Delaware River Basin Commission

# Existing Water Quality Atlas of the Delaware River Special Protection Waters

DRBC Special Protection Waters Program

September 2016 – Edition 1.0

Delaware River Basin Commission
DELAWARE • NEW JERSEY
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# Acknowledgments

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The authors wish to express their gratitude to the many individuals and agencies (see below) that undertook and supported this multi-year effort (2000-2016). Omissions or errors are entirely the fault of the authors. The Delaware River Basin Commission (DRBC) and the National Park Service (NPS) have long worked together in support of the Scenic Rivers Monitoring Program (SRMP), which started in the early 1980's. Most project funding came from the U.S. EPA 106 monitoring grant to DRBC, and additional funds were provided through a Haas Foundation grant and three NPS/USGS Cooperative monitoring projects in the Upper and Middle Delaware.


During this project, we lost two of the program's most visionary and influential leaders from its earliest days: **Richard C. Albert** (far left) and **Todd W. Kratzer** (left). Though both had departed DRBC before this project started, they continued to provide expert guidance until their final days. As engineers, scientists, and most importantly friends and mentors, they were integral to turning the concept of anti-degradation into practical science and water resource protection policy that keeps clean water clean. They are sorely missed.


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## Abbreviations

| | |
|---|---|
| #/100 ml | Colonies per 100 milliliters, a unit of bacteria concentration |
| BaSE | Baseline Streamflow Estimator (USGS computer application) |
| BCP | Boundary Control Point: A fixed monitoring location on a tributary to the Delaware River. |
| CDF | Cumulative Distribution Function, a statistical plot |
| CFS | Cubic Feet per Second |
| DO | Dissolved Oxygen |
| DO% | Dissolved Oxygen Percent Saturation |
| DEWA | Delaware Water Gap |
| DRBC | Delaware River Basin Commission |
| DWGNRA | Delaware Water Gap National Recreation Area |
| EWQ | Existing Water Quality, the baseline water quality defined for antidegradation targets |
| ICP | Interstate Control Point: A fixed monitoring location on the Delaware River |
| LDEL | Lower Delaware (Delaware River mile 134.3 at Trenton to mile 209.5 at Portland) |
| mg/L | Milligrams per Liter, a unit of concentration |
| N+N | Nitrate plus Nitrite |
| NMC | No Measurable Change, specifically defined in DRBC rules |
| NJDEP | New Jersey Department of Environmental Protection |
| NWIS | USGS National Water Information System |
| NYSDEC/NYDEC | New York State Department of Environmental Conservation |
| OP | Orthophosphate |
| PADEP | Pennsylvania Department of Environmental Protection |
| Post-EWQ | The 2009-2011 test water quality data used to assess water quality changes from baseline |
| QAPP | Quality Assurance Project Plan |
| QA/QC | Quality Assurance / Quality Control |
| SPW | Special Protection Waters |
| SRMP | Scenic Rivers Monitoring Program |
| SpC | Specific Conductance |
| TDS | Total Dissolved Solids |
| TKN | Total Kjeldahl Nitrogen |
| TN | Total Nitrogen |
| TP | Total Phosphorus |
| TSS | Total Suspended Solids |
| UDSRR | Upper Delaware Scenic and Recreational River |
| µg/L | Micrograms per liter, a unit of concentration |
| µS/cm | Micro-Siemens per centimeter, a unit of specific conductance |
| UPDE | Upper Delaware |
| USEPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |
| WQN | Water Quality Network: PADEP's long-term fixed water quality stations |

## Introduction

This document has been prepared to inform the Delaware River Basin Commission's (DRBC) Special Protection Waters (SPW) policies. Using data collected in the past 15 years, DRBC, along with state and federal monitoring agencies, has improved the scientific record of background water quality conditions known as Existing Water Quality (EWQ). We have completed EWQ definition at Delaware River and tributary locations throughout the Upper, Middle and Lower Delaware River. Delaware River or interstate West Branch Delaware River sites are termed "Interstate Control Points" (ICP) and tributary sites are "Boundary Control Points" (BCP).

The DRBC Special Protection Waters are organized into Upper, Middle and Lower Delaware reaches in alignment with the National Park Service (NPS) Upper Delaware Scenic and Recreational River (UPDE, Figure 2), the Delaware Water Gap National Recreation Area (DEWA, Figure 3), and the Lower Delaware Scenic and Recreational River (LDEL, Figure 4). All are part of the National Wild and Scenic Rivers system. DRBC and NPS share operation of the Scenic Rivers Monitoring Program (SRMP), a long term water quality monitoring partnership in the Upper and Middle Delaware, while DRBC monitors Lower Delaware sites.

DRBC rules state that It is the policy of DRBC to maintain the quality of interstate waters, where existing quality is better than the established stream quality objectives, unless it can be affirmatively demonstrated to the Commission that such change is justifiable as a result of necessary economic or social development or to improve significantly another body of water. Furthermore, it is the policy of the Commission that there be no measurable change in existing water quality except towards natural conditions in waters considered by the Commission to have exceptionally high scenic, recreational, ecological and/or water supply values (DRBC Administrative Manual – Part III; Water Quality Regulations; 18 CFR Part 410; Article 3, Section 3.10.3). The difference between EWQ and stream quality objectives (or water quality standards) is shown in Figure 1.

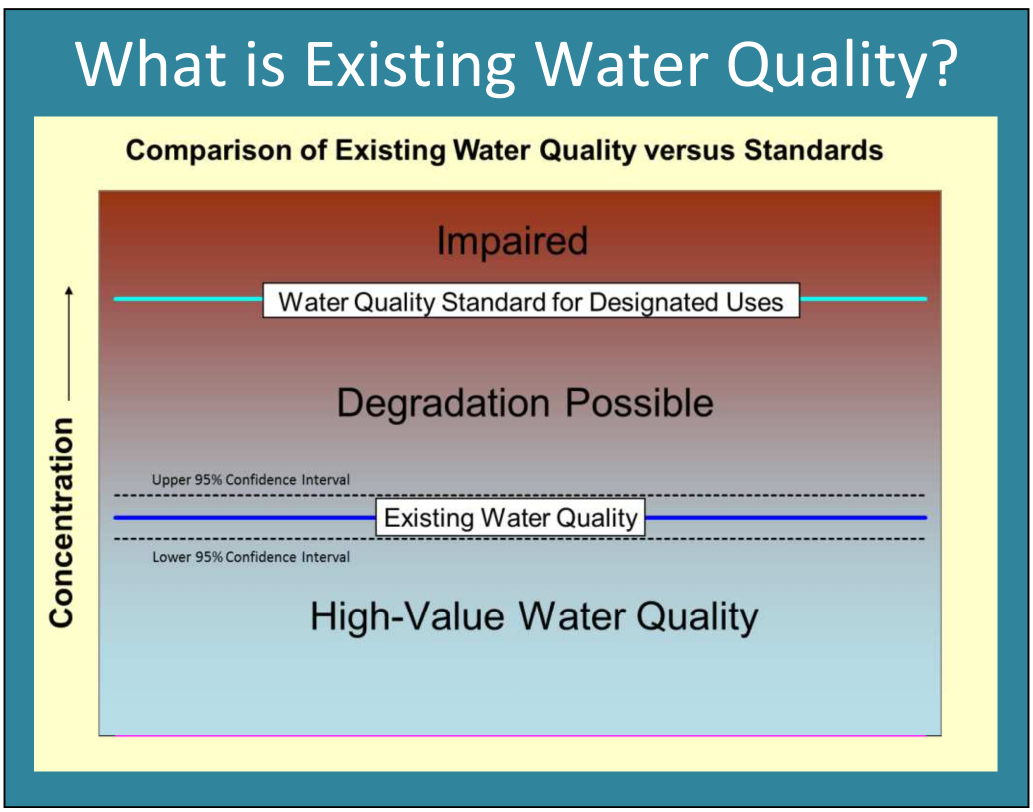


**Figure 1. Existing Water Quality vs. Water Quality Standards.**

Upper and Middle Delaware River Special Protection Waters rules were passed by DRBC in 1992. Within those rules Existing Water Quality was defined on a reach-wide basis (DRBC 2013, pages 18-22) for the Delaware River only. The rules listed tributaries within SPW purview, but EWQ was not defined for those watersheds. EWQ was based upon the best available water quality data at the time.

