The vision of WMA 3 is clean and plentiful water and a healthy ecosystem for now and the future. Through comprehensive management and education we will inspire and enable cooperative stewardship, restoration and conservation of all of our resources by means that are environmentally sound as well as economically viable. – WMA 3 PAC

Watershed Characterization and Assessment of WMA 3

WMA 3 Highlights

Watershed Management Area 3 (WMA 3) of the Passaic River Basin:

- Covers 238 square miles of area which is over 58% forested,
- Watersheds include the Pequannock, Wanaque, Ramapo and Pompton Rivers
- Provides extensive habitat for fish and wildlife
- Has over 244,000 residents
- Most residents (approximately 95%) depend on groundwater for supply
- Diverts approximately 89 billion gallons of water per year, with more than 90% exported outside of WMA 3
- Provides surface water supply to over 2 million residents in other WMAs
- Receives surface flow from 140 square miles in New York
- Suffers from impairment of some surface and groundwater
- Surface water loadings are attributed primarily to:
    - non-point sources in NJ and NY for fecal coliform, BOD_5, sodium and suspended solids
    - point sources in NJ and NY for phosphorus and nitrates
    - both point and non-point sources for ammonia
- Effective planning will require interstate cooperation between NJ and NY

A. IMPORTANCE OF INTEGRATED PLANNING

Interplay between meteorological and deep tectonic forces have been forming the mountains and valleys in what is now the Passaic River Basin for many millions of years. Glaciers advanced and receded (the last about 10,000 years ago), sculpting the land and leaving moraines and a variety of soil deposits. Melting glaciers and runoff from rain and snow contributed to the development of the rivers, streams, lakes and marsh areas that we now see on the surface of the earth. As the last glacier receded, it blocked the flow of the north flowing rivers and formed glacial lakes. These lakes eventually drained and their remnants have gradually filled in through the accumulation of mineral and organic sediments forming marshes and bogs. These areas have become valuable wetlands. Other wetlands formed due to changes in drainage patterns, sedimentation of lakes and ponds, and other natural processes. As vegetation and animals returned after the last ice age, nature established a certain balance. The land, streams and rivers were able to assimilate the biological waste produced by the inhabitants of the land and water. If there was not enough food to support a population of a certain species, some members of the species migrated or starved. Movement or loss of one species would affect other species in the ecological community. Different species would respond to changes in the environment in different ways. Some would have been able to adapt to a variety of stresses, adjusting their habits to address the changes. Others migrated. Those that could not change their habits or migrate would simply perish.

When man first arrived in the Passaic River Basin, he was in balance with nature, migrating to find food, with a small population in a large area. The pre-Columbian Passaic Basin was nearly completely forested. Then things began to change. Man felled trees to build permanent shelters and cleared forest areas for farming. These land use changes altered the environment to some degree. European settlers cleared larger areas of forest for agriculture, building materials and fuel. Roads were cleared to allow transportation of goods to other areas. Population in some areas could expand beyond the ability of the local area to provide food, since food could be brought in from other areas. However, the population still depended on local water supplies. Dams were built to harness waterpower for mills and later for generation of electricity. The Morris Canal was constructed from Newark to the western limit of the Passaic Basin and on to the Delaware River at Phillipsburg to provide improved transportation across New Jersey. It also served as the local water supply in some areas, including part of Newark. Dams were built to enlarge existing lakes or form new lakes to provide water for the Canal. These activities greatly changed the environment.

Industrial Era

Railroads and better roads were constructed to provide for more economical movement of goods and people. Industrial activities flourished, particularly where power and transportation was available. As cities grew, people were attracted away from the rural areas to better paying jobs in the cities. Wastes from industrial activities were dumped in the river or on local land areas. Wetland areas were filled for development and some wetlands were used as dump sites for waste materials. Some of these industrial wastes caused contamination of river sediments. Macroinvertebrates in the sediments picked up the contaminants, which then progressed up the food chain to the flesh of fish, and to those who ate the contaminated fish. All of these activities changed the environment.

The population growth and industrial activities in city areas resulted in pollution of local water supplies. People in city areas died of typhoid due to poor sanitation. Habits needed to change, people would migrate or perish. It became necessary to convey water from the more rural areas to provide potable water for the city populations. Dams were constructed to form reservoirs. Pipelines and aqueducts were constructed to convey the water to the cities. Fortunately, considerably sized areas in the Passaic River Basin were preserved to protect these water resources. However, the large reservoirs affected flows and water temperatures in the rivers, which in turn affected the fish population. Clearing of trees from the buffer zone along streams and rivers also affected the water quality, including the temperature of the water. Sewers were built to convey sanitary waste and stormwater runoff to streams and rivers. In some areas along the Lower Passaic, combined sewers were built to carry both sanitary waste and stormwater. During storms producing flows exceeding the conveyance capacity of the combined sewers, excess flows, including a mixture of storm water and sanitary waste, are discharged through combined sewer overflows (CSOs) to the Lower Passaic River. Pollutants from wastewater discharges overwhelmed the streams and rivers, and wastewater treatment facilities were built to reduce the level of pollutants discharged to the water bodies.

Suburban Expansion

Improved roads and the increased use of the automobile permitted people to return to the more rural areas for housing yet commute daily to work in the cities or other economic centers. People moved from the more densely populated areas to individual homes in the outlying areas. Roads became more crowded and were enlarged. Land use underwent major changes. Some corporations moved their business offices out of the cities to more rural locations. More forests were cleared, wetlands filled, sewers, wastewater treatment plants, roads, houses, shopping centers and office facilities were built or expanded. Lands were cleared to provide fields for athletic activities and large lawns in corporate parks. Large fields or lawns near bodies of water provided favorable habitat for Canada geese, and the species has flourished in New Jersey. Stormwater runoff from these areas carries a significant biological loading to the receiving lakes, streams and rivers. Additional pollutants were discharged to water bodies from wastewater plants, from storm sewer discharges, and from runoff from parking lots, streets, lawns, and fields. Increased peak flows due to higher rates of stormwater runoff from increased impervious areas caused erosion of streams. All of these actions changed the environment. Habits had to change, or people would relocate or suffer the effects.

