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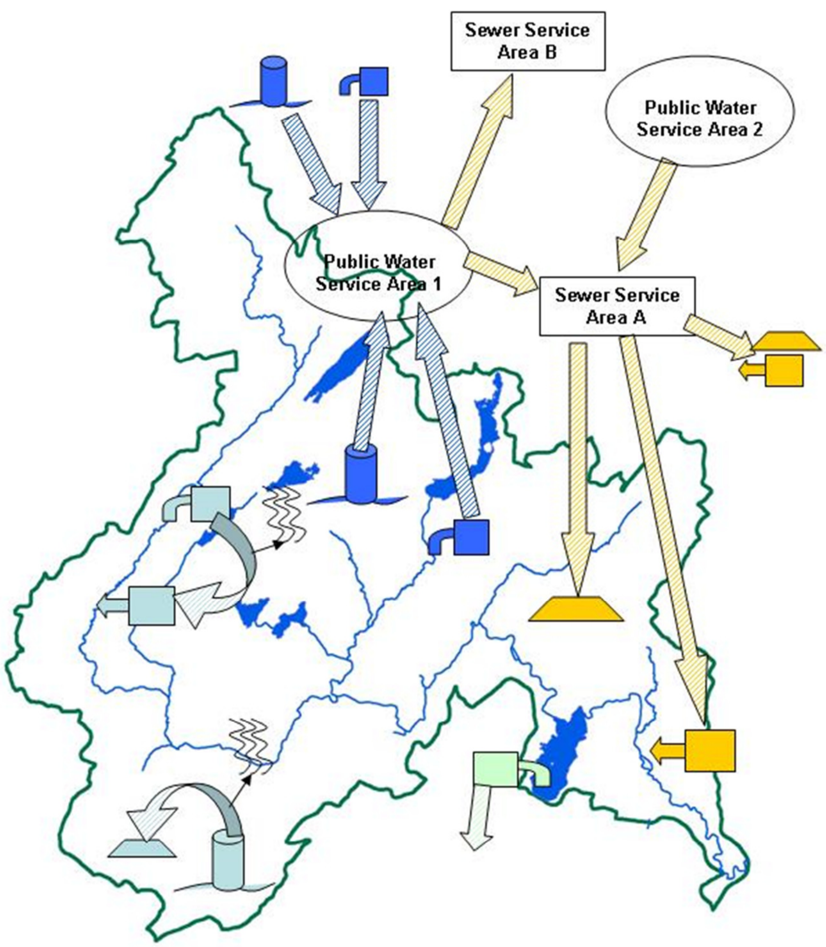
Technical Memorandum 13-3

Using the Stream Low Flow Margin Method to Assess Water Availability in New Jersey's Water-Table-Aquifer Systems



New Jersey Department of Environmental Protection

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NEW JERSEY GEOLOGICAL & WATER SURVEY

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On the cover: Schematic showing depletive and consumptive inputs and outputs to a watershed as defined by the stream low flow margin method to assess water availability. Withdrawals are in blue and wastewater returns are in yellow. Conveyances are shown by arrows.

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Using the Stream Low Flow Margin Method to Assess Water Availability in New Jersey's Water-Table-Aquifer Systems

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Epigrams:

“A good plan implemented today is better than a perfect plan implemented tomorrow."
— attributed to General George S. Patton

“Multiple functions can be served by a single volume of water in a well-managed watershed. On-site uses, the most important of which is rain-fed agriculture, benefit from water that in most cases would not otherwise enter the economy. Streamflow uses are often nonconsumptive in that the water remains available for further exploitation downstream, but they must still be counted among the demands made on the total supply.”
— Ambroggi, 1980.

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Using the Stream Low Flow Margin Method to Assess Water Availability in New Jersey's Water-Table-Aquifer Systems

Abstract

The stream low flow margin method is a water-table-aquifer-system-based water-budget method designed to estimate water availability for water-supply planning. It is based on the potential impact of depletive and consumptive water use on streamflow during ecologically-critical low-flow periods. It assumes that a percentage of streamflow can be removed without adversely affecting stream ecology. For this application, the water-table-aquifer system is defined as including both the water-table (unconfined) aquifer and surface water that is not regulated as part of a reservoir safe-yield system.

The low flow margin is defined as the difference between a stream's 7Q10 flow (a typical drought flow) and the September median flow (a typical dry-season flow). Available water is defined as a percentage of this difference. These flow statistics should be based on a baseline time period free of major hydromodifications in the watersheds.

The amount of water currently lost from the watershed to depletive uses (water that is exported from a watershed) and consumptive uses (water that is lost to evaporation or transpiration) must be counted against the available water. The volume of water withdrawn and then returned to the watershed is not a net loss and is not counted against the available water. This report describes how to calculate the depletive and consumptive water loss using data available for New Jersey withdrawals and discharges.

The low flow margin method is not intended to replace more rigorous groundwater modeling or other detailed hydrogeologic-hydrologic assessment methods. Rather, it provides water-supply planners with an estimate of water availability. It is a screening tool that can identify watersheds with potential water-availability shortages that may require more detailed assessments. The method can be applied statewide with data that is typically available at the state level.

Overview of the Stream Low Flow Margin Method

The stream low flow margin method is a water-table-aquifer-system water-budget method (which includes the hydrologically connected surface water) designed to estimate water availability. It is intended for water-supply planning purposes and is one tool in a suite of water-availability assessment tools.

The method of water availability requires a four-step process:

1) Calculate the low flow margin in a watershed during a baseline period.
2) Determine what percentage of the low flow margin can be lost from the watershed without unacceptable ecological impacts (termed available water).
3) Calculate the volume of water lost to depletive and consumptive water uses at current and at full allocation use rates.
4) Calculate the volume of water that remains available for additional depletive and consumptive loss from the water-table-aquifer-system at current and full allocation use rates.

This report describes how to calculate the low flow margin (step 1) and the depletive and consumptive water loss (step 3). It does not provide an estimate of what percentage of the low flow margin can be lost without having undesirable impacts (step 2). As a result remaining available water is not calculated (step 4).

Total water-resource availability in any specific area is a function of the combined natural water-resource availability of the water-table-aquifer-system (discussed in this report), the confined aquifer system(s) (if present), and the reservoir safe-yield source(s) (if present), plus imported water including inter-basin transfers (if present) and non-consumptive discharges (if present). Water availability for any one of these sources is typically quantified using a specific set of tools and methods unique to each source. Hydrologic connections exist between them all and each methodology must account for those hydrologic interactions (for example, leakage to or from confined aquifers, or reductions of streamflow above safe yield reservoirs). The stream low flow margin method is intended to quantify only the water-table aquifer and non-safe-yield surface water; it does not quantify total availability in any one area. It takes into account the hydrologic interaction among the other water resources.

The total volume of water available for allocation is typically greater than the total water-resource availability because allocations are likely to include some non-consumptive component of use. The consumptive portion of total use may be large (as would be expected from a turf irrigation operation) or it may be non-existent (in-stream hydro-power electrical-generation operation). This variability must be accounted for when comparing water allocations to water availability.

The location of the non-consumptive return also affects water availability. If the non-consumptive return location is not in the same watershed as the withdrawal then the withdrawal is 100 percent consumptive with regards to that watershed. Non-consumptive returns that are not returned to the same watershed are referred to as depletive losses. A depletive loss to one watershed is an accretive gain to another.

In order to apply this methodology several assumptions are necessary. The assumptions should be reasonably conservative so as to not over- or under-estimate water availability.

Acknowledgements

The authors wish to acknowledge the contributions of several individuals who assisted with the development of this report. Robert Canace of NJGWS (retired) was instrumental in developing the initial concept of the stream low flow margin method and advocating for its development. Joe Mattle and Steve Doughty provided input from the New Jersey Department of Environmental Protection (NJDEP) Division of Water Supply and Geoscience (DWSG).

New Jersey Watersheds

A watershed is all the area that drains to a defined point. Accurate definition of watersheds is vital for programs that analyze and manage surface-water quality and quantity as a function of land use. For management purposes, large drainage areas are subdivided into smaller ones. Each drainage area is called a hydrologic unit. Each unit may be a valid watershed, or it may have upstream hydrologic units that drain into it. Past practice in New Jersey has termed these hydrologic units ‘watersheds’ even though some do not conform to the definition of a valid watershed. The Federal Government defines these hydrologic units through its Watershed Boundary Dataset (WBD) program (USGS and USDA, 2012).

Each successive level of subdivision is identified by a code that starts with the number of its parent hydrologic unit and adds additional digits as suffixes. Accordingly, watersheds with a greater number of digits represent a smaller geographical area. In the 1990's the land area of New Jersey was covered by twelve regional watersheds each with a unique 8-digit hydrologic-unit code. These regional watersheds are called HUC8 watersheds (or HUC8s) for convenience (fig. 1). Seaber and others (1987) delineated HUC8s for the entire nation.

Ellis and Price (1995) subdivided the HUC8s in New Jersey into 150 11-digit hydrologic units (HUC11s) (fig. 2) and 921 14-digit hydrologic units (HUC14s) (fig. 3). In 2008, the U.S. Environmental Protection Agency regrouped the drainage basins in a set of 12-digit hydrologic units (HUC12s) that are not totally conformable with the current HUC11 watersheds (Hoffman and Pallis, 2009).

NJDEP uses the hydrologic units for a variety of management purposes (fig. 4). They are grouped into 20 watershed-management areas (WMAs) (Cohen, 1997). NJDEP’s water-supply-planning process tends to be done on the WMA and HUC11 scales. The NJ Highlands Council, however, conducted its water-supply-planning process on the smaller HUC14s (NJ Highlands Council, 2008).

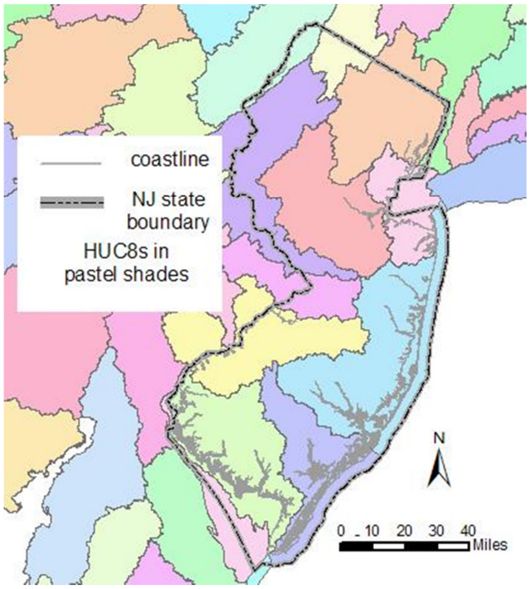

Figure 1. HUC8s in and near New Jersey.

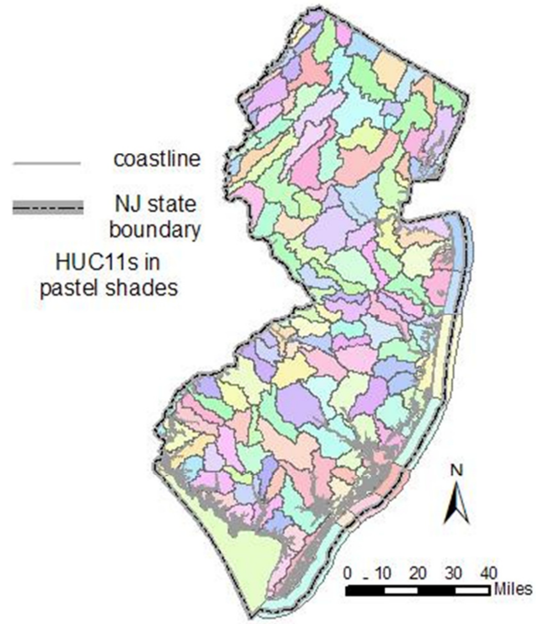

Figure 2. HUC11s in New Jersey.

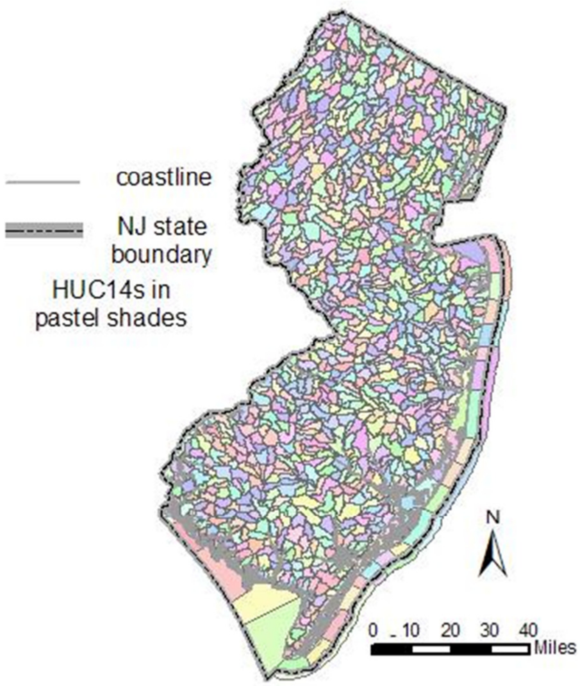

Figure 3. HUC14s in New Jersey

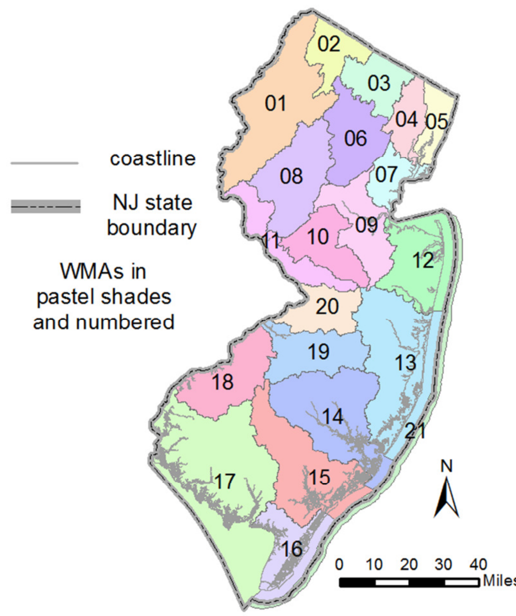

Figure 4. Watershed Management Areas in New Jersey

Low Flow Margin

The stream low flow margin method defines the low flow margin (LFM) as the difference between normal dry-season flow and drought flow during a time when streamflow is unaffected by withdrawals. A critical and typical dry season flow regime for aquatic ecology is the lowest monthly flow, which in New Jersey tends to occur in September. The September median flow is the "common" low flow that occurs in September; half of the September flows will be higher and half will be lower. The drought or low flow statistic traditionally used by New Jersey water supply planners is the seven-day, 10-year low-flow or 7Q10. 7Q10 is a 7-day average low-flow that has a 10 percent chance of occurring in a given year (Gillespie and Schopp, 1982). It can also be thought of as the annual seven-day minimum low-flow that is expected to occur on average once in ten years. It is often used to define an extreme low-flow condition. Instantaneous, daily, or multi-day flows lower than the 7Q10 may still occur, but with a different statistical reoccurrence interval. Figure 5 shows daily streamflow for the Flatbrook, New Jersey streamgage, along with September median and 7Q10 flows for 2010 and 2011. In September 2010 daily flows were below the long-term September median flow for most of the month. However, in September 2011, the daily flow never descended below the long-term September median.

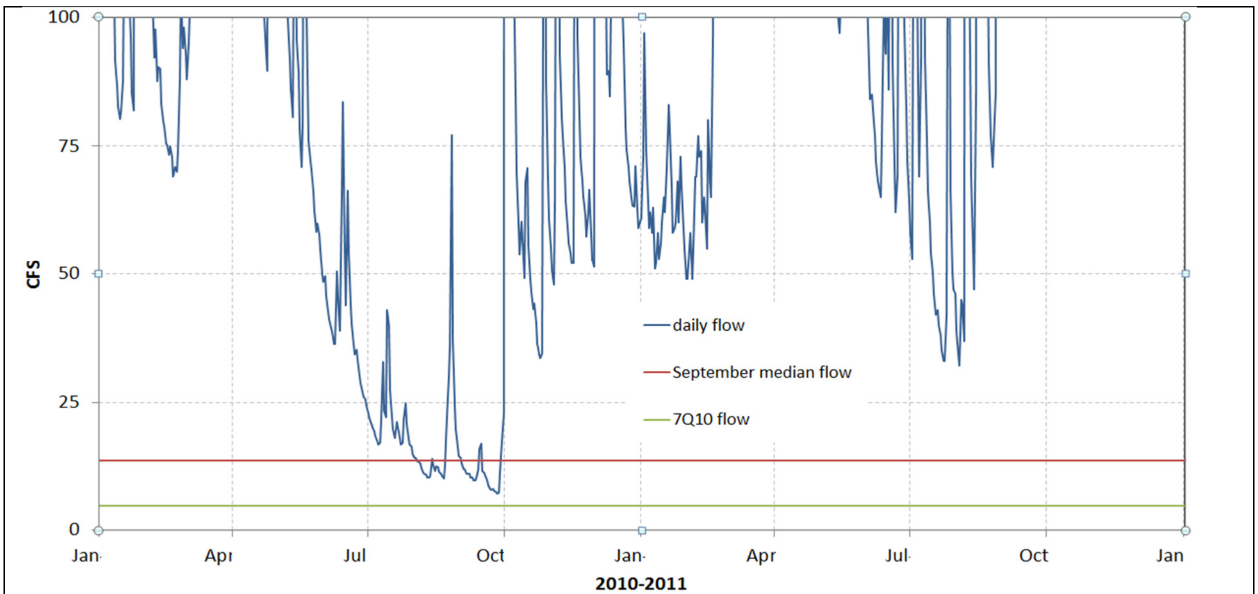

Figure 5. Daily streamflows at Flatbrook, New Jersey, 2010 – 2011.

It is important to calculate these flow statistics based on a period when the stream was not significantly affected by upstream withdrawals or impoundments. These baseline periods are known for many streams in New Jersey (Esralew and Baker, 2008).

The West Trenton Water Science Center of the U.S. Geological Survey estimated baseline September median flow and the 7Q10 flow for all HUC11 watersheds in New Jersey. The two flow statistics were first developed for continuous gaging stations with 20 or more years of observations and for low-flow partial-record gaging stations with five or more observations. Excluded from the analysis are gaging stations with significant, regulated upstream flow, stations where upstream-annual sewer discharges accounted for a significant part of the calculated low-flow statistic, and stations close to either significant groundwater withdrawals or surface-water diversions. These gaging-station-specific data served as the basis for developing statistics for all of the 151 HUC11s. Drainage area, land use, impervious cover and geology data for each HUC11 and gaging-station watershed are used to identify gaging stations that may be used to estimate the two low-flow statistics for each HUC11. Details on development of the low-flow statistics are provided in appendix A. Figure 6 shows the low flow margin per square mile of the HUC11watershed.

The method described in this report assumes that a part of the low flow margin can be continuously removed from the stream without creating unacceptable ecological impacts. The low flow margin is an estimate of the water in a stream at low-flow times. If the entire margin is removed continuously, then normal low-flows would become drought flows and drought flows would become even lower extreme low-flows. However, removing only a portion of this margin lowers streamflow to levels which the ecology has developed to periodically withstand.

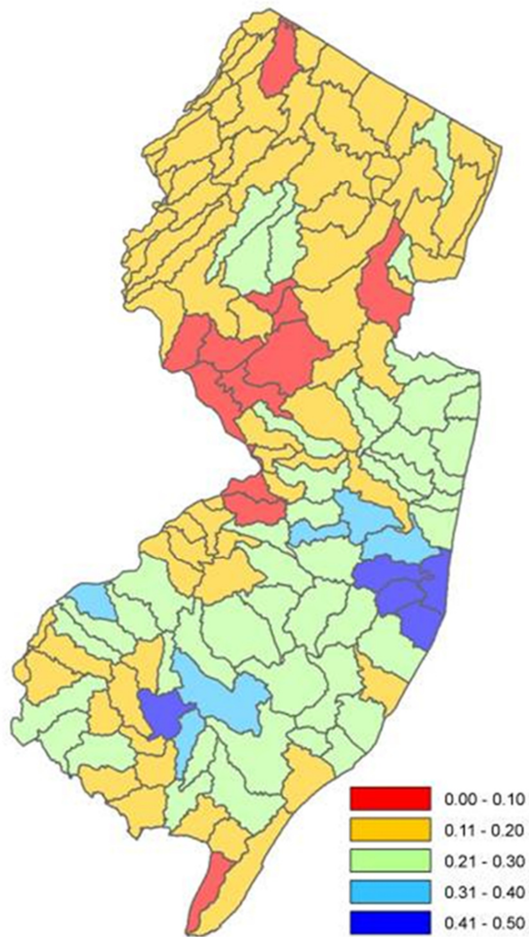

Figure 6. Estimated low flow margin for HUC11 watersheds (million gallons per day per mile^2).

What percentage of the low flow margin may be removed without unacceptable impacts is guided by an analysis of the sensitivity of the surface water and a policy decision on acceptable impacts. For example, the NJ Highlands Council applies three different percentages (5, 10, or 20 percent) depending on the predominant land use and ecological sensitivities of the watersheds (N.J. Highlands Council, 2008).

This report does not include an assessment of the appropriate percentage of the LFM that may be removed from New Jersey's watersheds without unacceptable impacts.

Estimating Depletive and Consumptive Losses

Overview

The stream low flow margin method is based on estimates of consumptive and depletive water use. Consumptive uses are those that result in evaporation and/or transpiration of water. These include both agricultural and non-agricultural irrigation, and some industrial and commercial processes. The term "depletive use" applies to the exportation of water from the watershed of interest (out of basin transfer). This is accomplished primarily by the transmission of water supply and wastewater. A watershed may gain water that is depletively removed from another watershed.

