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RESOURCE EVALUATION

This sheet describes water use, water budgets, and population changes in the Rancocas Creek study area. Population data for 1990 for the study area and changes in population during 1930-90 are presented. Water-use data are compiled; quantities of water withdrawn and consumed from the unconfined aquifers, the confined aquifers, and surface-water sources in the study area are estimated; and water budgets are calculated for three budget areas for 1986-95. The three budget areas are (1) the entire Rancocas Creek study area, (2) the Rancocas Creek Basin above the streamflow-gaging station, and (3) the Crosswicks Creek Basin above the streamflow-gaging station (fig. 1-3).

Population

The census data that are gathered at the beginning of each decade (decennial census) were used to describe population trends in the Rancocas Creek study area. The estimated total population of the study area at each decennial census beginning in 1930 is shown in figure 5-1. Population of the study area for each decennial census period was estimated by multiplying the reported population of each municipality by a percentage equal to the percentage of that municipality that coincides with the study area. The population was assumed to be evenly distributed throughout the municipality; this assumption may result in underestimation of the population in urban areas and overestimation of the population in rural areas. The 1990 population of the Rancocas Creek study area, land area of each municipality in the study area, and total estimated population of the study area are listed in table 5-1. The estimated population of the study area in 1990 was 521,273, which is about 6.7 percent of the total population of New Jersey in 1990 (New Jersey Department of Labor, 1991). From 1930 to 1990, the population of the Rancocas Creek study area increased 188 percent. The period of most rapid growth was from 1950 to 1970, when the population increased 79 percent.

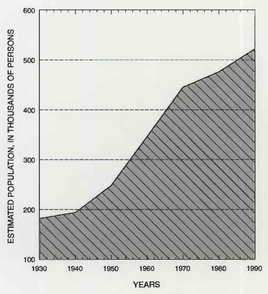

Figure 5-1. Estimated population in the Rancocas Creek study area, New Jersey, 1930-90. (Data from N.J. Department of Labor, 1991)

Table 5-1. Estimated population of the Rancocas Creek study area, New Jersey, 1990

[Population data from N.J. Department of Labor, 1991]

Municipality	Total population	Land area within study area (percent)	Estimated population within study area
Burlington County			
Beverly City	2,973	100	2,973
Bordentown City	4,341	100	4,341
Bordentown Township	7,683	100	7,683
Burlington City	9,835	100	9,835
Burlington Township	12,454	100	12,454
Chesterfield Township	5,152	100	5,152
Delanco Township	3,316	100	3,316
Delran Township	13,178	37	4,876
Eastampton Township	4,962	100	4,962
Edgewater Park Township	8,388	100	8,388
Evesham Township	35,309	75	26,482
Fieldsboro Borough	579	100	579
Florence Township	10,266	100	10,266
Hainesport Township	3,249	100	3,249
Lumberton Township	6,705	100	6,705
Mansfield Township	3,874	100	3,874
Medford Township	20,526	84	17,242
Medford Lakes Borough	4,462	100	4,462
Moorestown Township	16,116	22	3,546
Mount Holly Township	10,639	100	10,639
Mount Laurel Township	30,270	53	16,043
New Hanover Township	9,546	100	9,546
North Hanover Township	9,994	100	9,994
Pemberton Borough	1,367	100	1,367
Pemberton Township	31,342	100	31,342
Riverside Township	7,974	97	7,735
Shamong Township	5,765	3	173
Southampton Township	10,202	100	10,202
Springfield Township	3,028	100	3,028
Tabernacle Township	7,360	26	1,914
Westampton Township	6,004	100	6,004
Willingboro Township	36,291	100	36,291
Woodland Township	2,063	44	908
Wrightstown Borough	3,843	100	3,843
Camden County			
Berlin Township	5,466	40	2,186
Gibbsboro Borough	2,383	1	24
Voorhees Township	24,559	35	8,596
Mercer County			
East Windsor Township	22,353	5	1,118
Ewing Township	34,185	52	17,776
Hamilton Township	86,553	100	86,553
Hopewell Township	11,590	4	464
Lawrence Township	25,787	82	21,145
Trenton City	88,675	60	53,205
Washington Township	5,815	95	5,524
West Windsor Township	16,021	37	5,928
Monmouth County			
Allentown Borough	1,828	100	1,828
Millstone Township	5,069	32	1,622
Roosevelt Borough	884	84	743
Upper Freehold Township	3,277	100	3,277
Ocean County			
Jackson Township	33,233	6	1,994
Lacey Township	22,141	2	443
Manchester Township	35,976	40	14,390
Plumsted Township	6,005	89	5,344
Total	1,693,615		521,273

