# Section 2 Resource Assessment and Conservation Values

Photograph by George M. Aronson

"We abuse the land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect."

*Aldo Leopold, Conservationist*

# SECTION 2 RESOURCE ASSESSMENT AND CONSERVATION VALUES

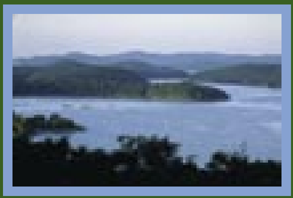
For the resource assessment phase of this study, the study team and work group selected five resource components that provide a comprehensive view of the water and land resources across the Highlands region. These resource components were also chosen to align with the goals for the original 1992 Highlands Regional Study, which were stated in Section 1.

This section describes the status of water, forest, biodiversity, farmland, and recreation resources in the Highlands. It shows their distribution throughout the study area. These resources are then integrated into a Conservation Values Assessment Model to provide a range of conservation values for the resources across the region.

## WATER

The water resources of the Highlands have long been recognized as the region's most valuable resource. More than a century ago, before the construction of large-capacity storage reservoirs, water supply reports documented the natural advantages of the region as a collecting ground and as the future source of water supply for rapidly developing urban centers in northeastern New Jersey and New York City (Vermeule 1894, La Forge 1905). These advantages include the Highlands' many natural storage basins, its elevation, and abundant rainfall. The region's elevation allowed the economical delivery of water by gravity flow to dense population centers immediately to the east. The Highlands were noted as an area of good water quality because the area was sparsely settled, largely forested, and poorly adapted for agricultural use. For all of these reasons, these early reports emphasized the need for conservation.

The Highlands ground water and surface water are the direct source of water for more than 4.5 million people in New York and New Jersey. Millions more depend on water that is transferred through Highlands reservoirs from Delaware System reservoirs located in upstate New York and by flow augmentation to streams.





The quality of ground and surface water within the region continues to be among the best nationally, and in some areas stream quality and aquatic communities have improved over the last decade owing to increased environmental regulation and improved wastewater treatment facilities. Although less serious water quality problems occur within Highlands watersheds, the U.S. Environmental Protection Agency (1999) considers the watersheds to be highly vulnerable based on indicators such as urban runoff potential, population change, and hydrologic modification.

Land-use activities are major factors in changing hydrologic and environmental conditions within watersheds. The expected continued growth of population and development in the Highlands would have a significant effect on stream and ground water quality and aquatic communities. Declining ground water levels, changes in the natural flow of streams, habitat degradation, reduction in biological diversity, and a shift toward species more tolerant of disturbance are associated with increasing urban and suburban development. Given the prospect for continued development of the Highlands and increased dependence on Highlands water resources both within the Highlands and in adjacent areas, an increased vigilance in terms of adequate monitoring and assessment of water quantity and quality, and biological resources is warranted in the region.

## GROUND WATER—AQUIFERS AND WELLS

Ground water is the primary source of water for residents and businesses in the Highlands region. Aquifer characteristics and the function of the ground water flow system are directly related to the underlying geology, which controls the aquifer's ability to store and transmit significant quantities of water for various uses. Descriptions of aquifer types are provided to aid in understanding the information on ground water use that follows.

### AQUIFER TYPES

Five aquifer types within the Highlands study area are classified by the bedrock or surficial materials that are exposed at or near the land's surface. These include crystalline, carbonate, and clastic rocks typical of Highlands geologic formations (Figure 2-1). The study area also includes sedimentary and igneous rocks of the Newark Basin along the eastern boundary that are typical of the Piedmont physiographic province to the east. Locally, all of these bedrock units are overlain by surficial deposits of glacial origin.

#### *BEDROCK AQUIFERS*

The crystalline aquifers are composed of crystalline metamorphosed sedimentary and igneous rocks of Pre-Cambrian age and are exposed over 65 percent of the study area. Rock types consist primarily of coarse-grained gneiss, schist, and granite of various mineral compositions. Fine-grained metamorphic slates such

## Water: Ground Water—Aquifers and Wells

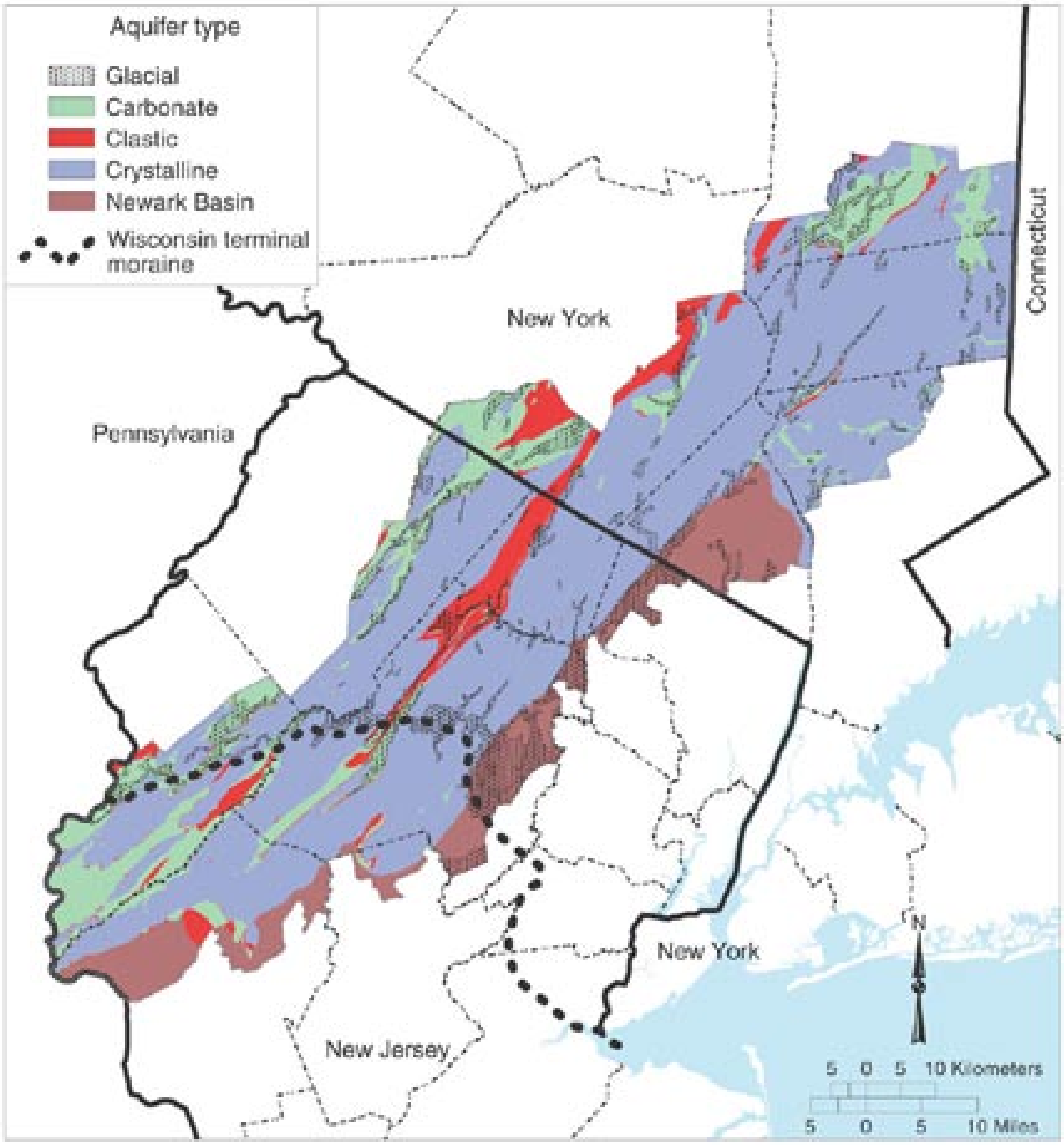
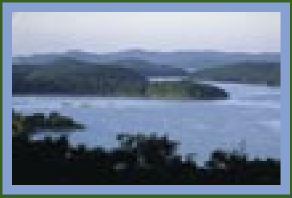



