# 2.0 UNDERSTANDING FLOW MANAGEMENT IN THE DELAWARE RIVER BASIN

## 2.1 What is Flow Management?

Flow management is the collection of actions taken to affect flow in order to achieve environmental, social, or economic objectives. Three examples of flow management are:

- Coordinated releases from reservoirs to meet instream flow targets
- A coordinated program of water conservation practices or demand restrictions, both drought-related and during normal periods, to improve the reliability of long term supply
- A program for coordinated use of ground water and surface water designed to increase base flow in a stream or increase the reliability of supply

The goal of flow management is to produce a politically acceptable and economically efficient mix of social and environmental benefits. Two keys to effective flow management are 1) setting flow targets that achieve user objectives, and 2) achieving multiple benefits from releases of stored water wherever possible. Section 6 sets forth the steps believed necessary to establish the flow relationships needed to determine the benefits of a particular flow regime. Daily flow models such as that developed as part of this project provide a means for evaluating potential flow targets and for developing operating strategies that realize multiple benefits from release of stored water. The process for resolving disputes is designed to help achieve consensus on the mix of benefits.

There is a wide range of objectives for flow management. Objectives include increasing the reliability of current and future water supplies, improving instream water quality, providing or enhancing recreational boating and fishing opportunities, and protecting aquatic habitat and natural resources. Flow is often managed by setting a flow target to achieve such objectives, and that target is normally expressed as a pattern of flows (that may vary according to time or some other condition) at a particular point on the river.

River flow targets in the Delaware River Basin have been established for the Delaware River at Montague and Trenton, New Jersey. These targets were established to maintain equity in interstate water allocation and to provide control of salinity and protection of water quality. Flow management is also accomplished through minimum reservoir releases (usually referred to as conservation releases) for protecting and improving natural resources and stream channels and through releases for the control of water temperature to protect cold water fisheries. Significant efforts have been devoted to the evaluation of potential flow targets in the East and West Branches of the Delaware River, and the Neversink River.

Other, less direct means of flow management in the Delaware River Basin include:

- Conjunctive use of ground and surface water
- Minimum stream passby flow requirements as conditions for surface water withdrawals
- Ground water withdrawal limits in the Southeastern Pennsylvania Ground Water Protected Area
- A basinwide water conservation program which includes water saving fixtures and water pricing requirements

All of these measures serve to protect streamflow during dry periods.

Flow targets may serve single or multiple purposes. The Montague flow target does not relate directly to any use, but is used as a means of providing equity to the downbasin community which relinquished future use of 800 mgd of water exported to New York City. The minimum flow thus provides a quantity of water to the downstream community for instream uses as well as for meeting and protecting current and projected water supply needs. The U.S. Supreme Court, which set the Montague target and the 800 mgd export limit which necessitated the target, based its 1954 Amended Decree on the best available information at the time, and also on the practical limitations of then-available water supply and flow management techniques.

## 2.2 Water Uses

Water is used in the Basin in many ways. It is useful to distinguish between traditional, out-of-stream water uses and uses that depend on the water being in streams, lakes, or reservoirs. All projections in this section come from "Preliminary Consumptive Water Use Estimates for the Delaware River Basin for 1996 Including Projections for 2020 and 2040" (DRBC, November 2000).

### 2.2.1 Withdrawals and Consumptive Water Use

New York City and New Jersey export water from the Delaware River Basin for municipal and industrial uses. Under the Supreme Court Decree, New York City is entitled to a total diversion of 800 mgd from its three reservoirs and New Jersey is entitled to 100 mgd, which is now taken through the Delaware and Raritan Canal near Trenton.

In-basin consumptive use is the portion of the water withdrawn by users within the Basin that is not returned to the Basin. DRBC staff has categorized withdrawals and estimated consumptive use for each of 22 major subbasins in the Basin. Table 2.1 shows the average annual in-basin consumptive use by use category and the portion of the total withdrawal that is used consumptively.

### 2.2.2 Instream Water Uses

The demand for instream water uses, particularly cold water fishing and recreational boating, has grown substantially over the past several decades. The enhancement of cold water fisheries below the NYC reservoirs, as well as the growth of boating liveries, particularly in the upper part of the Basin, have resulted in increased public appreciation of the value of instream flow as a resource.

#### 2.2.2.1 Fishing

Fisheries for cold water, warm water, and diadromous (migratory) species are present in the study stream segments and produce both recreational and economic benefits. The demand for fishing contributes to local economies, particularly since anglers often spend considerable sums on gear, guides, and accommodations. The annual value of cold water fishing to the economy in the Upper Delaware region is approximately $30 million, according to a 1998 report entitled *"The Economic Impact of Trout Fishing on the Delaware River Tailwaters in New York,"* (American Sportfishing Association and Trout Unlimited, 1998). Flow management provides water to support fish survival during low flow or high temperature conditions and may also improve fishing conditions by providing suitable depth and velocities for floating or wading and the proper stream velocities for casting flies.

Fishery experts with the New York State Department of Environmental Conservation (NYSDEC) note that the Delaware River watershed includes many high quality trout streams. One such example is the Beaverkill River. However, the original baseline fishery surveys, conducted in 1935, prior to construction of the three NYC Delaware Basin reservoirs, indicate that trout populations in most of the lower East and West Branches and all of the main stem were "poor or limited in scope." Trout were present in patches near springs or the mouths of cold tributaries. The 1935 study recommended that the lower 21 miles of the East Branch and lower 47 miles of the West Branch be managed as smallmouth and walleye waters. Only the lower 12 miles of the Neversink were viewed as non-trout waters. At that time, the section of the Neversink managed for trout extended 25 miles below what is now the site of Neversink Dam.

A description of the impact of the cold water reservoir releases on the fishery environment in the East Branch is provided in the unpublished report entitled, "*A History of Fishery Resources in the Upper Delaware Tailwaters from 1800-1983*" (NYSDEC, 1990). Following construction and filling of Pepacton Reservoir in 1955, cold water releases had substantial impact on downstream aquatic resources. Summer cold water releases in 1956 created a thermal environment unsuitable for warm water species historically present in the river. Largemouth and smallmouth bass and other fishes were reduced to remnant levels. A brown trout stocking program begun in 1956, wild trout recruitment from tributary streams, and substantial reservoir release to meet the Montague flow target (Cannonsville had yet to be constructed) resulted in flourishing trout populations until the summer of 1960. The onset of the 1960's drought in the summer of 1960 caused releases to be reduced to conservation release levels (19 cfs) and resulted in unsuitable

**Table 2.1 Summary of In-Basin Consumptive Water Use**
**(See notes below table)**

| Use Category | Annual Consumptive Use - 1996 | Percent Increase in Dry Year | Percent of Basin's Total Consumptive Use | Percent of Withdrawal Used Consumptively |
|---|---|---|---|---|
| Public Water Supply (1)(2) | 91.8 mgd | 20 | 29.5 | 10 |
| Commercial/Institutional | 1.3 | 20 | < 1 | 10 |
| Snowmaking | 0.25 | | < 1 | 22 |
| Domestic Self-Supply (3) | 19.8 | 20 | 6.4 | 10 |
| Industrial (4) | 71.0 | N/A | 22.8 | 10 |
| Non-Agricultural Irrigation (5) | 5.5 | 70 | 1.8 | 90 |
| Agricultural Irrigation (6) | 30.3 | 80 | 9.7 | 90 |
| Energy Production (7) | 92.5 | N/A | 29.7 | 1.5 |

(1) Public Water Supply is defined as water withdrawn from streams or aquifers and distributed by a public water supply utility. Consumptive use for public water supply is about 10 percent of the total withdrawal on an average annual basis, but that percentage may be as much as three times higher in the summer than it is in the winter.

(2) Ground water accounts for about 30 percent of the total public water supply use in the Basin (DRBC, 1996). Because ground water flows to the river vary over time and are highest in non-drought periods, and because ground water pumping during droughts results in substantial flows through sewage treatment plants, it is likely that the use of ground water for public water supply provides a substantial supplement to surface water flow during critical droughts. Without further study, it is not possible to provide a quantitative estimate of this effect, but it probably serves to offset some of the impact of ground water and surface water withdrawals during low flows.

(3) Domestic self-supplied use is mainly ground water and occurs throughout the Basin.

(4) Industrial use is assumed to be independent of wet or dry years.

(5) Non-agricultural irrigation in the Basin consists mainly of golf courses.

(6) There is substantial agricultural irrigation in the Basin. While it is estimated that average consumptive use was about 30 mgd in 1996, the summer peak can be as high as 65 mgd.

(7) Based on an analysis of power generation in the Basin, consumptive use for energy production is estimated at .013 mgd per MW of installed capacity in the peak month, which is assumed to be August regardless of the cooling process used. Consumptive use is at a minimum in February, at about 81 percent of the peak. The overall average consumptive use is 1.5 percent because once-through cooling uses such a large volume of water relative to the fraction of water evaporated.

conditions for trout. A rotenone sample survey in July 1961 produced only one-tenth as many trout as did a July 1960 survey. Similar conditions continued through most of the 1960s. Rainbow trout populations in the main stem below Hancock most likely benefitted from the substantial cold water releases in the late 1950s. Warm water species continued to reside in the main stem during this period.

Cold water releases from Pepacton and Cannonsville reservoirs have enhanced and expanded cold water fisheries on the East and West Branches and the main stem Delaware. According to the NYSDEC, the upper main stem Delaware, the entire West Branch, and the Mongaup River below Rio Reservoir support wild trout. The East Branch and Neversink tailwaters contain wild trout populations that are supplemented by "put, grow, and take" stocking. The NYSDEC notes that absent cold water releases during the summer, trout fisheries below the NYC reservoirs would be much reduced. Other tailwater reaches which support trout include Tulpehocken Creek below Blue Marsh Dam, Pohopoco Creek below Beltzville Dam, the Lackawaxen River below Lake Wallenpaupack, and the reaches of the Mongaup River and its tributaries below the Mongaup system reservoirs. The trout fishery in the Lehigh River is enhanced by stocking programs, but has not been strongly influenced by cold water reservoir releases.