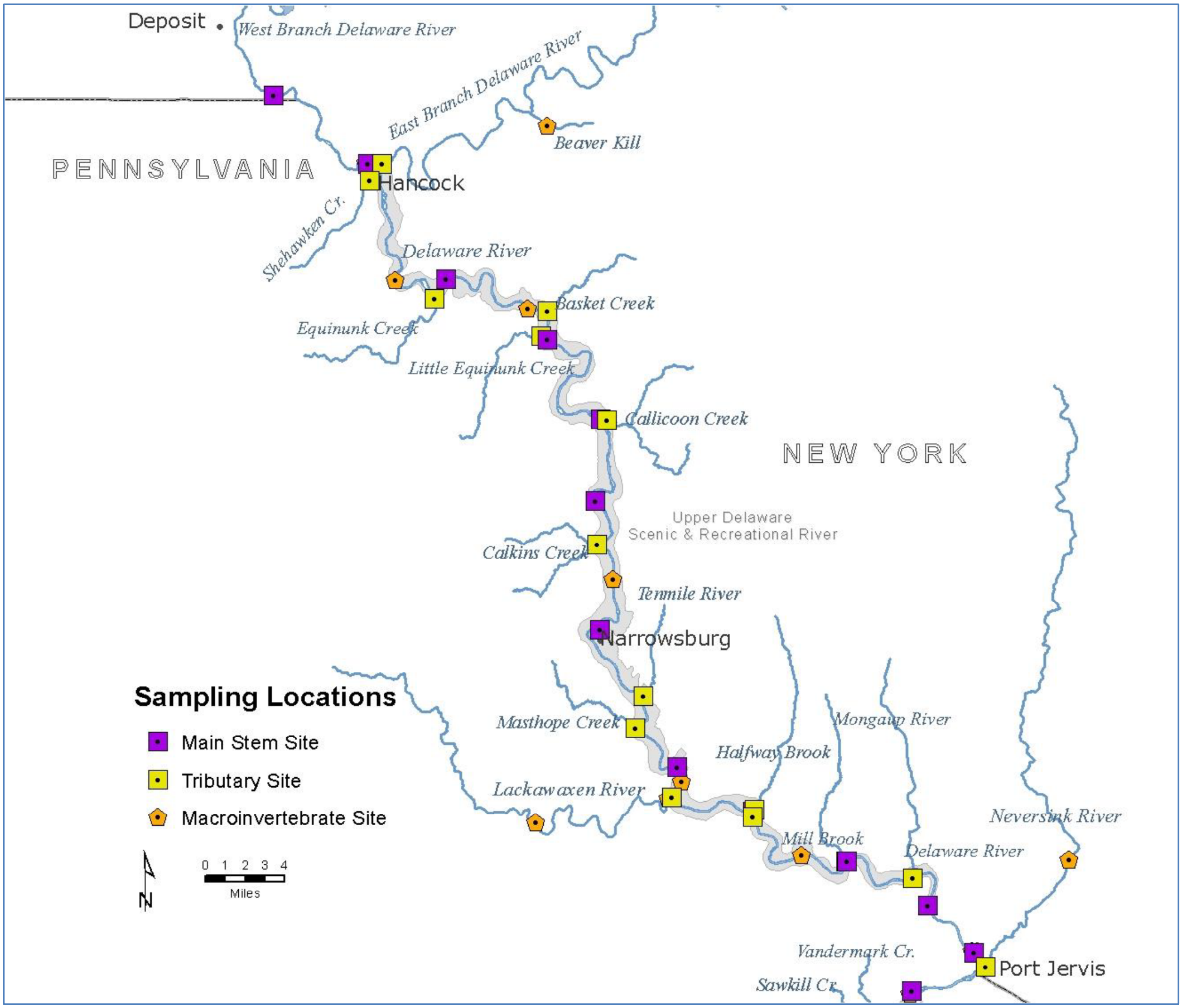


**Figure 2: Upper Delaware River monitoring locations of the Scenic Rivers Monitoring Program and the Delaware River Biomonitoring Program. The boundaries of the Upper Delaware Scenic and Recreational River are shown as the light gray border around the Delaware River.**

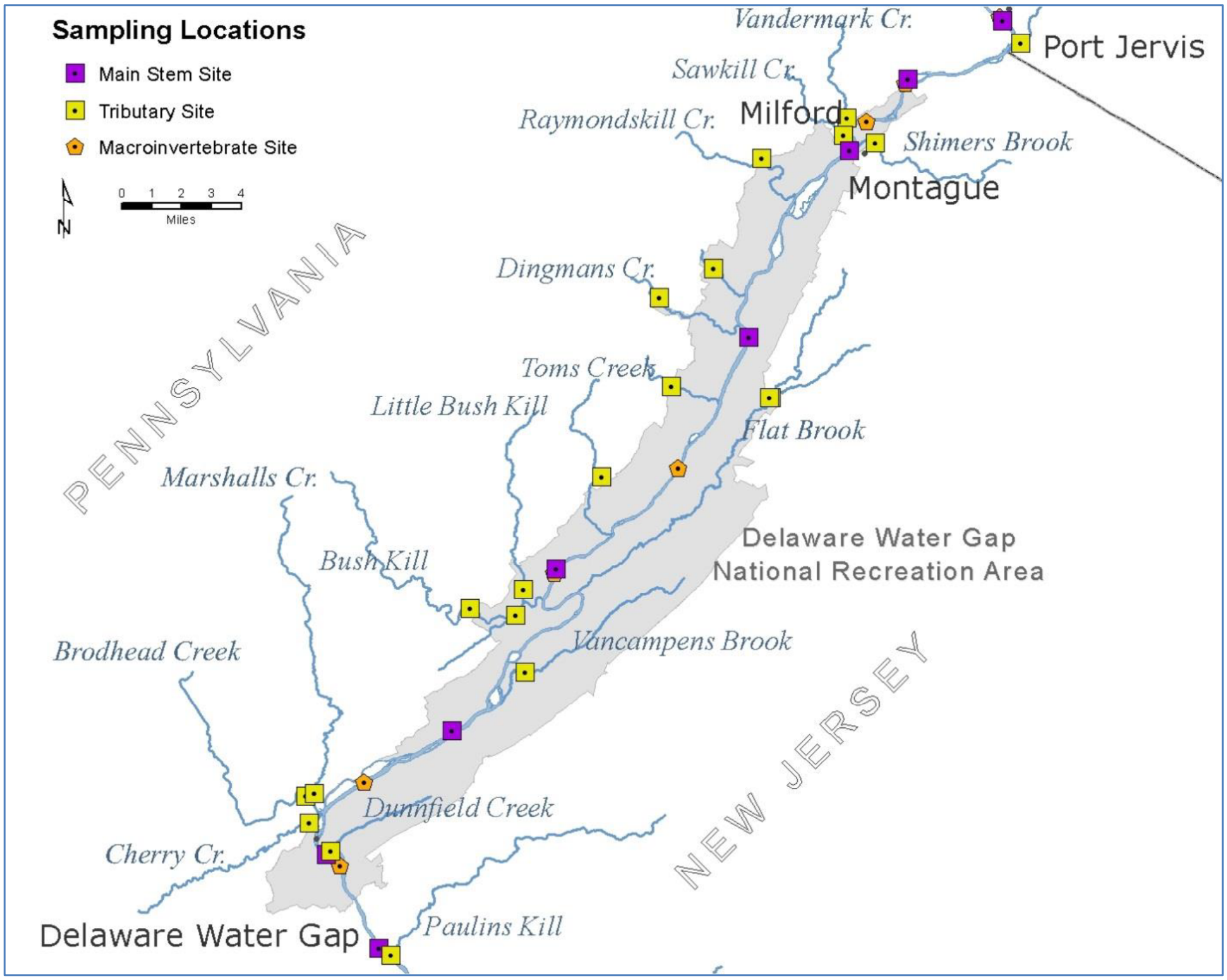


**Figure 3: Middle Delaware monitoring locations encompass the Delaware Water Gap National Recreation Area (light gray shaded) and the segment of the Delaware River and its tributaries from Millrift, NY to Delaware Water Gap, PA.**

