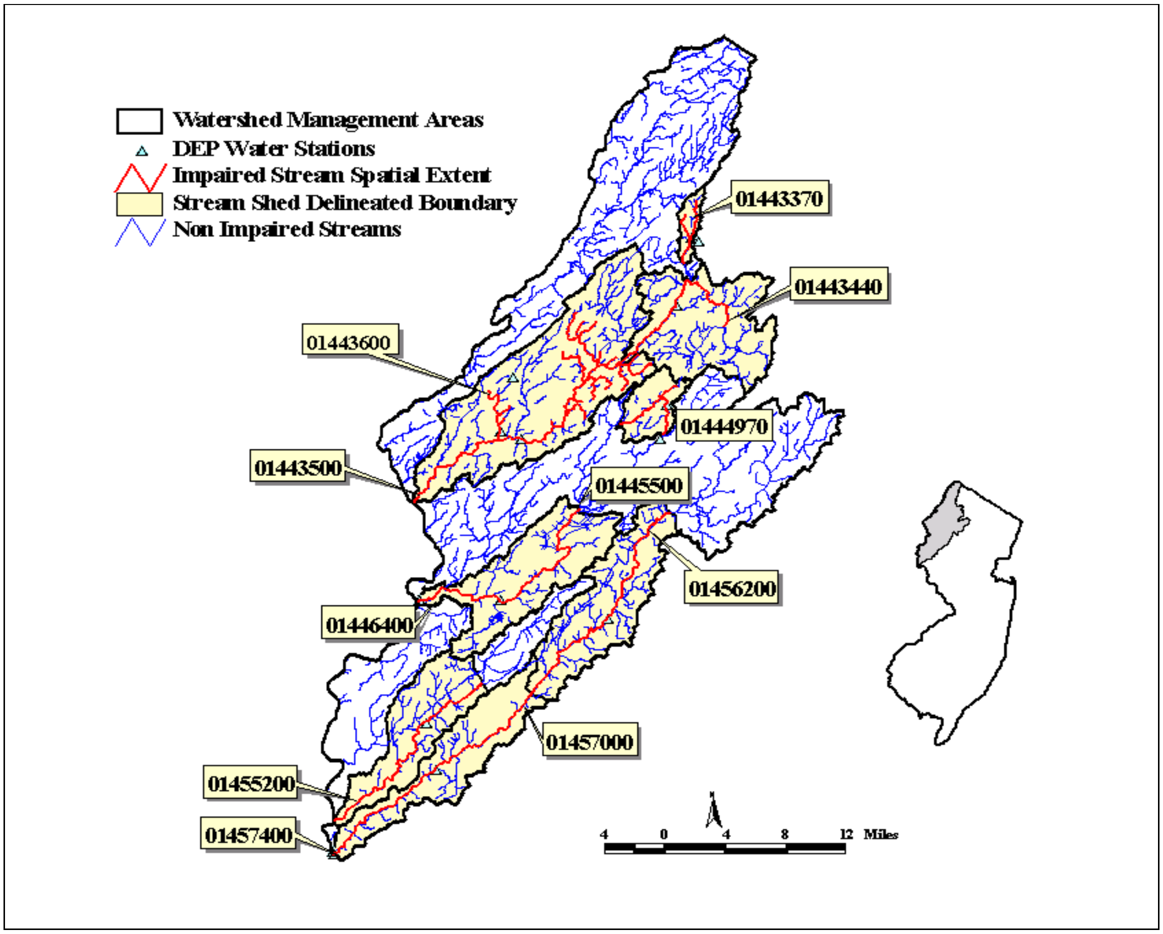
A. Parameter: Fecal Coliform

Fecal Coliform TMDLs for Waterbodies in the Upper Delaware and Wallkill WMAs

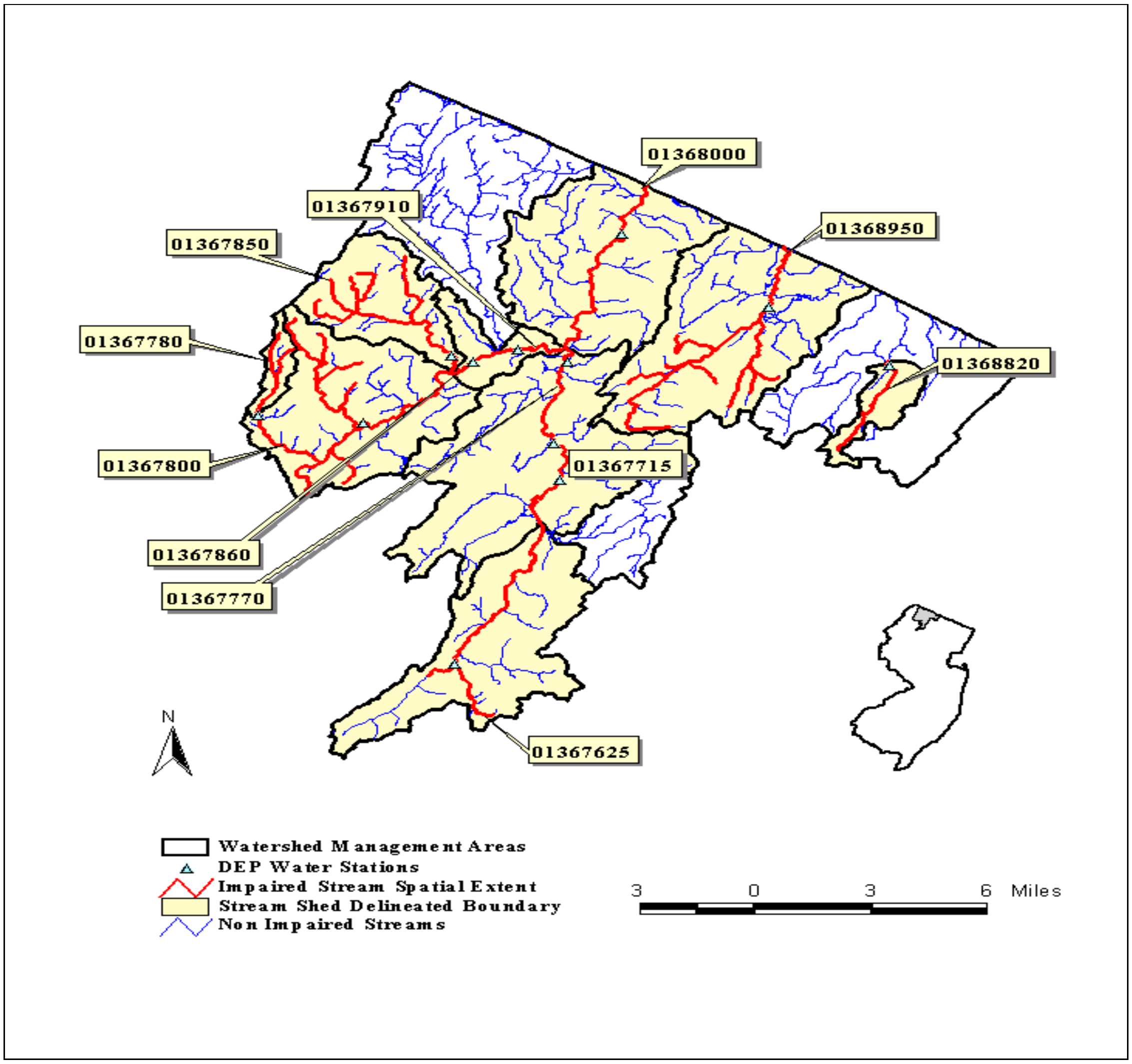
MONITORING SITES	HUC 14	WATERBODY NAME	PERCENT REDUCTION WITH MOS	TMDL Document
01443500	02040105050050, 02040105050010, 02040105030030, 02040105030020, 02040105040090	Paulins Kill at Blairstown	78%	1
01445500	02040105090060, 02040105090030, 02040105090020, 02040105090010, 02040105070060	Pequest River at Pequest	93%	1
01446400	02040105090060	Pequest River at Belvidere	93%	1
01455200	02040105140070, 02040105140060, 02040105140050, 02040105140030, 02040105140020	Pohatcong Creek at New Village	99%	1
01456200	02040105160020, 02040105160010, 02040105150100, 02040105150080	Musconetcong River at Beattystown	93%	1
01457000	02040105160060, 02040105160050, 02040105160040, 02040105160030, 02040105160020	Musconetcong River near Bloomsbury	93%	1
01457400	02040105160070, 02040105160060	Musconetcong River at Riegelsville	93%	1
01367625	02020007010010, 02020007010020, 02020007010040	WallKill River at Sparta	90%	1
01367715	02020007010070, 02020007010040	WallKill River at Scott Rd. at Franklin	93%	1
01367770	02020007030010, 02020007010070	Wallkill River near Sussex	93%	1
01367850	02020007020050, 02020007020040	WB Papakating Creek at McCoys Corner	99%	1
01367860	02020007020070	Papakating Creek near Sussex	99%	1
01367910	02020007020070	Papakating Creek at Sussex	99%	1
01368000	02020007030040, 02020007030030, 02020007030010	Wallkill River near Unionville	95%	1
01368820	02020007040050	Double Kill at Waywayanda	47%	1
01368950	02020007040050, 02020007040020, 02020007040030	Black Creek near Vernon	99%	1
01445900	02040105100020, 02040105100030	Honey Run near Hope	94%	2
DRBCNJ0028	02040105120020	Lopatcong Creek at Main St in Phillipsburg	88%	2
01455801	02040105150080, 02040105150070	Musconetcong River at Lockwood	81%	2
01443250	02040105040060	Paulins Kill at Warbasse Junction Rd near Lafayette	95%	2

MONITORING SITES	HUC 14	WATERBODY NAME	PERCENT REDUCTION WITH MOS	TMDL Document
DRBCNJ0027	02040105140070, 02040105140060, 02040105140050, 02040105140030, 02040105140020	Pohatcong Creek at River Rd Bridge	93%	2
Forest Lake-01	02040105070020	Forest Lake	98%	3
Fox Hollow Lake-01	02040105040050	Fox Hollow Lake	98%	3
Furnace Lake-01	02040105090050	Furnace Lake	93%	3
Green Valley Beach Campground-01		Green Valley Lake	92%	3
Lackawanna Lake-01	02040105150050	Lackawanna Lake	93%	3
Lake Hopatcong-01	02040105150020; 02040105150030	Lake Hopatcong	97%	3
Lake Winona-01	02040105150020	Lake Winona	98%	3
Crystal Springs Pond-02		Crystal Springs Pond	76%	3
Deer Trail Lake-02	02020007010030	Deer Trail Lake	88%	3
Lake Mohawk-02	02020007010010	Lake Mohawk	98%	3
Sleepy Valley Lake-02		Sleepy Valley Lake	95%	3

1 Total Maximum Daily Loads for Fecal Coliform to Address 28 Streams in the Northwest Water Region2 Total Maximum Daily Loads for Fecal Coliform to Address 10 Streams in the Northwest Water Region
3 Total Maximum Daily Loads for Pathogens to Address 11 Lakes in the Northwest Water Region



Spatial Extent of Impaired Segments Addressed in "Total Maximum Daily Loads for Fecal Coliform to Address 28 streams in the Northwest Water Region."



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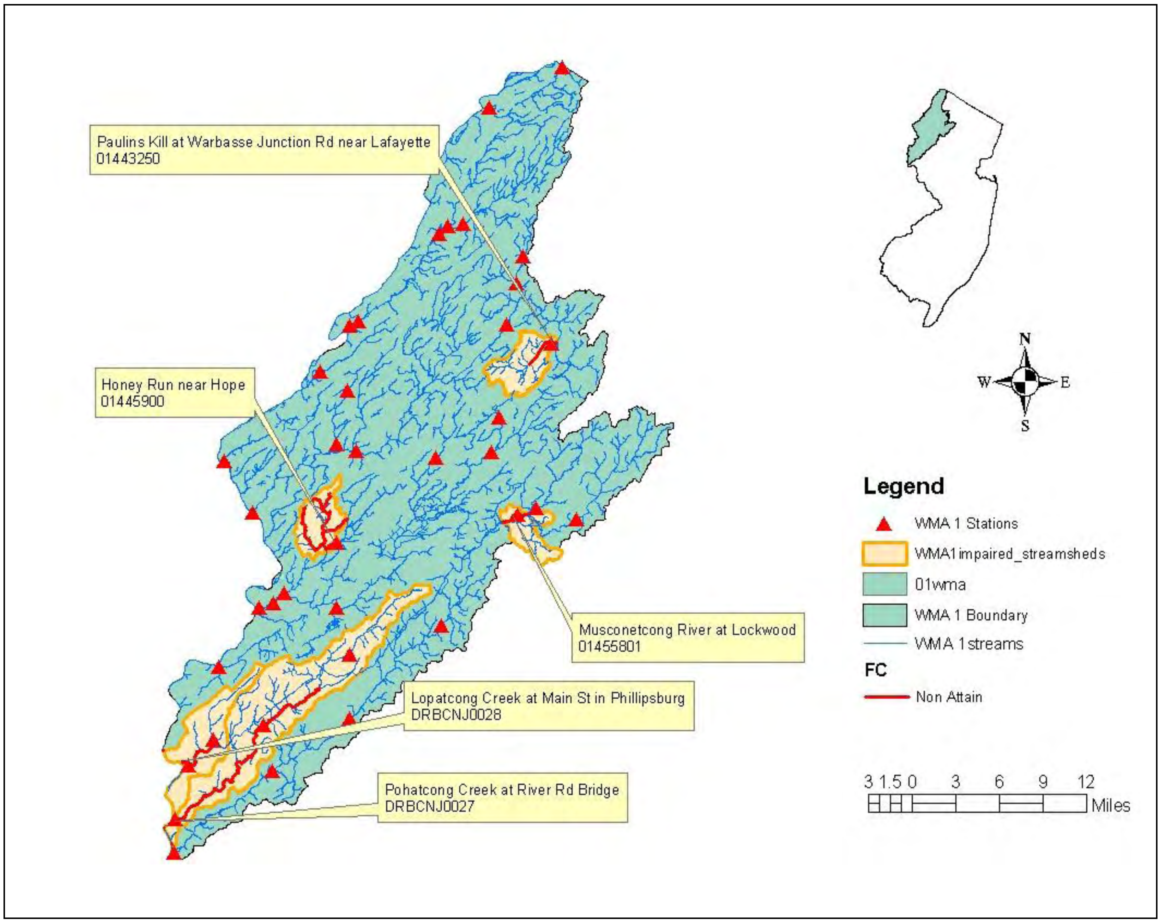
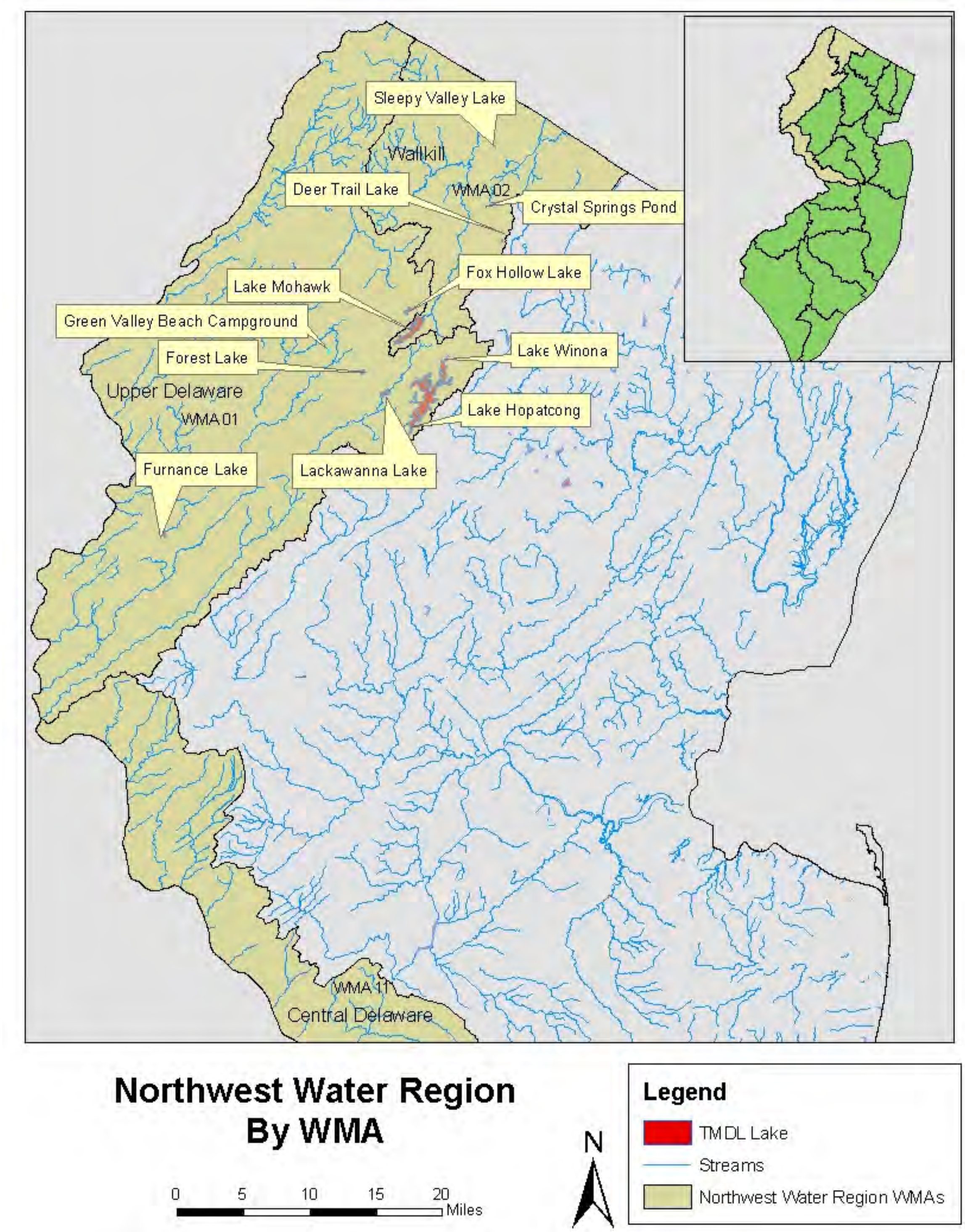


Spatial Extent of Impaired Segments Addressed in "Total Maximum Daily Loads for Fecal Coliform to Address Ten streams in the Northwest Water Region"



Spatial Extent of Impaired Lakes Addressed in "Total Maximum Daily Loads for Pathogens to Address 11 Lakes in the Northwest Water Region"

B. Parameter: Phosphorus

Waterbodies for which TMDL have been developed for phosphorus

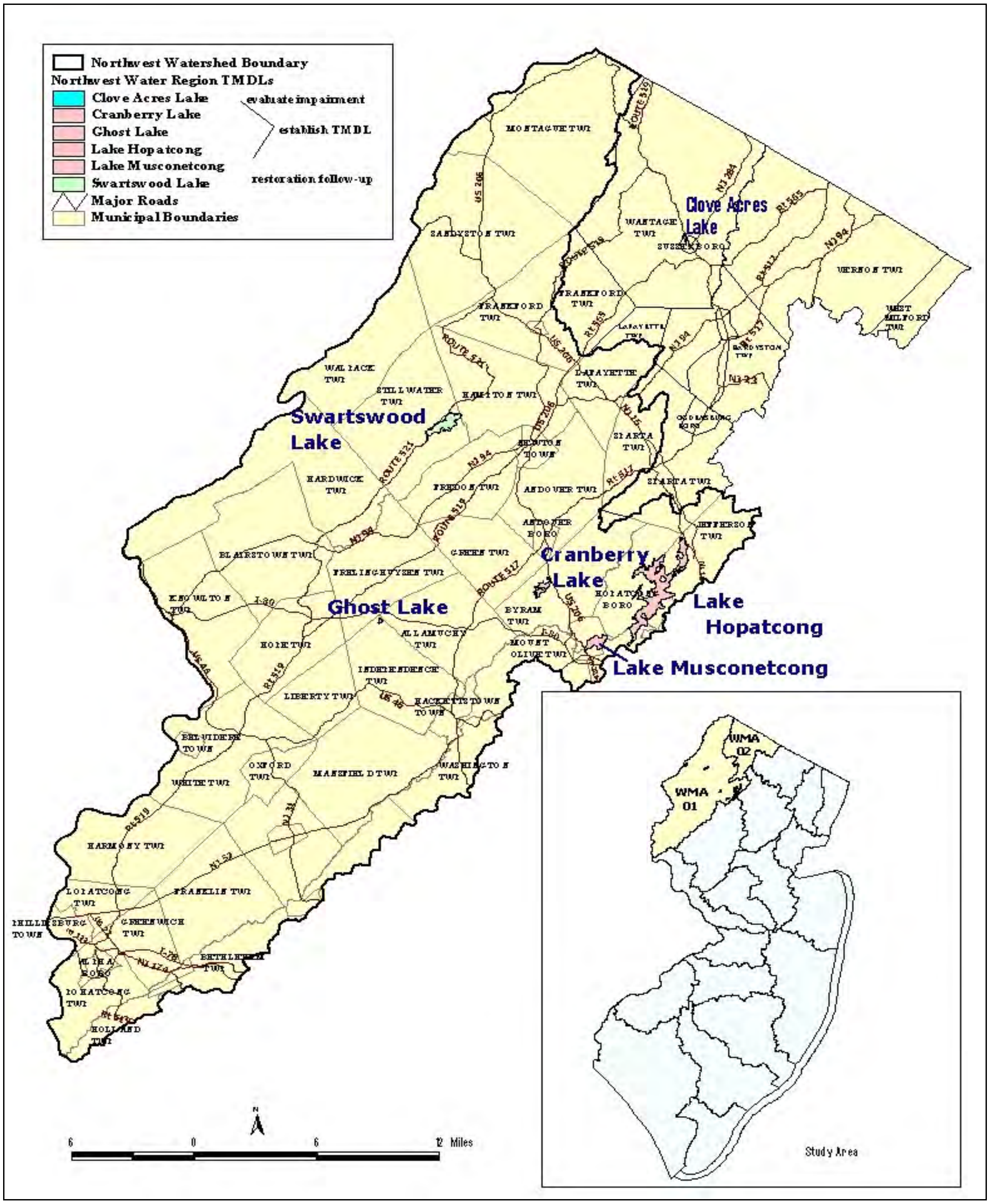
Monitoring Sites	HUC 14	Waterbody Name	Percent Reduction with MOS	Overall Percent Reduction	TMDL Document
01368950; 01367620; Wallkill H	02020007040030; 02020007040020	Black Creek near Vernon	50%	37.20%	1
Wallkill F	02020007040010	Black Creek at Rt. 94 and Rt 517 in Vernon	50%	14.30%	1
01368900	02020007040050	Wawayanda/ Pochuck River at Rt. 515 in Maple Grange	70.82%	47%	1
Wallkill G	02020007040020; 02020007040010	Black Creek at Sand Hill Rd in Vernon	Based off of Black Creek near Vernon (50%)	37.2%	1
01367910	02020007020070	Papakating Creek at Sussex	31%	40%	2