The Delaware, its tributaries and the Delaware Estuary support warm water species such as smallmouth and largemouth bass. These species are not as directly affected by reservoir releases as are cold water fish in the tailwater reaches. They are more tolerant of changes in dissolved oxygen and water temperature, but can be adversely affected by reduced stream habitat due to large changes in flow.

Diadromous fish species such as the American shad, striped bass and herring, as well as catadromous species such as the American eel are present in the regulated river system. Their migration takes them through the Delaware Estuary. The number of migrating shad and striped bass have increased with improved treatment of wastewater and the subsequent improvement of Estuary water quality since the 1960s. Recreational fishing for shad, herring, and striped bass is popular and commercial fishing for American eel takes place in the upper main stem of the Delaware.

#### 2.2.2.2 Boating

Recreational boating in the Delaware River and its tributaries depends on sufficient flow and is affected by flow management. While spring flows are usually sufficient, adequate flow through the summer and fall is not guaranteed. Existing flow management has produced benefits for boating. Releases for whitewater recreation are made from F.E. Walter, Nockamixon, and the Mongaup system reservoirs. Boating releases for the Lackawaxen River have also been evaluated in the FERC relicensing process for Lake Wallenpaupack, currently underway. Boating in the main stem Delaware and its tributaries benefits from reservoir releases for the Montague and Trenton flow targets, but special releases for boating are not made. Sudden changes in releases impact boating quality, but advance scheduling of releases makes the boating conditions more predictable and adds to the value of flow management for boating.

#### 2.2.2.3 Waste Assimilation

Discharge permits are issued based on the assimilative capacity of the stream at a given flow and temperature, usually the 7Q10 coupled with a water temperature typical of summer low flow. (The 7Q10 is the minimum running average flow over seven consecutive days, which would be expected to occur, on average, once every 10 years.) If flows fall below the 7Q10, where it has been used to set waste allocations, then there is a risk that water quality will not meet minimum standards. Flows other than the 7Q10 can also be used for this purpose. For example, waste load allocations for aquatic life protection in the Delaware Estuary have been established assuming a target flow of 2500 cfs for the Delaware River at Trenton. Reservoir releases are required to meet this flow target during most years. This flow target is approximately 138 percent of the 7Q10 (1810 cfs) computed for the post-regulation period of record (1954-1989).

#### 2.2.2.4 Chloride Control

The upper portions of the Delaware Estuary are classified for use as a public water supply. In times of drought, when inflows are low, diluted seawater can extend far up into the Estuary, increasing the level of chloride and lowering the quality of municipal and industrial water supply. Mathematical models are used to evaluate the impact of alternative flow management programs on chloride concentrations in the Estuary. A flow target for the Delaware River at Trenton, New Jersey is used to control chloride intrusion in the upper Estuary, and reservoir releases are required to maintain this flow target.

#### 2.2.2.5 Special Protection Waters

Several reaches of the Delaware are designated as Special Protection Waters because of their unique environmental value. Flow management can assist in maintaining the ecological integrity of these areas and support their use for recreational purposes.

### 2.2.3 Trends in Water Use

Table 2.2 shows projected trends in consumptive water use (DRBC, November 2000). The greatest projected increase, by far, is the use for cooling electrical generation facilities. This projection is driven by the assumption that electrical demand will continue to increase and that the resulting power plants will be located in the Basin, proximate to the load. In 2004, the DRBC staff initiated a study to update the demand projections for the Basin.

Public water supply is projected to increase about 15 percent by 2040. Domestic self supply (i.e., ground water) is expected to increase by 35 percent, but the absolute magnitude of the increase is just over half that for public supply. No growth is projected in industrial use, and agricultural use is expected to decrease, largely due to development of agricultural land. The other categories of use are small enough to be inconsequential on a basinwide basis, but they may be very important locally.

**Table 2.2**
**Trends in Consumptive Water Use by Category (mgd)**

| Type of Use | 1996 | 2020 | 2040 |
|---|---|---|---|
| Public Supply | 92 | 99 | 105 |
| Commercial/Industrial | 1 | 1 | 2 |
| Ski Areas Snow Generation | <1 | <1 | <1 |
| Domestic Self Supply | 20 | 24 | 27 |
| Industrial Supply | 71 | 71 | 71 |
| Agricultural Supply | 30 | 24 | 21 |
| Non-Agricultural Irrigation (primarily golf courses) | 5.5 | 12.5 | 16.9 |
| Electrical Generation | 93 | 162 | 230 |

New York City water use has decreased over the past decade due to conservation measures, but the New York City Department of Environmental Protection (NYCDEP) expects demands to increase in the future. Eventually, NYCDEP expects that the City may approach the maximum diversion allowable under the Supreme Court Decree.

As shown in Table 2.2, the projected increase in consumptive use for public water supply, based on projected population change, is relatively small. Yet the reliability of flows for current and future water supply in the downbasin states is a concern. Analysis of the present reservoir system, under the rules of the DRBC drought operating plans, shows that the New York City Delaware Basin reservoirs would become severely depleted during a repeat of the drought of record and would be unable to sustain the Montague flow target during some periods. In such cases, the Lower Basin reservoirs would be required to make up shortfalls to maintain the Trenton flow target. Although the ability to physically withdraw water is generally not a concern in the Lower Basin, the ability to maintain the Trenton flow target, and that target's relationship to estuary water quality, have been and continue to be major concerns to Estuary water users and the Lower Basin states.

Demand for instream uses is expected to continue to increase. Given the financial and environmental obstacles facing the development of new storage projects, the competition for the limited storage available for flow augmentation is expected to become greater over time.

Data provided by the National Ocean Service (Lyles, et al., 1988) indicate that sea level has been increasing at the mouth of the Delaware Estuary (Lewes, Delaware) at a rate of 3.1 mm per year over the last several decades. Additional increases have been projected by the US EPA (Titus and Narayanan, 1995). Both the historical and the additional sea level rise have the potential to increase salinity levels in the Delaware Estuary. Increased costs to water users posed by salinity increases and potential changes in wetland and oyster habitat are concerns.

The U.S. Geological Survey has found that the impact of climate change on river flow is impossible to predict with any certainty at this time. Projections of changes in rainfall and temperature vary much too widely between studies to provide useful management information.

Waste load allocations based on Total Maximum Daily Loads (TMDLs) for watersheds and the use of non-degradation policies such as those for Special Protection Waters are expected to further constrain flow management in the future.

## 2.3 History and Current Policy

Current Delaware River Basin flow management policy requires reservoir releases to meet minimum flow targets on the main stem Delaware River at Montague and Trenton, New Jersey. At present, these targets are 1750 cfs (0.50 cfsm) at Montague and 3000 cfs (0.44 cfsm) at Trenton under normal conditions and as low as 1100 cfs (0.32 cfsm) at Montague and 2500 cfs (0.37 cfsm) at Trenton under drought conditions. During dry periods, reservoir releases are required to meet these flow targets. At times (for example, several days in August, 1999), reservoir releases have comprised more than 90 percent of the flow in the Delaware River at Montague, New Jersey, and over 50 percent of the Delaware River flow at Trenton, New Jersey. (USGS, Reports of the River Master of the Delaware River).

In addition to releases to maintain flow targets at Montague and Trenton, policies aimed at protecting fisheries in reservoir tailwaters prescribe minimum or "conservation" releases from reservoirs. Reservoir operating policies have been negotiated whereby diversions, target releases, and conservation releases are based on reservoir operating rule curves that relate reservoir levels to instream flow targets exist for both basinwide and Lower Basin (downstream of Montague, NJ) operations.

A major component of the river's flow management policy has centered on ocean salinity intrusion in the Delaware Estuary. During drought conditions, flow targets at Montague and Trenton vary in accordance with the location of the 7-day average 250 mg/l isochlor or "salt front." Flow targets increase as salinity intrusion increases, but decrease as available storage decreases. The Commission's policy is to maintain the 7-day average chloride level below the established 250 mg/l standard at Delaware River Mile 95, the downstream end of Zone 3 of the Estuary. Zone 3 is used as a water supply source by both the City of Philadelphia, Pennsylvania and the Camden, New Jersey, metropolitan areas.

The rest of this section provides information about how current interstate flow management policy developed, and the legal aspects of flows, releases, and diversions, focusing particularly on drought (low flow) conditions. The information in this section was taken from the following references: Damming the Delaware (Albert, 1987), the doctoral dissertation of Jeffrey Featherstone (Featherstone, August 1999), "New York City's Delaware Basin Supply - A Study in Interstate Cooperation" (Conway and Hurwitz, 1990), personal communications with Raphael Hurwitz, in January 2001, and "The Delaware River Drought Emergency" (Hogarty, 1970). It traces the history of current policy beginning with the conflict among the Basin States that resulted in the 1931 Supreme Court Decree, through the 1954 Amended Decree, to the Delaware River Basin Compact and the formation of the DRBC in 1961. This section also describes the issues and events, such as the 1960's drought, that led to negotiations by the Decree Parties and to unanimous agreement on strategies for long-term flow management. It concludes with a discussion of the resulting flow management policy governing the Basin.

### 2.3.1 The U.S. Supreme Court Decree of 1931 and the Amended Decree of 1954

In the early 1920s, major cities sought new water supply sources to meet increasing demand and to replace local supply sources of poor quality. Allocation of the water resources of the Upper Delaware River Basin was the focus of debate among New Jersey, New York and Pennsylvania. After two failed attempts by these states to form a three-state Compact agency, the New York City Board of Water Supply developed a three-stage reservoir development plan for the Upper Basin that was based on the principle of equitable apportionment, an approach recognized by the Supreme Court in other cases. This plan was approved by the New York State Water Power and Control Commission. New

Jersey subsequently filed suit against New York State and New York City in the U.S. Supreme Court; Pennsylvania joined the suit as an intervenor.

The Supreme Court's 1931 decision was based on the principle of equitable apportionment. Under the ruling, New York State was entitled to its share of the water and was permitted to divert that share out of the Delaware River Basin. The Court limited the diversion to 440 mgd, the amount corresponding to the first two phases of New York City's plan. The City was required to make compensating releases from its reservoirs of up to 61 cfs when the flow at Trenton, NJ or Port Jervis, NY fell below 0.5 cfsm (approximately 3400 cfs at Trenton and 1540 cfs at Port Jervis). The City was also required to correct the water quality problems caused by releases of sewage from Port Jervis, NY. Neversink Reservoir, the first Delaware Basin project, was completed in 1950.