Addressing the Problems

Under the provisions of the federal Clean Water Act of 1972, much has been done to mitigate the impacts of the major land use changes that have occurred in the Passaic Basin in the last century. For two decades the emphasis of the program was on addressing the point sources of pollution, such as domestic wastewater treatment plants and industrial process discharges, and on protecting wetlands. There was a dramatic improvement in the quality of the water in the Passaic River and major tributaries in the 1980's. However, the job is far from finished. The improvements were in rivers affected by wastewater treatment facilities, and were accomplished through an extensive program of treatment plant process upgrades. Most of these improvements did not address removal of phosphorus, and nitrate concentrations increased as a result of reduction of ammonia loading at wastewater plants. Excess phosphorus and nitrates can lead to algae blooms, resulting in eutrophication in lakes and adversely affecting water supplies.

A review of water quality data for rivers in the Passaic River Basin for the period of 1992 through 2000 reveals an increase in concentrations of certain pollutants at several stream monitoring stations. Increases are noted for BOD_5, fecal coliform, chloride, sodium and other solids loadings. These pollutants, as well as a significant portion of the ammonia loading in the rivers, are attributed to non-point sources (NPS) of pollutants. Non-point sources are those sources which discharge pollutants but are not identifiable as a specific single source location. The NPS pollutants are usually associated with developed areas, but can also come from farms. Residential practices such as over fertilization of lawns, washing an automobile in a driveway, failure to pick up pet waste, feeding geese in the local park, or dumping unwanted materials into a storm drain or onto the ground can all result in non-point source pollutants entering our waterways as they are carried by stormwater runoff. These pollutants have an effect on the environment and on our supply of safe drinking water.

Proper planning and implementation of actions to reduce the pollutants in our waterways must involve not only point source discharges, as has been done for the last 30 years, but must also take into consideration the:

- Effects of land use changes,
- Need to clean up contaminated areas,
- Need to preserve environmentally sensitive areas
- Need to educate the public to avoid contributing to the pollution of lakes and rivers,
- Need to change our habits to protect our environment.

EPA has promulgated Phase I and Phase II Stormwater Management Rules to address NPS pollution. The Phase I rules applied to municipalities with separate storm sewer systems (not CSOs) and with a population exceeding 100,000. Phase I affected few areas in New Jersey, while the Phase II rules will apply to communities with a population exceeding 10,000. The rules include an educational component, identification of illegal discharges, and controls for site disturbance. For many years, New Jersey has had a program requiring installation of soil erosion and sediment control measures in association with land disturbance of more than 5,000 square feet. New Jersey has also advocated adoption of stormwater management ordinances addressing the quantity and quality of runoff from new construction. The *Residential Site Improvement Standards* adopted in 1997 unified stormwater management regulations applicable to new residential development in the State, but do not apply to non-residential development, nor to the impacts of existing development.

Planning must be done on an integrated approach, with consideration of the often competing interests of the ecological system, water supply and wastewater assimilation, and the interests of many stakeholders in the region. The combined effects of point sources and non-point sources of pollutants must be considered, goals identified, and management strategies developed to protect and improve the water resources of the region on an integrated basis. Attacking the problems individually may result in improvement in one area to the detriment of another. Analysis of the problems on an integrated basis will result in the development of a comprehensive management plan addressing the multiple needs of the area and of the stakeholders.

The Passaic River Basin includes an area of approximately 936 square miles in New Jersey and New York. The Passaic Basin in New Jersey has been divided into three (3) watershed management planning areas (WMAs), identified as WMAs 3, 4 and 6. WMA 3 includes the area tributary to the mouth of the Pompton River near Two Bridges.

WMA 4 includes the area tributary to the Passaic River from Two Bridges to the Newark Bay, and WMA 6 includes the area tributary to the Passaic River upstream of Two Bridges.

B. CHARACTERIZATION OF WMA 3

1. Drainage Areas – Major Subwatersheds

Watershed Management Area 3 (WMA 3) covers 238 square miles in New Jersey, and includes four major subwatersheds: the Wanaque, Pequannock, Ramapo and Pompton River watersheds. The drainage areas of the Wanaque and Ramapo Rivers extend northerly into New York and include an additional area of approximately 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.

Table B.1.1
Major Subwatersheds of WMA 3

Major Subwatershed	Area in NJ – Sq. Mi.	Area in NY–Sq. Mi.	Total Sq. Mi.
Wanaque	79	36	115
Pequannock	87	-	87
Ramapo	48	104	152
Pompton	24	-	24
Total	238	140	378

The Passaic River in WMA 6, upstream of the Pompton River confluence, has a drainage area of 361 square miles. Below the Pompton confluence, the Passaic River, with a combined drainage area of 739 square miles, enters WMA 4.

2. Topography, Geology, Soils, and Climate

Approximately 80 percent of WMA 3 is in the Highlands Physiographic Province. The remainder, in the southeastern portion of the WMA, is in the Newark Basin subprovince of the Piedmont Physiographic Province. The Highlands extends far beyond the New Jersey – New York area. 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 50 percent 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 elevation 1,350 feet.

The Newark Basin is primarily lowlands formed on inclined siltstone, shale, and sandstone strata, interrupted in places by long traprock 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 elevation 200 and 400 feet, and a few ridges reaching elevation 680 feet.

During the Pleistocene Epoch of the Quaternary Period, the advance of ice sheets caused the erosion of hills and the deposition of various stratified 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. As the ice sheet advanced across the Newark Basin portion of WMA 3, it formed several lakes, which ranged in size and longevity. The largest and most prominent in northern New Jersey was Glacial Lake Passaic. Remnants extend from Kinnelon and Wayne Township in the north to Bernards Township in the south (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 meltwater from retreating glaciers form prolific aquifers along the Ramapo River. Due to their high permeability these surficial deposits are vulnerable to contamination.

Soils in WMA 3 appear to be 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, while infiltration rates of B and A soils are progressively higher.

