Our established vision for Watershed Management Area 6 is to maintain, and to restore, as needed, a watershed that is valued for the many environmental, economic, and aesthetic benefits it provides, including clean and available ground and surface water supplies, environmentally responsible economic activities, maintenance of aquatic ecosystem health, and recreational opportunities. – WMA 6 PAC

Watershed Characterization and Assessment of WMA 6

WMA 6 Highlights

Watershed Management Area 6 (WMA 6) of the Passaic River Basin:

- Covers 361 square miles of area, which is more than 43% developed, but is still about 34% forest
- Watersheds include the Upper Passaic, Rockaway and Whippany Rivers
- Has several large habitat areas and several smaller areas which are encroached upon by development
- Has approximately 540,000 residents, with approximately 90% dependent on local groundwater for supply
- Diverts more than 42 billion gallons of water per year for potable supply,
    - About half from surface water sources and half from groundwater
    - Receives approximately 3 billion gallons of treated surface supply per year from WMA 3 and 4
    - Exports approximately 18 billion gallons of surface water per year to WMA 5 (Jersey City)
- Passaic River flow leaving WMA 6 serves as surface supply source for diversions in WMA 3 and 4
- Suffers from impairment of some surface and groundwater
- Surface water loadings are attributed primarily to:
    - non-point sources for fecal coliform, BOD_5, sodium and suspended solids
    - point sources for phosphorus and nitrates
    - both point and non-point sources for ammonia
- To be effective, planning must be coordinated with planning for WMAs 3 and 4, particularly for the main stem of the Passaic River downstream of WMA 6.

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 6

1. Drainage Areas – Major Subwatersheds

Watershed Management Area 6 (WMA 6) covers 361 square miles, mostly in Morris County, but including parts of western Essex and Union Counties, northern Somerset County, and eastern Sussex County. WMA 6 includes watersheds of the Whippany and Rockaway Rivers, and the Passaic River upstream of Two Bridges. The Passaic River above Two Bridges is divided into two areas, the Middle Passaic from the Pompton River to Pine Brook, and the Upper Passaic above Pine Brook. The Middle Passaic receives flow from the Rockaway and Whippany Rivers, while only a short reach of the Upper Passaic receives flow from these two watersheds.

The approximate area of each of these major sub-watersheds is listed below.

Subwatershed	Area (sq. miles)
Upper Passaic River (above Pine Brook)	143*
Whippany River	70
Rockaway River	137
Middle Passaic River (Pompton River to Pine Brook)	11*
Total	361

* Values rounded down to maintain total value of 361 square miles.

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 50 percent of WMA 6 is in the Highlands Physiographic Province. 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 55 percent of the Highlands area in

WMA 6, north of the Rockaway River, exhibits 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 in the extreme north of WMA 6 that reach above an elevation of 1350 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 6 that lies in the Newark Basin is generally lower, with the majority of the land between elevation 200 and 400 feet above sea level, and a few points along the crest of the Second Watchung Mountain reaching above an elevation of 600 feet. The lowest point is at an elevation of approximately 160 feet, where the Passaic River exits WMA 6 at its confluence with the Pompton River.

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 6, 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 (WMA 3) to Bernards Township in the south. 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 meltwater 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. They are not as vulnerable to contamination as the surficial deposits, but easily propagate contamination, once it is introduced.

Soils in WMA 6 appear to be 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.

The climate of the Passaic Basin is classified as continental climate due to the prevalence of westerly winds from the continental interior. The region experiences moderately cold winters and hot wet summers. Snow can be expected between November and April. The first frost usually falls in late September/early October and the last frost in early May.

Prevailing wind directions are from the northwest from October to April and from the southwest during the rest of the year. Average winter temperatures are in the high twenties and low thirties on the Fahrenheit scale. Average summer temperatures are in the low seventies. Midsummer weather is characterized by high humidity and frequent thunderstorms. Average annual rainfall is approximately 48 inches to 50 inches throughout most of WMA 6, but is less in some areas and averages 50 inches to 52 inches in some of the higher elevation areas to the west and northwest.

3. Land Use and Habitat

As of 1995, approximately 43% of WMA 6 was urban land (as a general category, includes all residential, commercial and industrial development), about 34% was forest, and approximately 20% was water or wetlands. Only about 2% of the area of WMA6 was in agricultural use at that time. The significant wetland area (62.5 square miles, or approximately 17% of WMA 6) includes two critical areas, the Passaic Meadows Macrosite (including Troy Meadows and Great Piece Meadows), and the Great Swamp Macrosite. These two macrosites cover much of the wetland in the area that was once Glacial Lake Passaic.