Water that is lost through consumptive and depletive water uses is removed from the source watershed. However, the nonconsumptive and nondepletive part of that water use is not removed and is available for use downstream within the same watershed. The total withdrawal in a watershed does not equate to water loss in the same watershed.

In order to use currently available data, the stream low flow margin method requires a number of assumptions:

- Monthly consumptive use estimates are derived from multiplying the reported total withdrawal by a monthly consumptive-use coefficient. This coefficient is a number between 0 and 1, with 0 representing no consumptive loss and 1 representing 100 percent consumptive loss. The coefficients are based on a literature search and are very similar to those defined by Shaffer and Runkle (2007) for the Great Lakes Region. Table 5 lists month-specific and annual average-consumptive-use coefficients for eight use groups: power generation, mining, industrial, commercial, public-supply, irrigation, agriculture, and unclassified. These use groups are further subdivided into 38 water-use types.

- Depletive use is the exportation of water from the watershed of interest. The exported water is no longer available for use in that watershed and is equivalent to a 100 percent consumptive use. However, depletive uses differ from consumptive ones because the water is not necessarily "lost" entirely to New Jersey. The depletive use is discharged in another watershed and becomes a gain for the receiving watershed. Any use of water could potentially result in a depletive loss for a watershed, particularly at smaller scales. However, at the HUC11 scale used in this method, only public drinking water supply uses (excluding individual or private domestic wells) are assumed to potentially deplete water.

- Public-supply uses typically are characterized by both consumptive and depletive losses. Consumptive uses result from irrigation and outdoor water use of public water supplies. Depletive uses occur by raw water transfers to a different watershed and by water-service and sewer-collection networks that move water from one HUC11 to a different HUC11. This combination of consumptive and depletive uses, along with inadequate mapping of water and sewer-service areas, creates complications in calculating the net depletive and consumptive loss for a HUC11. As a result, a different approach is needed to estimate the net impacts of public-supply water use in a HUC11. For the stream low flow margin method the net depletive and consumptive loss for public-supply use is defined as the difference between the total public supply withdrawal of fresh water and the total sanitary-sewer return (i.e. treated wastewater discharges) in a HUC11. The withdrawal data are taken from reports to the NJDEP Division of Water Supply and Geoscience. The sanitary-sewer-discharge data are taken from reports to the NJDEP Division of Water Quality. This approach includes all treated sanitary-sewer discharges to surface water and discharges to groundwater exceeding 20,000 gallons per day. The treated sanitary-sewer discharge is the non-consumptive part of the total public-supply use.

- The difference between the withdrawal and return in any one HUC11 is the net effect of depletive and consumptive uses on that HUC11. Nothing is determined about the distribution or source of water in the HUC11, only the net difference between withdrawals and discharges is quantified. However, it is precisely this net difference that affects the HUC11's water budget.

- Leakage from the water-distribution systems is assumed to be a relatively small volume. Likewise, inflow and infiltration into the sanitary sewer system is also assumed to be a relatively small volume. This is a reasonable assumption because September discharge volumes are used and this is typically a time of low water-table elevations and reduced inflow into sewer systems. Since statewide inflow and infiltration estimates are lacking, this assumption cannot be verified.

- Inaccuracies in the depletive and consumptive estimates are unavoidable for areas with public water and private-septic systems or areas with private domestic wells and sewer systems. In the first case, the nonconsumed part of water use, which returns to the water-table system, is not accounted for in the quantification of sewage returns. In the second case, the loss to on the water-table system caused by the pumpage by private domestic wells is not quantified but unconsumed water is quantified as part of sewage returns. The losses are assumed to be a small part of the HUC11's water budget.

- Leakage from or changes to discharge from an unconfined aquifer as a result of confined aquifer pumping are accounted for as a loss to the unconfined-aquifer water budget. The non-consumptive returns from confined-aquifer withdrawals are also accounted for (as a gain) to the unconfined aquifer.

- This method does not address the consumptive and depletive losses associated with regulated surface-water (RSW) withdrawals. These withdrawals include surface water withdrawals from rivers that are augmented by reservoir releases, diversions from on-stream reservoirs, and pumped storage intakes for potable-supply reservoir systems. Flows in the augmented rivers (for example, the Raritan River and the main stem Delaware River) are assumed to be maintained at levels adequate to protect both stream ecology and the diversion. Withdrawals from on-stream reservoirs are assumed to have captured earlier peak flows and stored them for later use. Withdrawals from pumped storage intakes are closely related to the safe yield of its reservoir system and assumed to not create unacceptable impacts. Water availability for these sites is calculated using other established methods (NJDEP, 2012). This category also includes unconfined-groundwater withdrawals that are close to and get most if not all of their water from regulated surface water. While, approximately 70 of the 10,000 withdrawal sites in New Jersey water-use databases are in the RSW category, these sites account for approximately 40 percent of total withdrawals.

- This method does account for returns to the water-table system (via sanitary-sewer discharges) that are supplied by RSW withdrawals.

- Confined-aquifer groundwater withdrawals are not directly included in this analysis. The impact of confined-aquifer withdrawals on water availability is dealt with by utilizing available groundwater models and other tools. Only the confined aquifers of the New Jersey Coastal Plain Physiographic Province are treated as confined in this analysis. All of the water withdrawals in northern New Jersey of semi-confined and locally confined origins are treated as unconfined. Induced leakage out of the unconfined aquifers in the Coastal Plain as a result of withdrawals from confined aquifers was estimated by the USGS using the NJ Coastal Plain RASA groundwater model (Voronin, 2003) for each of the 97 HUC11 watersheds all or partially underlain by Coastal Plain confined aquifers. The leakage values are summarized in Appendix B.

As new data become available that make these assumptions unnecessary, the analysis is expected to be updated.

Stream-base-flow Depletion

New Jersey's aquifers can store large amounts of water. If they are of adequate hydraulic transmissivity, they are reliable sources of water. However, withdrawing water from an unconfined aquifer may result in a reduction of groundwater discharge to nearby surface-water bodies. This phenomenon has been observed numerous times throughout New Jersey (Canace and Hoffman, 2009; Winter and others, 1998).

The specific magnitude and timing of the impact of the groundwater withdrawal on surface water depends on many factors. These include, but are not limited to, the distance of the well to the surface water, aquifer hydraulic conductivity, presence of confining units, depth and extent of the well's screened interval, magnitude of the diversion, and groundwater-recharge rates. These factors may have the net effect of reducing the magnitude of the groundwater withdrawal on the surface water and delaying the impact. A well adjacent and hydraulically connected to a surface-water body may have a 1-to-1 immediate impact of withdrawal to reduction in streamflow; however, this is not common. Canace and Hoffman (2009) conclude that 90 percent of groundwater pumpage is compensated for by a reduction in nearby stream base flow. This 90 percent factor is used as the streamflow depletion factor in the stream low flow margin method.

The stream low flow margin method focuses on the impacts of withdrawals on September flows because these are typically the lowest monthly flows in New Jersey. In order to account for any transient hydrologic responses, the stream low flow margin method uses the depletive and consumptive part of average June, July and August withdrawals. This volume is modified by the stream-depletion factor and assumed to reduce September surface-water flows by a corresponding value.

Table 1. Water Use Groups and Types with Annual and Monthly Consumptive-Use Coefficients

Water Use Group	Water Use Type	Consumptive Use Coefficients												
		Average Annual	Monthly											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Power generation	power generation	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	geothermal/ heat pump	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	hydro power	0	0	0	0	0	0	0	0	0	0	0	0	0
	thermal power	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026	.026
Mining	mining	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Industrial	air conditioning	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	dewatering	0	0	0	0	0	0	0	0	0	0	0	0	0
	cooling (industrial)	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	industrial	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	injection	0	0	0	0	0	0	0	0	0	0	0	0	0
	pollution control	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Commercial	commercial (non-commercial)	0.23	0	0	0	0.01	0.27	0.41	0.49	0.50	0.32	0.14	0	0
	fire	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	recreation (non-community)	0	0	0	0	0	0.1	0.1	0.1	0.1	0.1	0	0	0
Public-supply	bottling	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
	domestic	0.13	0	0	0	0.03	0.15	0.24	0.29	0.24	0.15	0.08	0	0
	medicinal value	0.13	0	0	0	0.03	0.15	0.24	0.29	0.24	0.15	0.08	0	0
	public non-community	0.13	0	0	0	0.03	0.15	0.24	0.29	0.24	0.15	0.08	0	0
	public-supply*	0.13	0	0	0	0.03	0.15	0.24	0.29	0.24	0.15	0.08	0	0
	institutional	0.13	0	0	0	0.03	0.15	0.24	0.29	0.24	0.15	0.08	0	0
	unused	0.13	0	0	0	0.03	0.15	0.24	0.29	0.24	0.15	0.08	0	0
	desalination	--	--	--	--	--	--	--	--	--	--	--	--	--
	other	0.13	0	0	0	0.03	0.15	0.24	0.29	0.24	0.15	0.08	0	0
	industrial - food processing	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Irrigation	golf	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	non-agricultural irrigation	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Agriculture	aquaculture	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	general agriculture	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	blueberries	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	cranberries	0.06	.001	0.001	0.001	.001	0.18	0.18	0.18	0.18	0.001	0.001	0.001	0.001
	field crops	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	greenhouse	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	agriculture irrigation	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	sod	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	tree fruit	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	vegetables, leaf crops	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
	Christmas trees	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Not Classified	not classified	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1

* - average of all public water systems in state, not used in analysis of depletion and consumption,

Calculation of Depletive and Consumptive Water Use

The following section describes in detail the steps and equations used to quantify depletive and consumptive (DC) water loss in a HUC11 based on available data. This enables consistent calculation. This approach applies to DC losses from unconfined-groundwater withdrawals and most surface-water withdrawals. It does not apply to withdrawals from:

- potable-supply reservoirs
- pumped-storage intakes
- streams augmented by reservoir releases
- wells hydraulically connected to and close to streams augmented by reservoir releases
- confined aquifers (except for returns to the unconfined system).

Figure 7 is a schematic showing the calculation process for a net depletive and consumptive loss for a HUC11. Table 2 is a summary of the steps used.

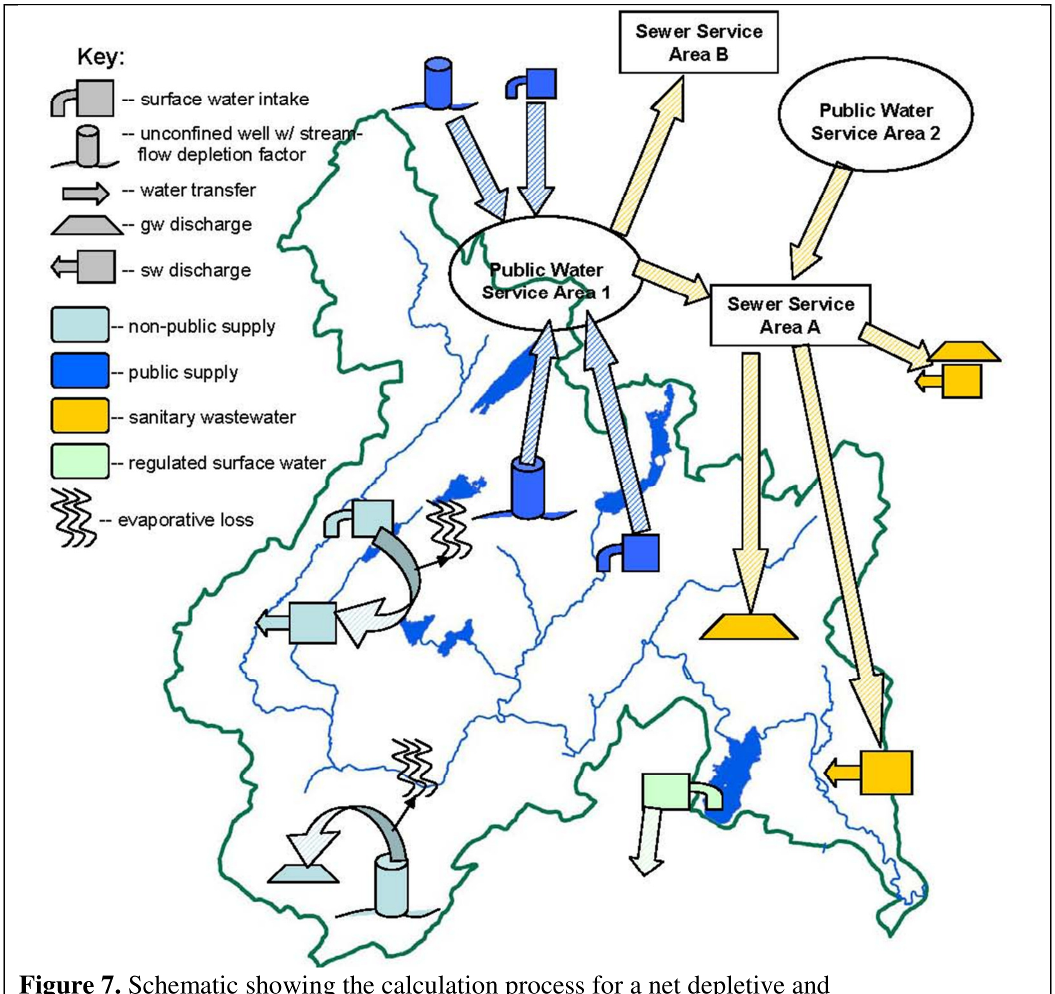

Figure 7. Schematic showing the calculation process for a net depletive and consumptive loss for a HUC11.

Table 2. Overview of depletive and consumptive loss calculations, by use and source of water.

Use of Water	Source of Water	Notes
Non-public-supply	Unregulated surface water	September withdrawals are modified by consumptive use coefficients because non-consumed volumes are assumed to be returned directly by user and not via sewer system. Thus only the estimated consumed volume is used in DC calculation.
	Unconfined-groundwater	Consumed volume used in DC calculations is the average of summer (June, July, August) total withdrawals (as modified by the streamflow depletion factor) minus the non-consumed part of average summer total withdrawals. This approach assumes non-consumed volume returned on site. This category includes estimated withdrawals by private domestic wells.
	Confined groundwater	*Withdrawn volumes are not directly accounted for. The average summer non-consumed volumes are assumed to be returned to the unconfined system directly by the user, not via sewer system. Thus the estimated summer non-consumed volume is used in the DC calculation (and serves to reduce the total loss).
Public-supply	Unregulated surface water	September total withdrawals are used in the DC calculation. Nonconsumed volumes assumed to be accounted for in sewer returns.
	Unconfined-groundwater	Loss to stream is the average of summer (June, July, August) total withdrawals (as modified by the streamflow depletion factor). Non-consumed volumes are assumed to be accounted for in sewer returns.
	Confined groundwater	**Withdrawn volumes are not directly accounted for. The non-consumed volumes are assumed to be accounted for in sewer returns and are not used in the DC calculation.
Public-supply & non-public-supply	Regulated surface water	Withdrawals are not accounted for in DC calculation. Water availability accounted for by other methods (for example, reservoir safe yield).

* Impact of total confined aquifer withdrawals on unconfined system is accounted for by an estimated leakage volume for all HUC11s in the New Jersey Coastal Plain underlain by one or more confined aquifers. The volumes are based on a U.S. Geological Survey groundwater model (appendix B).
** Domestic well withdrawals are treated as a non-public-supply unconfined-groundwater withdrawal.

Step 1. Categorize Withdrawal Sites

Withdrawal sites are first divided into non-public supply or public supply groups and then again by source of water; unregulated surface water, unconfined-groundwater, or confined water. These categories were developed based on three factors; 1) the degree to which the water is transferred within or between HUC11s, 2) the source of the water, and 3) the degree to which the source of the water is stored and/or regulated. DC water loss from each of these six categories is calculated differently.

This method does not address DC losses resulting from withdrawals for non-public and public-supply from regulated surface water. It does include non-consumptive returns from RSW potable-supply sources consisting of treated sanitary-sewer discharges.

Non-public-supply (NPS) withdrawals include agriculture, non-agricultural irrigation (e.g. golf course turf irrigation), commercial, industrial, mining, power generation and private domestic well uses from groundwater and unregulated surface-water sources. The withdrawal, use, consumptive loss, and discharge are assumed to occur at or near the same location and therefore in the same HUC11.

Public-supply (PS) withdrawals include all potable-supply uses from unconfined groundwater and unregulated surface-water sources. It assumes that withdrawn water, after treatment, may be used in a service area that spans more than one HUC11 (fig. 7). After use, the water may be collected by a sewer service area that also spans more than one HUC11. The net effect is that water may be withdrawn from one HUC11, used in a second, and discharged in a third. Both potable water and wastewater may move across HUC11 boundaries, causing any one HUC11 to potentially be a net loser or gainer of water. The exports outside of a HUC11 are referred to as depletive losses.

Confined-aquifer groundwater withdrawals are not directly included in this analysis. However the method does include an estimate of induced leakage from New Jersey Coastal Plain unconfined aquifers to deeper confined aquifers (appendix B). This applies to 81 HUC11s and is accounted for in Step 4 below as a loss to the unconfined water budget. The non-consumptive return from a confined-aquifer non-public-supply withdrawal is accounted for by adding the discharge back in to the unconfined HUC11 water budget. Confined-aquifer withdrawals for non-pubic supply sites are accounted for in Step 2c and for public-supply sites in Step 3 as part of the treated sanitary-sewer returns.

Step 2. Non-Public-Supply Withdrawals

Current depletive and consumptive loss for non-public-supply category withdrawals is calculated for each site in an individual HUC11. Losses are calculated as the difference between the withdrawal's impact on streamflow and the non-consumptive return. This is calculated differently for surface-water non-public withdrawals, unconfined-groundwater non-public withdrawals, and confined-groundwater non-public withdrawals.

Step 2a. Estimate September DC losses for each unregulated surface-water non-public-supply withdrawal:

$$swDCnps = \frac{(CUC)(swWith_{(Sept)})}{30}$$

where:

swDCnps = surface-water depletive use and non-consumptive loss for a specific non-public withdrawal for a given year (mgd).

$swWith_{(Sept)}$ = September surface-water withdrawal for the same year (mgm).

CUC = September consumptive-use coefficient specific to the use type. (1-CUC) is the non-consumptive return. See Table 1 for consumptive use coefficients.

Step 2b. Estimate September DC loss for each unconfined-groundwater non-public-supply withdrawal:

$$gwDCnps = \left[\left(\sum_{Jun.}^{Aug} gwWith \right) \Big/ 92 \right] * sfd - \left[\left(\sum_{Jun.}^{Aug} (1 - CUC) * gwWith \right) \Big/ 92 \right]$$

where:

gwDCnps = unconfined-groundwater depletive and consumptive loss for a specific non-public withdrawal site based on the average June, July and August withdrawals in a given year (mgd).

gwWith = unconfined-groundwater withdrawal for June, July and August for a specific site in the HUC11 for the same year (mgm).

CUC = June, July or August consumptive-use coefficient specific to the use type. (1-CUC) is the non-consumptive return. See Table 1 for consumptive use coefficients.

sfd = streamflow depletion factor of 0.9.

Step 2c. Estimate September returns resulting from summer confined groundwater non-public-supply withdrawals:

$$congw\mathrm{Re}turn = \left[\left(\sum_{Jun.}^{Aug} congwWith * (1 - CUC) \right) \Big/ 92 \right]$$

where:

congwReturn = the volume of water returned to the unconfined system from a specific confined-aquifer non-public site based on the average June, July and August withdrawal for the peak year in the HUC11 (mgd)

congwWith = the volume of confined-aquifer withdrawal for June, July and August for a specific site for the year in the HUC11 (mgm)

CUC = June, July or August consumptive-use coefficient specific to the use type. (1-CUC) is the non-consumptive return. See Table 5 for consumptive use coefficients.

Step 2d. For each HUC sum all September DC losses associated with non-public-supply withdrawals in that HUC11:

$$totalDCnps_{(HUC)} = \sum_{HUC} swDCnps + \sum_{HUC} gwDCnps - \sum_{HUC} congwReturn$$

where:

$totalDCnps_{(HUC)}$ = estimated September DC loss associated with all non-public-supply withdrawals in the HUC11 (mgd). It is the sum of all individual surface-water (Step 2a) and groundwater depletive-consumptive (Step 2b) withdrawals minus the sum of the individual non-consumptive returns of confined-aquifer withdrawals (Step 2c) for all non-public-supply category sites in the HUC11 for the year of the calculation.

Step 3. Public-supply Withdrawals

Current depletive and consumptive loss for public-supply-category withdrawals is calculated for each HUC11. Due to the water transfers that can occur in this category, total public-supply withdrawals for a HUC11 are compared to the total sanitary-sewer discharges (both surface water and groundwater >20,000 gpd) for the same HUC11. The difference between the two is assumed to be the net depletive and consumptive loss (or gain where the value is negative) for that HUC11.