1: Total Maximum Daily Loads for Phosphorus to Address 7 Stream Segments in the Northwest Water Region
2: Total Maximum Daily Loads to Address Phosphorus in the Clove Acres Lake and Papakating Creek Northwest Water Region

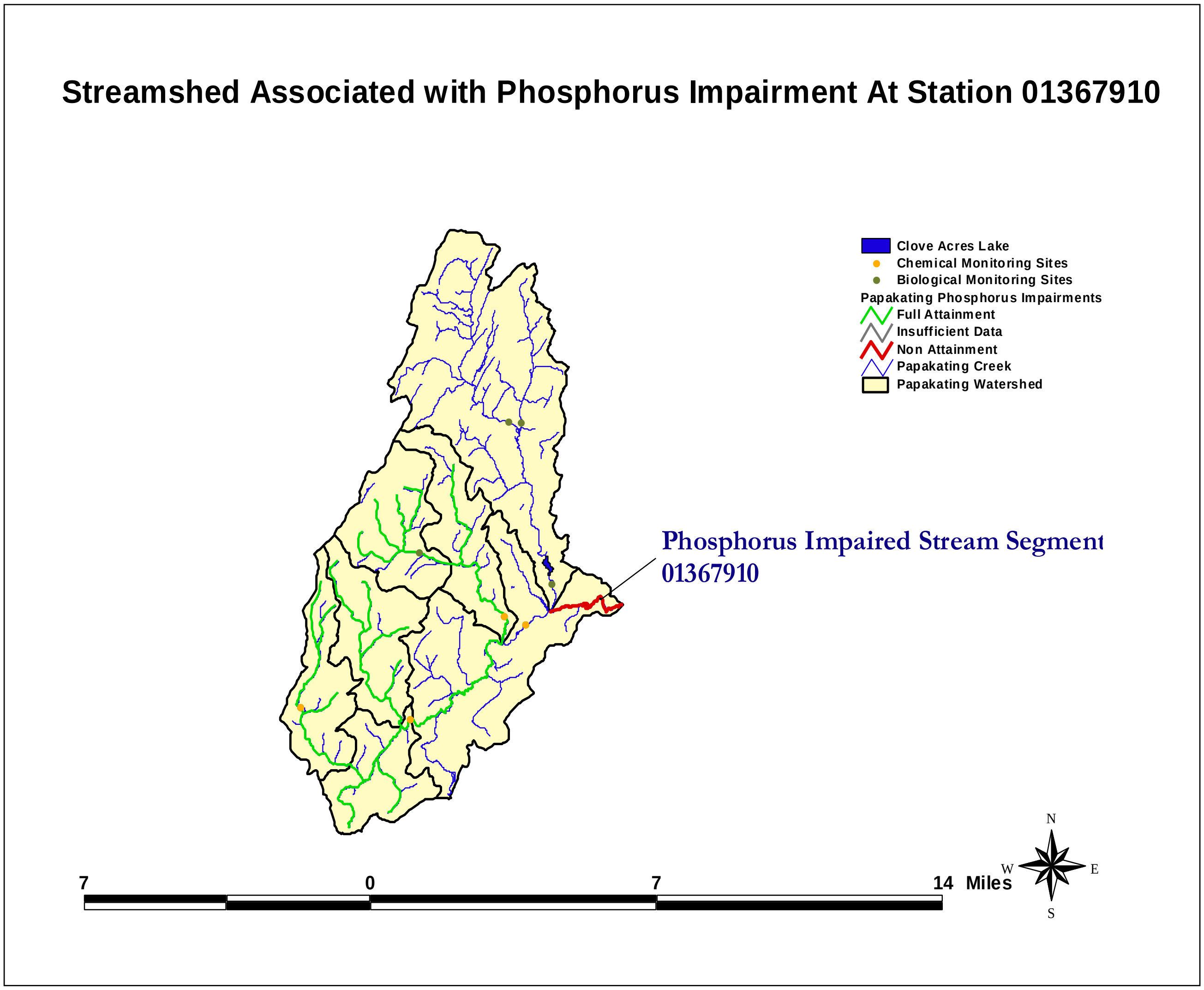
Eutrophication TMDLs for Waterbodies in the Upper Delaware WMA

Monitoring Sites	HUC 14	Waterbody Name	Percent Reduction with MOS	Overall % Reduction	TMDL Document
Cranberry Lake-01	02040105150060	Cranberry Lake	88%	73%	1
Lake Hopatcong-01	02040105150030; 02040105150020	Lake Hopatcong	47%	36%	1
Lake Musconetcong-01	02040105150030	Lake Musconetcong	41%	34%	1
Ghost Lake-02	02040105090010	Ghost Lake	N/A	N/A	1

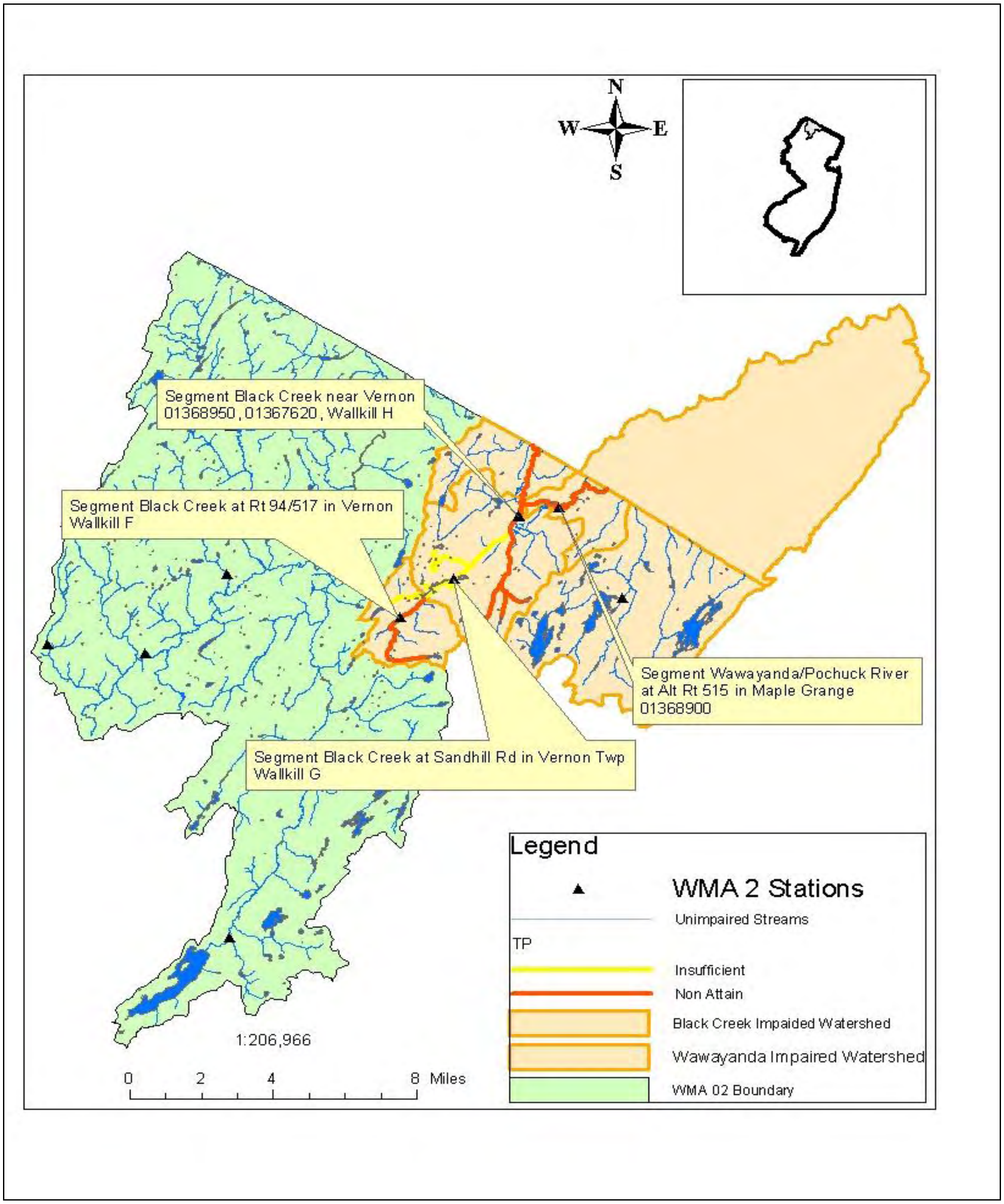
1: Total Maximum Daily Load to Address 4 Eutrophic Lakes in the Northwest Water Region



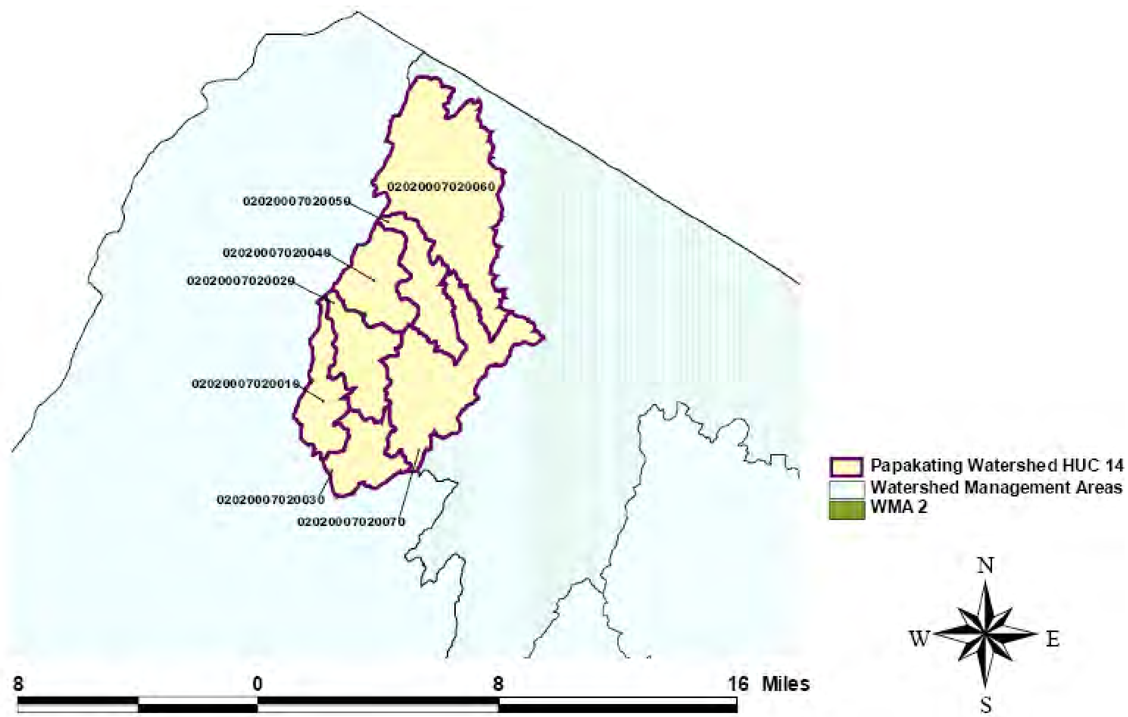
Spatial Extent of Impaired Lakeshed Addressed in "Total Maximum Daily Loads for Phosphorus to Address 4 Eutrophic Lakes in the Northwest Water Region"



Spatial Extent of Impaired Segment Addressed in "Total Maximum Daily Loads to Address Phosphorus in the Clove Acres Lake and Papakating Creek Northwest Water Region"



Spatial Extent of Impaired Segments for "Total Maximum Daily Loads for Phosphorus in the Black Creek Watershed in the Northwest Water Region"



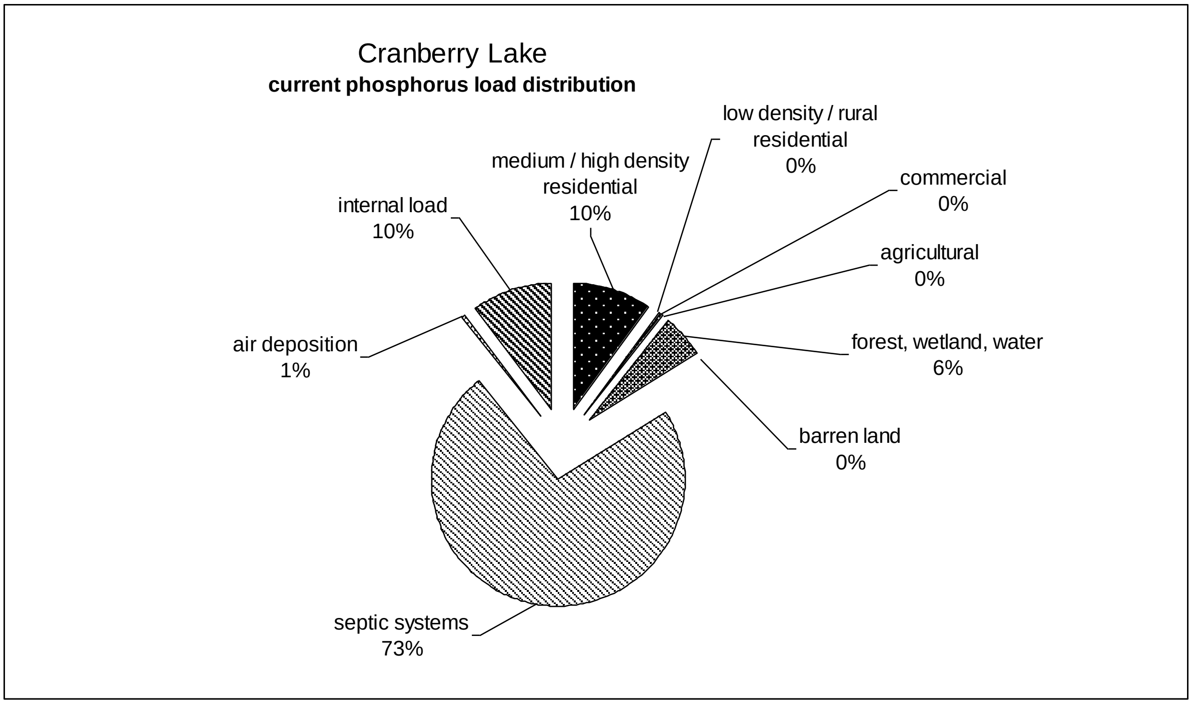
Spatial extent of the Papakating Creek addressed in "Total Maximum Daily Load to Address Phosphorus in the Clove Acres Lake and Papakating Creek Northwest Water Region."

Summary of Loading Capacity and Load Allocations for Cranberry Lake and Ghost Lake

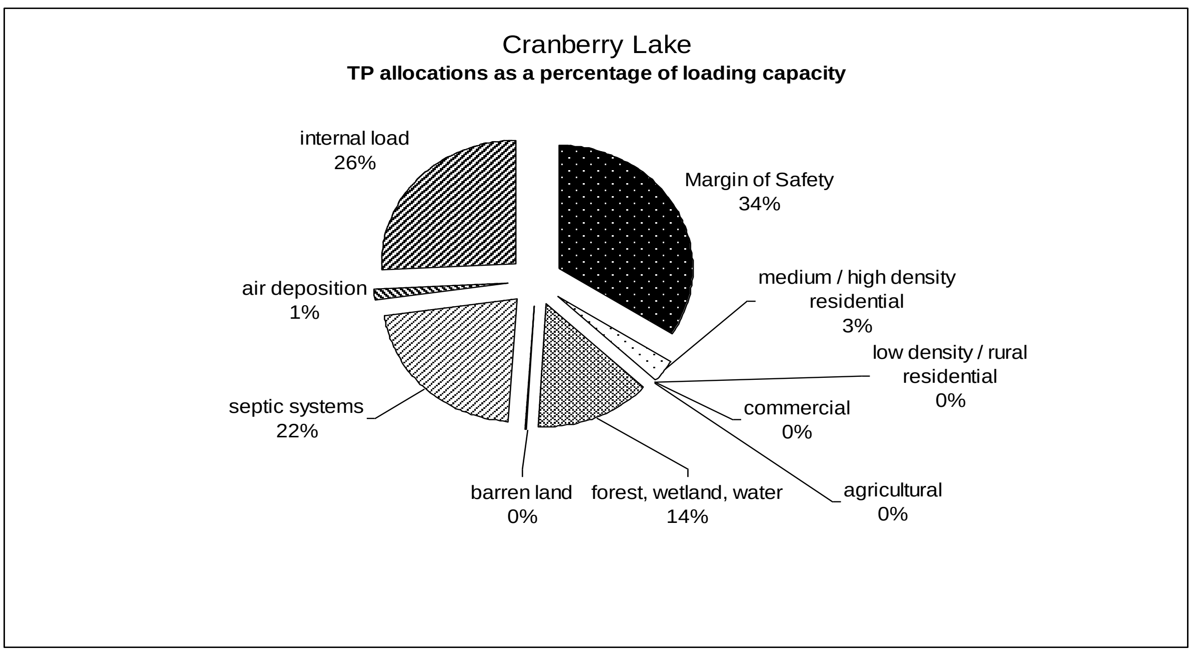
lake	Cranberry Lake kg TP/yr	Cranberry Lake % of LC	% reduction	Ghost Lake kg TP/yr	Ghost Lake % of LC	% reduction
loading capacity (LC)	400	100%	n/a	33	100%	n/a
Point Sources other than Stormwater	n/a			n/a		
Nonpoint and Stormwater Sources						
medium / high density residential	12	3.0%	88%	0.00	0.0%	n/a
low density / rural residential	0.30	0.08%	88%	0.91	2.8%	0%
commercial	0.15	0.04%	88%	0.00	0.0%	n/a
industrial	0.00	0.00%	n/a	0.00	0.0%	n/a
Mixed urban / other urban	0.00	0.00%	n/a	0.00	0.0%	n/a
agricultural	0.23	0.06%	0%	0.27	0.81%	0%
forest, wetland, water	56	14%	0%	7.7	23%	0%
barren land	1.4	0.34%	0%	0.00	0.0%	n/a
air deposition onto lake surface	5.4	1.3%	0%	0.52	1.6%	0%
septic systems	87	22%	88%			
internal load	100	26%	0%	12	38%	0%
Other Allocations						
explicit Margin of Safety	140	34%	n/a	11	34%	n/a
Reserve Capacity	n/a			n/a		

Summary of Loading Capacity and Load Allocations for Lake Hopatcong and Lake Musconetcong