**Figure 2-1. Aquifer types.** Major aquifer types of the New York – New Jersey Highlands are classified by their bedrock or surficial materials, which affect water infiltration, storage, availability, and chemistry.



as phyllite are common in the New York part of the study area. These rock types are the most resistant to erosion. Therefore, they form the upland regions and generally provide the highest elevations, steepest slopes, and relief typical of Highlands topography.

Carbonate aquifers are composed predominantly of Paleozoic age limestones and dolomites and are exposed over 16 percent of the area. These rock types are less resistant to erosion, are subject to dissolution, and therefore are found on the valley floors interspersed between the more resistant crystalline and clastic rocks that form the valley walls.

Clastic aquifers are composed of Paleozoic age sedimentary sandstone, shale, conglomerates, and quartzite, and comprise 7 percent of the study area. These rock types locally overlie carbonates in some valleys; the more resistant rocks form predominant northeast-southwest trending ridges known locally as Green Pond, Bearfort, Kanouse, and Bellvale Mountains.

Newark Basin aquifers of Mesozoic age are exposed over 12 percent of the area. These rocks are predominantly red sandstones and shales. Conglomerates, particularly near the Ramapo border fault, and basalt and diabase units are also present.

#### Glacial Aquifers

Glacial aquifers are composed mainly of unconsolidated sand, silt, and gravel of Pleistocene age, and form narrow belt-like deposits of small areal extent. The aquifers comprise channels up to 300 feet thick in some places and can provide significant storage and yields of water.

### Aquifer Recharge

Recharge to Highlands bedrock aquifers is predominantly through precipitation that percolates downward through the overlying soil to fractures, joints, or solution openings in the underlying bedrock (Illustration 2-1). The ground water moves from upland recharge areas to discharge areas, such as springs and streams at lower altitudes.

Glacial valley-fill aquifers receive most of their recharge from runoff caused by precipitation that falls on the surrounding bedrock uplands. Some recharge is by infiltration from precipitation that falls directly on the valley-fill aquifers, and some is by inflow from adjacent bedrock aquifers. These sources are sufficient to maintain aquifer water levels above those of streams, so that water moves from the aquifer to the stream (Illustration 2-2A). However, during droughts, discharge by seepage to adjacent bedrock, evapotranspiration, and withdrawals from wells can lower aquifer water levels until flow is reversed and water moves from the stream to the aquifer (Illustration 2-2B).

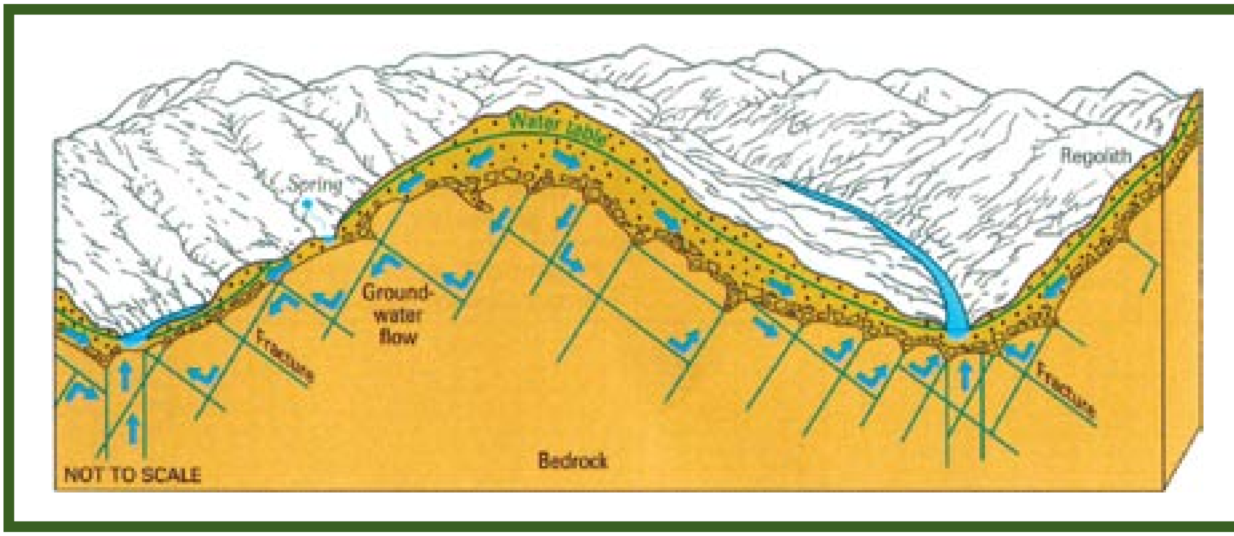



**Illustration 2-1. Recharge and flow in bedrock aquifers.** Ground water in bedrock aquifers is predominantly precipitation that has infiltrated the overlying soil and the bedrock. At lower elevations the ground water feeds springs and streams (modified from Heath 1980, p. 10).