Water Use

Water supply in the Rancocas Creek study area comes from confined aquifers, unconfined aquifers, and surface-water sources. Most of the supply, however, comes from confined aquifers. Because available information was insufficient to determine whether wells tap the confined or unconfined parts of the aquifers, those wells downdip from the outcrop areas of the aquifer were considered to be confined, and those in the outcrop were considered to be unconfined. Well-screen depths and well logs only of wells in the outcrop of the Potomac-Raritan-Magothy aquifer system were examined further to determine whether the wells were in confined or unconfined aquifers.

Water use changes constantly as industries and businesses close down or start up and as the population distribution changes. Therefore, using the most recent complete yearly data available, rather than averaging the data over many years, provides the most accurate assessment of water use in the study area. Reported water-use values for 1995 were used to estimate annual withdrawals of water in the Rancocas Creek study area for public- and self-supplied domestic, irrigation, industrial, mining, and commercial use. These estimates are presented below.

The principal purpose of summarizing water use is to calculate the consumptive use (that part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment (Solley and others, 1983, p. vi)) and artificial recharge for the water budget. The percentage of the total water use that is consumptive depends on what the water is used for and its disposition after use. For example, consumptive use of domestic water that is discharged to the unconfined ground-water system or the surface-water system in the same basin from which it was withdrawn is considered to be 18 percent (Solley and others, 1983, p. 29). The remaining 82 percent of the withdrawal is assumed to be returned to one of these systems. When water is withdrawn and not returned to the ground-water system or surface-water system within the basin, consumptive use with respect to the basin is considered to be 100 percent.

When water is withdrawn from confined aquifers or from neighboring basins and released to a surface-water body or to septic systems within the basin, the water is artificial recharge to the unconfined system. For example, public-supply withdrawals from the confined aquifer system in Willingboro Township, Burlington County, totaled 1,637 Mgal during 1995, of which 18 percent (349 Mgal) is considered to be consumptive use and 82 percent (1,588 Mgal) is considered to be artificial recharge, because the water is discharged to Rancocas Creek. Values for consumptive use of unconfined ground water and of surface water and artificial recharge of confined ground water that is discharged within the basin for each water-use category are estimated and used in the water budget.

Water Budgets

The following water budgets provide estimated values (in inches per year) for the components of the hydrologic cycle in the Rancocas Creek study area for 1986-95. Although the flow and storage of water between different parts of the hydrologic system can change yearly, seasonally, and daily (as a result of storms), it is assumed that for the long-term average water budget presented here, no substantial long-term changes occur in the flow and storage of water. The water budget for the entire study area, which includes the Rancocas, Crosswicks, Assunpink, Assiscunk, Blacks, and Crafts Creek Basins, is discussed. Separate water budgets are calculated for the (1) Rancocas Creek Basin and (2) Crosswicks Creek Basin, upstream from their respective streamflow-gaging stations.

Water-Budget Equations

The hydrologic cycle in the study area can be represented by a long-term water budget in which inflows are balanced by outflows and, thus, no long-term change in storage occurs. The following budget analyses account for all water-system gains and losses in the budget areas. The water budget can be evaluated through use of two internal budgets and their corresponding balance equations: one that describes gains and losses to and from the land surface (or surface-water system), and another that describes gains and losses to and from the saturated, unconfined ground-water system. Many of the variables in the two internal budgets are difficult to evaluate. Recharge, a variable that cannot be measured or estimated except from other hydrologic data, was determined separately in both equations, and the two values were compared. The values of precipitation, direct runoff, base flow, evapotranspiration, and withdrawals by pumping were discussed in previous sections.

In order to calculate the amount of ground water and surface water moving through the budget area, a budget volume must be defined. A budget volume is the "package" of geologic material through which the movement of water is calculated. For the purposes of this analysis, the budget volume is defined by the extent of the unconfined aquifers and the shallow parts of the confining units in the study area (sheet 1, tables 1-2 and 1-3). It is assumed that neither surface- nor ground-water flow is gained or lost across the lateral boundaries of the study area. Generalized hydrogeologic sections through the study area that illustrate the budget volume and generalized flow patterns within the system are shown in figures 5-2 and 5-3. Figure 5-2 shows generalized flow in the unconfined aquifer in the southwest-northeast direction; figure 5-3 shows generalized flow from unconfined to confined aquifers in the northwest-southeast direction.