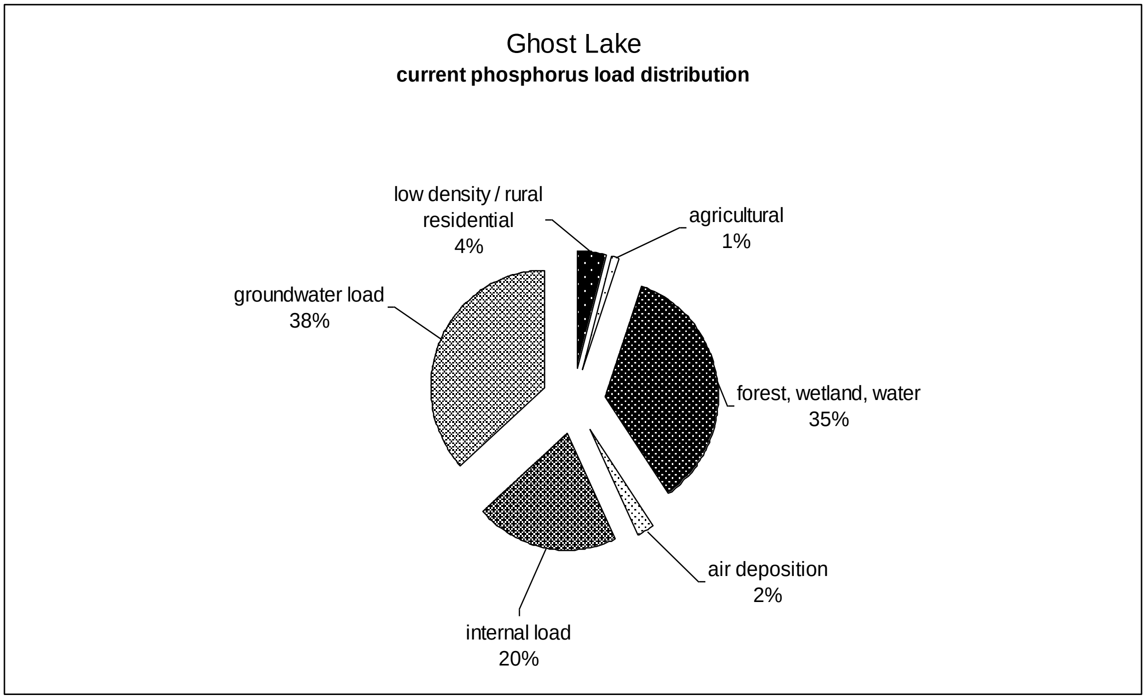
lake	Lake Hopatcong		% reduction	Lake Musconetcong		% reduction
	kg TP/yr	% of LC		kg TP/yr	% of LC	
loading capacity (LC)	4800	100%	n/a	2200	100%	n/a
Point Sources other than Stormwater	5.5	0.11%	69%[b]	n/a		
Nonpoint and Stormwater Sources						
medium / high density residential	960	20%	47%	290	13%	41%
low density / rural residential	64	1.3%	47%	20	0.89%	41%
commercial	100	2.1%	47%	52	2.4%	41%
industrial	2.8	0.06%	47%	15	0.69%	41%
Mixed urban / other urban	110	2.3%	47%	50	2.3%	41%
agricultural	0.0	0.0%	n/a	0.52	0.02%	0%
forest, wetland, water	390	8.1%	0%	55	2.5%	0%
barren land	33	0.69%	0%	15	0.67%	0%
air deposition onto lake surface	68	1.4%	0%	8.9	0.41%	0%
septic systems	850	18%	47%	n/a		
internal load	600	12%	0%	150	6.9%	0%
tributary load	n/a			790	36%	36%
Other Allocations						
explicit Margin of Safety	1600	34%	n/a	740	34%	n/a
Reserve Capacity	n/a			n/a		



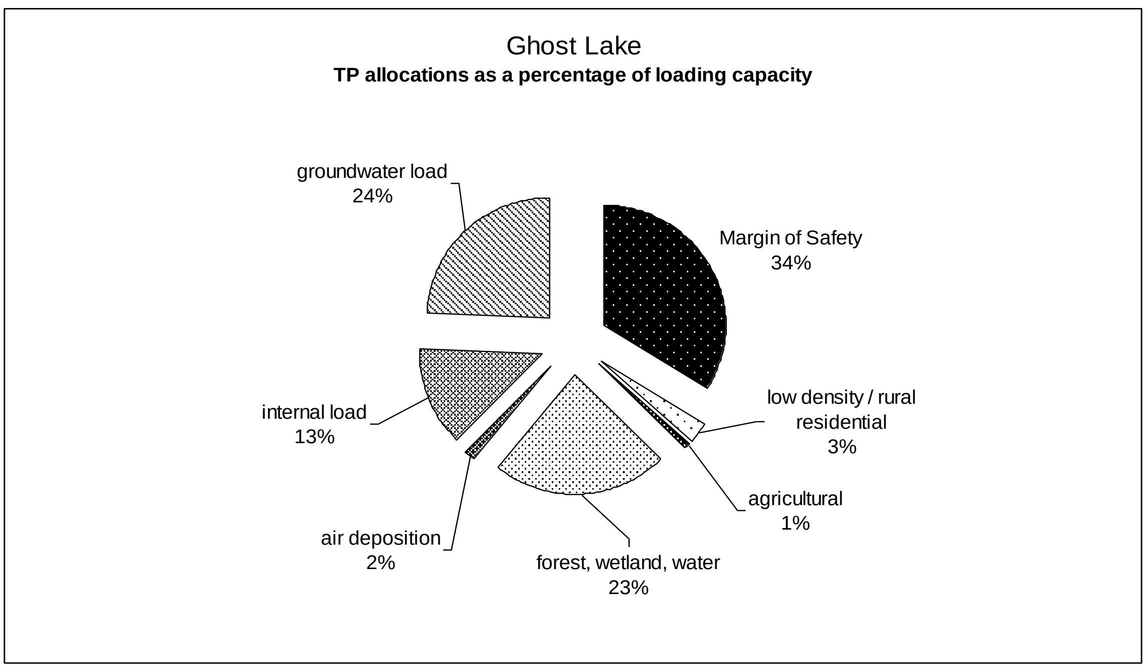
Current Distribution of Phosphorus Load for Cranberry Lake



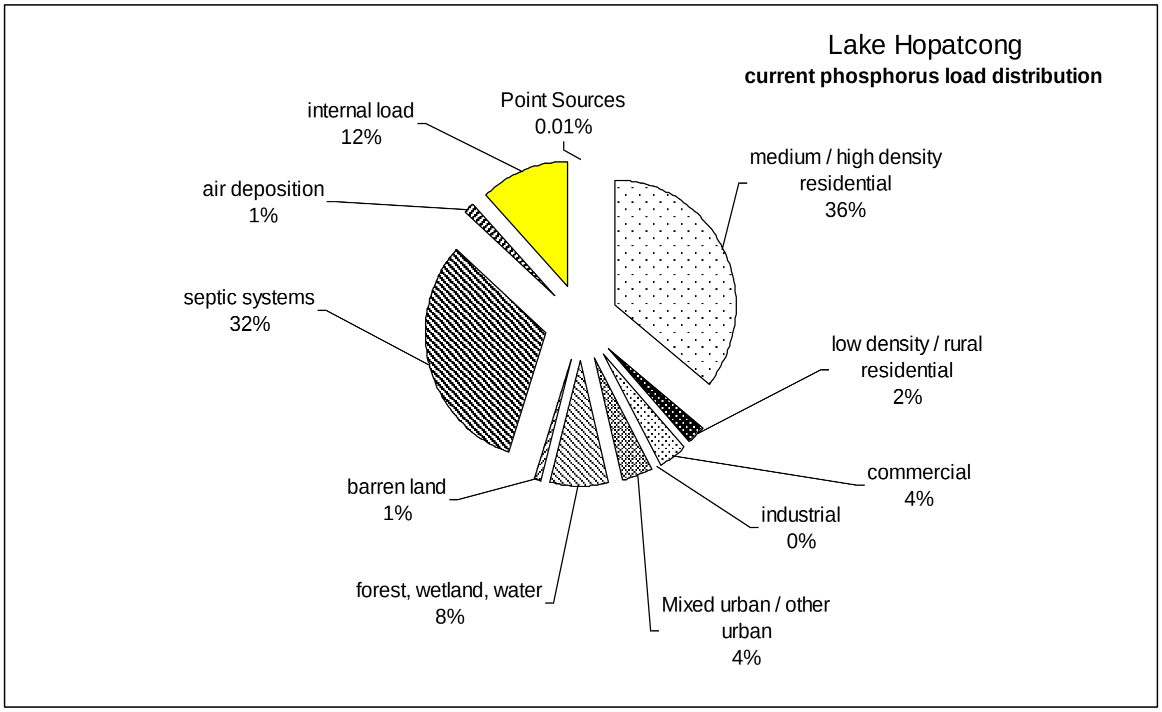
Phosphorus Allocations for Cranberry Lake TMDL



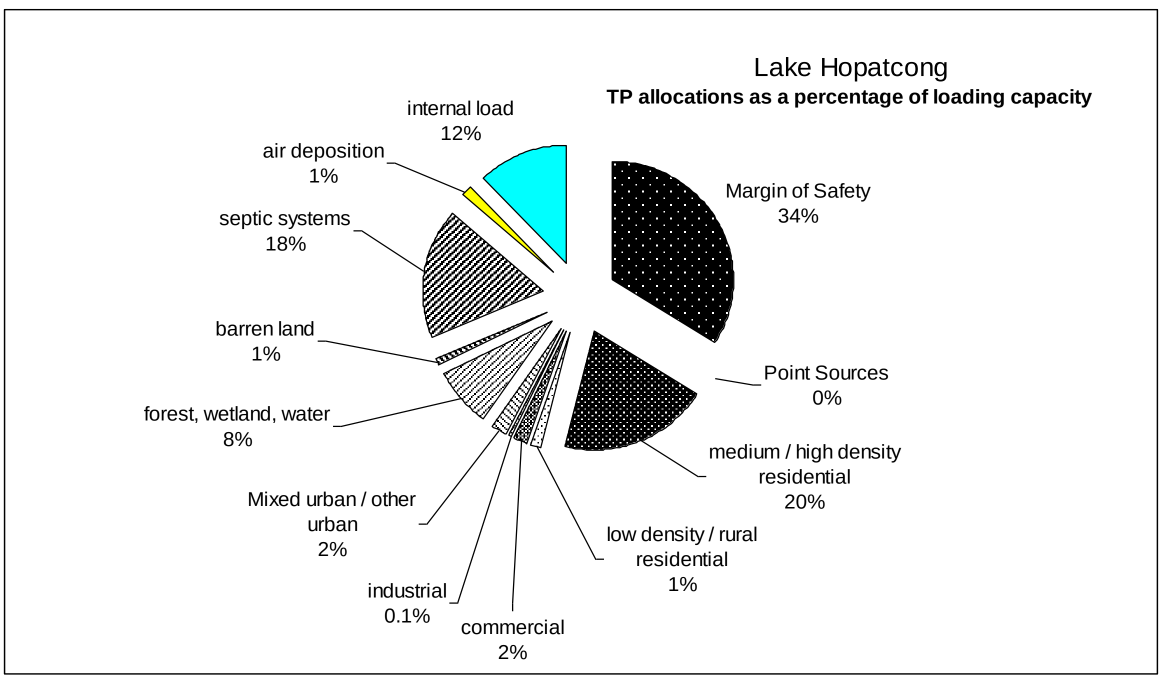
Current Distribution of Phosphorus Load for Ghost Lake



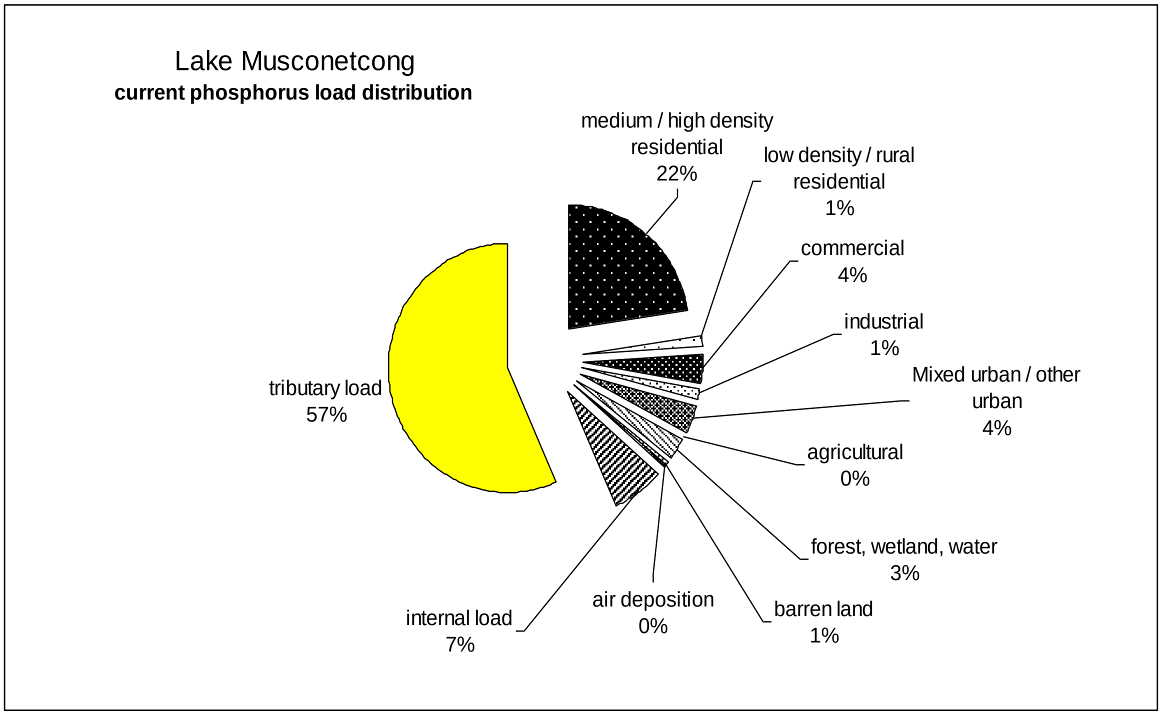
Phosphorus Allocations for Ghost Lake



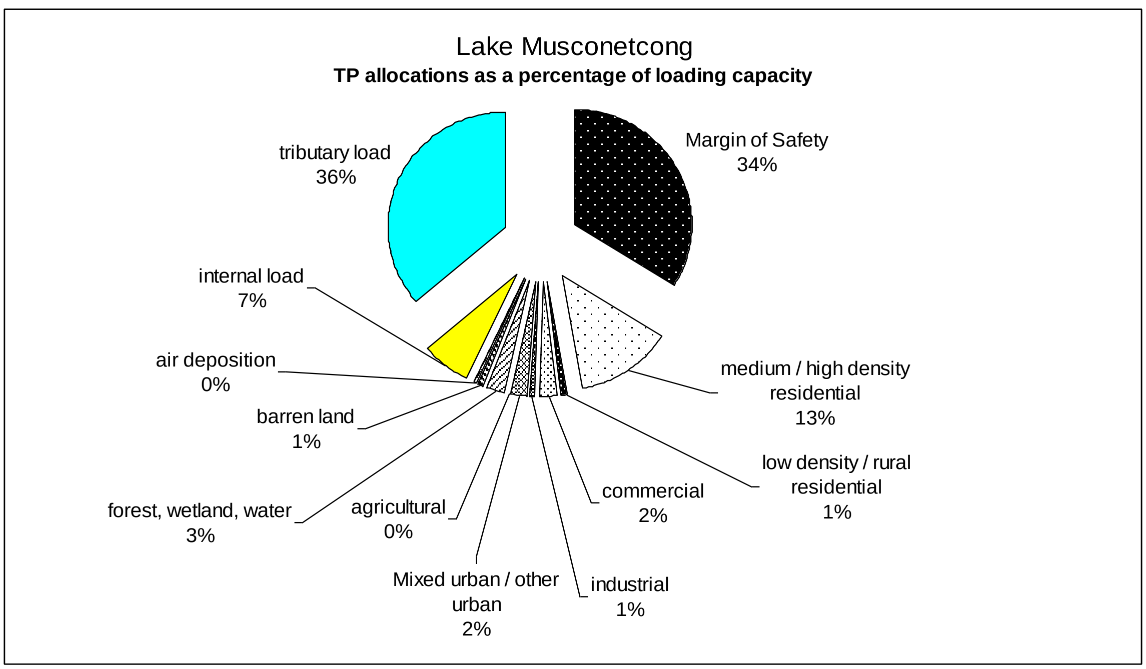
Current Distribution of Phosphorus Load for Lake Hopatcong



Phosphorus Allocations for Lake Hopatcong TMDL



Current Distribution of Phosphorus Load for Lake Musconetcong



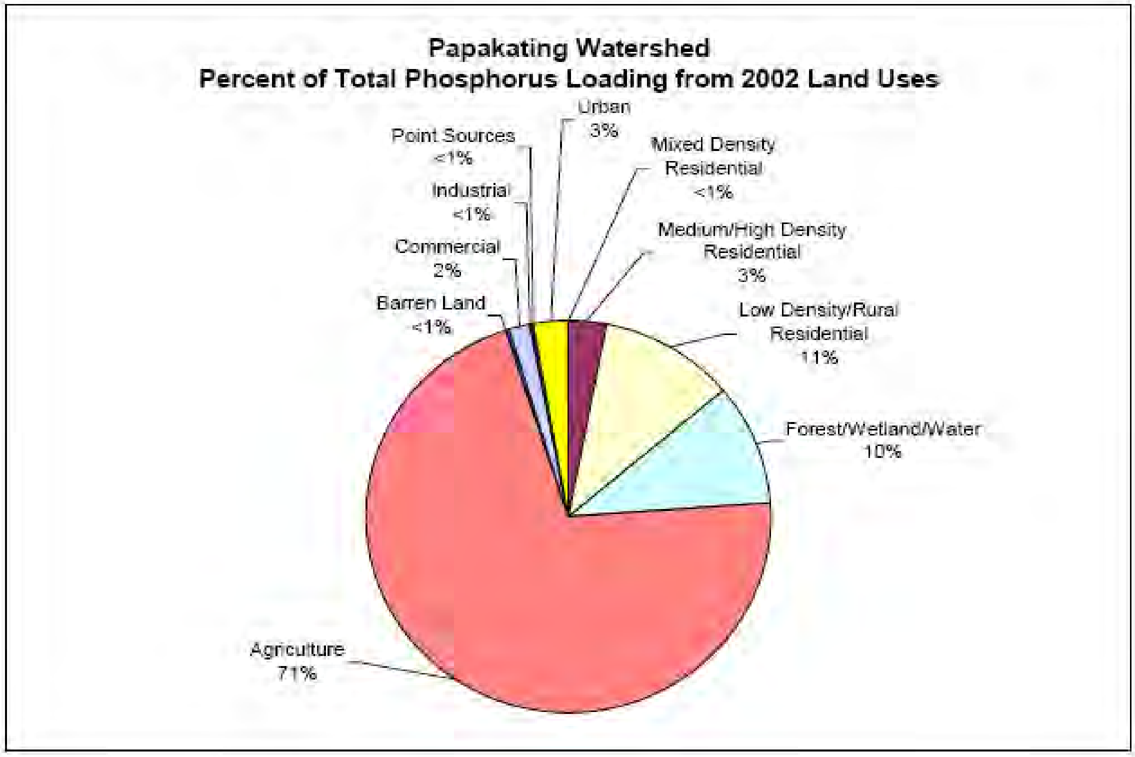
Phosphorus Allocations for Lake Musconetcong TMDL

Lake	Current Avg Influent [TP] (mg/l)	Target Avg Influent [TP] (mg/l)	Current Areal TP load (g/m²/yr)	Target Areal TP load (g/m²/yr)	Areal Water Load (m/year)
Cranberry Lake	0.265	0.071	1.31	0.35	4.9
Ghost Lake	0.049	0.049	0.19	0.19	6.0
Lake Hopatcong	0.126	0.080	0.52	0.33	4.1
Lake Musconetcong	0.045	0.030	1.73	1.14	38.1

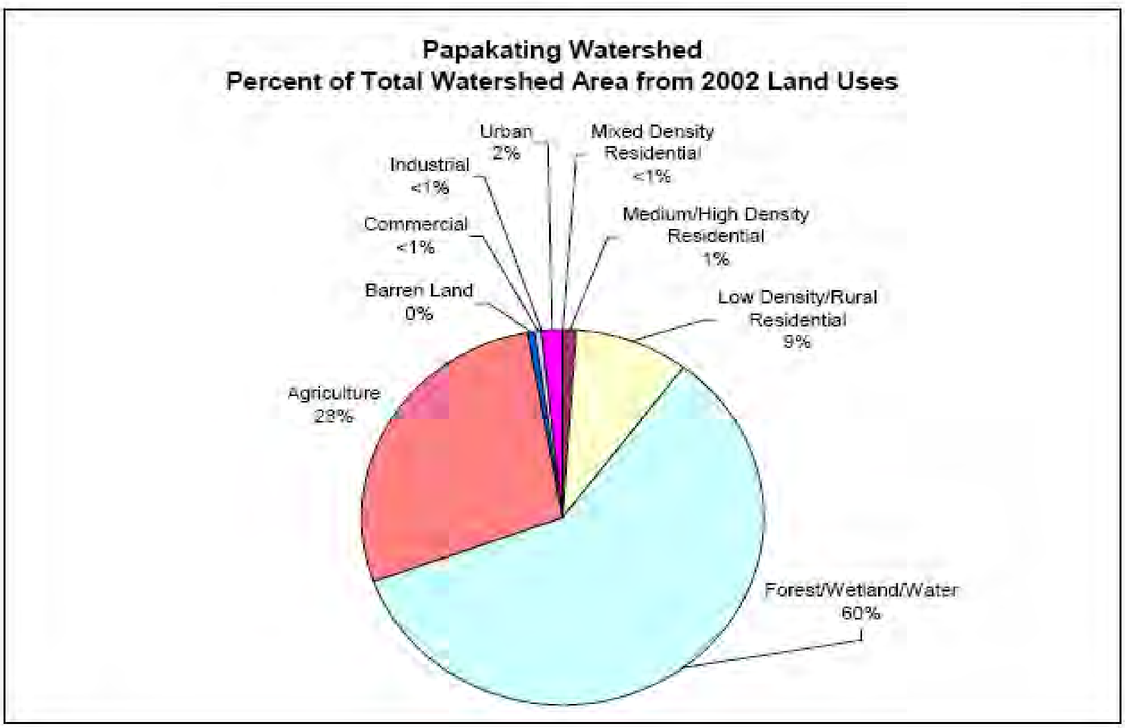
Hydrologic and loading characteristics of lakes