In 1952, the City of New York petitioned the U.S. Supreme Court to re-open the 1931 case. New York City sought to build the Cannonsville Reservoir (the third stage in the plan) and increase its allowable diversion to 800 mgd. New York State joined the New York City petition, New Jersey and Pennsylvania responded, and the State of Delaware was later granted intervenor status. The five parties negotiated an agreement, which the Court-appointed Special Master then submitted to the U.S. Supreme Court.

To adjudicate the dispute, a determination had to be made as to the compensation to which the downbasin community was entitled in return for the loss of the 800 mgd which was to be impounded in the headwaters of the Delaware Basin and exported to the most downstream point of the Hudson River Basin, for use by New York City and neighboring communities in southeastern New York State. The compensation took the form of requirements that New York City make releases from its impoundments "in quantities designed to maintain a basic minimum rate of flow." While different minimum flows and measurement points were provided as New York City progressed in its reservoir construction phases, when all three Delaware River Basin reservoirs were completed, the 1954 Amended Decree specified a design flow of 1,750 cfs at Montague, NJ (approximately 0.5 cfs per square mile of drainage area upstream of Montague). This flow rate was exceeded approximately 80 percent of the time. In other words, the minimum flow that New York City was required to maintain at Montague had been exceeded on the average four out of every five days prior to the construction of the reservoirs. The 1750 cfs minimum flow at Montague was the quantity determined by the Supreme Court as the required compensation for the downstream community. To administer the Amended Decree, the Court established the position of River Master, drawn from the staff of the USGS.

The 1954 Amended Decree allowed New York City to increase its diversion from 440 mgd to 800 mgd in steps that coincided with the completion of Pepacton and Cannonsville Reservoirs. In addition, New Jersey was permitted to divert 100 mgd from the Basin and was granted the right to future expansion of its out-of-basin diversion, so long as it provided compensating releases.

The Lower Basin states agreed to facilitate the development of a main stem dam at Wallpack Bend on the Delaware River (this was later replaced by a proposal for a dam at Tock's Island), which was to have added an additional 1,800 cfs of reliable flow at Trenton, New Jersey. The release requirements in the Amended Decree were based on the drought of the 1930s, the drought of record at the time.

As compensation for the 800 mgd exportation of water, the releases from the City's reservoirs were to be designed to maintain a basic rate of flow of 1,750 cubic feet per second (cfs) at Montague upon the completion of Cannonsville Reservoir (the Montague Formula). In addition, a volume of water designated the "excess quantity," defined as 83 percent of the difference between the safe yield of the reservoirs and anticipated annual consumption, was to be released to the downbasin states in a controlled manner. The excess releases were to be made during the summer and fall months in order to provide additional low-flow augmentation using water that otherwise would be likely to spill during the following spring. This "excess quantity" release was to be reduced as New York City's consumption approached the safe yield of its entire water supply system (including the Croton and Catskill supplies) obtainable without pumping.

The 1954 Amended Decree contained the following diversion allowances and release requirements:

Neversink Only:

- Diversion allowance: 440 mgd maximum
- Release requirements: releases of 61 cfs required when flow at Montague dropped below 1,740 cfs, or flow at Trenton, NJ dropped below 3,400 cfs

Neversink and Pepacton:

- Diversion allowance: 490 mgd maximum
- Release requirements: releases required to meet a target of 1,525 cfs at Montague

Neversink, Pepacton, and Cannonsville:

- Diversion allowance: 800 mgd maximum
- Release requirements: releases required to meet a target of 1,750 cfs at Montague
- Excess releases (described below)

The 1954 Amended Decree did not provide for minimum conservation releases from the three reservoirs. They were subsequently negotiated by New York State and New York City. Minimums for Neversink were 5 cfs in winter and 15 cfs in summer; for Pepacton, 6 cfs in winter and 19 cfs in summer; and for Cannonsville, 8 cfs in winter and 23 cfs in summer.

### 2.3.2 The Delaware River Basin Compact

On October 27, 1961, the Delaware River Basin Compact created the Delaware River Basin Commission (DRBC). The Compact was enacted jointly by Delaware, New Jersey, New York, Pennsylvania and the federal government. It was the first time in U.S. history that the federal government and a group of states had joined together as equal partners in a river basin planning, development, and regulatory agency. The duration of the Compact covers an initial period of 100 years. It automatically continues for successive 100-year periods if none of the signatory states gives notice of intent to terminate. The U.S. may withdraw at any time.

The members of the Commission are the governors of the four Basin states (Pennsylvania, Delaware, New York, and New Jersey) and a federal member appointed by the President of the United States. Although the federal member was initially the U.S. Secretary of the Interior, it is presently the Chief of the U.S. Army Corps of Engineers. The President also appoints an alternate Commissioner, as do each of the four governors. These alternates are usually high-ranking officials in the four state environmental regulatory agencies and the Corps of Engineers. The Compact specified the mayor of the City of New York as an official advisor to the State of New York on Commission matters.

At the time the Commission was founded, powers and duties within the watershed were exercised by some 43 state agencies, 14 interstate agencies, and 19 federal agencies. The Compact consolidated this arrangement by creating a regional body with the legal authority to coordinate the development and control of the river system.

During the drafting of the Compact, its relationship to the 1954 Amended Decree was a topic of debate. Although the Compact gives the Commission power over new diversions and flow releases unrelated to the Decree, it strictly limits the Commission in Decree-related matters. The Compact gives the Commission authority to make adjustments to the Decree formula if there is unanimous consent of the five Decree Parties (the four Basin States and New York City). During a declared emergency not limited to drought, the formula may be temporarily modified with the unanimous consent of the Commissioners. This structure allows the Decree Parties to negotiate through the Commission to avoid further litigation over the use of the Basin's waters.

### 2.3.3 New York City Delaware System Operations

The three New York City Delaware Basin Reservoirs control a total drainage area of 917 square miles, or approximately one-quarter of the drainage area upstream of Montague, New Jersey. Neversink Reservoir, on the Neversink River, was the first reservoir built with a total usable storage of 34.9 billion gallons. Pepacton Reservoir, on the East Branch of the Delaware River, has 140.2 billion gallons of usable storage. Cannonsville Reservoir, on the West Branch, has 95.7 billion gallons of usable storage. Storage of water began at Neversink Reservoir on June 2, 1953, at Pepacton Reservoir on September 15, 1954, and at Cannonsville Reservoir on September 30, 1963. However, New York City records the official start of operations as the date when each reservoir began to supply drinking water to the City: Neversink Reservoir on December 3, 1953 (first diversion), Pepacton Reservoir on January 6, 1955 (first diversion), and Cannonsville Reservoir on March 31, 1967 (when storage reached 50 billion gallons above lowest diversion structure and release outlet, as required by the Supreme Court Amended Decree). Note that although storage at Cannonsville began in 1963, it filled for the first time only in 1967, after the end of the multi-year drought of record.

Pursuant to the 1954 Amended Decree, these reservoirs are operated as a system. The Decree authorized New York City to divert up to 800 mgd (as a running average), but required as compensation that a minimum flow of 1,750 cfs be maintained at Montague, New Jersey by supplemental releases from the reservoirs. The Decree also authorized the State of New Jersey to divert an average of 100 mgd of uncompensated water from the Delaware River. Subsequent adjustments to the 1954 Decree formula resulted from the Good Faith Recommendations of 1982, which were negotiated through the unanimous consent of the Decree Parties. Adoption and implementation of these recommendations by the DRBC has resulted in a reservoir operating plan with phased reductions in diversions and Montague flow targets based on drought severity. The Delaware River Master, established by the Supreme Court, specifies the releases to be made in order to meet the flow target, monitors the City's reservoir operations, and monitors the New Jersey diversion. In addition, New York State Department of Environmental Conservation Reservoir Releases Regulations (Title 6, Part 671) require conservation and thermal releases from the reservoirs for fisheries protection to maintain minimum flows and prevent excessive water temperatures. These conservation release requirements are also included in the DRBC Comprehensive Plan and reflected in Docket D-77-20 CP (Revised).

During most of the year, natural flows are sufficient to meet or exceed the Montague requirements without any directed releases from City reservoirs. During the summer and fall, however, directed reservoir releases are generally necessary. The City operates the system so as to have the reservoirs full after the spring runoff (June 1). Because the quality of water in Pepacton and Neversink Reservoirs is better than that in Cannonsville Reservoir, the City prefers to divert water for drinking from these two reservoirs. As a result, about 80 percent of the releases to meet the Montague flow target are made from Cannonsville.

Diversions to New York City from the three reservoirs travel through tunnels into Rondout Reservoir, located just outside of the Delaware River Basin. Diversions from all three reservoirs are normally passed through the hydroelectric plants located at each tunnel outlet. When diversion rates outside the operational ranges of the hydroelectric plants are required, bypass control valves may be used. Bypass control valves are also used to allow flow for diversion through the tunnels when the hydroelectric facilities are out of service for maintenance or repair work. The generating capacities of the Neversink, Pepacton, and Cannonsville facilities are 25 MW, 20 MW, and 8 MW, respectively.

Excess Releases: In addition to requiring those releases needed to meet the 1,750 cfs flow target at Montague, the 1954 Amended Decree also required excess releases. Each year, during normal hydrologic conditions, the so-called "excess quantity" is released, primarily to supplement the Montague target to support fisheries and habitat needs. This quantity is calculated based on the difference between the City's estimated annual water consumption and the pre-1960's estimate of safe yield (1,665 mgd). The Decree defines the excess quantity as "a quantity of water equal to 83 percent of the amount by which the estimated consumption for each calendar year is less than the City's estimate of the continuous safe yield during such year of all its sources obtainable without pumping." Thus, the excess release is expected to be reduced over time as the City's water use increases. The conditions for release of the excess quantity also have been temporarily modified through unanimous agreements of the Decree Parties.