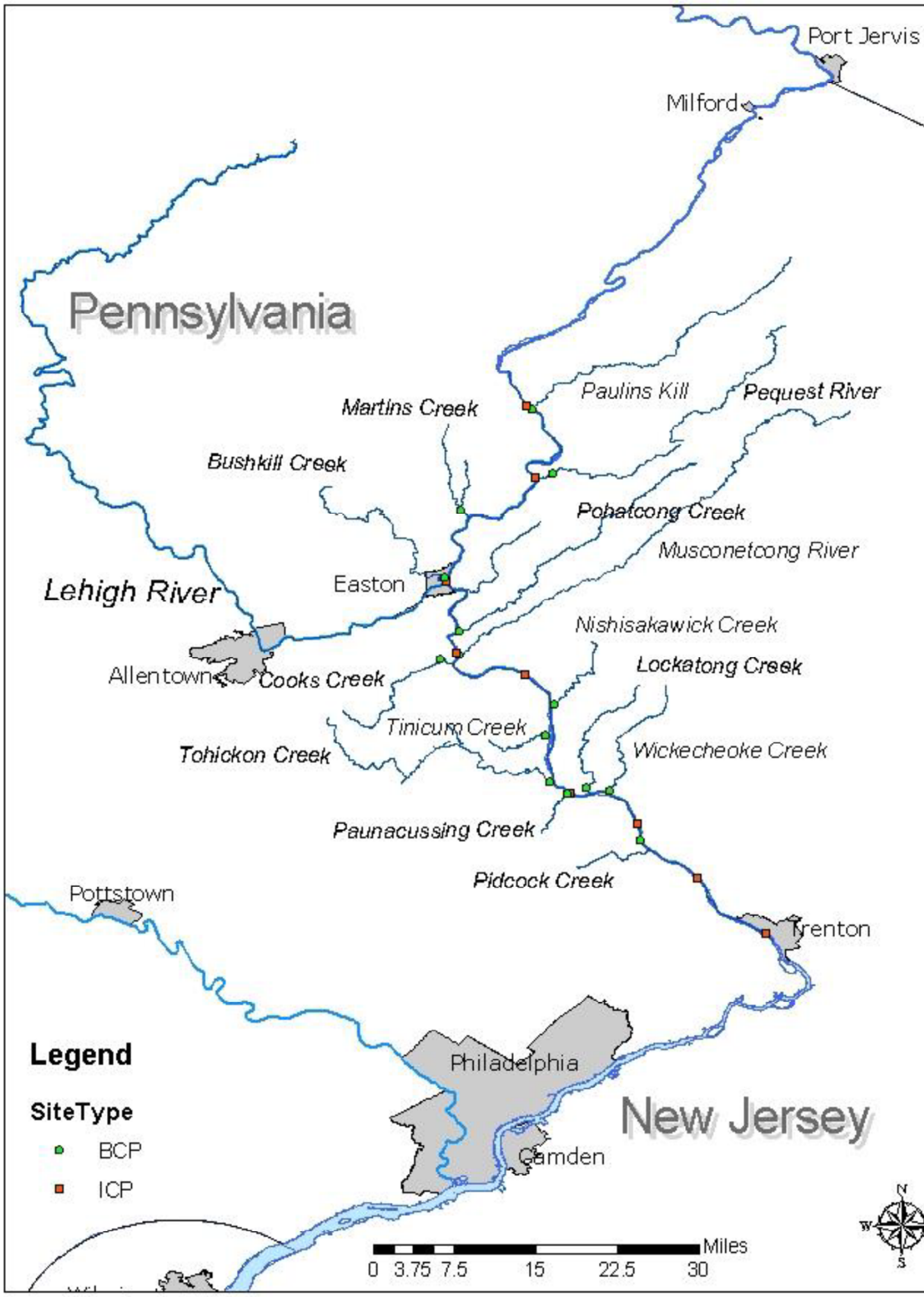


**Figure 4: Lower Delaware monitoring locations encompass the NPS-designated segments of the Lower Delaware Recreational River. The Lower Delaware from Portland, PA to Trenton, NJ has been designated by DRBC as Significant Resource Waters.**

The Lower Delaware was permanently added to the SPW program in 2008 using site-specific Existing Water Quality from a 2000-2004 baseline period. Those tables are presented in this document so that a complete EWQ record exists for the entire non-tidal portion of the Delaware River and its tributaries. The tables are listed longitudinally from upstream to downstream, and include some small corrections to the tables presented in DRBC water quality rules.

The first purpose of EWQ is well-served by 1992 reach-wide EWQ: to create discharge limits for wastewater treatment facilities so that EWQ does not degrade. However, there are information gaps filled by subsequent studies and presented here:

- Definition of EWQ upon tributaries to the Delaware River (1992 reach-wide EWQ was defined only for the river itself and not the tributaries); and
- Improving Delaware River EWQ from reach-wide to site-specific quality.

The second purpose of EWQ is as a baseline for replicable assessment of measurable changes over time. 1992 reach-wide EWQ was problematic for assessment of the Upper and Middle Delaware. Assessing measurable change from the 1992 reach-wide targets has been impossible for several reasons:

- The data upon which EWQ was based were unevenly distributed geographically and temporally within the river segments, making it impossible to go back and reassess water quality in the same way as originally defined;
- Quality assurance of the data was incomplete;
- Detection limits were much higher then than now; and
- Some of the statistical methods used to define EWQ, though considered suitable at the time, have been shown to be inappropriate for the practical application of the rules.

In order to achieve the assessment objective as a replicable process, DRBC and NPS started in 2006 to revisit EWQ definition on a site-specific basis in the Upper and Middle Delaware River. While working for passage of Lower Delaware SPW regulations in 2007, it was noted that DRBC successfully made use of site-specific Existing Water Quality targets and have since demonstrated a practical and repeatable assessment process. The first Lower Delaware assessment of measurable change took place from 2009-2011, and provided a practical and replicable precedent for future assessments, and whose results are available in the following DRBC publication:

Delaware River Basin Commission. 2016. Lower Delaware River Special Protection Waters Assessment of Measurable Changes to Existing Water Quality, Round 1: Baseline EWQ (2000-2004) vs. Post-EWQ (2009-2011). Delaware River Basin Commission, DRBC/NPS Scenic Rivers Monitoring Program, West Trenton, NJ. Authors: Robert Limbeck, Eric Wentz, Erik Silldorff, John Yagecic, Thomas Fikslin, Namsoo Suk.

Using the same control-point study design method as in the Lower Delaware, the objectives of this project were to:

- Improve our ability to detect water quality changes at specific sites over time;
- Provide previously-missing site specific EWQ for tributaries to the Upper and Middle Delaware River; and
- Enable determination of water quality and hydrologic impacts of each tributary upon the Delaware River.

As a technical document, we expect these data to inform policy decisions. The primary use of these baseline site-specific data is to be able to assess changes in the river over time so that SPW program effectiveness can be measured. The 1992 reach-wide tables can still be used to inform effluent limitation development, but they are unsuitable for assessment. By defining EWQ in a replicable manner at specific sites, we can now revisit those sites in the future and definitively repeat the assessment process. These site-specific targets will serve to provide a consistent baseline against which future changes may be compared at a 95% confidence level.