The climate of WMA 3 is classified as continental climate since the prevailing winds come from the west, over the continent. Prevailing winds are from the northwest from October to April and from southwest during the rest of the year. Average winter temperatures are in the high twenties and low thirties Fahrenheit. Midsummer weather is characterized by high humidity and frequent thunderstorms. Average annual rainfall varies from approximately 46 inches to 54 inches across WMA 3.

3. Land Use and Habitat

As of 1995, more than 58% of WMA 3 was forest, and about 16% was water and wetlands. Approximately 24% was classified as urban area. Comparison of land use data for 1986 and 1995 reveals that during that 10-year time span there was a loss of approximately 4.5 square miles of forest area and approximately 0.8 square mile of wetland, and an increase of approximately 4.5 square miles of urban area and one (1) square mile of water area.

WMA 3 remains one of the most pristine areas of the Passaic River Watershed. As such it provided extensive habitat for wildlife and fish communities in the region, and provides recreational opportunities for the population in WMA 3 and surrounding areas. It also serves as an excellent source of water for a large part of the population in northeast New Jersey.

4. Water Supply

With its high percentage of forest lands, steep slopes and predominance of Hydrologic Soil Group C soils, WMA 3 serves as an excellent source of water for the population of northeast New Jersey. Between 1990 and 2000, an average of approximately 89 billion gallons of water per year was withdrawn from watersheds in WMA 3 for water supply purposes in New Jersey. This estimate includes the total of both surface and groundwater diversions used within WMA 3 and transferred out of the basin. Additional surface and groundwater diversions are made in the New York portions of the watersheds.

Approximately 92% of the withdrawals in New Jersey was from surface water sources and 8% was from groundwater sources. The surface water withdrawals in WMA 3 are primarily used for potable supply outside of WMA 3.

The published safe yield of the combined Wanaque North Project and Wanaque South Project is 173 MGD. Of this amount, 133.5 MGD is allotted to contracting municipalities that receive finished water from NJDWSC. The remaining safe yield of 39.5 MGD is allotted to United Water NJ, is delivered as raw water, and constitutes an interbasin transfer from WMA 3 to WMA 5. Review of diversion records for 1990 through 1999 indicates that approximately 120 MGD of the aforementioned 133.5 MGD available from NJDWSC as finished water has actually been utilized on an annual average basis.

The safe yield issue is to be addressed through the NJ Statewide Water Supply Planning process. The Scope of Work of the "New Jersey Statewide Water Supply Plan, 2002 Revision" includes "analysis of the need to recalculate the safe yield of existing systems, due to changes in climate, differences in water accounting and management assumptions, and increases in consumptive water uses."

The NJSWSP recommended consideration of capital projects such as new interconnections within the region and with adjacent planning areas (such as the Raritan Basin), sharing a Hudson River project with New York City (if initiated), increasing the size of existing storage facilities, constructing new storage facilities (including aquifer storage and recovery (ASR) systems in buried valley aquifers), and direct and indirect wastewater re-use. Among the management initiatives to be evaluated are programs aimed at modifying demand and improving operations, such as water conservation, improved drought rule curves, depletive use reduction programs, and improved coordination among presently interconnected purveyors. In addition, it was recommended that a detailed simulation model be developed of the Passaic and Hackensack Rivers that evaluates the region's storage facilities' capability to withstand various drought conditions and changing demand scenarios. The model would include a means for assessing groundwater diversions and wastewater flows in the region in order to properly model available water resources.

Finished water has been transferred from the Raritan to the Passaic Basin for drought relief for NJDWSC, and in turn for NJAWC, Jersey City, PVWC and United Water NJ.

The groundwater characterization and assessment indicates a variety of groundwater sources that vary from low producing to prolific. Comparing current and projected groundwater withdrawals to estimated groundwater availability, there is evidence to suggest available groundwater supply for future uses. However, the available groundwater may not be in the same location as the wells that are suffering from dropping static levels. The most prolific groundwater 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. This is an area that requires significantly more investigation and improved methods of estimating the interrelationship between groundwater and surface water availability.

5. Population

Based upon a comparison of US Census data from 1990 and 2000, the population of the watersheds of WMA 3 (NJ and NY) has increased by approximately 9 percent over that 10-year period.

Table 1.20.1
Population of Watershed Management Area 3

	1990 Census	2000 Census	Change	% Change
New Jersey	228,194	244,058	15,864	6.95
New York	67,809	79,161	11,352	16.74
Total	296,003	323,219	27,216	9.19

Source: US Census Bureau

Most of the surface water supplied from WMA 3 is used outside of the watershed in Bergen, Passaic, and Essex Counties. The following population forecasts from the New Jersey Division of Labor were available:

Table 1.16.14
Population Forecast (New Jersey Department of Labor)

County	Est. 1998	2005	2008	2010	2015
Bergen	875,200	905,600	918,800	928,800	953,500
Passaic	494,900	498,600	501,100	503,800	505,300
Essex	766,400	778,400	783,600	787,000	800,600
Total	2,136,500	2,182,600	2,203,500	2219600	2,259,400

This indicates a trend for increase in population of 5.7 percent by the Year 2015. These counties are dependent upon surface supply from PVWC, NJDWSC, and the City of Newark. The potential for population growth and increased demands indicates that these stakeholders must work together with the State of New Jersey to develop proactive plans for providing water in the future.

6. Watershed Stressors

The waterways of WMA 3 receive pollutants from both point and non-point sources. The point sources in WMA 3 mainly consist of discharges from domestic wastewater treatment plants. Non-point sources are numerous and include sources such as stormwater runoff from developed areas, fertilizers and pesticides from golf courses and lawn areas, leaking sewer lines and underground storage tanks, surface runoff and groundwater seepage from contaminated soil areas, soil erosion and sediment. WMA 3 has several identified contaminated sites, including 12 listed Superfund sites.