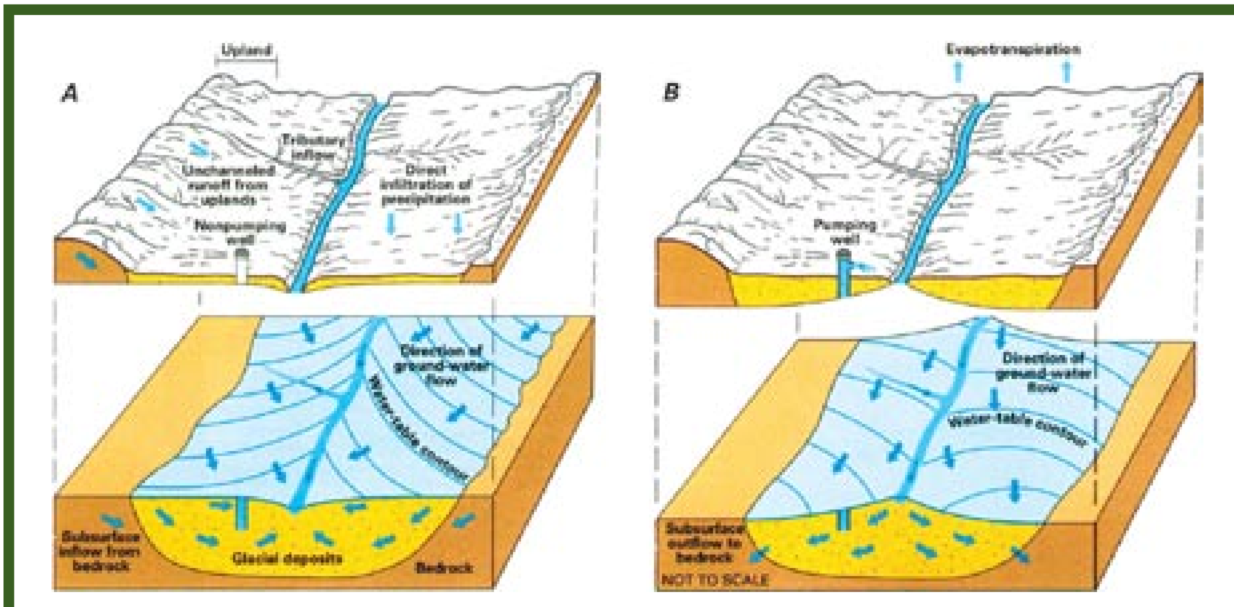



**Illustration 2-2. Recharge and flow in glacial aquifers.** Ground water enters glacial aquifers in three ways: as runoff from the surface of surrounding bedrock, as underground flow from adjacent bedrock, and by infiltration of precipitation that falls directly over the aquifer. (A) When the water level in a glacial aquifer is above that in streams, ground water flows from aquifer to stream. (B) When the water level in a glacial aquifer drops below that in streams—due to withdrawal from wells, drought, evapotranspiration, and seepage into adjacent bedrock—water flows from stream to aquifer (modified from Rosenshein 1988, p. 168).



Aquifer recharge can be highly variable because it is determined by local precipitation and is influenced by topographic relief and the capacity of the land surface to accept infiltrating water. The degree to which Highlands aquifers have the ability to store and transmit recharge water is based on the amount and connectivity of openings in the underlying rock or sediment. This is also known as the aquifer's permeability and has a direct bearing on the aquifer's ability to yield sufficient quantities of water to wells.

## GROUND WATER USE

### *HIGH-CAPACITY WELLS*

Water-use data for 1995 was compiled for more than 1,200 wells for which owners are required to report water withdrawal data to Federal, State, or local agencies. These wells include those used for high-capacity municipal supply, industrial, commercial, irrigation, and mining uses. Figure 2-2 shows the location of wells operating in 1995 and provides information on the volume of withdrawals per well by aquifer type. Areas of note include the large withdrawals from glacial aquifers in central and eastern Morris County and along the eastern boundary of the study area in Passaic and Bergen counties in New Jersey and in Rockland County, New York. Carbonate aquifers provide the majority of ground water in the southwestern part of the study area in eastern Warren and southern Morris counties. These are areas where overlying glacial deposits provide increased ground water storage and yield to the underlying carbonate rocks.

Figure 2-2 also shows the importance of Newark Basin aquifers to Rockland County and crystalline bedrock aquifers in Putnam County, New York. Also notable are the widespread consistency of low yields of crystalline rock aquifers and the paucity of wells drawing water from clastic rock aquifers.

The graph in Figure 2-2 provides a comparison of total ground water withdrawals by aquifer type within the Highlands study area, differentiated by the amount withdrawn by wells in New York and New Jersey. Glacial aquifers are the most productive with almost 60 million gallons per day (Mgal/d) withdrawn. The combined total withdrawal from the four bedrock aquifers is about 56 Mgal/d.

### *DOMESTIC WELLS*

The amount of water supplied by domestic wells across the region was estimated in order to account for this significant source of potable water in rural areas. The number of people in each township in 1995 that depended on water from domestic wells was estimated from the 1990 census data. Each person supplied by a domestic well was assumed to use 85 gallons per day.

Figure 2-3 shows the estimated domestic water use by township. Total domestic withdrawals for 1995 in the Highlands region was estimated to be approximately 30 Mgal/d. Areas with the largest domestic withdrawals in New York are western Dutchess, Putnam, and Westchester counties, and Warwick Township in Orange