A third large critical area, the Green Pond Macrosite, 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. The East Orange Water Reserve is located in Livingston and Millburn, primarily along the lower reaches of Canoe Brook. Some well fields and parts of watershed areas around reservoirs are preserved in other areas in WMA 6. The three macrosites, 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.

Comparison of land use data for 1986 and 1995 reveals that during that 10-year time span there was a loss of approximately 9.4 square miles of forest area, 2.1 square miles of agriculture, and approximately 1.3 square mile of wetland, and an increase of approximately 12 square miles of urban area. Thus the total change in land use in that period involved about 3.5% of the area of WMA 6.

WMA 6 is fortunate to have several large areas for natural habitat. Land in these sites is owned by several entities and is not necessarily protected from changes in land use. Existing development borders on, and in some locations drains into, these areas, and there remain pressures for continued growth to meet housing and business needs of the area. Habitats for wildlife and fish communities in the region are stressed by the effects of widespread development, including point discharges and pollution from surface water runoff from developed areas. Care must be taken to ensure that continued occupation and development of adjacent areas does not adversely affect the natural areas.

4. Water Supply

Between 1990 and 2000, an average of approximately 42 billion gallons of water per year was diverted in WMA 6 for public water supply purposes, and about 1.3 billion gallons per year for industrial purposes. Approximately half of this water was from surface supply, and half from groundwater. Of the 42 billion gallons, approximately 19 billion gallons per year (mostly from surface supply) is exported from WMA 6 to WMA 4 and WMA 5. This includes the Boonton Reservoir System that provides the City of Jersey City with approximately 50 MGD. In addition, stream flow passed through WMA 6 supports downstream environmental flow and water supply allocation requirements.

The characterization and assessment 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.

The public water supply used within WMA 6 is approximately 90% from groundwater. Most of the eastern portion of WMA 6, in the Newark Basin, is located over a medium yielding (101 to 250 gpm) bedrock aquifer. In the same area, there is an extensive network of surficial and buried valley aquifers (the Buried Valley Aquifer System). With the exception of the wetland areas and the East Orange Water Reserve, substantial areas above the surficial aquifers in the eastern half of WMA 6 have been developed such that the impervious cover is in the range of 21% to 45% (see Plate 1.14.1).

The groundwater characterization and assessment indicates a variety of groundwater sources that vary from low producing to prolific. Based on data from 1990-2000, groundwater 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 groundwater withdrawals to estimated groundwater availability, there is evidence to suggest a growing groundwater deficit. The evaluation of the available groundwater for the future is an area that requires significantly more investigation and improved methods of estimating the interrelationship between groundwater and surface water availability.

A significant portion of the surface water and groundwater diverted for potable water supply within WMA 6 is returned to the streams by discharge from wastewater treatment plants, or returned to the ground through septic systems and thus is potentially available for reuse.

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.

5. Population

A comparison of US Census data from 1990 and 2000 shows that over this period, population in WMA 6 has increased by 56,937 or over 11%.

Table 1.20.1
Population of Watershed Management Area 6

	1990 Census	2000 Census	Change	% Change
Population	482,258	539,195	56,937	11.81

Source: US Census Bureau

Population projections recently developed by the New Jersey Department of Labor, Division of Labor Market & Demographic Research as part of the department's economic and demographic projections series, indicate the following population growth within Morris County (which covers most of WMA 6):

Table 1.16.6
Population Forecast (New Jersey Department of Labor)

County	Est. 1998	2005	2008	2010	2015
Morris	470,700	500,500	512,500	520,600	545,500

This indicates a much more dramatic increase in population with WMA 6 of almost 16 percent by the Year 2015.

6. Watershed Stressors

The waterways of WMA 6 receive pollutants from both point and non-point sources. The point sources in WMA 6 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 6 has several identified contaminated sites, including 46 listed Superfund sites.

There are 26 permitted domestic wastewater treatment facilities that discharge to the surface waters in the watersheds of WMA 6, with a total permitted average design discharge of approximately 67 MGD. The average daily discharge in 2000 was reported to be about 47 MGD.