There are 41 permitted domestic wastewater treatment facilities that discharge to the surface waters in the watersheds of WMA 3, with a total permitted average design discharge of approximately 17.6 MGD. Of these facilities, 23 are in New Jersey and 18 are in New York. Only nine (9) facilities have a design capacity of 0.1 MGD or more, and the total design capacity of these nine is 16.6 MGD. Of these nine, the four (4) located in New York have a combined design capacity of 6.3 MGD, with most of the capacity in the upper reaches of the Ramapo River watershed. The five (5) in New Jersey have a combined design capacity of 10.3 MGD, with most of the capacity in the lower reaches of the Wanaque, Ramapo and Pompton Rivers.

The only facilities with design capacity exceeding 2 MGD are the Orange County Sewer District #1 facility, with a capacity of 4 MGD, located at Harriman, NY in the upper reaches of the Ramapo River watershed, and the Two Bridges Sewerage Authority facility, with a design capacity of 7.5 MGD, located in Lincoln Park, NJ in the most downstream reach of the Pompton River. Thus these two larger facilities account for approximately 65% of the domestic wastewater design capacity in the watersheds of WMA 3. The Two Bridges facility provides treatment by activated sludge process followed by sand filters. The Orange County facility provides treatment by activated sludge for 2 MGD and oxidation ditches for 2 MGD, each followed by rapid sand filters.

7. Surface Water Quality Impairments

The NJDEP has recommended delisting certain parameters previously listed on the 1998 303(d) List for waterways in WMA 3. The delisted parameters mostly are heavy metals. NJDEP has also proposed listing some additional parameters. The resultant list of parameters not attaining standards at four primary sampling stations in WMA 3, as indicated in NJDEP's 2002 Integrated List, is presented in the Table 4.7.3, which is repeated below.

A more detailed list of waterways and parameters not attaining standards, based on reported data from numerous monitoring points on streams and at lakes in WMA 3, is presented in Table 4.7.4 in Section 4 of this report. The non-attainment parameters vary with location, but non-attainment for temperature (T), fecal coliforms (FC), recreation, or aquatic life appears for several sites. Non-attainment for temperature is identified primarily for reaches of the Pequannock River based upon data furnished to NJDEP by the Pequannock River Coalition. Data revealing other non-attainments was furnished by several governmental agencies, including USGS, NJDEP, the Passaic County Health Department, and Pequannock Township.

(Repeated) Table 4.7.3 2002 Integrated List for Primary Stations vs. 1998 303(d) List*

Waterway	Site ID	Parameters Non- Attaining Standards (2002)	Previously on 1998 303(d) List	Parameters Delisted
Pequannock River, Macopin Intake Dam	01382500	FC, T, Pb	TP, pH, T, Cu, Pb	TP, pH, Cu,
Pompton River at Packenack Lake	01388600	FC, Pb	As, Cd, Cu, Fe, Pb, Hg	As, Cd, Cu, Fe, Hg
Ramapo River at Mahwah	01387500	TP, FC	TP, FC, Na, As, Cr, Pb, Hg	Na, As, Cr, Pb, Hg
Wanaque River at Wanaque	01387000	FC, TP, DO	FC, TP, DO	-

* Source: NJDEP website

C. ASSESSMENT OF WATER QUALITY FOR WMA 3

1. Trends

1. Review of stream water quality data reveals that a distinct water quality improvement occurred during the period from the mid-1980s through the early-1990s. Results from the short-term trend analysis (1992-2000) were markedly different from the result of the long-term assessment. Apparently, most of the significant beneficial water quality trends were achieved by 1992 and, in the period since then through 2000, a more stable water quality regime was present. Outside of increasing trends related to chlorides, there has not been a significant change in water quality.

Statistical tests were conducted to determine if significant differences could be attributed to seasonal effects. Various seasonal effects can include: an increase in streamflows during the winter; an increase in biological activity during the summer, and the relaxation of seasonal effluent limitations during the winter. For discharge-related parameters, the expected difference is that higher concentrations should be present during the summer due to reduced in-stream dilution and a relatively constant point source discharge load.

As expected, dissolved oxygen and streamflows are significantly higher in the winter at all stations – this is a typical seasonal pattern.

Many discharge-related parameters are expected to have significantly higher concentrations in the summer. These parameters can include TKN, total phosphorus, and dissolved phosphorus. This tendency holds true for most parameters at station 01387500 (Ramapo River at Mahwah). Given that mean summer flows are only 30%-50% of those in winter, this finding is readily understandable.

For one station 01387000 (Wanaque River at Wanaque), significantly higher winter concentrations are present for BOD5, ammonia, total nitrogen, and total phosphorus. The higher winter phosphorus concentration may propagate downstream where it can be detected at station 01388600 (Pompton River at Packanack Lake).

Higher summer pH levels are present at two stations – a finding that may be an indication of algal activity. At one station 01388000 (Ramapo River at Pompton Lakes), this difference is extreme with a mean summer pH of about 8.4 and a mean winter pH of about 7.6. By contrast, the nearest downstream station 01388600 (Pompton River at Packanack Lake) has a mean summer pH of about 7.8 and a mean winter pH of about 7.6.

Higher winter concentrations of chlorides and sodium at one station (01388600-Pompton River at Packanack Lake) may be caused by road de-icing operations.

2. Loading Assessment

A loading assessment was completed to provide an indication of the relative loading in WMA 3 from point and non-point sources for parameters of concern. The analysis was based on four years (1997-2000) of data for stream flow and water quality, and discharge data for permitted domestic wastewater treatment plants in New Jersey and New York. The simulation was conducted based on a mass balance approach, which considered the effects of dilution by stream flow on loadings from the wastewater facilities, and estimated the magnitude of the non-point source load based on calibration to the observed in-stream concentration data.

The loading assessment was conducted for those parameters with a significant point source and stream water quality database. A simplified assessment was conducted for total suspended solids (TSS) and fecal coliforms, which suggested that, typically, there is less than 1% of the TSS loading and less than 0.1% of the fecal coliforms loading originating from point sources. Thus these two parameters are considered to be non-point source dominated. Lack of data did not allow for such an assessment of chlorides and sodium, which tend to be associated with both point sources and non-point sources, such as road salting in winter.