Lake	current condition [TP] (mg/l)	reference condition [TP] (mg/l)	upper bound target condition [TP] (mg/l)	target condition [TP] (mg/l)	% overall TP load reduction
Cranberry Lake	0.075	0.005	0.030	0.020	73%
Ghost Lake	0.016	0.006	0.024	0.016	0%
Lake Hopatcong	0.031	0.004	0.030	0.020	36%
Lake Musconetcong	0.030	0.011	0.030	0.020	34%

Current condition, reference condition, target condition and overall percent reduction for each lake



Percent of TP Loading from LU/LC Cover within Papakating Creek Watershed



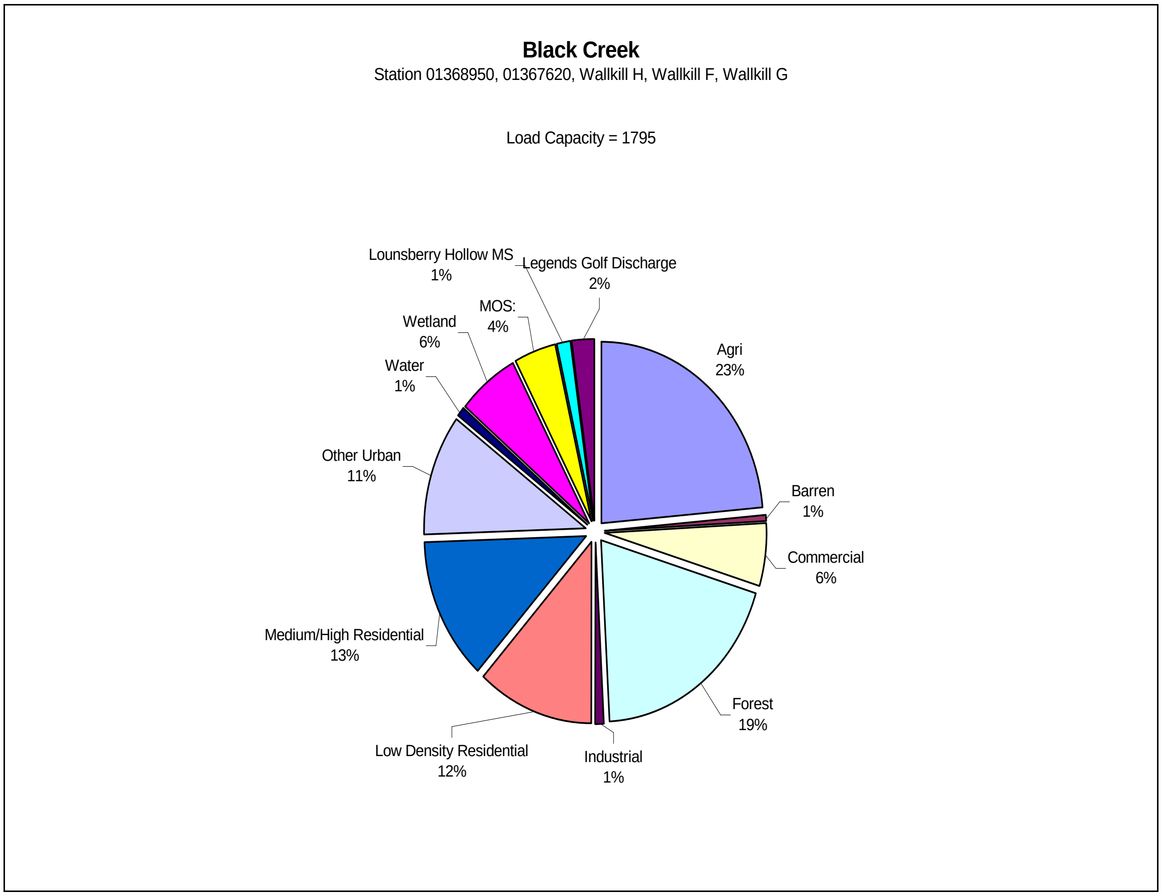
Papakating Creek Watershed Land Use Distribution

Current condition, reference condition, target condition and overall percent reduction for Papakating Creek Segment 01367910

Segment	current condition (TP) (kg/day/cfs)	target condition (TP) (kg/day/cfs)	% overall TP load reduction
Papakating Impaired Segment 01367910	0.408	0.245	40

Load allocation for the portion of Papakating watershed, excluding the Clove Acres Lakeshed

Papakating Excluding Clove Acres Lake	Estimating TP/yr	% of LC	% reduction
Loading Capacity (LC)	5274.9	100%	n/a
Stormwater Point Sources			
Mixed density residential	7.4	0.10%	31%
medium/ high density residential	164.5	3.10%	31%
low density/ rural residential	518.3	9.80%	31%
commercial	76.1	1.40%	31%
industrial	11.1	0.20%	31%
mixed urban/ other urban	112	2.10%	31%
Nonpoint Sources			
agricultural	3365.3	63.80%	31%
forest, wetland, water	590.5	11.20%	0%
barren land	32.7	0.60%	0%
air deposition onto lake surface		0%	0%
High Point High School	45.2	0.80%	0%
County Concrete Company	1.4	0.03%	0%
Margin of Safety	350.5	6.60%	



Phosphorus Allocation for the Black Creek Impaired Watershed

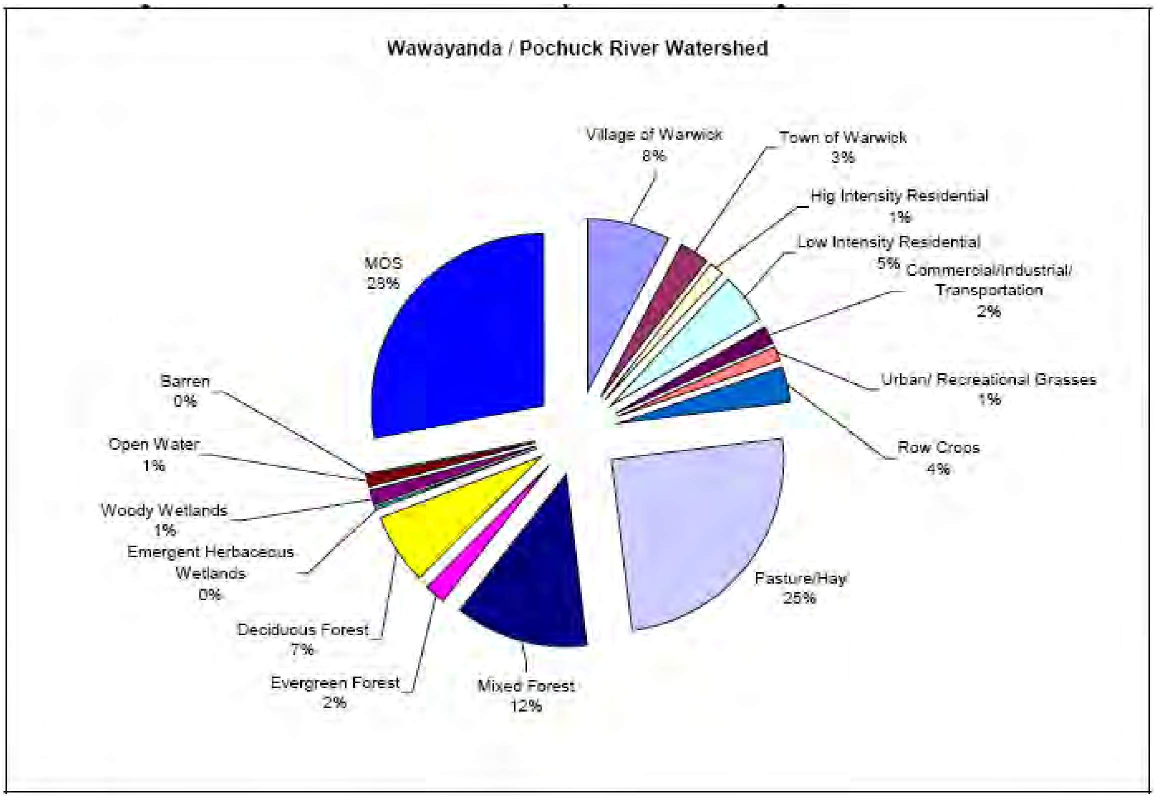
TMDL calculations for the Black Creek Watershed (Black Creek at Vernon)

	Current Load	Load Capacity		% reduction
	kg TP/yr (lbs/yr)	kg TP/yr)	% of LC	
Load allocation				
Point Sources other than Stormwater				
Lounsberry Hollow MS	4.85 (10.67)	22.09 (48.59)	1.2	0
Legends Golf Discharge	7.71 (16.96)	42.18 (92.79)	2.3	0
Nonpoint and Stormwater Sources				
medium/high density residential	459.47 (1010.83)	229.45 (504.79)	12.8	50
low density/rural residential	419.41 (922.7)	209.44 (460.76)	11.7	50
commercial	199.43 (438.74)	99.58 (219.07)	5.5	50
industrial	26.8 (58.96)	13.38 (29.43)	0.7	50
mixed urban/ other urban	393.12 (864.86)	196.31 (431.88)	10.9	50
agricultural	850.97 (1872.13)	425.48 (934.89)	23.7	50
forest, wetland, water	472 (1038.4)	472 (1038.4)	26.3	0
barren land	22.13 (48.68)	11.05 (24.31)	0.6	0
Margin of Safety	n/a	74.49 (163.87)	4.2	n/a
Total:	2855.89 (628.93)	1794.92 (3948.78)	100	

*Notes:

1) From the NJDES Permit NJ0023949 Lounsberry Hollow MS, the current effluent limit for phosphorus is 1.0 mg/l. After 4/1/2008 the monthly average will be 0.211 mg/l.

2) Discharge from Legends Resort and Country Club (NJ0023949) to the Black Creek is allowed from November through March



Phosphorus allocation for the Wawayanda Creek impaired watershed

TMDL calculations for the Wawayanda/Pochuck River Watershed

	Current Load	Load Capacity		% reduction
	kg TP/yr (lbs/yr)	kg TP/yr)	% of LC	
Load allocation				
Point Sources other than Stormwater			(from New York portion of watershed)	
Village of Warwick	1,380.50	402.81	7.80%	70.82
Town of Warwick	497	145.02	2.80%	70.82
Nonpoint and Stormwater Sources				
high intensity residential	242.59	70.78	1.40%	70.82
low intensity residential	829.22	241.95	4.70%	70.82
commercial/industrial/transportation	282.77	82.51	1.60%	70.82
urban/ recreational grasses	241.51	70.47	1.40%	70.82
row crops	632.88	184.67	3.60%	70.82
pasture/hay	4,411.99	1287.36	24.90%	70.82
mixed forest	643.02	643.02	12.40%	0
evergreen forest	104.81	104.81	2%	0
deciduous forest	349.71	349.71	6.80%	0
emergent herbaceous wetlands	7.2	7.2	0.10%	0
woody wetlands	71.68	71.68	1.40%	0
open water	61.01	61.01	1.20%	0
barren	0.63	0.63	0.01%	0
Margin of Safety	n/a	1447		n/a
Total:		5170	100	

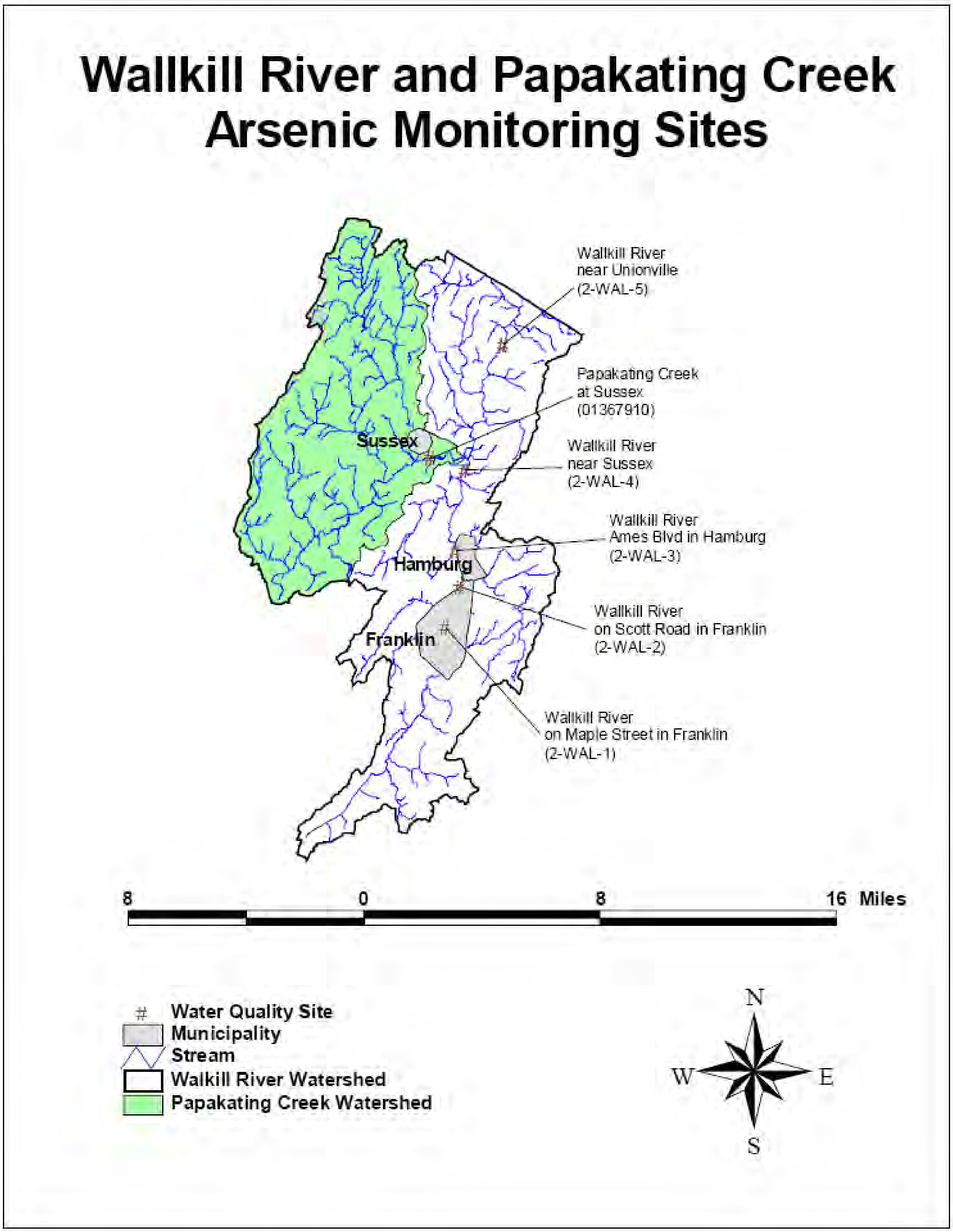
* The reductions for the New York point sources, other than stormwater point sources are illustrative only; New York will determine the actual allocation of loads to achieve the New Jersey SWQS at the border.

C. **Parameter: Arsenic**

Waterbodies Listed in Upper Delaware and Wallkill WMAs for Which TMDLs Have Been Developed for Arsenic.

Monitoring Sites	HUC 14	Waterbody Name	Percent Reduction	TMDL Document
01367700, Wallkill C,2-WAL-1	02020007010040	Wallkill River near Franklin	N/A	1
01367715, Wallkill D, 2-WAL-2	02020007030040	Wallkill River at Scott Road in Franklin	N/A	1
2-WAL-3, 01367729	02020007010070	Wallkill River at Route 94 in Hamburg	N/A	1
01367770, 2-WAL-4	02020007030010	Wallkill River near Sussex	N/A	1
01368000, Wallkill E, 2-WAL-5	02020007030040, 02020007030030	Wallkill River near Unionville	N/A	1
01367910, 01367909, 2-PAP-1	02020007020070	Papakating Creek at Sussex	N/A	1

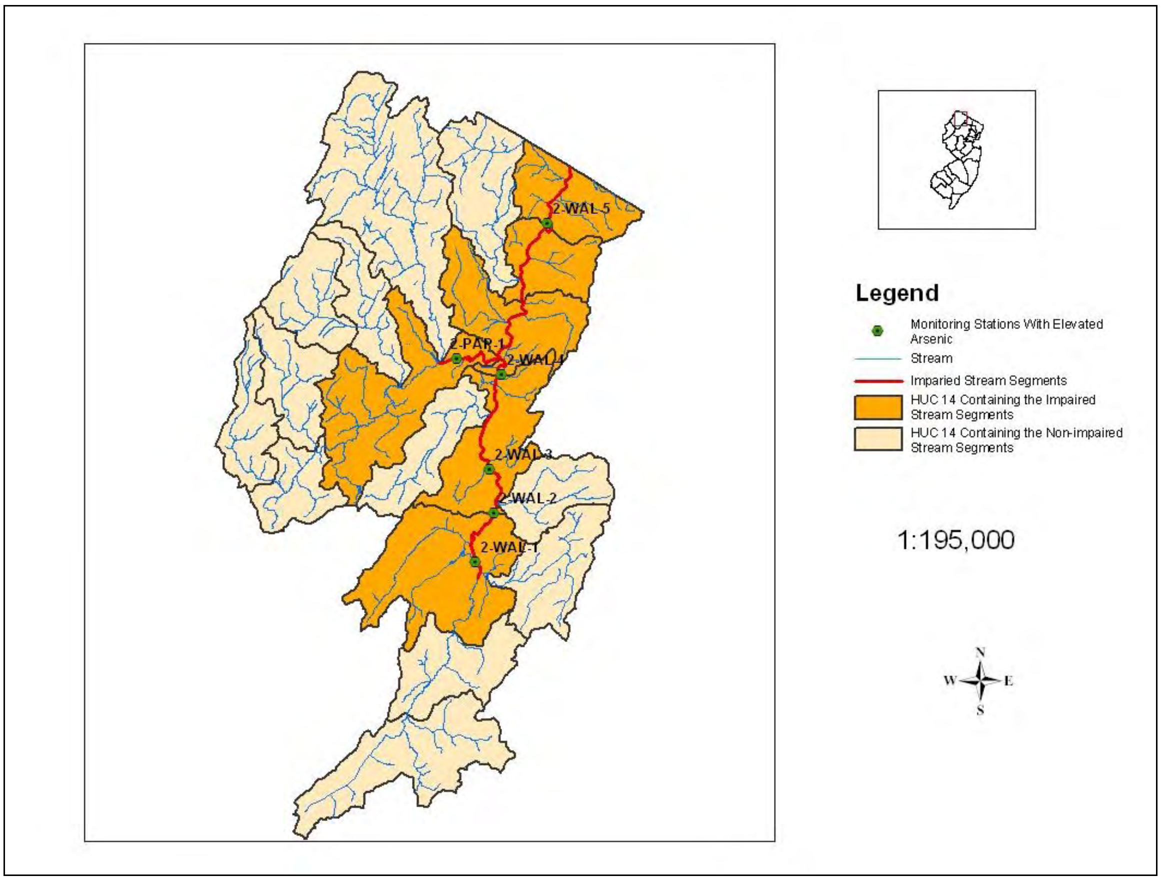
1 Total Maximum Daily Load to Address Arsenic in the Wallkill River and the Papakating Creek Northwest Water Region



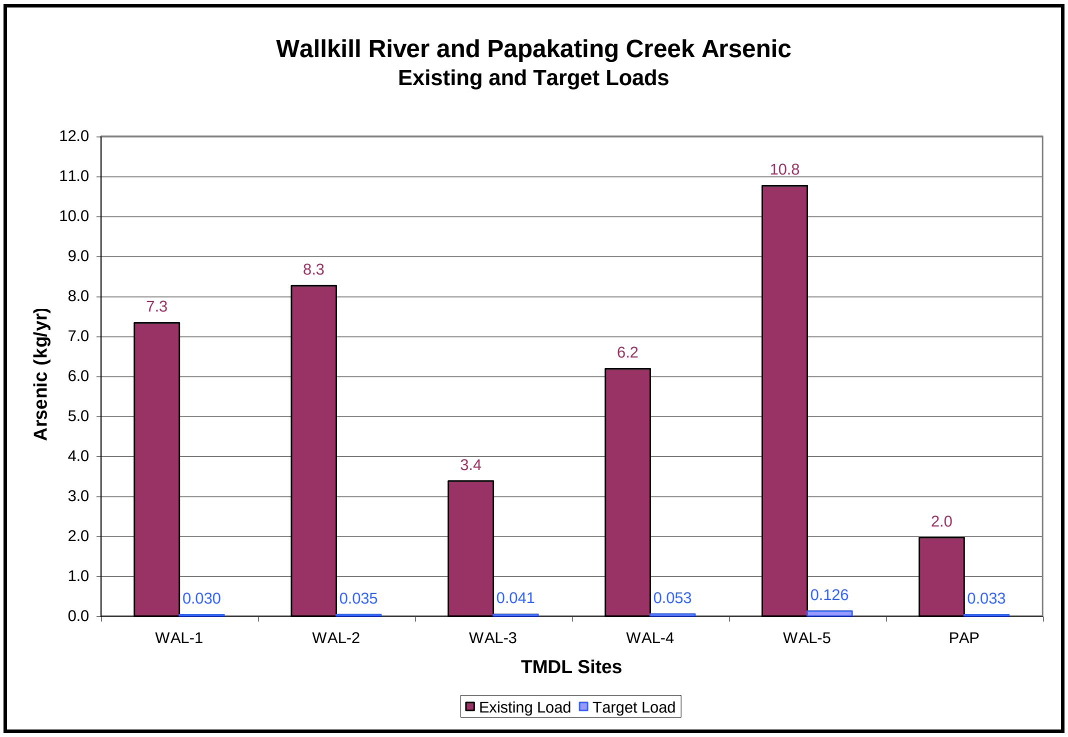
Locations of Impaired Monitoring Stations for the Wallkill River and Papakating Creek Watersheds in the "Total Maximum Daily Load to Address Arsenic in the Wallkill River and Papakating Creek Northwest Water Region"