<u>Conservation Releases</u>: New York State and DRBC regulations require the City to make minimum releases from each reservoir for conservation purposes, primarily to meet fisheries habitat needs. The 1954 Amended Decree did not provide for minimum conservation releases from the reservoirs. A gentlemen's agreement between New York City and New York State allowed for such releases from Neversink and Pepacton reservoirs. Conservation releases from Cannonsville Reservoir were a requirement stipulated in New York City's permit from New York State for that facility. The conservation releases for all three reservoirs were eventually incorporated into a Stipulation resolving litigation between New York State and New York City regarding claims for riparian damage on the Delaware tributaries below the reservoirs. Subsequently, an augmented conservation releases program was negotiated by New York State, New York City, and the other Parties to the Supreme Court Decree, and several experimental release programs and temporary extensions of these programs have been employed. The "basic" (pre-1977), augmented, and experimental conservation release requirements as of April 1999 are shown in Table 2.3. On November 30, 1983, after unanimous consent of the Decree Parties, Docket D-77-20 CP (Revised) established a permanent program of augmented conservation releases during periods of normal reservoir operation. Temporary experimental programs for conservation releases have been established through a series of later revisions to Docket D-77-20 CP.

**Table 2.3**
**Reservoir Minimum Release Rates**
**D-77-20 CP (Revision No. 4 – April 28, 1999)**

| Reservoir and Operative Dates | Basic Conservation Release | Augmented Conservation Release | Experimental Augmented Conservation Release |
|---|---|---|---|
| Pepacton | | | |
| 1/1 - 3/31 | 6 cfs | 50 cfs | 45 cfs |
| **4/1 - 4/7** | 6 | 70 | 45 |
| 4/8 - 4/30 | 19 | 70 | 45 |
| 5/1 - 5/31 | 19 | 70 | 70 |
| 6/1 - 8/31 | 19 | 70 | 95 |
| 9/1 - 9/30 | 19 | 70 | 70 |
| 10/1 - 10/31 | 19 | 70 | 45 |
| 11/1 - 12/31 | 6 | 50 | 45 |
| Neversink | | | |
| 1/1 - 3/31 | 5cfs | 25 cfs | 25 cfs |
| 4/1 - 4/7 | 5 | 45 | 25 |
| 4/8 - 4/30 | 15 | 45 | 25 |
| 5/1 - 9/30 | 15 | 45 | 53 |
| 10/1 - 10/31 | 15 | 45 | 25 |
| 11/1 - 12/31 | 5 | 25 | 25 |
| Cannonsville | | | |
| 1/1 - 3/31 | 8 cfs | 33 cfs | 45 cfs |
| 4/1 - 4/15 | 8 | 45 | 4/1 - 5/31: 45 cfs |
| 4/16 - 6/14 | 23 | 45 | |
| 6/15 - 8/15 | 23 | 325 | 6/1 - 9/15: 160 cfs |
| 8/16 - 10/31 | 23 | 45 | |
| 11/1 - 11/30 | 23 | 33 | |
| 12/1 - 12/31 | 8 | 33 | 9/16 - 3/31: 45 cfs |

NOTE: On July 17, 2002, DRBC Resolution No. 2002-21 (DRBC Docket D-77-20 CP Revision 5 Amended) temporarily modified this release program to include a flow target for the West Branch Delaware River at Hale Eddy, a minimum experimental release from Cannonsville Reservoir of 45 cfs, and a habitat bank comprised of the 9,200 cfs-day thermal stress bank and 5,700 cfs-days from the excess release quantity. The Docket was extended for one year on March 19, 2003 with the provisions that the excess release portion of the habitat bank be reduced by 20 percent and the NYSDEC submit a longer term proposal for tailwaters fishery protection by September 30, 2003. In April of 2004, the program was revised on an interim basis to include flow targets at Hale Eddy, Harvard and Bridgeville.

Special Thermal Stress Releases: DRBC Docket D-77-20 CP and its revisions direct additional releases to relieve thermal stress conditions, which pose a threat to fisheries. The Docket established a thermal bank of 6,000 cfs-days (drawn from all reservoirs) from which NYSDEC can direct releases whenever the maximum water temperature in designated downstream reaches is projected to exceed either a maximum temperature of 75º F or a 72º F daily average. The designated downstream reaches include:

- The East Branch of the Delaware between Pepacton Dam and the confluence of the East Branch and the Beaver Kill
- The West Branch of the Delaware River between Cannonsville Dam and Hancock
- The Delaware River between Hancock and Callicoon
- The Neversink River between Neversink Dam and Bridgeville

If the thermal bank is not used by October 31 of any year, it does not carry over into the subsequent year. No thermal releases are made between November 1 and April 30 of any year, and the releases are suspended altogether during *drought warning* and drought conditions. The original 6,000 cfs-day bank was later temporarily increased to 9,200 cfs-days by revision of DRBC Docket D-77-20 CP. Table 2.3 provides a summary of the current conservation release requirements from the three New York City reservoirs. Experience with temperature management has shown that the existing thermal bank is insufficient for management of the 75-degree criterion to Callicoon. The bank provides for management to Hankins in most years.

Flows in the major tributaries (West Branch Delaware River, East Branch Delaware River, and Neversink River) and the Upper Delaware River are greatly affected by both directed releases for the Montague target and conservation releases from the reservoirs. This raises a number of flow management issues related to the quantity, timing, temperature, and quality of water released from reservoirs.

### 2.3.4 Drought of the 1960s

Between 1961 and 1967, the northeastern United States experienced the most severe drought in its recorded history. The USGS estimated the recurrence interval in some parts of the Basin to be 500 years. This drought revealed that the New York City reservoir storage capacity in the Delaware River Basin was insufficient to meet both the 800 mgd diversion to New York City and the 1,750 cfs flow requirement at Montague. The record low 7-day average flow of 565 cfs was recorded at Montague in July of 1965. At Trenton, July of 1965 produced the minimum monthly mean flow of record (1,548 cfs). The mean monthly flows for June, July, and August of 1965 are each the lowest on record for those months. During the drought of the 1960s, the 7-day average 250 mg/l isochlor in the Delaware Estuary reached its maximum extent upstream, reaching River Mile 101, approximately 20 miles upstream of its normal October/November location. In addition, several Camden, NJ-area wells withdrawing from the Potomac-Raritan-Magothy (P-R-M) aquifer yielded water with increased chloride levels.

On June 1, 1965, storage in the Neversink and Pepacton Reservoirs was only 68 billion gallons (38 percent of capacity). At this time, Cannonsville Reservoir was only partially complete and had only 15 billion gallons of available storage. On June 14, 1965, New York City decided to reduce downstream releases from Neversink and Pepacton to the approximate amount of the inflow to those reservoirs, despite the requirements of the Amended Decree. The City's action created a crisis in water management and represented the newly-formed DRBC's first major challenge.

At the time of the crisis, the four Basin governors had two options: they could either return to the Supreme Court for enforcement or suspend the Decree administratively under the Compact's emergency provisions. The governors chose the latter course of action. In July 1965, at the request of DRBC Chairman Richard Hughes (Governor of New Jersey), the DRBC members evaluated a number of ad hoc schemes developed by DRBC staff to temporarily apportion the waters of the Basin. Following a July 7, 1965, public hearing, the DRBC formally declared a *drought emergency* in the Basin. Among its other effects, the drought declaration lowered the Montague, NJ, flow objective from 1,525 cfs to 1,200 cfs and reduced New York City's diversion from 490 mgd to a 30-day average of 335 mgd.

Also as a result of its July 7, 1965 *drought emergency* declaration, the DRBC enacted Conservation Order No. 1, which directed owners of Lake Wallenpaupack and the Mongaup Reservoirs to make releases from their reservoirs in accordance with a schedule furnished by the DRBC. Releases of 200 mgd (309 cfs) from Lake Wallenpaupack and 66 mgd (102 cfs) from Rio Reservoir were directed.

On August 18, 1965, the DRBC Commissioners met again to negotiate a series of technical proposals, including a "water bank" plan proposed by Stewart Udall, then Secretary of Interior and the DRBC Federal Commissioner. Such a bank would allow the DRBC some flexibility in addressing the drought crisis. Depending upon the greatest need, the DRBC could release water from the bank either to New York City or to the Lower Basin. Furthermore, the Delaware River Basin and service area were declared a federal drought disaster area in August of 1965, which provided federal disaster funds for the construction of various drought-related projects, including a proposal (not implemented) to relocate Philadelphia's Torresdale water intake farther upstream.

The water crisis abated somewhat with the improvement of hydrologic conditions in December 1965. While drought conditions persisted into 1966, a long, wet fall and winter in 1966-1967 completely ended the crisis. In March 1967, the DRBC terminated its *drought emergency* declaration. At the same time, Cannonsville Reservoir became fully operational, which allowed the City to increase its average daily diversion from the Basin to 800 mgd in accordance with the Amended Decree. The Montague flow target was concurrently returned to 1,750 cfs.

The drought of the 1960s highlighted the flaw in basing fixed water allocations on the flow during the 1930's drought (the drought of record at the time). Safe yield estimates based on the drought of the 1960s were 40 percent lower than those based on the 1930's drought. The 1930's drought was the basis for the Amended Decree. The 1960's drought pointed out the need for a more flexible approach to allocation, one that could adapt to future and potentially more severe droughts.

### 2.3.5 1982 Good Faith Recommendations

The drought of the 1960s made it clear that it would not be possible to meet the 800 mgd diversion to New York City and the 1,750 cfs flow target at Montague simultaneously during extreme droughts. It also provided additional support for the then-proposed Tocks Island project, which would have added 133 billion gallons (bg) of additional storage for water supply, recreation, and power generation. Despite the water supply shortages experienced during the mid-1960s and initial basinwide support for the project, local opposition to Tocks Island gradually intensified in the early 1970s. Propelled by the increasing national support for environmental protection, by 1975 both New Jersey and New York had withdrawn their earlier political support for the project. Over the vigorous opposition of Pennsylvania, the DRBC voted to recommend against congressional appropriations to construct the project. In 1978, Congress designated a portion of the Delaware River, which would have been flooded by the Tocks Island project, as part of the National Wild and Scenic Rivers System. Such a designation precludes construction of any dam in the designated area.

