Lower Delaware Monitoring Program: 2000-2003 Results and Water Quality Management Recommendations

"Forks of the Delaware"

Delaware River Basin Commission

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Delaware River Basin Commission

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Delaware River Basin Commission staff:

Carol R. Collier, Executive Director. Robert A. Tudor, Deputy Executive Director.

Robert L. Limbeck, Watershed Scientist, primary author.
Geoffrey Smith, Biologist, contributing author.
Todd W. Kratzer, Water Resources Engineer, contributing author.

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Contents

Executive Summary

In the May to September periods of 2000 through 2003, the Delaware River Basin Commission's (DRBC) Lower Delaware Monitoring Program (LDMP) conducted a bi-weekly water-quality survey of the Delaware River and selected tributaries located between the Delaware Water Gap and Trenton, NJ. The purpose of this report is to 1) document water quality conditions for the period 2000-2003, and 2) to present evidence and advise the Delaware River Basin Commission in its determination of the Lower Delaware River's suitability for designation as **Special Protection Waters (SPW)**. Objectives of the LDMP are to define **existing water quality (EWQ)** for this segment of the Delaware River, and subsequently to link long-term water quality monitoring to integrated water management.

This report describes existing water quality, the control point approach used to produce site-specific targets for water quality management, and results of the first four years of the five year effort to describe existing water quality in the Lower Delaware. For the Special Protection Waters eligibility determination, Lower Delaware water quality and biological monitoring results are compared with the most stringent criteria or targets available in DRBC or State rules. Delaware River results were also compared with high-quality tributary waters, specifically those designated as High Quality (HQ) and Exceptional Value (EV) waters in Pennsylvania and Category One (C-1) waters in New Jersey.

Biological results from 2001 Delaware River biomonitoring show that the Lower Delaware River contains a diverse, taxonomically rich, and pollution intolerant benthic macroinvertebrate assemblage. Selected metrics were compared with the most stringent targets: the Upper Delaware existing water quality targets for diversity and EPT Richness, and New Jersey's Hilsenhoff Biotic Index value of 4.0 defining an intolerant assemblage. All results were optimal, indicating exceptional biological value. Aquatic habitat was assessed during macroinvertebrate sampling in 2001, and scores are optimal in the Lower Delaware.

LDMP water quality results were determined to be representative of 95% of the range of flow conditions at Trenton and Belvidere. Existing water quality as defined by the 2000-2003 data set represents a range of flow from approximately 2,000 cfs to 40,000 cfs.

Reach wide existing water quality is presented for comparison with Upper and Middle Delaware reach wide targets set in the early 1990's in DRBC Special Protection Waters rules. Use of reach wide targets for the Lower Delaware is not recommended, since water quality differs substantially from Delaware Water Gap to Trenton. It is also difficult to assess water quality changes using reach wide targets.

Delaware River results indicate that existing water quality is better than criteria levels, with the exception of bacteria. Of 153 possible comparisons of EWQ to most stringent criteria (9 ICP sites, 17 parameters), 94% showed that EWQ is better than criteria.. 74% were better at all times, 20% met criteria about 90% of the time, and 6% never met criteria. For most sites and parameters, EWQ based targets would provide protection for maintenance of existing good water quality. Enterococcus bacteria concentrations are the single major problem. Fecal coliform and E. coli bacteria concentrations were problematic during storms. Phosphorus concentrations were relatively high but did not render the Lower Delaware unsuitable for aquatic life use. At certain locations, pH and TDS were naturally divergent from criteria levels, indicating that perhaps the criteria themselves need revision. EWQ targets will provide additional water quality protection by establishing targets for 10 more parameters without currently established criteria.