Water is introduced to the land surface and surface-water system through precipitation and artificial recharge. Artificial recharge is water that was pumped from confined aquifers, used, treated, and then released into the surface-water system, or water that was withdrawn from sources outside the study area but released to streams within the study area. Water is lost from the land surface through evapotranspiration, direct runoff, consumptive use of water withdrawn from surface-water bodies, and natural recharge to the ground-water system. These terms represent the components of the land-surface (surface-water-system) equation.

Water is introduced to the ground-water system through natural recharge and as artificial recharge from septic systems that treat wastewater that initially was pumped from confined aquifers or that originated outside the study area. Water is lost from the ground-water system through consumptive use of water withdrawn from the unconfined aquifer, leakage to confined aquifers and flow from the unconfined to the confined part of an aquifer, and ground-water discharge to surface-water bodies. These terms represent the components of the ground-water-system equation. The budget equation used for the land surface (surface-water system) is

$$P + R_{as} = Q_{dr} + ET + W_s + R_n \ ,$$

and the budget equation for the ground-water system is

$$R_{ag} + R_n = L + W_g + Q_g \ .$$

The variables used in the water budgets are

P = precipitation,
Q_{dr} = direct runoff,
Q_b = base flow,
ET = evapotranspiration,
L = leakage and flow to confined aquifers,
W_s = consumptive water use from surface-water withdrawals,
W_g = consumptive water use from unconfined-ground-water withdrawals,
R_{as} = artificial recharge to the surface-water system,
R_{ag} = artificial recharge to the ground-water system,
R_n = natural recharge to the aquifer, and
Q_g = ground-water discharge ($Q_b - R_{as} + W_g$) .

Values of Water-Budget Variables

The precipitation value (P) used in the water budget is consistent with reported values for the Coastal Plain of New Jersey. A single precipitation value was used for all budget areas and was based on the average recorded precipitation at the Pemberton and Moorestown weather stations during 10 years of record, 1986-95. This average value, 47.3 in., was used in the water-budget equations.

Total-discharge values were separated into base-flow (Q_b) and direct-runoff (Q_{dr}) components for use in the water-budget analysis. Extensive streamflow records are available for two of the major basins in the study area, the Rancocas Creek and Crosswicks Creek Basins. Discharge measurements from the North Branch Rancocas Creek at Pemberton, N.J. (01467000), streamflow-gaging station for water years 1986-95 were used in the water budget for the Rancocas Creek Basin. Discharge measurements from the Crosswicks Creek at Extonville, N.J. (01464500), streamflow-gaging station for water years 1986-95 were used in the water budget for the Crosswicks Creek Basin. Because only 29 percent of the study area drains to these two streamflow-gaging stations, the discharge components for the remaining area were estimated. Values from the low-flow correlations for the low-flow partial-record stations at the most downstream point on the major streams or rivers were selected. A weighted average based on the standard error of estimation of the three correlations listed in table 3-2 was used. Discharge for areas where no streamflow-gaging station or low-flow partial-record station was located was estimated from values for areas that are comparable with respect to geology and flow regime. Discharge values for the Rancocas Creek Basin, discharge values for the Crosswicks Creek Basin, and estimated values for the remainder of the study area then were weighted on the basis of the subbasin area. These values then were used in the water budget for the entire study area.

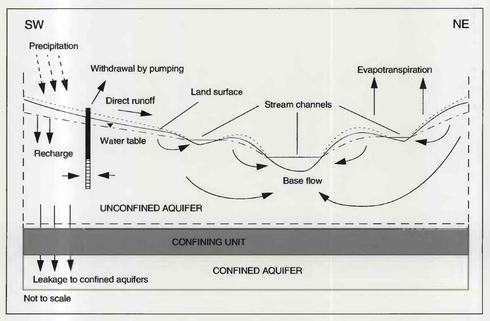

Figure 5-2. Generalized southwest-northeast hydrogeologic section through the Rancocas Creek study area, New Jersey, showing a schematic diagram of the hydrologic cycle. (Dashed line is budget-volume boundary.)

