4.0 FLOW ISSUES AND TECHNICAL RECOMMENDATIONS

This section provides guidance for implementing Steps 1, 2, and 3 of the issue resolution process presented in Section 3. The section describes each of the 12 stream segments studied and lists the flow management issues identified for each. Potential index displays (performance measures) to evaluate alternative operating policies for various stream segments are described. The stream segment descriptions and segment-specific recommendations are followed by additional general technical recommendations at the end of this section. In order to thoroughly research the flow-related issues, a detailed issues paper was prepared and distributed to all interested parties and a six-month review period was provided during the winter and spring of 2001. Although an effort was made to include all issues for each stream segment, we acknowledge that some issues may have been missed during the literature review and interviews. It is also understood that issues will change as conditions change in the regulated river system.

4.1 East Branch Delaware River from Pepacton Dam to Junction with West Branch

4.1.1 Setting

The East Branch Delaware River segment (Figure 4.1) extends 33 miles from New York City's Pepacton Reservoir to Hancock, New York, where it meets the West Branch and forms the main stem of the Delaware River. Pepacton Reservoir is situated in the middle section of the East Branch watershed and controls slightly less than one-half of the watershed. The Beaver Kill, a major tributary, enters the East Branch approximately midway between the reservoir and Hancock.

The East Branch downstream from Pepacton Reservoir flows through a generally wide, "U"-shaped valley containing farms, woodland, and several small communities. Outside of the valley itself, the land is wooded and sparsely settled. Industry in the basin includes agriculture, forest products, and the quarrying of building stone. Somewhat more than 90 percent of the land adjacent to the stream is privately owned. The area is dotted with motels, campgrounds, bed and breakfasts, restaurants, guide services, fishing tackle stores, gas stations and canoe and boating livery services. The stream is fairly accessible due in part to New York Routes 30 and 17, which parallel the course of the stream between Downsville and Hancock.

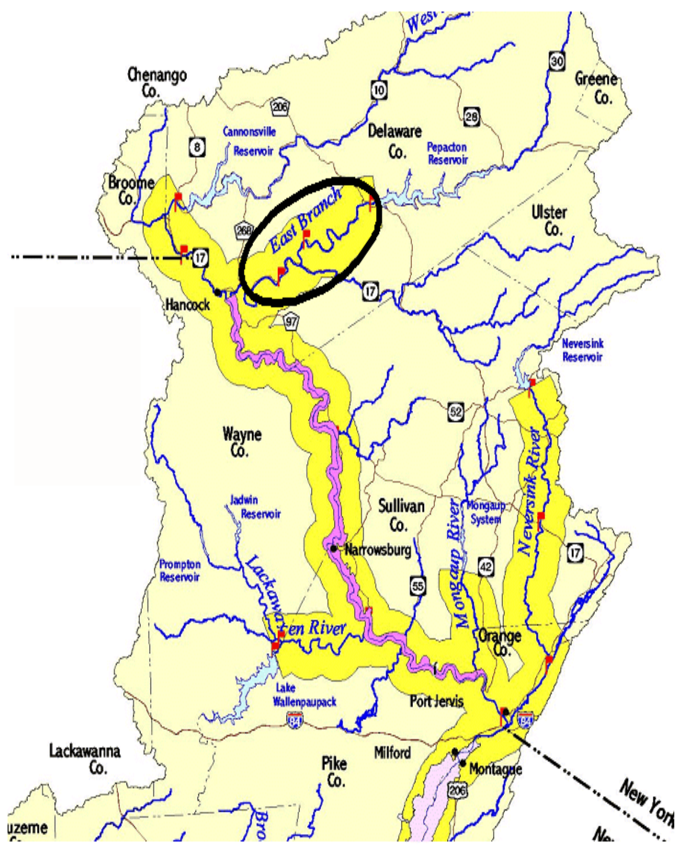

Figure 4.1
East Branch, Delaware River

The construction of Pepacton Reservoir fundamentally changed the hydrology of the East Branch. As a result of New York City's diversions for water supply, total annual flow immediately downstream from the reservoir is approximately 30 percent of the pre-reservoir flow. (This figure results from comparing the average annual flow at the USGS gaging station at Downsville, New York, before [1942-1953] and after [1955-2001] Pepacton Reservoir started operations). Median monthly flows for all months are also lower than their pre-reservoir rates. The magnitude and frequency of high flows, including flood events, have been reduced, and stream temperatures during late spring, summer, and early fall are typically cooler than those recorded prior to the reservoir's construction.

Some reaches of the East Branch downstream of the Pepacton Dam at Downsville supported seasonal cold water fisheries prior to construction of the dam. The cold water fishery has been extended and enhanced by releases from the reservoir. The East Branch has a wild trout population that is augmented by put, grow, and take stocking. Prior to reservoir construction, the lower 21 miles of the East Branch were managed as smallmouth bass and walleye waters. Currently the NYSDEC classifies the entire East Branch as Class C(TS), which designates the river as suitable for fish propagation and survival, particularly trout spawning (TS). All streams designated as C(T), C(TS), B, or A are subject to the stream protection provisions of the NYSDEC Protection of Waters regulatory program. (The denominations C, B, or A correspond to the water's best use - fishing, primary contact recreation, or drinking water supply, respectively). Upstream from the confluence with the Beaver Kill, streamflow conditions are closely related to the quantity and character of the release water. During hot weather, the water temperature in the Beaver Kill, which is unregulated and has no large reservoirs making cold water releases, is affected by solar radiation and air temperature, making it substantially warmer than the water released to the East Branch of the Delaware from Pepacton Reservoir. Below the confluence with the Beaver Kill, water temperatures in the East Branch are influenced by the relative magnitude and temperature of the water added by the Beaver Kill.

American shad continued to use the East Branch all the way to Downsville following the construction of Pepacton Reservoir. According to the NYSDEC, Cemetary Pool on the East Branch continues to be a popular fishing spot.

Both the East and West Branches of the Delaware River are in Delaware County, New York. In 1992, 1,182 business establishments in Delaware County produced nearly $2 billion in annual revenues (1992 U.S. Census of Businesses) and supported nearly 12,400 employees. Nearly half of the economy (47%) is supported by manufacturing, which employs over 4,100 people. Fishing-related businesses are included in the Services and Retail Trade sectors. Services and Retail Trade represent 18 percent and 14 percent, respectively, of the county economy and account for over 6,000 employees. In their 1998 report on the importance of the trout fishing business in Delaware County, (Economic Impact of Trout Fishing on the Delaware River Tailwaters in New York, 1998), the American Sportfishing Association and Trout Unlimited reported that trout fishing generates a total of $29.9 million a year (about 1.5 percent of Delaware County's total annual revenues), and 348 local resident jobs.

Water quality in the Upper Delaware is very good and is improving further as a result of New York City's program to control point and non-point source pollution. The City's program was initiated to protect and improve the water quality of the three City reservoirs as a means of avoiding the expense of water filtration. Its intensive efforts with regard to land acquisition, wastewater treatment plant upgrades, and non-point source controls in the headwaters benefit both the reservoirs and other users of the East and West Branches and the Neversink River.

4.1.2 Issues and Analysis

Flow management issues on the East Branch stem from the use of Pepacton Reservoir for out-of-Basin water supply and releases from that reservoir for in-channel habitat protection. Releases are also made in support of the Montague flow target, although less frequently than from Cannonsville Reservoir. The following flow management issues were identified:

- Section 4.1.2.1 Trout Fishing Conditions/Trout Habitat
- Section 4.1.2.2 American Shad Habitat

The NYSDEC has recommended that additional diadromous fisheries such as river herring, channel maintenance, and assessment of annual spillage be considered as flow management issues for the East Branch. Channel maintenance was also cited by NYSDEC as a general concern applicable to all study reaches.

The desired flows for these various purposes are not necessarily the same, and the desired flows for the same purpose may be different among different interest groups. Nevertheless, the groups are able, albeit with poor precision, to identify the flows that satisfy their particular objectives. The identified flow objectives serve as the basis for potential index displays, which are described in the following sections.

4.1.2.1 Trout Fishing Conditions/Trout Habitat

Much work has been done by the NYSDEC to establish minimum releases for habitat needs in the Upper Delaware River and tributaries. This work has been documented in several NYSDEC reports listed with the references. These include NYSDEC reports 80-1, 83-5, and the 1992 Fishery Management Plan for the Upper Delaware Tailwaters. The work has been the technical basis for NYSDEC in its negotiations with the City of New York concerning minimum reservoir releases. This work, the resulting negotiations between the City and NYSDEC and the Decree Parties, and the information provided by anglers that relate the quality of the fishery to flow and flow patterns have resulted in substantial improvements in the cold water fishery since reservoir construction. Support for further examination of the ecology of the Upper Delaware has recently been provided through the efforts of The Nature Conservancy and Trout Unlimited. The results of the NYSDEC research are continuing to be used by NYSDEC to support additional increases in releases over those now in place. These additional releases, in the form of flow targets in each of the three tailwaters, were under negotiation as of mid-2003.

The following are potential index displays and supporting technical recommendations for addressing this issue:

a) Spawning habitat - acres, by year.