Additional information is shown in the report "Lower Delaware River Eligibility Determination for DRBC Declaration of Special Protection Waters" (DRBC 2004) that accompanies this document. The following recommendations are based upon LDMP 2000-2003 monitoring results:

Recommendation 1. Designate & Implement Special Protection Waters

Recommendation 2. Protect or Restore Priority Watersheds

Recommendation 3. Build Watershed Partnerships

Recommendation 4. Fill Critical Information Needs

Recommendation 5. Consider Changes to Water Quality Rules

Recommendation 6. Support Monitoring to Meet Recommendations

Lower Delaware Monitoring Program:
2000-2003 Results and Water Quality Management Recommendations

Introduction

In the May to September periods of 2000 through 2003, the Delaware River Basin Commission's (DRBC) Lower Delaware Monitoring Program (LDMP) conducted a bi-weekly water-quality survey of the Delaware River and selected tributaries located between the Delaware Water Gap and Trenton, NJ. The purpose of this report is to 1) document water quality conditions for the period 2000-2003, and 2) to present evidence and advise the Delaware River Basin Commission in its determination of the Lower Delaware River's suitability for designation as **Special Protection Waters (SPW)**. Objectives of the LDMP are to define **existing water quality (EWQ)** for this segment of the Delaware River, and subsequently to link long-term water quality monitoring to integrated water management.

Traditionally and historically, water quality standards and criteria have been developed to protect certain uses of the water resource. Resultant numeric criteria have been oriented only toward effect levels upon these uses, where negative effects upon human health, aquatic life, recreation, or suitability for water supply are likely to occur. There is a gap in water resource protection created by this approach. Poole et al. (2004) determined that while conventional standards have proved valuable in reduction of toxic substances in U.S. waters, regime-based standards are better structured to address human caused imbalances in dynamic, natural water quality parameters. In very high-quality waters, typical concentrations of water quality constituents are far better than effect levels. Existing Water Quality (EWQ) is the typical range of concentration levels of all measurable constituents of ambient waters, as determined over a defined time period. Existing Water Quality is defined either by design or by summary of historical data, and these water quality levels are used in combination with antidegradation policies to protect water quality at concentrations where they exist today. The main objective of such "no measurable change" policy is to protect water quality from degrading from current high quality levels.

Declaration of Special Protection Waters by DRBC is a major statement of antidegradation policy, or a declaration of intent that the waters of the Delaware shall be managed to maintain water quality at EWQ levels and not to allow change toward effect-level criteria or worse. Of course, natural water quality may vary widely throughout the course of the day and the season, so monitoring must capture the natural range of variation. Once sufficient data are collected to describe EWQ with confidence, the natural range of EWQ is statistically expressed either non-parametrically in terms of median, 10^{th} and 90^{th} percentiles; or parametrically in terms of mean and 95% confidence limits. Once EWQ is defined, the monitoring focus then shifts to determine whether water quality is changing (and why) over time using the statistically expressed range of variability to detect "measurable change."

This report presents water quality results in context of adopted water quality standards. A related report, entitled Lower Delaware River Eligibility Determination for DRBC Declaration of Special Protection Waters (DRBC 2004) uses data from this report and other evidence to make best-professional judgment recommendations concerning the Lower Delaware River's eligibility for Special Protection Waters designation. Management and policy issues are also discussed in the related report. Both reports contain recommended program requirements for future implementation.

Background and Context

The LDMP operates in support of the Lower Delaware River Management Plan, produced by the Lower Delaware River Wild and Scenic River Study Task Force and the National Park Service (1997). The first goal of the Management Plan is to **"maintain existing water-quality in the Delaware River and its tributaries from measurably degrading and improve it where practical."** The National Park Service (1999) surveyed river-corridor landowners, finding that 98% of respondents strongly support this water quality goal. The "maintain EWQ" objective requires Special Protection Waters status in order for anti-degradation policy to carry the force of law in DRBC water quality standards. On January 28, 1998, the DRBC passed Resolution No. 98-2, which endorsed the Lower Delaware River Management Plan and resolved to "…take such action as it deems appropriate to implement the goals of the plan commensurate with available resources."