The two larger wastewater plants have a combined capacity of 28 MGD, and include the Parsippany-Troy Hills facility (16 MGD), tributary to the lower reach of the Whippany

River, and the Rockaway Valley Regional Sewerage Authority facility (12 MGD) on the Rockaway River downstream of the Boonton Reservoir. The Parsippany–Troy Hills facility is an activated sludge plant that provides tertiary treatment by pressure filters. The Rockaway Valley facility treatment process includes oxidation channels and clarifers.

While most of the more densely developed areas of WMA 6 are served by sanitary sewers, much of the area in the north and in the west is served by on-site septic facilities.

7. Surface Water Quality Impairments

The NJDEP has recommended delisting certain parameters previously listed on the 1998 303(d) List for waterways in WMA 6. The delisted parameters for the Whippany River sites include total phosphorus and heavy metals. However, these categories of parameters remain listed for the three Passaic River stations. The resultant list of parameters not attaining standards at seven primary sampling stations in WMA 6, 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 6, is presented in Table 4.7.4 in Section 4 of this report. The non-attainment parameters vary with location, but non-attainment for fecal coliforms (FC), aquatic life or recreation appears for several sites. Total phosphorus (TP) appears for two sites. Data revealing non-attainments was furnished primarily by governmental agencies, including USGS, NJDEP and several municipal health departments.

(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
Passaic River	Near Millington 01379000	TP, FC, DO, As, Cd, Cu, Pb, Hg, Ag, Zn, Cn	TP, FC, As, Cd, Cu, Pb, Hg, Ag, Zn, Cn	
Passaic River	near Chatham 01379500	TP, FC, TSS, As, Cd, Cu, Pb, Hg, Ag, Zn, Cn	TP, FC, As, Cd, Cu, Pb, Hg, Ag, Zn, Cn	
Rockaway River	at Boonton 01380500	As, Cd,, Cr, Pb, Hg, Se, Zn trichloroethylene, tetrachloroethylene	TP, FC, As, Be, Cd,, Cr, Pb, Hg, Se, Zn trichloroethylene, tetrachloroethylene	TP, FC, Be
Rockaway River	at Pine Brook 01381200	TP, FC, Pb, trichloroethylene, tetrachloroethylene	TP, FC, pH, As, Be, Cd,, Cr, Pb, Hg, Se, Zn trichloroethylene, tetrachloroethylene	pH, Be
Whippany River	at Morristown 01381500	FC	TP, FC, As, Cd, Cr, Cu, Pb, Hg	TP, As, Cd, Cr, Cu, Pb, Hg
Whippany River	near Pine Brook 01381800	FC, DO, TSS, Pb	TP, FC, DO, As, Cd, Cr, Cu, Pb, Hg	TP, FC, As, Cd, Cr, Cu, Hg
Passaic River	at Two Bridges 01382000	TP, FC, As, Cr, Cu, Pb, Hg	TP, FC, DO, As, Cr, Cu, Pb, Hg	DO

* Source: NJDEP website

C. ASSESSMENT OF WATER QUALITY FOR WMA 6

1. Trends

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 completed by 1992 and, in the period since then, 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.

The results of the seasonal differences review are summarized below:

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

2. Many discharge-related parameters have significantly higher concentrations in the summer. These parameters include nitrate nitrogen, total phosphorus, and dissolved phosphorus. This tendency is particularly true at stations 01381800 (Whippany River near Pine Brook) and 01382000 (Passaic River at Two Bridges). Given that mean summer flows are only 30%-50% of those in winter, this finding is readily understandable.

3. In some cases, the seasonal variations in effluent quality could partially offset the natural seasonal dilution pattern. One such constituent that is limited on a seasonal basis is ammonia, which actually has a higher in-stream concentration in the winter at one station (01382000 – Passaic River at Two Bridges).

4. Higher summer pH levels are present at three stations (the two on the Rockaway River and the Passaic River at Two Bridges) – a finding that may be an indication of algal activity.

5. Higher winter concentrations of chlorides and sodium at three stations Whippany River near Millington and Passaic River at Two Bridges) may be caused by road de-icing operations – an expected result.