Successful trout spawning depends on having the right combination of substrate (gravel), depth of flow, and instream velocity for the entire spawning season. The Instream Flow Incremental Methodology (IFIM) can be used to assess the area of suitable habitat as a function of flow, but in the case of the East Branch, temperature is critical as well. Producing an estimate of the acres of suitable habitat thus requires both temperature and IFIM models as well as a time series of flows. Although IFIM modeling has been completed for the East Branch by the NYSDEC, development of an improved temperature model is recommended. Daily flow models, such as the DRBC OASIS model developed as part of this study, can be used to produce a time series of flows for comparing management alternatives.

b) Water temperature at Harvard, number of days temperature exceeds criteria, by year.

DRBC Docket D-77-20 CP (and revisions) permit the use of thermal stress releases whenever the maximum water temperature at Harvard, Hale Eddy, Woodbourne, or Callicoon is projected to exceed a maximum of 75° F or a 72° F daily average (Sheppard). The number of such "thermal stress days" and the number of violations of thermal criteria serve as good indicators for evaluating operating scenarios. Existing temperature models are quite crude and need to be upgraded to improve the precision of the displays. In particular, existing models predict only maximum temperature. It may be helpful to add a weighting factor for successive days of violations, but determining the additional effect of longer term warm water episodes will require further scientific investigation.

c) Water temperature at Harvard, daily average and daily maximum.

This display should be useful to fisheries biologists for generating overall assessments of temperature-related conditions. Again, note that the existing temperature models estimate only the maximum temperature. The precision of these estimates could also be substantially improved by employing a better temperature model.

d) Daily Flow at Harvard, number of days below threshold, by year.

The NYSDEC tailwater fishery study (Fishery Management Plan for the Upper Delaware Tailwaters, 1992) recommended, for example, a threshold daily average flow for trout habitat at Harvard of 175 cfs. IFIM studies performed for the reach showed that below this value the habitat for mature trout quickly diminishes as flows diminish. Thus, it may be useful to plot the number of days per year that flows fall below 175 cfs, or other flow rates that are determined to be critical for fishery protection. Using single number flow thresholds, however, can be problematic, since it fails to incorporate the effects that time of year, temperature, and other factors have on the species. More comprehensive displays would consider flow requirements that vary over both the course of the year and also as water temperature changes. The NYSDEC (Sheppard) has indicated that there should be sufficient physical habitat simulation (PHABSIM) stations on the East Branch between Downsville and Harvard to assess seasonal ecosystem base flow requirements for use with daily flow modeling.

e) Area of trout habitat damaged by ice, by year.

During cold weather, ice can form on the bottom of river beds, thereby altering fish and insect habitat. At present, however, it is impossible to evaluate this problem because of insufficient scientific knowledge concerning ice formation and the lack of detailed mapping of vulnerable habitat. Until the requisite scientific work has been done, it will be impossible to evaluate these impacts except through the use of anecdotal evidence.

4.1.2.2 American Shad Habitat

Based on HydroLogics' conversations with fisheries research personnel and fishermen, there did not appear to be a well-defined relationship between low flows and upstream shad migration. Shad migrate upstream in the spring, probably in response to solar angle and water temperature, which is normally not influenced by cold water reservoir releases at that time of year.

A NYSDEC fisheries expert (Elliot, personal communication) confirmed that shad are spawning in the East Branch, for the most part in the segment downstream from the Beaver Kill, where cold water releases from Pepacton have less influence. Some years' runs are better than others, but this is true throughout the Delaware. It was suggested that there may be some threshold of flow at the mouth of the East Branch below which shad may choose not to swim upstream. Thus, in those spring seasons with floods below this threshold (whatever that threshold is), there could be a benefit of timing a release pattern that would put streamflow in the desirable range, so long as the water does not become too cold. According to a second NYSDEC source, a Delaware River Fisheries Cooperative study in the late 1970s determined that the experimental releases program on the East Branch was not having a detrimental effect on American shad.

Young shad migrate downstream when flows are generally lower than during the upstream migration of the adults. Low flows are not considered an impediment to their migration, but survival rates may be lower during low flow periods. The young migrating shad swim downstream at night and rest (and hide) during the day in very shallow water out of the reach of predators (such as bass). Since river levels that expose large portions of the riverbed reduce the potential hiding areas for the young fish, lower flows may increase the mortality of the young of the year, which in turn reduces the number of spawning fish two or three years later.

IFIM study results could provide information on the habitat available at various flows for downstream migration as well as upstream migration and spawning. Daily flow model output for a given operations alternative could then be used to determine the number of days when habitat conditions were acceptable. Existing IFIM data should be evaluated to determine if it provides adequate information to assess migration habitat for shad.

4.1.3 Additional Information and Study Needs - East Branch Delaware River

These steps are suggested, in priority order, for acquiring the information necessary to establish additional flow relationships and support the index displays listed for the East Branch Delaware River. Several of the information needs for the East Branch are common to the West Branch and the Neversink River as well. They are listed separately for clarity but could be combined into a single research effort.

1) Assemble data with which to correlate shad and herring reproduction/migration with releases from Pepacton Reservoir, seasonal precipitation, and temperature.

2) Improve flow forecasting and thermal modeling for the East Branch, in combination with the NYCDEP thermal model of Pepacton Reservoir. The instream temperature model should address the impacts of releases from all three reservoirs as well as local runoff.

   Together, these models would allow better quantification of the cold water available and more effective utilization of releases targeted at maintaining instream temperatures. The Delaware River Master has made a similar recommendation.

3) Assemble data with which to correlate Pepacton Reservoir releases and air temperature with river ice formation downstream of the reservoir. Assemble data for the correlation of heavy ice formation with fish survival. The U.S. Army Corps of Engineers' Cold Regions Research Laboratories may provide valuable information in this effort. Analytical approaches to address ice issues include research concerning historical, pre-reservoir ice conditions and the development of analytical models of ice formation and ablation in the stream as a function of flow, source of flow, and air temperature.

4) Incorporate existing research results and consult with the NYSDEC Bureau of Fisheries and others to verify the adequacy of existing IFIM information for establishing ecological flow requirements and channel maintenance. Also assemble data relating observed fishing conditions to flow, and determine the usefulness of existing IFIM data for analysis of flow versus shad and herring migration.

5) Conduct an assessment of annual spills from Pepacton Reservoir and their impacts on downstream ecology.

4.2 West Branch Delaware River from Cannonsville Dam to Junction with East Branch

4.2.1 Setting

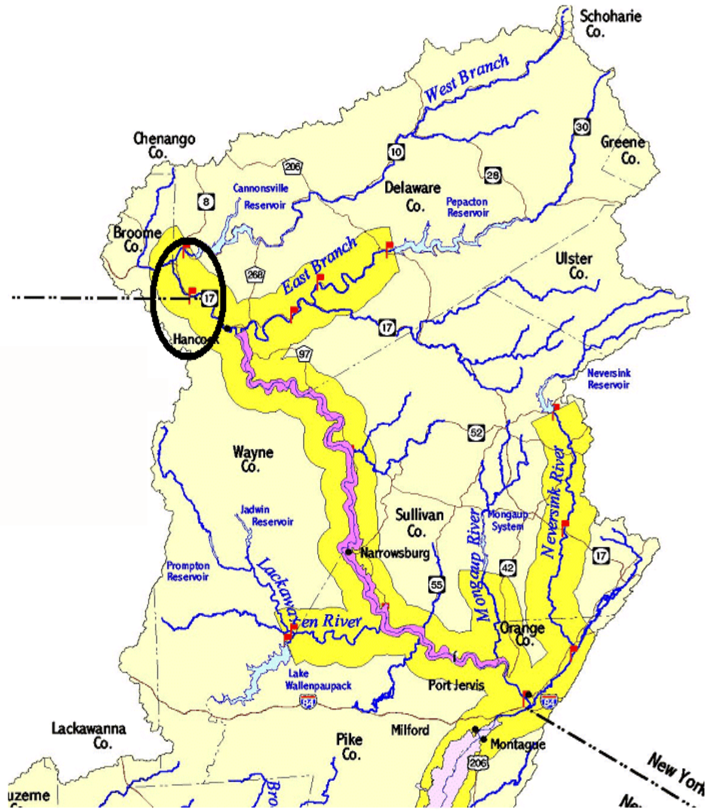

Figure 4.2
West Branch, Delaware River

The West Branch Delaware River project segment (Figure 4.2) extends 18 miles from New York City's Cannonsville Reservoir to Hancock, New York, where it meets the East Branch of the Delaware and forms the main stem Delaware River. Steep, forested hills and the "U"-shaped valley dominate the landscape. Concentrated residential development is largely limited to a few small villages, the largest of which is Hancock; the remaining land is sparsely settled. Close to 99 percent of the land along the stream is privately owned, making public access to the stream extremely limited. Commercial activities in the area outside of Hancock are largely related to outdoor recreation.