Public Supply

Although most of the Rancocas Creek study area is rural, many municipalities provide at least some of their residents with water for public supply. Public supply provides water for many purposes, including domestic, commercial, and industrial use, as well as public use (for example, fire protection, parks, and schools), and includes system water losses and maintenance. In the study area, public-supply deliveries for domestic use, commercial use, and industrial use account for 89 percent of the total water withdrawn for public supply. The remaining 11 percent is accounted for by public use and system water losses and maintenance. In this study, commercial and industrial withdrawals have been separated from withdrawals for domestic supply by examining NJDEP water-utilization reports and U.S. Census data on service, retail, and wholesale trade to estimate an average distribution of residential, commercial, and industrial use by township. In general, the estimated distribution in the northern and northwestern parts of the study area is 64 percent domestic, 33 percent commercial, and 3 percent industrial. In the more rural eastern and southeastern parts of the study area, the distribution is 90 percent domestic and 10 percent commercial. Commercial and industrial water-use values are discussed in later sections of this report.

More than 90 percent of public-supply deliveries for domestic use in the study area is from confined aquifers. During 1995, most deliveries in the study area (85 percent) were from the confined and unconfined parts of the Potomac-Raritan-Magothy aquifer system (table 5-2). Combined deliveries from the Wenonah-Mount Laurel aquifer, the part of the Stockton Formation that functions as an aquifer, and the Kirkwood-Cohansey and Englishtown aquifer systems during 1995 made up about 12 percent of all public water withdrawals for domestic use (table 5-2). During 1995, public-supply deliveries for domestic use totalled 7,090 Mgal--434 Mgal from the unconfined aquifers, 240 Mgal from surface water, and 6,416 Mgal from the confined aquifers (U.S. Geological Survey Site-Specific Water Use Data System, unpublished data on file at the U.S. Geological Survey office in West Trenton, N.J.). Use of unconfined ground water that is discharged outside the basin (248 Mgal) is 100 percent consumptive. Use of unconfined ground water and surface water that is discharged within the basin (426 Mgal) is considered to be 18 percent consumptive (Solley and others, 1993, p. 29). The total amount of public-supply deliveries in the Rancocas Creek study area consumed for domestic use during 1995 was 325 Mgal, or 0.027 in. over the study area. Artificial recharge to the unconfined-aquifer and surface-water system, primarily from deliveries from confined aquifers but also from withdrawals outside the study area that were discharged within the study area, was 5,650 Mgal, or 0.48 in. over the study area.

Domestic Self-Supply

Estimation of self-supplied domestic water use is difficult because withdrawals are not reported to any public agency. The amount of self-supplied domestic water withdrawn in the Rancocas Creek study area was approximated by estimating the percentage of the population in each municipality that is served by wells on the basis of U.S. Census data. This percentage was multiplied by a per capita domestic-water-use value of 85 gal/d (gallons per day) (J.P. Nawyn, U.S. Geological Survey, oral commun., 2001). Each township then was evaluated to determine the percentage of wells that likely would be drilled in the unconfined aquifer on the basis of hydrogeologic and well-construction information from published reports (Rush, 1968; Jablonski, 1968; Vecchioli and Palmer, 1962; Zapecza, 1989) and information from the USGS GWSI database. The percentage of all wells that were screened in unconfined aquifers was greater in townships in the eastern and southern parts of the study area than in townships in the central part of the study area, where many confining units crop out. Unconfined aquifers provide roughly half the self-supplied water withdrawn for domestic purposes in the study area.

Not all residents who use self-supplied water were assumed to treat their water with on-site septic systems. Information on the number of wells and septic systems and on the wastewater-treatment plants that serve each municipality was used to determine which townships were served solely by septic systems and which townships had both septic and sewer services. Because wells outnumber septic systems in three townships in the study area (Lacey Township, Hopewell Township, and Burlington City), a percentage of their self-supplied domestic water (14 Mgal) was assumed to be treated in a wastewater-treatment plant that discharges outside the study area. This water use is 100-percent consumptive. The total amount of self-supplied domestic water withdrawn from the unconfined aquifers and disposed of within the basin by means of septic systems or sewers was multiplied by the consumptive-use rate of 18 percent for domestic water used in New Jersey (Solley and others, 1993, p. 29). Total withdrawals from unconfined aquifers in the Rancocas Creek study area for self-supplied domestic use during 1995 are estimated to be about 1,044 Mgal, of which about 197 Mgal, or 0.017 in. over the study area, was consumptive use. (Small differences in totals are the result of independent rounding.) Total withdrawals from the confined aquifers are estimated to be about 1,245 Mgal, of which 1,021 Mgal, or 0.09 in. over the study area, was artificial recharge to the unconfined system or to surface water.