A new plan for flow management was needed. In 1976, with funding from the U.S. Water Resources Council, DRBC initiated a new comprehensive water resources study known as the Level B Study (DRBC, 1981). Completed in 1981, the Level B Study supported a scaled-back program for reservoir construction and placed more emphasis on non-structural and regulatory alternatives such as conservation. The Level B study also substantially lowered earlier projections of population growth and water use. In December 1978, the DRBC unanimously approved a motion, championed by Pennsylvania member Dr. Maurice Goddard, calling upon the Parties to the 1954 Amended Decree to "…enter into good faith discussions to establish the arrangements, procedures, and criteria for management of the waters of the Delaware River Basin, consistent with the Compact" (Albert, 1987). The Level B Study served as the technical support for the "good faith negotiations" that would ensue.

After intense discussions over the course of three years, the good faith negotiators drafted a set of fourteen recommendations that were then signed by the four Basin state governors and the mayor of New York City. The final agreement, presented to the DRBC in November of 1982, was entitled "Interstate Water Management Recommendations of the Parties to the U.S. Supreme Court Decree of 1954 to the Delaware River Basin Commission Pursuant to Commission Resolution No. 78-20" and is commonly referred to as the Good Faith Recommendations.

Since 1982, interstate flow management policy in the Delaware River Basin has been driven by the Good Faith Recommendations. The control of salinity intrusion was the basis for many of the 14 recommendations, which also included interstate drought management based on staged water conservation, increased reservoir storage, and fisheries protection downstream of the New York City reservoirs. Each of the parties pledged to support all of the recommendations. Using the Compact authority to adjust the Amended Decree with the unanimous consent of the Decree Parties, the Commission adopted the following 10 of the 14 recommendations in 1985. (The wording of the recommendation is taken directly from or paraphrased from Albert, 1987)

**1. Revisions to the salinity standard for the Estuary.**

Changes to DRBC's 1967 salinity standards were recommended because the existing and anticipated Delaware River Basin reservoirs lacked sufficient capacity to maintain the old chloride standards during drought. The recommendations also proposed a new reference point for the standards in order to provide protection to the Camden well fields. A standard for sodium was recommended as well.

**2. Adoption of the drought of record (1961-1967) as the basis for water supply planning.**

A drought equal in magnitude to the 1960's drought was recommended as the basis for all future water supply planning in the Delaware River Basin. By using the 1960's drought, the recommendation declared, the Basin would protect itself from any future such event, even if the risk of such a drought was very low.

**3. Adoption of a schedule of phased reductions in diversions, releases, and flow objectives for drought management.**

The 1980-81 drought demonstrated the value of a formula for reducing reservoir releases and water diversions when drought conditions appeared in the Basin. The recommendation included criteria developed by the Drought Task Group that out-of-Basin water diversions be reduced by as much as 35 percent and that the amount of water flowing down the Delaware River also be decreased by reducing both the Montague flow requirement and the Trenton flow objective.

**4. Adoption of a Lower Basin drought operating plan for defining Lower Basin drought conditions.**

This recommendation assumed that the DRBC would direct releases from federal, state, and power company reservoirs during a drought, as it had done twice in the past. A plan was proposed for coordinating the operation of the New York City reservoirs with the other reservoirs in the Delaware River Basin during drought periods.

**5. Completion of a study to examine potential solutions to the over-pumping of the Potomac-Raritan-Magothy aquifer in southern New Jersey.**

By 1985, the State of New Jersey was to develop a plan for solving the ground water problems of the Camden metropolitan area, to be implemented by 1990. The purpose of this recommendation was to reduce the region's reliance on the vulnerable Potomac-Raritan-Magothy aquifer.

**6. Amendment of the Comprehensive Plan to update the status of Tocks Island Dam to place it in reserve for development, if needed for water supply after the year 2000.**

Tocks Island Dam was not to be de-authorized, but held in reserve for development after the year 2000 if the additional water supply was needed. The project's description in the DRBC Comprehensive Plan was to be modified to reflect its change in status. The project has since been de-authorized by Congress.

**7. Adoption of a drought trigger policy for mandatory conservation measures based upon storage conditions in the three New York City Delaware Basin reservoirs.**

The amount of water in New York City's Delaware River Basin reservoirs was to be the principal basis for declaring and suspending drought emergencies. The recommendation established as policy the criteria proposed in Recommendation 3.

**8. Adoption of a policy to reduce freshwater consumptive use during drought periods by 15 percent.**

A goal of reducing depletive water use by 15 percent was recommended for adoption as a DRBC policy. The 15 percent figure had been derived from the Level B study, and reductions in water use during the 1980-81 drought had verified that a 15 percent reduction was attainable.

**9. Preparation of state drought contingency plans to achieve the 15 percent reduction in consumptive use.**

Each state was to develop a drought contingency plan describing how it would achieve the desired reduction stated in Recommendation 11.

**10. Authorization of augmented conservation releases from the New York City Delaware Basin reservoirs on a permanent basis.**

Experimental studies had demonstrated that such a program had a beneficial impact on the cold water fishery. (In addition to the augmented releases, a number of subsequent experimental programs for conservation releases have been approved by the Decree Parties and the Commission.)

Four of the Good Faith Recommendations either have not been adopted or have been only partially adopted. They are:

**11. Construction of Merrill Creek Reservoir and modification of two flood control reservoirs-F.E. Walter and Prompton Reservoirs–to add permanent water supply storage.**

Merrill Creek Reservoir, a pumped storage reservoir located on a small tributary of the Delaware River, was completed in 1988 by a consortium of electric utility companies for the purpose of replacing the freshwater equivalent consumptive use of water evaporated by electric power generation units during low flow periods, per DRBC requirements. The project is managed by the Merrill Creek Owners Group and has approximately 15.7 bg of usable storage. The yield for the facility is estimated at approximately 160 cfs during extreme drought conditions. The combined freshwater equivalent consumptive use of the presently operating electric generating units is approximately 80 cfs.

The F.E. Walter flood-control reservoir, located on the upper Lehigh River and owned and operated by the U.S. Army Corps of Engineers, was to have been enlarged by the Corps for water supply storage by 1990. The proposed enlargement would have provided a permanent storage pool of approximately 23 billion gallons with a flow augmentation potential of 285 cfs during extreme drought while retaining the current flood storage capacity of 35.1 bg (DRBC Annual Report, 1985, DRBC Water Management of the DRB, 1975). The Corps of Engineers performed a preliminary design and complete environmental assessment for the project. The DRBC pursued funding for the project by seeking both state and federal appropriations and modification of its water charging program under Section 15.1(b) of the Compact. The Commission supported the funding requests with a draft revised drought operating plan that would have significantly reduced the frequency of drought declarations based on reservoir operating criteria in the Delaware River Basin. Funding was not obtained, and the modification was not constructed (Greeley-Polhemus Group, 1993).

Prompton Reservoir, located on the upper Lackawaxen River, is also owned and operated by the U.S. Army Corps of Engineers. It includes a 1.15 bg permanent storage pool for recreation and an authorized flood storage capacity of 6.6 bg. The recommended modification of the Prompton dam would have provided 10.4 bg for the permanent storage pool for water supply and would have maintained the authorized flood storage capacity. The permanent water supply storage pool would have had a flow augmentation capability of 130 cfs during extreme drought conditions (DRBC Annual Report, 1985, DRBC Water Management of the DRB, 1975). Again, the Corps of Engineers performed preliminary design and environmental assessment for the project, but local support was lacking and funding was not obtained to construct the modification.

**12. Enlargement of Cannonsville Reservoir, if practicable, based on feasibility and environmental studies.**

The enlargement of New York City's Cannonsville Reservoir was also recommended. The enlargement was to be completed by the State of New York by 1990 and would have resulted in an additional storage pool of 13 bg for flow management and water supply in the West Branch and Upper Basin. In 1985, a consultant to New York State determined the project to be "technically and environmentally feasible," but found a marginal benefit/cost ratio (1.1 to 1). New York State officials abandoned the project in 1987 (Featherstone, 1999).

**13. Evaluation of pumping glacial alluvium to supplement flow during droughts.**

Ground water located in alluvial deposits in the Upper Basin was to be examined as a potential emergency source of water for use after the year 2000. This recommendation, which was highly controversial, was based on the idea that ground water could be used to augment river flows during drought. Pumping the ground water into the river would make it available for downstream users and instream flows. This proposal was strongly opposed by local interests in upstate New York, where the demonstration project was proposed. In a meeting conducted by the DRBC in late November 1982 in Port Jervis, New York, several hundred citizens and local officials voiced their displeasure with the proposed pumping scheme. Given such local opposition, the project never materialized (Albert, 1987; Featherstone, 1999).

**14. Implementation of a regulatory program to limit consumptive water use based on a budget which would balance future consumptive water uses with available storage capacity designed to meet salinity objectives.**

DRBC was to develop a program to regulate new consumptive water uses. Increased consumptive water use could offset any gains in water storage brought about by the agreement. This was a very important recommendation, since it recognized that the amount of reservoir storage that can be built is limited. Due to its controversial nature, however, this program has not been implemented (Albert, 1987; Featherstone, 1999).

### 2.3.6 <u>Drought Operating Plans</u>

This section presents a historical analysis derived from Albert, 1987 and Featherstone, 1999, and summarizes the current DRBC drought operating plans. (DRBC Resolution 88-22 (revised), 1988 - Amendment to the Comprehensive Plan Relating to Criteria and Operations Formulae)

The next major drought after that of the 1960s occurred in 1980-81. The drought began in the summer of 1980, when precipitation deficits and water use demands diminished storage in the three New York City reservoirs to 40 percent of capacity by December. By the second week of January 1981, storage in the three reservoirs had dropped to 33 percent of capacity. On January 15, 1981, the then-DRBC Chairman, Governor Brendan Byrne of New Jersey, called the DRBC into a special session, whose attendees included the four Basin governors and the mayors of New York City and Philadelphia. During the session, the DRBC formally declared its second *drought emergency*.

In contrast to the drought of the 1960s when there were no emergency plans in place, the DRBC now had drafted proposed drought operating criteria as a result of the "good faith" negotiations initiated in 1978. Utilizing these proposed criteria, the DRBC took several actions. Once again, the DRBC administratively adjusted the provisions of the 1954 Amended Decree and simultaneously reduced the diversions to both New York City and New Jersey and the Montague flow objective. In addition, the DRBC exercised jurisdiction over reservoirs owned by the Federal government, the Commonwealth of Pennsylvania, and two electric utility companies to help maintain flows in the river. The DRBC also recommended a series of non-essential-use bans that were adopted and enforced by the four states.