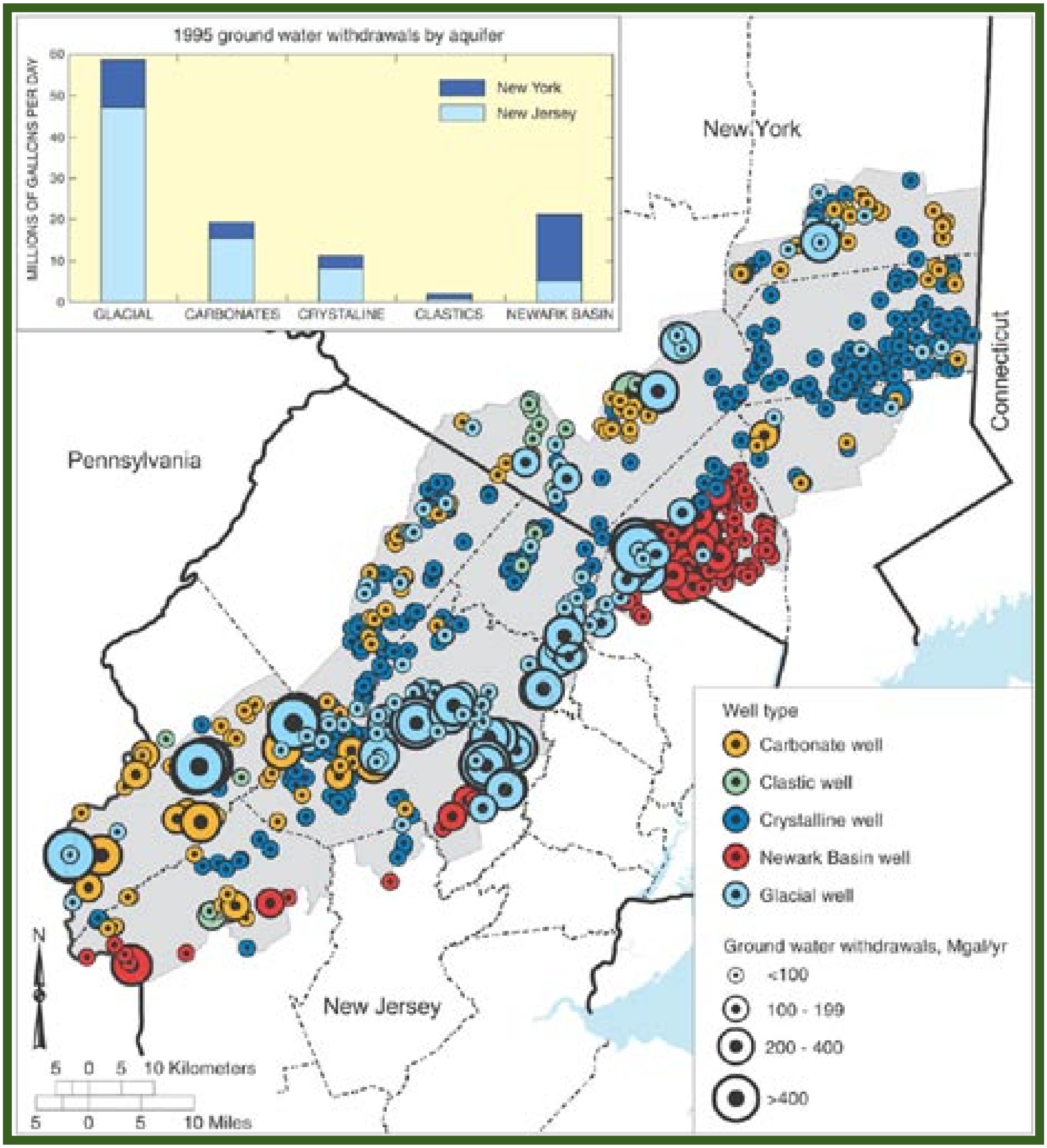
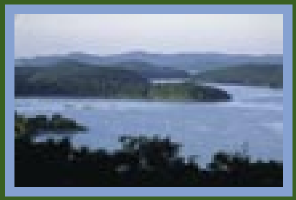



**Figure 2-2. Withdrawals from high-capacity wells.** The map shows the areal distribution of 1995 withdrawals from major water supply wells in the Highlands. The amount of water withdrawals differs regionally and by aquifer type.



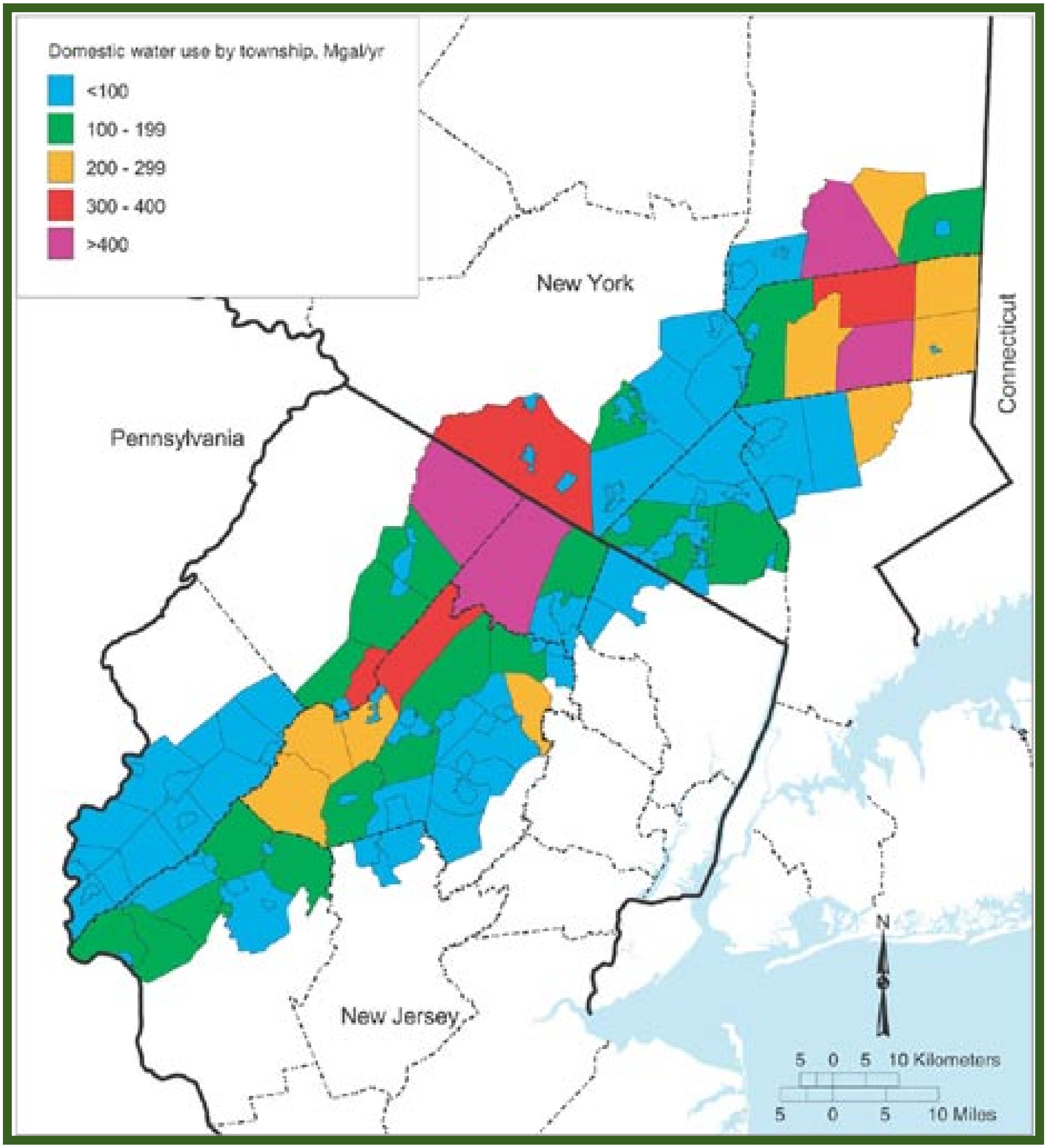



**Figure 2-3. Withdrawals from domestic wells by township.** Estimated water withdrawals from domestic wells in the Highlands in 1995 were greatest in townships in Dutchess, Putnam, Westchester, and Orange counties in New York; and in Sussex, Passaic, and Morris counties in New Jersey.