This document contains summaries of water quality information for 85 Control Points of the Upper, Middle and Lower Delaware River. There are 28 ICP locations on the Delaware River and West Branch Delaware River. There are 57 tributary watershed BCP locations: 11 BCP sites are in New York, 30 in Pennsylvania, and 16 in New Jersey. There is also a summary table of population changes in each BCP watershed (Table 1). As of 2016, DRBC and NPS are still working to define EWQ at 7 sites: Alexauken Creek, NJ; Hakihokake Creek, NJ; Cherry Creek, PA; Flat Brook at Flatbrookville, NJ; Beaver Brook, NY; Little Equinunk Creek, PA; and Basket Creek, NY. These tables will be updated once SRMP monitoring efforts are complete. In the future, additional tributaries will be added to the network as necessary.

**Table 1: Population of Boundary Control Point watersheds of the Upper, Middle and Lower Delaware. The Special Protection Waters region grew more between 2000 and 2010 than each of its Delaware River Basin states: PA +3.43%; NJ +4.49%; NY +2.12%; SPW Region +11.3% (CensusViewer.com, accessed 6/22/2016).**

| SPWunit | RiverMile | EWQ Watershed | Population 2000 | Population 2010 | Change | % |
|---|---|---|---|---|---|---|
| LDEL | 146.3 | Pidcock Creek, PA | 1,960 | 2,012 | 52 | 2.6 |
| LDEL | 149.5 | Alexauken Creek, NJ | 2,409 | 2,496 | 87 | 3.6 |
| LDEL | 152.5 | Wickecheoke Creek, NJ | 3,095 | 3,167 | 72 | 2.3 |
| LDEL | 154.0 | Lockatong Creek, NJ | 2,413 | 2,514 | 101 | 4.2 |
| LDEL | 155.6 | Paunacussing Creek, PA | 2,359 | 2,588 | 199 | 8.4 |
| LDEL | 157.0 | Tohickon Creek, PA | 38,249 | 42,600 | 4,351 | 11.4 |
| LDEL | 161.6 | Tinicum Creek, PA | 3,297 | 3,103 | (194) | -5.9 |
| LDEL | 164.1 | Nishisakawick Creek, NJ | 2,077 | 2,114 | 37 | 1.8 |
| LDEL | 167.2 | Hakihokake Creek, NJ | 4,262 | 4,325 | 63 | 7.4 |
| LDEL | 173.7 | Cooks Creek, PA | 4,744 | 4,813 | 69 | 1.4 |
| LDEL | 174.6 | Musconetcong River, NJ | 84,699 | 89,538 | 4,659 | 5.5 |
| LDEL | 177.4 | Pohatcong Creek, NJ | 19,781 | 19,547 | (234) | -1.2 |
| LDEL | 182.0 | Lopatcong Creek, NJ | 11,262 | 14,540 | 3,278 | 29.1 |
| LDEL | 183.7 | Lehigh River, PA | 604,954 | 676,939 | 71,985 | 11.9 |
| LDEL | 184.1 | Bushkill Creek, at Easton, PA | 59,221 | 70,864 | 11,643 | 19.7 |
| LDEL | 190.7 | Martins Creek, PA | 18,814 | 19,952 | 1,138 | 6.0 |
| LDEL | 197.8 | Pequest River, NJ | 31,927 | 34,023 | 2,096 | 6.6 |
| LDEL | 207.0 | Paulins Kill, NJ | 37,762 | 39,226 | 1,464 | 3.9 |
| DEWA | 209.5 | Slateford Creek, PA | 173 | 283 | 110 | 63.9 |
| DEWA | 211.4 | Dunnfield Creek, NJ | 4 | 5 | 1 | 27.1 |
| DEWA | 212.8 | Cherry Creek, PA | 1,915 | 2,204 | 289 | 15.1 |
| DEWA | 213.0 | Brodhead Creek, PA | 85,986 | 103,182 | 17,196 | 20.0 |
| DEWA | 213.0 | Marshalls Creek, PA | 6,975 | 9,023 | 2,048 | 29.4 |
| DEWA | 219.9 | Van Campens Brook, NJ | 4 | 5 | 1 | 35.4 |
| DEWA | 225.3 | Flat Brook at Flatbrookville, NJ | 2,028 | 2,272 | 244 | 12.0 |
| DEWA | 225.3 | Big Flat Brook @ DEWA Bdy, NJ | 682 | 797 | 115 | 16.9 |
| DEWA | 225.3 | Little Flat Brook @ DEWA Bdy, NJ | 1,285 | 1,444 | 159 | 12.3 |
| DEWA | 226.9 | Bush Kill Creek at DEWA Bdy, PA | 10,920 | 16,114 | 5,194 | 47.6 |
| DEWA | 226.9 | Little Bushkill Creek at DEWA Bdy, PA | 2,398 | 3,452 | 1,054 | 44.0 |
| DEWA | 226.9 | Sand Hill Creek at DEWA Bdy, PA | 452 | 729 | 277 | 61.2 |
| DEWA | 230.4 | Toms Creek at DEWA Bdy, PA | 2,074 | 2,299 | 225 | 10.9 |
| DEWA | 236.4 | Hornbecks Creek at DEWA Bdy, PA | 1,927 | 2,264 | 337 | 17.5 |
| DEWA | 239.2 | Dingmans Creek at DEWA Bdy, PA | 2,563 | 3,032 | 469 | 18.3 |
| DEWA | 240.3 | Adams Creek at DEWA Bdy, PA | 1,337 | 1,615 | 278 | 20.8 |
| DEWA | 243.9 | Raymondskill Creek at DEWA Bdy, PA | 6,461 | 8,924 | 2,463 | 38.1 |
| DEWA | 246.6 | Shimers Brook at DEWA Bdy, NJ | 1,659 | 1,804 | 145 | 8.8 |
| DEWA | 247.0 | Sawkill Creek at DEWA Bdy, PA | 2,644 | 3,085 | 441 | 16.7 |
| DEWA | 247.5 | Vandermark Creek at DEWA Bdy, PA | 771 | 815 | 44 | 5.7 |
| DEWA | 253.6 | Neversink River, NY | 35,783 | 37,668 | 1,885 | 5.3 |
| UPDE | 261.1 | Mongaup River, NY | 19,151 | 19,570 | 419 | 2.2 |
| UPDE | 265.6 | Mill Brook, NY | 983 | 1,234 | 251 | 25.6 |
| UPDE | 273.2 | Shohola Creek, PA | 3,545 | 4,322 | 777 | 21.9 |

| SPWunit | RiverMile | EWQ Watershed | Population 2000 | Population 2010 | Change | % |
|---|---|---|---|---|---|---|
| UPDE | 273.4 | Halfway Brook, NY | 1,210 | 1,327 | 117 | 9.6 |
| UPDE | 275.4 | Beaver Brook, NY | 697 | 778 | 81 | 11.6 |
| UPDE | 277.7 | Lackawaxen River, PA | 49,519 | 57,006 | 7,487 | 15.1 |
| UPDE | 282.5 | Masthope Creek, PA | 1,253 | 1,434 | 181 | 14.5 |
| UPDE | 284.2 | Tenmile River, NY | 1,191 | 1,310 | 119 | 10.0 |
| UPDE | 295.6 | Calkins Creek, PA | 1,707 | 1,631 | -76 | -4.4 |
| UPDE | 303.6 | Callicoon Creek, NY | 6,512 | 6,448 | -64 | -1.0 |
| UPDE | 312.2 | Little Equinunk Creek, PA | 640 | 613 | -27 | -4.2 |
| UPDE | 313.5 | Basket Creek, NY | 240 | 226 | -14 | -5.8 |
| UPDE | 322.5 | Equinunk Creek, PA | 1,136 | 1,002 | -134 | -11.8 |
| UPDE | 330.7 | East Branch Delaware River, NY | 17,165 | 16,537 | -628 | -3.7 |
| UPDE | 331.0 | Shehawken Creek, PA to WBR | 290 | 290 | 0 | 0.0 |
| UPDE | 331.2 | West Branch Delaware R. at Hancock, NY/PA | 23,212 | 23,774 | 562 | 2.4 |
| UPDE | 331.9 | Sands Creek, PA to WBR | 259 | 265 | 6 | 2.4 |
| UPDE | 335.0 | Balls Creek, NY to WBR | 242 | 215 | -27 | -11.2 |
| UPDE | 339.8 | West Branch Delaware River Hale Eddy, NY | 22,075 | 22,598 | 523 | 2.4 |
| UPDE | 344.8 | Oquaga Creek, NY to WBR | 1,346 | 1,303 | -43 | -3.2 |
| | | TOTALS | 1,239,601 | 1,379,842 | +140,241 | 11.3 |
| Note: Indented watersheds are not counted in totals. They are sub-watersheds to those not indented above them. For example, Sands Creek, Balls Creek, West Branch Delaware River at Hale Eddy and Oquaga Creek are sub-watersheds to West Branch Delaware River at Hancock listed above them. | | | | | | |