For all unconfined-groundwater and non-RSW public-supply sites in HUC:

$$totalDCps_{(HUC)} = \left[\frac{HUCswWith_{(Sept)}}{30} + \frac{\left(\sum_{Jun}^{Aug} HUCgwWith \right) * sfd}{92} \right] - SewerReturns$$

where:

$totalDCps_{(HUC)}$ = net combined September groundwater and surface-water depletive and consumptive losses (or gains identified by a negative value) for all public-supply sites in a HUC11 for a given year (mgd)

$HUCswWith_{(Sept)}$ = September surface-water withdrawal for all public-supply withdrawals in the HUC11, for the same year (mgm)

$HUCgwWith$ = unconfined-groundwater withdrawals for June, July and August for all public-supply sites in the HUC11, for the same year (mgm).

sfd = streamflow depletion factor of 0.9

$SewerReturns$ = all discharges of treated waste water to the surface water and discharges to groundwater >20,000 gpd in the HUC11 for the same year (mgd)

<u>*Step 4. Combine Non-Public and Public-Supply Withdrawals*</u>

Depletive and consumptive losses for the non-public-supply and public-supply categories are combined with leakage for each HUC11 to get the total depletive and consumptive loss for the year.

$$totalDC_{(HUC)} = totalDCnps_{(HUC)} + totalDCps_{(HUC)} + Leakage_{(HUC)}$$

where:

$totalDC_{(HUC)}$ = the total net DC loss in a HUC11 from non-public and public-supply sources. A positive value is a net loss and a negative value is a net gain for that HUC11 (mgd).

$totalDCnps_{(HUC)}$ = estimated September DC loss associated with all non-public withdrawals in the HUC11 (mgd).

$totalDCps_{(HUC)}$ = net combined September groundwater and surface-water DC loss (or gain identified by a negative value) for all public-supply sites in the HUC11 for a given year (mgd).

$Leakage_{(HUC)}$ = Estimated flow to an underlying confined aquifer from unconfined aquifers in the HUC11 due to natural and induced leakage (mgd). (From Appendix B.)

Estimating Remaining Available Water

Remaining available water (RAW) is an estimate of how much water remains in a stream that may be removed without creating undesirable water supply and/or ecological impacts. This can be calculated using current withdrawals or withdrawals at full allocation rates. The process requires comparing the estimate of available water (the percentage of the low flow margin that can be removed from a stream without creating undesirable impacts) to the depletive and consumptive losses (calculated using the process described above) from the water-table system.

Current Remaining Available Water

The amount of currently available water in each HUC11 is a function of the current withdrawals and DC water losses. It is calculated as:

$$CurrentRAW_{(HUC)} = LFM_{(HUC)}*AP_{(HUC)} - totalDC_{(HUC)}$$

where:

$CurrentRAW_{(HUC)}$ = the amount of water available for new depletive and consumptive uses. The term does not account for allocated waters currently not being utilized.

$LFM_{(HUC)}$ = The HUC11's low flow margin (September median flow minus the 7Q10 flow) (mgd).

$AP_{(HUC)}$ = the percentage of the HUC11's low flow margin that can be lost by depletive and consumptive water uses without adverse hydrologic and ecologic impacts. This percentage is not quantified in this report (dimensionless).

$totalDC_{(HUC)}$ = the total net DC loss in a HUC11 from non-public and public-supply sources. A positive value is a net loss and a negative value is a net gain for that HUC11 (mgd).

Full-Allocation-Remaining Available Water

In general, the full-allocation depletive and consumptive losses are calculated using the same approach identified for the current use above. However, some assumptions regarding the distribution of allocation between multiple withdrawal sites, the timing of the maximum-month withdrawal, and the increased sanitary-sewer discharges have to be made. These assumptions were chosen conservatively to ensure that the peak impact of depletive and consumptive losses would not be underestimated. First, maximum-month allocations were divided proportionally based upon the allocation group's member sites that had a reported withdrawal for the most recent year of data. Second, the maximum groundwater-allocation withdrawal was assumed to occur in July and the maximum surface-water-allocation withdrawal was assumed to occur in September. Only July's groundwater withdrawal (not June or August) was used to estimate groundwater depletive and consumptive loses. Lastly, due to the difficulty in estimating the destination of increased public-supply sanitary-sewer discharges, current sanitary-sewer discharges were held constant. Private-domestic-well losses were kept the same as current losses. Together these allocation volumes were used with the above equations to estimate the net depletive and consumptive loss under full-allocation conditions.

For each HUC:

$$FARAW_{(HUC)} = LFM_{(HUC)} * AP(_{HUC)} - totalDC@FA_{(HUC)}$$

where:

$FARAW_{(HUC}$ = the amount of water in the HUC11 available for new depletive and consumptive uses after accounting for all allocated (currently used or unused) consumptive and depletive losses (mgd).

$LFM_{(HUC)}$ = The HIC11's low flow margin (September median flow minus the 7Q10 flow) (mgd).

$AP_{(HUC)}$ = the percentage of the HUC11's low flow margin that can be lost by depletive and consumptive water uses without adverse hydrologic and ecologic impacts. This percentage is not quantified in this report (dimensionless).

$totalDC@FA_{(HUC)}$ = total depletive and consumptive loss for a HUC11 assuming maximum monthly allocations are withdrawn (mgd).

Limitations to the Stream Low Flow Margin Method

The stream low flow margin method is a water-table-aquifer-system water-budget method to estimate water availability for water-supply-planning purposes. It is designed so that it can be developed for all of New Jersey's 151 HUC11 watersheds with existing or readily available data. It is intended to be used to identify areas with adequate water supply or areas with potential water-supply problems as a result of undesirable ecological stresses, but it is not intended to replace the more rigorous, but data-intensive methods that already exist. The selection of any statewide water-supply-availability method potentially has inherent limitations because it cannot precisely or comprehensively accounts for all water use functions of a HUC11 watershed, such as account for the specific nature of water flow, hydrogeology, or the specific location of particular diversion(s) and their impact(s) in a watershed. With this in mind it is important to recognize the limitations to this method, which include:

- The HUC11 aggregate approach does not identify specific impacts of individual diversions within the HUC11; it is not intended to replace the site-specific evaluations. For example, a large diversion adjacent to a small headwater stream may create unacceptable impacts, but if it were located at a downstream position the impact might be acceptable.
- Diversion(s) above a safe yield reservoir where increased depletive and consumptive losses would reduce reservoir inflow during a repeat of the drought-of-record and reduce available water in that reservoir system (i.e. reduce safe yield).
- The method does not account for existing regulatory programs that already limit the amount of available water or supersede this method.
- The method does not recognize variations within and between HUCs where hydrologic classifications are different, such as those identified in the Surface Water Quality Standards.
- Depending on the hydrologic characteristics of a basin and the specific appropriate percentages chosen, in some cases the low flow margin water availability could approach or even exceed the 7Q10 value for the basin. This could theoretically result in extremely low-flows occurring more frequently than acceptable.
- Passing flow requirements have been used by the Department to prevent diversions from causing harm during periods of extremely low flows at some sites (Hoffman and Domber 2013).
- The method only addresses water quantity; it does not account for water-quality limitations.
- Water available for depletive and consumptive use is quantified at the outlet of the HUC; therefore the actual available water at any specific location(s) in the upper reaches of the HUC may or may not be available.

Ultimately, the stream low flow margin method is part of a suite of water-availability quantification tools used to continually update water availability in New Jersey.

Conclusions

The stream low flow margin method is a water-table aquifer-system water-budget method designed to estimate water availability for water-supply-planning purposes at the HUC11 watershed scale. It assumes that some percentage of normal flow may be removed from a stream without adversely impacting stream ecology. It defines available water as a percentage of the difference between the normal dry-season flow and drought flow.

The method applies to water-table or unconfined aquifers and unregulated or non-safe yield surface water. It does not apply to confined aquifers or reservoirs, and water sources with an assigned safe yield. It defines the amount of water that is available for depletive and consumptive loss and not necessarily total allocable water. A series of steps are detailed to quantify the volume of depletive and consumptive use in a HUC11.

The method is not intended to replace other more rigorous methods but rather to be used for water-supply-planning purposes to identify watershed(s) where current and/or allocated water use potentially exceed ecological thresholds and threaten water supplies. Stream low flow margin identified watersheds could then be evaluated using one of the more detailed and rigorous methods; e.g. groundwater models, ecological limits to hydrologic alterations (ELOHA or eco-flow goals), or hydraulic models, to quantify stress and identify solutions. As with any method its limitations need to be considered when the results are used.

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Appendix A. Development of HUC11 Streamflow Statistics

The U.S. Geological Survey, at the request of the N.J. Department of Environmental Protection, developed a methodology to estimate the September median flow and the 7Q10 flow at the base of every HUC11 in New Jersey (U.S. Geological Survey, 2008). The following sections and tables are quoted from that report.

Introduction

The low-flow margin uses stream-low-flow statistics to indicate the probable amount of water in streams from ground-water discharge during times of reduced precipitation. The low-flow statistic used traditionally in quantifying surface-water-safe yields is the lowest total flow over seven consecutive days during a ten year period, the 7Q10. The 7Q10 is also often used to define an extreme low-flow condition. A critical-flow regime for aquatic ecology is the lowest monthly flow, which in New Jersey tends to occur most years in September. The low-flow margin is the difference between a stream's September median and the 7Q10 flows.

The methods used to calculate values of low-flow margin for New Jersey's HUC11 watersheds are described, and results presented. The value of low-flow margin was determined at the point (or points) at which streamflow leaves the HUC11 watershed, but does not include streamflow entering a HUC11 watershed from an upstream watershed. The methods used to calculate the low-flow margin minimized anthropogenic effects on streamflows from land use change, dams and reservoirs, sewer discharges to streams, and withdrawals from the streams or the surficial aquifer of the HUC11 watershed.

New Jersey's HUC11 Watersheds

Some of the HUC11 watersheds include adjacent bodies of water including the Delaware River, coastal bays, and the Atlantic Ocean. New Jersey's HUC11 watersheds were edited for this assessment by terminating them at the Atlantic Coast and Delaware River shore lines. These edits resulted in the elimination of some HUC11s and the merging of HUC11s which had become greatly reduced in area with adjacent HUC11s. Additionally, the HUC11s that ended at the New Jersey-New York state boundary but which receive streamflow from New York were extended into New York to natural hydrologic boundaries. The 138 HUC11 watersheds which resulted from these modifications are shown in figure A1.

Low-Flow Margins of Highlands HUC11 Watersheds

The New Jersey Highlands Water Protection and Planning Council, in cooperation with the U. S. Geological Survey, determined discharge values for the September-median and 7Q10 flows for New Jersey Highlands HUC14 subwatersheds (New Jersey Highlands Council, 2006) as part of the Highlands water-capacity analysis. The Highlands HUC14 low-flow statistics were derived using two methods, the drainage-area-ratio method and multiple regression. The drainage-area-ratio (DAR) method assumes that the streamflow at an ungaged site is the same per unit area as that at a nearby, hydrologically similar station. Requirements were that the ungaged basin be nested with the station's basin and that the ratio of the ungaged to gaged area fall within a range of 0.3 to 1.5. When the requirements for application of the DAR method were not met, a weighted-least-squares multiple-regression model was used to assign discharge values to the ungaged watershed. Values were regressed on the basis of their relationship to watershed characteristics such as drainage area, glacial-aquifer area, mean-annual recharge and mean-basin slope. An "aggregate-flow method", that aggregated the HUC14 low-flow statistics within a HUC11, was used to assign flow statistics to Highlands HUC11 watersheds. The aggregate-flow method was selected for this study because of the rigorous HUC14-subwatershed analysis, and in order to retain consistency with the previously documented Highlands study.

This method was applied to HUC11 watersheds with at least 50 percent of their area within the New Jersey Highlands (fig. A1). The aggregate-flow method summed the value of the low-flow statistics for all HUC14 subwatersheds within the HUC11 watershed to get its HUC11 value, for the 18 HUC11 watersheds completely within the Highlands. There were 8 HUC11 watersheds that were not completely in the Highlands, but had at least 50 percent of their area within the Highlands. The low-flow statistics for these HUC11s were determined by summing the statistic of interest for the Highlands' HUC14s within the HUC11, then dividing the aggregate statistic by the aggregate area of the HUC14s. The statistics could then be transferred to the HUC11 on a per-unit-area basis.

Low-Flow Margin of HUC11 Watersheds Outside the Highlands

The September median and 7Q10 flows used to calculate the low-flow margin for the remaining HUC11 watersheds outside of the Highlands were determined from these low-flow statistics calculated for stream low-flow stations throughout New Jersey. The basin characteristics of these stations were used to select the stations whose flow statistics would be transferred to the HUC11 watersheds. The transfer of low-flow statistics of these stations to HUC11 watersheds is termed the "flow-transfer method".

Stream Low-Flow Stations

The USGS operates two types of streamflow stations in New Jersey for which low-flow statistics were estimated, continuous-record stations and low-flow partial-record (LFPR) stations. Continuous-record stations record flow data at regular intervals throughout the day, usually at 15 minute intervals. Their flow data were used to compute daily-mean flows, from which September median and 7Q10 flows were directly calculated.

Watson and others (2005) determined the 7Q10 flows for continuous-record stations throughout New Jersey for periods of record up to 2001. These 7Q10 flows for were used where available if their period of record met this study's criteria. September median flows at continuous-record stations were determined for the same periods of records for which values of 7Q10 were determined. The September median flow was determined by taking the median of all daily flows measured during all Septembers (complete months only).

LFPR stations are often established where streamflow information is needed, but either it is not physically or economically feasible to continuously monitor streamflows at the location, or the amount or accuracy of the streamflow information needed does not require continuous monitoring at the location. At LFPR stations a series of stream-discharge measurements are made during independent low-flow periods when all or nearly all streamflow is from ground-water discharge. The methods for calculating low-flow statistics at a LFPR station are generally described in Watson and others (2005). A series of relations were created using the MOVE1 method (Hirsch, 1982) for each low-flow partial-record station. Each relation was between discrete measurements of streamflow at the LFPR station and values of daily streamflow at a continuous-record station on the days of the discrete measurements. Values of 7Q10 and September median flows at the LFPR station were determined from each relation. An average of each statistic (weighted with the inverse of the standard error of estimate of the relation) was then calculated. Some 7Q10 flows reported here are different than reported by Watson and others (2005) due to the inclusion of more recent discharge measurements than those available to them.

Characteristics of HUC11 Watersheds and Station Basins

Characteristics that related the HUC11 watersheds and station basins were developed to assist in selecting the stations used in estimating the low-flow statistics of the HUC11 watersheds. The most important characteristic was area. The area of the HUC11 watersheds was taken from the HUC11 GIS layer developed for this analysis. The station-basin boundaries were delineated for 613 of the continuous- and partial-record stations examined in the analysis. The basins were initially delineated using an automated Geographic Information System (GIS) technique that interprets basin boundaries using a digital elevation model (DEM) starting at the basin outlet point. However, in areas of low relief, such as wetlands, this technique can produce incorrect basin boundaries. Additionally, inconsistencies in the DEM data may contribute to the delineation error. For increased accuracy, the final basin boundaries were produced by overlying this preliminary boundary on digital-topographic and/or orthophoto quads and manually delineating the basin boundaries. The areas were taken from the GIS delineated basins.

The station basins and HUC11 watersheds were used to determine some characteristics of their areas. Percent of Anderson Level 1 land use and impervious surface were calculated for the delineated basins and watersheds using the New Jersey Department of Environmental Protection (NJDEP) 1995 integrated terrain unit digital data set (New Jersey Department of Environmental Protection, 2000). Generalized geology of the basins and watersheds was interpreted using a bedrock geology GIS layer from NJDEP (New Jersey Department of Environmental Protection, 1999). These basin characteristics were an aid in determining station basins and HUC11 watersheds with hydrologically-similar characteristics.

The other characteristic of the HUC11 watersheds and station basins examined in this analysis was water use. NJDEP's Bureau of Water Allocation (BWA) monthly water-use data was collected for all water-use withdrawal sites covered by the permits, registrations and certifications it issued in New Jersey from 2000 to 2003. Withdrawals from wells open to confined aquifers were excluded from the analysis, because these withdrawals have little effect on streamflow. There were 4,151 ground-water withdrawal wells and 1,171 surface-water intakes with BWA permitted withdrawals from 2000-2003. Of these withdrawal stations, 3,027 withdrawal wells and 811 surface-water intakes were within the basins of continuous- and partial-record stations used in the analysis. Ground- and surface-water withdrawals within the station basins used in the water-capacity analysis are given in Table A1. Generally, stations with large withdrawals in their basins were excluded from the water-capacity analysis.

The other type of water-use data examined was sewer discharges to New Jersey streams from sewage-treatment plants. The NJDEP (2006) has published a 1994 to 2004 annual summary of the state discharges. There were 201 sewage treatment plants that discharged to streams within the HUC11 watersheds; discharges to the Delaware River or the Atlantic Ocean were excluded. The sum of the mean annual discharges during the period 1994 to 2004 to the HUC11 basins was 416.4 million gallons per day. There were 171 sewage treatment plants that discharged to streams within the station basins used in the water-capacity analysis. As previously mentioned, stations where upstream-annual sewer discharges accounted for a significant portion of the calculated low-flow statistic were not used. The discharge data from these plants is included in Table A1.

Index Stations

The continuous-record and LFPR stations whose low-flow statistics were used to determine the low-flow margin for non-Highlands HUC11 watersheds are termed index stations. The low-streamflow data and basin characteristics for 645 continuous-record and LFPR stations were examined to select the index stations for these HUC11 watersheds.

Areal variation of values in 7Q10, median September flow, and low-flow margin at continuous-record and LFPR stations result from variation in basin characteristics. The index stations for a HUC11 watershed were selected based, in part, on the similarity between its basin characteristics (area, geology, impervious surface, and land use) and a HUC11 watershed. The stations whose basin extents closely matched that of their associated HUC11 watersheds were important index stations, since the station-basin and HUC11-watershed characteristics were necessarily similar. Multiple index stations were used to calculate a HUC11 watershed's low-flow statistics when:

1) there was no index-station with a basin extent similar to that of the HUC11, or
2) there was no index station within the HUC11 watershed, or
3) the data quality of a single index station was not sufficient for flow transfer to the HUC11 (data quality is related to station type, number of measurements for a LFPR station or period of record for a continuous-record station, and anthropogenic influences on streamflow), or
4) the index-station basin characteristics did not closely compare to those of the HUC11 watershed, or
5) any combination of the above.

Continuous-record stations with a minimum of twenty years of record were selected as index stations to minimize errors in calculating low-flow statistics from a short period of record. Statistics were calculated for more than one period for selected stations with a long period of record; the statistics of these stations used in this report are those for the period least affected by human activities. LFPR stations selected as index stations required 5 or more discrete measurements. Excluded from the analysis were stations with significant upstream flow regulation, stations where upstream-annual sewer discharges accounted for a significant portion of the calculated low-flow statistic, and stations in close proximity to either significant ground-water withdrawals or surface-water diversions.

There were 39 continuous-record stations, and 166 LFPR stations that met the selection criteria and were used in the analysis. Additionally, there were 16 continuous-record stations which had a period of record less than 20 years, but had sufficient data to allow them to be analyzed as a LFPR station. The 221 index stations are shown in Figure A1 and index station information and their low-flow statistics margin are given in Table A2.

The index stations for all non-Highlands HUC11 watersheds are given in Table A3. Multiple index stations were selected for 58 of the HUC11 watersheds while 54 HUC11 watersheds used a single index station for calculating its statistics. A lack of high quality-index stations within HUC11 watersheds resulted in applying data from 38 selected index stations which were outside the area draining to the outflow point of the HUC11.

Flow-Transfer Methods

The flow-transfer methods calculated incremental low-flow statistics for 112 HUC11 watersheds by transferring the September median and 7Q10 flows calculated from index-station data to a HUC11 watershed. Incremental statistics are representative of the streamflow that originated within a HUC11 watershed. There were 3 flow-transfer methods utilized to obtain a HUC11 watershed's incremental low-flow statistics. The choice of method was dependent on the HUC11 watershed's geography and the index stations available for calculation of its low-flow statistics.

<u>Method 1 - Outflow with no Inflow</u>

Flow-transfer method 1 was used for the 81 HUC11 watersheds with no influent (upstream) watersheds. The low-flow statistics for these HUC11s were transferred from their index station(s) corresponding statistics on an area weighted basis. Once a HUC11's index stations were selected, the following calculations were made to obtain its incremental low-flow margin:

1) The 7Q10 and September median flows (in million gallons per day) for the HUC11's index stations were each summed.
2) The basin areas of the HUC11's index stations were summed.
3) The area of the HUC11 watershed was divided by the sum of the areas of its index-stations basins to determine the drainage-area correction.
4) The sum of the index stations 7Q10 flows was multiplied by the drainage-area correction to calculate the HUC11's incremental 7Q10, and the sum of the index stations September

median flows was multiplied by the drainage area correction to calculate the HUC11's incremental September median flow.

5) The incremental low-flow margin for the HUC11 watershed was calculated by subtracting its incremental 7Q10 flow from its incremental September median flow.

<u>Method 2 - Outflow Minus Inflow</u>

Flow-transfer method 2 was used for 20 HUC11 watersheds with influent watersheds and index stations with data that could be used for calculation of the HUC11's outflow statistics. The outflow statistics for a HUC11 watershed represent the streamflow that both originated within the HUC11 and its upstream basin. The HUC11 watershed's incremental low-flow statistics were calculated by subtracting its influent statistics (the outflow statistics of the watershed immediately upstream of it) from its outflow statistics. The index stations used to calculate the HUC11's outflow statistics had basins of similar extent to the HUC11 outflow basin. The HUC11 watersheds incremental low-flow margin was calculated with these steps:

1) The 7Q10 and September median flows (in million gallons per day) for the HUC11's index stations were each summed.
2) The basin areas of the HUC11's index stations were summed.
3) The area draining to the outflow point of the HUC11 watershed was divided by the sum of the areas of the index stations basins to determine the drainage-area correction.
4) The sum of the index stations 7Q10 flows was multiplied by the drainage-area correction to calculate the HUC11's outflow 7Q10, and the sum of the index stations September median flows was multiplied by the drainage area correction to calculate the HUC11's outflow September median flow.
5) The upstream HUC11 for the HUC11 watershed was determined.
6) The incremental September median and 7Q10 flows for the HUC11 watershed were calculated by subtracting the outflow September median and 7Q10 flows of the upstream HUC11 from the outflow September median and 7Q10 flows of the HUC11.
7) The incremental low-flow margin for the HUC11 watershed was calculated by subtracting its incremental 7Q10 flow from its incremental September median flow.