The four parameters included in the detailed loading assessment are:

- Biochemical oxygen demand (BOD_5)
- Ammonia nitrogen (NH_3)
- Total phosphorus (TP)
- Nitrate nitrogen (NO_3)

A more detailed assessment was performed for primary stations that may receive significant point source impacts, namely the Ramapo River at Mahwah, Ramapo River at Pompton Lakes, and Pompton River at Packanack Lake. The point source discharges upstream of the primary stations on the Pequannock River and on the Wanaque River are small, and therefore most of the pollutant loading in the watersheds is attributed to non-point sources.

For the detailed loading assessment, a simulation of concentrations for the period 1997 – 2000 was conducted based on the assumption that the streams were effluent dominated. This procedure was able to describe a fair degree of the trends and variability in the observed data. Results from this loading assessment are displayed in Plates 5.16.1 – 5.16-6 (see Section 5.16 of this report) as plots of projected concentration versus streamflow and projected concentration versus time. The projected non-point load and the percentage of point source loads are presented in Tables 5.16.1 and 5.16.2, which are repeated below. Observations and limitations relevant to the approach are presented in Section 5.16 of this report.

(Repeated) Table 5.16.1 Projected Non-Point Load (Daily Mean) (1997 to 2000)

Station	Location	Cumulative Non-Point Load (lbs/day)			
		BOD_5	NH_3	TP	NO_3
01387500	Ramapo R. @ Mahwah	1598	44	33	252
01388000	Ramapo R. @ Pompton Lake	5585	56	42	321
01388600	Pompton R. @ Packanack	10669	107	80	613
01389000*	Pompton R. @ Two Bridges	10907	109	82	627

* a simulation was conducted for this site as part of the endpoint analysis

(Repeated) Table 5.16.2 Percent Point Source Load Contribution (Daily Mean) (1997-2000)

Station	Location	Percentage Point Source Load			
		BOD_5	NH_3	TP	NO_3
01387500	Ramapo R. @ Mahwah	9%	56%	60%	60%
01388000	Ramapo R. @ Pompton Lake	3%	50%	54%	55%
01388600	Pompton R. @ Packanack	3%	40%	41%	52%
01389000	Pompton R. @ Two Bridges	4%	58%	71%	67%

As indicated above, a substantial portion of the total loading entering WMA 3 from New York via the Ramapo River is attributed to point sources for ammonia, total phosphorus and nitrates. The estimated percentage contribution of total loading to WMA 3 watersheds from point vs. non-point sources for the indicated parameters is summarized below.

WMA 3 Watersheds
Percentages of Total Loading (1997-2000)

Source	BOD_5	NH_3	TP	NO_3
Point	4%	58%	71%	67%
Non-point	96%	42%	29%	33%

The above estimated loading percentages should not be viewed in terms of their absolute numbers, since they are based on a preliminary (screening-level) analysis. However, they do serve as an indication of the relative contributions from point and non-point pollution sources in WMA 3, and can provide some guidance as to where efforts should be concentrated to reduce loadings of those parameters exceeding standards.

Initial results for station 01387500 – Ramapo River at Mahwah tend to overpredict nitrate and phosphorus concentrations during summer conditions. Data indicates that there is less loading in the stream at the monitoring point than is present in the upstream effluent discharges (which are located in New York). As low flows at this site can approach the magnitude of the upstream discharge and the upstream reach is known to be affected by groundwater withdrawals, it is speculated that a considerable part of the upstream load may be lost to groundwater. For the purposes of this study, it was established that about 50% of the upstream load does not enter WMA 3. Based on this input, downstream, stations provided an acceptable result. This finding should be considered and further explored in connection with future detailed analyses, such as in a TMDL analysis for WMA 3.

Findings suggest that much of the Ramapo and Pompton Rivers are effluent dominated with regard to total nitrogen, nitrate nitrogen, total phosphorus, and dissolved phosphorus. While a detailed analysis was not possible for total dissolved solids, chlorides, and sodium, preliminary results suggest both point source and non-point source influences. Non-point sources are likely the major contributors to in-stream BOD_5, TSS, and fecal coliform loads. The above percentages indicate that point sources and non-point sources each contribute a significant percentage of the ammonia nitrogen loading. However, other processes**,** such as the in-stream decay of ammonia, also have an important effect on in-stream concentrations and transported loads. While this effect was factored into this first-order analysis, its presence adds an additional degree of uncertainty to this result. Similar in-stream processes can also affect the concentrations of other parameters, such as BOD5.

Since the point source discharges in the Pequannock River watershed and in the Wanaque River watershed upstream of Wanaque Reservoir are small, non-point sources are expected to be the major contributors to in-stream pollutant loadings in those watersheds**.**

3. Data Gaps

Due to the large volume of data being collected by multiple agencies, the major waterways can be fairly well addressed with regard to an assessment of status. Additional data collection is desirable with regard to sensitive waterbodies, Westbrook (trout stream), Ringwood Creek out of Sterling Forest, potable water reservoirs and intakes**,** lakes and lower-order streams. A central repository should be established for all pertinent data.

With regard to specific parameters, it was noted that there was a lack of consistent data with respect to Total Suspended Solids and chlorophyll-a due to an intermittent test schedule at most stations. These two parameters should be sampled on a regular (preferably monthly) basis.

The existing monitoring network in New Jersey appears to adequately represent the water quality in the major streams in the watershed. However, sampling should be coordinated between the different agencies in order to develop a more consistent and comprehensive database. In addition a more comprehensive set of nutrient data should be collected within a) wastewater treatment plants and b) at about 2 in-stream stations located in New York State.

A more comprehensive set of nutrient data should be collected at wastewater treatment plants. It would also be desirable to acquire additional effluent data related to certain other parameters such as TDS, chlorides, and sodium.

The procedures utilized are highly dependent of accurate flow data – particularly under low flow conditions. Data from some streamflow monitoring sites suggests the presence of seasonal hydrologic sinks during which observed streamflows could be less than observed upstream inputs. Additional work is need to verify and quantify the presence of these sinks which may be due to evapotranspiration from adjacent wetland areas or groundwater withdrawals for water supply purposes.