Commercial

Annual use of public- and self-supplied water in the Rancocas Creek study area for commercial facilities during 1986-95 is shown in table 5-3. Commercial water use includes water used by motels, hotels, restaurants, office buildings, and other commercial facilities (Solley and others, 1993, p. 30). In 1995, 11 percent of the water used for commercial purposes was self-supplied, whereas 89 percent was from public-supply deliveries. In the Rancocas Creek study area, only 8 percent of the water used for commercial purposes is from unconfined ground water. The largest withdrawals (92 percent) from both a confined and an unconfined aquifer are from the Potomac-Raritan-Magothy aquifer system. In 1995, 2,651 Mgal was used for commercial purposes--224 Mgal from unconfined ground water, 29 Mgal from surface water, and 2,398 Mgal from confined ground water (U.S. Geological Survey Site-Specific Water Use Data System, unpublished data on file at the U.S. Geological Survey office in West Trenton, N.J.). Of the total, 2,359 Mgal was from public supply and 291 Mgal was from self supply. Use of unconfined ground water that is discharged outside the basin (128 Mgal) is 100 percent consumptive. Use of unconfined ground water and surface water that is discharged within the basin (125 Mgal) is considered to be 4 percent consumptive (Solley and others, 1983, p. 33). Total consumptive use from unconfined aquifers and surface water in the Rancocas Creek study area for commercial purposes during 1995 was estimated to be 133 Mgal, or 0.011 in. over the study area. Artificial recharge from the confined aquifers to the unconfined-aquifer and surface-water systems was estimated to be 2,579 Mgal, or 0.22 in. over the study area.

Irrigation

Almost one-third of the land in the Rancocas Creek study area is used for agriculture, and most of that land is irrigated. Agricultural irrigation withdrawals are regulated by the State under an agricultural/horticultural certification program and withdrawals typically are estimated on the basis of pump capacity and time of pumping (Nawyn and Clawges, 1995). On average, 75 percent of water used for irrigation in the Rancocas Creek study area is withdrawn from surface-water sources. These withdrawals typically occur over about 4 months during the growing season. More than any other type of water use, irrigation is highly dependent on climatic conditions. Less irrigation is required in years that are cool and wet than in years that are hot and dry. Reported withdrawals for irrigation in the study area during 1986-95 are listed in table 5-4 (U.S. Geological Survey Site-Specific Water Use Data System, unpublished data on file at the U.S. Geological Survey office in West Trenton, N.J.).

Reported irrigation withdrawals for non-cranberry irrigation in the Rancocas Creek study area during 1995 were 3,037 Mgal: 90 percent (2,741 Mgal) from surface-water sources, 8 percent (240 Mgal) from confined ground water, and 2 percent (56 Mgal) from unconfined ground water. Water-use values reported for irrigation in 1995 were higher than those for all other years because of the extremely hot and dry climatic conditions. About 90 percent of water used for irrigation in New Jersey is consumed (Solley and others, 1993, p. 37). This coefficient was used to estimate consumptive use of all non-cranberry irrigation water in the study area. One Mgal (used to raise kcal) was considered to be non-consumptive. Consumptive water use, therefore, was 2,516 Mgal, or 0.21 in. over the study area. Artificial recharge from the confined aquifer system to the unconfined-aquifer and surface-water systems was 24 Mgal, or 0.002 in. over the study area.

The Rancocas Creek study area contains substantial cranberry acreage. Information from Farmland Assessment, from the Cranberry Marketing Committee, and from visual inspection of USGS 1:100,000-scale topographic maps was used to estimate the number of acres in cranberries that were used to grow cranberries. About 1,600 acres in the Rancocas Creek study area were used to grow cranberries; this is almost 50 percent of the cranberry acreage in the entire State. Reported withdrawals from ground-water and surface-water sources for cranberry irrigation in the study area during 1986-95 are listed in table 5-5 (U.S. Geological Survey Site-Specific Water Use Data System, unpublished data on file at the U.S. Geological Survey office in West Trenton, N.J.).