## Methods

The remainder of this document consists of watershed and river segment maps, watershed facts, flow statistics, and site-specific EWQ tables. The document is intended to be updated annually as additional information becomes available. This online document is also accompanied by DRBC interactive mapping services where the same information can be used in combination with other available layers of geographic information.

All watershed maps were prepared by DRBC using ArcMap 10.3. ArcMap watershed polygons were used to summarize and compare U.S. Census 2000 and 2010 block data (https://www.census.gov/geo/maps-data/), aggregated to watershed level and presented here. The maps show monitoring locations where EWQ was defined, wastewater discharge points with National Pollutant Discharge Elimination System (NPDES) permits, and U.S. Geological Survey stream gage locations. Future editions of the EWQ Atlas will include improved NPDES locations and inventories of dischargers, land use and population updates as well as other GIS analyses such as road density, stream crossings, dams and reservoirs, water withdrawals, and other features that affect water quality.

Extensive use was made of the USGS Stream Stats application: http://water.usgs.gov/osw/streamstats/. StreamStats is described as follows from the website (accessed July 11, 2016):

> StreamStats is a Web application that incorporates a Geographic Information System (GIS) to provide users with access to an assortment of analytical tools that are useful for a variety of water-resources planning and management purposes, and for engineering and design purposes. In version 3 as well as beta version 4, StreamStats users can select USGS data-collection station locations shown on a map and obtain previously published information for the stations, including descriptive information, and previously published basin characteristics and streamflow statistics. Currently, StreamStats provides additional tools that allow users to select sites on ungaged streams and do the following:

- obtain the drainage-basin boundary (version 3 and beta version 4),
- compute selected basin characteristics (version 3 and beta version 4),
- estimate selected streamflow statistics using regression equations (version 3 & beta version 4),
- download a shapefile of the drainage-basin boundary, as well as any computed basin characteristics and flow statistics (version 3 and beta version 4),
- edit the delineated basin boundary (beta version 4 only),
- modify the basin characteristics that are used as explanatory variables in the regression equations and get new estimates of streamflow statistics (beta version 4 only),
- print the map (beta version 4 only),
- measure distances between user-selected points on the map (beta version 4 only),
- plot the elevation profile between user-selected points on the map (beta version 4 only).

> The streamflow statistics that StreamStats can provide for data-collection stations and for user-selected ungaged sites vary among the states that are implemented in StreamStats and among data-collection stations within states. Unless otherwise noted on a state's introductory page, estimates obtained for ungaged sites assume natural flow conditions at the site.

All monitoring sites were delineated using Stream Stats version 2.0 and 3.0 in 2012-2014, including watershed land use (National Land Cover Data 2001) statistics and flow statistics. We also used another USGS product developed for DRBC from the Pennsylvania Baseline Streamflow Estimator, or BaSE (http://pa.water.usgs.gov/projects/surfacewater/flow_estimation/) to estimate mean daily stream flow at ungaged sites. These estimates were associated with our water quality samples at some sites where we could not adequately measure stream flow in any other way. The version of BaSE used by DRBC was developed by Marla Stuckey of USGS specifically for the Delaware River Basin. Updated land use and flow statistics from Stream Stats updates will be included in future editions of this EWQ Atlas. The most important flow statistic presented is Harmonic Mean Flow, which best represents the flow conditions under which EWQ samples were taken.

Both Stream Stats and BaSE work best where the stream experiences natural flow conditions, so we could not use these tools where flow is managed or where reservoirs and quarries modify the natural stream flow. This includes: all Delaware River locations; East Branch and West Branch Delaware River; Lackawaxen River, PA; Mongaup River, NY, Neversink River, NY; Paulins Kill, NJ; Bushkill Stream, Easton, PA; Lehigh River, PA; Musconetcong River, NJ; and Tohickon Creek, PA. Fortunately there are USGS gages on all these streams so there was no need to use Stream Stats or BaSE to estimate flow at these sites. Stream Stats was used only to summarize basin characteristics and delineate the watershed areas; and flow statistics were calculated directly from the USGS gage data.

For site-specific Existing Water Quality tables, the Scenic Rivers Monitoring Program sampled selected control points biweekly within the May through September periods from 2006-2011 (See DRBC Quality Assurance Project Plans, DRBC 2006-2013). Data produced from three USGS/NPS water quality studies are also included: DEWA 2002-2004 (Hickman and Fischer 2008); UPDE 2005-2007 (Siemion and Murdoch 2010); and UPDE 2012-2015 (Senior 2015, report in progress). In addition these targets include co-located quarterly or monthly long term monitoring data collected by USGS, PADEP, NYSDEC, and NJDEP from 1999-2011 or later. All data are available from DRBC in a water quality database maintained by the DRBC Science and Water Quality Section, or online at the following locations:

USGS and State data: U.S. Geological Survey, NWIS: http://waterdata.usgs.gov/nwis;
SRMP and State data: U.S. Environmental Protection Agency, STORET: http://www.epa.gov/storet/;
or combined NWIS/STORET data at the National Water Quality Data Portal: http://waterqualitydata.us/portal/ hosted by the National Water Quality Monitoring Council.

The EWQ tables are composed of mixed agency data at some locations, and only SRMP or USGS data at other locations. In the Lower Delaware 2000-2004 EWQ definition period, DRBC built and maintained its own independent and well-controlled data set, using co-located USGS and State data only to check DRBC results. In the Upper and Middle Delaware this was not economically feasible for all of the sites. We used existing data from other agencies and supplemented SRMP data. USGS and states typically do not collect the exact same water quality parameters as the SRMP. USGS often collects dissolved forms of several parameters, while SRMP tests for total forms in order to maintain consistency with historical SRMP samples from the 1980's and 1990's.

As a result of the mixed data approach to defining EWQ used here, the EWQ tables are not exactly alike. Some sites contain long lists of parameters where all agencies sampled, and the lists include dissolved and total forms, ions, and metals. USGS and state data are comparable with DRBC data where parameters are measured in common, though monitoring objectives differed. USGS and state data typically are long-term quarterly sampling results or short synoptic surveys, while the SRMP monitoring objective requires more frequent May through September sampling within specific 3 to 5 year periods, but not necessarily every year for many years like the states and USGS. DRBC employs the same EPA-approved field and laboratory methods as USGS and the states, and maintains quality assurance practices so that SRMP data are of sufficient quality to be comparable with other agencies.

The sections are organized by River Mile and Site in upstream to downstream order. For example, the northernmost sites are upstream of the Upper Delaware Scenic and Recreational River: 3448 BCP Oquaga Creek, NY, a tributary BCP to the West Branch Delaware River at interstate River Mile 344.8; and 3398 ICP West Branch Delaware River at Hale Eddy, an ICP located at interstate River Mile 339.8. At the southern end of the Middle Delaware is 2095 BCP Slateford Creek at National Park Drive, PA. The Slateford Creek site is a Pennsylvania BCP located at River Mile 209.5. From Portland, PA south to Trenton are listed all ICP and BCP monitoring locations previously published in DRBC rules, along with newer sites. Each map shows the watershed's location in the Delaware River Basin.