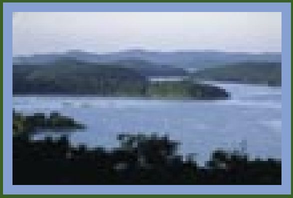
County. Areas with the largest domestic withdrawals in New Jersey are Vernon Township in Sussex County, West Milford Township in Passaic County, and Jefferson Township in Morris County.

### Monitoring Ground Water Levels

Changes in water levels reflect the general response of the Highlands ground water system to climate changes, changes in recharge patterns, and ground water withdrawals. Water levels typically are highest in winter and early spring as a result of reduced evapotranspiration, low temperatures, snowmelt, and spring rains that recharge the aquifers. Ground water levels typically start to decline as summer begins and continue to decline through late fall. Water use is highest in summer when water is used for irrigation and recreation. More water evaporates from the land surface and transpires from plants also reducing recharge.
Water levels are typically lowest in late fall, and they rise again during winter, completing the cycle.

Figure 2-4A shows hydrographs from four selected monitoring wells in Morris County, New Jersey, with 10 years of continuous daily records. These hydrographs show typical fluctuations of ground water levels within the various aquifers of the study area. During periods of prolonged drought, such as from mid-1994 to late 1995 and mid-1998 to mid-1999, water levels fell approximately 5 to 15 feet on average. Shallow wells constructed just below the water table could have problems with water yield or go dry during these prolonged dry periods.

Figure 2-4B shows a water-level hydrograph from a well in East Hanover Township, Morris County, New Jersey. Periodic measurements have been made in this observation well since 1966. This well is used to monitor water levels in the glacial aquifer system within the Whippany River Basin. The declining water levels shown in this well are typical of those from wells located in this part of the Highlands and in wells in municipalities to the east within the basin. The declining water levels are a result of ground water withdrawals from the aquifer exceeding the natural recharge rate of the aquifer.



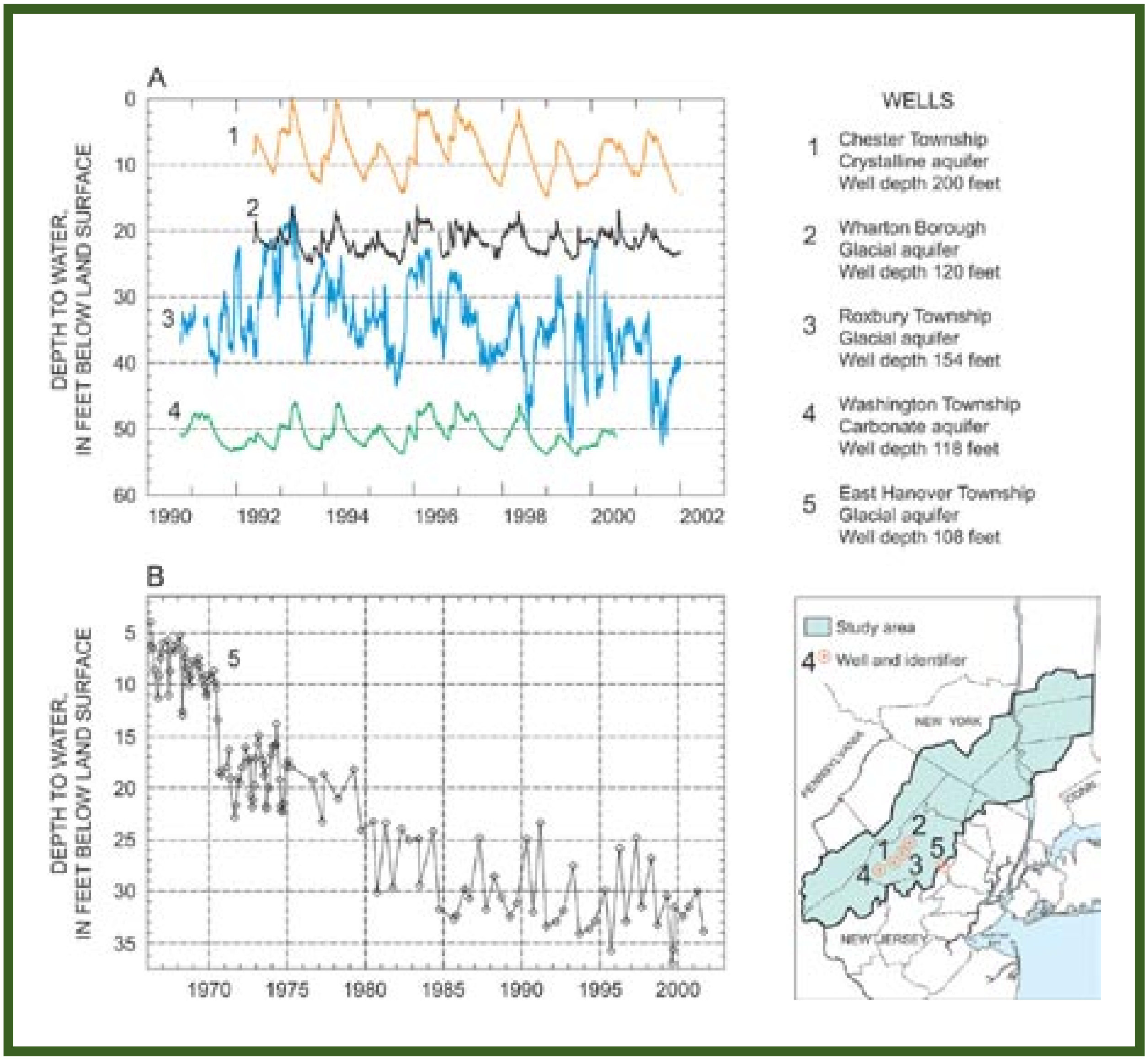



**Figure 2-4. Trends in ground water levels.** Hydrographs for five wells in Morris County, New Jersey, show (A) typical seasonal fluctuations in ground water levels in wells 1-4, and (B) long-term decline in the ground water level at well 5. Inset map shows the location of each well.

### KEY FINDINGS:

- **In 1995, more than 145 million gallons of water per day were withdrawn** from Highlands aquifers.
- **Water use data show that glacial aquifers are the most productive with 60 million gallons per day withdrawn. Crystalline, carbonate, clastic, and Newark Basin aquifers combined produce approximately 56 million gallons per day.**
- **Total domestic withdrawals for 1995** in the Highlands region **are estimated to be approximately 30 million gallons per day.**
- **Long-term monitoring has recorded** water-level **declines of about 5 to 15 feet during drought conditions over the last decade.**
- **Water levels have declined locally as much as 25 to 30 feet since 1965 in the glacial aquifer system within the Whippany River Basin.** Declining water levels within the basin are the result of ground water withdrawals exceeding the natural recharge rate of the aquifer.