The 1980-1981 drought was relatively short-lived. Although storage in the New York City reservoirs had dropped to 25 percent of capacity by early February 1981, a dramatic increase in precipitation together with snow melt in late February and March added 100 billion gallons of water. This inflow allowed for full restoration of the New York City and New Jersey out-of-Basin diversions in May of 1981. Storage remained adequate for the remainder of 1981, and the *drought emergency* declaration was terminated by the DRBC early in 1982.

Through the adoption of several "good-faith" recommendations in 1983, the DRBC had formalized its drought operating procedures so as to equitably share water between upstream and downstream users during periods of shortage. The two most important provisions were (1) a rule curve for determining *drought warning*s and emergencies based upon the

combined storage in the three New York City reservoirs and (2) a schedule of phased reductions in diversions, releases, flow objectives, and salinity control.

The current drought operating plan is intended to provide reliable water supplies for essential uses during a drought equal in severity to the 1960's drought of record while sustaining river flows to meet the Estuary's salinity standard. Response to a drought more severe than that of the 1960s would be negotiated separately, depending upon its severity. Under normal conditions, provisions of the 1954 Amended Decree apply. During the different stages of drought, the rules in the following table apply.

**Table 2.4**
**Interstate Operation Formula for Reductions In Diversions, Releases and Flow Objectives During Periods of Drought**
**Table Reflects Temporary Operations as of March 2003 based on Docket D-77-20 CP and its Revisions**

| NYC Storage Condition | NYC Diversion (mgd) | NJ Diversion (mgd) | Montague Flow Objective (cfs) | Trenton Flow Objective (cfs) |
|---|---|---|---|---|
| Normal | 800 | 100 | 1,750 | 3,000 |
| Drought Watch | 680 | 100 | 1,655 | 2,700 |
| Drought Warning | 560 | 70 | 1,550 | 2,700 |
| Drought | 520 | 65 | 1100 - 1,650* | 2,500 - 2,900* |

Severe Drought (to be negotiated based upon conditions).
*Varies with time of year and location of salt front in Delaware Estuary.

The drought operating procedures have been employed eleven times since their adoption in 1983. While the Basin has only experienced two additional drought emergencies (in 1985 and 2001), DRBC has periodically declared *drought warnings*. In all instances, *drought warning* or *emergency* declarations were terminated by the DRBC once conditions returned to normal, as specified in the rule curve and operating procedures.

In addition to the above "Basinwide" operating plan, which is triggered by New York City Delaware Basin reservoir storage, the DRBC adopted a "Lower Basin" operating plan in 1988. This plan is triggered by storage levels in Beltzville, Blue Marsh, and Nockamixon reservoirs and controls the Trenton flow target and the New Jersey diversion. If both plans are triggered simultaneously, the plan producing the most stringent conditions for the Trenton target and New Jersey diversion applies.

### 2.3.7 River Master (Daily Operations)

The 1954 Amended Decree established the position of Delaware River Master to administer the Decree. The U.S. Geological Survey was chosen because it is a neutral federal agency. The Supreme Court carefully specified the River Master's duties, which are to:

- Administer the provisions of the Decree relating to yields, diversions, and releases so as to have the provisions of this Decree carried out with the greatest possible accuracy.
- Conserve the waters of the river, its tributaries and in any reservoirs maintained in the Delaware River Watershed by the City of New York or any which may hereafter be developed by any of the other parties.
- Compile and correlate all available data on the water needs of the Parties to the Decree.
- Check and correlate the pertinent streamflow gagings on the Delaware River and its tributaries.
- Observe, record, and study the effects of developments on the Delaware River, and its tributaries on water supply and other necessary, proper and desirable uses.
- Make periodic reports to the Supreme Court, not less frequently than annually, and send copies to the governors of the four Basin States, and the Mayor of New York City.

Thus, the primary duty of the River Master, in cooperation with the City of New York, is to monitor and adjust daily water releases to maintain the flow of the river at Montague in accordance with the provisions of the Decree. The River Master does not direct conservation or thermal releases, which are made in accordance with a fishery protection program approved by the Decree Parties and the DRBC.

The River Master considers several factors when planning to meet the Montague flow target:

- Present conditions in the Basin (water in the streams and on the ground),
- Forecasts by power companies of releases from power plants (based on forecasted power needs), and
- Precipitation forecasts. (The travel time of water from Pepacton Reservoir to the Montague gage is 60 hours, so releases must take place at least that far in advance.)

Because the flow releases from the NYC reservoirs generally take between 33 and 60 hours to reach Montague (depending upon which facility the water is released from), they must be based on forecasts. As a result of errors in the forecasts, the releases are sometimes too large, resulting in flows higher than the target, or too low. The Delaware River Master keeps track of the actual flows at Montague and determines, day-by-day, if the releases made in previous days turned out to be too large or too small due to flow forecasting errors. For example, if the River Master had called for releases of 300 cfs two days previous in order to meet today's 1750 cfs flow target, and the actual flow turned out to be 1760 cfs, then the over release for today would have been 10 cfs. If today's flow was 2500 cfs, due to an unexpected storm, then the over-release would be 300 cfs less the minimum required conservation release from each of the individual dams. If today's flow were 1720 cfs, then the under-release would be 30 cfs.

A balancing adjustment is made based on the cumulative difference since June 1 between the directed releases and the amount that would have been required if the forecasts had been exact. Each day the cumulative difference (over-release minus under-release) is divided by ten and added to or subtracted from the directed release for the following day. The division by ten is performed in order to smooth out the correction of the forecast-induced errors over a period of many days and to avoid large fluctuations in directed releases. In the end, the releases are adjusted over the summer, fall, and winter so that approximately the same amount of water is released from the NYC reservoirs as would have been released if there were no errors in the forecasts. Major consideration is given to balancing the reservoirs to maximize the "probability of refill" for the entire reservoir system by June 1 (the beginning of the maximum consumption period by users of the water supplied by NYCDEP).

As indicated previously in Section 2.3.3, the Decree also specified that because New York City had an excess of capacity over demand, part of that excess capacity must be released downstream.

## 2.4 Current Delaware River Basin Operations

The Delaware River Basin Water Code prescribes the operations of major diversions and reservoirs within the Basin; it is summarized in this section. For ease of discussion, the section first discusses the operation of the NYC reservoirs, then describes the operation of Lake Wallenpaupack, the Mongaup system, and the Merrill Creek project. Finally, the section describes the operation of Beltzville, Blue Marsh, and Nockamixon reservoirs, the Trenton flow target, and the D&R Canal Diversion.

### 2.4.1 NYC Reservoir Operations and the Montague Target

Diversions from the NYC reservoirs to Rondout Reservoir are limited by the 1954 Amended Decree and adjustments resulting from the implementation of the Good Faith Recommendations. The allowable diversions vary from a running average of 800 mgd when basinwide conditions are normal to a running average of 520 mgd during basinwide drought (See Table 2.4). In times of plentiful runoff, the total diversion varies with the New York City demand and with the amount of available storage in the City's Catskill and Croton systems. When drought threatens, the City generally increases its Delaware Basin diversion to enhance the reliability of its overall supply. Diversions are taken preferentially from Neversink, Pepacton, and Cannonsville Reservoirs, in that order, to maximize water quality. Consideration is given to balancing the reservoirs to minimize the possibility of spill and the probability of depleting storage in any one of the reservoirs. NYC operators determine the diversions from each reservoir.

Conservation releases are the minimum downstream releases from each of the three reservoirs. They are scheduled according to the most recent revision of DRBC Docket D-77-20 CP, and depend on basinwide conditions and the time of year. The NYSDEC release manager ensures that the minimum releases are met by NYC operators.

By using forecasts of weather and flow conditions three days in advance, the River Master determines the New York City reservoir releases that are required to meet the Montague target. The target varies based on basinwide conditions and on the additional "excess quantity" release. The River Master adjusts the Montague target to account for past releases that turned out to be either too high or too low, as described above. If the directed release is greater than the sum of the conservation releases, NYC operators will make additional releases to satisfy the Montague requirement. The portion of the directed release that exceeds the conservation releases is normally made from Cannonsville Reservoir. If the refill probability of Cannonsville approaches that of Pepacton, then some of the burden of meeting the directed release will be shifted to Pepacton.

The NYSDEC uses a series of graphical relationships (nomographs based on computer modeling results) and air temperature forecasts to determine the amount of water required to meet temperature targets (75 degrees maximum, 72 degrees daily average) at Hankins, Harvard, and Bridgeville, New York. Although normally made from Cannonsville Reservoir, NYC operators will shift directed releases (over and above conservation releases) in an attempt to meet the thermal release requirements with the same water. If the thermal releases sum is more than the directed release and more than the conservation releases, then the difference is subtracted from the water available in the thermal bank. Limitations in the graphs and the underlying temperature models, as well as in the temperature forecasts, make it likely that temperature targets will sometimes not be met in practice.

When the thermal bank is depleted, available water can be released from the habitat bank. In the event that banks are depleted and only directed releases can be made, the potential for significant harm to the cold water fisheries exists if hot weather does occur. For this reason, as the thermal bank becomes increasingly depleted, NYSDEC may abandon temperature targets at lower stations on the main stem (particularly below Hancock) in order to save water to continue to meet upstream tributary targets.

### 2.4.2 Lake Wallenpaupack and the Mongaup System

Lake Wallenpaupack and the Mongaup system are normally operated for peak power generation. PPL, the owner of Lake Wallenpaupack, has provided the DRBC with the rule curves that it follows to maintain adequate lake levels for power generation and summer recreation. In general, these rules take the water surface up to an elevation of 1187 on June 1 and then let it gradually fall to elevation 1177.8 on April 1, 10 months later. Monday through Friday, the water entering the reservoir in excess of the amount needed to maintain the rule curve storage is released through the turbines to generate electricity. Generally, no releases are made on weekends unless the inflows cause the lake to rise into the flood pool (elevation 1188), which is evacuated as soon as practicable. No conservation releases from Lake Wallenpaupack are currently required, although they may be as a result of the current FERC relicensing process. PPL applied for a new license in September 2002. The current license expires in September 2004.