2. Loading Assessment

A loading assessment was completed to provide an indication of the relative loading in WMA 6 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. 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 Passaic River at Two Bridges, near Chatham, and near Millington, the Whippany River at Pine Brook and at Morristown, and the Rockaway River at Pine Brook. The point source discharges upstream of the primary station on the Rockaway River above the Reservoir at Boonton are small, and therefore most of the pollutant loading in the upstream watershed 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 – 5.16-12 (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**
01379000	Passaic R. @ Millington	2733	18	14	46
01379500	Passaic R. @ Chatham	3355	34	25	335
01381200	Rockaway R @ Pine Brook	3406	34	26	341
01381500	Whippany R. @ Morristown	1210	12	9	121
01381800	Whippany R. @ Pine Brook	2917	29	22	292
01382000	Passaic R. @ Two Bridges	13698	137	103	1370

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**
01379000	Passaic R. @ Millington	1%	18%	39%	*
01379500	Passaic R. @ Chatham	6%	37%	87%	76%
01381200	Rockaway R @ Pine Brook	11%	54%	84%	71%
01381500	Whippany R. @ Morristown	2%	29%	73%	68%
01381800	Whippany R. @ Pine Brook	3%	45%	82%	74%
01382000	Passaic R. @ Two Bridges	8%	52%	91%	79%

* Indicates a net loss of load – that the observed in-stream load is less than point source load

As indicated above, a substantial portion of the total loading in WMA 6 is attributed to point sources for total phosphorus (TP) and nitrates (NO_3). Both point and non-point sources provide significant contributions to ammonia nitrogen (NH_3) loading. BOD_5 is primarily attributed to non-point sources. The estimated percentage contribution of total loading to WMA 6 watersheds from point vs. non-point sources for the indicated parameters is indicated by the data for the Passaic River at Two Bridges station and is summarized below.

WMA 6 Watersheds
Percentages of Total Loading (1997-2000)

Source	BOD_5	NH_3	TP	NO_3
Point	8%	52%	91%	79%
Non-point	92%	48%	9%	21%

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 6, and can provide some guidance as to where efforts should be concentrated to reduce loadings of those parameters exceeding standards.

Results for station 01379000 (Passaic River near Millington) tend to overpredict nitrate concentrations during summer conditions. Data indicates that there is less nitrate loading in the stream than is present in the upstream effluent discharges. The reaches upstream of this station (the Great Swamp) have a documented seasonal loss of flow due to excessive evapotranspiration. Even though the normalization of flows at this site (based on station 01379500 –Passaic River near Chatham) allowed a relatively good simulation of other parameters, the nitrate result remained anomalous. While additional data is needed to confirm this result, it currently suggests an upstream sink for at least this constituent. This finding should be considered and further explored in connection with future detailed analyses, such as in a TMDL analysis for WMA 6.

Findings suggest that much of the Passaic, Lower Rockaway, and Lower Whippany 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 contribute relatively similar percentages 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 BOD_5.

Since the point source discharges in the Rockaway River watershed upstream of Boonton Reservoir are small, non-point sources are expected to be the major contributors to in-stream pollutant loadings in the upper part of the Rockaway River watershed.

3. Data Gaps

In this regard, the term "data gaps" refers to geographic areas (or streams) that do not have sufficient (or any) monitoring data – streams that could not be addressed in the previous analyses. 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, 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.

Nitrate data was available for only about 25% of the treatment facilities and then only for the final 6-18 months of the simulation period. For the analysis presented in this report, the missing data was replaced with the facility mean concentration if available or, otherwise, with the mean of all available data. Additional effluent nitrate data is desirable to better refine this procedure. 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.

In recent years, the USGS/NJDEP sampling program has re-oriented its priorities. One result of these changes is a marked reduction in data collection within WMA6 -- this program is now sampling only two of the previously selected primary stations (Passaic River at Two Bridges and Whippany River at Pine Brook). Water purveyors (PVWC) are now the primary source of data for these stations. However, data is being collected at monthly (or better) intervals at only three stations (Passaic River at Two Bridges, Whippany River at Pine Brook, and Rockaway River at Pine Brook). Other sites are being sampled on a quarterly basis. Of special concern, there will be no sampling -- on more than a quarterly basis -- along the entire mainstem of the Passaic River above Two Bridges. Quarterly sampling will not provide an adequate basis for future assessments. The data needs for future water quality assessments should be addressed.

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 watershed management area characterization and assessment.