Arsenic TMDL Calculations: Load Reductions Representing a 5% MOS

Station number	Loading Capacity (kg/yr)	MOS (5%, kg/yr)	Load Allocation (kg/yr)	Wasteload Allocation (kg/yr)
WAL-1	0.172	0.009	0.163	0
WAL-2	0.239	0.012	0.227	0
WAL-3	0.252	0.013	0.239	0
WAL-4	0.356	0.018	0.338	0
WAL-5	0.821	0.041	0.78	0
PAP-1	0.341	0.017	0.324	0



Spatial Extent of Impaired Segments Addressed in "Total Maximum Daily Loads to Address Arsenic in the Wallkill River and the Papakating Creek in the Northwest Water Region"



Relative Difference between Existing and Target Arsenic Loading, Using a 7Q10 Reference Flow

APPENDIX H.2

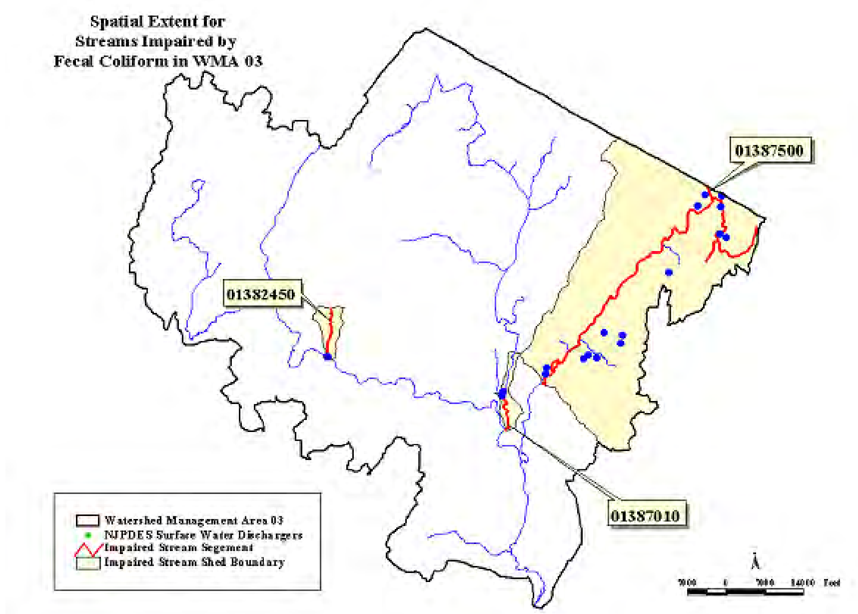
WMA 3 – TMDL DATA

A. **Parameter: Fecal Coliform**

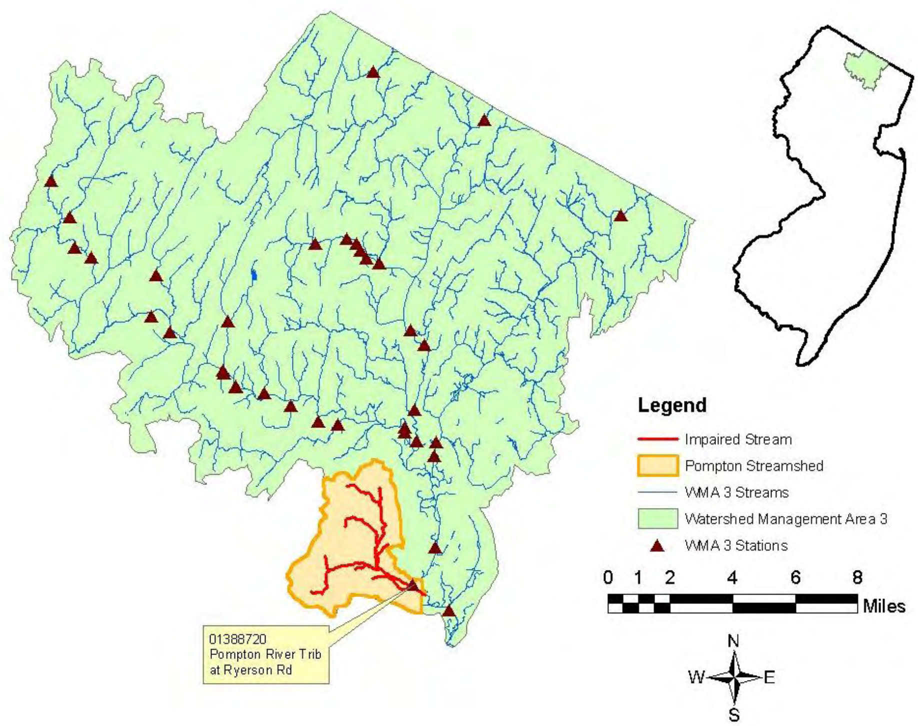
Waterbodies in the Highlands Region of Pompton Tributaries WMA (3) for which TMDLs have been Developed for Fecal Coliform

Monitoring Sites	HUC 14	Waterbody Name	Percent Reduction	TMDL Document
01382450	02030103050060	Macopin River at Macopin Reservoir (Macopin gage to Charl'brg)	37%	1
01387010	02030103070070	Wanaque R at Highlands Ave/Posts Bk (below reservior)	85%	1
01387500	02030103100010	Ramapo River near Mahwah (above 74d 11m 00s)	91%	1
	02030103100020	Masonicus Brook	91%	1
	02030103100030	Ramapo R (above Fyke Bk to 74d 11m 00s)	91%	1
	02030103100040	Ramapo R (Bear Swamp Bk thru Fyke Bk)	91%	1
	02030103100050	Ramapo R (Crystal Lk br to BearSwamp Bk)	91%	1
	02030103100060	Crystal Lake/Pond Brook	91%	1
	02030103100070	Ramapo R (below Crystal Lake bridge)	91%	1
01388720	02030103110010	Pompton River Trib at Ryerson Rd	96%	2
Bubbling Springs-03	02030103070010	Bubbling Springs	94%	3
Crystal Lake-03	02030103100060	Crystal Lake	97%	3
Erskine Lake-03	02030103070050	Erskine Lake	96%	3
Forest Hill Lake-03	02030103050080	Forest Hill Lake	95%	3
Kitchell Lake-03	02030103070040	Kitchell Lake	95%	3
Lake Edenwold-03		Lake Edenwold	97%	3
Lake Ioscoe-03	02030103070070	Lake Ioscoe	97%	3
Lionhead Lake-03		Lionhead Lake	98%	3
Skyline Lakes-03	02030103070060	Skyline Lakes	96%	3

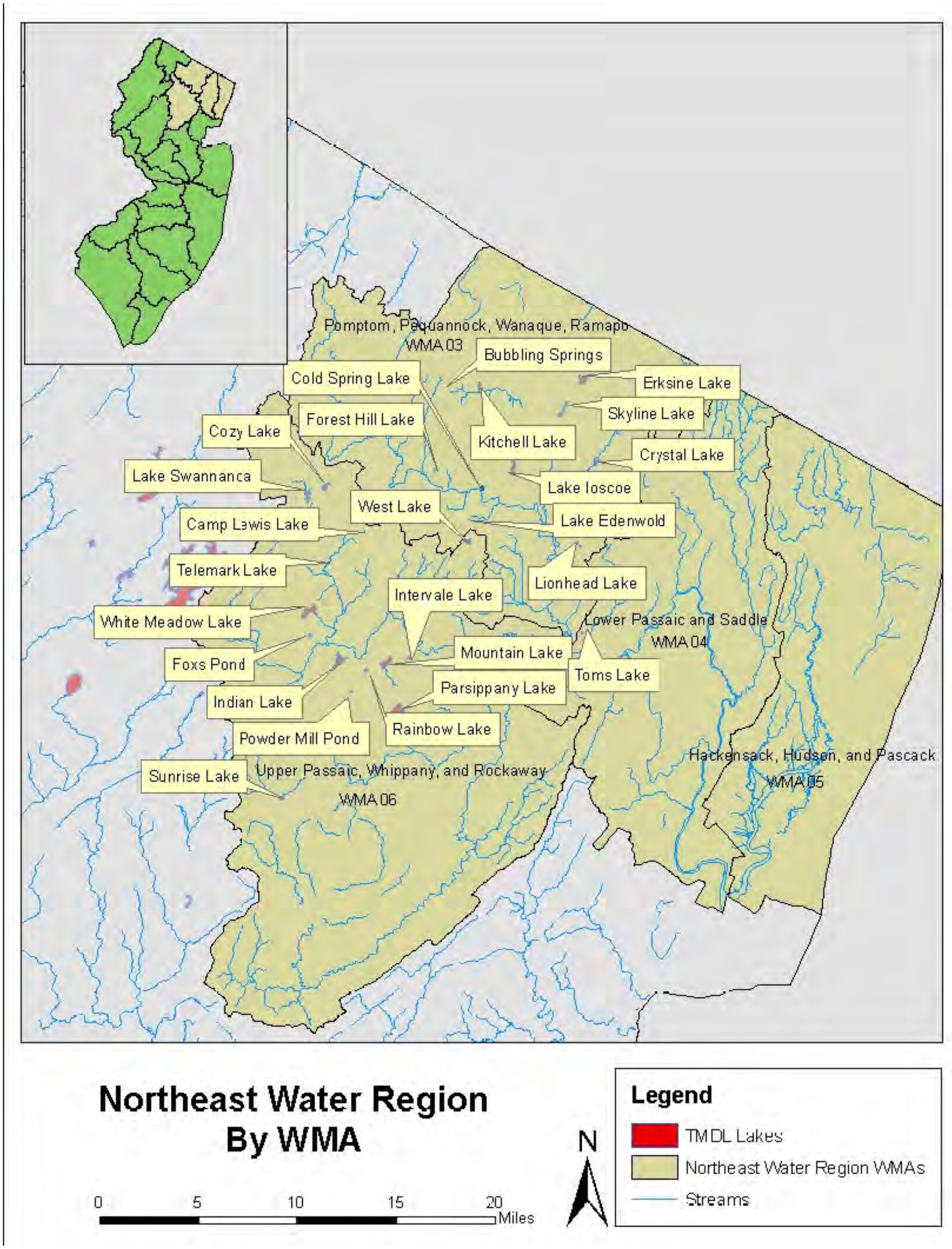
1 Total Maximum Daily Loads for Fecal Coliform to Address 32 Streams in the Northeast Water Region
2 Total Maximum Daily Loads for Fecal Coliform to Address 2 Streams in the Northeast Water Region
3 Total Maximum Daily Loads for Pathogens to Address 25 Lakes in the Northwest Water Region



Spatial Extent of Impaired Segments Addressed in "Total Maximum Daily Loads for Fecal Coliform to Address 32 Streams in the Northeast Water Region"



Spatial Extent of Impaired Segments Addressed in "Total Maximum Daily Loads for Fecal Coliform to Address 2 Streams in the Northeast Water Region"



Spatial Extent of impaired Lakes addressed in "Total Maximum Daily Loads for Pathogens to Address 25 Lakes in the Northwest Water Region"

B. Parameter: Phosphorus

Waterbodies Listed for Total Phosphorus Impairment Addressed in Total Maximum Daily Load for Phosphorus to Address Greenwood Lake in the Northeast Water Region

Monitoring Sites	HUC-14	Waterbody Name	Percent Reduction	TMDL Document
Greenwood Lake	02030103070020	Belcher Creek (Pinecliff Lake & below)	43%	1
Greenwood Lake	02030103070030	Wanaque R/Greenwood Lk(aboveMonks gage)	43%	1
Greenwood Lake	02030103070010	Belcher Creek (above Pinecliff Lake)	43%	1

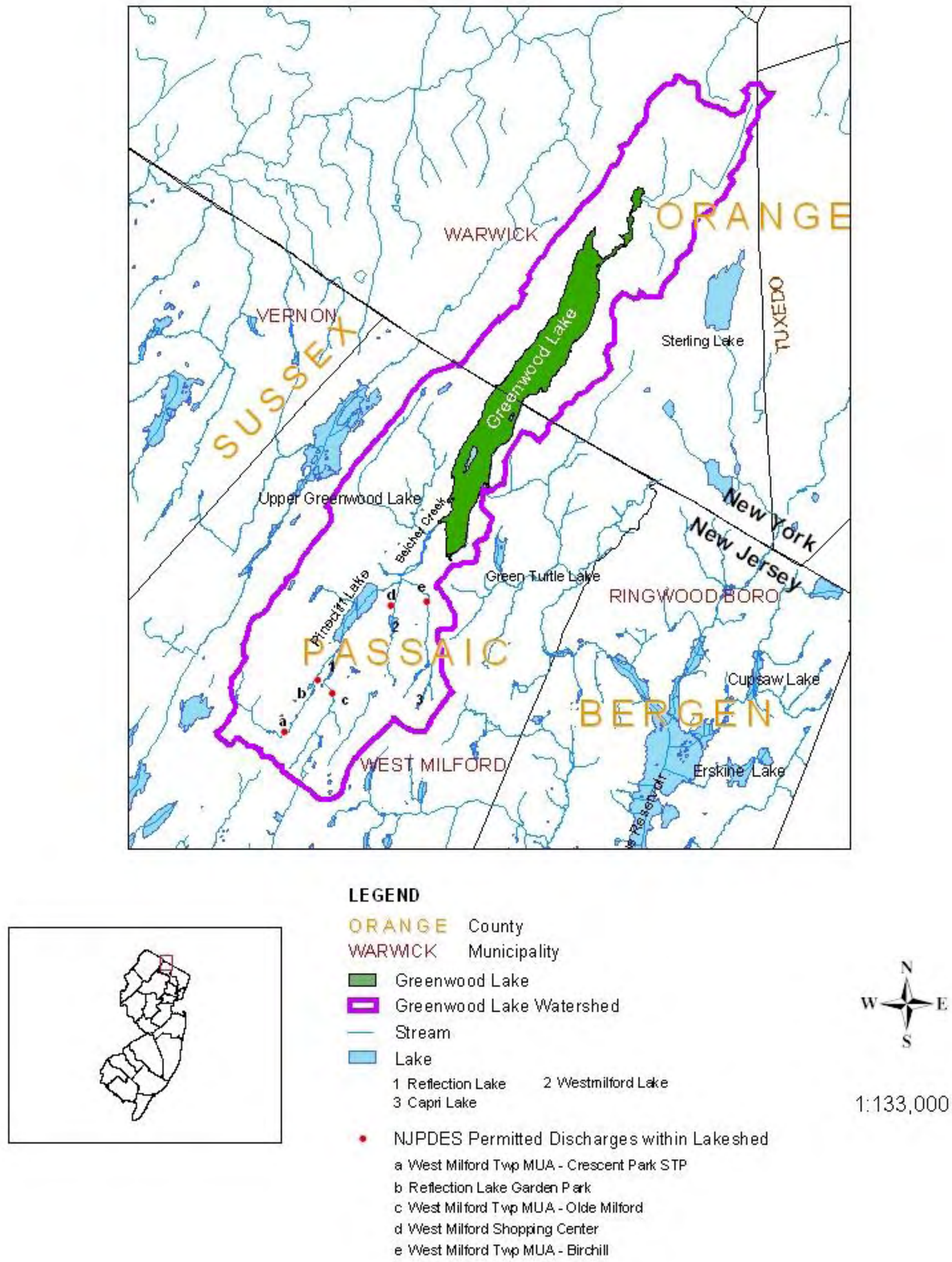
1 Total Maximum Daily Load for Phosphorus to Address Greenwood Lake in the Northeast Water Region

Waterbodies Listed for Total Phosphorus Impairment

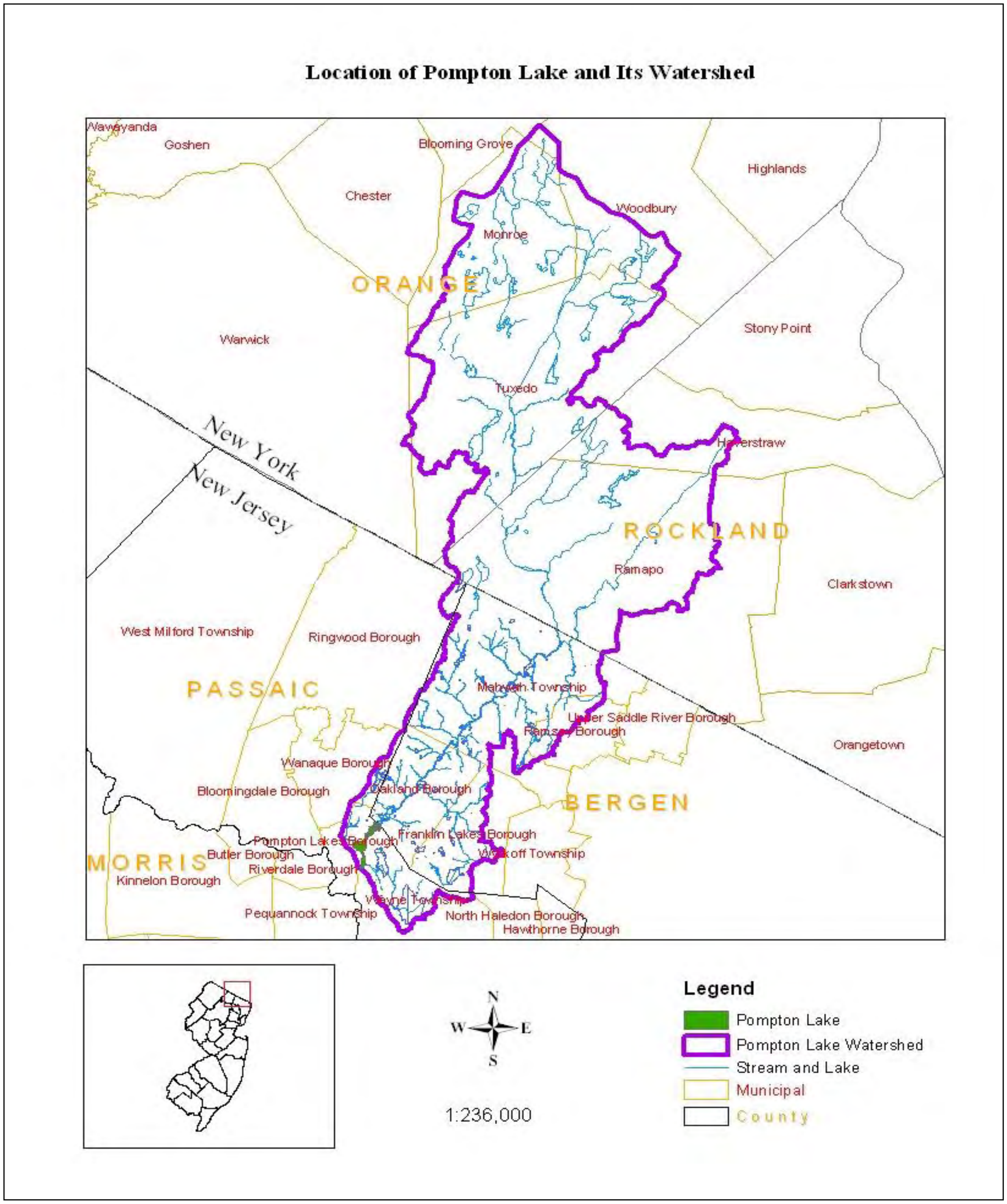
Monitoring Sites	HUC 14	Waterbody Name	Percent Reduction	TMDL Document
	02030103100010	Ramapo R (above74d 11m 00s)	68%	2
	02030103100050	Ramapo R (Crystal Lk br to Bear Swamp Bk)	68%	2
	02030103100070	Ramapo R (below Crystal Lake bridge)	68%	2
Wanaque Reservoir- 03	02030103070050	Wanaque Reservoir	57%	3
	02030103070070	Wanaque R/Posts Bk (below reservoir)	60%	3
	02030103110010	Lincoln Park Tribs (Pompton River)	60%	3
	02030103110020	Pompton River	60%	3
	02030103070050	Wanaque Reservoir (below Monks gage)	68%	3

2 Total Maximum Daily Load Report to Address Phosphorus Impairment in Pompton Lake and Ramapo River in the Northwest Water Region