Little information was available in 1998 about status and trends of Lower Delaware water quality. As a baseline for future management, EWQ is being defined using LDMP 2000-2004 water quality data. These data may be used to create water quality targets for adaptive management – meaning that targets may be refined as the data set expands and/or water quality improves. The study thus far required U.S. EPA Water Quality Monitoring Grant support of about $50,000 per year for laboratory analyses, plus DRBC General Fund support of numerous staff and interns.

Evaluation Approach

In order to determine eligibility of the Lower Delaware River for Special Protection Waters status, **evidence must be shown that these waters are considered to have exceptionally high scenic, recreational, ecological, and/or water supply values** (DRBC Water Quality Standards, 1996).

In the Upper and Middle Delaware River, the values listed above were examined using available information, but the determination of SPW status was not conducted using quantitative benchmarks or criteria. In terms of water quality, it was generally accepted that the Upper and Middle Delaware resources were of exceptional value. The same assumption cannot be made for the Lower Delaware.

In DRBC water quality regulations, the rule language provides no quantitative criteria to judge 'exceptionally high' values. Quantitative indicators for SPW determination were derived by parsing the statement from DRBC rules into measurable component parts. As the focus of this investigation, measures of water quality are judged in terms of ecological, recreational, and water supply values. As an indicator of 'exceptionally high' value, water quality was compared with only the most stringent criteria chosen from among DRBC, Pennsylvania, or New Jersey water quality standards. Water quality of the river was also compared with that of designated EV, HQ, or C1 waters. If there are no standards for a certain parameter, federal guidelines were used. For ecological value, further consideration was given to measures of biological integrity. Measurable biological traits include taxonomic richness, diversity, balance, pollution intolerance and physical habitat value.

Scenic and recreational value was discussed at length in the Lower Delaware Management Plan (1997) and the National Park Service Lower Delaware Wild and Scenic Study (1999). In segments of the Lower Delaware that were designated in the federal Wild and Scenic legislation, scenic and recreational resources are found to be of exceptional value. These reports and the federal designation provide part of the weight of evidence necessary for DRBC to make a Special Protection Waters determination.

Water supply value may be the most critical and vulnerable resource issue relevant to SPW designation. The Lower Delaware certainly can be described as an exceptional value water supply resource. Sayers (Personal Communication, 2004) related that as of 2004, an estimated 2.9 million people directly depend upon water supplied by the Lower Delaware.

Withdrawals directly from the Lower Delaware River for the purpose of public water supply total 131.6 million gallons per day. These water suppliers serve 1.1 million customers:

City of Easton;
North Penn and North Wales Water Authorities, via the Point Pleasant water diversion;
New Jersey Water Supply Authority, via the Delaware and Raritan Canal diversion;
Pennsylvania American Water Company, Yardley District;
Morrisville Borough; and
Trenton Water Works.

Additional downstream water suppliers are also dependent upon water quality of the Lower Delaware as freshwater inflow to the upper Delaware Estuary. Downstream withdrawals total 219.8 million gallons per day, serving about 1.8 million people. Customers of the Philadelphia Water Department; Lower Bucks County Joint Municipal Authority; New Jersey American Water Company Delran Intake; Bristol Borough and Burlington City are served by fresh water from the Lower Delaware.

There are undesignated gaps between the designated scenic and recreational river segments of the Lower Delaware. These are typically river segments located in the vicinity of urban and industrial centers, where such uses as industrial supply and water supply are important. It is not possible to allow water quality degradation in undesignated segments without expecting water quality to degrade in designated segments. For consistent management, the same benchmarks must be applied to all locations in the river system, without regard to artificial or political boundary lines along the longitudinal corridor.

As further evidence in support of SPW determination, this report contains four years of water quality data as well as a summary of one season of available biological and habitat data taken in 2001 by DRBC biologists. These findings represent DRBC efforts thus far to numerically define existing water quality, to measure tributary water quality influences upon the Delaware River, and to determine water quality values that inform the process of determination of Special Protection Waters eligibility. While these data do not represent the final definition of EWQ, they will facilitate the designation process. DRBC has not yet fully characterized influences, causes, or effects upon water quality. Final EWQ targets will be created after an additional year of monitoring and will be based upon data from 2000-2004.