Because cranberries have unique water requirements, estimation of consumptive water use is difficult. Cranberries require water for three purposes: frost protection on cold nights, cooling and irrigation during the summer, and harvesting. Cranberries are grown in bogs, which are constructed adjacent to streams. Reservoirs upstream from the bogs hold water until it is needed for one of the above purposes. For frost protection, the bogs are flooded from December to early spring to a depth of about 18 in. Irrigation takes place during the summer months to cool and to meet the nutritive needs of the plants. Plants are irrigated in the early morning or evening to reduce the amount of water lost to evapotranspiration. Cranberries are harvested in September and October, when the bogs are again flooded with 6 to 18 in. of water to completely cover the berries and to allow the farmers to harvest more easily. (This information was provided by Joseph Darlington (American Cranberry Growers Association, oral commun., 1992.)

Most of the water used to produce cranberries is not consumed. Evapotranspiration and irrigation during summer consume the most water, but evaporation is naturally low during the flooding periods in fall and winter. Recharge to the aquifer takes place when the bogs are flooded. The release of water from the bogs in spring and after harvesting returns a substantial amount of water to the system. Therefore, although the cranberries use a large amount of water each year, comparatively little is consumed. Data on the actual amount of water that cranberries consume is scarce, but Clawges and Titus (1993, p. 77) consider cranberry growing to be primarily non-consumptive. Also, calculations based on the number of acres used to grow cranberries, the amount of product produced per acre, estimates of evapotranspiration rates, and the amount of water used to flood and irrigate the land yield a consumptive rate of 0.19 (J.P. Nawyn, U.S. Geological Survey, oral commun., 2001).

For the purpose of this study, cranberry irrigation is assumed to be non-consumptive. In 1995, 28,230 Mgal, or 2.4 in. over the entire basin, from confined, unconfined, and surface-water sources was used to grow cranberries in the Rancocas Creek study area. Artificial recharge from the confined aquifer to the unconfined-aquifer and surface-water system was 343 Mgal, or 0.029 in. over the study area.

Industry

Annual use of public- and self-supplied water in the Rancocas Creek study area by industries during 1986-95 is shown in table 5-6. In 1995, 69 percent of the water used for industrial purposes was self-supplied, and the remaining 11 percent consisted of public-supply deliveries. Most of the industries are in townships along the Delaware River in the western and northwestern parts of the study area; therefore, most of the water used (98 percent) is withdrawn from the confined and unconfined parts of the Potomac-Raritan-Magothy aquifer system. Surface water had been a major source until several businesses closed in 1995. During that year, 1,656 Mgal of water was withdrawn for industrial use--16 Mgal from unconfined ground water, 1,614 Mgal from confined ground water, and 26 Mgal from surface water. Of the total, 1,471 Mgal is self-supply and 185 Mgal is public-supply deliveries (U.S. Geological Survey Site-Specific Water Use Data System, unpublished data on file at the U.S. Geological Survey office in West Trenton, N.J.). Use of unconfined ground water that is discharged outside the basin (11.6 Mgal) is 100 percent consumptive. Use of the water withdrawn for industrial purposes from unconfined ground water and surface water that is discharged within the basin (30.4 Mgal) is considered to be about 8 percent consumptive (Solley and others, 1993, p. 45). The total amount of water consumed for industrial purposes in the Rancocas Creek study area is 14 Mgal, or 0.001 in. over the study area. Artificial recharge to the unconfined aquifer or surface-water system from confined aquifers or from withdrawals outside the study area equals 1,489 Mgal, or 0.13 in. over the entire study area.

Mining

Annual water use for mining in the Rancocas Creek study area reported by sand and gravel companies during 1986-95 is shown in table 5-7. All of the water used in the study area for mining purposes is from surface-water sources. According to Solley and others (1993, p. 49), about 8 percent of the water withdrawn for mining purposes in New Jersey is consumed. In 1995, 1,521 Mgal of surface water was withdrawn for mining use (U.S. Geological Survey Site-Specific Water Use Data System, unpublished data on file at the U.S. Geological Survey office in West Trenton, N.J.), which results in a consumptive use of 122 Mgal, or 0.01 in. over the entire study area.