## SURFACE WATER—STREAMS, RIVERS, AND RESERVOIRS

The Highlands streams and rivers are a significant natural resource to communities both within and outside the Highlands. The rivers and streams within the Highlands are contained within seven major drainage basins: the Housatonic, Fishkill/Hudson, Croton/Hudson, Wallkill/Hudson, Passaic, Upper Delaware, and Raritan (Figure 2-5). The Housatonic River basin has only a small part of the river's upper reaches in the Highlands, and comprises less than 1 percent of the total Highlands area. The Fishkill/Hudson basin contains Fishkill Creek and Moodna Creek, both of which flow into the Hudson River. The Croton River and Peekskill Hollow Creek discharge to the Hudson River in the Croton/Hudson basin, which contains 10 reservoirs. The Wallkill/Hudson basin contains the Wallkill River, which flows northward out of the Highlands, is a Hudson River tributary, and a Highlands boundary. The largest Highlands tributary to the Wallkill River is Pochuck Creek. The Passaic basin has 16 reservoirs and is the largest of the Highlands basins, covering over 29 percent of the Highlands area. The major rivers of the Passaic basin completely or almost completely within the Highlands are the Pompton, Rockaway, Whippany, Pequannock, and Ramapo Rivers. The Hackensack and Passaic Rivers have only short reaches within the Highlands. The Upper Delaware basin has three major Highlands streams that discharge to the Delaware River: the Pequest River, the Musconetcong River, and Pohatcong Creek. The Highlands portion of the Raritan basin contains two reservoirs and parts of the Lamington River, North Branch Raritan River, and South Branch Raritan River.

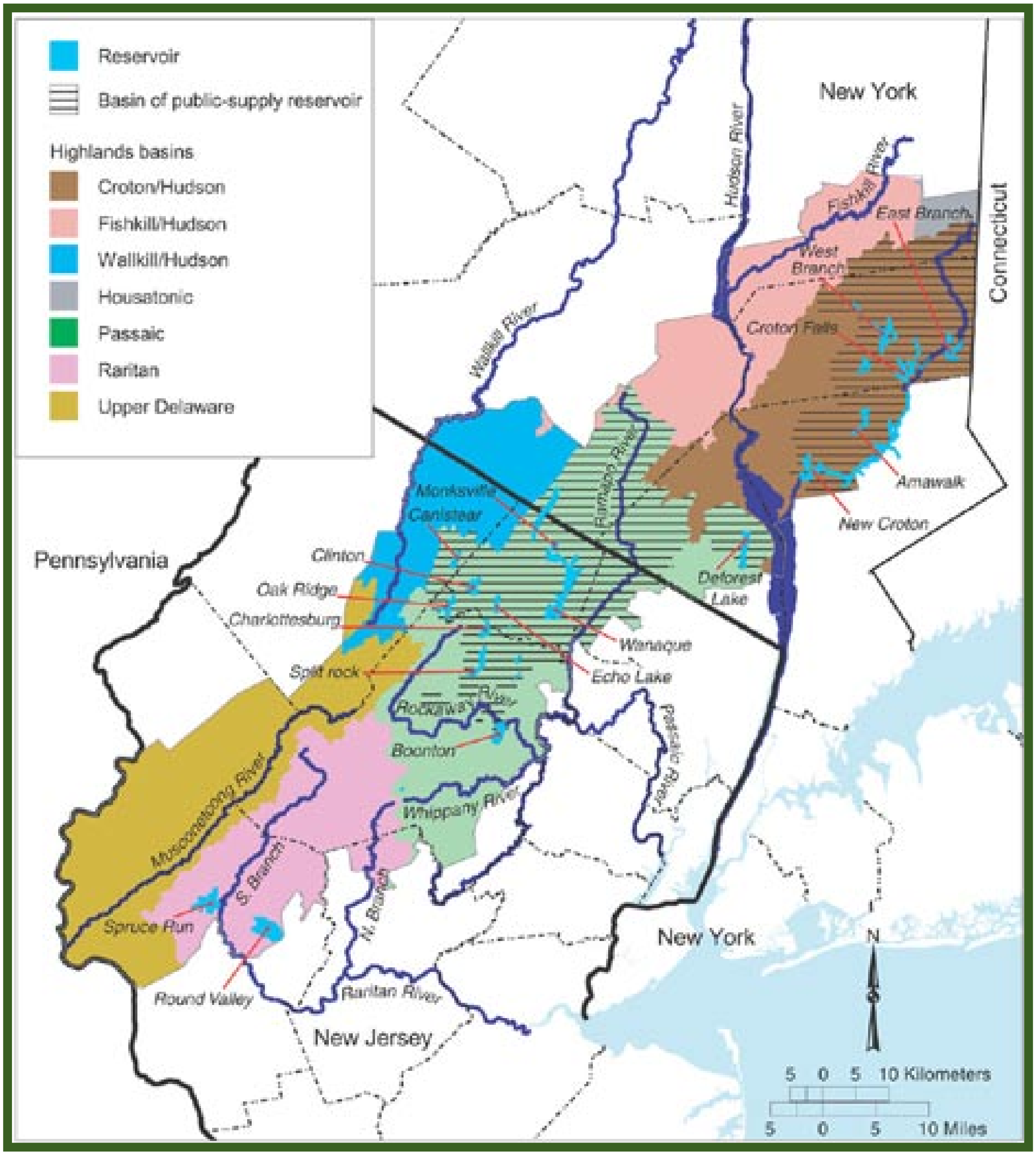
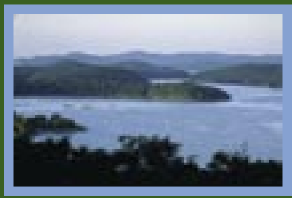



**Figure 2-5. Major reservoirs.** Seventeen major reservoirs are located within the Highlands study area. Drainage basins are shown for the public-supply reservoirs.





## SURFACE WATER USE

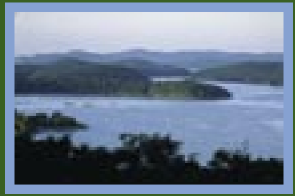
The use of Highlands streams and rivers was studied by collecting data on surface-water withdrawals for 1995, the year with the best available Highlands data. There was one exception to the use of 1995 water-use data: the data for the Croton Reservoir system in New York is from 1990 (Linsey and others 1999), because 1995 data could not be obtained. Withdrawals were categorized as irrigation, commercial, industrial, electric utility plant, mining, public supply, or flow augmentation. Highlands surface-water withdrawals for 1995 are estimated at more than 200 billion gallons (Table 2-1). Public-supply withdrawals accounted for 78.3 percent of total withdrawals, followed by flow augmentation (13.4 percent), and industrial (7.7 percent); the other four categories of use represented 0.6 percent of the total.