Control Point Monitoring Concepts

Throughout this document, extensive use is made of certain terms associated with the way DRBC evaluates water quality data. Since DRBC evaluates its data along the geographical boundaries of a longitudinal river corridor, it is necessary to segment the river so that changes from upstream to downstream can be documented at particular locations. The points on the Delaware River where changes to water quality are assessed are known as **Interstate Control Points (ICP)**, since these are located along the river which is the boundary between states. Delaware River bridges are normally chosen to serve as ICP locations for safety, cost effectiveness, and ease of access for monitoring. Interstate Control Points were placed between major tributaries to the Delaware River.

A common approach to impact assessment for water resource scientists is the "upstream-downstream" evaluation, where water quality is assessed upstream of an input or point source, at the point source itself, and the combined effect is assessed downstream of the confluence of the upstream and point source inputs. In the LDMP monitoring design, each tributary is considered a discrete input or point source to the Delaware River. The LDMP monitors these **Boundary Control Points (BCP)** near to their confluence but away from backwater influence of the Delaware River. To evaluate the effects of each tributary upon the Delaware River, it is necessary to monitor the tributary BCP and to relate the resulting information to the nearest upstream and downstream ICP. This approach provides regulatory advantages in that any criteria or targets created using such a monitoring approach are site-specific. Site-specific targets can be monitored at a high accuracy level with the ability to detect water quality changes, unlike the diffuse reach-wide targets set in the early 1990's for the Upper and Middle Delaware River SPW, where DRBC and the National Park Service have since experienced difficulty implementing antidegradation policy and detecting "measurable change" to water quality. In addition, the control point approach allows for creation of watershed-specific water quality targets, where effects of each tributary upon the river are differentiated and requirements for maintenance or restoration of water quality can be modeled and quantified. The site-specific control point approach has advantage over the reach-wide target approach in current DRBC rules in that if measurable change in the Delaware River or tributary is detected, it is possible to determine the source of change and take appropriate action at small relative cost and effort.

Study Area and Water Use Overview

The River System

From the confluence of its East and West Branches at Hancock, New York, the Delaware River flows 330 miles through the Appalachian Highlands, Valley and Ridge, Piedmont, Triassic Lowlands, and Coastal Plain physiographic regions of New York, Pennsylvania, New Jersey, and Delaware. The Delaware River basin watershed area is 13,539 sq. mi. The non-tidal portion is about 200 miles long and drains 6,780 sq. mi. above the fall line at Trenton, NJ. The Delaware River is an interstate water body that forms the boundary between the basin States.

The 75-mile long study reach **(Figure 1)** is contained within the 80-mile long Lower Delaware River, which extends from the Delaware Water Gap to the head of tide at Trenton, NJ. Approximately 2,610 square miles of drainage area are located within the segment. Along the river corridor, 53 named tributaries meet the Delaware River in Bucks, Northampton, and Monroe Counties in Pennsylvania and Warren, Hunterdon, and Mercer Counties in New Jersey.

The Lower Delaware region is densely populated in the Lehigh Valley and lower Bushkill Creek watersheds, yet the rest of the study area is relatively bucolic and very scenic. The river corridor features historic small towns, agriculture, and isolated industries. Regional cities include Allentown, Bethlehem, Easton, East Stroudsburg, Phillipsburg, Lambertville, and Trenton. Major transportation corridors pass through the region, including Interstates 95, 78 and 80; U.S. Highway 22; and State Routes 611, 29, 32, and 46. Most tributary watersheds are rapidly urbanizing in headwater areas and along transportation corridors.

Figure 1. The Lower Delaware River Study Area

Uses and Designations

In DRBC Water Quality Regulations (DRBC 1996), the Lower Delaware River is designated for **water supply, primary contact recreation, industry, agriculture, and aquatic life**. These are significant and sometimes competing uses of the water resources. Maintenance of water quality and flow is critically important for present and future use of the resource.