The construction and operation of the Cannonsville Reservoir changed the hydrology of the West Branch in three ways. First, due to water supply diversions, the observed total annual flow downstream from the reservoir is now approximately 80 percent of that under pre-reservoir conditions. (This figure results from comparing the average annual flow at the USGS gaging station at Stilesville, New York before [1953-1962] and after [1964-2001] Cannonsville Reservoir started operations.) Second, the natural flow regime has been altered. In most years, average summer flows are higher than before while fall, winter, and spring flows are lower than prior to the dam's construction. Both the magnitude and frequency of high flow events, including floods, have been reduced. Due to the small drainage area contributing to the West Branch downstream of the reservoir, Cannonsville releases during dry conditions often represent nearly all the water in the stream down to the confluence with the East Branch. Third, due to reservoir releases, stream temperatures during summer and early fall are almost always substantially cooler than those recorded prior to the reservoir's construction.

Cannonsville Reservoir makes the bulk of the releases required to meet the Montague flow target during dry weather conditions. Since the late 1960s, these cold water releases have improved what was originally a very limited trout fishery in the West Branch. The entire reach of the West Branch downstream of Cannonsville Reservoir now supports wild trout. The quality of the wild trout fishing makes the West Branch a popular destination for wading and guided float fishing for trout. The West Branch is within a three-hour drive of nearly 30 million people. Trout fishermen from the Middle Atlantic states and beyond come to the West Branch to fish. The recreational industry they support includes fishing resorts, campgrounds, guides, and tackle shops. Local construction, retailers, and other businesses are directly and indirectly supported by the recreational industry.

Between Cannonsville Reservoir and the New York-Pennsylvania border, NYSDEC classifies the West Branch as Class B (TS); they classify the stream as A (TS) from that point to the confluence with the East Branch.

The NYSDEC's 'A' and 'B' designations specify that the waters are suitable for both contact recreation and fish propagation and survival. 'A' waters are also suitable for potable water supply. The 'TS' designation applies this classification specifically to trout (TS stands for trout spawning). Pennsylvania Department of Environmental Protection (PADEP) classifies this same section of the West Branch as CWF, MF. PADEP's 'CWF' indicates that the stream is suitable for maintenance and/or propagation of trout as well as additional flora and fauna indigenous to a cold water habitat. 'MF' designates the segment as suitable for passage, maintenance, and propagation of anadromous and catadromous fishes as well as other fishes which ascend to flowing waters to complete their life cycle. Such fishes include the Atlantic shad and the American eel. All the above stream designations allow these stream segments to be protected under existing state regulations.

4.2.2 Issues and Analysis

Flow management issues on the West Branch stem from the use of the Cannonsville Reservoir for out-of-Basin water supply and in-channel uses (within both the West Branch and the main stem Delaware).

The following flow management issues were identified:

- Section 4.2.2.1 Recreational Trout Fishing
- Section 4.2.2.2 Trout Habitat Conditions
- Section 4.2.2.3 Irregular and Uncertain Releases Stress West Branch and Upper Delaware Fishery
- Section 4.2.2.4 Temperature Stress Release Bank
- Section 4.2.2.5 Water Quality

The NYSDEC also cited channel maintenance as a flow management issue on the West Branch.

Potential index displays for these issues are described in the following sections.

4.2.2.1 Recreational Trout Fishing

Because downstream releases from Cannonsville Reservoir are generally larger than those from Pepacton or Neversink, the West Branch supports the most significant recreational fishery in the Upper Basin. It is therefore appropriate to include some measure of the quality and quantity of the resource available. One such potential measure is discussed below.

a) Recreational fishing index

Excellent recreational fishing days occur when a) the streamflow is right for either wading or drifting, and b) the water temperature change over the course of the day induces mayfly and other larvae to hatch. It may be possible to determine which days in a simulation fit all the criteria for excellent fishing for a number of sites along the West Branch. These days could be weighted by day of week with the weight based on the ratio of anglers on different days of the week, or using other factors such as time of year and weather conditions. The details of this display would need to be developed in collaboration with the fishing community.

4.2.2.2 Trout Habitat Conditions

The measures indexing trout habitat conditions would be identical to those identified for the East Branch, except that the displays would be focused on conditions at Hale Eddy instead of Harvard. The scientific and data concerns regarding the indices are also very similar. Although IFIM modeling has been completed for the West Branch by the NYSDEC, development of an improved temperature model is recommended. Daily flow models, such as the DRBC OASIS model, can be used to produce time series of flows for comparing management alternatives. The issue of ice damage to trout habitat also applies to the West Branch.

4.2.2.3 Irregular and Uncertain Releases

One of the impediments to recreation and to ecological balance in the Upper Delaware Basin, particularly in the West Branch, is the unnatural variation in flow caused by releases to meet the Montague target. This variation is further exacerbated by the adjustments made to compensate for releases made from Lake Wallenpaupack and the Mongaup system to generate on-peak energy. To the extent that this variation can be controlled and/or forecasted, it would become possible to advertise times when conditions are expected to be good and thus increase the benefits gained in terms of environmental improvements, visitor days, and the quality of the recreational experience. Much of the current forecast error is due to last minute changes in power generation schedules and changes in weather conditions. Using one- to five-day forecasts of energy prices, temperature, rainfall, flow, and temperature conditions may make it possible to improve the predictions. Ramping of releases for the Montague flow target could also be considered. A potential index display for improved forecasting capability is suggested below.

a) <u>Number of excellent fishing days forecast with at least 3-day lead time, by year</u>

Producing this display would require prior development of the recreational fishing index discussed in 4.2.2.1 in order to establish which days should be classified as "excellent." This classification would be combined with a forecast methodology for predicting three days in advance when such days would occur. The number of correctly forecast excellent days could then be counted and displayed on an annual basis. Weekend days might be given additional weight in the displays.

4.2.2.4 Temperature Stress Release Bank

As with the extreme drawdown of water supply reservoirs, the extreme drawdown of the water available for environmental quality control puts vital resources at risk. The frequency with which supplies reach a critical state provides one measure of system performance. Such an index display would characterize the frequency of critical drawdown of the Thermal Stress Bank, as described below.

a) <u>Frequency of Critical Drawdown of the Thermal Stress Bank</u>

The number of times that the thermal bank empties or reaches a critical level can be tracked using daily flow and thermal release modeling. The time at which the bank empties is also important since depletion by mid-summer would produce a longer period of temperature stress for the fishery. The daily flow and temperature modeling capabilities of the DRBC OASIS model can be used for producing this index display, but improved temperature modeling is recommended for more accurately representing the West Branch temperature profile.

4.2.2.5 Water Quality

Water quality in the West Branch is generally good, with the exception of occasional turbidity problems. The cause of the turbidity is not clear. Some NYSDEC biologists (Elliot, 2003) believe that most of the turbidity comes from dead phyto- and zoo-plankton in the Cannonsville releases. It typically develops "...in the late summer or fall in years when high releases have exhausted the hypolimnion." Turbidity indicates the presence of suspended solids, which may fill the interstitial spaces in the gravel in spawning beds, thereby reducing oxygen levels and the likelihood of successful trout spawning. However, inorganic particles remaining in suspension after passage through a reservoir are likely to be very fine and therefore unlikely to settle in a dynamic river environment. It would be advisable to conduct a preliminary assessment of the extent of the problem by measuring turbidity on a daily basis at a few stations in the West Branch. This data could be used in conjunction with reservoir release and precipitation data to determine the correlation between releases and instream turbidity. Watershed and instream water quality models and a reservoir water quality model may be necessary to accurately predict turbidity as a function of releases. The daily time step now used for daily flow modeling may be too long for turbidity modeling. A potential index display would be hourly turbidity measured at Hale Eddy.

The Philadelphia Water Department has traced a cucumber-like odor to algae in Cannonsville Reservoir and has reported that other water systems are also affected. This may not be a flow management issue in the traditional sense because at least part of the problem is associated with uncontrolled winter spills from the reservoir. Rather, to the extent that amelioration is possible, it has more to do with the elevations from which water is released and operations that might reduce the frequency of winter spills.

4.2.3 Additional Information and Study Needs - West Branch Delaware River

The following steps are suggested, in priority order, for acquiring the information necessary to establish additional flow relationships and support the index displays listed for the West Branch Delaware River. Several of the information needs for the West Branch are common to the East Branch and the Neversink River as well. They are listed separately for clarity but could be combined into a single research effort.

1) Assemble a data set of all known occurrences of downstream taste and odor problems and correlate it with data on Cannonsville releases, and flow above the water supply intakes. In addition, identify the species of algae causing the taste and odor problems and determine whether that species exists in Cannonsville Reservoir. Finally, determine the additional treatment costs associated with control of taste and odor from algae and the extent to which reservoir releases affect those costs.

2) Monitor turbidity on the West Branch and determine the correlation with reservoir releases. A reservoir water quality model that predicts turbidity levels in the reservoir as a function of inflow, outflow, and storage, and a watershed model that predicts the impacts of best management practices and land use changes on reservoir water quality could be required to address this issue.

3) Improve flow forecasting and thermal modeling for the West Branch of the Delaware River.

4) Assemble data with which to correlate Cannonsville Reservoir releases and air temperature with river ice formation downstream of the reservoir. Assemble data for the correlation of heavy ice formation with fish survival.