<u>Method 3 - Incremental Plus Inflow</u>

Flow-transfer method 3 was used for 11 HUC11 watersheds that did have influent basins but did not have adequate index stations for calculation of outflow statistics. The incremental low-flow statistics for these HUC11s were calculated from data of index stations with basins within or proximate to the HUC11 watershed, and with total basin areas that were of different extents than the HUC11 watershed. To compensate for variations between HUC11 watershed and index-station location and basin area, the other station-basin characteristics were kept as similar to those of the HUC11 watershed as possible. The transfer of the index stations low-flow statistics to the HUC11 watersheds was done in the same way as flow-transfer method 1, on a direct area weighted basis.

Outflow values of 7Q10 and September median flows were needed for HUC11 watersheds utilizing this method for use as the inflows to HUC11 watersheds using method 2. The Outflow 7Q10 and September median flows were calculated by summing the incremental 7Q10 and September median flows 4 with the outflow 7Q10 and September median flows of the HUC11 watershed immediately upstream.

HUC11 Watershed Water Capacity

The September median flow, 7Q10 flows and the low-flow margin statistics for each of New Jersey's 138 HUC11 watersheds are listed in table A4 and shown areally in Figures A2, A3 and A4 respectively. HUC11 area-weighted water capacities based on the low-flow margin method range from less than 0.1 MGD per square mile (MGD/mi^2) to more than 0.4 MGD/mi^2. Water capacity is greater in HUC11 watersheds underlain by Coastal Plain sands and gravels and watersheds in the central Highlands containing glacial buried valley fill deposits. Surficial aquifers in these areas are able to store and transmit greater quantities of water than in watersheds underlain by fractured rock aquifers of the Piedmont, Highlands and Valley and Ridge.

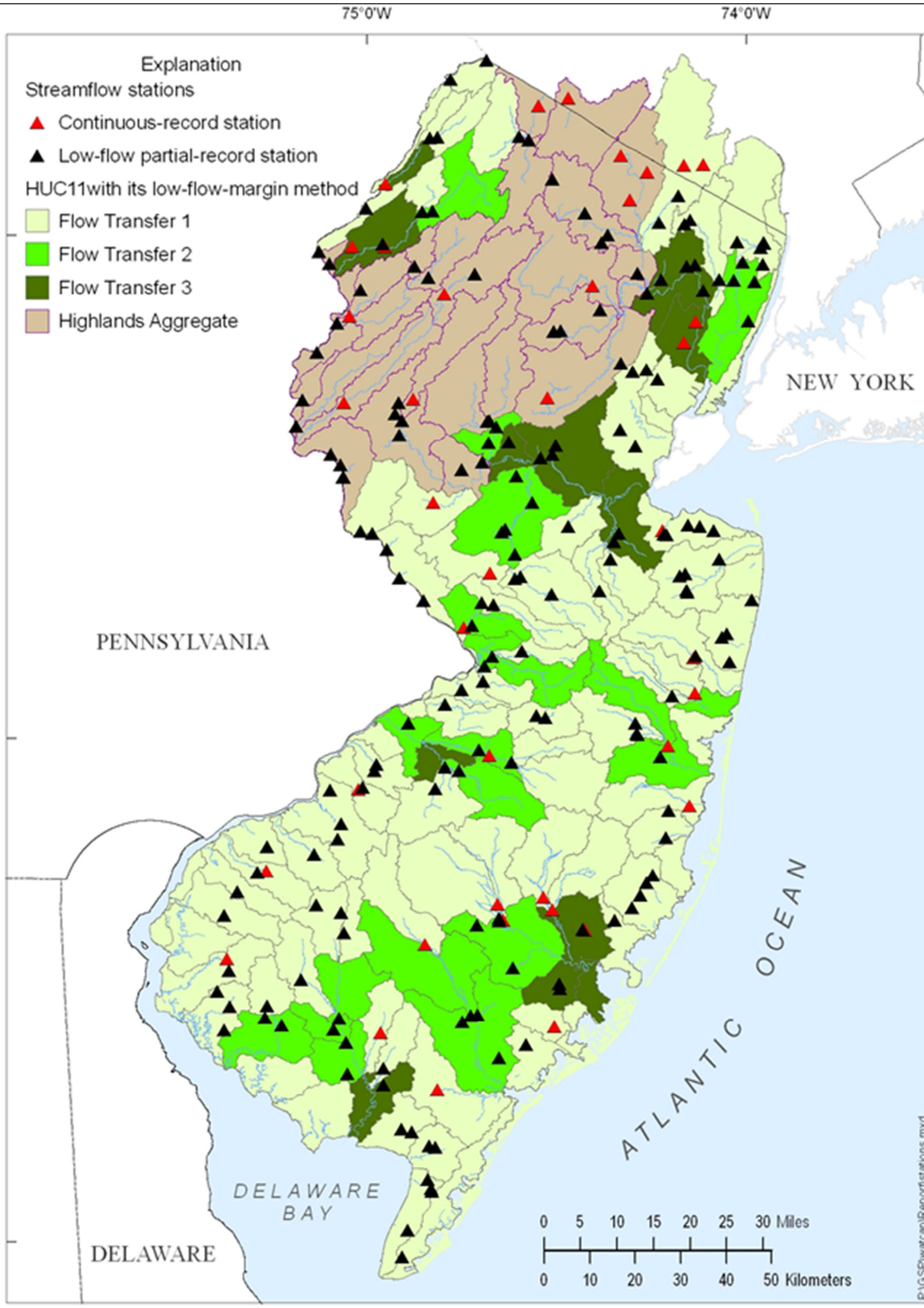

Figure A1. HUC11 watersheds showing the method used to calculate their low flow margins, and the continuous-record and partial-record stations whose data were used in calculating the low-flow margins for the New Jersey water-capacity analysis.

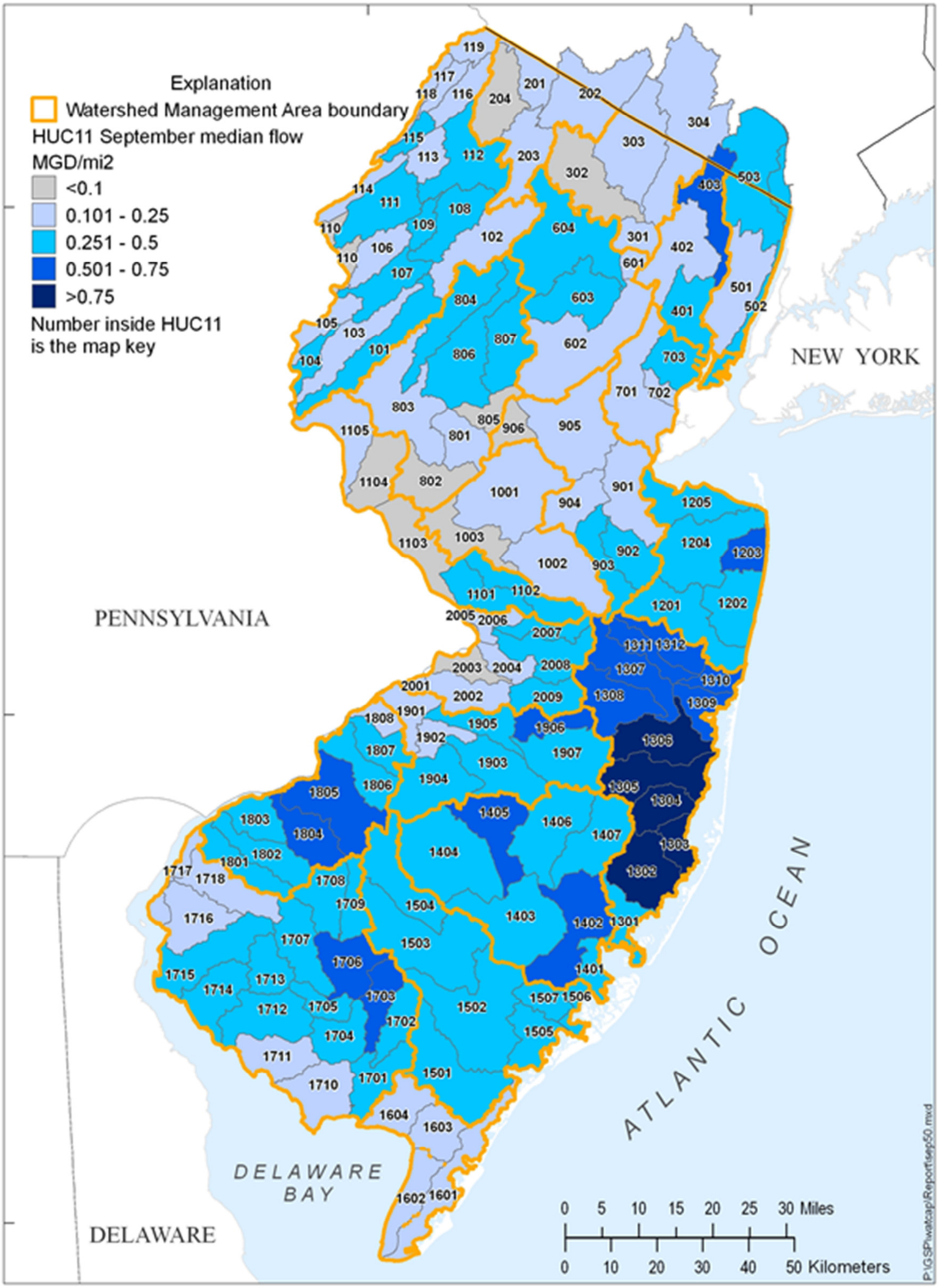

Figure A2. Distribution of September median flows in million gallons per day per square mile (MGD/mi^2) for HUC11 watersheds of New Jersey.

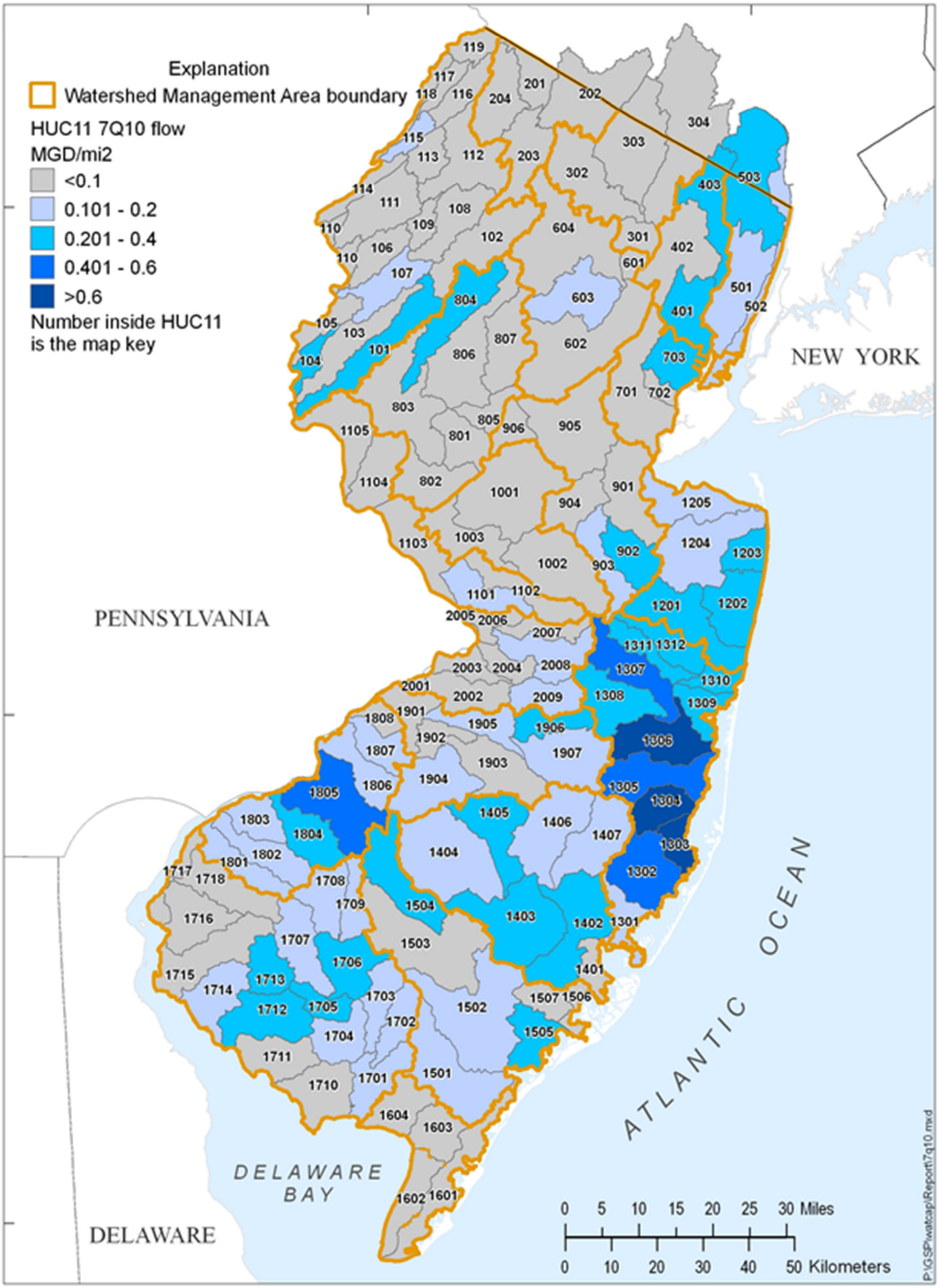

Figure A3. Distribution of 7-day 10-year low-flows (7Q10) in million gallons per day per square mile (MGD/mi^2) for New Jersey's HUC11 watersheds.

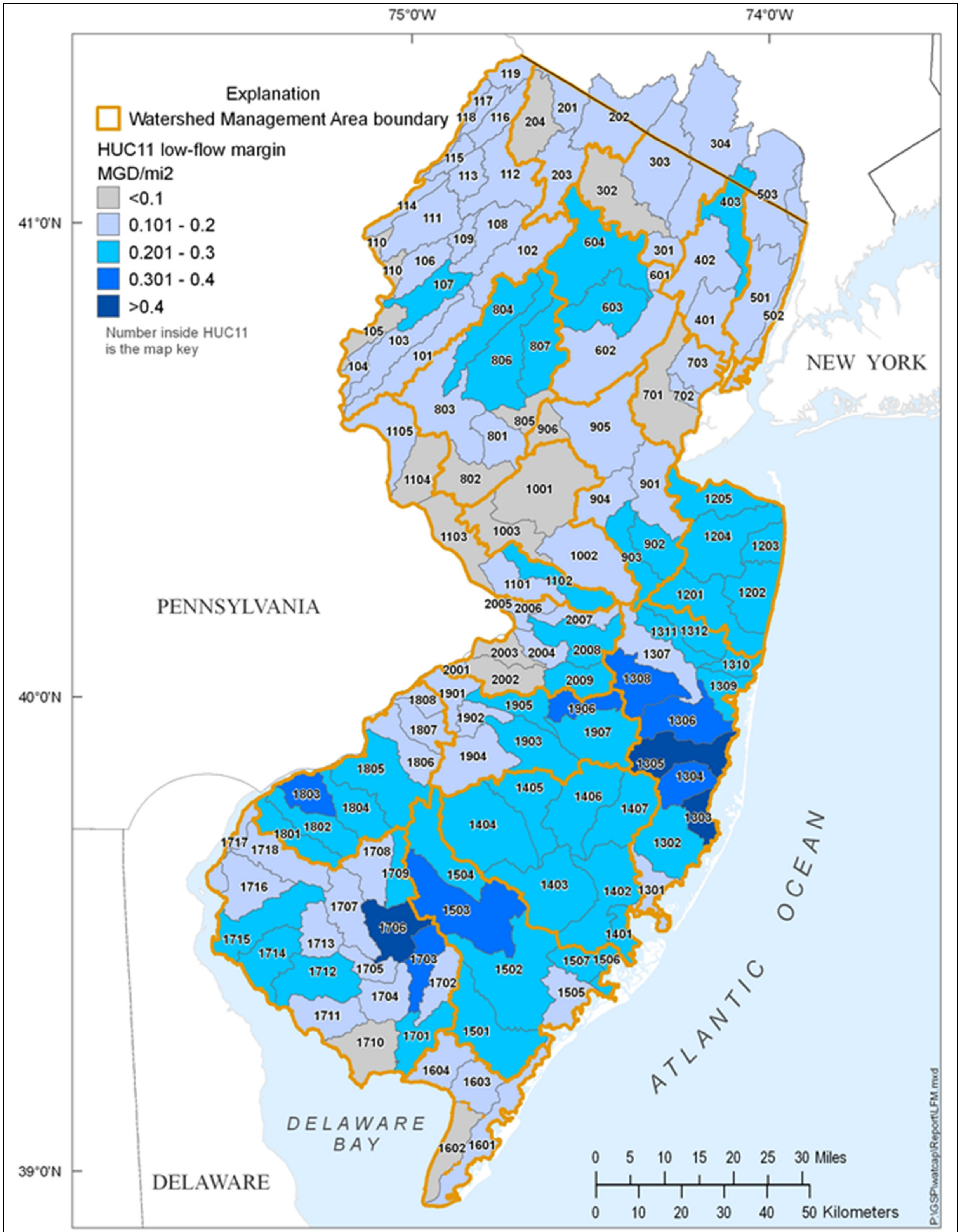

Figure A4. Distribution of low-flow margin in million gallons per day per square mile (MGD/mi^2) for New Jersey's HUC11 watersheds.

Table A1. Surface- and ground-water withdrawals and sewer returns within the basins of continuous-record and low-flow partial-record stations used in the New Jersey water capacity analysis. (All abbreviations are at the end of the table).

United States Geological Survey Streamgaging Station				Withdrawals (MGD)		Sewer Returns (MGD)
ID	Name	Type	Area, (mi^2)	Groundwater	Surface water	
01367770	Wallkill River near Sussex, NJ	LFPR	60.98	2.55	.72	1.50
01367910	Papakating Creek at Sussex, NJ	LFPR	59.25	.01	.36	.26
01368000	Wallkill River near Unionville, NY	Continuous	140.49	2.60	1.08	1.78
01369000	Pochuck Creek near Pine Island, NY	Continuous	97.84	.58	.42	.08
01377490	MUSQUAPSINK BROOK AT WESTWOOD NJ	LFPR	6.67	0	0	0
01378350	Tenakill Brook at Cresskill, NJ	LFPR	3.08	.03	0	0
01378385	Tenakill Brook at Closter, NJ	LFPR	8.64	.03	0	0
01378410	Dwars Kill at Norwood, NJ	LFPR	3.16	0	0	0
01378430	Norwood Brook at Norwood, NJ	LFPR	2.01	.03	0	0
01378520	Hirshfeld Brook at New Milford, NJ	LFPR	4.50	0	0	0
01378560	Coles Brook at Hackensack, NJ	LFPR	6.62	.02	0	0
01378590	Metzler Brook at Englewood, NJ	LFPR	1.57	.01	0	0
01378615	Wolf Creek at Ridgefield, NJ	LFPR	1.74	0	0	0
01379000	Passaic River near Millington, NJ	Continuous	54.17	3.07	.24	2.04
01379525	Canoe Brook near Millburn, NJ	LFPR	10.12	3.45	.03	0
01380500	Rockaway River above Reservoir at Boonton, NJ	Continuous	117.34	10.27	6.96	.10
01381400	Whippany River near Morristown, NJ	Continuous as LFPR	13.93	0	.19	.01
01381490	Watnong Brook at Morris Plains, NJ	LFPR	7.75	.01	0	.23
01381700	Troy Brook at Troy Hills, NJ	LFPR	10.05	5.65	0	0
01382050	Pequannock River near Stockholm, NJ	LFPR	5.40	0	0	0
01382360	Kanouse Brook at Newfoundland, NJ	LFPR	3.85	0	0	0
01382550	Pequannock River tributary 1 at Kinnelon, NJ	LFPR	1.20	0	0	0
01382700	Stone House Brook at Kinnelon, NJ	LFPR	3.45	0	0	0