The Highlands streams, rivers, and reservoirs are an important water-supply source for many communities outside the Highlands (Figure 2-6). Highlands surface-water withdrawals for water-supply use were estimated to be 430.9 million gallons per day (Mgal/d) in 1995. Of this amount, more than 88 percent (379.3 Mgal/d) was transferred to communities outside the Highlands. New York City and 98 New Jersey communities outside the Highlands use Highlands surface water as part of their drinking water supply.

**Table 2-1.** Use of Highlands surface water, 1995 (Mgal/yr—million gallons per year; Mgal/d—million gallons per day)

| Type of use | Withdrawals (Mgal/yr) | Withdrawals (Mgal/d) | Use outside the Highlands (Mgal/d) |
|---|---|---|---|
| Commercial | 3.8 | 0.01 | -- |
| Electric utility Plant | 761.2 | 2.09 | -- |
| Flow augmentation | 26,827.5 | 73.50 | 48.2 |
| Industrial | 15,395.9 | 42.18 | -- |
| Irrigation | 469.8 | 1.29 | -- |
| Mining | 15.2 | 0.04 | -- |
| Public supply* | 157,276.8 | 430.90 | 379.3 |
| **Totals** | **200,750.2** | **550.01** | **427.5** |

*Part of the public supply withdrawals—those from the Croton Reservoir System—are from 1990.



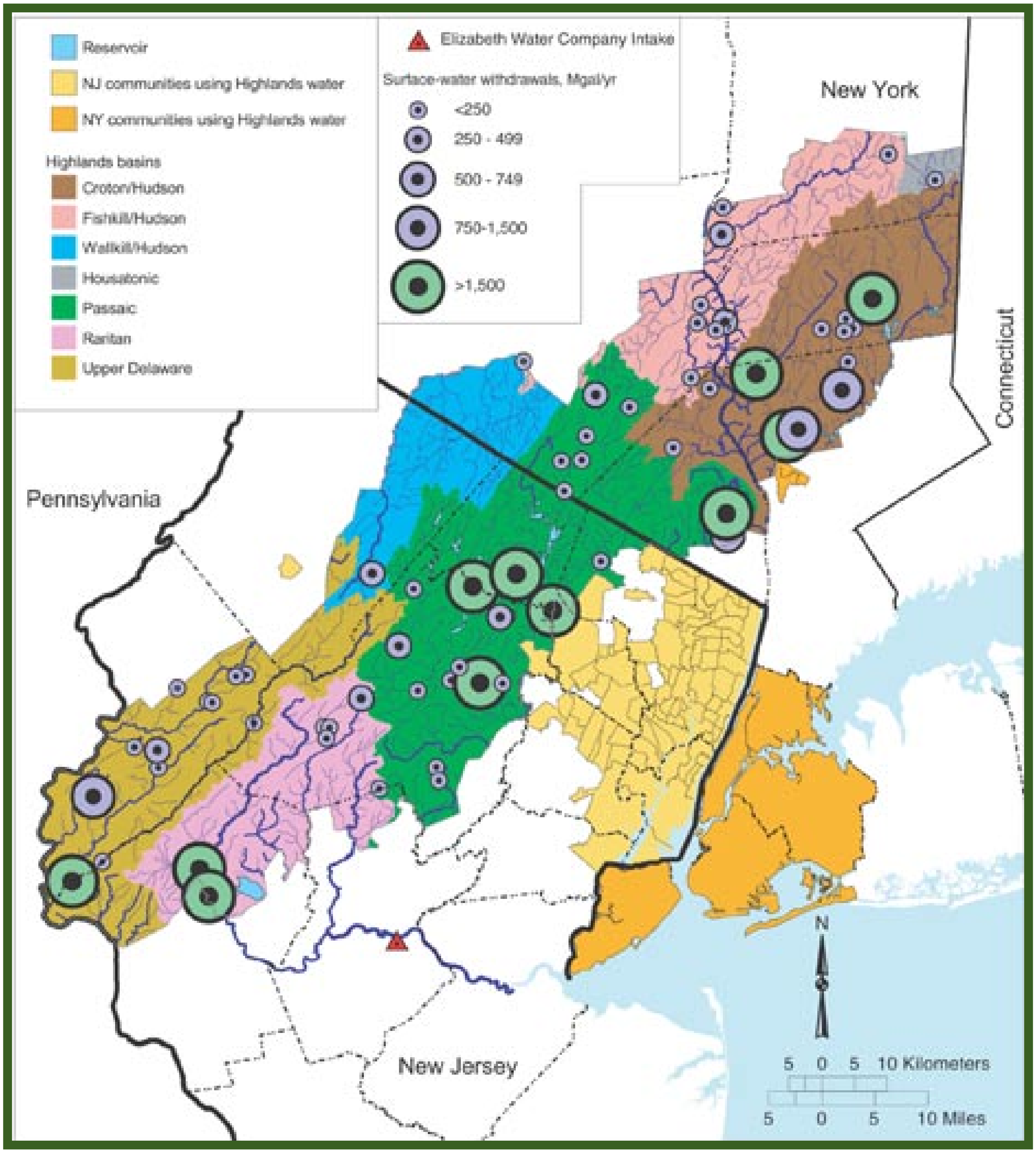



**Figure 2-6. Surface water withdrawals.** Highlands' streams, rivers, and reservoirs within seven major drainage basins supply communities within and outside the study area, including New York City.



## RESERVOIR STORAGE AND TRANSFER

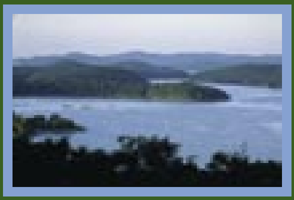
The storage of Highlands surface waters in reservoirs permits the year-round distribution of water for public use. The five major reservoir systems in the Highlands have a combined storage capacity of 323.6 billion gallons (Table 2-2). The 379.3 Mgal/d of Highlands surface water transferred in 1995 to out-of-Highlands communities for public water supply use, originated in either the Wanaque, Newark Water Department, Jersey City Water Department, or the Croton reservoir systems. Figure 2-5 shows the location of the major reservoirs within the Highlands study area.

Water withdrawn from the Croton Reservoir system supplies about 10 percent of New York City's water. Delaware Watershed Reservoir water that passes through the Croton System's West Branch Reservoir provides an additional 50 percent of the City's water supply. The Delaware (River) watershed reservoirs are located northwest of the Highlands, but water from these reservoirs is transferred via an aqueduct into the Highlands West Branch Reservoir—a part of the Croton system—which functions as a settling basin (Figure 2-5). The aqueduct delivers water into the northwestern end of the West Branch Reservoir, and after a residence time, an intake at the southern end of the reservoir returns "settled," less turbid water to the aqueduct on its way to New York City. In 1990, the aqueduct delivered 838 Mgal/d to the West Branch Reservoir (Linsey and others 1999).