5) Incorporate existing research results and consult with the NYSDEC Bureau of Fisheries and others to verify the adequacy of existing IFIM information for establishing ecological flow requirements and channel maintenance. Also assemble data which relates observed fishing conditions to flow.

6) Consult with NYSDEC concerning the issue of channel maintenance and additional required work to define flow requirements for channel maintenance vs. those now defined for fisheries management.

7) Conduct an assessment of spills from Cannonsville Reservoir and their impacts on downstream ecology.

4.3 Neversink River from Neversink Dam To Mouth

4.3.1 Setting

The Neversink River segment (Figure 4.3) extends 42 miles from New York City's Neversink Reservoir to Port Jervis, New York, where it enters the Delaware River seven miles upstream of the Montague gaging station. The Neversink Reservoir is in the headwaters of the watershed. More than 70 percent of the Neversink Rivers contributing drainage basin lies downstream of the reservoir.

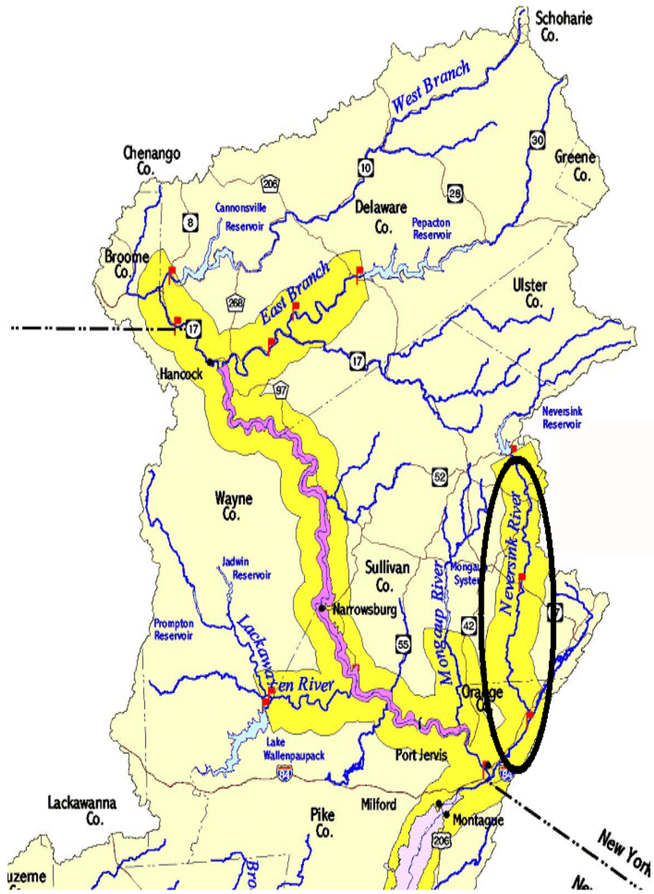

Figure 4.10
Neversink River

From the dam downstream to Bridgeville, the stream flows through a gently sloping valley occupied by farms, the town of Monticello, and several small villages. Much of the land is wooded and is home to a large resort industry that includes hotels, summer camps, and vacation cottages. Other industries include sand and gravel mining and forestry. Downstream from Bridgeville, the creek cascades through a steep-sided, heavily forested, seven-mile long gorge that lies primarily within state-owned parkland until it reaches the more moderately sloped Oakland Valley. From there, the stream valley continues to broaden and decrease in slope until, downstream of Godeffroy, the stream flows through a broad, largely rural, "U"-shaped valley with wooded hillsides. Port Jervis, the largest community in the Upper Basin, occupies the last few miles of the river's course and includes a mix of residential, commercial, and industrial land uses.

The construction and operation of the Neversink Reservoir fundamentally changed the hydrology of the Neversink River downstream of the dam. Total annual streamflow immediately downstream of the reservoir is approximately 20 percent of the pre-reservoir flow, as a result of diversion for water supply. (This figure results from comparing the average annual flow at the USGS gaging station at Neversink, New York, before [1942-1952] and after [1954-2001] Neversink Reservoir started operations.) Median monthly flows for all months are lower than their pre-reservoir rates. The magnitude and frequency of high flows, including flood events, have been reduced. Stream temperatures during late spring, summer, and early fall are cooler than prior to the reservoir, although the change is diminished further downstream as uncontrolled tributaries enter the river.

Year-round cold water releases from Neversink Reservoir help maintain a cold water trout fishery throughout much of the Neversink's course, though the reach of the Neversink extending to 25 miles below the dam was suitable for trout propagation and survival prior to construction of the reservoir. NYSDEC classifies the Neversink from the dam to Godeffroy as Class B(TS) and from Godeffroy to the mouth as Class B. The B(TS) classification specifies that the stream is suitable for trout propagation and survival, in addition to primary contact recreation (B). The ‘TS’ applies to trout; its absence indicates the stream is suitable for warm water fishes, such as smallmouth bass. The whole Neversink River segment - from the dam to the mouth - is protected under the NYSDEC Protection of Waters regulatory program because of its designation as Class B waters.

4.3.2 Issues and Analysis

The following flow management issue was identified based on HydroLogics’ research of the Neversink River:

- Section 4.3.2.1 Recreational Trout Fishing

The NYSDEC also cited channel maintenance as a flow management issue on the Neversink.

The primary issue identified for the Neversink River is the quality of recreational trout fishing. There has also been interest by The Nature Conservancy in altering the pattern of releases from Neversink Reservoir to promote increased survival of freshwater mussels. There are several rare or threatened species of freshwater mussels in the Neversink River including the dwarf wedgemussel. Habitat for these species may become an issue in the future. Ice damage to fish habitat has also been cited as an issue for the Neversink River tailwaters.

4.3.2.1 Measures Associated with Recreational Trout Fishing

Index displays similar to those recommended for the East and West Branches of the Delaware, including acres of spawning habitat and number of days meeting habitat flow or temperature targets, could also be used to evaluate operating alternatives for the Neversink River.

4.3.3 Additional Information and Study Needs - Neversink River

The following steps are suggested, in priority order, for acquiring the information necessary to establish additional flow relationships and support index displays for the Neversink River. Some of these items could be combined with those for the East and West Branches into a single research effort.

The following steps are suggested, in priority order, for establishing additional flow relationships:

1) Improve flow forecasting and thermal modeling for the Neversink River. This same recommendation was made for the East Branch. See Section 4.1.3 for a more complete discussion.

2) Assemble data for correlating Neversink Reservoir releases and air temperature with river ice formation downstream of the reservoir. Assemble data for the correlation of heavy ice formation with fish survival.

3) Coordinate with The Nature Conservancy to assemble data for correlating mussel survival/reproduction with flow patterns downstream of Neversink Reservoir. Other factors affecting survival such as temperature and water quality should also be investigated.

4) Incorporate existing research results and consult with the NYSDEC Bureau of Fisheries and others to verify the adequacy of existing IFIM information for establishing ecological flow requirements and channel maintenance. Also assemble data which relates observed fishing conditions to flow.

5) Consult with NYSDEC concerning the issue of channel maintenance and additional required work to define flow requirements for channel maintenance versus those now defined for fisheries management.

6) Conduct an assessment of spills from Neversink Reservoir and their impacts on downstream ecology.

4.4 Main Stem Delaware River from Hancock to Trenton

4.4.1 Setting

The non-tidal main stem of the Delaware River extends 200 miles, from Hancock, New York, to Trenton, New Jersey. The Delaware is one of the last major U.S. rivers without a dam on the main stem. From Hancock to Port Jervis, New York, the river serves as the border between New York and Pennsylvania; from Port Jervis to Trenton it is the border between Pennsylvania and New Jersey.

The main stem can be divided into three parts: (1) the Upper Delaware -- the 73.4-mile reach between Hancock, New York and Sparrow Bush, New York, designated a National Scenic River; (2) the Middle Delaware -- the 38-mile segment from Milford, Pennsylvania to Stroudsburg, Pennsylvania that comprises the Delaware Water Gap National Recreational Area & Scenic and Recreational River; and (3) the Lower Non-tidal Main Stem -- the segment covering the approximately 80 river miles from the Delaware Water Gap to Trenton, New Jersey, which is also protected as a scenic and recreational river from the Delaware Water Gap to Washington Crossing (upstream of Trenton).

UPPER DELAWARE

The 73.4-mile segment of the river extending from the confluence of the East and West Branches near Hancock downstream to the railroad bridge below Cherry Island near Sparrow Bush, New York (Figure 4.4) was designated a component of the National Scenic Rivers System by the National Parks and Recreation Act of 1978. Approximately two-thirds of this segment is classified as recreational while the remaining third is classified as scenic under the national system.

A River Management Plan was prepared and adopted in 1986 to provide for the conservation and enhancement of the major valley resources within the 56,095-acre area. These resources include the sport fishery, water quality, and scenic, cultural, economic, and recreational qualities. The Upper Delaware Council, composed of local, state, and federal representatives, was established to implement the Plan. The Plan recommended that the National Park Service (NPS) acquire only 130 acres for the support of visitor management responsibilities. The rest of the land was to remain in private ownership.