United States Geological Survey Streamgaging Station				Withdrawals (MGD)		Sewer Returns (MGD)
ID	Name	Type	Area, (mi^2)	Groundwater	Surface water	
01383500	Wanaque River at Awosting	Continuous	0	0	0	0
01384500	Ringwood Creek near Wanaque, NJ	Continuous	16.86	0	0	0
01386000	West Brook near Wanaque, NJ	Continuous	11.82	.02	.03	0
01387400	Ramapo River at Ramapo, NY	Continuous	87.02	0	0	0
01387450	Mahwah River near Suffern, NY	Continuous	12.35	0	0	0
01387600	Darlington Brook near Darlington, NJ	LFPR	3.37	.67	.13	0
01387880	POND BROOK AT OAKLAND NJ	LFPR	7.11	.97	0	.04
01388720	Beaver Dam Brook at Ryerson Road, at Lincoln Park, NJ	LFPR	12.84	2.60	.14	0
01389090	NAACHTPUNKT BROOK AT TOTOWA NJ	LFPR	1.13	0	0	0
01389140	Deepavaal Brook at Two Bridges, NJ	LFPR	7.67	.18	0	0
01389850	Goffle Brook at Hawthorne, NJ	LFPR	8.77	4.75	0	0
01389860	DIAMOND BROOK AT FAIR LAWN NJ	LFPR	3.14	0	0	0
01389905	Fleischer Brook at Elmwood Park, NJ	LFPR	1.80	.49	0	0
01390700	Hohokus Brook at Wyckoff, NJ	LFPR	5.30	.27	0	0
01390800	Valentine Brook at Allendale, NJ	LFPR	2.47	.52	0	0
01391485	Sprout Brook at Rochelle Park, NJ	LFPR	5.51	.47	0	0
01392210	Third River at Passaic, NJ	Continuous	11.91	.53	.09	0
01392500	Second River at Belleville, NJ	Continuous	11.43	1.38	0	0
01393200	Elizabeth River below Chancellor Avenue Bridge at Irvington, NJ	LFPR	5.14	0	0	0
01393890	East Branch Rahway River at Maplewood, NJ	LFPR	5.15	.35	0	0
01394000	West Branch Rahway River at Millburn, NJ	Continuous as LFPR	7.09	2.42	.05	0
01395500	Robinsons Branch at Goodmans, NJ	Continuous as LFPR	12.48	1.29	0	0
01396030	South Branch Rahway River at Colonia, NJ	LFPR	9.28	0	0	0
01396500	South Branch Raritan River near High Bridge, NJ	Continuous	66.28	5.50	.24	.96
01396600	Spruce Run near Clinton, NJ	LFPR	18.05	.40	0	.03

United States Geological Survey Streamgaging Station				Withdrawals (MGD)		Sewer Returns (MGD)
ID	Name	Type	Area, (mi^2)	Groundwater	Surface water	
01396700	Mulhockaway Creek near Clinton, NJ	LFPR	20.49	0	0	0
01396815	BEAVER BROOK AT CLINTON NJ	LFPR	6.89	0	0	0
01396900	Capoolong Creek at Lansdowne, NJ	LFPR	14.10	.06	.08	0
01398000	Neshanic River at Reaville, NJ	Continuous	25.45	.50	0	0
01398075	Pleasant Run at Centerville, NJ	LFPR	8.06	0	.03	0
01398110	HOLLAND BK AT SOUTH BRANCH NJ	LFPR	12.23	.01	.08	0
01399120	North Branch Raritan River at Burnt Mills, NJ	LFPR	63.92	.16	.12	2.41
01399780	LAMINGTON RIVER AT BURNT MILLS NJ	LFPR	99.18	3.91	.90	2.21
01399820	Chambers Brook near North Branch, NJ	LFPR	4.71	.19	0	0
01399900	Chambers Brook at North Branch Depot, NJ	LFPR	10.19	.01	0	0
01400300	Peters Brook near Raritan, NJ	Continuous as LFPR	4.18	.05	.03	0
01400580	Millstone River at Hightstown, NJ	LFPR	19.73	0	.04	0
01400725	Cranbury Brook at Plainsboro, NJ	LFPR	22.04	1.04	.32	0
01400810	Bear Brook at Princeton Junction, NJ	LFPR	12.29	.02	.03	0
01401000	Stony Brook at Princeton, NJ	Continuous	44.43	.47	.05	.27
01401400	Heathcote Brook at Kingston, NJ	LFPR	9.00	0	0	0
01401600	Beden Brook near Rocky Hill, NJ	LFPR	26.98	.40	.05	.52
01401700	Pike Run near Rocky Hill, NJ	LFPR	22.18	.49	.01	.32
01401900	Six Mile Run at Blackwells Mills, NJ	LFPR	16.09	.04	0	0
01402700	Royce Brook at Manville, NJ	LFPR	12.31	.01	0	0
01403200	MIDDLE BROOK AT BOUND BROOK NJ	LFPR	17.16	0	0	0
01403900	Bound Brook at Middlesex, NJ	Continuous as LFPR	48.46	17.41	.04	0
01404060	Ambrose Brook at Middlesex, NJ	LFPR	13.91	.04	0	0
01404500	Lawrence Brook at Patricks Corner, NJ	Continuous as LFPR	29.27	.79	.76	0

United States Geological Survey Streamgaging Station				Withdrawals (MGD)		Sewer Returns (MGD)
ID	Name	Type	Area, (mi^2)	Groundwater	Surface water	
01405290	Matchaponix Brook at Texas, NJ	LFPR	41.90	0	2.49	5.14
01405340	Manalapan Brook at Federal Road near Manalapan, NJ	LFPR	20.81	0	.24	0
01405470	Iresick Brook at East Spotswood, NJ	LFPR	2.23	0	0	0
01406040	Deep Run at Route 516, near Old Bridge, NJ	LFPR	15.63	0	0	.01
01407000	Matawan Creek at Matawan, NJ	Continuous	6.04	0	0	0
01407012	Gravelly Brook at Church Street, at Matawan, NJ	LFPR	2.38	0	0	0
01407026	Mohingson (Wilkson) Creek at Church Street, at Matawan, NJ	LFPR	1.67	0	0	0
01407055	East Creek at North Centerville, NJ	LFPR	1.32	0	0	0
01407070	Waackaack Creek near Keansburg, NJ	LFPR	5.50	0	0	0
01407102	Town Brook at Church Street, at New Monmouth, NJ	LFPR	3.35	0	0	0
01407253	WILLOW BK NR HOLMDEL NJ	LFPR	7.52	0	0	0
01407300	Big Brook at Vanderburg, NJ	LFPR	8.40	.02	0	.13
01407400	Yellow Brook at Colts Neck, NJ	LFPR	9.72	0	.20	0
01407450	Mine Brook at Colts Neck, NJ	LFPR	5.45	0	.06	0
01407532	Poricy Brook at Red Bank, NJ	LFPR	2.52	0	0	0
01407618	Whale Pond Brook near Oakhurst, NJ	LFPR	6.17	0	0	0
01407700	Shark River at Glendola, NJ	LFPR	9.47	0	.01	0
01407755	Jumping Brook above reservior, near Neptune City, NJ	LFPR	5.58	0	0	0
01407800	Wreck Pond Brook near Spring Lake, NJ	LFPR	7.05	.02	0	0
01408000	Manasquan River at Squankum, NJ	Continuous	44.03	.04	.13	0
01408020	Mingamahone Brook at Squankum, NJ	LFPR	10.62	.01	0	0
01408120	North Branch Metedeconk River near Lakewood, NJ	Continuous	34.54	.49	0	0
01408140	South Branch Metedeconk River at Lakewood, NJ	Continuous as LFPR	26.18	.04	.07	0
01408440	Union Brook at Lakehurst, NJ	LFPR	18.87	.61	0	0
01408460	Manapaqua Brook at Lakehurst, NJ	LFPR	6.33	.99	0	0

United States Geological Survey Streamgaging Station				Withdrawals (MGD)		Sewer Returns (MGD)
ID	Name	Type	Area, (mi^2)	Groundwater	Surface water	
01408490	Ridgeway Branch near Lakehurst, NJ	LFPR	28.17	.34	0	0
01408500	Toms River near Toms River, NJ	Continuous	123.33	4.78	5.98	.02
01408592	Wrangel Brook at Mule Road, near Toms River, NJ	LFPR	13.96	2.05	.04	0
01409000	Cedar Creek at Lanoka Harbor, NJ	Continuous	53.14	.50	1.50	0
01409050	North Branch Forked River near Forked River, NJ	LFPR	13.36	.02	0	0
01409100	Oyster Creek near Waretown, NJ	LFPR	10.01	0	0	0
01409150	Mill Creek near Manahawkin, NJ	LFPR	10.35	.17	0	0
01409200	Fourmile Branch near Manahawkin, NJ	LFPR	5.24	.44	.02	0
01409250	Cedar Run near Manahawkin, NJ	LFPR	3.45	0	0	0
01409280	Westecunk Creek at Stafford Forge, NJ	Continuous as LFPR	15.95	0	0	0
01409300	Mill Branch near Tuckerton, NJ	LFPR	4.89	0	0	0
01409400	Mullica River near Batsto, NJ	Continuous	46.23	.58	.38	0
01409406	Sleeper Branch at Batsto, NJ	LFPR	36.14	.61	.76	0
01409411	Nescochague Creek at Pleasant Mills, NJ	LFPR	43.77	3.09	.21	0
01409416	Hammonton Creek at Wescoatville, NJ	LFPR	9.51	1.58	.16	.79
01409500	Batsto River at Batsto, NJ	Continuous	68.20	.95	6.32	0
01409575	Landing Creek at Philadelphia Avenue at Egg Harbor City, NJ	LFPR	4.83	0	0	0
01409810	West Branch Wading River near Jenkins, NJ	Continuous	83.93	4.39	47.79	0
01410000	Oswego River at Harrisville, NJ	Continuous	72.42	.05	28.52	0
01410150	East Branch Bass River near New Gretna, NJ	Continuous	8.14	.01	0	0
01410200	West Branch Bass River near New Gretna, NJ	LFPR	6.47	0	0	0
01410215	Clarks Mill Stream at Port Republic, NJ	LFPR	8.59	.52	0	0
01410225	Morses Mill Stream at Port Republic, NJ	LFPR	8.04	.66	.05	0
01410500	Absecon Creek at Absecon, NJ	Continuous	17.97	10.72	1.64	0
01411000	Great Egg Harbor River at Folsom, NJ	Continuous	56.94	3.61	3.42	.02

United States Geological Survey Streamgaging Station				Withdrawals (MGD)		Sewer Returns (MGD)
ID	Name	Type	Area, (mi^2)	Groundwater	Surface water	
01411170	Great Egg Harbor River at Mays Landing, NJ	LFPR	204.43	9.90	6.31	.33
01411200	Babcock Creek at Mays Landing, NJ	LFPR	19.99	.53	.03	0
01411220	South River near Belcoville, NJ	LFPR	20.38	.54	0	0
01411250	English Creek near Scullville, NJ	LFPR	3.74	.13	.04	0
01411300	Tuckahoe River at Head of River, NJ	Continuous	30.76	.04	.24	0
01411305	Mill Branch near Northfield, NJ	LFPR	7.50	.13	.02	0
01411388	Mill Creek at Cold Spring, NJ	LFPR	1.35	0	0	0
01411400	Fishing Creek at Rio Grande, NJ	LFPR	2.29	0	0	0
01411410	Bidwell Creek tributary near Cape May Court House, NJ	LFPR	.41	0	0	0
01411412	Bidwell Creek tributary 2 near Cape May Court House, NJ	LFPR	.18	0	0	0
01411418	Goshen Creek at Goshen, NJ	LFPR	.34	0	0	0
01411428	Dennis Creek tributary 2 at Dennisville, NJ	LFPR	4.03	0	0	0
01411438	Dennis Creek tributary 1 near North Dennis, NJ	LFPR	2.76	0	0	0
01411442	East Creek near Eldora, NJ	LFPR	8.07	0	0	0
01411445	West Creek near Eldora, NJ	LFPR	11.87	.03	0	0
01411450	Still Run at Aura, NJ	LFPR	3.21	0	0	0
01411456	Little Ease Run near Clayton, NJ	Continuous as LFPR	9.77	1.16	.07	0
01411462	Scotland Run at Franklinville, NJ	LFPR	14.82	2.25	0	0
01411700	Muddy Run at Centerton, NJ	LFPR	37.66	2.47	.57	0
01411800	Maurice River near Millville, NJ	Continuous as LFPR	190.27	20.77	.91	0
01411850	Mill Creek near Millville, NJ	LFPR	15.16	.16	0	0
01411880	Maurice River at Sharp Street at Millville, NJ	LFPR	215.22	21.82	.91	0
01411955	Gravelly Run at Laurel Lake, NJ	LFPR	3.36	0	0	0
01412000	Menantico Creek near Millville, NJ	Continuous	23.20	3.62	.14	0
01412100	Manumuskin River near Manumuskin, NJ	LFPR	32.25	1.12	0	0

United States Geological Survey Streamgaging Station				Withdrawals (MGD)		Sewer Returns (MGD)
ID	Name	Type	Area, (mi^2)	Groundwater	Surface water	
01412120	Muskee Creek near Port Elizabeth, NJ	LFPR	13.45	0	5.31	0
01412800	Cohansey River at Seeley, NJ	Continuous as LFPR	280	5.68	.87	0
01413010	Barrett Run near Bridgeton, NJ	LFPR	6.98	.35	.05	0
01413020	Indian Fields Branch at Bridgeton, NJ	LFPR	4.63	.08	1.04	0
01413050	Stow Creek at Jericho, NJ	LFPR	8.14	.11	.01	0
01413060	Canton Drain near Canton, NJ	LFPR	2.48	0	0	0
01413080	Raccoon D at Davis Mill, NJ	LFPR	3.22	.04	.01	0
01438090	Clove Brook at N.J. Route 23 at Duttonville, NJ	LFPR	9.84	0	0	0
01438400	Shimers Brook near Montague, NJ	LFPR	6.97	.12	.04	0
01439830	Big Flat Brook at Tuttles Corner, NJ	LFPR	29.30	0	0	0
01439920	Little Flat Brook at Peters Valley, NJ	LFPR	14.66	0	0	0
01440000	Flat Brook near Flatbrookville, NJ	Continuous	650	0	0	0
01440100	Vancampens Brook near Millbrook, NJ	LFPR	7.59	0	.02	0
01442760	Dunnfield Creek at Dunnfield, NJ	LFPR	3.55	0	0	0
01442800	Stony Brook near Columbia, NJ	LFPR	3.52	0	0	0
01443460	Paulins Kill at Paulins Kill, NJ	LFPR	72.74	.79	5.95	1.05
01443475	Trout Brook near Middleville, NJ	LFPR	23.96	0	0	0
01443500	Paulins Kill at Blairstown, NJ	Continuous	126.02	.91	5.98	1.05
01443510	Blair Creek at Blairstown, NJ	LFPR	13.08	0	0	0
01443900	Yards Creek near Blairstown, NJ	Continuous	5.32	0	0	0
01445100	PEQUEST RIVER AT LONG BRIDGE NJ	LFPR	48.31	.43	0	0
01445200	Bear Creek near Johnsonburg, NJ	LFPR	12.85	.02	0	0
01445800	Honey Run near Ramseyburg, NJ	LFPR	2.20	0	0	0
01446000	Beaver Brook near Belvidere, NJ	Continuous	36.61	0	.01	0
01446400	Pequest River at Belvidere, NJ	LFPR	156.56	10.54	.98	.61

United States Geological Survey Streamgaging Station				Withdrawals (MGD)		Sewer Returns (MGD)
ID	Name	Type	Area, (mi^2)	Groundwater	Surface water	
01446568	Buckhorn Creek at Hutchinson Road, at Hutchinson, NJ	LFPR	8.38	.01	0	0
01455100	Lopatcong Creek at Phillipsburg, NJ	LFPR	14.19	.20	.04	0
01455300	Pohatcong Creek at Carpentersville, NJ	LFPR	57.01	1.43	0	.71
01455780	Lubbers Run at Lockwood, NJ	LFPR	16.26	.31	0	0
01456000	Musconetcong River near Hackettstown, NJ	Continuous	68.91	2.93	2.57	1.80
01457000	Musconetcong River near Bloomsbury, NJ	Continuous	141.22	5.63	3.45	4.01
01458100	Hakihokake Creek at Milford, NJ	LFPR	17.24	.40	.01	0
01458400	Hakihokake Creek near Frenchtown, NJ	LFPR	9.78	0	0	0
01458600	Nishisakawick Creek at Frenchtown, NJ	LFPR	11.03	.09	0	0
01458700	Little Nishisakawick Creek at Frenchtown, NJ	LFPR	3.48	.03	0	0
01460880	LOCKATONG CREEK AT RAVEN ROCK NJ	LFPR	22.90	0	0	0
01461300	Wickecheoke Creek at Stockton, NJ	LFPR	26.53	.16	0	.02
01461900	Alexauken Creek near Lambertville, NJ	LFPR	14.86	0	0	0
01462200	Moores Creek near Titusville, NJ	LFPR	10.22	.01	0	0
01462800	Jacobs Creek at Somerset, NJ	LFPR	13.33	.09	0	0
01463620	Assunpink Creek near Clarksville, NJ	Continuous as LFPR	34.26	.13	.26	.20
01463670	Shipetaukin Creek at Bakersville, NJ	LFPR	9.51	.14	0	0
01463980	Pond Run at Trenton, NJ	LFPR	8.92	.24	0	0
01464000	Assunpink Creek at Trenton, NJ	Continuous	90.46	3.93	.32	10.72
01464300	Crosswicks Creek near Cookstown, NJ	LFPR	20.03	.02	.50	0
01464380	North Run at Cookstown, NJ	LFPR	7.31	.01	.04	.92
01464504	Crosswicks Creek at Groveville Road, at Groveville, NJ	LFPR	93.15	.06	1.30	1.46
01464515	Doctors Creek at Allentown, NJ	LFPR	17.45	0	.41	.19
01464525	Thorton Creek at Bordentown,, NJ	Continuous as LFPR	.77	0	0	0
01464530	Blacks Creek at Mansfield Sqaure, NJ	LFPR	19.64	0	.59	0

United States Geological Survey Streamgaging Station				Withdrawals (MGD)		Sewer Returns (MGD)
ID	Name	Type	Area, (mi^2)	Groundwater	Surface water	
01464540	Crafts Creek at Hedding, NJ	LFPR	10.54	0	.04	0
01464590	Assiscunk Creek near Burlington, NJ	LFPR	36.34	0	.07	.14
01465850	South Branch Rancocas Creek at Vincentown, NJ	Continuous as LFPR	64.72	1.95	12.52	.32
01465884	SHARPS RUN AT ROUTE 541 AT MEDFORD NJ	LFPR	4.38	0	0	0
01465900	Southwest Branch Rancocas at Eayerstown, NJ	LFPR	75.94	.62	1.76	3.56
01466900	Greenwood Brook at New Lisbon, NJ	Continuous as LFPR	77.87	.09	9.55	0
01467000	North Branch Rancocas Creek at Pemberton, NJ	Continuous	117.54	.12	11.79	0
01467021	MILL CREEK AT LEVITT PKY AT WILLINGBORO NJ	LFPR	9.18	0	0	0
01467070	North Branch Pennsauken Creek at Maple Shade, NJ	LFPR	13.26	0	.04	0
01467150	Cooper River at Haddonfield, NJ	Continuous	17.08	.02	.14	0
01467180	North Branch Cooper River at Ellisburg, NJ	LFPR	10.51	.03	.04	0
01467312	Newton Creek at West Collingswood, NJ	LFPR	4.54	0	0	0
01467330	South Branch Big Timber Creek at Blackwood, NJ	LFPR	20.80	.47	.03	0
01467359	NB BIG TIMBER C AT GLENDORA NJ	LFPR	18.91	0	0	0
01475020	Mantua Creek at Sewell, NJ	LFPR	14.46	.19	.33	0
01476600	Still Run near Mickleton, NJ	Continuous as LFPR	3.96	0	.05	0
01477120	Raccoon Creek near Swedesboro, NJ	Continuous	25.94	.19	.57	.31
01477130	Basgalore Creek at Russell Mill Road, near Swedesboro, NJ	LFPR	3.36	0	.02	0
01477510	Oldmans Creek at Porches Mill, NJ	LFPR	20.98	.18	.67	0
01482520	Salem River at Sharptown, NJ	LFPR	27.15	.03	.08	.33
01483000	Alloway Creek at Alloway, NJ	Continuous	20.31	.19	.14	0
01483010	Deep Run near Alloway, NJ	LFPR	5.28	0	0	0
0146700260	INDIAN RUN AT BIRMINGHAM NJ	LFPR	5.92	0	0	0

Abbreviations

USGS - U.S. Geological Survey
ID - identifier
MGD - million gallons per day
7Q10 - 7-day 10 year low-flow
LFPR - low-flow partial-record station
Continuous - continuous-record
NJ – New Jersey
NY – New York

Table A2. Streamflow stations used in the New Jersey water capacity analysis**.** (All abbreviations are at the end of table.)