Neither the available data nor the preliminary analysis provides much insight into the level of biological productivity within the subject streams. Studies of in-stream productivity often require the use of both long-term and short-term (intensive) data collection to evaluate conditions. Additional work in this area will be needed if such issues need to be addressed.

The current study focused on conventional pollutants. Non-conventional ones were not included due to limited availability of historic data and/or questions related to its reliability. However, the WMA's status with regard to such parameters can be a source of concern. Future sampling may be conducted to address these concerns – all such sampling should make use of the current "clean method" techniques.

Many of the GIS data sources accessed in preparation of this report are periodically correcting, updating and expanding their databases. Therefore there will be a need to periodically update the GIS database prepared for this study. There is significantly more GIS data available for the New Jersey portions of the WMA 3 watersheds than there is for the New York portions. Approximately 140 square miles, about 37%, of the total watershed area is in New York. Future land use changes in New York can have a profound affect on water resources in WMA 3 in New Jersey. Therefore it would be appropriate to make arrangements for sharing of pertinent data with New York agencies.

D. KEY ISSUES

WMA 3 contains very large contiguous areas of pristine lands that provide habitat for wildlife and fish communities, provide recreational opportunities, and provide a high quality of surface water runoff to reservoirs and water supply intakes in the watersheds. Preservation of the quality of water in WMA 3 is essential to continued support of natural and human communities dependent upon this water supply.

Some of the key issues regarding surface water quality in WMA 3 are described below.

1. Existing water quality impairments (per NJDEP 2002 Integrated List)
    a. Pequannock River at Macopin intake – for fecal coliforms, temperature and lead concentrations
    b. Pompton River at Packanack Lake – for fecal coliforms and lead concentrations
    c. Ramapo River at Mahwah – for total phosphorus and fecal coliforms
    d. Wanaque River at Wanaque – for fecal coliforms, total phosphorus, and low DO
    e. Approximately 25 monitoring locations throughout WMA 3 – for non-attainment for fecal coliforms, temperature, aquatic life or recreation.

2. Water quality parameters not listed by NJDEP for WMA 3
    a. Upper Greenwood Lake – nitrates (while the lake is located outside of WMA 3, there is a provision for diversion of water from the lake into WMA3 if needed).
    b. Greenwood Lake – herbicides and pesticides
    c. Post Brook near Wanaque Reservoir – sodium
    d. Ramapo River at Pompton Lakes – pH
    e. Pompton River at Jackson Avenue P.S. – ammonia nitrogen
    f. Passaic River downstream of WMA 4 – nitrates and total phosphorus

3. Water Quality Assessment Findings (with respect to conventional parameters – DO, BOD5, pH, total phosphorus, dissolved phosphorus, ammonia, nitrate, total nitrogen, TKN, fecal coliforms, total dissolved solids, total suspended solids, chlorides and sodium):
    a. Status Assessment
        i. For most parameters, highest concentrations were present in the upper Ramapo River (near Mahwah) and the lowermost portion of the Pompton River (at Two Bridges)
        ii. Somewhat lower, but elevated, concentrations in the reaches of the Ramapo and Pompton Rivers between Mahwah and Two Bridges.
        iii. Distinctly higher water quality found for the Wanaque and Pequannock Rivers, but with more elevated concentrations in downstream reachs.
        iv. Fecal coliform exceedances common throughout WMA 3 (at 15 of 18 water quality data stations), and median values exceeded criteria near Wanaque-Pequannock River confluence, in the upper Ramapo River (near Mahwah) and within the Pompton River.
        v. Total phosphorus exceedances at 14 of 21 stations, and median values exceed criterion at the Ramapo near Mahwah, and the Pompton River at Two Bridges.
    b. Trend Analysis
        i. Long-term reductions in the 1980s for ammonia, TKN, total phosphorus and dissolved phosphorus concentrations, accompanied by increased (often doubling) concentrations for nitrates, primarily along the Ramapo and Pompton Rivers.
        ii. Steady increasing trend at all primary stations for chloride, sodium and TDS concentrations. Concentrations significantly higher in winter (possible impact from road de-icing).
        iii. Since early 1992 little change in overall water quality except for continuation in increase in chlorides.
    c. Loadings Assessment
        i. Three largest domestic wastewater dischargers (Two Bridges facility in NJ, Orange County Sewer District facility in Harriman NY, and Suffern NY facility) together discharge 10.6 MGD, 81% of the total wastewater discharge. These facilities affect the Ramapo and Pompton Rivers.
        ii. The discharge load within New York clearly affects the water quality of the Ramapo River. However, approximately 50% of the load appears to be mitigated before entering NJ, possibly due to water supply withdrawals in NY.
        iii. Pollutant loadings in the Pequannock and Wanaque Rivers are primarily attributed to non-point sources.
        iv. Analysis of wastewater effluent data and stream water quality data for 1997-2000 suggests the following preliminary breakdown between point source and non-point source contributions:

1. Point sources contribute between 40% and 75% of the ammonia, nitrate, and total phosphorus.
2. Seasonal assessment indicates that point source contribution could be 10%-20% higher during a critical summer low flow period.
3. Point sources contribute less than 10% of BOD5 loads – non-point sources are dominant for this parameter.
4. Fecal coliform and TSS loads are attributed almost entirely to non-point sources.
5. Existing data not sufficient to estimate relative contributions for TDS, chlorides and sodium. Seasonal (winter) increases point towards road de-icing, but there may also be point source contributions.

4. Land use and preservation
    a. Land use data from 1995 indicates that WMA 3 remains about 58% forested. The combined area of forest, water and wetlands is approximately 75% of the total area of WMA 3. Changes in land use can have a dramatic effect on the quality and quantity of water in this area, due to loss of pristine areas and increases in non-point and point sources of pollution associated with development.
    b. Large areas in WMA 3 have been preserved as State forests and State parks, County parks, wildlife management area, Boy Scout camps and watershed lands preserved near the major reservoirs. The City of Newark owns most of the land tributary to its reservoirs in the Pequannock River watershed. Federal, state and private funding has aided in preserving much of the Highlands, including Sterling Forest, which contains much of the headwaters of the Wanaque River watershed in New York. Efforts to preserve additional Highlands areas in the Pequannock and the Ramapo River watersheds are continuing. There is the risk that some of these lands may be sold in the future, particularly those not publicly owned.