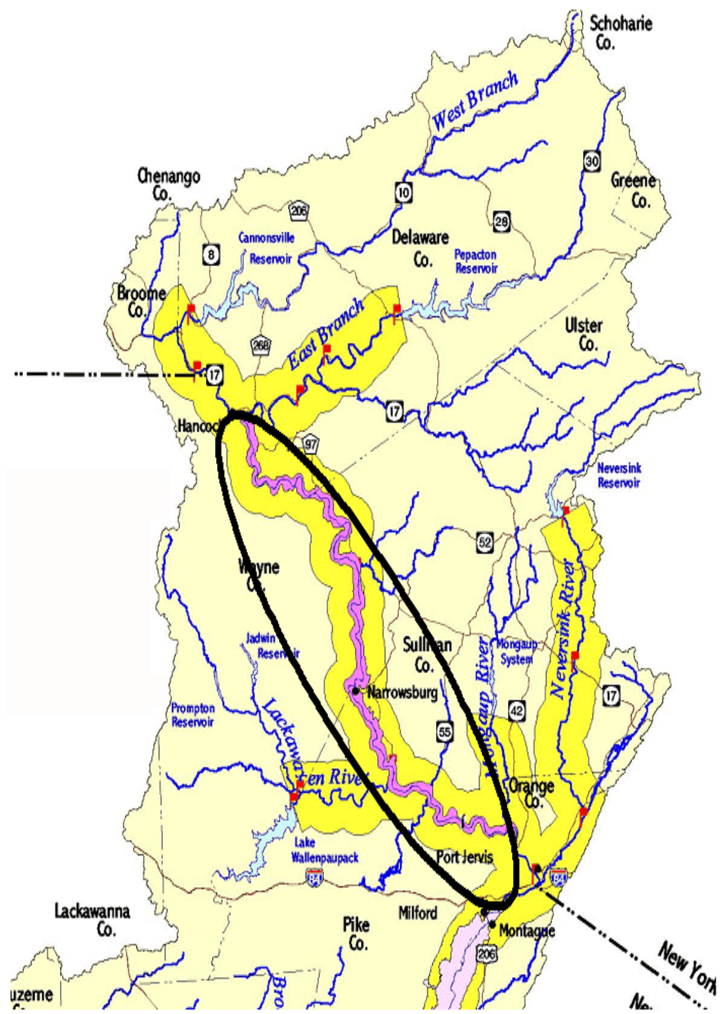

Figure 4.4
Upper Delaware River

This segment exhibits a variety of geomorphological forms. The headwaters portion ends at Narrowsburg, New York, where the river narrows and deepens, forming a pool over 113 feet deep. In the 36 miles between

Narrowsburg and Port Jervis, the average gradient is eight feet per mile. This segment contains over 30 Class I rapids, defined as having moving water with a few riffles and small waves. In addition, the stretch contains six Class II rapids--Ten Mile Falls, Westcolang Rapid, Narrow Falls Rift, Big Cedar Rapid, Shohola Falls, and Mongaup Rift. These rapids are fast flowing, but have waves of less than three feet, and the passages are wide and clear. The Delaware River does not have any Classes III to VI rapids.

Recreational opportunities are abundant in the Upper Delaware. The mountainous, rural setting, the clear, clean water, and numerous small rapids provide an outstanding canoeing environment. Most of this river segment is between 300 and 500 feet wide, with pools or eddies located in between long stretches of riffle. In some 2-mile stretches the gradient ranges from 13 to 30 feet per mile, creating whitewater during periods of medium to high water levels. The most heavily boated sections extend from Narrowsburg, New York to Cherry Island, New York (five miles upstream of Port Jervis).

The proximity of the Upper Delaware to the New York City and Philadelphia metropolitan areas has contributed to the establishment of a significant recreational boating industry. For the purposes of this section, the term 'boating' includes canoeing, kayaking, and rafting.

The northern 25-mile segment of the river between Hancock and Callicoon supports an excellent cold water fishery due to the large volumes of cold water releases from the Cannonsville Reservoir on the West Branch. This stretch supports abundant self-sustaining populations of rainbow and brown trout and is considered by many anglers to be one of the finest trout fishing destinations in the Northeast (Schultz, 1998). Almost all of the tributaries provide important trout spawning and nursery areas. Below Callicoon, the river is well known for its warm water sport fishing opportunities. Anglers (both in boats and along the shoreline) fish for smallmouth bass, sunfish, walleye, and fallfish.

Because the main stem of the Delaware River is free flowing, undammed, and uncontrolled from Hancock all the way to the Atlantic Ocean, the entire length of the Upper Delaware provides key spawning and nursery habitat for the anadromous American shad, an important recreational fishing species in the Delaware. Shad range in weight from two to five pounds and are a very popular sport fish. Since the late 1970s, water quality improvements and state and federal programs to support the species have resulted in a resurgence of this species and related recreational fishing in the Delaware River from the Bay all the way up to the East Branch. The NYSDEC (Sheppard, January 2003) reports that American shad continued to use the East Branch all the way to Downsville Dam following the construction of Pepacton Reservoir, and notes that Cemetery Pool on the East Branch continues to be a popular fishing spot. In contrast, the West Branch shad fishery declined dramatically with the construction and operation of Cannonsville Dam.

River temperature, flow, and solar angle are thought to be critical environmental triggers for up-river shad migration and spawning. Migration occurs in springtime when the water temperature is cool and flows are generally ample. High flows, not low flows, are considered impediments to upstream migration. After the spring spawning, the young of the year begin their migration to the ocean in the fall when they are just a few inches in length. Low flows are not considered an impediment to their migration, but survival rates may be lower during low flow periods. The young migrating shad swim downstream at night and rest (and hide) during the day in very shallow water out of the reach of predators (such as bass). Since river levels that expose large portions of the riverbed reduce the potential hiding areas for the young fish, lower flows may increase the mortality of the young of the year, which in turn reduces the number of spawning fish two or three years later.

The most important shad nursery areas are located in the deep pools between Belvedere and Hancock and up into the East Branch. It is estimated that populations of up to 500,000 shad migrate annually to the upper reaches of the Delaware. The peak of the spawning period usually occurs in June, when large numbers of anglers follow the spawning "run" up the river.

The NYSDEC (Elliot, March 2003) reports that striped bass have substantially increased in numbers and range as far upstream as Hancock. The 1935 fisheries survey, which included seine net catches and interviews with local anglers, did not list striped bass as being present in the Upper Delaware at that time. In the section of the report about shad, there is a discussion about pollution in the Estuary impacting shad migration. It is probable that the pollution would similarly inhibit striped bass from migrating upstream. Also, striped bass feed on young shad, which were diminished in number by the 1930s.

One NYSDEC source (Sheppard, January 2003) commented that shortnose sturgeon have reappeared upstream of Port Jervis. None were reported in the 1935 fisheries survey. This is a federally protected species.

According to NYSDEC (Elliot, March 2003), blueback herring and gizzard shad have returned to the Upper Delaware and East Branch in the last 10 to 15 years. Neither are sport fish, but they are food for other fish, eagles, etc. Again, they were not observed in the 1935 fishery survey.

Commercial trapping for the American eel, a catadromous species, continues in this reach of the main stem Delaware.

Total visitation, including land- and water-based activities, at the Upper Delaware National Recreation Area in 1999 and 2000 was 356,486 and 278,308 people, respectively. Since a large part of the visitation is river-related, the fluctuations in numbers may be related to weekend/holiday weather and flow conditions.

MIDDLE DELAWARE

The 1978 National Parks and Recreation Act designated the 38-mile segment between Milford, Pennsylvania, and the Delaware Water Gap (the Middle Delaware River, Figure 4.5) as a component of the National Scenic Rivers System. This segment, which starts about eight miles downstream of the southern boundary of the Upper Delaware, is protected through extensive Federal land acquisition and as a national park.

Both the Upper and Middle Delaware River segments are used heavily for sightseeing, canoeing, fishing, hiking, and hunting. In addition, the
Middle Delaware segment has five environmental education centers, a crafts village, a restored farmstead, and a crossroads village.

From Port Jervis to Stroudsburg, Pennsylvania, the water flows calmly in a wide channel, most of which lies within the boundaries of the Delaware Water Gap National Recreation Area. Of the 20 islands that dot this stretch of the river, Tocks Island (the site of the de-authorized Tocks Island Dam), is one of the

Figure 4.5
Middle Delaware River

largest. One unique physical feature of this section of the river is the Wallpack Bend where, in a major loop, or S-turn, the river completely reverses its direction within three miles. The water at Wallpack Bend reaches a depth of 25 feet, one of the deepest parts of this segment. As the river is forced around the bends, it produces a high current, resulting in eddy whirlpools.