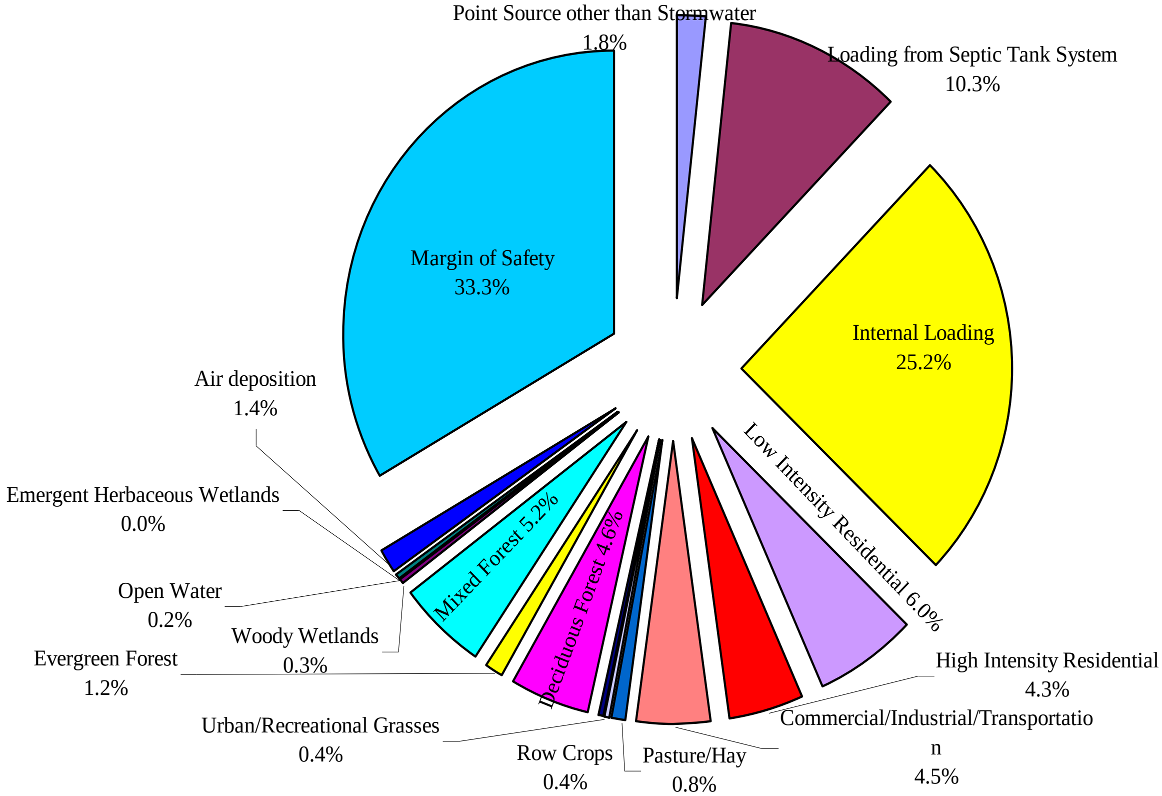
3 Total Maximum Daily Load Report for the Non-Tidal Passaic River Basin Addressing Phosphorus Impairments



Spatial Extent of Impaired Segments Addressed in Total Maximum Daily Load for Phosphorus to Address Greenwood Lake in the Northeast Water Region



Spatial Extent of Impaired Segments



Phosphorus Allocations for Greenwood Lake TMDL

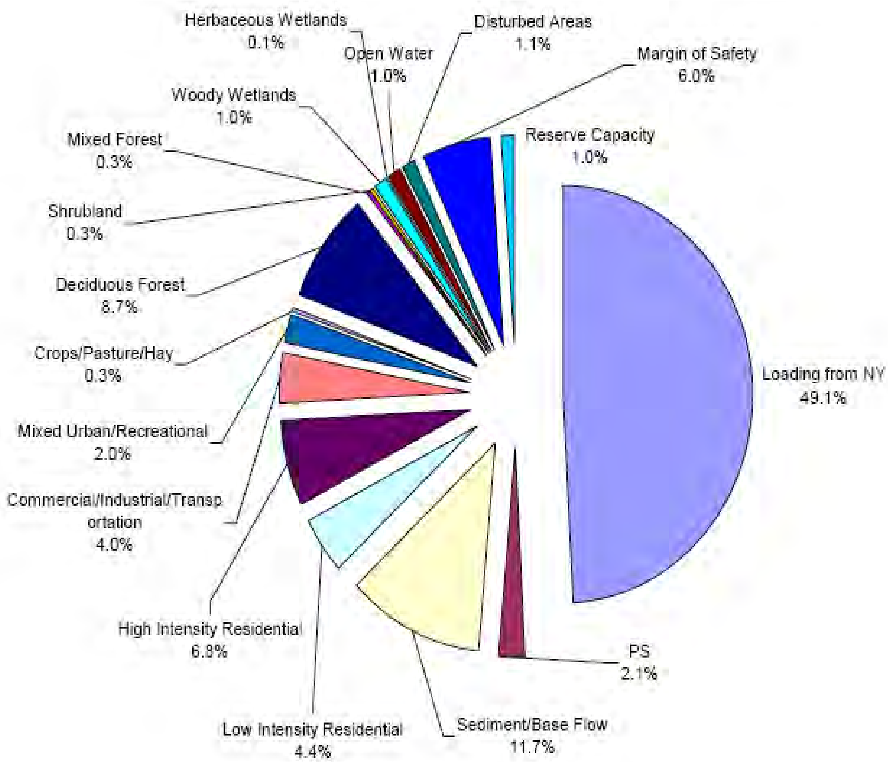
TMDL calculations for Greenwood Lake (annual loads and percent reductions)

	kg TP/yr	%of LC	% reduction
Loading Capacity (LC)	3,895	100%	n/a
Point Sources other than Stormwater	70	1.80%	0%
Loading from Septic Tank System	401	10%	43%
Internal Loading	983	25%	43%
Land Use Surface Runoff			
Low Intensity Residential	235	6%	43%
High Intensity Residential	166	4.30%	43%
Commercial/Industrial/Transportation	174	4.50%	43%
Pasture/Hay	32	0.80%	43%
Row Crops	15	0.40%	43%
Urban/ Recreational Grasses	15	0.40%	43%
Deciduous Forest	180	5%	0%
Evergreen Forest	48	1.20%	0%
Mixed Forest	202	5%	0%
Woody Wetlands	13	0.30%	0%
Emergent Herbaceous Wetlands	1	0.03%	0%
Open Water	7	0.20%	0%
Air deposition	53	1.40%	0%
Other Allocation			
Margin of Safety	1,298	33%	n/a
Reserve Capacity	0	0%	n/a

TMDL calculations for Pompton Lake

	TMDL Allocation Type	Existing Conditions[1] kg TP/day	Existing Conditions[1] % of LC	TMDL Specification kg TP/day	TMDL Specification % of LC	Percent Reduction[2]
Cumulative Watershed Load (CWL)		54.6	100%	17.4	100%	68%
Point Sources other than Stormwater						
NJPDES Dischargers[3]	WLA	0.05	0.1%	0.37 (0.4)[5]	2.1%	0%
Internal Loading						
Sediment/Base Flow	n/a	2.0	3.7%	2.0	11.7%	0%
Boundary Inputs						
New York[4]	n/a	35.2	64.5%	8.5	49.1%	76%
Land Use Surface Runoff						
Low Intensity Residential	WLA	3.9	7.0%	0.8	4.4%	80%
High Intensity Residential	WLA	5.9	10.8%	1.2	6.8%	80%
Commercial/Industrial/Transportation	WLA	3.5	6.3%	0.7	4.0%	80%
Mixed Urban/Recreational	WLA	1.8	3.2%	0.4	2.0%	80%
Crops/Pasture/Hay	LA	0.2	0.4%	0.04	0.3%	80%
Deciduous Forest	LA	1.5	2.7%	1.5	8.7%	0%
Evergreen Forest	LA	0.01	0.0%	0.01	0.0%	0%
Mixed Forest	LA	0.05	0.1%	0.05	0.3%	0%
Shrubland	LA	0.05	0.1%	0.05	0.3%	0%
Woody Wetlands	LA	0.2	0.3%	0.2	1.0%	0%
Herbaceous Wetlands	LA	0.01	0.0%	0.01	0.1%	0%
Open Water	LA	0.2	0.3%	0.2	1.0%	0%
Disturbed Areas	LA	0.2	0.3%	0.2	1.1%	0%
Other Allocations						
Margin of Safety	n/a	n/a	n/a	1.0	6.0%	n/a
Reserve Capacity	n/a	n/a	n/a	0.2	1.0%	n/a

1 average annual loads for existing conditions based on 1993-2002 model simulation
2 = 1 - (TMDL load /Existing load)*100
3 a detailed listing of individual discharge facilities is provided in Table 12
4 includes PS and NPS discharges to the Ramapo River within New York State
5 Rounded value used in Cumulative Watershed Load summation.



Loading Capacity Distribution at Pompton Lake

Distribution of WLAs and LAs among source categories for the Wanaque Reservoir

	TMDL Allocation Type	Existing Conditions[1] **Total watershed		**Post-TMDL allocations	TMDL Specification* Wanaque Reservoir only		
		**Total watershed	Wanaque Reservoir only				
		kg TP/day	kg TP/day	kg TP/day	kg TP/day	% of LC	Percent Reduction[2]
Loading Capacity (LC)		59.00		25.22		-	57%
Point Sources other than Stormwater							
NJPDES Dischargers[3]	WLA	0.32	0.13	0.19[4]	0.08[4]	0.3%	38%
Loading from Intake Diversions							
Diversions from Ramapo River[5]	LA	3.23	3.23	0.68	0.68	2.7%	79%
Diversions from Two Bridges[6]	LA	37.48	37.48	11.20	11.20	44.4%	70%
Internal Loading							
Sediment/Base Flow	LA	3.14	1.79	3.14	1.79	7.1%	0%
Greenwood Lake input	LA	-	7.82	-	4.67	23.9%	Greenwood Lake TMDL
Land Use Surface Runoff[7]							
Low Intensity Residential	WLA	1.90	1.08	0.88	0.43	1.7%	60%
High Intensity Residential	WLA	4.14	2.36	1.91	0.95	3.7%	60%
Commercial/Industrial/Transportation	WLA	1.82	1.04	0.84	0.42	1.6%	60%
Mixed Urban/Recreational	WLA	0.67	0.38	0.31	0.15	0.6%	60%
Crops/Pasture/Hay	LA	0.56	0.32	0.25	0.13	0.5%	60%
Deciduous Forest	LA	3.37	1.93	3.37	1.93	7.6%	0%
Evergreen Forest	LA	0.34	0.19	0.34	0.19	0.8%	0%
Mixed Forest	LA	0.83	0.47	0.83	0.47	1.9%	0%
Shrubland	LA	0.05	0.05	0.05	0.05	0.2%	0%
Woody Wetlands	LA	0.29	0.17	0.29	0.17	0.7%	0%
Herbaceous Wetlands	LA	0.03	0.02	0.03	0.02	0.1%	0%
Open Water	LA	0.67	0.38	0.67	0.38	1.5%	0%
Disturbed Areas	LA	0.16	0.16	0.16	0.16	0.6%	0%

* an implicit MOS and Reserve Capacity has been specified in terms of chlorophyll-*a* level achieved compared to target.
** The total watershed for the Wanaque Reservoir includes the Greenwood Lake drainage area. Greenwood Lake and its drainage area were addressed in a previously established TMDL by NJDEP that was approved by EPA on September 29, 2004. The loads from the Greenwood drainage area are taken as boundary conditions and input into the Wanaque Reservoir TMDL.
1 average annual loads for existing conditions based on 1993-2002 model simulation
2 = 1 - (TMDL load /Existing load)*100
3 WLA for 2 facilities within Reservoir tributary watershed downstream from the Greenwood Lake TMDL (2004)
4 The mathematic error 0.20 kg TP/day has been corrected to 0.27 kg TP/day.
5 diversion load typically equals 3%-5% of the annual river load - for river load see Table 6.2 (Najarian 2005)
6 phosphorus concentrations at diversion intake were computed per Omni Environmental, 2007
7 see Table 6.9 for associated land use areas (Najarian 2005)

C. Parameter: Temperature

Water bodies listed for temperature impairment addressed in Total Maximum Daily Load to Address Temperature in the Pequannock River Northeast Water Region

Monitoring Sites	HUC 14	Water body Name	TMDL document
PQ1	02030103050010	Pequannock R (above Stockholm/Vernon Rd)	1
PQ3	02030103050030	Pequannock R (above OakRidge Res outlet)	1
PQ4, PQ5, PQ16	02030103050050	Pequannock R (Charlottesburg to OakRidge)	1
PQ8,	02030103050080	Pequannock R (below Macopin gage)	1
PQ6, PQ7, 01382410	02030103050060	Pequannock R (Macopin gage to Charlottesburg)	1
PQ 10		Pequannock River- Butler	1

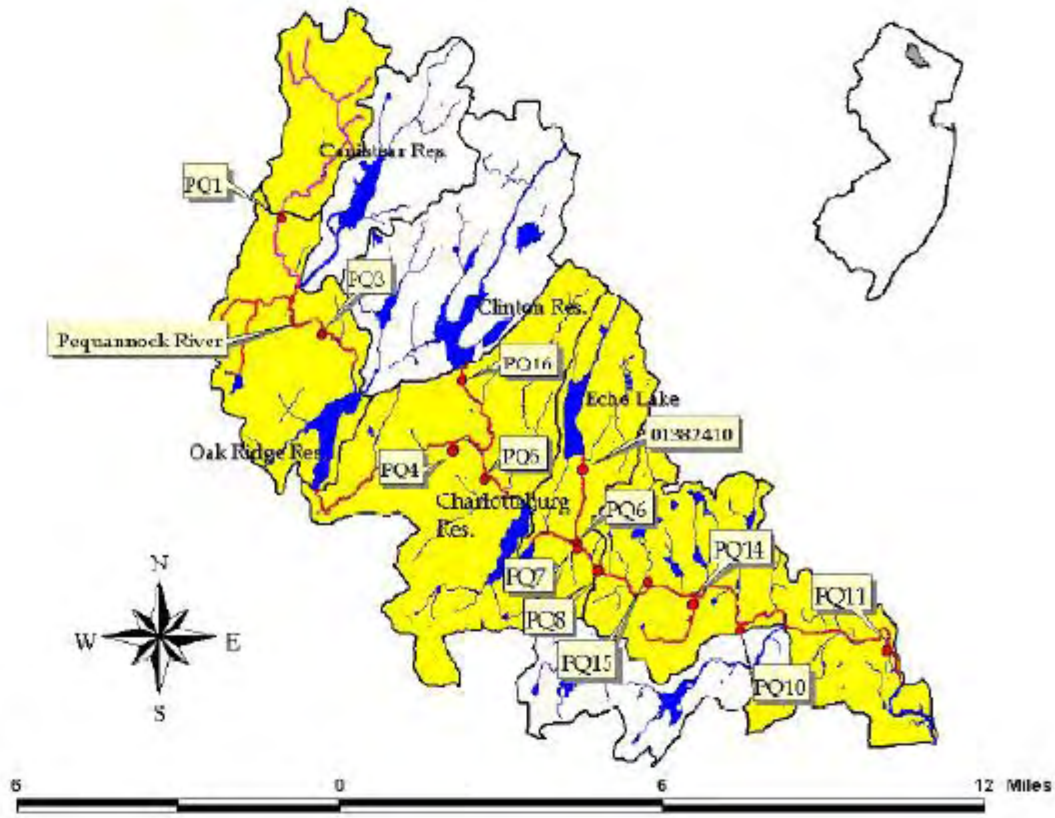
1 Water bodies listed for temperature impairment addressed in "Total Maximum Daily Load to Address Temperature in the Pequannock River Northeast Water Region"

The reservoir load allocations are as follows:

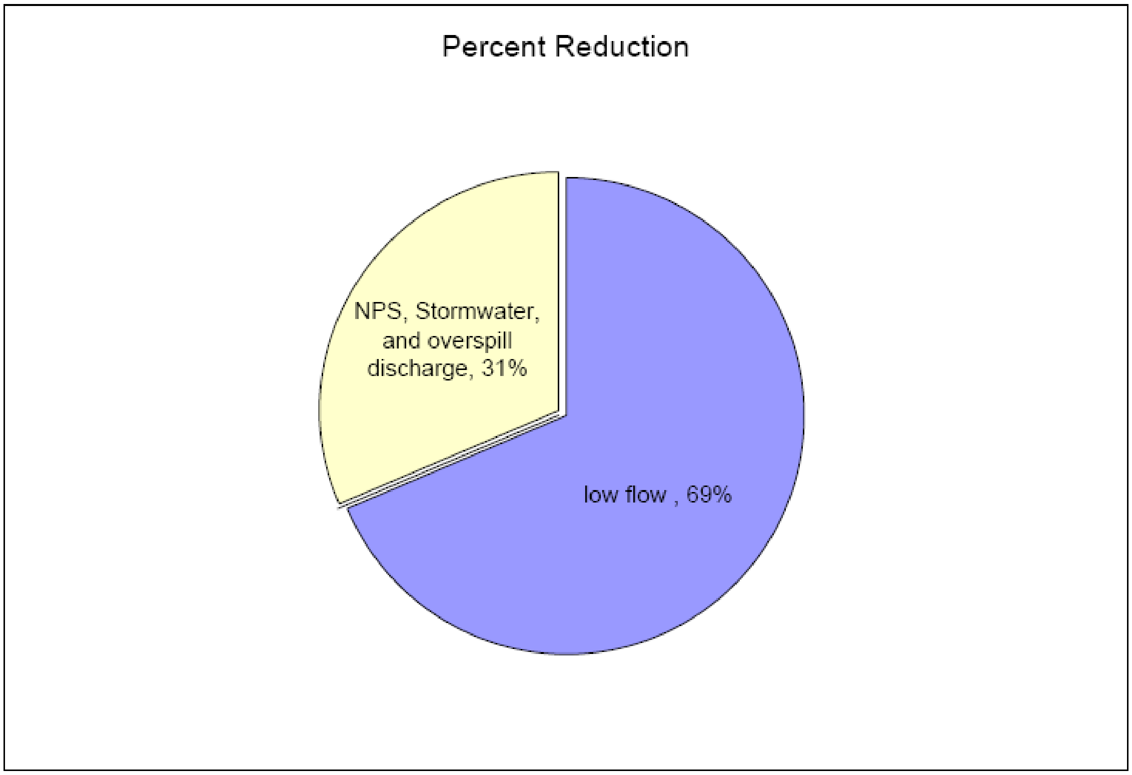
Reservoir Results for Pequannock Temperature TMDL

	Flow (cfs)	Temperature (° F)	Downstream Control Point
Canistear Reservoir	6.3	65.0	Entrance to the Oak Ridge Res.
Oak Ridge Reservoir	6.3	63.0	Entrance to the Charlottesburg Reservoir
Echo Lake	1.5	66.0	Confluence of Macopin and Pequannock Rivers
Clinton Reservoir	4.0	65.0	Confluence of Clinton Br. and Pequannock Rivers
Charlottesburg Reservoir	10.8	67.0	Confluence of Pompton and Pequannock Rivers

Margin of Safety = 0.3 degrees F



Spatial Extent of Impaired Segments addressed in "Total Maximum Daily Loads to Address Temperature in the Pequannock River Northeast Water Region"



Percent Reduction addressed in "Total Maximum Daily Loads to Address Temperature in the Pequannock River Northeast Water Region"

APPENDIX H.3

WMA 6 – TMDL DATA

A. Parameter: Fecal Coliform

Waterbodies Listed for Fecal Coliform Impairment in the Highlands Region of the Upper Passaic WMA for Which TMDLs Have Been Developed