Water Supply

This is perhaps the most critical water use category to be protected by resource managers. A distinction of the Lower Delaware is that it is a vital piece of the Delaware River Basin, a small watershed that covers only 0.4% of U.S. land area, yet serves water to more than 5% of the entire U.S. population. Much of the population of the southern portion of the Basin is directly dependent upon water from the Lower Delaware.

Significant water supply risks are associated with Lower Delaware River water quality degradation, including increased water treatment costs, taste and odor problems, reduced useful lifetime of treatment facilities, potential human health risks, loss of future supply and economic potential, and reduced wastewater assimilative capacity of the Delaware River as a receiving waterway. Water supply sources are very concentrated within the Lower Delaware and downstream. Negative changes to water quality here affect a much larger surrounding region including the Delaware Estuary, Neshaminy watershed, Schuylkill watershed, Raritan watershed, or other watersheds where Lower Delaware diversions are carried.

Recreation

Recreational use includes boating, fishing, canoeing, tubing, swimming, wildlife watching, and tourism at numerous historical and cultural sites along the river. Recreational use of the river is very substantial. The NPS Wild and Scenic Study (1999) provides evidence to this effect, though casual observance reveals the sight of people on the river at any time of day, unless the river is in flood. On hot summer days, the canoe liveries send hundreds of canoes and tubes on day trips. Delaware River Biomonitoring Program observers (unpublished DRBC field notes, 2001-2003) typically recorded about 40 boats, canoes, tubes or waders per hour passing Lower Delaware biomonitoring sites, but flotillas of up to 220 per hour have been noted. Fishing pressure is heavy, particularly when the American Shad and River Herring are running in the spring. Events centering upon the annual return of these migratory species to the Delaware River, such as the Lambertville Shad Fest, are culturally and economically significant to the region. Opportunities abound for wildlife watching. DRBC staff commonly note the presence of snakes, turtles, salamanders, hawks, owls, osprey, bald eagles, herons, egrets, and many types of songbirds. Otters are sighted occasionally, and reports of bear or deer crossing the river have been noted. River-centered recreation and tourism is of increasing economic importance, and its resource value must be protected.

Industry

The Lower Delaware River is the source of water for numerous industries. Chief among these in water use are four major power generation facilities: Portland, Martins Creek, Gilbert, and Limerick Nuclear, which is fed by the Point Pleasant Diversion. Every river town contains some industry, though not as many as in years past.

Agriculture

Once the most dominant of all uses, agriculture is no longer a major land use activity near the river. Some riverside farming remains wherever the Delaware River floodplain is wide, particularly in northern Hunterdon County, Warren County, and Northampton County. Tributary watersheds support substantial agricultural use, and pollution impacts by farming and grazing activity upon Delaware River water quality may be significant. To address these non-point source pollution effects, New Jersey's recent approval of the USDA Conservation Reserve Enhancement Program is expected to have a positive effect upon water quality of the Delaware River. At this time, Pennsylvania is working to implement a similar program. The LDMP is in position to monitor the changes to water quality resulting from these and many other management measures. No withdrawals take directly from the Delaware River for agricultural purposes.

Aquatic Life

The river's geological variety and flow regime provides suitable and very heterogeneous habitat for a diverse, rich and abundant aquatic community. The Lower Delaware is a generally wide, shallow, gravel and cobble-bottom river that flows through a very diverse landscape. Geological features such as the Piedmont's Triassic Rock outcrops and boulder-field remnants of two glaciers, combined with numerous islands, riffles, pools, aquatic vegetation beds, back-channels, and forested riparian canopy provide a wide range of habitat types for biological activities such as feeding, reproduction and refuge. The Delaware River's continuity of diverse habitat is much reduced or absent in nearly all other large rivers of the eastern U.S., where dams, levees, and channelization have fragmented the river continuum. The free-flowing nature of the Delaware River is unique and exceptional. The Delaware River Biomonitoring Program has sampled habitat and benthic macroinvertebrates since 2001, and early results are quite positive. All of the first year samples have shown that the benthic assemblage is rich, diverse, well balanced, and intolerant of

pollution – scoring as well as or better than the Special Protection Waters of the Middle and Upper Delaware. While a single season of monitoring data is insufficient for a complete assessment, DRBC and USGS river biologists find that a high-quality biological community exists in the Lower Delaware River, which also indicates high water quality.