In accordance with the DRBC Water Code, the Lake Wallenpaupack rule curve is modified during declared drought emergencies. The high elevation is still 1187 on June 1, but the low is reduced to 1170 on December 1. The storage area between these two elevations totals 29.8 bg. DRBC is authorized to direct release of that storage during drought emergencies. PPL has formally proposed an enhanced drought operations plan that would make additional storage available to DRBC for release during *drought watch*, *drought warning*, and *drought emergency* operations.

The Mongaup system, with approximately 15 bg of storage, is also primarily used to produce power. According to documentation provided by the NYSDEC, the minimum release from Rio Reservoir, the downstream-most reservoir in the system, is driven by inflow to Swinging Bridge Reservoir. The release requirement is 100 cfs when inflow equals or exceeds 100 cfs. Releases decrease with decreasing inflow to 60 cfs and are maintained at 60 cfs regardless of further declines in inflow. Should the DRBC declare *drought emergency* conditions, the minimum release may be lowered further. Releases were lowered to 30 cfs by the DRBC during the *drought emergency* of 2001-2002. As is the case with Lake Wallenpaupack, the DRBC can call for releases from the Mongaup system during drought emergencies. Unlike Lake Wallenpaupack, however, the DRBC Water Code does not specify a drought operating rule curve for the Mongaup system.

The Water Code severely constrains DRBC from effectively utilizing power reservoir storage to augment river flows below Montague. Subsections D(3)(e)(iii) and (iv) of Section 2.5.6, in effect credit NYC with the first 350 cfs of power reservoir releases if needed to meet the Montague flow objective, and thus do not constitute any additional augmentation for points downstream of Montague.

### 2.4.3 Beltzville, Blue Marsh, Nockamixon and F.E. Walter Reservoirs and the Trenton Flow Target

Beltzville (Corps of Engineers, completed 1971), Blue Marsh (Corps of Engineers, completed 1979), and Nockamixon (Commonwealth of Pennsylvania, completed 1973) Reservoirs are operated to ensure that the Trenton flow target is met. While Beltzville and Blue Marsh may be used for this purpose during normal, *drought watch*, *drought warning*, and drought conditions, Nockamixon may be used only during declared drought emergencies. Blue Marsh releases are counted toward the Trenton target even though they enter the main stem below Trenton. The Trenton flow target depends upon the basinwide or Lower Basin drought condition, which is defined by either storage levels in the New York City Delaware Basin reservoirs or storage levels in Beltzville and Blue Marsh reservoirs. Each reservoir has a minimum release requirement that depends on the time of year and also on the basinwide or Lower Basin drought condition. When the flow at Trenton would otherwise fall below the target, releases in excess of minimum flows are made from the Lower Basin Reservoirs in order to maintain the target. (Because of travel times, the releases are actually scheduled two days in advance based on forecast flows.)

Under normal hydrologic conditions, the Trenton flow target is 3,000 cfs. When the basinwide drought condition falls below normal, the target is reduced to 2,700 cfs. When basinwide conditions reach drought or when the Lower Basin drought condition falls below normal to either warning or drought, the Trenton flow target is dependent on the position of the salt front in the Delaware Estuary. When the salt front is below mile 82.9, the target falls to 2,500 cfs. As the front moves upstream, the target increases – to 2,700 cfs at mile 87 and to 2,900 cfs (May through November) at mile 92.5.

The DRBC Water Code defines the order in which reservoirs are drawn down to meet the Trenton target. Water is released from Beltzville and Blue Marsh Reservoirs during *drought watch* and *drought warning* conditions, and from Nockamixon Reservoir and F.E. Walter Reservoir, when available, during *drought emergency* conditions. Beltzville has approximately 13 bg of usable storage, Blue Marsh has 6.5 bg (summer pool) or 4.7 bg (winter pool) of usable storage, and Nockamixon has 13 bg of usable storage.

F.E. Walter Reservoir (Corps of Engineers, completed 1961) is operated as a flood control reservoir with two very limited exceptions. The first exception stores water for up to five whitewater rafting releases per year, two in June, one in September, and two in October. The amount of water used for these releases is relatively small, but because the reservoir inflows in the summer may be insufficient to provide even this small amount of water as well as the mandated minimum release of 50 cfs, the releases are sometimes canceled.

During some droughts, DRBC has negotiated with the Corps of Engineers to purchase temporary storage in F.E. Walter and Prompton reservoirs from which flow augmentation releases could be made to support downstream flow targets. Because the procedures are not implemented until a drought is in progress, the amount of water in storage is highly dependent on the time of year. When it is available, water stored in F.E. Walter is released before releases are made from Beltzville and Blue Marsh Reservoirs.

### 2.4.4 D&R Canal Diversion

The State of New Jersey diverts up to 100 mgd (monthly average) of water into the D&R canal. During *drought watch* conditions as defined by New York City Delaware Basin Reservoir storage, under the temporary provisions of revisions to DRBC Docket D-77-20 CP, the allowable diversion remains at 100 mgd. During basinwide or Lower Basin warning conditions, the maximum diversion is reduced to 70 mgd. In the event that either condition reaches drought, the maximum diversion is further reduced to 65 mgd.

### 2.4.5 Merrill Creek Reservoir and Electrical Generation Cooling Water Use Replacement

Merrill Creek Reservoir is a pumped storage project containing approximately 16 bg of usable storage. It was designed to provide water to offset the consumptive use of post-Compact power plants during *drought warning* and drought events. Merrill Creek makes a small conservation release at all times. When either a Lower Basin or a basinwide *drought watch*, *drought warning*, or drought operating condition exists and flows at Trenton would otherwise fall below 3,000 cfs, Merrill Creek makes an additional release equal to that day's total consumptive use from the power plants owned by the utilities that purchased storage in the reservoir. Because there is surplus storage in the reservoir, the owner companies have thus far made voluntary releases for pre-Compact units as well.

Water is pumped from the Delaware River to refill storage in the reservoir. Pumping is not permitted when additional releases are being made or when the pumping would cause the flows at Trenton to fall below specified levels. These levels depend on the time of year and the position of the salt front in the Delaware Estuary; the farther upstream the salt front encroaches, the less pumping is permitted.

Merrill Creek Reservoir was constructed in 1989 to provide makeup water for current and future power generation facilities located in the Basin. As discussed above, the majority of increases in water use in the Basin over the next 40 years is expected to be associated with new electric generation facilities. Substantial capacity in Merrill Creek is currently unused and is thus available for future purchase as makeup water for new facilities.

### 2.5 Assessing Flow Management Benefits and Costs

Flow augmentation in the study stream reaches results in higher than natural flows during dry periods. Yet the benefits of these flows have not been fully evaluated. In order for the benefits and costs of flow augmentation policy to be fully assessed, relationships which relate flow rate to stream uses are required. Salinity modeling and Instream Flow Incremental Methodology (IFIM) work in the Upper Delaware tributaries and along Tulpehocken Creek are examples of previous efforts to develop a scientific basis for flow relationships. Much additional work is required and has become a priority in the work of the Decree Parties, the DRBC, and its partner organizations. The following provides a qualitative list of benefits and costs of flow augmentation, and gives an example of how daily flow modeling can be used to help evaluate benefits.

The benefits of flow augmentation in the Delaware may be measured in terms of:

- Improvements in water supply reliability
- Reductions in salinity-related costs in the Upper Delaware Estuary
- Improvements in water quality
- Improvements in aquatic habitat
- Improvements in scheduled and unscheduled recreational opportunities for fishing and boating
- Hydropower production, as measured by the value of electricity produced

The costs of flow management include:

- The costs of building and operating storage facilities
- The costs incurred by users when water use is restricted
- Costs to purveyors and customers who own or rely on reservoirs for water supply
- Costs to those who use the reservoirs that supply the water for flow management (e.g., a loss of boat ramps when the reservoir falls, damage to reservoir fish populations and water quality, and scenic impairment)

Daily flow modeling makes it possible to compare the streamflows, reservoir storage, and drought event frequency that would result from alternative flow augmentation policy. With flow relationships it is possible to translate the basic flow model outputs into attributes such as fish habitat, boating suitability, or salinity intrusion, which has been modeled for many years by the DRBC. To demonstrate the role of daily flow modeling in the assessment of benefits and costs, an example comparing "natural" conditions to those approximating current operations is provided here. The "natural" conditions are estimated by assuming that no reservoirs are in place and that no out-of-Basin diversions are made. Note that this understates the actual impact of flow management because it assumes that no water would be diverted to New York City, which is entitled to divert up to 800 mgd under the 1954 Supreme Court Amended Decree. Because these scenarios are so different, they have a clearly identifiable impact on the high and low end of the flow hydrograph.

Figures 2.1, 2.2, and 2.3 illustrate the differences in minimum monthly flows under the flow augmentation program which approximately represents DRBC Docket D-77-20 CP (Revision 4), absent thermal releases, and flows as if no reservoirs were in place. These graphs plot the minimum daily flow for each month between 1975 and 1984 at Bridgeville, Hale Eddy, and Harvard, New York for both the managed flow and natural flow. In the summer and fall, natural flows at all three sites are less than the managed minimums in most years.

The flow traces produced by these two model scenarios can be compared to the flow rates desired or required for specific stream uses. For example, based on IFIM work by the NYSDEC, flow targets to support cold water fisheries have been proposed for each of the three locations (Bridgeville, Hale Eddy, and Harvard). Using these targets and the flow traces, the number of times that monthly minimum flows, or daily flows using another output format, would not meet the habitat targets could be determined. This is an example of an "index" or measure of relative success of a particular management scenario in meeting a particular stream use objective. While such a measure is not as complete as the assignment of dollar costs for failure to meet a particular objective, such indices, if available for each stream segment, would be useful for flow management decision-making because they enable policy alternatives to be more explicitly quantified. This is necessary for a better understanding of flow management costs and benefits.