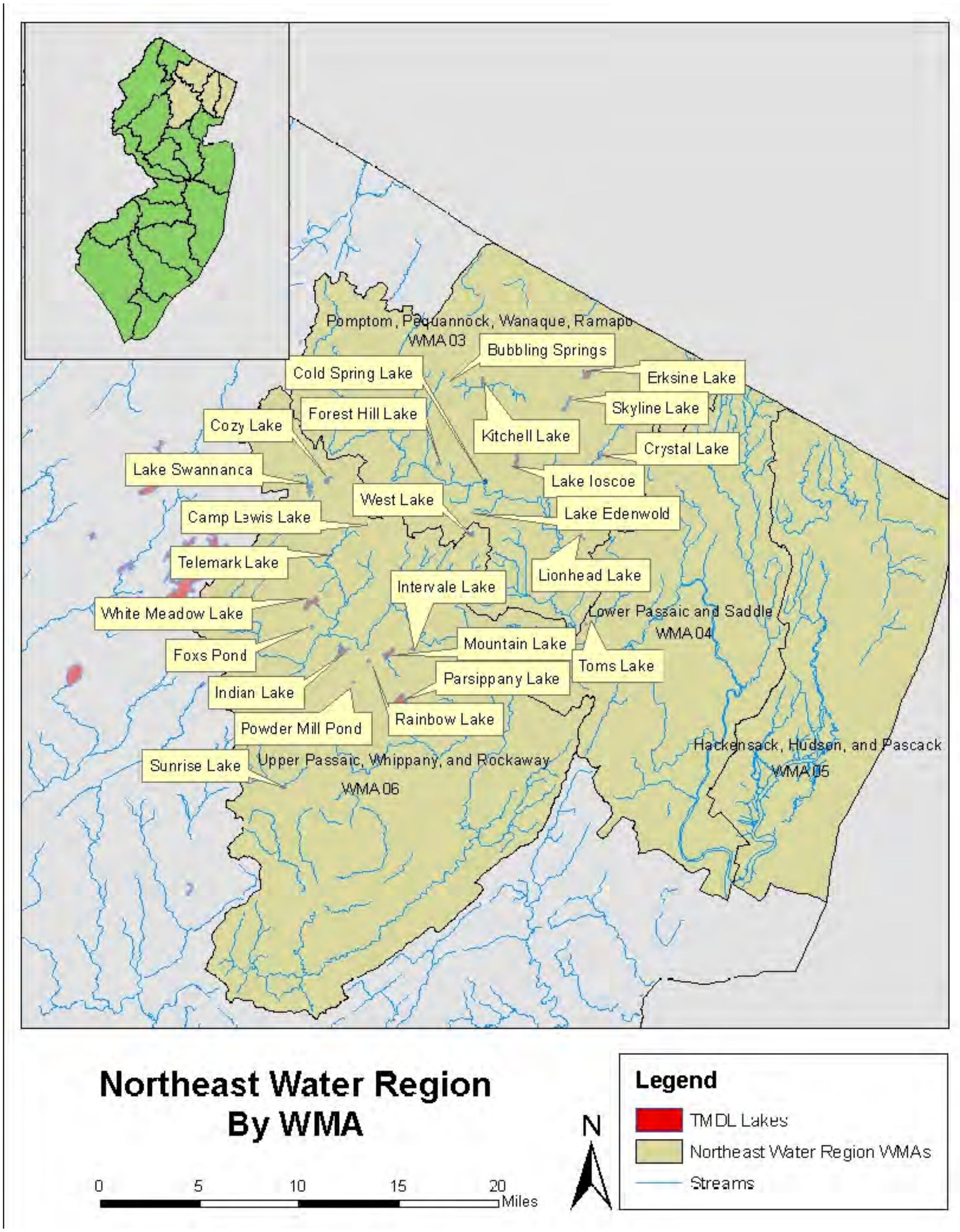
Monitoring Sites	HUC 14	Waterbody Name	Percent Reduction	TMDL Document
1378855	02030103010060	Black Brook at Madison	96%	1
1379000	02030103010070	Passaic River near Millington	96%	1
1379200	02030103010100	Dead River near Millington	96%	1
1379500	02030103010130	Passaic River near Chatham	96%	1
1379530	02030103010140	Canoe Brook near Summit	96%	1
1379680	02030103030040	Rockaway River at Longwood Valley	92%	1
1379853	02030103030090	Rockaway River at Blackwell Street	92%	1
1380100	02030103030110	Beaver Brook at Rockaway	89%	1
1380320	02030103030130	Stony Brook at Boonton	78%	1

Monitoring Sites	HUC 14	Waterbody Name	Percent Reduction	TMDL Document
1381200	02030103030170	Rockaway River at Pine Brook	91%	1
1382000	02030103040010	Passaic River at Two Bridges	83%	1
1378660	02030103010010	Passaic River at Tempewick Rd near Mendham	92%	2
	02030103024020	Whippany River at Morristown	58.50%	3
	02030103024020	Whippany River near Pine Brook	58.50%	3
Camp Lewis Lake-06	02030103030030	Camp Lewis Lake	89%	4
Cold Springs Pond-06	02030103010050	Cold Springs Pond	80%	4
Cozy Lake-06	02030103030030	Cozy Lake	97%	4
Foxs Pond-06	02030103030090	Foxs Pond	98%	4

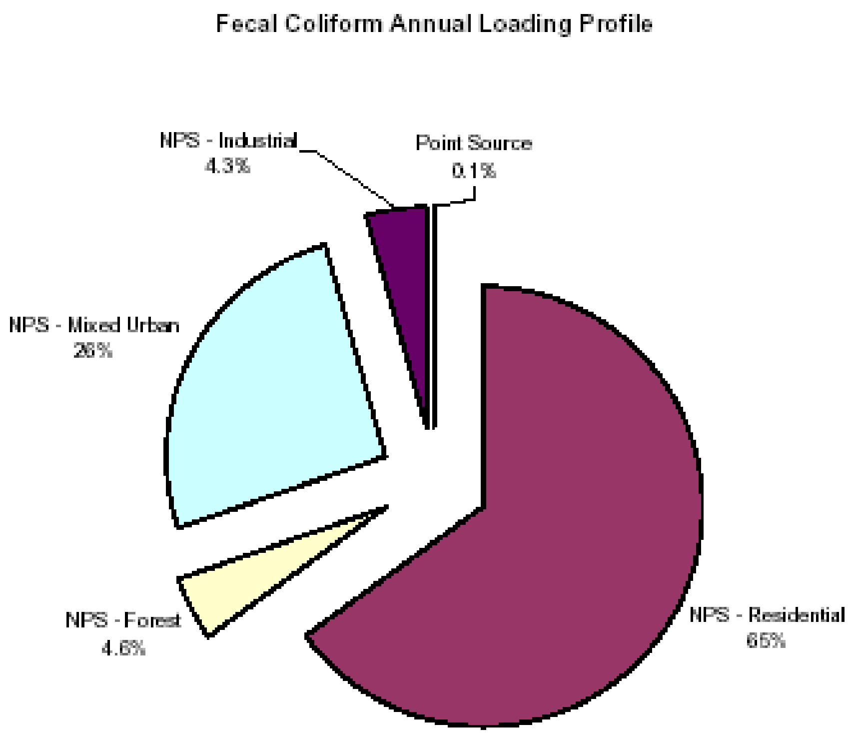
Indian Lake-06	02030103030120	Indian Lake	95%	4
Intervale Lake-06	02030103020080	Intervale Lake	96%	4
Lake Shannanoa-06	02030103030020	Lake Shannanoa	92%	4
Mountain Lake-06	02030103020080	Mountain Lake	96%	4
Parsippany Lake-06	02030103020080	Parsippany Lake	97%	4
Powder Mill Pond-06	02030103020030	Powder Mill Pond	96%	4
Rainbow Lakes-06	02030103020080	Rainbow Lakes	77%	4
Sunrise Lake-06	02030103020020	Sunrise Lake	95%	4
Telemark Lake-06	02030103030100	Telemark Lake	94%	4
West Lake-06	02030103030130	West Lake	83%	4

White Meadow Lake-06	020301030110	White Meadow Lake	96%	4

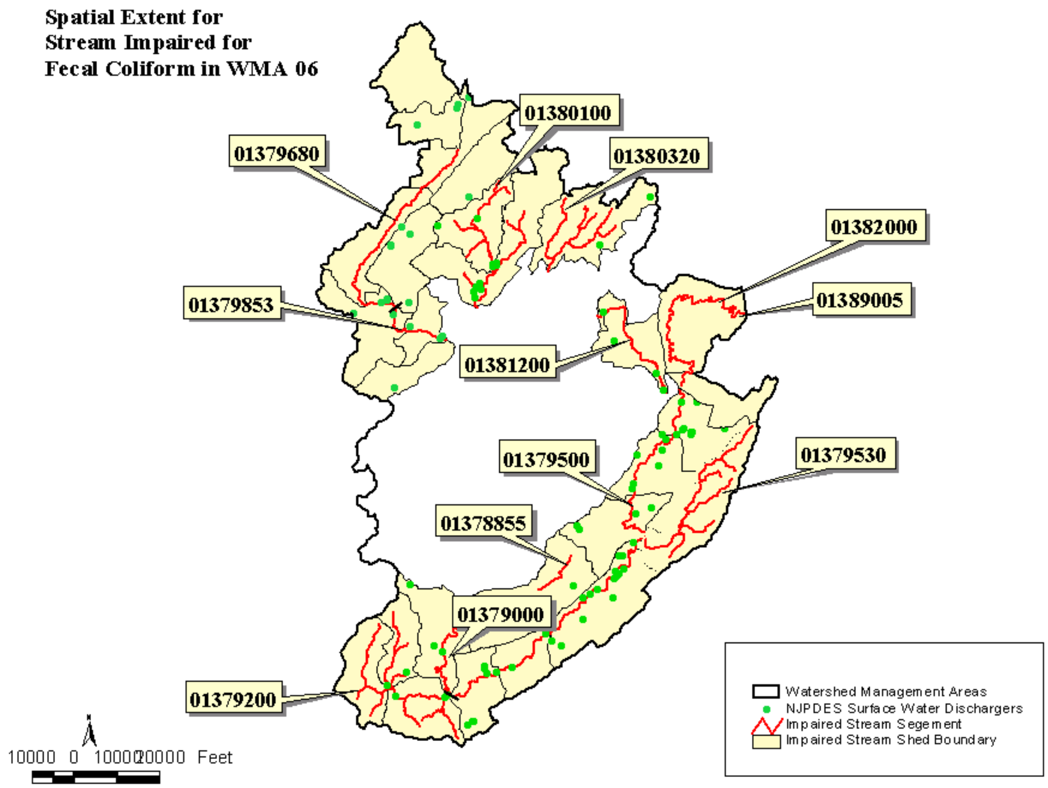
1 Total Maximum Daily Loads for Fecal Coliform to Address 32 Streams in the Northeast Water Region
2 Total Maximum Daily Loads for Fecal Coliform to Address 2 streams in the Northeast Water Region
3 New Jersey Department of Environmental Protection Report on the Establishment of a Total Maximum Daily Load for Fecal Coliform and the Interim Total Phosphorus Reduction Plan for the Whippany River Watershed
4 Total Maximum Daily Loads for Pathogens to Address 25 Lakes in the Northeast Water Region



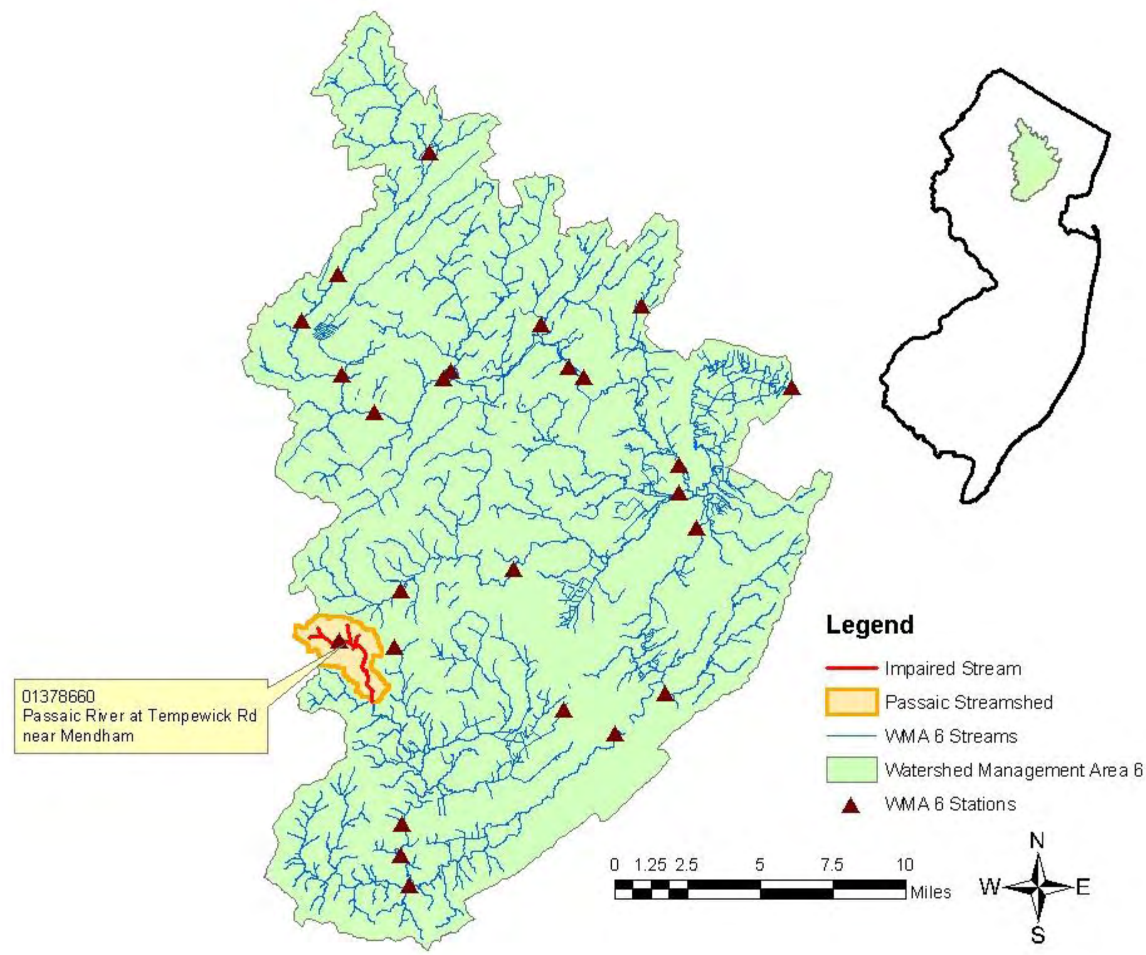
Spatial Extent of impaired Lakes addressed in "Total Maximum Daily Loads for Pathogens to Address 25 Lakes in the Northwest Water Region"



Loading allocation for impaired segments addressed in "New Jersey Department of Environmental Protection Report on the Establishment of a Total Maximum Daily Load for Fecal Coliform and an Interim Total Phosphorus Reduction Plan for the Whippany River Watershed"



Spatial Extent of Impaired Segments Addressed in "Total Maximum Daily Loads for Fecal Coliform to Address 32 Streams in the Northeast Water Region"



Spatial Extent of Impaired Segments Addressed in "Total Maximum Daily Loads for Fecal Coliform to Address 2 Streams in the Northeast Water Region"

B. Parameter: Phosphorus

Waterbodies Listed for Phosphorus Impairment in the Highlands Region of the Upper Passaic WMA for Which TMDLs Have Been Developed

HUC 14	Waterbody Name	Percent Reduction	TMDL Document
02030103040010	Passsaic R Upr (Pomton R to Pine Bk)	60%	1
02030103030170	Rockaway R (passaqic R to Boonton dam)	60%	1
02030103020100	Whippany R (Rockaway R to Malapardis Bk)	60%	1
02030103010180	Passaic R Upr(Pine Bk br to Rockaway)	60%	1
02030103020040	Whippany R (Lk Pochahontas to Wash Val Rd)	60%	1
02030103020050	Whippany R (malapardiss to Lk Pocahontas)	60%	1
02030103010060	Black Brook (Great Swamp NWR)	60%	1
02030103010080	Dead River (above Harrisons Brook)	60%	1
02030103010110	Passic River Upr (Plainfield Rd to Dead R)	60%	1
02030103010100	Dead River (below Harrisons Brook)	60%	1

1. Total Maximum Daily Load Report for the Non- Tidal Passiaic River Basin Addressing Phosphorus Impairments

APPENDIX H.4

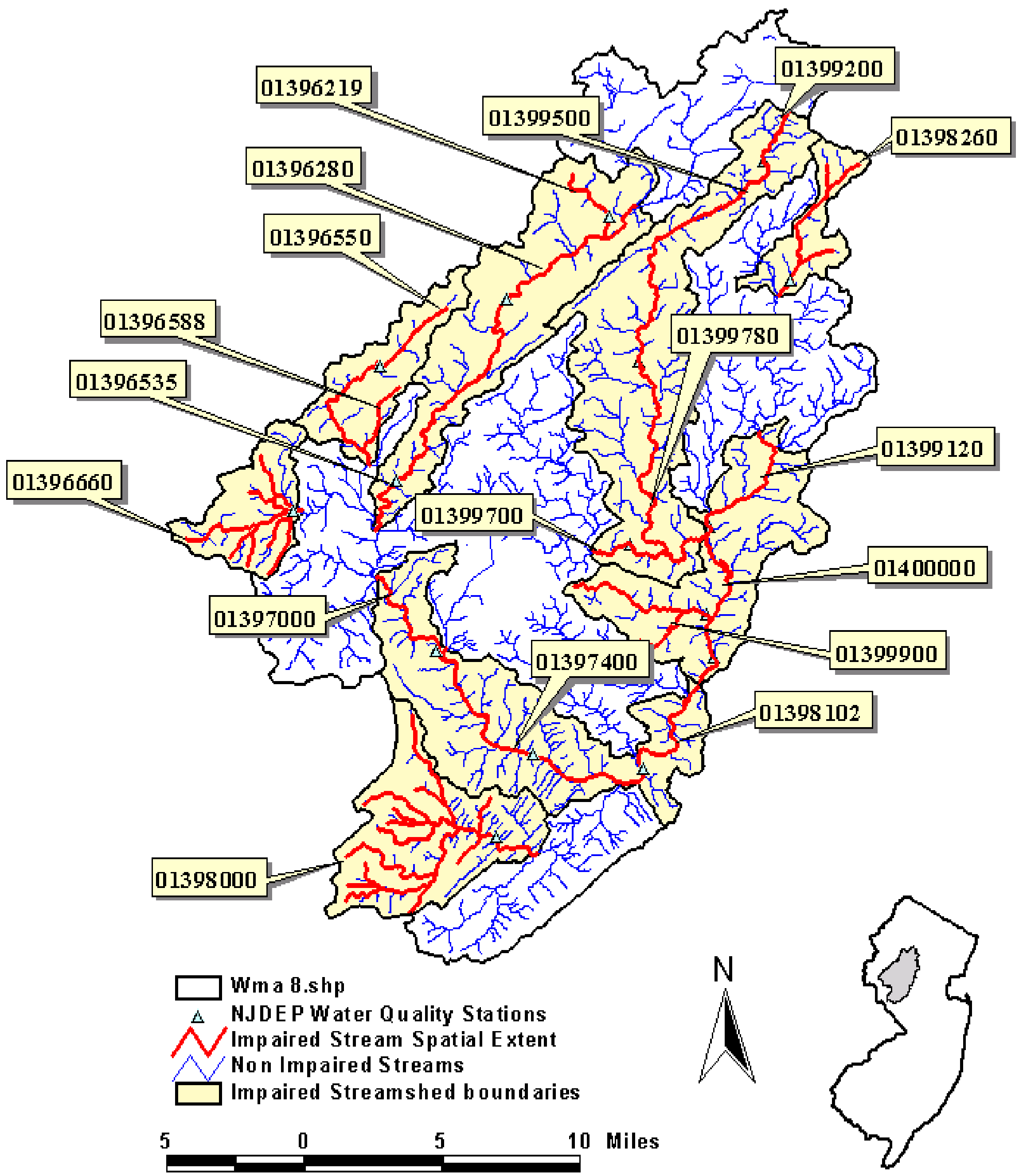
WMA 8 – TMDL DATA

A. Parameter: Fecal Coliform

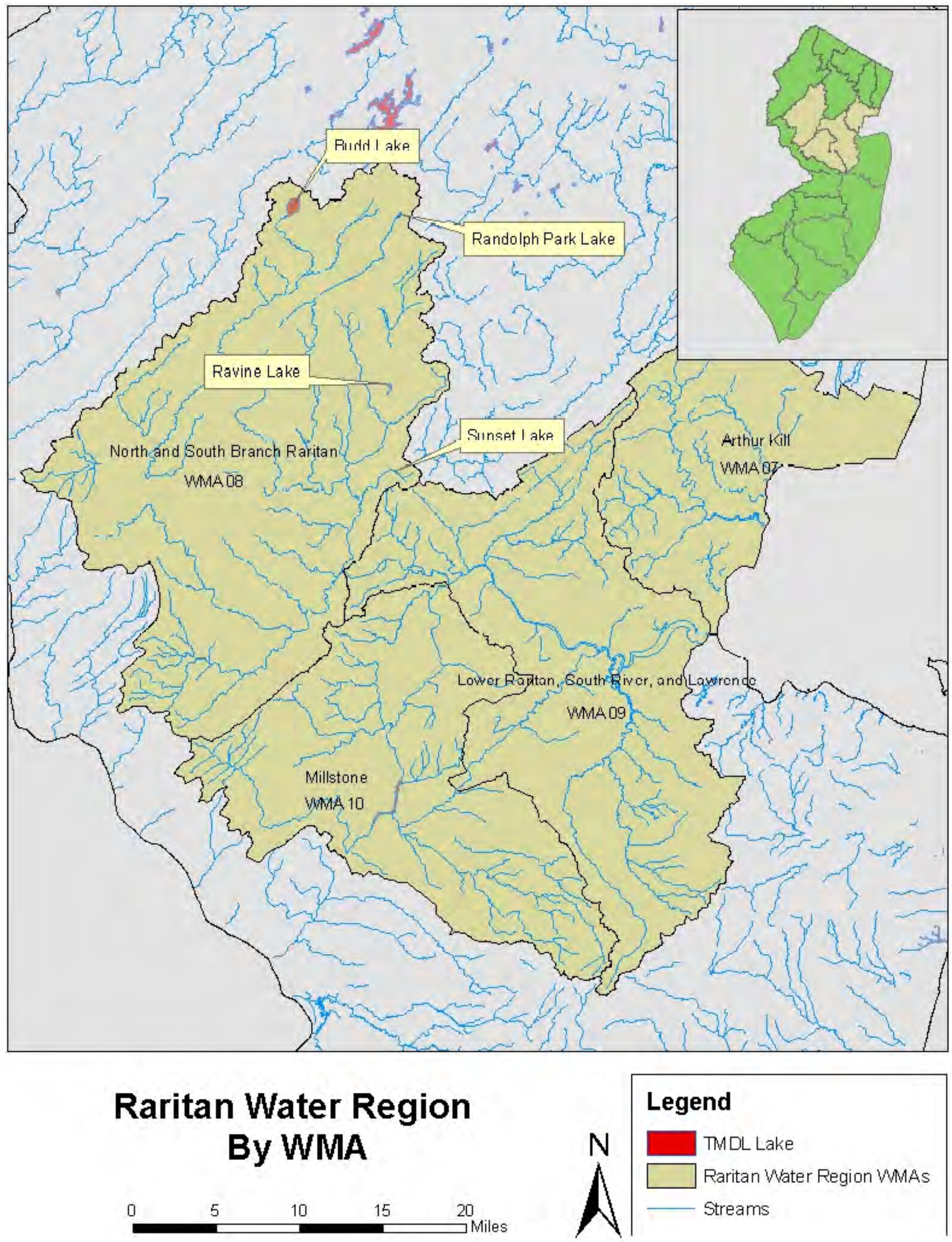
Waterbodies in WMA 8 for Which TMDLs Have Been Developed for Fecal Coliform