5. Attraction of large projects to large land areas
    a. Since there are large tracts of land, and surrounding areas may be undeveloped or preserved, there is an attraction by large projects that cannot be located near highly developed areas.

6. Contaminated groundwater sites
    a. There is a concern that the contaminated groundwater may migrate to the streams (e.g. contaminated wells in Pompton Lakes, attributed to industrial site pollution).

7. Lake and reservoir management
    a. Reduce nutrient loading
    b. Reduce use of chemicals for weed control
    c. Temperature and DO conditions, particularly in summer months

   d. Maintain adequate flows and water temperatures downstream by proper control of releases (and the associated issue of temperatures and low flows in streams)
   e. Sediment control (including Greenwood Lake)
   f. Cleanup of contaminated lake sediments (Pompton Lake)
   g. High color and turbidity
   h. Presence of new exotic species of algae
   i. Formation of hazardous algae blooms (HABs)
   j. Potential presence of algae toxins
   k. Potential for formation of TTHMs
   l. Failure at diversion to maintain SWQS results in loss of available supply

8. Cleanup of contaminated sites
   a. Superfund sites (approximately 9 listed within WMA 3 and 3 in upstream areas in New York)
   b. Other contaminated sites (numerous listings in WMA 3)

9. Need for coordinate planning with agencies in New York with jurisdiction over the tributary areas in the Ramapo and Wanaque watersheds.
   a. Approximately 140 square miles in New York in watersheds tributary to WMA 3.
   b. Approximately 18 (see list below) domestic wastewater treatment facilities in New York in watersheds tributary to WMA 3.
   c. Two significant sized wastewater facilities (Orange County SD#1 Harriman STP and Suffern STP) in the Ramapo River watershed, with a combined design capacity of 5.8 MGD, contribute a significant loading of phosphorus, nitrates and ammonia to the Ramapo and Pompton Rivers.
   d. Three small facilities (Kings College, Sterling Lake and Blue Lake Sewage facilities), with a combined design capacity of 0.25 MGD, in the Wanaque River watershed.
   e. Relatively high yielding surficial aquifers extend along the Ramapo River from New Jersey into New York (the Ramapo is designated as a sole source aquifer). Withdrawals from these aquifers in New York and in New Jersey can affect surface flows in the Ramapo River, particularly during low flow and drought conditions.

List for 9b above- Domestic wastewater treatment facilities in New York area tributary to WMA 3, based on New York SPDES dischargers list furnished by NYDEC:

Rockland County:

Suffern (V) at Suffern
Sloatsburg-Ramapo at Ramapo (NYS Thruway)
Sloatsville WWTP at Sloatsville
Ramapo Tandem at Ramapo (NYS Thruway)

Orange County:

Kings College at Warwick
Orange County at Harriman
South County Sewer, Sterling Lake at Warwick
South County Sewer, Sterling Forest at Tuxedo
South County Sewer, Blue Lake Sewage at Warwick
South County Sewer, Indian Kill Sewage at Tuxedo
Tuxedo Park (V) at Tuxedo
Tuxedo Hamlet at Tuxedo
Tuxedo Mountain at Tuxedo
South County Sewer, New York at Tuxedo
St Patrick's at Harriman
Kiryas Joel (V) at Kiryas
Cromwell Hills Condo at Monroe

a. NYS Thruway at Harriman

E. MANAGEMENT APPROACHES

Watershed Management Area 3 Area-Specific Management Options

Note: The following WMA-Specific Options are intended to illustrate the potential implementation of goals and approaches discussed in Section 8, Parts 1 and 2, based on water quality findings. This is not intended as a "Management Plan", which needs to be developed during project phases subsequent to this "characterization phase".

Observations: re: Discharges – Pompton and Ramapo Rivers

The results of the loading assessment suggest that much of the Ramapo and Pompton Rivers are effluent dominated with regard to total nitrogen, nitrate nitrogen, total phosphorus, and dissolved phosphorus. Point source discharges contribute approximately 58% of the ammonia-N, 71% of TP, and 67% nitrate loads. Point source discharges become even more problematic during lower flow conditions during the summer growing season.

A distinct water quality improvement occurred during the period from the mid-1980's through the early-1990's. Improvements were detected for ammonia-N (which also reduces in-stream nitrogenous oxygen demand), TKN, BOD, and total phosphorus. The decreasing ammonia-N was accompanied by an increasing trend in nitrate nitrogen, suggesting that nitrification activity was shifted from the receiving stream to a treatment process. In-situ continuous data-logging of dissolved oxygen, pH, and conductivity, should be performed through an annual cycle to verify that adequate dissolved oxygen persists at all times (including the low-flow dark cycles).

Considering that less than 3% of the water load (i.e. the wastewater treatment plant effluent portion) contributes more than 58% of the ammonia, TP, and Nitrate loads to the WMA 3 River Resources (especially in the Ramapo and Pompton Rivers), one management option that should be considered is improved wastewater treatment. An ambitious water conservation program is also suggested for consideration. The loadings from various wastewater treatment plant facilities vary widely. Dissolved Inorganic Nitrogen (DIN) / MGD varies from 122 to 277 lb DIN/MGD. Discharged phosphorus varies from 0.18 lb TP/MGD to 33 lb TP/MGD. The N:P ratio at discharges is very variable, from about 4.0 to over 680 (lb DIN/MGD : lb TP/MGD). "Water quality goals" (and/or surface water quality standards) should be established that adequately protect specific resources (for example stream order reaches). Major wastewater treatment plants should be designated highest priority for upgrading for significant improvement in water quality of river flow. All wastewater treatment plant discharges should collectively be improved to ensure compliance with water quality standards and goals during all flow regimes of receiving waters (especially lower flows). Phosphorus discharge reduction should be accomplished while maintaining a DIN:TP ratio well above 7.2 (mg:mg), maintaining nitrate concentrations below an achievable concentration (e.g. 2-4 mg/L), and maintaining dissolved oxygen concentrations above the water quality standard/goal at all times. Some treatment processes and discharge quantities may need to be seasonal or flow-stage based.