The last page of each section shows the site-specific definition of Existing Water Quality by parameter, including:

| | |
|---|---|
| N | Number of samples; |
| Median | The Median concentration; |
| L95CL | Lower 95% confidence limit; |
| U95CL | Upper 95% confidence limit; |
| Period of Record (all May-Sep data) | Agencies and years the samples were taken; OR |
| Flow Relationship | Regression equation if significantly related to flow, from DRBC rules |

## Data Sufficiency for Existing Water Quality Definition

Some EWQ tables are incomplete, and will be updated over time in future editions of this document. These are sites where sampling is still underway and EWQ has not yet been completely defined, or where insufficient data exist to define EWQ. Depending on observed range and variability of a given parameter, we require 20 to 50 or more samples to adequately describe EWQ with 95% confidence so that the confidence limits approximately correspond to (at most) the $40^{th}$ and $60^{th}$ percentiles of the data distributions. Using the median concentration keeps out extreme values, keeps out undetected laboratory results, and gives a reliable indication of water quality concentrations expected under normal summer conditions. There are some parameters presented with as few as 5 samples. These are from various one-time studies where the results showed very low concentrations and very low variability – there were no extreme outliers, and even though 95% confidence limits included just about all of the data, variability was so low that the upper and lower values were similar.

USGS and NPS recently completed sampling and reporting EWQ for the following Upper Delaware control points, yet the number of results are insufficient to describe EWQ: Oquaga Creek, NY; Balls Creek, PA; Sands Creek, NY; and Shehawken Creek, PA. The SRMP is sampling Basket Creek and Little Equinunk Creek in 2016 and 2017 to provide additional data for EWQ definition, and will also sample Shehawken Creek, PA in 2018. The SRMP has not yet completed sampling Beaver Brook, NY. It's table will be updated after the 2016 sampling season is completed. Summary statistics are shown for the sites possessing few data, but additional sampling must be conducted to fully define EWQ. Until water quality is sufficiently described for EWQ, the tables are not ready for regulatory use but present water quality found at the site.

In the Middle Delaware, some EWQ work remains for the following control points: Flat Brook, NJ; and Cherry Creek, PA. The Flat Brook table will be updated after the 2016 sampling season, and Cherry Creek will be completed after the 2017 season.

In the Lower Delaware, DRBC began sampling Alexauken Creek, NJ, and Hakihokake Creek, NJ in 2014. Existing NJDEP/USGS data are being supplemented by DRBC data, and EWQ will be completed after the 2016 sampling season. Based upon an analysis of dischargers in Lower Delaware watersheds, DRBC will add three more BCP's starting in 2017: Jacobs Creek, NJ; Jericho Creek, PA; and Gallows Run, PA. All are previously unmonitored and contain two or more dischargers regulated under the National Pollutant Discharge Elimination System (NPDES).

Once data are numerous and of sufficient quality, the EWQ tables are considered complete and would not be changed unless found in error or unless new parameters are added, such as site-specific biological targets presently being created by the Delaware River Biomonitoring Program. Overall EWQ definition is nearly complete, providing baseline EWQ tables for:

- All watersheds of 20 square miles or more;
- Smaller streams that represent physiographic regions or ecoregions of the Delaware River;
- Watersheds containing significant wastewater discharge projects;
- Streams of local or national interest such as Wild and Scenic or state-designated high-quality streams; or
- Streams requested by agencies, municipalities, non-governmental organizations or private citizens.

Finally, there are parameters in some of these tables that serve as indicators of natural gas development: Barium, Strontium and others that we monitored using 2009-2010 archived samples (DRBC 2010). These parameters represent background water quality and serve as baseline antidegradation targets.

## DRBC Usage of Existing Water Quality Tables

These tables are expected to be used for the following:

1. In DRBC Water Quality Regulations (WQRs), there are currently 24 site-specific EWQ tables. Presently, staff have created an additional 61 tables, for a total of 85 EWQ tables. Adoption of all 85 pages directly into the WQRs would be very cumbersome. DRBC rules could be streamlined by adoption of this document as SPW guidance under "best available scientific data" rule provisions. These tables represent the best scientific information available, and DRBC rules provide for use of these data without direct inclusion in the rules.
2. At all ICP and BCP sites: as baseline EWQ for future assessment of measurable changes to Delaware River and tributary water quality. These assessments are not comparisons to water quality standards, but of measurable changes relative to EWQ upper or lower confidence intervals. These tables are water quality targets, not criteria. The main question to be answered each study period: did water quality statistically change at this location?

3. At BCP sites: as EWQ targets for Special Protection Waters discharge permits, non-point source planning, and water quality modeling in selected watersheds. For these sites, we calculate pollutant loadings to the Delaware River (using harmonic mean flow), and answer the questions:
   a. Does this tributary improve or degrade the Delaware River?
   b. Are the pollutant loadings from dischargers or from other sources?
   c. Do cumulative pollutant loadings cause the antidegradation target to be exceeded?
   d. What regulatory actions, whether through permitting or voluntary improvements, are necessary to maintain Existing Water Quality?

## Reach-Wide vs. Site-Specific Existing Water Quality

ICP site-specific targets are not expected to replace the Upper and Middle Delaware reach-wide targets of 1992, since those targets have been in the WQRs for a long time. However, more parameters that might be useful for permitting are added in these tables, such as those that might be associated with natural gas development activities (strontium, barium, some metals) as well as others (enterococcus, E. coli, TDS, pH, water temperature and more) that were not included in 1992 rules.

ICP tables are meant to be used for assessment of measurable changes, but not necessarily for permitting unless the WQRs are revised. Use of these Upper and Middle Delaware River ICP targets for permitting has not yet been addressed by the Commission.

### Monitoring and Data Quality Improvements since 1992

Pertinent to the Special Protection Waters rules and potential revisions, it must be noted that both water quality and standard statistical practices have changed since 1992:

- Delaware River concentrations have substantially declined since 1992 for many parameters in the water quality tables, and additional parameters have been defined since 1992.
- Laboratory analytical methods have improved since 1992, and we are now able to measure water quality at much lower concentrations than in the past.
- Standard statistical practices for water resources are better understood. Current practices employ non-parametric statistics (the median and its confidence intervals), which are better suited to non-normal water quality data distributions. There were common but unfavorable practices in 1992 such as:
  - substitution of replacement values in undetected results;
  - use of geometric means (an estimation of the median) and t-tests instead of medians and more powerful non-parametric tests for water quality comparisons; and
  - creation of confidence intervals by back-calculating from geometric mean confidence intervals (making the confidence intervals too narrow).

Since water quality test methods, quality assurance practices, statistical practices, computing power and data quality practices have significantly improved since 1992, DRBC staff maintains that the reach-wide targets of 1992 are less scientifically defensible as true “existing water quality” at the time than more recent data. Richard Albert, one of the originators of Special Protection Waters, often referred to the 1992 reach-wide targets as “numerical policy.” He acknowledged that the targets were based on unsystematically-gathered available data.

In the late 1990’s a SRMP statistical workgroup reviewed the statistical basis for the 1992 tables and recognized the difficulties in replicable assessment of measurable change using these un-replicable data (Evans, April 1998). Regarding this review, Richard Albert commented (Albert, May 1998):

"At the recent SPW workshop, I attempted to explain that our existing water quality/no measurable change definition embodies both technical and policy decisions (remember the numbers are not water quality standards). In essence we used science to develop the numbers, but the Commission's decision to use them for anti-degradation purposes was a policy decision.

Once the Commission made this policy decision, the number of samples inherent in the numbers, the years represented by the samples, whether the analyses were composited or not, the precise locations where data were collected, laboratory protocols, and so forth do not particularly matter. The data could have come from the Ohio.