In this area, the Delaware River cuts through a narrow valley of farmland and woodland that contains swift-flowing streams and waterfalls, significant geologic features, a variety of plants and wildlife, and a wealth of cultural resources. The Middle Delaware is even closer than the Upper Delaware to the large concentrations of people in New York City and Philadelphia, and its variety of recreational opportunities has been widely used by vacationers since the mid-19th century. Approximately 30 million people currently live within 100 miles of the river. Given, the access provided by routes such as I-84, I-80, I-78, and the Northeast Extension of the Pennsylvania Turnpike, these people are within 2-1/2 hours driving time of the Middle Delaware.

Recreation in the Delaware Water Gap National Recreation Area is managed by the NPS. The National Parks and Recreation Act of 1978 transferred all federal lands that were part of the proposed Tocks Island Reservoir Project, as well as land acquisition authority within the boundary of the National Recreation Area, to the NPS. This Act also designated the section of the Middle Delaware within the National Recreation Area as a scenic and recreational river under the National Wild and Scenic Rivers System. The river segment from the northern boundary to the Shawnee area is classified as scenic. The remainder of the segment is classified as recreational.

The recreational objectives differ little from those of the Upper Delaware, but the means by which they are to be achieved are extremely different. Of the 69,629 acres included in the National Recreation Area boundary, the federal government (NPS) currently owns and manages approximately 52,700 acres. The NPS has sole responsibility for interpreting, managing, protecting the natural and cultural values and processes, and for providing appropriate recreational opportunities and public facilities.

The most popular form of boating in the Middle Delaware is canoeing. Rapids are less prevalent and less challenging in the Middle Delaware and canoeing in the National Recreation Area (NRA) does not require as much skill as it would on the Upper Delaware. The NPS owns and operates seven major river access sites located every eight to ten miles. Other boating uses include tubes, rafts, powerboats, and fishing boats.

Flows in the Middle Delaware River are influenced by (1) natural base flows, (2) releases from the New York City water supply reservoirs, (3) hydroelectric power generation releases from a series of five reservoirs on the Mongaup River, and (4) releases from two reservoirs on the Lackawaxen River (Lake Wallenpaupack for hydropower and Prompton Reservoir for flood control).

LOWER NON-TIDAL DELAWARE

At Stroudsburg, Pennsylvania, the Delaware River breaks through the Kittatinny Mountains to form the Delaware Water Gap. At this point, the river flows through a narrow gorge with cliffs rising to a height of over 1,000 feet on either side. South of the Water Gap are long stretches of calm water interrupted by strong rapids only at Foul Rift.

From the mouth of the Lehigh River at Easton, Pennsylvania to the fall line at Trenton, the river has a modest gradient. Although the river has many small riffles in this section, it has only one major rapid, Wells Falls (below the Lambertville Wing Dam). Three wingwall dams in this section, located downstream of Washington's Crossing at Lumberville, Lambertville, and Scudders Falls, create artificial pools in the river.

In October 2000, federal legislation was signed extending the "Wild and Scenic" portions of the Delaware River from the Delaware Water Gap down to Washington Crossing (upstream of Trenton, New Jersey). The extension provides protection for the Delaware River water corridor (for about 1,000 feet on either side), which passes through 30 municipalities in Pennsylvania and New Jersey. The corridor also includes Tohickon Creek (Section 3.9) Twenty-four participating communities have priority for federal grants to protect the environment and must commit to the goals of preserving water quality, protecting natural and historic resources, encouraging low-impact recreational use, and preserving open space. Several industrialized areas, including Easton and New Hope in Bucks County are exempted. Six communities elected not to join the corridor: Durham, Upper Mount Bethel, and Williams Townships in Pennsylvania, and Pohatcong, White, and Alexandria Townships in New Jersey. The legislation prohibits the federal government from spending money on public works projects in the River and commits the NPS to developing and administering a management plan.

In the lower part of the non-tidal main stem, the river is still heavily used for recreation, but other uses become important as well. The region is much more densely populated. Industry and urbanization increase the demands on the River for both water supply and for assimilative capacity for industrial and municipal wastewater discharges.

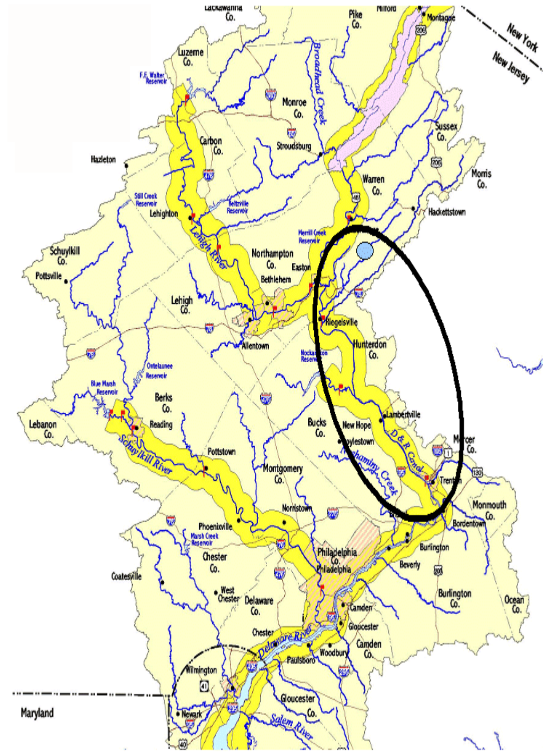

Figure 4.6
Lower Delaware River

4.4.2 Issues and Analysis

Several flow management issues in the Upper Delaware River are the same as issues in the West Branch of and potential index displays for these issues were previously discussed in the sections indicated below:

- Section 4.2.2.3 Irregular and Uncertain Releases
- Section 4.2.2.4 Thermal Release Bank
- Section 4.2.2.5 Water Quality

The following additional flow management issues were identified for the Upper**,** Middle, and Lower Delaware River:

- Section 4.4.2.1 Flows for Recreational Boating
- Section 4.4.2.2 Drought Declarations and Lower Flow Targets
- Section 4.4.2.3 New Jersey's Delaware and Raritan Canal Diversion
- Section 4.4.2.4 Downstream Water Supply Treatment
- Section 4.4.2.5 Improved Design of Reservoir Releases
- Section 4.4.2.6 Habitat Flow Requirements and Channel Maintenance
- Section 4.4.2.7 Special Protection Waters
- Section 4.4.2.8 Flow Target Locations

Potential index displays for these issues are described in the following sections.

4.4.2.1 Flows for Recreational Boating

a) Flow Traces at Barryville and Trenton

Flows at these points are critical to boating interests. The stage (water level) of the river can make the difference between an enjoyable day floating down the river and a miserable day of dragging canoes and rafts across the rocky riverbed. Flow traces (hydrographs***)*** at these two points indicate the range of conditions that recreationists may encounter, the duration of those conditions, and their frequency of occurrence. Since commercial liveries usually refer to flow at Barryville in terms of river stage, the flow trace should be related to river stage to interpret boating suitability. Relationships showing river stage at Barryville versus boating quality, and showing Trenton flow versus boating quality, are shown in Tables 4.1 and 4.2.

b) Number of good or excellent boating days, by season and by year

Interviews with boating livery owners indicated a fairly consistent grading of Upper Delaware boating conditions based on the river stage at Barryville and Lower Delaware boating conditions based on the flow at Trenton. The gradings are given in Tables 4.1 and 4.2, respectively. Per these tables, a river stage of between 3.2 and 8.0 feet at Barryville ranks from good to excellent, and a flow of 3500 cfs or better at Trenton is rated good to excellent. Given these criteria, it is easy to count the number of good or better canoeing and/or rafting days by season and by year in a simulation and display them in a bar chart. Weekend days are more important for boating interests than weekdays, and could be displayed separately. This will highlight the boating benefits induced by release schedules which target maintaining boating flows on weekends. Likewise, late spring, summer, and early fall days are more important than winter days.

c) Number of correctly forecast good boating days, by year

As is the case with fisheries, forecasts may afford boaters some assurance that their experience will be a good one. Accurate forecasting may encourage more boaters overall and will certainly decrease disappointments. Flow forecasts for boaters can be made based on expected releases, antecedent flows, and projected rainfall, and should be reasonably accurate. Good forecasting will involve coordination between the National Weather Service (which makes and publicizes flow forecasts) and the agencies responsible for short term planning for reservoir releases. The National Weather Service has recently introduced graphical river stage forecast products which are available on-line through the Mid-Atlantic River Forecast Center. Text products listing river stage forecasts are also available on-line. The U.S. Geological Survey provides on-line flow and stage hydrographs of near real-time stream conditions. While not flow forecasts, these hydrographs provide usesful information about the types of flow or stage fluctuations that may be caused by diversions or hydropower releases.