Monitoring Sites	HUC 14	Waterbody Name	Percent Reduction	TMDL Document
1396219	02030105010050	Stony Brook at Fairview Avenue at Naughright	94%	1
1396280	02030105010060	South Branch Raritan River at Middle Valley	94%	1
1396535	02030105010080	South Branch Raritan River Arch St at High Bridge	94%	1
1396550	02030105020010	Spruce Run at Newport	53%	1
1396588	02030105020020	Spruce Run near Glen Gardner	53%	1
1396660	02030105020030	Mulhockaway Creek at Van Syckel	91%	1
1397000	02030105020080	South Branch Raritan River at Stanton Station	80%	1
1397400	02030105040010 02030105020100	South Branch Raritan River at Three Bridges	80%	1
1398260	02030105060030	North Branch Raritan River near Chester	69%	1
1399120	02030105060090	North Branch Raritan River at Burnt Mills	90%	1
1399200	02030105050020	Lamington River near Ironia	90%	1
1399500	02030105050070 02030105050040	Lamington River near Pottersville	90%	1
1399700	02030105050110	Rockaway Creek at Whitehouse	90%	1
1399780	02030105050110	Lamington River at Burnt Mills	90%	1
Budd Lake-08	02030105010030	Budd Lake	99%	2
Randolph Park Lake-08	02030105050010	Randolph Park Lake-08	98%	2
Ravine Lake-08	02030105060040	Ravine Lake	95%	2
Sunset Lake-08		Sunset Lake	97%	2

1 Total Maximum Daily Loads for Fecal Coliform to Address 48 Streams in the Raritan Water Region
2 Total Maximum Daily Loads for Pathogens to Address 4 Lakes in the Raritan Water Region



Spatial Extent of Impaired Segments Addressed in "Total Maximum Daily Loads for Fecal Coliform to Address 48 Streams in the Raritan Water Region"

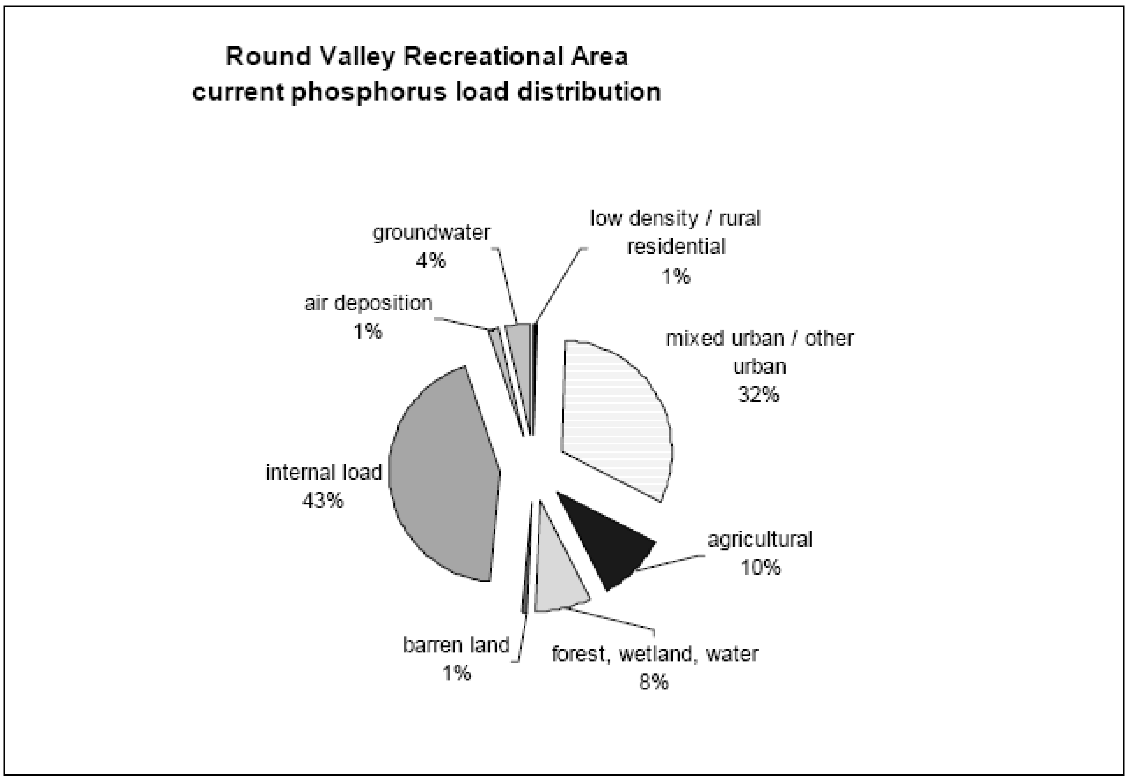


Spatial Extent of Impaired Segments Addressed in "Total Maximum Daily Loads for Pathogens to Address 4 Lakes in the Raritan Water Region"

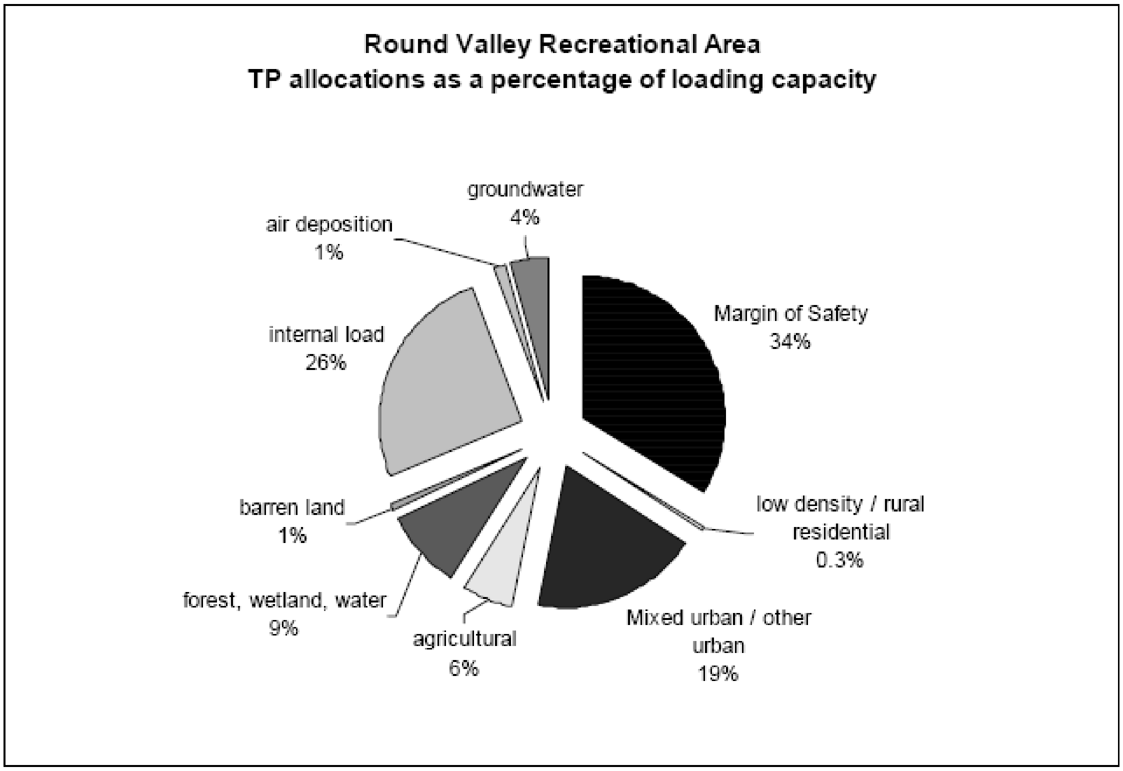
B. Parameter: Phosphorus
Waterbodies for which TMDL have been developed for phosphorus

Monitoring Sites	HUC 14	Waterbody Name	Percent Reduction with MOS	TMDL Document
	02030105020090	Round Valley Rec Area	39%	1

1: Total Maximum Daily Loads for Phosphorus to Address 7 Streams in the Raritan Water Region



Current distribution of phosphorus load for Round Valley Recreational Area



Phosphorus allocations for Round Valley Recreational Area

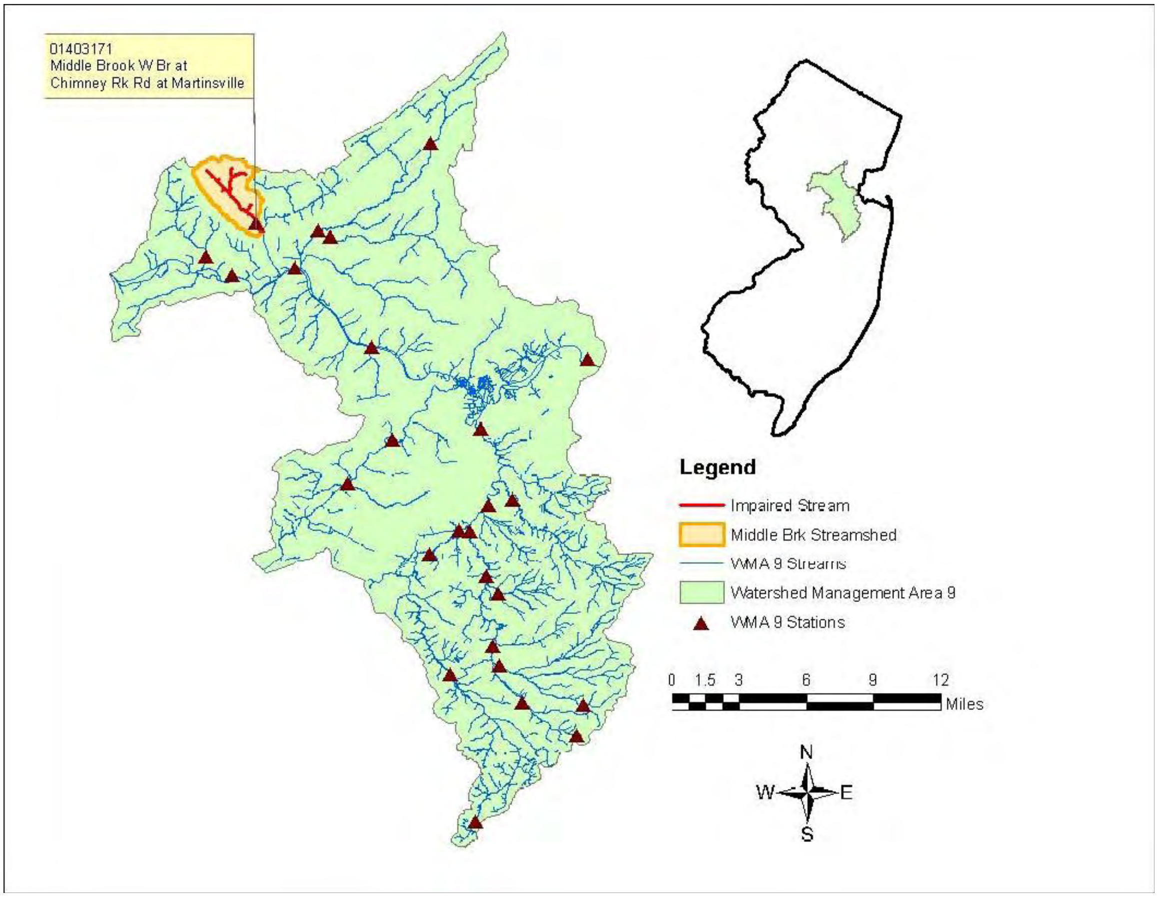
APPENDIX H.5
WMA 9- TMDL DATA

A. Parameter: Fecal Coliform

Waterbodies for which TMDL have been developed for fecal coliform

Monitoring Sites	HUC 14	Waterbody Name	Percent Reduction with MOS	TMDL Document
01403171	02030105120060	Middle Brook W. Br. At Chimney Bk Rd at Martinsville	84%	1

1: Total Maximum Daily Loads for Fecal Coliform to Address 3 Streams in the Raritan Water Region



Spatial extent the impaired segments addressed in "Total Maximum Daily Loads for Fecal Coliform to Address 3 Streams in the Raritan Water Region"

APPENDIX H.6

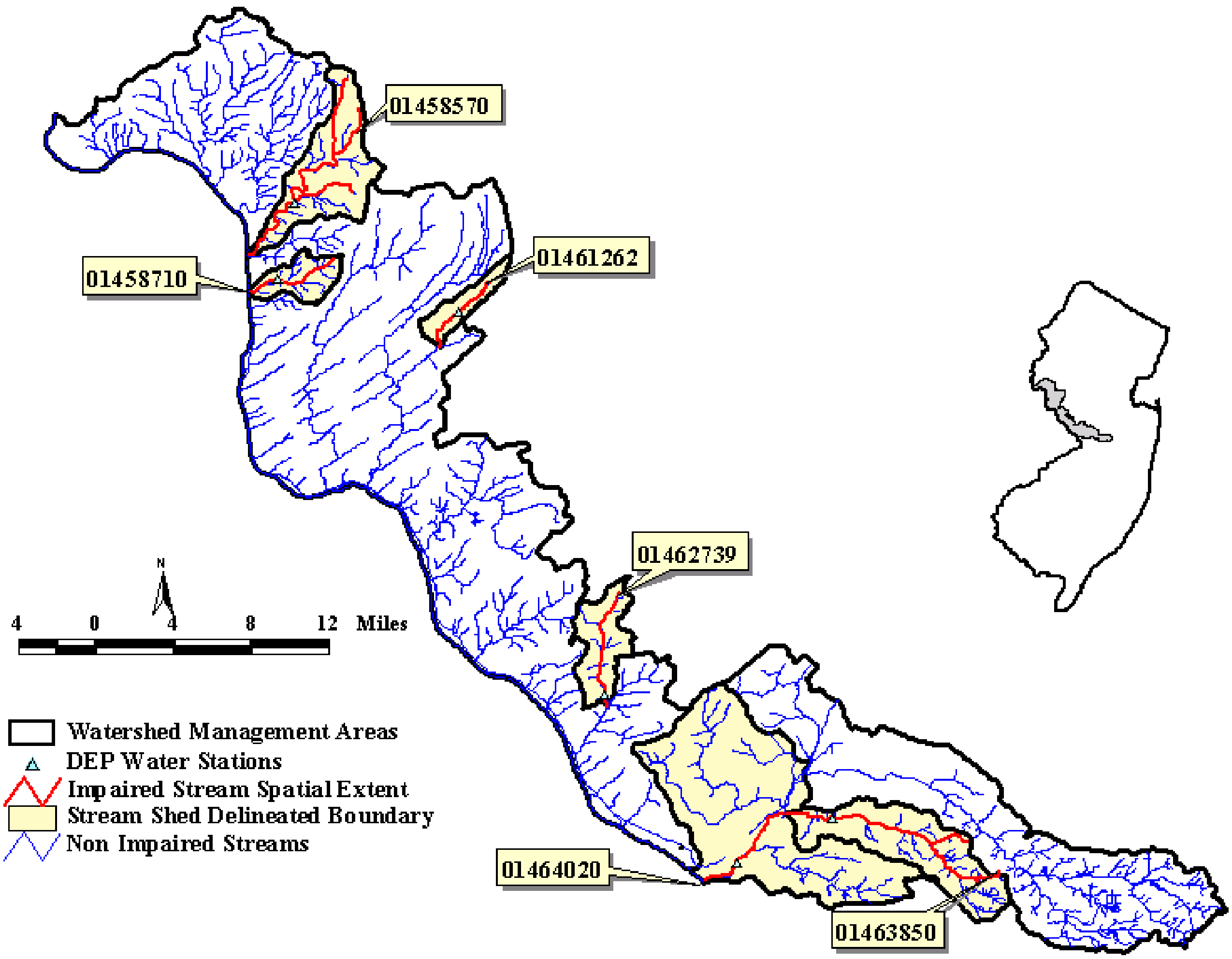
WMA 11 – TMDL DATA

A. **Parameter: Fecal Coliform**

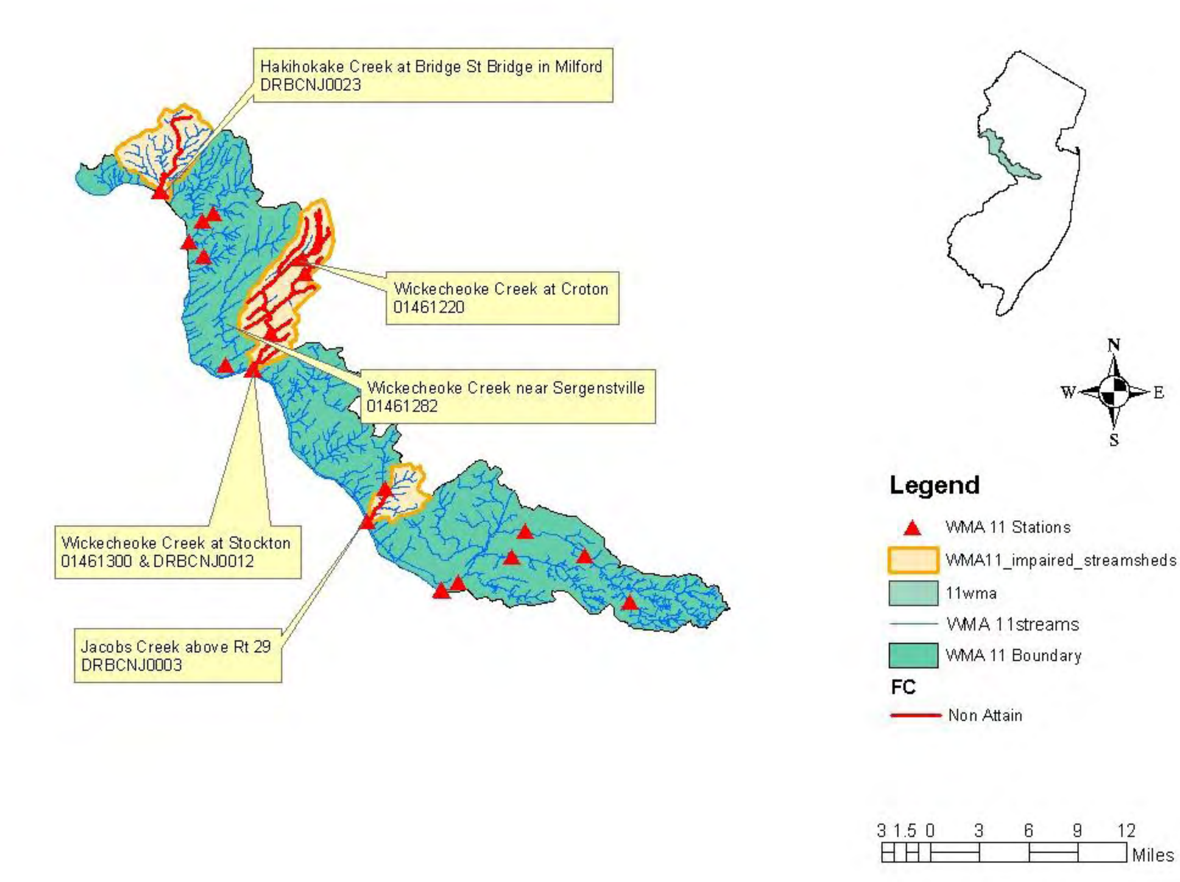
Water Bodies in the Highlands Region of the Central Delaware Tributaries - WMA 11 for Which TMDLs Have Been Developed for Fecal Coliform

Monitoring Sites	HUC 14	Water body Name	Percent Reduction	TMDL Document
01458570	02040105170040, 02040105170050	Nishisakawick Creek near Frenchtown	77%	1
	02040105170020	Hakihokake Creek at Bridge St Bridge in Milford	80%	2

1 Total Maximum Daily Loads for Fecal Coliform to Address 28 Streams in the Northwest Water Region
2 Total Maximum Daily Loads for Fecal Coliform to Address 10 Streams in the Northwest Water Region



Waterbodies Addressed in "Total Maximum Daily Loads for Fecal Coliform to Address 28 Streams in the Northwest Water Region"



Waterbodies addressed in "Total Maximum Daily Loads for Fecal Coliform to Address 10 Streams in the Northwest Water Region"