## 2.6 Improving Flow Management within Existing Limitations

The high quality and extensive use of the recreational resources provided by the study stream segments has focused attention on ways to improve flow management for the benefit of both fisheries habitat and recreation. HydroLogics believes that changing flow management policy does not mean that the water equity established by the 1954 Amended Decree must be abandoned. With the strategy proposed in this report, we believe it will be possible to fully evaluate alternatives to the 1954 regime that preserve the equitable allocation of water. Flow modeling provides the means to efficiently test whether a proposed regime is better than the existing management scheme.

HydroLogics believes that the following should be addressed to improve flow management in the Delaware River Basin:

1) *Lack of information to establish flow relationships:* The recommendations section of this report details and prioritizes actions to improve on existing knowledge. A lack of knowledge regarding flow versus use relationships hinders efforts to evaluate flow augmentation policy and to assess the benefits of existing storage or additional storage that might be proposed.

2) *Lack of institutional processes and technology to allow stakeholders to have effective input to flow management decisions:* While stakeholders are welcome to attend and to speak at DRBC Flow Management Technical Advisory Committee and Commission meetings, their lack of access to the technical tools and information needed to analyze flow management alternatives has made it difficult for them to present convincing arguments. The process proposed in Section 3 is aimed at giving stakeholders access to the technical tools they need to evaluate alternatives and to have input to flow management policy decisions. While the actual use of the technical tools may require expertise and training, access to and understanding of the underlying analytical concepts allows for better stakeholder input. Development of the index displays suggested in Section 4 is a first step toward obtaining policy input from stakeholders.

The terms of the 1954 Amended Decree and the legal framework of the DRBC Compact provide the context within which changes in flow management must be approached by the DRBC. Adjustments to the diversion and release formulae cannot be made without the unanimous consent of the Decree Parties. This includes any proposal for banking or adaptive management. In addition to Decree-related matters, all potential policy changes must be evaluated against DRBC water quality regulations, such as those in the Special Protection Waters and Delaware Estuary.

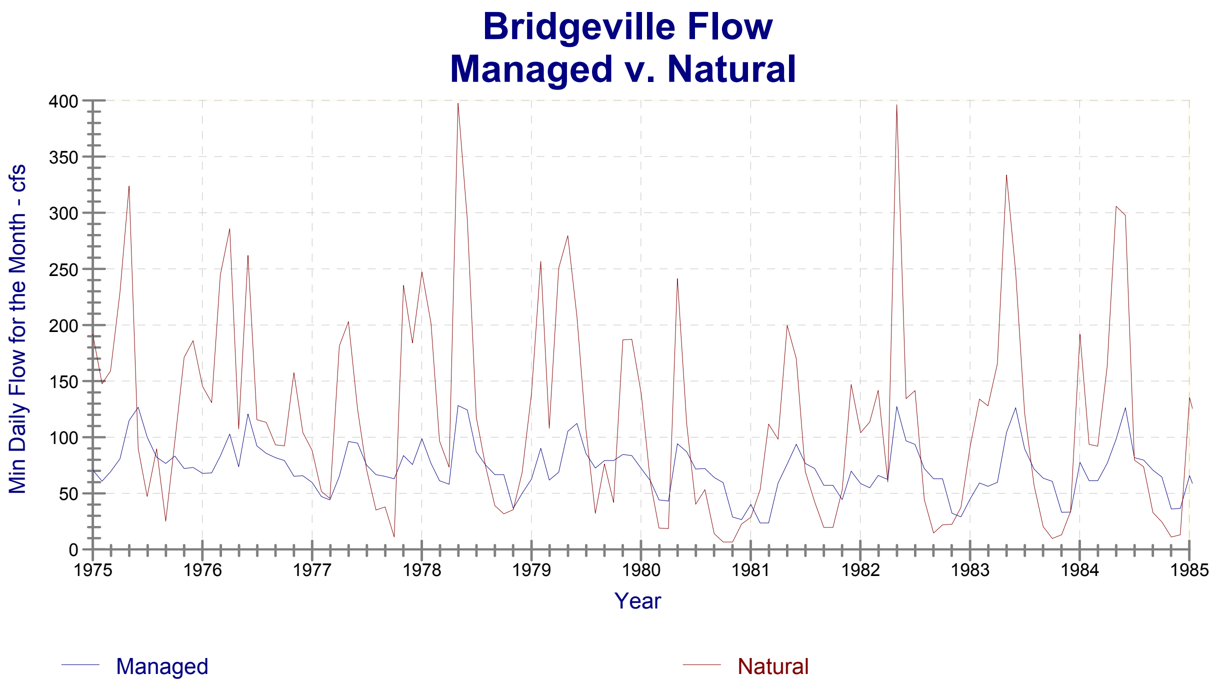


**Figure 2.1 Comparison of Flows Below Neversink Reservoir**

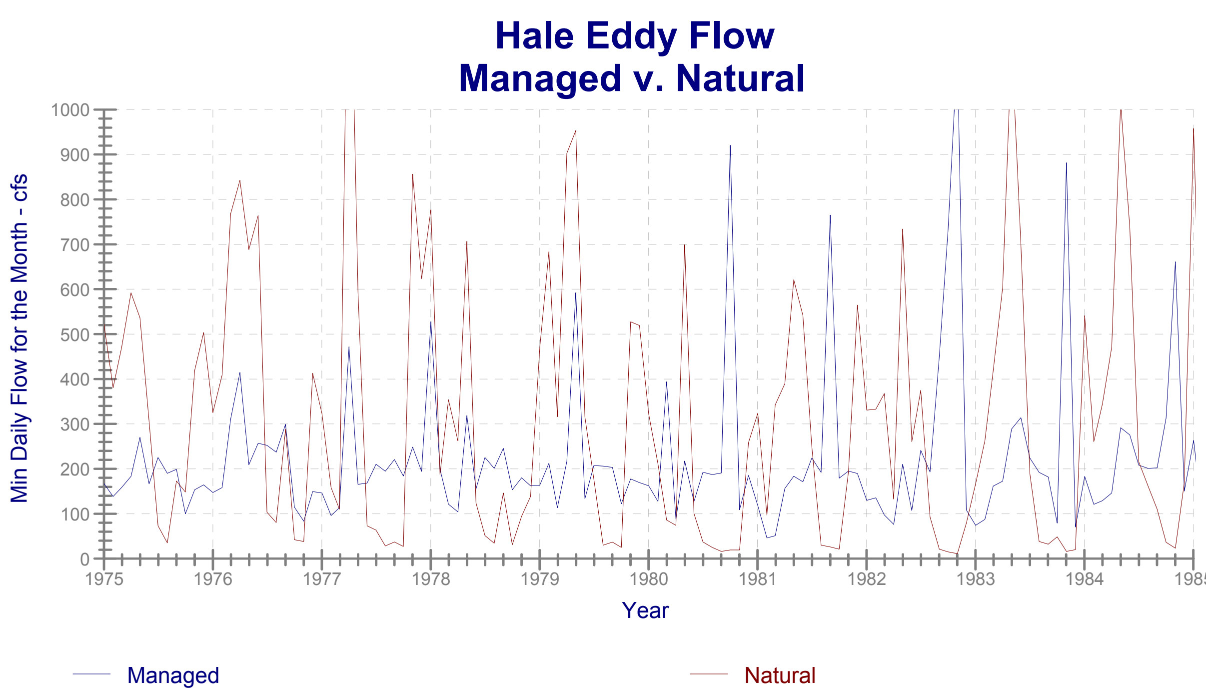


**Figure 2.2 Comparison of Flows Below Cannonsville Reservoir**

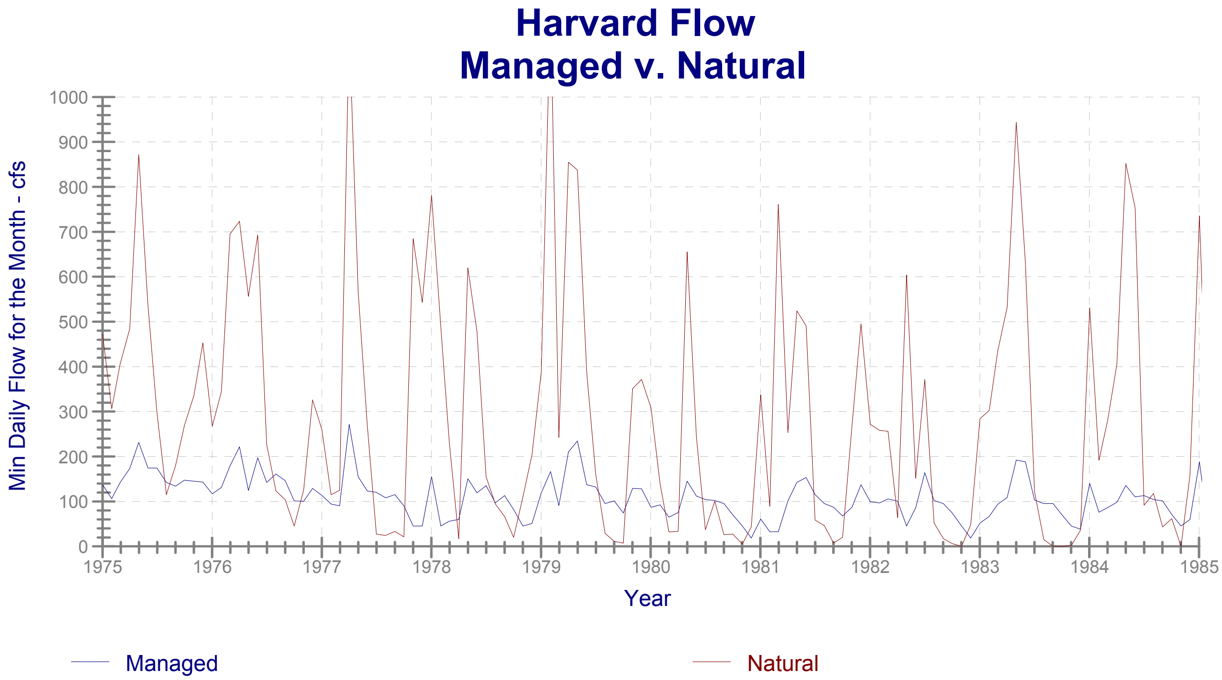


**Figure 2.3 Comparison of Flows Below Pepacton Reservoir**