Table 4.1, Flow vs. Quality of Canoeing/ Rafting Experience, Upper Delaware River

Stage (feet) at Barryville	Flow (cfs)	Quality of Experience	Comment
<2.5	<737	Extremely poor	Most liveries will not rent boats at this condition
2.5	737	Very poor	Most boaters will be unhappy due to excessive grounding, portaging, and risks of stumbling
2.7	880	Poor	
3.0	1131	Fair	
3.2	1327	Good	
3.5	1779	Good	
4.0	2761	Very good	Excellent for nonexpert canoer
5.0	4887	Excellent	Excellent for experienced canoers, fair to poor for non-experts
6.0	7611	Excellent	Excellent for rafting, excellent for highly skilled kayakers
7.0	10,930	Excellent	Same
8.0	14,930	Excellent	Perfect for rafting
>8.0	>14,930	Variable	Waves flatten

Table 4.2, Flow vs. Quality of Canoeing/ Rafting Experience, Delaware River below Montague

Flow at Trenton (cfs)	Quality of Experience
<2000	too low to operate
2000	poor
2500-3000	fair
3500	good
5000	excellent
9000	ideal

Note: Rainfall events can affect the reliability of Table 4.2 as an indicator of boating quality for this large section of the main stem. Boaters should always check rainfall and river stage forecasts when planning boating activity**.**

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4.4.2.2 Drought Operations and Lower Flow Targets

The Delaware River Basin Commission Water Code spells out the conditions for drought operations, which are based on reservoir storage and include reductions in out-of-Basin diversions and associated flow target reductions. It is critical to the effective management of the Delaware's water resources that these reductions in exports and releases be implemented in a timely manner. If they are not, the risks to water supply increase dramatically. New York City's reservoirs are by far the largest source of storage in the Delaware Basin; their storage levels are the triggers for reductions in flow targets at Montague and Trenton, and in exports to the City of New York and the State of New Jersey. Flow targets are also governed by the river mile location of the salt front in the Delaware Estuary. The salt front is defined as the seven-day running average chloride concentration of 250 mg/l. Storage levels in Lower Basin reservoirs (Beltzville and Blue Marsh) may also trigger reductions to the Trenton flow target and the export to New Jersey during Lower Basin droughts.

The following displays have been used in flow management since the development of the existing DRBC Daily Flow Model in the early 1980s and are therefore both well established and well understood.

a) Number of days in *Drought Watch*, Warning, and *Emergency* conditions

This display is a three-entry table recording the number of days in each condition as counted from a simulation run.

b) Number of *Watch, Warning,* and *Emergency* events

This display is also a three-entry table that reports the total number of times each threshold was crossed.

c) Number of days below flow or storage thresholds

This display includes one entry (the number of days) for each threshold desired.

d) Minimum storage in all reservoirs

This display includes a single entry (the minimum storage) for each desired reservoir.

4.4.2.3 Delaware and Raritan Canal Diversion

The Delaware and Raritan Canal diversion conveys New Jersey's allocation of Delaware water eastward for use in northern New Jersey. It has been reported that a low river stage hydraulically restricts the rate of withdrawal at the D&R Canal intake, but this impact has not been well documented. Index displays could include:

a) the number of days of withdrawal restrictions at each level of drought declaration, or

b) the number of days that the River stage falls below the stage at which withdrawal problems occur.

4.4.2.4 Water Supply Treatment-related Displays

In general, the analytical tools needed to create water supply treatment-related displays have not been developed. Water supplies such as Philadelphia's do experience taste and odor problems, but the causes are hard to pinpoint. It is highly likely that they are caused in part by non-point source pollution, but they may also be related to releases from upstream reservoirs with poor quality water. The first step in developing these displays will be to identify the dissolved and suspended pollutants that cause the problems. The causative agents will then need to be traced back to sources, and models will have to be developed for both the generation and transport of the pollutants. Modeling the generation of these pollutants is likely to require watershed models for critical watersheds, and perhaps for the entire Basin. Such modeling will require very sophisticated reservoir water quality models. Index displays could include the following:

a) Concentrations of taste- and odor-causing chemicals at water supply intakes

b) Number of days with taste and odor problems

c) Time series trace of treatment costs

d) Total treatment costs

4.4.2.5 Measures Relating to the Precision in Meeting Flow Targets

Because of the high visibility of Delaware Basin issues, citizens observe and note when flow targets are and are not met, particularly at Montague. While it is desirable to meet the targets as closely as possible, it is not possible to meet them exactly. The Delaware River Master compensates for days when the target is not met by raising and lowering releases on subsequent days in order to achieve the appropriate balance in the long run. Statistics on daily deviations between the water actually released from the reservoirs and that needed to exactly meet the prevailing flow target can provide a performance measure of the overall operating system and methods. Due to the uncertainty of both precipitation and hydroelectric power generation forecasts, only limited control over these daily deviations is possible. The Office of the Delaware River Master (Paulachok) reports that the office receives only a few, occasional inquiries concerning the balancing adjustment used to compensate for under- or over-releases, and that it has had no instances where critics have been dissatisfied with the application of the balancing adjustment procedure.

a) Deviations from target flows

This index display is a table similar to Table 4.3 showing the number of positive deviations, the number of negative deviations, the average overall deviation, average positive and average negative deviations, maximum positive deviation, maximum negative deviation, and median positive and negative deviations from all target flows of interest when (and only when) releases are being made (or should have been made) to meet target flows. These deviations represent the difference between the water actually released from the reservoirs and that needed to exactly meet the prevailing flow target. The negative deviation is simply the difference between the target flow and the actual flow. If the flow is higher than the target, no negative deviation is recorded. The positive deviation is equal to the minimum of the release made to meet the target and the difference between the actual flow and the target flow. If the flow is lower than the target or if no release is made, then no positive deviation is recorded. The example in Table 4.3 is a hypothetical example of a display of deviation statistics for potential flow targets at Bridgeville and Hale Eddy, and the flow target at Montague. This type of comparison should be based on observed data and operating procedures. The existing daily flow and OASIS models for the Basin represent operating rules and historic hydrology and are useful for comparison of operating rule alternatives, but they do not replicate the decisions of the Delaware River Master's office in the day-to-day incorporation of precipitation and power generation forecasts in the design of reservoir releases.

Table 4.3, Deviation Statistics for Meeting Target Flows

Station	Tot Dev	Avg Dev	Pos Dev	Pos Avg	Pos Med	Pos Max	Neg Dev	Neg Avg	Neg Med	Neg Max
Bridgeville	3.2	50	1.7	67	60	400	1.5	32	24	40
Hale Eddy	5.7	75	3.4	82	74	627	2.3	63	52	42
Montague	8.9	120	5.2	145	120	850	3.7	75	60	250

4.4.2.6 Habitat Flow Requirements and Channel Maintenance

Smallmouth bass habitat and the recent observation of a significant population of dwarf wedgemussels in the main stem Delaware are examples of additional issues requiring better definition of flow and channel maintenance needs. Future flow management decisions will be dependent upon flow relationships established through monitoring, modeling, and ecological assessment. Such efforts are in progress for the dwarf wedgemussel.

4.4.2.7 Special Protection Waters

DRBC's Water Quality Regulations designate portions of the Delaware River as Special Protection Waters. The Commission's policy is to prohibit degradation of Special Protection Waters by any point or non-point source of pollution, regardless of class.

To date, the Commission has including the following Delaware River reaches in the program under two classifications.

Outstanding Basin Waters:

- Upper Delaware River (RM 330.7 to RM 258.4),
- Tributaries within the boundary of the Upper Delaware River corridor,
- Middle Delaware River (RM 250.1 to RM 209.5), and
- Tributaries within the boundary of the Delaware Water Gap National Recreation Area.

Significant Resource Waters:

- Delaware River (RM 258.4 to RM 250.1) between the Upper Delaware River and the Middle Delaware River as designated in the National Wild and Scenic Rivers System.

The Commission is considering including the Lower Delaware River in the special protection waters program. The Commission has been monitoring water quality in the Lower Delaware for several years in order to obtain the requisite background data to establish the water quality standards to be maintained.

The Special Protection Waters regulations do not specify a means to achieve the non-degradation objectives of the special protection designation. Flow prescription might be a component of the strategy, but the analyses needed to define the relationship between water quality and changes in flow due to flow augmentation policies have not been performed. This relationship would have to be defined to determine whether flow augmentation programs in the main stem violate the prohibition on water quality degradation.

4.4.2.8 Location of Flow Targets

As better information defines flow relationships for various habitat or recreational objectives, establishing additional flow targets on the main stem, particularly at Callicoon, has become an issue. Additional habitat assessment and flow modeling are needed to establish flow objectives and their management implications for existing or new reservoir storage. This is a particularly important issue with respect to the dwarf wedgemussel.

4.4.3 Additional Information and Study Needs - Main Stem Delaware River from Hancock to Trenton

The following steps are suggested, in priority order, for acquiring the information necessary to establish additional flow relationships and support index displays for the Main Stem Delaware River from Hancock to Trenton:

1) Review main stem water quality modeling results and monitoring data to determine the correlation of critical water quality parameters to changes in low flow rates. Determine low flow rates which would result in violation of water quality standards, assuming existing and projected rates of effluent discharge.

2) Obtain additional data concerning rates of the diversion from the Delaware and Raritan Canal and low flows in the Delaware River at Riegelsville, NJ. Determine the rate of flow at which the allocated diversions cannot be made.

   The New Jersey Water Supply Authority claims to have had difficulty making the needed diversions under some conditions of low flow. Additional information is needed before the necessary flow relationship and potential ameliorative action can be identified.