Under Pennsylvania DEP water quality standards, the Lower Delaware is classified as a Warm Water Fishery. Warm water fishes such as bass, perch, white suckers and many other species are abundant year-round; and the fish community is supplemented annually by major migrations of American Shad, American Eel, and River Herring. Owing to its free-flowing character and good water quality, the Delaware River is a major sport-fishing draw for anglers who seek these migratory species. This fishery provides enormous economic and quality of life benefits to the region.

The Lower Delaware Study Area

Upstream reaches determine the river's character at the beginning of the Lower Delaware study area. The Delaware River Basin's headwaters contain large New York City reservoirs that maintain flow in the river, especially during the critical May to September low-flow season covered by this survey. New York City has invested tremendous financial resources to ensure that these reservoirs continue to provide the highest quality water, and such high quality reservoir releases are barely diminished by the time the water reaches the Lower Delaware. Immediately upstream of the Lower Delaware is the Middle Delaware Scenic and Recreational River, located within the Delaware Water Gap National Recreation Area (DWGNRA). The nearest upstream large tributaries are Brodhead Creek, Bushkill Creek, and the Flat Brook, all joining the Delaware within the DWGNRA. Among these, the urbanizing Brodhead is the nearest upstream and negatively influences the Delaware River's water quality, even though the Brodhead meets all PADEP water quality criteria. PADEP 2000-2003 data were retrieved from the STORET data system and compared with reach wide EWQ in the Middle Delaware. The Brodhead increases concentrations of nutrients, bacteria, and solids in the Delaware River such that Middle Delaware EWQ is different from that at Portland, only a few miles downstream. This demonstrates how water quality at Portland, the farthest upstream monitoring site of the LDMP, integrates all upstream influences. The Portland site thus serves as the baseline station where all upstream water quality entering the Lower Delaware is measured.

Table 1 lists LDMP monitoring locations. Nine Delaware River bridge sites were chosen for description of existing water quality and establishment of Interstate Control Points. Fifteen major and minor tributaries were chosen for description of existing water quality at Boundary Control Points. It is notable that many New Jersey and Pennsylvania tributaries in **Table 1** are classified by state agencies as High Quality (HQ), Exceptional Value (EV), or Category One (C1) waters where the states apply antidegradation policy.

Portland to Riegelsville

The northern portion of the Lower Delaware flows through the Valley and Ridge region. This reach of the river is a transition zone where both natural and human-induced changes to water quality occur. Significant limestone bands influence water quality of the river and tributary streams. Until it receives input of these limestone streams, the river's character reflects that of its relatively nutrient-poor, low-alkalinity, and exceptionally high quality headwaters. As each limestone-influenced tributary enters the Delaware River, it imparts natural changes to water quality of the river. Here also the river flows through terminal deposits remaining from glaciers that once covered the valley, leaving boulder fields, ledges, islands, cobble/gravel riffles, mostly long and shallow pools, a few very deep pools, and scour holes that provide exceptional diversity of instream habitat and add to the river's biological, scenic and recreational value. Effects of urbanization become most apparent in the vicinity of Easton, PA, and Phillipsburg, NJ.

At Easton two major urban tributaries enter the Delaware River, the Lehigh River and Bushkill Creek. The Lehigh and Bushkill are both heavily urbanized in their lower watersheds. The Lehigh is the second largest tributary to the Delaware River, and its hydrologic influence alone changes water quality of the Delaware River. Just below the confluence of the Musconetcong River in Riegelsville, the river leaves the Valley and Ridge and enters the Piedmont Region.