United States Geological Survey Streamflow Station			Area (mi^2)		Years of Record		Flows (MGDb)		
ID	Name	Type	Published	GIS	First	Last	September median	7Q10	Low-flow margin
01367770	Wallkill River near Sussex, NJ	LFPR	60.80	60.98	1977	1996	14.92	4.36	10.56
01367910	Papakating Creek at Sussex, NJ	LFPR	59.40	59.25	1977	2003	6.06	1.20	4.87
01368000	Wallkill River near Unionville, NY	Continuous		140.49	1937	1981	25.85	5.70	20.15
01369000	Pochuck Creek near Pine Island, NY	Continuous	98.00	97.84	1937	1978	16.80	2.38	14.43
01377490	Musquapsink Brook at Westwood, NJ	LFPR	6.59	6.67	1993	2005	3.06	2.17	.90
01378350	Tenakill Brook at Cresskill, NJ	LFPR	3.01	3.08	1964	1999	1.44	.97	.47
01378385	Tenakill Brook at Closter, NJ	LFPR	8.56	8.64	1964	2000	3.61	1.62	1.99
01378410	Dwars Kill at Norwood, NJ	LFPR	3.23	3.16	1973	1999	.66	.21	.45
01378430	Norwood Brook at Norwood, NJ	LFPR	2.03	2.01	1973	1980	.41	.21	.21
01378520	Hirshfeld Brook at New Milford, NJ	LFPR	4.54	4.50	1999	2006	1.40	.81	.59
01378560	Coles Brook at Hackensack, NJ	LFPR	7.00	6.62	1965	2005	1.19	.47	.72
01378590	Metzler Brook at Englewood, NJ	LFPR	1.54	1.57	1964	1994	.26	.08	.18
01378615	Wolf Creek at Ridgefield, NJ	LFPR	1.18	1.74	1964	1982	.37	.09	.28
01379000	Passaic River near Millington, NJ	Continuous	55.40	54.17	1979	2006	9.51	1.81	7.70
01379525	Canoe Brook near Millburn, NJ	LFPR	10.17	10.12	1989	2006	.45	.06	.39
01380500	Rockaway River above Reservoir at Boonton, NJ	Continuous	116.00	117.34	1937	2001	38.78	9.61	29.17
01381400	Whippany River near Morristown, NJ	Continuous as LFPR	14.00	13.93	1964	2004	4.45	1.56	2.89
01381490	Watnong Brook at Morris Plains, NJ	LFPR	7.77	7.75	1966	2002	3.93	1.82	2.11
01381700	Troy Brook at Troy Hills, NJ	LFPR	10.10	10.05	1961	1973	4.38	2.38	2.00
01382050	Pequannock River near Stockholm, NJ	LFPR	5.39	5.40	1959	2005	.20	.01	.19
01382360	Kanouse Brook at Newfoundland, NJ	LFPR	3.87	3.85	1963	2005	.47	.07	.40
01382550	Pequannock River, Trib 1 at Kinnelon, NJ	LFPR	1.18	1.20	1992	2001	.13	.03	.10
01382700	Stone House Brook at Kinnelon, NJ	LFPR	3.45	3.45	1992	2000	.54	.12	.42
01383500	Wanaque River at Awosting	Continuous	27.10	.00	1918	2001	5.17	.38	4.79

United States Geological Survey Streamflow Station			Area (mi²)		Years of Record		Flows (MGDb)		
ID	Name	Type	Published	GIS	First	Last	September median	7Q10	Low-flow margin
01384500	Ringwood Creek near Wanaque, NJ	Continuous	19.10	16.86	1934	2001	2.13	.24	1.89
01386000	West Brook near Wanaque, NJ	Continuous	11.80	11.82	1934	1978	1.94	.38	1.56
01387400	Ramapo River at Ramapo, NY	Continuous	86.90	87.02	1978	2001	14.22	5.76	8.45
01387450	Mahwah River near Suffern, NY	Continuous	12.30	12.35	1958	1995	1.94	.43	1.51
01387600	Darlington Brook near Darlington, NJ	LFPR	3.38	3.37	1963	2002	.54	.16	.38
01387880	POND BROOK AT OAKLAND NJ	LFPR	6.76	7.11	1981	2004	1.66	.47	1.19
01388720	Beaver Dam Brook at Ryerson Road, at Lincoln Park, NJ	LFPR	13.10	12.84	2000	2006	1.62	.18	1.44
01389090	Naachtpunkt Brook at Totowa, NJ	LFPR	1.14	1.13	2001	2005	.36	.20	.16
01389140	Deepavaal Brook at Two Bridges, NJ	LFPR	7.59	7.67	1983	1999	1.35	.43	.92
01389850	Goffle Brook at Hawthorne, NJ	LFPR	8.77	8.77	1963	2004	1.29	.32	.98
01389860	DIAMOND BROOK AT FAIR LAWN NJ	LFPR	3.19	3.14	2001	2005	1.10	.55	.55
01389905	Fleischer Brook at Elmwood Park, NJ	LFPR	1.78	1.80	1964	1972	.31	.12	.19
01390700	Hohokus Brook at Wyckoff, NJ	LFPR	5.31	5.30	1963	1994	2.90	1.27	1.63
01390800	Valentine Brook at Allendale, NJ	LFPR	2.48	2.47	1963	1995	1.01	.30	.70
01391485	Sprout Brook at Rochelle Park, NJ	LFPR	5.56	5.51	1964	2002	3.49	1.96	1.53
01392210	Third River at Passaic, NJ	Continuous	11.80	11.91	1976	1997	5.14	2.84	2.29
01392500	Second River at Belleville, NJ	Continuous	11.60	11.43	1936	1964	4.65	2.36	2.29
01393200	Elizabeth River below Chancellor Avenue Bridge at Irvington, NJ	LFPR	5.14	5.14	1954	1965	2.33	1.28	1.05
01393890	E. Branch Rahway River at Maplewood, NJ	LFPR	5.11	5.15	1999	2005	2.06	1.07	.99
01394000	West Branch Rahway River at Millburn, NJ	Continuous as LFPR	7.10	7.09	1940	2002	.68	.10	.58
01395500	Robinsons Branch at Goodmans, NJ	Continuous as LFPR	12.70	12.48	1921	1924	1.52	.55	.97
01396030	South Branch Rahway River at Colonia, NJ	LFPR	9.31	9.28	1979	2000	1.19	.52	.67
01396500	South Branch Raritan River near High Bridge, NJ	Continuous	65.30	66.28	1918	2001	29.73	14.24	15.49
01396600	Spruce Run near Clinton, NJ	LFPR	18.10	18.05	1959	1987	4.65	1.47	3.17

United States Geological Survey Streamflow Station			Area (mi^2)		Years of Record		Flows (MGDb)		
ID	Name	Type	Published	GIS	First	Last	September median	7Q10	Low-flow margin
01396700	Mulhockaway Creek near Clinton, NJ	LFPR	20.50	20.49	1959	1963	5.22	1.96	3.26
01396815	BEAVER BROOK AT CLINTON NJ	LFPR	6.90	6.89	2002	2005	1.41	.25	1.16
01396900	Capoolong Creek at Lansdowne, NJ	LFPR	14.10	14.10	1959	2002	3.39	1.14	2.26
01398000	Neshanic River at Reaville, NJ	Continuous	25.70	25.45	1930	2001	1.55	.12	1.43
01398075	Pleasant Run at Centerville, NJ	LFPR	8.11	8.06	1981	1989	.49	.02	.47
01398110	HOLLAND BK AT SOUTH BRANCH NJ	LFPR	12.20	12.23	2001	2002	3.73	1.02	2.71
01399120	N. Branch Raritan River at Burnt Mills, NJ	LFPR	63.80	63.92	1975	2000	19.16	5.67	13.48
01399780	Lamington River at Burnt Mills, NJ	LFPR	100.00	99.18	936	955	29.92	8.45	21.47
01399820	Chambers Brook near North Branch, NJ	LFPR	4.71	4.71	1963	1972	.23	.01	.21
01399900	Chambers Brook at North Branch Depot, NJ	LFPR	10.20	10.19	1959	1975	1.00	.19	.80
01400300	Peters Brook near Raritan, NJ	Continuous as LFPR	4.19	4.18	1978	1996	.20	.03	.17
01400580	Millstone River at Hightstown, NJ	LFPR	19.70	19.73	1960	1974	3.81	.96	2.85
01400725	Cranbury Brook at Plainsboro, NJ	LFPR	22.10	22.04	1971	2006	4.35	1.05	3.30
01400810	Bear Brook at Princeton Junction, NJ	LFPR	12.40	12.29	1962	1971	2.03	.38	1.65
01401000	Stony Brook at Princeton, NJ	Continuous	44.50	44.43	1953	2001	2.71	.13	2.59
01401400	Heathcote Brook at Kingston, NJ	LFPR	9.00	9.00	1971	2004	1.56	.34	1.22
01401600	Beden Brook near Rocky Hill, NJ	LFPR	27.00	26.98	1959	2001	2.18	.21	1.98
01401700	Pike Run near Rocky Hill, NJ	LFPR	22.20	22.18	1959	2003	1.84	.30	1.53
01401900	Six Mile Run at Blackwells Mills, NJ	LFPR	16.10	16.09	1983	2003	5.02	1.76	3.26
01402700	Royce Brook at Manville, NJ	LFPR	11.70	12.31	1960	2002	.67	.05	.61
01403200	Middle Brook at Bround Brook, NJ	LFPR	17.20	17.16	1975	2005	3.15	.60	2.55
01403900	Bound Brook at Middlesex, NJ	Continuous as LFPR	48.40	48.46	1975	2003	7.42	2.24	5.18
01404060	Ambrose Brook at Middlesex, NJ	LFPR	13.90	13.91	1979	1991	1.84	.52	1.32
01404500	Lawrence Brook at Patricks Corner, NJ	Continuous as LFPR	29.00	29.27	1922	1926	4.69	1.31	3.37
01405290	Matchaponix Brook at Texas, NJ	LFPR	41.70	41.90	2000	2005	19.36	9.82	9.53

United States Geological Survey Streamflow Station			Area (mi^2)		Years of Record		Flows (MGDb)		
ID	Name	Type	Published	GIS	First	Last	September median	7Q10	Low-flow margin
01405340	Manalapan Brook at Federal Road near Manalapan, NJ	LFPR	20.90	20.81	1986	2003	7.68	2.80	4.88
01405470	Iresick Brook at East Spotswood, NJ	LFPR	2.29	2.23	1973	1980	.28	.03	.25
01406040	Deep Run at Rte 516, near Old Bridge, NJ	LFPR	15.60	15.63	2000	2005	3.36	.58	2.79
01407000	Matawan Creek at Matawan, NJ	Continuous	6.11	6.04	1931	1955	1.75	.00	1.75
01407012	Gravelly Brook at Church Street, at Matawan, NJ	LFPR	2.36	2.38	1986	1993	1.40	.79	.61
01407026	Mohingson (Wilkson) Creek at Church Street, at Matawan, NJ	LFPR	1.70	1.67	1986	2006	1.07	.76	.30
01407055	East Creek at North Centerville, NJ	LFPR	1.33	1.32	1969	1993	.88	.45	.43
01407070	Waackaack Creek near Keansburg, NJ	LFPR	4.30	5.50	1986	1993	2.84	1.09	1.75
01407102	Town Brook at Church Street, at New Monmouth, NJ	LFPR	3.35	3.35	1986	1993	1.63	.60	1.03
01407253	WILLOW BK NR HOLMDEL NJ	LFPR	7.56	7.52	1979	1988	2.92	1.12	1.80
01407300	Big Brook at Vanderburg, NJ	LFPR	8.41	8.40	1969	1988	3.86	1.73	2.13
01407400	Yellow Brook at Colts Neck, NJ	LFPR	9.71	9.72	1970	2006	5.12	2.40	2.71
01407450	Mine Brook at Colts Neck, NJ	LFPR	5.48	5.45	1969	2003	2.17	.78	1.40
01407532	Poricy Brook at Red Bank, NJ	LFPR	2.54	2.52	1986	1993	1.23	.41	.83
01407618	Whale Pond Brook near Oakhurst, NJ	LFPR	6.20	6.17	1989	1997	3.42	1.66	1.76
01407700	Shark River at Glendola, NJ	LFPR	9.14	9.47	1976	2003	4.96	3.19	1.78
01407755	Jumping Brook above reservior, near Neptune City, NJ	LFPR	5.58	5.58	1989	2003	1.56	.50	1.06
01407800	Wreck Pond Brook near Spring Lake, NJ	LFPR	7.00	7.05	1956	2002	3.86	2.14	1.72
01408000	Manasquan River at Squankum, NJ	Continuous	44.00	44.03	1931	2001	21.97	10.83	11.14
01408020	Mingamahone Brook at Squankum, NJ	LFPR	10.70	10.62	1966	1974	3.53	1.27	2.26
01408120	North Branch Metedeconk River near Lakewood, NJ	Continuous	34.90	34.54	1972	2001	17.45	8.25	9.20
01408140	South Branch Metedeconk River at Lakewood, NJ	Continuous as LFPR	26.00	26.18	1973	1975	15.52	7.88	7.65
01408440	Union Brook at Lakehurst, NJ	LFPR	19.00	18.87	1960	1994	15.41	7.42	7.99

United States Geological Survey Streamflow Station			Area (mi²)		Years of Record		Flows (MGDb)		
ID	Name	Type	Published	GIS	First	Last	September median	7Q10	Low-flow margin
01408460	Manapaqua Brook at Lakehurst, NJ	LFPR	6.32	6.33	1960	1992	2.58	.92	1.65
01408490	Ridgeway Branch near Lakehurst, NJ	LFPR	28.20	28.17	1959	1993	10.19	2.70	7.50
01408500	Toms River near Toms River, NJ	Continuous	123.00	123.33	1928	1966	73.68	42.93	30.75
01408592	Wrangel Brook at Mule Road, near Toms River, NJ	LFPR	14.30	13.96	1998	2003	15.78	10.93	4.85
01409000	Cedar Creek at Lanoka Harbor, NJ	Continuous	53.30	53.14	1931	1971	48.47	22.51	25.96
01409050	North Branch Forked River near Forked River, NJ	LFPR	13.40	13.36	1961	1965	6.89	3.24	3.65
01409100	Oyster Creek near Waretown, NJ	LFPR	9.95	10.01	1961	1965	17.61	11.83	5.78
01409150	Mill Creek near Manahawkin, NJ	LFPR	10.40	10.35	1972	2003	10.52	8.16	2.35
01409200	Fourmile Branch near Manahawkin, NJ	LFPR	5.24	5.24	1961	1967	2.55	1.06	1.49
01409250	Cedar Run near Manahawkin, NJ	LFPR	3.34	3.45	1961	1967	1.27	.56	.72
01409280	Westecunk Creek at Stafford Forge, NJ	Continuous as LFPR	15.80	15.95	1971	2003	14.28	8.67	5.62
01409300	Mill Branch near Tuckerton, NJ	LFPR	4.89	4.89	1961	1995	1.64	.67	.97
01409400	Mullica River near Batsto, NJ	Continuous	46.70	46.23	1956	2001	25.85	9.39	16.46
01409406	Sleeper Branch at Batsto, NJ	LFPR	36.20	36.14	1975	2005	1.76	.54	1.22
01409411	Nescochague Creek at Pleasant Mills, NJ	LFPR	43.70	43.77	1975	2005	20.33	9.33	11.01
01409416	Hammonton Creek at Wescoatville, NJ	LFPR	9.57	9.51	1974	2005	4.65	2.00	2.66
01409500	Batsto River at Batsto, NJ	Continuous	67.80	68.20	1927	2001	43.95	26.14	17.81
01409575	Landing Creek at Philadelphia Avenue at Egg Harbor City, NJ	LFPR	4.86	4.83	1974	2005	2.35	.99	1.36
01409810	W. Branch Wading River near Jenkins, NJ	Continuous	84.10	83.93	1974	1997	37.16	16.57	20.59
01410000	Oswego River at Harrisville, NJ	Continuous	72.50	72.42	1930	2001	30.38	13.73	16.64
01410150	E. Branch Bass River near New Gretna, NJ	Continuous	8.11	8.14	1977	2001	7.11	4.17	2.94
01410200	W. Branch Bass River near New Gretna, NJ	LFPR	6.54	6.47	1969	2002	4.82	2.43	2.39
01410215	Clarks Mill Stream at Port Republic, NJ	LFPR	8.61	8.59	1986	2005	3.85	1.89	1.96
01410225	Morses Mill Stream at Port Republic, NJ	LFPR	8.25	8.04	1986	2005	2.64	1.17	1.47

United States Geological Survey Streamflow Station			Area (mi^2)		Years of Record		Flows (MGDb)		
ID	Name	Type	Published	GIS	First	Last	September median	7Q10	Low-flow margin
01410500	Absecon Creek at Absecon, NJ	Continuous	17.90	17.97	1945	1985	5.04	.04	5.00
01411000	Great Egg Harbor River at Folsom, NJ	Continuous	57.10	56.94	1924	2001	28.44	14.01	14.43
01411170	Great Egg Harbor River at Mays Landing, NJ	LFPR	205.00	204.43	1988	2001	94.68	31.18	63.50
01411200	Babcock Creek at Mays Landing, NJ	LFPR	20.00	19.99	1959	2005	4.92	1.57	3.35
01411220	South River near Belcoville, NJ	LFPR	20.39	20.38	1994	2003	9.46	3.93	5.53
01411250	English Creek near Scullville, NJ	LFPR	3.80	3.74	1986	2005	1.93	1.05	.88
01411300	Tuckahoe River at Head of River, NJ	Continuous	30.80	30.76	1969	2001	10.99	4.65	6.33
01411305	Mill Branch near Northfield, NJ	LFPR	7.47	7.50	1986	2005	3.17	1.67	1.49
01411388	Mill Creek at Cold Spring, NJ	LFPR	1.34	1.35	1991	2005	.23	.06	.17
01411400	Fishing Creek at Rio Grande, NJ	LFPR	2.29	2.29	1966	2005	.37	.09	.28
01411410	Bidwell Creek tributary near Cape May Court House, NJ	LFPR	.41	.41	1968	2005	.01	.01	.01
01411412	Bidwell Creek tributary 2 near Cape May Court House, NJ	LFPR	.19	.18	1967	1990	.00	.00	.00
01411418	Goshen Creek at Goshen, NJ	LFPR	.33	.34	1968	2005	.01	.01	.00
01411428	Dennis Creek tributary 2 at Dennisville, NJ	LFPR	4.00	4.03	1990	2004	.67	.11	.56
01411438	Dennis Creek tributary 1 near North Dennis, NJ	LFPR	2.74	2.76	1990	2005	.20	.01	.19
01411442	East Creek near Eldora, NJ	LFPR	8.10	8.07	1990	2002	1.49	.34	1.16
01411445	West Creek near Eldora, NJ	LFPR	11.90	11.87	1990	2002	1.45	.17	1.28
01411450	Still Run at Aura, NJ	LFPR	3.21	3.21	1966	1990	1.12	.36	.76
01411456	Little Ease Run near Clayton, NJ	Continuous as LFPR	9.77	9.77	1976	2003	1.47	.32	1.15
01411462	Scotland Run at Franklinville, NJ	LFPR	14.80	14.82	1978	1990	6.40	2.75	3.65
01411700	Muddy Run at Centerton, NJ	LFPR	36.50	37.66	1976	1984	13.55	6.57	6.98
01411800	Maurice River near Millville, NJ	Continuous as LFPR	191.00	190.27	1966	1998	91.06	36.77	54.29
01411850	Mill Creek near Millville, NJ	LFPR	15.10	15.16	1973	1997	4.26	1.79	2.47
01411880	Maurice River at Sharp St. at Millville, NJ	LFPR	216.00	215.22	1973	1993	101.84	42.60	59.23

United States Geological Survey Streamflow Station			Area (mi^2)		Years of Record		Flows (MGDb)		
ID	Name	Type	Published	GIS	First	Last	September median	7Q10	Low-flow margin
01411955	Gravelly Run at Laurel Lake, NJ	LFPR	3.19	3.36	1998	2006	.47	.16	.30
01412000	Menantico Creek near Millville, NJ	Continuous	23.20	23.20	1930	1985	13.57	4.63	8.94
01412100	Manumuskin River near Manumuskin, NJ	LFPR	32.10	32.25	1964	1997	12.59	6.03	6.56
01412120	Muskee Creek near Port Elizabeth, NJ	LFPR	13.10	13.45	1969	1984	5.56	2.49	3.07
01412800	Cohansey River at Seeley, NJ	Continuous as LFPR	28.00	28.00	1977	2002	11.90	6.59	5.31
01413010	Barrett Run near Bridgeton, NJ	LFPR	7.02	6.98	1966	1984	1.89	.93	.96
01413020	Indian Fields Branch at Bridgeton, NJ	LFPR	4.64	4.63	1976	1984	3.65	1.93	1.72
01413050	Stow Creek at Jericho, NJ	LFPR	8.07	8.14	1966	1974	3.21	.83	2.38
01413060	Canton Drain near Canton, NJ	LFPR	2.50	2.48	1959	1963	.99	.32	.67
01413080	Raccoon D at Davis Mill, NJ	LFPR	3.19	3.22	889	901	1.96	1.07	.89
01438090	Clove Brook at N.J. Route 23 at Duttonville, NJ	LFPR	10.40	9.84	2000	2004	2.28	.66	1.62
01438400	Shimers Brook near Montague, NJ	LFPR	7.06	6.97	1958	2002	1.91	.63	1.28
01439830	Big Flat Brook at Tuttles Corner, NJ	LFPR	28.30	29.30	1963	2002	5.27	1.41	3.86
01439920	Little Flat Brook at Peters Valley, NJ	LFPR	14.70	14.66	2001	2002	2.70	.70	2.00
01440000	Flat Brook near Flatbrookville, NJ	Continuous	64.00	65.00	1923	2001	13.57	4.75	8.82
01440100	Vancampens Brook near Millbrook, NJ	LFPR	7.40	7.59	1958	2002	1.62	.43	1.19
01442760	Dunnfield Creek at Dunnfield, NJ	LFPR	3.56	3.55	1998	2006	.71	.16	.56
01442800	Stony Brook near Columbia, NJ	LFPR	3.53	3.52	1958	2002	.19	.03	.17
01443460	Paulins Kill at Paulins Kill, NJ	LFPR	73.00	72.74	1973	1979	21.60	7.63	13.97
01443475	Trout Brook near Middleville, NJ	LFPR	24.00	23.96	1979	1989	4.07	.70	3.37
01443500	Paulins Kill at Blairstown, NJ	Continuous	126.00	126.02	1921	2001	34.90	10.59	24.31
01443510	Blair Creek at Blairstown, NJ	LFPR	13.10	13.08	1989	2001	2.13	.54	1.59
01443900	Yards Creek near Blairstown, NJ	Continuous	5.34	5.32	1966	2001	1.23	.37	.86
01445100	PEQUEST RIVER AT LONG BRIDGE NJ	LFPR	48.40	48.31	1940	2006	12.49	4.15	8.34
01445200	Bear Creek near Johnsonburg, NJ	LFPR	12.90	12.85	1940	2001	3.28	1.12	2.15
01445800	Honey Run near Ramseyburg, NJ	LFPR	2.21	2.20	1982	1990	.29	.06	.23