3) Assemble a data set of occurrences of downstream taste and odor problems and correlate it with data on reservoir releases and flow above the water supply intakes. In addition, identify the algae or other parameters causing the taste and odor problems and determine whether that species exists in Cannonsville Reservoir. Assess the need for additional water quality modeling to define taste and odor relationships to reservoir releases. Finally, determine the additional treatment costs associated with control of taste and odor and the extent to which reservoir releases affect those costs.

4) Perform a screening level habitat assessment to identify those reaches that are most vulnerable to or which benefit from low flows and flow fluctuations due to reservoir releases. Based on this screening, select reaches for possible IFIM analysis to establish critical flow rates.

4.5 Lackawaxen River from Wallenpaupack Creek to Mouth

4.5.1 Setting

The Lackawaxen River segment (Figure 4.7) extends 13 miles from PPL Generation's Lake Wallenpaupack hydropower generating plant outfall (2.5 miles east of Hawley, Pennsylvania) to the river's junction with the Delaware River at Lackawaxen, Pennsylvania. Land bordering this segment is steeply sloping, heavily forested, and sparsely developed. Vacation homes and small villages occupy portions of the narrow valley, much of which is state game land. A state road runs parallel to the Lackawaxen River, which is used for recreational fishing and boating.

Upstream from the PPL generating station, the watershed area is a mix of forest and small farms. Two Corps of Engineers single-purpose flood control reservoirs (Jadwin and Prompton) lie in this portion of the Basin. These have little impact on daily streamflows except during and immediately after large precipitation events.

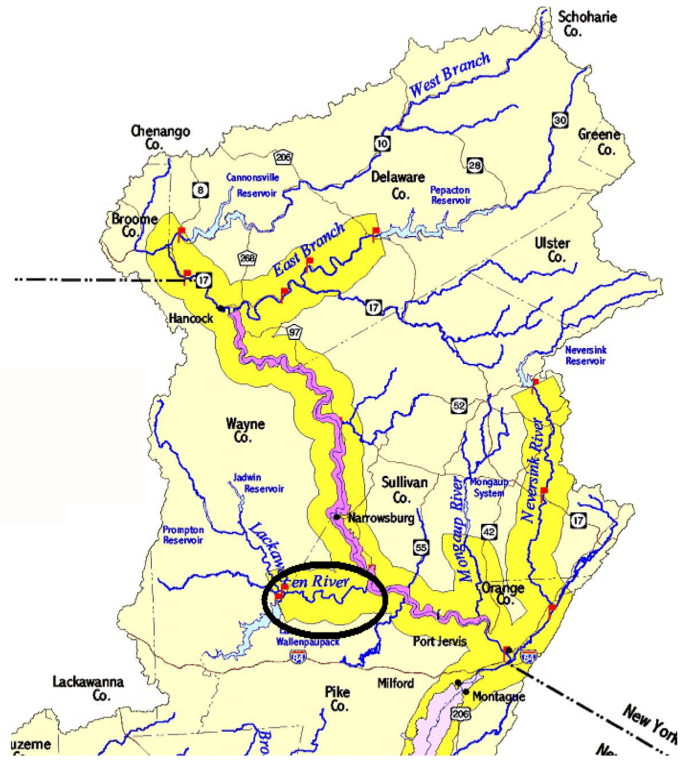

Figure 4.7
Lackawaxen River

Flow in the Lackawaxen River study segment is substantially affected by the rate and timing of releases from Lake Wallenpaupack to the hydropower generating plant. There are currently no required minimum conservation releases from the lake to Wallenpaupack Creek. Summer releases are generally timed to coincide with peak electric energy needs in the northeastern United States and are typically 10-12 hours in duration. Station output is dictated by the regional demand for electricity, and plant discharge varies from a minimum of 125 cfs to a maximum of 1750 cfs. Releases generally are not made on weekends unless lake levels are higher than desired.

Lake Wallenpaupack is also managed for recreation. A large number of vacation homes border the lake, which is extensively used for recreational boating and fishing. Upstream of the lake, the watershed area is a mix of forest and vacation resort development.

PADEP classifies the entire Lackawaxen River segment as Class HQ-TSF, MF. The "HQ" designation indicates high quality streams and watersheds that have excellent quality waters as well as environmental or other features that require special water quality protection. TSF designates a stream that is suitable for maintenance of stocked trout from February 15 to July 31 (additional stocking is performed in the fall) and that is home to additional flora and fauna indigenous to warm water habitat. (Trout are not known to successfully reproduce in the lower Lackawaxen River.) The MF designation is for migratory fish such as American shad.

During drought conditions, the DRBC has the authority to direct releases from Lake Wallenpaupack for maintaining the Montague flow target, and under certain conditions, the Trenton flow target.

4.5.2 Issues and Analysis

Flow in the Lackawaxen is substantially affected by the rate and timing of hydropower releases from Lake Wallenpaupack. PPL is in the process of applying for a renewal of its Federal Energy Regulatory Commission (FERC) license for the facility. As part of this process, PPL has worked with a group of stakeholders to identify resource issues related to management of flows into the Lackawaxen River.

The following flow management issues have been identified:

4.5.2.1 Trout Habitat
4.5.2.2 Recreational Fishing
4.5.2.3 Recreational Boating
4.5.2.4 Use of Lake Wallenpaupack in Drought Management

As a result of boating- and fishing-related surveys and its work with stakeholders, PPL has developed a FERC relicensing application which includes an operating plan to address the listed issues. Peripheral issues, including the effect of changed Lake Wallenpaupack release patterns on New York City release requirements for meeting the Montague target and downstream water quality, have been raised, and continued analysis and negotiations are in progress. OASIS flow modeling was used extensively by PPL to analyze and present the flow- and storage-related impacts of its FERC application on the Delaware River Basin reservoir system. In addition, a revised Lake Wallenpaupack drought operating proposal by PPL is under consideration by the DRBC, and was analyzed by PPL using OASIS.

4.5.2.1 Trout Habitat

Trout are stocked in the Lackawaxen River, but trout spawning is limited in the study reach. IFIM studies are available for the lower Lackawaxen. Consideration of temperature releases to improve summer thermal conditions for trout has been included in the FERC relicensing process for Lake Wallenpaupack.

4.5.2.2 Recreational Fishing

Reports developed by PPL during the FERC relicensing process indicate that anglers prefer flows in the range below 600 cfs and are unhappy with flows in excess of 850 cfs. Combining this information with the modeled hydrographs for reservoir operating alternatives would provide an index display for the number of days of preferred fishing conditions under a particular operating plan.

4.5.2.3 Recreational Boating

Boating condition survey information collected by PPL during the FERC relicensing process indicates that boaters considered flows of 700 cfs to be “good,” but that the quality of the boating experience rose rapidly as flows increased from 900 to 1200 cfs. During the summer, these flows occur when the Lake Wallenpaupack station is generating. Modeled flow hydrographs for reservoir operating alternatives, when combined with this boater survey information, would provide an index display of the success of specific alternatives in achieving preferred boating conditions.

4.5.2.4 Use of Lake Wallenpaupack in Drought Management

In conjunction with its FERC relicensing process, PPL has proposed modification of the drought operating plan for Lake Wallenpaupack. This would expand DRBC’s ability to direct releases from the lake beyond drought emergencies to both *drought watch* and *drought warning* conditions. Because of the interplay between releases from Lake Wallenpaupack and the directed releases from the NYC reservoirs for meeting the Montague flow target, there has been concern that additional releases from Lake Wallenpaupack during these periods would significantly lessen release requirements from the NYC reservoirs to the detriment of tailwater fisheries. PPL has performed extensive flow modeling using the OASIS model and these results have been used to evaluate the impacts of the proposed change in drought operations. The DRBC has approved the proposed drought operating plan conditioned on the mitigation of adverse impacts it may have on the NYSDEC fishery management program for the NYC reservoir tailwaters. The mitigation measures are currently under negotiation.

The dwarf wedgemussel, classified as endangered under the federal Endangered Species Act, has recently been identified in the Upper Delaware River, in the vicinity of Calicoon, Hankins, and Equinunk. There is concern that changes in Lake Wallenpaupack operation could affect the species. The flow relationship for the dwarf wedgemussel is not yet defined and studies to develop this information are in the planning stage as of late 2003. Findings would be applicable to flow management policy as adopted by the Decree Parties and DRBC. Such policy affects all Upper Basin reservoirs, and primarily affects the management of the three New York City Delaware Basin reservoirs.

4.5.3 Additional Information and Study Needs - Lackawaxen River from Wallenpaupack Creek to Mouth

Flow-related issues on the Lackawaxen stream segment are being addressed in the current FERC relicensing of the Lake Wallenpaupack hydropower project. A substantial amount of work has been done relating flow to benefits. These include fisheries management, re-watering Wallenpaupack Creek directly below the reservoir, fishing conditions, and recreational boating both on the lake and in the river. Significant detail on Lake Wallenpaupack has already been included in the DRBC OASIS model through independent work by PPL. In order to avoid conflicts with determinations that may result from the FERC re-licensing process, which involves numerous regulatory agencies, recommendations for additional study on the Lackawaxen River have not been included in this report.