Significant improvement in riverine ecosystems and water quality, and compliance with NJ SWQS, will only be accomplished by improvements in discharges to receiving waters. The Two Bridges Sewerage Authority discharge is located immediately upstream of the Wanaque South Pump Station, which diverts substantial flow volumes from the Lower Pompton River to Wanaque Reservoir. The Two Bridges Sewerage Authority discharge contributes 5 MGD of flow (70% of all NJ permitted surface water discharges in WMA 3), 115 lb TSS/day (60%), 113 lb BOD/day (49%), 84 lb NH_3 / day (88%), 142 lb TP/day (96%), and 609 lb NO_3 / day (68%). To reduce nutrient load from the discharge of the Two Bridges wastewater treatment plant should be a top priority for water quality objectives of the Pompton River. In addition, alternatives which reduce the direct influence of the upstream Two Bridges wastewater discharge on the Wanaque South Intake should be fully evaluated, including in-stream current deflector structures and low-head deflector weirs.

Non-Point Sources

The loading assessment suggests that Flow, TSS, and BOD loading are strongly dominated by non-point loading sources. A comprehensive Non-Point Source program should be established. "Local disposal" and "first flush" techniques should be emphasized.

Pequannock River: The Pequannock River is a major riverine ecosystem that has not experienced serious impacts related to surface water discharges through most of its length. It is a particularly important river ecosystem to preserve. Minimum flow standards should be firmly established and maintained to its confluence with the Pompton River. Minimum passing flows, consistent with existing standards (MA1CD10, MA7CD10, MA30CD5), should be required even during times of low flow. Low flow orifices or other flow-passing devices should be built into impounding structures to ensure minimum downstream flow. Several reservoir impoundments occur along the

Pequannock River; surface outflow effects temperature regime in downstream river reaches. The feasibility and potential effects (benefits and impacts) of automated depth-selective outflow routing should be examined for the impoundments. Additionally, an aggressive program to preserve (and restore) the riparian corridor habitats (including proximal canopy) should be developed (purchase, purchase of development rights, and other methods of preserving riparian land).

Pompton Lakes: A research study should be performed to evaluate seasonal and flow-stage loading, interflow characteristics during stratification, and biological transformations of nitrogen compounds as they influence the DIN:TP ratio and phytoplankton species assemblage. These may be important “forcing factors” for water quality in the Pompton Lake Ecosystem, in water supply storage reservoirs receiving diverted water, and in the downstream reaches of the Pompton and Passaic Rivers (which tend to “behave” like shallow lakes during low flow summer periods).

Wanaque Reservoir: Diverted water should meet NJ water quality standards at the point of entry to the reservoir (< 0.050 mg/L TP). In order to maintain adequate storage reserve to meet the demand, significant water volumes need to be diverted to Wanaque Reservoir. Diversion is most active during the “higher flow months”, yet potential impacts (especially eutrophication effects, Cyanobacteria bloom potential) can occur during the subsequent growing season. Pre-treatment of withdrawn water, prior to discharge to Wanaque Reservoir, is an alternative approach in addition to accomplishing compliance with water quality standards in the diversion source waters. It is especially important to maintain a high DIN:TP ratio in diverted waters (to avoid stimulation of N-fixing Cyanobacteria). Additional reservoir-specific approaches should also be evaluated.

Glacial Lake Passaic (WMA 3, 4, and 6): Approximately 15,000 to 25,000 years ago, the Wisconsin Glacier reached its southern extreme and began to withdraw. The meltwater created a great lake approximately 200 ft deep, 30 miles long and 10 miles wide, extending from the area now known as the Great Swamp to the Little Falls Gap and the Great Falls in Patterson. Glacial Lake Passaic resulted in the deposition of impermeable clays and silts over sand and gravel aquifers. Today, extensive wetland resource areas exist where the ancient Glacial Lake Passaic once was, including the Great Swamp, Black Meadows, Great Piece Meadows, Lee Meadows, Troy Meadows, and Hatfield Swamp. Preservation of these wetland resources, and associated upland habitat areas is very important. Impact potential includes changes in peak runoff and increased flooding of wetland areas due to increased development and impervious areas.

Stormwater management is essential to maintain historic peak flow, baseflow conditions, and prevent increased inundation frequency or intensity. Loading of sediments and nutrients are also of concern in the “Glacial Lake Passaic Region” as increased loading would cause reduced water storage capacity, excessive growth of algae and plants, and changes in floristic composition (altering habitat structure). During the development of a “Watershed Management Plan”, subsequent to this characterization phase study, the “Glacial Passaic Lake Region” from the Great Swamp to Great Falls in Patterson, should be closely examined to establish adequate protective measures for extensive wetland resource areas and river corridors. Some of the important potential impacts, and management options for resource protection, include:

- *Increased Flooding* (frequency and intensity) – Stormwater management to prevent increased peak flow and to maintain adequate baseflow; consider managed turf areas (lawns, golf courses, etc.) as impervious areas during stormwater system design.
- *Aquifer Contamination* – preserve critical recharge areas and river riparian corridors by land acquisition, purchase of development rights, and protective easements.
- *Nutrient and Sediment Loads* – Identify sensitive nutrient-poor wetland areas (ombrotrophic bog formations, etc.), map floristic composition in sensitive wetland areas, develop stormwater management programs and regulations to protect against sediment and nutrient enrichment (local disposal of storm runoff, first flush approaches, sediment collection systems, created wetland systems for runoff water quality renovation). Collectively review discharges, and improve treatment of discharged waters to ensure compliance with NJ-SWQS during all flow regimes.

Other WMA 3 Water Resources: Identification of specific goals and management approaches for all water resources is beyond the scope of this "characterization phase". Indeed, individual water resources (lakes, reservoirs, stream order reaches) will need specific and individual study and evaluation in order to make informed management decisions. The information contained in Parts 1 and 2 (Sections 8.1 and 8.2) describe potential approaches to be examined.

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