**Table 2-2.** Highlands reservoir systems, storage capacity, yield, and 1995 withdrawals (Mgal/d—million gallons per day)

| Reservoir system | State | Type | Storage Capacity* (billion gallons) | Total Safe Yield* (Mgal/d) | Withdrawals 1995 (Mgal/d) |
|---|---|---|---|---|---|
| Wanaque | N.J. | Public supply | 36 | 173 | 149.7 |
| Newark Water Department | N.J. | Public supply | 14.4 | 49.1 | 40.6 |
| Jersey City Water Department | N.J. | Public supply | 115 | 56.8 | 43.6 |
| Croton | N.Y. | Public supply | 86.6 | 240 | 175.4** |
| Raritan Basin | N.J. | Public supply and flow augmentation | 66 | 160 | 48.2 |
| United Water New York | N.Y. | Public supply | 5.6 | Unknown | 6.3 |
| **Totals** | -- | -- | **323.6** | **678.9** | **463.8** |

*New Jersey reservoir data for storage capacity and total safe yield are from New Jersey Department of Environmental Protection and Energy (1992). The New York storage capacity data are from New York City Department of Environmental Protection (2002). New York total safe yield data are from Zimmerman (2001).
**Croton Reservoir System withdrawal data are for 1990 and are taken from Linsey and others (1999).



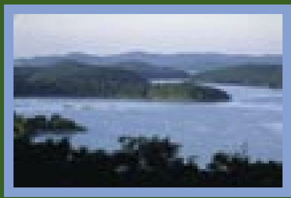


The Raritan Basin reservoirs are used for public water supply and flow augmentation. Flow augmentation is the transfer of water from a reservoir to a stream or river to meet a required minimum passing flow at a specified location or locations on that stream or river. The New Jersey State Water Supply Act of 1958 set minimum passing-flow requirements at three U.S. Geological Survey gauging stations outside the Highlands, but downstream of the Raritan Basin reservoirs: the South Branch Raritan River at Stanton (40 Mgal/d), the Raritan River at Manville (70 Mgal/d), and the Raritan River at Bound Brook (90 Mgal/d). These minimum passing flow requirements were established to ensure adequate flow in the Raritan River to support aquatic life, assure flow to downstream water users, and provide adequate flow to dilute pollution (New Jersey Water Supply Authority 2000).

Flow augmentation of the Raritan River by releases from the Raritan Basin are necessary because of the large quantity of water withdrawn by Elizabethtown Water Company from the Raritan River for public supply use. Elizabethtown Water Company withdrew 117 Mgal/d in 1995 from its intake on the Raritan River (Figure 2-6). The intake is downstream of the Stanton and Manville gauging stations, and upstream of the Bound Brook gauging station. Without flow augmentation, there would be times when Elizabethtown Water Company could not withdraw the amount needed for its public supply needs and still have the required minimum passing flows on the South Branch Raritan River and Raritan River.

A total distance of about 28 miles of the Raritan River has its flow augmented with water from the Raritan Basin reservoirs Spruce Run and Round Valley. Spruce Run Reservoir is filled naturally by Spruce Run Creek. Round Valley Reservoir was excavated on a hilltop above the South Branch Raritan River, has a small natural basin, and is filled mainly by water pumped up to it from the South Branch Raritan River (New Jersey Water Supply Authority 2000). Round Valley Reservoir has the largest storage capacity (55 billion gallons) of any New Jersey Highlands reservoir. Spruce Run and Round Valley reservoirs released an average of 48.2 Mgal/d in 1995 to meet the minimum required passing flows, and the released water was also a part of the 117 Mgal/d withdrawn from the Raritan River by Elizabethtown Water Company in 1995. The large natural drainage basin of Elizabethtown Water Company's intake and passing flow requirements prevent the quantification of the water released from the Raritan Basin reservoirs that is actually withdrawn for public water supply.

The Highlands reservoirs are especially important because of their ability to store water for use at critical times, such as during a prolonged drought. The ability of reservoirs to have sufficient storage capacity for such critical times is expressed as a reservoir's "safe yield." Safe yield is defined as the yield from a reservoir that can be continuously maintained throughout a repetition of the most severe drought of record, after compliance with required passing flows, and assuming no



significant changes in upstream patterns of water use (modified from New Jersey Department of Environmental Protection and Energy 1992, p. C-3).

Table 2-2 lists the documented storage capacities and safe yields for the Highlands reservoir systems. The safe yields are greater than the 1995 withdrawals, which indicates these reservoirs could meet public-supply demands even during the drought of record. This assumes the reservoir withdrawals for 1995 are representative of current mean annual withdrawals, and this also assumes that withdrawals during a drought equal to the drought of record would not increase significantly from the mean annual withdrawals. This assumption is reasonable since water-use restrictions during a drought emergency should decrease withdrawals. Reservoir withdrawals in 1995 from the Jersey City, Newark, and Wanaque systems ranged between 77 and 86 percent of published safe yield estimates. Reservoir withdrawals in 1990 from the Croton system were 73 percent of published safe yield estimates.

### KEY FINDINGS:

- **Surface-water withdrawals from Highlands reservoirs and streams were approximately 550 Mgal/d in 1995.** Public-supply withdrawals account for about 78 percent of the total withdrawals or 431 Mgal/d. Industrial use and streamflow augmentation comprise much of the remaining 22 percent.
- **Highlands surface water reservoirs are the major water-supply source for numerous communities outside the Highlands.** Approximately **88 percent (379 Mgal/d) of the 431 million gallons per day of surface water withdrawn for public supply use is transferred out of the Highlands** region to supply parts of New York City and 98 New Jersey municipalities.
- In addition to water that originates in the Highlands, **more than 838 million gallons per day is transferred from Delaware System reservoirs via aqueduct through the West Branch Reservoir within the Highlands on its way to the New York City area.** This water accounts for approximately 50 percent of New York City's water supply.
- **The major reservoir systems in the Highlands** including the Croton, Wanaque, Newark, Jersey City, and Raritan Basin **have a combined storage capacity of 324 billion gallons and a combined safe yield of about 679 million gallons per day. Total water withdrawals from these reservoirs was about 464 Mgal/d in 1995.**
- **Highlands reservoirs are especially important because of their ability to store water for use during critical times, such as prolonged drought.** Withdrawals from the Jersey City, Newark, and Wanaque reservoir systems in 1995 ranged between 77 and 86 percent of published safe yield estimates. Withdrawals from the Croton system in 1990 were 73 percent of published safe yield estimates.