D. KEY ISSUES

WMA 6 contains many areas that provide habitat for wildlife and fish communities, provide recreational opportunities, and provide a high quality of surface water runoff. As this runoff proceeds through widespread developed areas, pollutants are added from point and non-point sources, reducing the quality of the water. The area is approximately 43% urban and 34% forest. However, much of the forest is segmented and interspersed with development. There are 26 permitted domestic wastewater dischargers with a combined total design capacity of approximately 67.2 MGD. The reported actual average daily discharge in 2001 was 47.4 MGD.

There are three very large and five smaller critical habitat areas, numerous lakes and extensive reaches of streams and rivers.

About 52% of the water supply used within this WMA is from groundwater sources. In the eastern half of WMA 6, there is an extensive system of buried valley aquifers (the Buried Valley Aquifer System), which have extensive surficial aquifers above 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 by surface sources, it would have a dramatic effect on water supply within WMA 6.

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

Preservation of the quality of water in WMA 6 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 6 are described below.

1. Existing water quality impairments ("a" to "g" per NJDEP 2002 Integrated List, "h" per NJDEP Category 5 List):
    a. Passaic River near Millington – for total phosphorus, fecal coliforms, DO, and several heavy metals (As, Cd, Cu, Pb, Hg, Ag, Zn, Cn)
    b. Passaic River near Chatham – for total phosphorus, fecal coliforms, total suspended solids, and several heavy metals (same as at Millington)
    c. Rockaway River at Boonton – for As, Cd, Cr, Pb, Hg, Se, Zn, trichloroethylene, and tetrachloroethylene

   d. Rockaway River at Pine Brook – for total phosphorus, fecal coliforms, Pb, trichloroethylene, and tetrachloroethylene
   e. Whippany River at Morristown – for fecal coliforms
   f. Whippany River near Pine Brook – for fecal coliforms, DO, total suspended solids, Pb
   g. Passaic River at Two Bridges – for total phosphorus, fecal coliforms, As, Cr, Cu, Pb, Hg
   h. Approximately 20 additional monitoring sites throughout WMA 6 (see Table 4.7.4 in Section 4.7) – for non-attainment of standards for aquatic life, fecal coliforms or recreational use at many locations, total phosphorus at two locations (Black Brook at Madison and Dead River near Millington), and also nitrate and total suspended solids at one site (the Dead River near Millington).

2. Water quality parameters/areas of concern not listed by NJDEP for WMA 6 (based on areas of concern identified by PAC/TAC members):
   a. Upper Passaic River, Long Hill Twp. – turbidity, temperature, debris
   b. Taylortown Reservoir – nitrates, fecal coliforms
   c. Streams in Mendham – trout production and recreational use – for temperature, suspended solids, fecal coliforms
   d. Beaver Brook at Valley Road and at Berkshire Valley Road
   e. Reaches of the Rockaway River, Deer Lake, Dixon Pond – for recreation, fish and wildlife
   f. Buried valley aquifer – VOCs
   g. Passaic River and Shepherd Kollock Park – phosphorus and nitrates
   h. Streams discharging to Great Swamp – total suspended solids
   i. Great Swamp – phosphates, nitrates
   j. Millbrook – erosion
   k. Mount Hope Pond, White Meadow Lake, Lake Telemark, Lake Ames, Green Pond – for coliforms, nitrate, phosphorus
   l. Split Rock Reservoir – pathogens, trout production use
   m. Lake Denmark – for trout production use
   n. Loantaka Brook, Great Brook, Black Brook, Primrose Brook
   o. Glacial Lake Passaic
   p. Bedrock aquifers of southeast Morris County – coliforms, VOCs

3. Water Quality Assessment Findings (with respect to conventional parameters – DO, BOD_5, 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 main stem of the Passaic River (downstream of Millington) and the Dead River.
      ii. Slightly lower, but elevated, concentrations in the lower reaches of the Rockaway and Whippany Rivers.

   iii. Distinctly higher water quality found for the uppermost reaches of the Rockaway and Whippany Rivers.
   iv. Fecal coliform exceedances common throughout WMA 6 (with "unacceptable" ratings at 14 of 17 water quality data stations, and "marginal" at 1). Median values exceeded relevant criteria at 11 of 17 stations.
   v. Total phosphorus exceedances, with "unacceptable" ratings at 14 of 24 stations, and median values exceeded criterion at 9 of 24 stations.