United States Geological Survey Streamflow Station			Area (mi^2)		Years of Record		Flows (MGDb)		
ID	Name	Type	Published	GIS	First	Last	September median	7Q10	Low-flow margin
01446000	Beaver Brook near Belvidere, NJ	Continuous	36.70	36.61	1922	1961	7.76	1.16	6.59
01446400	Pequest River at Belvidere, NJ	LFPR	157.00	156.56	1974	2006	45.16	16.33	28.83
01446568	Buckhorn Creek at Hutchinson Road, at Hutchinson, NJ	LFPR	8.38	8.38	1990	2002	1.04	.37	.67
01455100	Lopatcong Creek at Phillipsburg, NJ	LFPR	14.50	14.19	1958	2005	5.95	4.00	1.95
01455300	Pohatcong Creek at Carpentersville, NJ	LFPR	57.00	57.01	1932	2002	14.32	5.65	8.67
01455780	Lubbers Run at Lockwood, NJ	LFPR	16.30	16.26	1982	2005	2.77	.36	2.41
01456000	Musconetcong River near Hackettstown, NJ	Continuous	68.90	68.91	1921	1974	33.61	7.74	25.86
01457000	Musconetcong River near Bloomsbury, NJ	Continuous	141.00	141.22	1903	2001	67.86	29.57	38.29
01458100	Hakihokake Creek at Milford, NJ	LFPR	17.20	17.24	1945	2003	6.08	2.23	3.85
01458400	Hakihokake Creek near Frenchtown, NJ	LFPR	9.75	9.78	1235	1263	1.17	.25	.92
01458600	Nishisakawick Creek at Frenchtown, NJ	LFPR	11.00	11.03	1958	2002	1.09	.07	1.01
01458700	Little Nishisakawick Creek at Frenchtown, NJ	LFPR	3.50	3.48	1959	1965	.13	.01	.12
01460880	Lockatong Creek at Raven Rock, NJ	LFPR	22.90	22.90	1978	2005	1.32	.17	1.15
01461300	Wickecheoke Creek at Stockton, NJ	LFPR	26.60	26.53	1946	1999	1.51	.16	1.36
01461900	Alexauken Creek near Lambertville, NJ	LFPR	14.80	14.86	1954	2002	.90	.06	.83
01462200	Moores Creek near Titusville, NJ	LFPR	10.20	10.22	1959	1964	.52	.05	.47
01462800	Jacobs Creek at Somerset, NJ	LFPR	13.30	13.33	1958	2000	.52	.01	.50
01463620	Assunpink Creek near Clarksville, NJ	Continuous as LFPR	34.30	34.26	1964	2001	9.88	2.49	7.39
01463670	Shipetaukin Creek at Bakersville, NJ	LFPR	8.97	9.51	1963	2002	2.24	.39	1.85
01463980	Pond Run at Trenton, NJ	LFPR	8.94	8.92	1963	1972	.21	.01	.20
01464000	Assunpink Creek at Trenton, NJ	Continuous	90.60	90.46	1923	1954	26.50	7.97	18.53
01464300	Crosswicks Creek near Cookstown, NJ	LFPR	24.90	20.03	1966	2002	9.30	4.19	5.11
01464380	North Run at Cookstown, NJ	LFPR	7.28	7.31	1966	2002	2.52	1.21	1.31
01464504	Crosswicks Creek at Groveville Road, at Groveville, NJ	LFPR	98.00	93.15	1998	2006	36.92	16.46	20.46

United States Geological Survey Streamflow Station			Area (mi^2)		Years of Record		Flows (MGDb)		
ID	Name	Type	Published	GIS	First	Last	September median	7Q10	Low-flow margin
01464515	Doctors Creek at Allentown, NJ	LFPR	17.40	17.45	1966	2005	4.95	1.51	3.44
01464525	Thorton Creek at Bordentown,, NJ	Continuous as LFPR	.84	.77	1976	1992	.08	.03	.06
01464530	Blacks Creek at Mansfield Sqaure, NJ	LFPR	19.70	19.64	1966	2002	4.87	1.71	3.16
01464540	Crafts Creek at Hedding, NJ	LFPR	10.60	10.54	1959	2001	.96	.21	.75
01464590	Assiscunk Creek near Burlington, NJ	LFPR	37.40	36.34	1966	2002	4.04	1.19	2.85
01465850	South Branch Rancocas Creek at Vincentown, NJ	Continuous as LFPR	64.50	64.72	1959	2006	19.35	5.75	13.60
01465884	Sharps Run at Rte 541 at Medford, NJ	LFPR	4.41	4.38	1981	1990	.39	.06	.32
01465900	SW. Branch Rancocas at Eayerstown, NJ	LFPR	76.00	75.94	1959	2001	26.80	12.89	13.91
01466900	Greenwood Brook at New Lisbon, NJ	Continuous as LFPR	77.90	77.87	1973	2003	31.18	13.64	17.53
01467000	North Branch Rancocas Creek at Pemberton, NJ	Continuous	118.00	117.54	1921	2001	53.00	22.33	30.67
0146700260	INDIAN RUN AT BIRMINGHAM NJ	LFPR	5.89	5.92	2001	2003	1.93	.81	1.12
01467021	Mill Creek at Levitt Pky, Willingboro, NJ	LFPR	9.12	9.18	1975	1977	1.79	.70	1.09
01467070	North Branch Pennsauken Creek at Maple Shade, NJ	LFPR	13.00	13.26	1959	1997	2.70	.94	1.76
01467080	South branch Pennsauken Creek, at Maple Shade, NJ	LFPR	8.10		1964	1967	3.07	1.65	1.42
01467150	Cooper River at Haddonfield, NJ	Continuous	17.00	17.08	1984	2004	6.18	3.01	3.17
01467180	North Branch Cooper River at Ellisburg, NJ	LFPR	10.50	10.51	1964	1997	3.59	1.76	1.82
01467312	Newton Creek at West Collingswood, NJ	LFPR	4.51	4.54	1964	1972	5.62	1.78	3.85
01467330	South Branch Big Timber Creek at Blackwood, NJ	LFPR	19.60	20.80	1964	2001	14.52	8.27	6.25
01467359	NB BIG TIMBER C AT GLENDORA NJ	LFPR	18.80	18.91	1997	2002	11.74	9.32	2.42
01475020	Mantua Creek at Sewell, NJ	LFPR	14.50	14.46	1966	1994	7.56	3.32	4.24
01476600	Still Run near Mickleton, NJ	Continuous as LFPR	3.98	3.96	1960	1966	1.93	.65	1.28
01477120	Raccoon Creek near Swedesboro, NJ	Continuous	26.90	25.94	1965	2001	10.99	4.75	6.24
01477130	Basgalore Creek at Russell Mill Road, near Swedesboro, NJ	LFPR	3.30	3.36	1957	2003	1.62	1.06	.56

United States Geological Survey Streamflow Station			Area (mi^2)		Years of Record		Flows (MGDb)		
ID	Name	Type	Published	GIS	First	Last	September median	7Q10	Low-flow margin
01477510	Oldmans Creek at Porches Mill, NJ	LFPR	21.00	20.98	1979	1996	7.65	3.17	4.48
01482520	Salem River at Sharptown, NJ	LFPR	27.30	27.15	1966	1974	6.00	2.53	3.47
01483000	Alloway Creek at Alloway, NJ	Continuous	20.30	20.31	1952	1973	4.43	.00	4.43
01483010	Deep Run near Alloway, NJ	LFPR	5.30	5.28	1978	2005	2.37	1.23	1.14

Abbreviations

USGS - U.S. Geological Survey
ID - identifier
MGD - million gallons per day
7Q10 - 7-day 10 year low-flow
LFPR - low-flow partial-record station
Continuous - continuous-record
NJ – New Jersey
NY – New York

Table A3. New Jersey HUC11 watersheds giving the flow-transfer method used to calculate their low-flow statistics, associated index stations, and upstream HUC11 watersheds utilized by flow-transfer method 2. (Index stations are identified by their Station ID; index stations in **bold** were not within the area draining to the outflow point of the HUC11; upstream HUC11 watersheds are identified by their map key number; all abbreviations are at the end of the table.)

HUC11		Flow Transfer Method	Index Stations						Upstream HUC11s		
ID	map key		#1	#2	#3	#4	#5	#6	#1	#2	#3
02040105050	111	FT3	01443500	01443510	01443900						
02040105040	112	FT2	01443460						113		
02040105030	113	FT1	01443475								
02040104240	114	FT1	01440100	01442760							
02040104150	115	FT3	01440000								
02040104140	116	FT1	01439830								
02040104130	117	FT1	01439920								
02040104110	118	FT1	**01439920**								
02040104090	119	FT1	01438090	01438400							
02020007020	204	FT1	01367910								
02030103100	304	FT1	01387400	01387450	01387600	01387880					
02030103150	401	FT3	01392210	01392500							
02030103120	402	FT3	01389090	01389140	01389850	01389860	01389905				
02030103140	403	FT1	01390700	01390800	01391485						
02030103180	501	FT2	01378520	01378560	01378590				503		
02030101170	502	FT1	**01378350**	**01378410**	**01378590**	**01378615**					
02030103170	503	FT1	01377490	01378385	01378430						
02030104050	701	FT1	01393890	01394000	01395500	01396030					
02030104030	702	FT1	**01393200**	**01395500**							
02030104020	703	FT1	01393200								
02030105030	802	FT1	01398000								
02030105070	805	FT2	01399820	01399900					806	807	

HUC11		Flow Transfer Method	Index Stations						Upstream HUC11s		
ID	map key		#1	#2	#3	#4	#5	#6	#1	#2	#3
02030105160	901	FT3	01405470	01406040							
02030105150	902	FT1	01405290								
02030105140	903	FT1	01405340								
02030105130	904	FT1	01404500								
02030105120	905	FT3	01403200	01403900	01404060						
02030105080	906	FT3	01400300	**01402700**							
02030105110	1001	FT2	01401400	01401600	01401700	01401900	01402700		1003	1002	
02030105100	1002	FT1	01400580	01400725	01400810						
02030105090	1003	FT1	01401000								
02040105240	1101	FT2	01464000						1102		
02040105230	1102	FT1	01463620	01463670							
02040105210	1103	FT1	01461900	01462200	01462800						
02040105200	1104	FT1	01460880	01461300							
02030104100	1201	FT1	01408000	01408020							
02030104090	1202	FT1	01407618	01407700	01407755	01407800					
02030104080	1203	FT1	**01407532**	**01407618**							
02030104070	1204	FT1	01407253	01407300	01407400	01407450					
02030104060	1205	FT1	01407000	01407012	01407026	01407055	01407102	01407070			
02040301140	1301	FT1	01409300								
02040301130	1302	FT1	01409150	01409200	01409250	01409280					
02040301120	1303	FT1	**01409100**	**01409200**							
02040301110	1304	FT1	01409050	01409100							
02040301090	1305	FT1	01409000								
02040301080	1306	FT2	01408592						1307		
02040301060	1307	FT2	01408500						1308		
02040301070	1308	FT1	01408440	01408460	01408490						

HUC11		Flow Transfer Method	Index Stations						Upstream HUC11s		
ID	map key		#1	#2	#3	#4	#5	#6	#1	#2	#3
02040301050	1309	FT1	**01408120**	**01408140**	**01408500**						
02040301040	1310	FT2	01408120	01408140	**01408500**				1312	1311	
02040301030	1311	FT1	01408140								
02040301020	1312	FT1	01408120								
02040301210	1401	FT3	**01409300**	01410225	**01410500**						
02040301200	1402	FT3	01410150	01410200	01410215	01410225					
02040301170	1403	FT2	01409416	01409575					1405	1404	
02040301160	1404	FT1	01409400	01409406	01409411						
02040301150	1405	FT1	01409500								
02040301190	1406	FT1	01409810								
02040301180	1407	FT1	01410000								
02040302070	1501	FT1	01411300								
02040302050	1502	FT2	01411200	01411220	01411250				1503		
02040302040	1503	FT2	01411170						1504		
02040302030	1504	FT1	01411000								
02040302060	1505	FT1	01411305								
02040302010	1506	FT1	**01410225**	01410500	**01411305**						
02040302020	1507	FT1	01410500								
02040302080	1601	FT1	01411388								
02040206230	1602	FT1	01411400	01411410	01411412	01411418					
02040206220	1603	FT1	01411428	01411438							
02040206210	1604	FT1	01411442	01411445							
02040206200	1701	FT3	01412120								
02040206190	1702	FT1	01412100								
02040206180	1703	FT1	01412000								
02040206170	1704	FT2	01411850	01411955					1705		

HUC11		Flow Transfer Method	Index Stations						Upstream HUC11s		
ID	map key		#1	#2	#3	#4	#5	#6	#1	#2	#3
02040206160	1705	FT2	01411880						1706		
02040206140	1706	FT2	01411800						1708	1709	1707
02040206150	1707	FT1	01411700								
02040206120	1708	FT1	01411450	01411456	**01411462**						
02040206130	1709	FT1	01411462								
02040206110	1710	FT1	**01411445**	**01411955**							
02040206100	1711	FT1	**01411445**	**01411955**	**01413080**						
02040206090	1712	FT2	01413010	01413020					1713		
02040206080	1713	FT1	01412800								
02040206070	1714	FT1	01413050	01413060	01413080						
02040206060	1715	FT1	01483000	01483010							
02040206040	1716	FT1	**01482520**	**01483000**							
02040206020	1717	FT1	**01482520**								
02040206030	1718	FT1	01482520								
02040202160	1801	FT1	01477510								
02040202150	1802	FT1	01477120	01477130							
02040202140	1803	FT1	01476600								
02040202130	1804	FT1	01475020								
02040202120	1805	FT1	01467312	01467330	01467359						
02040202110	1806	FT1	01467150	01467180							
02040202100	1807	FT1	01467070	01467080							
02040202090	1808	FT1	**01467021**	**01467070**							
02040202080	1901	FT2	01467021						1905	1902	
02040202070	1902	FT3	01465884	**0146700260**	**01467021**	**01467070**					
02040202050	1903	FT2	01465850						1904		
02040202060	1904	FT1	01465900								

HUC11		Flow Transfer Method	Index Stations						Upstream HUC11s		
ID	map key		#1	#2	#3	#4	#5	#6	#1	#2	#3
02040202040	1905	FT2	01467000						1906	1907	
02040202020	1906	FT1	**01466900**	01467000							
02040202030	1907	FT1	01466900								
02040201110	2001	FT1	**01467021**								
02040201100	2002	FT1	01464590								
02040201090	2003	FT1	01464540								
02040201080	2004	FT1	01464530								
02040201030	2005	FT1	**01464525**								
02040201070	2006	FT2	**01463980**	**01464530**					2008	2007	
02040201060	2007	FT1	01464515								
02040201050	2008	FT2	01464504						2009		
02040201040	2009	FT1	01464300	01464380							

Abbreviations
FT1 - Flow Transfer Method 1
FT2 - Flow Transfer Method 2
FT3 - Flow Transfer Method 3

Table A4. Results of the HUC11 watershed analysis, giving method of analysis, September median flow, the 7-day 10-year low-flow, and the low-flow margin (revised 11/2008 by NJDEP-NJGS)

HUC11					Flows (MGD)			Flows per Area (MGD/MI^2)		
map key	ID	name	Analysis method[1]	Area (mi^2)	September median	7Q10	Low-Flow Margin	September median	7Q10	Low-Flow Margin
101	2040105160	Musconetcong River (below incl Trout Bk)	HA	73.87	19.9	5.88	14.02	0.27	0.08	0.19
102	2040105150	Musconetcong River (above Trout Brook)	HA	81.59	13.65	3.2	10.45	0.17	0.04	0.13
103	2040105140	Pohatcong Creek	HA	57.98	13.53	4.17	9.36	0.23	0.07	0.16
104	2040105120	Lopatcong Creek	HA	19.49	6.25	2.94	3.32	0.32	0.15	0.17
105	2040105110	Pophandusing Brook / Buckhorn Creek	HA	27.57	5.28	1.43	3.86	0.19	0.05	0.14
106	2040105100	Beaver Brook	HA	36.66	5.91	1.45	4.46	0.16	0.04	0.12
107	2040105090	Pequest River (below Bear Swamp)	HA	47.38	9.71	2.54	7.17	0.2	0.05	0.15
108	2040105070	Pequest River (above/incl Bear Swamp)	HA	54.63	12.6	2.78	9.81	0.23	0.05	0.18
109	2040105080	Bear Creek	HA	18.32	3.97	1.01	2.96	0.22	0.06	0.16
110	2040105060	Stony Brook / Delawanna Creek	HA	18.66	3.75	0.95	2.8	0.2	0.05	0.15
111	2040105050	Paulins Kill (below Stillwater Village)	FT3	69.78	18.58	4.95	13.63	0.27	0.07	0.2
112	2040105040	Paulins Kill (above Stillwater Village)	FT2	79.31	23.55	8.32	15.23	0.3	0.1	0.19
113	2040105030	Trout Brook / Swartswood Lake	FT1	27.76	4.72	0.81	3.91	0.17	0.03	0.14
114	2040104240	Van Campens Brook / Dunnfield Creek	FT1	22.06	4.61	1.17	3.44	0.21	0.05	0.16
115	2040104150	Flat Brook	FT3	16.86	4.87	2.47	2.4	0.29	0.15	0.14
116	2040104140	Big Flat Brook	FT1	32.56	5.85	1.57	4.28	0.18	0.05	0.13
117	2040104130	Little Flat Brook	FT1	16.77	3.09	0.8	2.29	0.18	0.05	0.14
118	2040104110	Walpack Bend / Montague Riverfront	FT1	16.07	2.96	0.77	2.19	0.18	0.05	0.14
119	2040104090	Shimers Brook / Clove Brook	FT1	22.15	5.52	1.7	3.82	0.25	0.08	0.17
201	2020007030	Wallkill River (below road to Martins)	HA	32.16	4.14	0.86	3.28	0.13	0.03	0.1
202	2020007040	Pochuck Creek	HA	106.08	20.84	5.01	15.83	0.2	0.05	0.15
203	2020007010	Wallkill River (above road to Martins)	HA	60.99	11.1	2.68	8.42	0.18	0.04	0.14
204	2020007020	Papakating Creek	FT1	60.59	6.2	1.23	4.97	0.1	0.02	0.08
301	2030103110	Pompton River	HA	23.98	4.59	0.9	3.69	0.19	0.04	0.15
302	2030103050	Pequannock River	HA	86.79	18.38	4.85	13.52	0.21	0.06	0.16
303	2030103070	Wanaque River	HA	106.82	20.11	4.98	15.13	0.19	0.05	0.14

HUC11					Flows (MGD)			Flows per Area (MGD/MI²)		
map key	ID	name	Analysis method[1]	Area (mi^2)	September median	7Q10	Low-Flow Margin	September median	7Q10	Low-Flow Margin
304	2030103100	Ramapo River	FT1	161.02	26.91	10	16.91	0.17	0.06	0.11
401	2030103150	Passaic River Lower (Nwk Bay to Saddle)	FT3	53.54	22.45	11.93	10.52	0.42	0.22	0.2
402	2030103120	Passaic River Lower (Saddle to Pompton)	FT3	83.4	16.34	6	10.34	0.2	0.07	0.12
403	2030103140	Saddle River	FT1	59.54	33.18	15.83	17.35	0.56	0.27	0.29
501	2030103180	Hackensack R (below/incl Hirshfeld Bk)	FT2	84.98	19.09	9.11	9.98	0.22	0.11	0.12
502	2030101170	Hudson River	FT1	44.4	12.69	6.28	6.41	0.29	0.14	0.14
503	2030103170	Hackensack R (above Hirshfeld Brook)	FT1	112.42	45.95	25.96	19.99	0.41	0.23	0.18
601	2030103040	Passaic River Upr (Pompton to Pine Bk)	HA	11.87	2.68	0.67	2.02	0.23	0.06	0.17
602	2030103010	Passaic River Upr (above Pine Bk br)	HA	143.08	29.73	7.08	22.65	0.21	0.05	0.16
603	2030103020	Whippany River	HA	69.6	17.8	5.62	12.18	0.26	0.08	0.18
604	2030103030	Rockaway River	HA	136.73	30.4	7.91	22.49	0.22	0.06	0.16
701	2030104050	Rahway River / Woodbridge Creek	FT1	99.25	15.91	6.54	9.37	0.16	0.07	0.09
702	2030104030	Morses Creek / Piles Creek	FT1	11.8	2.58	1.23	1.35	0.22	0.1	0.11
703	2030104020	Elizabeth River	FT1	42.77	19.38	10.65	8.73	0.45	0.25	0.2
801	2030105040	Raritan River SB (NB to Three Bridges)	HA	41.81	7.96	1.84	6.11	0.19	0.04	0.15
802	2030105030	Neshanic River	FT1	55.69	3.39	0.26	3.13	0.06	0	0.06
803	2030105020	Raritan River SB (3 Brdgs to Spruce Run)	HA	110.89	26.39	8.26	18.13	0.24	0.07	0.16
804	2030105010	Raritan River SB (above Spruce Run)	HA	70.91	24.06	8.32	15.74	0.34	0.12	0.22
805	2030105070	Raritan River NB (SB to Lamington)	FT2	25.53	2.11	0.34	1.77	0.08	0.01	0.07
806	2030105050	Lamington River	HA	99.25	32.72	9.52	23.2	0.33	0.1	0.23
807	2030105060	Raritan River NB (above Lamington)	HA	63.92	19.64	5.39	14.24	0.31	0.08	0.22
901	2030105160	Raritan R Lower (below Lawrence)	FT3	73.18	14.91	2.5	12.41	0.2	0.03	0.17
902	2030105150	Matchaponix Brook	FT1	44.23	20.44	10.37	10.07	0.46	0.23	0.23
903	2030105140	Manalapan Brook	FT1	43.9	16.2	5.91	10.29	0.37	0.13	0.23
904	2030105130	Lawrence Brook	FT1	46.18	7.4	2.07	5.33	0.16	0.04	0.12
905	2030105120	Raritan R Lower (Lawrence to Millstone)	FT3	119.27	18.61	5.04	13.57	0.16	0.04	0.11
906	2030105080	Raritan River Lower (Millstone to NB/SB)	FT3	24.64	1.3	0.12	1.18	0.05	0	0.05
1001	2030105110	Millstone River (below/incl Carnegie Lk)	FT2	130.32	16.97	4	12.97	0.13	0.03	0.1
1002	2030105100	Millstone River (above Carnegie Lake)	FT1	98.78	18.62	4.37	14.25	0.19	0.04	0.14