Total Water Use

Water for domestic use (both public- and self-supply) and for irrigation, industrial, commercial, and mining purposes accounts for all significant water use in the Rancocas Creek study area. Estimates of consumptive use of unconfined ground water and surface water in the study area for each water-use category are summarized in table 5-8. In the Rancocas Creek study area, irrigation of non-cranberry crops is the largest consumptive use and accounts for 76 percent of total consumption; public-supply domestic use is the second largest, at 10 percent of total consumption, and self-supplied domestic use is third, at 6 percent. Withdrawals of confined ground water in the study area are substantial; estimates of artificial recharge from these withdrawals and as a result of interbasin transfers are summarized in table 5-9. Public-supply withdrawals for domestic use account for 51 percent of the artificial recharge; withdrawals for commercial and industrial use constitute the second and third largest percentages, respectively.

Table 5-2. Reported annual deliveries for public-supplied domestic use from ground water and surface water in the Rancocas Creek study area, New Jersey, 1986-95

[Withdrawal data from U.S. Geological Survey Site-Specific Water Use Data System--unpublished data on file at the U.S. Geological Survey office in West Trenton, N.J.; all values in million gallons; all values rounded to the nearest million gallons; small differences in totals may be caused by independent rounding; MRPA, Potomac-Raritan-Magothy aquifer system; MLRW, Wenonah-Mount Laurel aquifer; EGLS, Englishtown aquifer system; CKKD, Kirkwood-Cohansey aquifer system; SCKN, Stockton Formation; SW, surface water; GW, ground water; --, no reported withdrawals]

Year	Unconfined ground water MRPA	CKKD	SCKN	Total	Confined ground water MRPA	MLRW	EGLS	Total	Surface water	Total (GW and SW)	Percentage of total withdrawals from unconfined ground water
1986	220	10	116	345	5,129	650	62	5,841	455	6,641	5
1987	332	11	50	392	5,309	604	55	5,968	576	6,936	6
1988	127	38	40	204	5,898	674	71	6,642	407	7,253	3
1989	219	37	57	313	6,178	699	68	6,945	426	7,684	4
1990	299	39	70	408	6,023	711	32	6,766	458	7,632	5
1991	562	39	80	680	5,557	718	73	6,348	379	7,407	9
1992	293	68	71	433	5,470	682	67	6,220	--	6,653	7
1993	269	40	70	380	5,036	609	42	5,686	173	6,239	6
1994	192	42	59	293	5,381	539	177	6,096	383	6,772	4
1995	343	38	54	434	5,653	584	179	6,416	240	7,090	6

Table 5-3. Reported annual public-supplied and self-supplied withdrawals by commercial users from ground water and surface water in the Rancocas Creek study area, New Jersey, 1986-95

[Withdrawal data from U.S. Geological Survey Site-Specific Water Use Data System--unpublished data on file at the U.S. Geological Survey office in West Trenton, N.J.; all values in million gallons; all values rounded to the nearest million gallons; small differences in totals may be caused by independent rounding; MRPA, Potomac-Raritan-Magothy aquifer system; MLRW, Wenonah-Mount Laurel aquifer; EGLS, Englishtown aquifer system; CKKD, Kirkwood-Cohansey aquifer system; HPPM; undifferentiated Holocene, Pleistocene, Pliocene, and Miocene; SCKN, Stockton Formation; SW, surface water; GW, ground water; --, no reported withdrawals; <, less than]

Year	Unconfined ground water MRPA	MLRW	CKKD	HPPM	SCKN	Total	Confined ground water MRPA	MLRW	EGLS	Total	Surface water	Total (GW and SW)	Percentage of total withdrawals from unconfined ground water
1986	113	--	2	13	43	172	2,136	117	7	2,260	103	2,535	7
1987	171	--	11	17	32	230	2,050	115	6	2,172	116	2,518	9
1988	65	2	20	19	20	127	2,345	117	9	2,471	100	2,698	5
1989	113	<1	18	2	38	171	2,561	135	12	2,708	103	2,982	6
1990	154	1	7	--	33	194	2,547	132	5	2,684	80	2,959	7
1991	290	1	7	--	15	312	2,036	125	23	2,185	71	2,567	12
1992	151	--	16	--	11	179	2,030	117	20	2,167	12	2,357	8
1993	139	--	8	--	12	159	1,913	115	14	2,042	30	2,230	7
1994	99	--	8	--	38	145	2,233	98	33	2,364	48	2,558	6
1995	177	--	10	--	37	224	2,271	88	39	2,398	79	2,651	8