b. Trend Analysis
   i. Long-term reductions in the 1980s for concentrations of ammonia and TKN (as much as 80% or more), accompanied by increased (often doubling) concentrations for nitrates at 5 of the 7 primary stations evaluated. (Not observed for the Passaic River near Millington or the Rockaway River above Boonton – two stations less affected by wastewater treatment plant effluents).
   ii. Less dramatic improvements in water quality at the same 5 stations for DO BOD_5, total phosphorus and dissolved phosphorus.
   iii. For Whippany River near Pine Brook, dramatic improvements in DO and BOD_5.
   iv. For Whippany River at Morristown, dramatic improvement in total phosphorus.
   v. Steady increasing trend at all primary stations for chloride, and similar but less prominent increases for sodium and TDS concentrations. Concentrations significantly higher in winter (possible impact from road de-icing).
   vi. Since early 1992 little change in overall water quality except for continuation in increase in chlorides.

c. Loadings Assessment
   i. Two largest domestic wastewater dischargers (Parsippany-Troy Hills and Rockaway Valley Regional SA facilities) together discharge 21.8 MGD, 46% of the total wastewater discharge.
   ii. Pollutant loadings in the upper Rockaway River watershed are primarily attributed to non-point sources.
   iii. Data suggests that during drought conditions, flow in the Passaic River could almost totally consist of point source effluent. It is not clear what role flow losses (such as evapotranspiration or groundwater withdrawals) have in this result.
   iv. Simulation suggests that the biological productivity of the Great Swamp may have an effect on water quality, including a loss of nitrate load and possibly enhanced non-point input of BOD_5 upstream of the Passaic River at Millington station. (Prior studies have indicated that the Great Swamp can act as a sink for nutrients. Additional study is needed on this subject.)
   v. 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 70% and 90% of the nitrate and total phosphorus, and between 30% and 60% of the ammonia at the evaluated stations.
2. Seasonal assessment indicates that point source contribution could be 5%-15% higher during a critical summer low flow period.
3. Point sources contribute less than 12% of BOD_5 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. Water quality issues affecting the Pompton River in WMA 3 and those that affect the Passaic River at Little Falls in WMA 4, since these issues affect some of the water returned to WMA 6 for potable supply.

5. Land use and preservation of forests and wetlands
   a. Maintain storage of surface runoff
   b. Preserve significant groundwater recharge areas (for seepage of rainfall and snowmelt)
   c. Well head protection

6. Non-point source pollution from existing land use, as well as from new development

7. Groundwater recharge
   a. To reduce increases in peaks and volume of surface runoff associated with increases in impervious area
   b. To replenish groundwater and help maintain base flow in streams

8. 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

9. Cleanup of contaminated sites
   a. Superfund sites (approximately 46 listed within WMA 6)
   b. Other contaminated sites (numerous listings in WMA 6)
   c. Concern that the contaminated groundwater may migrate to the streams.

E. MANAGEMENT APPROACHES

Watershed Management Area 6 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 – Passaic, Lower Rockaway, and Lower Whippany Rivers

The results of the loading assessment suggest that much of the Passaic, Lower Rockaway, and Lower Whippany Rivers are effluent dominated with regard to total nitrogen, nitrate nitrogen, total phosphorus, and dissolved phosphorus. For WMA6 as a whole (at the outflow point from WMA6) point source discharges contribute approximately 52% of the ammonia-N, 91% of TP, and 79% 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 in lower river reaches in WMA6, to verify that adequate dissolved oxygen persists at all times (including the low-flow dark cycles).

Considering that less than 12% of the water load (i.e. the wastewater treatment plant effluent portion) contributes more than 45% of the ammonia, > 80% of TP, and > 70 % of the Nitrate loads to the WMA 6 River Resources (especially in the Passaic, lower Rockaway, and lower Whippany 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 facilities vary widely. Dissolved Inorganic Nitrogen (DIN) / MGD varies from 36 to 179 lb DIN/MGD. Discharged phosphorus varies from 0.07 lb TP/MGD to 1052 lb TP/MGD. The N:P ratio at discharges is also variable, from about 1.0 to over 500 (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, by 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. 2-6 mg/L depending on stream order), 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.

Non-Point Sources

The loading assessment suggests that Flow, TSS, and BOD loading are strongly dominated by non-point loading sources. The long-term increasing trend for TDS, chlorides, and sodium are of concern. A comprehensive Non-Point Source program should be established. "Local disposal" and "first flush" techniques should be emphasized.

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 silt 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 6 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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