HUC11					Flows (MGD)			Flows per Area (MGD/MI^2)		
map key	ID	name	Analysis method[1]	Area (mi^2)	September median	7Q10	Low-Flow Margin	September median	7Q10	Low-Flow Margin
1003	2030105090	Stony Brook	FT1	55.34	3.37	0.16	3.21	0.06	0	0.06
1101	2040105240	Assunpink Creek (below Shipetaukin Ck)	FT2	44.47	13.79	4.98	8.81	0.31	0.11	0.2
1102	2040105230	Assunpink Creek (above Shipetaukin Ck)	FT1	47.73	13.22	3.14	10.08	0.28	0.07	0.21
1103	2040105210	Alexauken Ck / Moore Ck / Jacobs Ck	FT1	61.08	3.09	0.19	2.9	0.05	0	0.05
1104	2040105200	Lockatong Creek / Wickecheoke Creek	FT1	54.08	3.1	0.36	2.74	0.06	0.01	0.05
1105	2040105170	Hakihokake/Harihokake/Nishisakawick Ck	HA	61.28	11.72	3.01	8.72	0.19	0.05	0.14
1201	2030104100	Manasquan River	FT1	82.48	38.48	18.26	20.22	0.47	0.22	0.25
1202	2030104090	Whale Pond Bk / Shark R / Wreck Pond Bk	FT1	60.69	29.62	16.08	13.54	0.49	0.26	0.22
1203	2030104080	Shrewsbury River (above Navesink River)	FT1	29.42	15.74	7.01	8.73	0.54	0.24	0.3
1204	2030104070	Navesink River / Lower Shrewsbury River	FT1	94.58	42.8	18.34	24.46	0.45	0.19	0.26
1205	2030104060	Raritan / Sandy Hook Bay tributaries	FT1	58.49	27.62	10.65	16.97	0.47	0.18	0.29
1301	2040301140	Lower Little Egg Harbor Bay tribs	FT1	35.2	11.8	4.82	6.98	0.34	0.14	0.2
1302	2040301130	Manahawkin/Upper Little Egg Harbor tribs	FT1	71.58	58.55	37.74	20.81	0.82	0.53	0.29
1303	2040301120	Waretown Ck / Barnegat Bay South	FT1	24.87	32.86	21.01	11.85	1.32	0.84	0.48
1304	2040301110	Forked River / Oyster Creek	FT1	38.92	40.79	25.09	15.7	1.05	0.64	0.4
1305	2040301090	Cedar Creek	FT1	67.83	61.86	28.73	33.13	0.91	0.42	0.49
1306	2040301080	Toms River (below Oak Ridge Parkway)	FT2	68.01	76.88	53.25	23.63	1.13	0.78	0.35
1307	2040301060	Toms River (above Oak Ridge Parkway)	FT2	60.23	40.36	29.88	10.48	0.67	0.5	0.17
1308	2040301070	Union/Ridgeway Branch (Toms River)	FT1	63.1	33.31	13.05	20.26	0.53	0.21	0.32
1309	2040301050	Kettle Creek / Barnegat Bay North	FT1	31.34	18.15	10.05	8.1	0.58	0.32	0.26
1310	2040301040	Metedeconk River	FT2	19.93	11.54	6.39	5.15	0.58	0.32	0.26
1311	2040301030	Metedeconk River SB	FT1	30.8	18.25	9.27	8.98	0.59	0.3	0.29
1312	2040301020	Metedeconk River NB	FT1	38.24	19.32	9.13	10.19	0.51	0.24	0.27
1401	2040301210	Great Bay / Mullica R (below GSP bridge)	FT3	21.72	6.55	1.32	5.23	0.3	0.06	0.24
1402	2040301200	Mullica River (GSP bridge to Turtle Ck)	FT3	95.65	56.4	29.58	26.82	0.59	0.31	0.28
1403	2040301170	Mullica River (Turtle Ck to Basto River)	FT2	109.93	53.66	22.92	30.74	0.49	0.21	0.28
1404	2040301160	Mullica River (above Batsto River)	FT1	127.25	48.36	19.43	28.93	0.38	0.15	0.23
1405	2040301150	Batsto River	FT1	67.85	43.72	26.01	17.71	0.64	0.38	0.26

HUC11					Flows (MGD)			Flows per Area (MGD/MI^2)		
map key	ID	name	Analysis method[1]	Area (mi^2)	September median	7Q10	Low-Flow Margin	September median	7Q10	Low-Flow Margin
1406	2040301190	West Branch Wading River	FT1	87.03	38.53	17.18	21.35	0.44	0.2	0.25
1407	2040301180	Oswego River	FT1	72.51	30.42	13.75	16.67	0.42	0.19	0.23
1501	2040302070	Tuckahoe River	FT1	102.14	36.49	15.44	21.05	0.36	0.15	0.21
1502	2040302050	Great Egg Harbor R (below Lake Lenape)	FT2	142.08	52.54	21.1	31.44	0.37	0.15	0.22
1503	2040302040	Great Egg Harbor R (Lk Lenape to HospBr)	FT2	133.4	59.2	13.71	45.49	0.44	0.1	0.34
1504	2040302030	Great Egg Harbor R (above HospitalityBr)	FT1	71.01	35.47	17.47	18	0.5	0.25	0.25
1505	2040302060	Patcong Creek/Great Egg Harbor Bay	FT1	42.68	18.04	9.5	8.54	0.42	0.22	0.2
1506	2040302010	Reeds Bay / Absecon Bay & tribs	FT1	14.81	4.8	1.27	3.53	0.32	0.09	0.24
1507	2040302020	Absecon Creek	FT1	26.42	11.52	5.84	5.68	0.44	0.22	0.21
1601	2040302080	Cape May Bays & Tribs East	FT1	69.05	11.76	3.07	8.69	0.17	0.04	0.13
1602	2040206230	Cape May Tribs West	FT1	45.14	5.47	1.54	3.93	0.12	0.03	0.09
1603	2040206220	Dennis Creek	FT1	41.17	5.28	0.73	4.55	0.13	0.02	0.11
1604	2040206210	West Creek / East Creek / Riggins Ditch	FT1	45.33	6.68	1.16	5.52	0.15	0.03	0.12
1701	2040206200	Maurice River (below Menantico Creek)	FT3	48.93	20.22	9.06	11.16	0.41	0.19	0.23
1702	2040206190	Manamuskin River	FT1	36.17	14.12	6.76	7.36	0.39	0.19	0.2
1703	2040206180	Menantico Creek	FT1	39.2	22.92	7.82	15.1	0.58	0.2	0.39
1704	2040206170	Maurice River (Menantico Ck to Union Lk)	FT2	44.6	11.39	4.7	6.69	0.26	0.11	0.15
1705	2040206160	Maurice River (Union Lk to Sherman Ave)	FT2	25.01	10.81	5.84	4.97	0.43	0.23	0.2
1706	2040206140	Maurice River (above Sherman Ave Bridge)	FT2	56.77	42.58	15.51	27.07	0.75	0.27	0.48
1707	2040206150	Muddy Run	FT1	57.85	20.81	10.09	10.72	0.36	0.17	0.19
1708	2040206120	Still Run / Little Ease Run	FT1	46.08	14.9	5.68	9.22	0.32	0.12	0.2
1709	2040206130	Scotland Run	FT1	29.81	12.87	5.53	7.34	0.43	0.19	0.25
1710	2040206110	Dividing Creek	FT1	60.63	7.64	1.31	6.33	0.13	0.02	0.1
1711	2040206100	Back / Cedar / Nantuxent Creeks	FT1	51.05	10.73	3.87	6.86	0.21	0.08	0.13
1712	2040206090	Cohansey River (below Cornwell Run)	FT2	69.6	33.21	17.15	16.06	0.48	0.25	0.23
1713	2040206080	Cohansey River (above Sunset Lake)	FT1	37.38	15.89	8.8	7.09	0.43	0.24	0.19
1714	2040206070	Stow Creek	FT1	55.03	24.49	8.83	15.66	0.45	0.16	0.28

HUC11					Flows (MGD)			Flows per Area (MGD/MI^2)		
map key	ID	name	Analysis method[1]	Area (mi^2)	September median	7Q10	Low-Flow Margin	September median	7Q10	Low-Flow Margin
1715	2040206060	Alloway Creek / Hope Creek	FT1	77.45	20.58	3.72	16.86	0.27	0.05	0.22
1716	2040206040	Salem River (below 39d40m14s dam)	FT1	58.62	12.88	3.12	9.76	0.22	0.05	0.17
1717	2040206020	Pennsville / Penns Grove tribs	FT1	22.72	5.02	2.12	2.9	0.22	0.09	0.13
1718	2040206030	Salem R(above 39d40m14s dam)/Salem Canal	FT1	58.26	12.88	5.43	7.45	0.22	0.09	0.13
1801	2040202160	Oldmans Creek	FT1	43.88	16	6.63	9.37	0.36	0.15	0.21
1802	2040202150	Raccoon Creek / Birch Creek	FT1	48.44	20.84	9.6	11.24	0.43	0.2	0.23
1803	2040202140	Cedar Swamp / Repaupo Ck / Clonmell Ck	FT1	35.8	17.44	5.87	11.57	0.49	0.16	0.32
1804	2040202130	Mantua Creek	FT1	50.12	26.2	11.51	14.69	0.52	0.23	0.29
1805	2040202120	Woodbury / Big Timber / Newton Creeks	FT1	95.74	68.98	41.91	27.07	0.72	0.44	0.28
1806	2040202110	Cooper River	FT1	48.51	17.17	8.39	8.78	0.35	0.17	0.18
1807	2040202100	Pennsauken Creek	FT1	36.2	9.78	4.39	5.39	0.27	0.12	0.15
1808	2040202090	Pompeston Creek / Swede Run	FT1	18.48	3.7	1.35	2.35	0.2	0.07	0.13
1901	2040202080	Rancocas Creek	FT2	34.71	6.77	2.65	4.12	0.2	0.08	0.12
1902	2040202070	SB Rancocas Creek (below Bobbys Run)	FT3	22.55	4.69	1.73	2.96	0.21	0.08	0.13
1903	2040202050	Rancocas Creek SB (above Bobbys Run)	FT1	68.58	20.5	6.09	14.41	0.3	0.09	0.21
1904	2040202060	Rancocas Creek SB SW Branch	FT2	75.99	26.81	12.9	13.91	0.35	0.17	0.18
1905	2040202040	Rancocas Creek NB (below New Lisbon dam)	FT1	37.63	17.72	7.37	10.35	0.47	0.2	0.28
1906	2040202020	Rancocas Creek NB (above New Lisbon dam)	FT1	32.11	17.66	7.03	10.63	0.55	0.22	0.33
1907	2040202030	Greenwood Branch (NB Rancocas Creek)	FT1	78.15	31.29	13.69	17.6	0.4	0.18	0.23
2001	2040201110	Burlington/Edgewater Park Delaware tribs	FT1	6.57	1.28	0.5	0.78	0.19	0.08	0.12
2002	2040201100	Assiscunk Creek	FT1	45.91	5.1	1.5	3.6	0.11	0.03	0.08
2003	2040201090	Crafts Creek	FT1	25.92	2.36	0.52	1.84	0.09	0.02	0.07
2004	2040201080	Blacks Creek	FT1	23.39	5.8	2.04	3.76	0.25	0.09	0.16
2005	2040201030	Duck Creek and UDRV to Assunpink Ck	FT1	2.69	0.28	0.1	0.18	0.1	0.04	0.07
2006	2040201070	Crosswicks Ck (below Doctors Creek)	FT2	20.05	3.56	1.21	2.35	0.18	0.06	0.12
2007	2040201060	Doctors Creek	FT1	25.93	7.35	2.24	5.11	0.28	0.09	0.2
2008	2040201050	Crosswicks Ck (Doctors Ck to New Egypt)	FT2	56.99	21.11	9.21	11.9	0.37	0.16	0.21

HUC11					Flows (MGD)			Flows per Area (MGD/MI^2)		
map key	ID	name	Analysis method[1]	Area (mi^2)	September median	7Q10	Low-Flow Margin	September median	7Q10	Low-Flow Margin
2009	2040201040	Crosswicks Ck (above New Egypt)	FT1	41.21	17.81	8.14	9.67	0.43	0.2	0.23

1. Analysis method abbreviations
   HA - Highlands aggregate
   FT1 - Flow Transfer Method 1
   FT2 - Flow Transfer Method 2
   FT3 - Flow Transfer Method 3

2. Other abbreviations
   MGD - million gallons per day
   MGD/MI^2 – million gallons per day per square mile
   7Q10- 7-day 10-year low-flow

Appendix B. Net Leakage from HUC11 Watersheds Underlain by the New Jersey Coastal Plain Aquifer System

Outputs are from the 1998 New Jersey Coastal Plain RASA Groundwater Model analysis developed by United States Geological Survey West Trenton Water Science Center.

WMA #	11-Digit Hydrologic Unit (HUC11)		Induced Leakage (MGD)
	#	name	
9	02030105080	Raritan River Lower (Millstone to NB/SB)	0
9	02030105120	Raritan R Lower (Lawrence to Millstone)	0
9	02030105130	Lawrence Brook	1.01
9	02030105140	Manalapan Brook	2.13
9	02030105150	Matchaponix Brook	1.21
9	02030105160	Raritan R Lower (below Lawrence)	0.49
10	02030105090	Stony Brook	0
10	02030105100	Millstone River (above Carnegie Lake)	3.21
10	02030105110	Millstone River (below/incl Carnegie Lk)	0
11	02040105170	Hakihokake/Harihokake/Nishisakawick Ck	0
11	02040105200	Lockatong Creek / Wickecheoke Creek	0
11	02040105210	Alexauken Ck / Moore Ck / Jacobs Ck	0
11	02040105230	Assunpink Creek (above Shipetaukin Ck)	0.57
11	02040105240	Assunpink Creek (below Shipetaukin Ck)	0.49
12	02030104060	Raritan / Sandy Hook Bay tributaries	0.4
12	02030104070	Navesink River / Lower Shrewsbury River	1.23
12	02030104080	Shrewsbury River (above Navesink River)	0.29
12	02030104090	Whale Pond Bk / Shark R / Wreck Pond Bk	0.12
12	02030104100	Manasquan River	0.78
12	02030104910	Raritan Bay / Sandy Hook Bay	0
12	02030104920	Atlantic Coast (Sandy Hook to WhalePond)	0
12	02030104930	Atlantic Coast (Whale Pond to Manasquan)	0
13	02040301020	Metedeconk River NB	0.28
13	02040301030	Metedeconk River SB	0.31
13	02040301040	Metedeconk River	0
13	02040301050	Kettle Creek / Barnegat Bay North	0
13	02040301060	Toms River (above Oak Ridge Parkway)	1.38
13	02040301070	Union/Ridgeway Branch (Toms River)	0.54
13	02040301080	Toms River (below Oak Ridge Parkway)	0
13	02040301090	Cedar Creek	0.84
13	02040301100	Barnegat Bay Central & Tribs	0.19
13	02040301110	Forked River / Oyster Creek	0.62
13	02040301120	Waretown Ck / Barnegat Bay South	0.42
13	02040301130	Manahawkin/Upper Little Egg Harbor tribs	1.09
13	02040301140	Lower Little Egg Harbor Bay tribs	0.27
13	02040301910	Atlantic Coast (Manasquan to Barnegat)	0
13	02040301920	Atlantic Coast (Barnegat to Little Egg)	0
14	02040301150	Basto River	0.18

WMA #	11-Digit Hydrologic Unit (HUC11)		Induced Leakage (MGD)
	#	name	
14	02040301160	Mullica River (above Basto River)	0.86
14	02040301170	Mullica River (Turtle Ck to Basto River)	1.57
14	02040301180	Oswego River	0.24
14	02040301190	West Branch Wading River	0.43
14	02040301200	Mullica River (GSP bridge to Turtle Ck)	0.91
14	02040301210	Great Bay / Mullica R (below GSP bridge)	0.02
14	02040302910	Atlantic Coast (Little Egg to Absecon)	0
15	02040302010	Reeds Bay / Absecon Bay & tribs	0.05
15	02040302020	Absecon Creek	0.1
15	02040302030	Great Egg Harbor R (above HospitalityBr)	0
15	02040302040	Great Egg Harbor R (Lk Lenape to HospBr)	1.4
15	02040302050	Great Egg Harbor R (below Lake Lenape)	0.93
15	02040302060	Patcong Creek/Great Egg Harbor Bay	0.15
15	02040302070	Tuckahoe River	1.56
15	02040302920	Atlantic Coast (Absecon to Great Egg)	0
15	02040302930	Atlantic Coast (Great Egg to 34th St)	0
16	02040206210	West Creek / East Creek / Riggins Ditch	0.5
16	02040206220	Dennis Creek	0.06
16	02040206230	Cape May Tribs West	0.03
16	02040302080	Cape May Bays & Tribs East	0.05
16	02040302940	Atlantic Coast (34th St to Cape May Pt)	0
17	02040204910	Delaware Bay (Cape May Pt to Fishing Ck)	0
17	02040206020	Pennsville / Penns Grove tribs	1.03
17	02040206030	Salem R(above 39d40m14s dam)/Salem Canal	0.94
17	02040206040	Salem River (below 39d40m14s dam)	0.9
17	02040206060	Alloway Creek / Hope Creek	0.12
17	02040206070	Stow Creek	0.05
17	02040206080	Cohansey River (above Sunset Lake)	0
17	02040206090	Cohansey River (below Cornwell Run)	0.03
17	02040206100	Back / Cedar / Nantuxent Creeks	0.13
17	02040206110	Dividing Creek	0
17	02040206120	Still Run / Little Ease Run	0.16
17	02040206130	Scotland Run	0
17	02040206140	Maurice River (above Sherman Ave Bridge)	0
17	02040206150	Muddy Run	0.69
17	02040206160	Maurice River (Union Lk to Sherman Ave)	0.88
17	02040206170	Maurice River (Menantico Ck to Union Lk)	0
17	02040206180	Menantico Creek	0.53
17	02040206190	Manamuskin River	0.05
17	02040206200	Maurice River (below Menantico Creek)	1.08
18	02040202090	Pompeston Creek / Swede Run	1.18
18	02040202100	Pennsauken Creek	4.08
18	02040202110	Cooper River	3.67
18	02040202120	Woodbury / Big Timber / Newton Creeks	4.02
18	02040202130	Mantua Creek	1.85

WMA #	11-Digit Hydrologic Unit (HUC11)		Induced Leakage (MGD)
	#	name	
18	02040202140	Cedar Swamp / Repaupo Ck / Clonmell Ck	1.27
18	02040202150	Raccoon Creek / Birch Creek	1.38
18	02040202160	Oldmans Creek	0.89
19	02040202020	Rancocas Creek NB (above New Lisbon dam)	0.26
19	02040202030	Greenwood Branch (NB Rancocas Creek)	0.01
19	02040202040	Rancocas Creek NB (below New Lisbon dam)	0.93
19	02040202050	Rancocas Creek SB (above Bobbys Run)	0.45
19	02040202060	Rancocas Creek SB SW Branch	2.11
19	02040202070	Rancocas Creek SB (below Bobbys Run)	0.56
19	02040202080	Rancocas Creek	1.32
20	02040201030	Duck Creek and UDRV to Assunpink Ck	0
20	02040201040	Crosswicks Ck (above New Egypt)	0.84
20	02040201050	Crosswicks Ck (Doctors Ck to New Egypt)	1.05
20	02040201060	Doctors Creek	0.42
20	02040201070	Crosswicks Ck (below Doctors Creek)	0.37
20	02040201080	Blacks Creek	0.19
20	02040201090	Crafts Creek	0.49
20	02040201100	Assiscunk Creek	0.52
20	02040201110	Burlington/Edgewater Park Delaware tribs	0.06

Appendix C. Acronyms

Acronym	Stands For
7Q10	7-day 10-year low flow
BWA	Bureau of Water Allocation
DAR	drainage area ratio
DC	depletive and consumptive
DEM	digital elevation model
DWQ	Division of Water Quality
DWSG	Division of Water Supply and Geosciences
ELOHA	ecological limit of hydrologic alteration
GIS	geographical information system
HUC	hydrologic unit code
HUC11	11-digit hydrologic unit code
HUC12	12-digit hydrologic unit code
HUC14	14-digit hydrologic unit code
HUC8	8-digit hydrologic unit code
LFM	low flow margin
LFPR	low-flow partial-record
MGD	million gallons per day
mi	mile
MOVE1	maintenance of variance-extension, type 1
NJ	New Jersey
NJDEP	New Jersey Department of Environmental Protection
NJGWS	New Jersey Geological and Water Survey
NJPDES	New Jersey Pollution Discharge Elimination System
NPS	non-public supply
NRCS	National Resource Conservation Service
PS	public supply
RAW	remaining available water
RSW	regulated surface water
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WBD	watershed boundary dataset
WMA	watershed management area