Table 5-4. Reported annual withdrawals for non-cranberry irrigation from ground water and surface water in the Rancocas Creek study area, New Jersey, 1986-95

[Withdrawal data from U.S. Geological Survey Site-Specific Water Use Data System--unpublished data on file at the U.S. Geological Survey office in West Trenton, N.J.; all values in million gallons; all values rounded to the nearest million gallons; small differences in totals may be caused by independent rounding; MRPA, Potomac-Raritan-Magothy aquifer system; MLRW, Wenonah-Mount Laurel aquifer; EGLS, Englishtown aquifer system; CKKD, Kirkwood-Cohansey aquifer system; SCKN, Stockton Formation; SW, surface water; GW, ground water; --, no reported withdrawals; <, less than]

Year	Unconfined ground water MRPA	CKKD	SCKN	Total	Confined ground water MRPA	MLRW	EGLS	Total	Unspecified ground water	Surface water	Total (GW and SW)	Percentage of total withdrawals from unconfined ground water
1986	<1	99	13	112	200	145	--	345	4	1,756	2,217	5
1987	<1	130	13	143	275	78	20	373	--	1,136	1,692	8
1988	<1	119	13	132	262	105	40	407	--	1,618	2,157	6
1989	--	7	7	14	51	26	26	103	--	488	605	2
1990	8	9	9	26	132	50	29	211	--	983	1,220	2
1991	<1	17	20	37	108	40	35	183	--	1,415	1,635	2
1992	7	12	7	26	134	56	32	222	--	1,003	1,251	2
1993	14	338	16	368	129	47	37	213	--	1,507	2,088	18
1994	6	16	11	33	126	151	37	314	--	1,338	1,685	2
1995	15	29	12	56	93	65	82	240	--	2,741	3,037	2

Table 5-5. Reported annual withdrawals for cranberry irrigation from ground water and surface water in the Rancocas Creek study area, New Jersey, 1986-95

[Withdrawal data from U.S. Geological Survey Site-Specific Water Use Data System--unpublished data on file at the U.S. Geological Survey office in West Trenton, N.J.; all values in million gallons; all values rounded to the nearest million gallons; small differences in totals may be caused by independent rounding; PNPN, Piney Point aquifer; CKKD, Kirkwood-Cohansey aquifer system; SW, surface water; GW, ground water; --, no reported withdrawals]

Year	Unconfined ground water CKKD	Confined ground water PNPN	Surface water	Total (GW and SW)	Percentage of total withdrawals from unconfined ground water
1986	374	--	14,904	15,278	3
1987	773	--	16,670	17,443	4
1988	1,061	--	17,191	18,252	6
1989	593	--	16,603	17,196	3
1990	511	10	16,379	16,900	3
1991	232	10	17,161	17,403	1
1992	41	10	10,361	10,412	0.4
1993	29	10	11,126	11,165	.3
1994	370	10	14,593	14,973	2
1995	1,433	343	26,454	28,230	5

Table 5-6. Reported annual public-supplied and self-supplied withdrawals by industrial users from ground water and surface water in the Rancocas Creek study area, New Jersey, 1986-95

[Withdrawal data from U.S. Geological Survey Site-Specific Water Use Data System--unpublished data on file at the U.S. Geological Survey office in West Trenton, N.J.; all values in million gallons; all values rounded to the nearest million gallons; small differences in totals may be caused by independent rounding; MRPA, Potomac-Raritan-Magothy aquifer system; MLRW, Wenonah-Mount Laurel aquifer; SW, surface water; GW, ground water]

Year	Unconfined ground water MRPA	MRPA	Confined ground water MLRW	Total	Surface water	Total (GW and SW)	Percentage of total withdrawals from unconfined ground water
1986	10	1,979	11	1,990	1,644	3,644	0.3
1987	16	1,978	10	1,988	926	2,930	.6
1988	16	1,871	10	1,881	949	2,836	.2
1989	18	2,137	49	2,186	1,441	3,645	.5
1990	20	1,983	57	2,040	1,189	3,249	.6
1991	26	1,777	3	1,780	1,412	3,217	.8
1992	14	1,804	3	1,807	4,604	6,426	.2
1993	13	1,189	6	1,195	8,348	9,556	.1
1994	9	1,652	11	1,663	6,782	8,453	.1
1995	16	1,599	15	1,614