Table 1. Lower Delaware Monitoring Program ICP and BCP Sites

Site Name	River Mile	Drainage Area (mi2)	Control Point Type	State AntiDeg Waters	Physiographic Province
Delaware River at Portland Footbridge	207.40	4,165.0	Interstate	-----	V/R
Paulins Kill, Warren Co., NJ	207.00	177.0	Tributary (major)	NJ C1	V/R (limestone)
Delaware River at Belvidere Bridge	197.84	4,378.0	Interstate	-----	V/R
Pequest River, Warren Co., NJ	197.80	157.0	Tributary (major)	NJ C1	V/R (limestone)
Martins Creek, Northampton Co., PA	190.80	45.5	Tributary (major)	-----	V/R (limestone)
Bushkill Creek, Northampton Co., PA	184.10	80.0	Tributary (major)	PA HQ-CWF	V/R (limestone)
Delaware River at Easton, Northampton St. Bridge	183.82	4,717.0	Interstate	-----	V/R
Lehigh River, Northampton Co., PA	183.66	1,364.0	Tributary (major)	-----	V/R
Pohatcong Creek, Warren Co., NJ	177.40	57.1	Tributary (major)	NJ C1	V/R
Delaware River at Riegelsville Bridge	174.80	6,328.0	Interstate	-----	V/R
Musconetcong River, Warren/Hunterdon Co., NJ	174.60	156.0	Tributary (major)	-----	V/R
Cooks Creek, Bucks Co., PA	173.73	29.5	Tributary (major)	PA EV	V/R
Delaware River at Milford Bridge	167.70	6,381.0	Interstate	-----	Piedmont
Nishisakawick Creek, Hunterdon Co., NJ	164.10	11.1	Tributary (minor)	NJ C1	Piedmont
Tinicum Creek, Bucks Co., PA	159.90	24.0	Tributary (minor)	PA EV	Piedmont
Tohickon Creek, Bucks Co., PA	157.00	112.0	Tributary (major)	-----	Piedmont
Paunacussing Creek, Bucks Co. PA	155.60	7.9	Tributary (minor)	PA HQ-CWF	Piedmont
Delaware River at Bulls Island Footbridge	155.40	6,598.0	Interstate	-----	Piedmont
Lockatong Creek, Hunterdon Co., NJ	154.00	23.2	Tributary (minor)	NJ C1	Piedmont
Wickecheoke Creek, Hunterdon Co., NJ	152.50	26.6	Tributary (minor)	NJ C1	Piedmont
Delaware River at Lambertville Bridge	148.70	6,680.0	Interstate	-----	Piedmont
Pidcock Creek, Bucks Co., PA	146.30	12.7	Tributary (minor)	-----	Piedmont
Delaware River at Washingtons Crossing Bridge	141.80	6,735.0	Interstate	-----	Piedmont
Delaware River at Calhoun St. Bridge	134.34	6,780.0	Interstate	-----	Piedmont

Riegelsville to Trenton

The Piedmont region of the Lower Delaware River is characterized by a severe narrowing of the watershed. Except for Tohickon Creek, direct tributaries to this reach are very small in watershed size. The tributaries originate atop the Piedmont plateau, spill through palisades or escarpments in their middle or lower reaches to the Delaware River floodplain, which is narrow in areas where the scenic and ecologically valuable palisades are close to the river. Piedmont topsoil is thin, and the fractured rock aquifer holds little water. The streams are naturally 'flashy' in their response to storm events – they rise and fall rapidly, and very low stream flow levels are common. Unless moderated by headwater or riparian wetlands, rainfall tends to run off very quickly in this area. Small towns and scattered industries are located along the river corridor. The geological features provide in-stream ledges, miles-long pools, numerous islands, and riffles with higher gravel content than the cobble-dominated ones upriver. This diversity of flow, depth, geological features, and islands creates excellent warm water habitat.