…In all respects except one, it does not matter anymore how real this is or not. The one exception is the link between monitoring and the criteria. If the primary assumption made at the time of SPW adoption is invalid, i.e., that the existing water quality/measurable change definition was not representative of the water quality in the reach for which it was adopted; there is a problem…"

The problem Richard Albert cautioned about was real, although based upon best available data at the time and upon 'standard' statistical practices at the time, both of which have been proven either poor by today's data quality standards or improperly used by judgment of statistical experts. None of the samples upon which 1992 EWQ was based were ever collected with the intention of establishing EWQ. EWQ was established after the fact. The samples upon which 1992 EWQ was partially based were collected either monthly or quarterly by USGS and state programs for long term trend analyses. Data were very rich at these few locations. The rest of the data were collected by DRBC and NPS as part of summer monitoring projects all over the Upper and Middle Delaware. DRBC/NPS samples were collected unsystematically and there were few samples collected at any of the more than 100 sites. 1980-1988 Upper and Middle Delaware data were retrieved from the EPA STORET data system and the USGS NWIS system and combined regardless of data quality to form the reach-wide 1992 EWQ tables. The 1992 tables were geographically unbalanced, representative only of wherever the most samples were collected. Much of the data and some of the statistical practices were flawed, and the collective reach-wide data did not represent many locations within the reach because of the geographic imbalance (Breidt and Boes 1989).

The reach-wide targets could not reliably be used for assessment of water quality changes over time. Thus the SRMP decision was made, once Lower Delaware site-specific EWQ was completed and successfully applied, that we would revisit the Upper and Middle Delaware to produce the EWQ tables presented here, with data gathered with the intention of creating site specific EWQ. The information presented here is better documented, water quality surveys were designed for the purpose of future assessment, and it is more cost-effective to work on a site-specific or smaller-reach basis.

During early analyses of these data, we noted several patterns and presented them at technical meetings (Limbeck 2013-2016). Some of those points should be emphasized here and considered within policy discussions:

1. For many parameters, concentrations are now lower than they were in 1992 (See example, Figure 3). Only Total Kjeldahl Nitrogen (TKN), alkalinity and hardness remained the same as in 1992 and closely match 1992 EWQ reach-wide patterns. Only specific conductance increased beyond the 1992 targets (Figure 4). Policy implications must be considered regarding update of 1992 EWQ to levels protective of current water quality.

2. Among parameters whose concentrations did not change since 1992, the reach-wide targets do not fully reflect actual water quality conditions within each reach due to spatially uneven patterns (See dissolved oxygen example, Figure 5).

3. The non-parametric approach employed in the Lower Delaware is superior to the parametric geometric means and confidence intervals of the 1992 data. Consider the non-normal, skewed distribution of many water quality parameters:
   a. The effect that outlier values (common in water quality data) have on means but not on medians;
   b. Data transformation is not necessary with the non-parametric approach;

c. Log-transformations and geometric means are ways to estimate the median, not the mean (Helsel 2013).

Given the above considerations, we abandoned reach-wide geometric means of 1992 in favor of the median for our site-specific targets. The approach used in 1992 was not recommended by expert statisticians at the time (Breidt et. al. 1991), and is less powerful than non-parametric tests for measures of frequency and typical water quality changes (Helsel and Hirsch 2002; Helsel 2013). Helsel recommends parametric tests only for measures of mass, total volumes and long term chronic effects. None are employed here, so the non-parametric approach is proper.

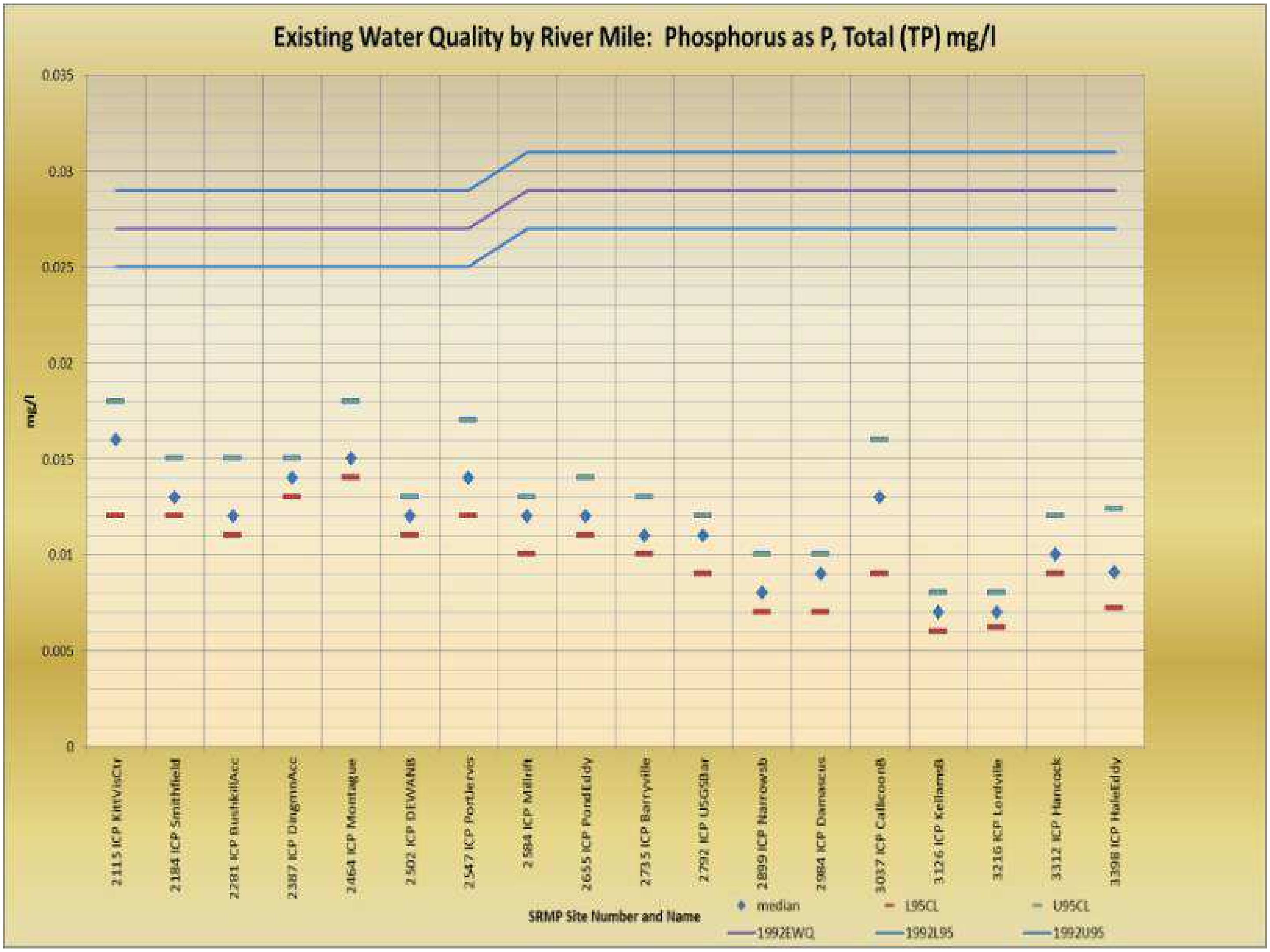


**Figure 3: Most parameters are now (2006-2013) present at lower concentrations than they were in 1992 reach-wide EWQ. Total phosphorus concentrations are shown above as an example, but the same pattern holds for nitrogen forms (ammonia, nitrate), fecal coliform bacteria, and total suspended solids (TSS).**

Downstream-----------------------------------------Upstream

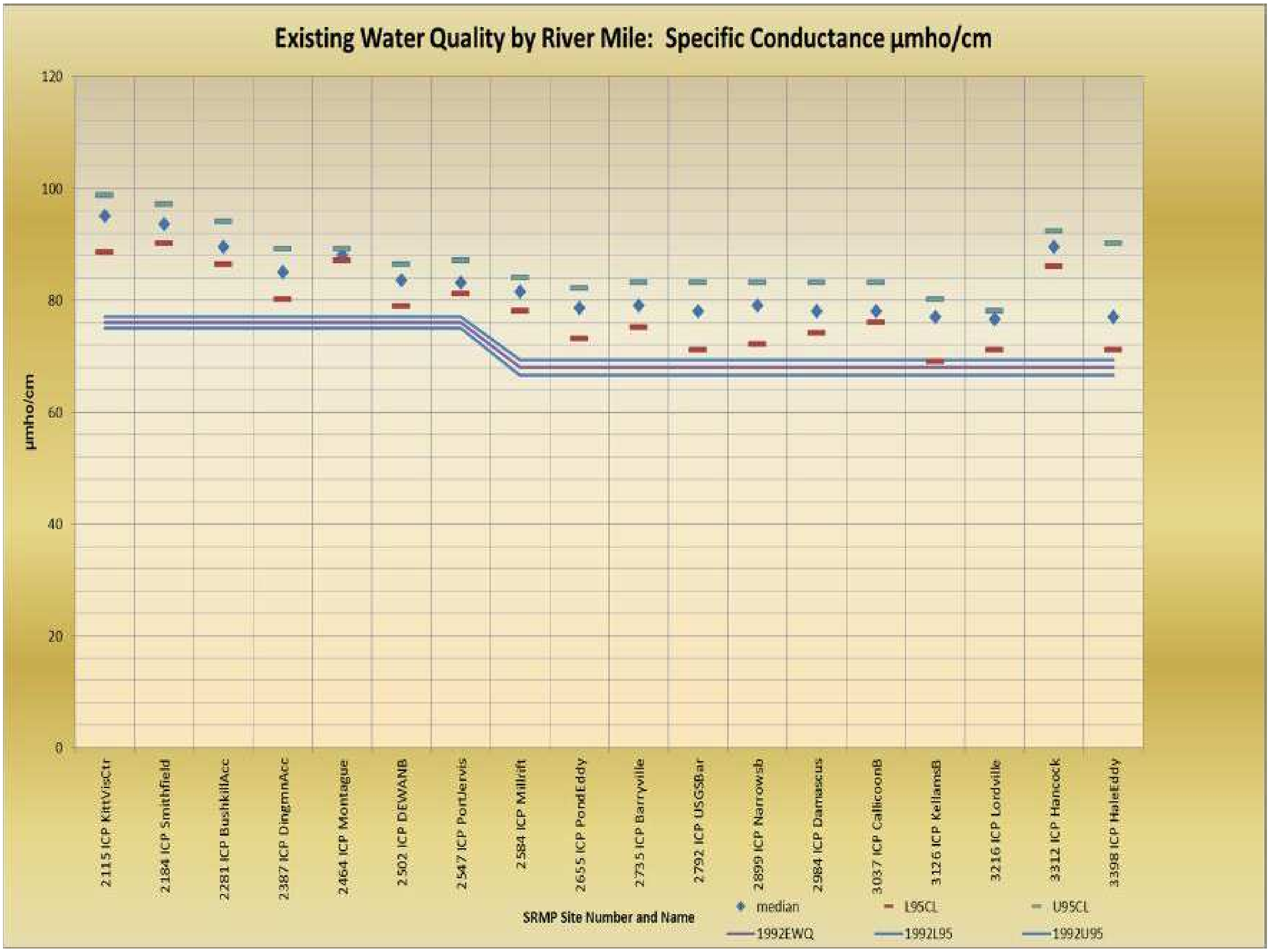


**Figure 4: Specific conductance is now (2006-2013) higher than the upper limits of 1992 reach-wide EWQ. This is common throughout the northeastern United States (Kaushal et. al. 2005). Specific conductance is not regulated by water quality criteria. This is the only parameter listed in 1002 rules that universally increased in concentration since 1992. Among parameters not listed in 1992 rules, chloride concentrations have also increased substantially.**

Downstream-----------------------------------------Upstream


**Figure 5: Even though 2006-2013 dissolved oxygen concentrations collectively remained the same as in 1992 EWQ, the present longitudinal pattern of concentrations does not match 1992 reach-wide EWQ. In both the Upper and Middle Delaware there are sites where DO concentrations are not within upper or lower reach-wide EWQ boundaries. The apparently worsened condition shown in the Middle Delaware (left) is not real, but an unfair comparison with the reach-wide combination of spatially and temporally uneven sampling that constructed 1992 EWQ. The declining upstream to downstream pattern in Upper and Middle Delaware concentration was similar to that of today, but the data used to construct 1992 EWQ were under-represented in places that differed from the reach-wide means.**

Downstream-----------------------------------------Upstream

## What Comes Next

There are several items and recommendations to consider as we continue to characterize the Special Protection Waters region:

1. This document is expected to be annually revised and updated as new sites and parameters are completed; as land use and population changes; and as new information is gathered for each watershed or river segment.

2. Wastewater discharge information data sets are gradually improving, and soon it will be possible to more accurately quantify cumulative pollutant loadings to streams. DRBC staff desire to monitor the effectiveness of the Special Protection Waters program: beginning with accurate lists of dischargers in each watershed and river segment; then compiling permit information, history since 1992, and monitoring reports to quantify the amounts of wastewater flows and pollutant loadings from all point sources, similar to the way DRBC and the states track water use. Over 150 wastewater dockets have thus far been issued under the Special Protection Waters rules, but it is not yet cumulatively known what pollutant load savings have been achieved by our regulated community within an antidegradation framework.

3. Additional guidance products are necessary for successful implementation of Special Protection Waters:

    a. Guide to assessment of measurable change using the numerical targets presented here;
    b. Guide to permitting wastewater projects, especially in light of administrative agreements between DRBC and the Delaware River Basin states;
    c. Methods and guidance for cumulative assessment of multiple pollutant sources within watersheds;
    d. Guidance for use of these antidegradation targets as objectives for watershed planning and restoration;
    e. Geographic Information System products in support of SPW objectives.

4. On the non-point source front, all projects approved under section 3.8 of the DRBC compact (DRBC 1961) require some type of conformance with a Non-Point Source Pollution Control Plan (NPSPCP), albeit one for a site specific project, or conformance with a municipal stormwater ordinance, or with a state model ordinance. In addition, DRBC had a hand in crafting the USDA Conservation Reserve Enhancement Program (CREP) for Pennsylvania's Delaware River Basin counties, but does not participate, manage, or track results of the program. There are many agencies and organizations that implement non-point source improvement projects, and DRBC has tracked many of these for its State of the Basin reports (DRBC 2008, 2013) within goals and objectives of the Water Resources Plan for the Delaware River Basin (DRBC 2004). However, water quality benefits of such projects have not been measured, and are not generally considered within the context of Special Protection Waters objectives. We know that many projects have been successfully implemented, yet it would be better if we could quantify their success in meeting antidegradation objectives.

5. DRBC possesses extensive water quality information for public consumption, and should work toward improving the outreach and education components of our technical programs. Now that 57 tributary watersheds to the Delaware River have EWQ characterized at BCPs, the Basin community can use those targets to achieve watershed protection and restoration goals. DRBC staff are working on internet applications and interactive maps for exploration of our water quality data via maps and graphics; and creating presentations for scientific conferences, regional organizations, and watershed groups. However, we must be more effective at reaching wider audiences in a less technical manner.

6. Planning has begun for the next major assessment of measurable changes to EWQ. The assessment will be conducted from 2019 to 2021 for about 50 of these 85 sites, encompassing the entire Upper, Middle and Lower Delaware River. The 2009-2011 Lower Delaware assessment indicated some improvements since 2000-2004 in concentrations of nutrients; no degradation of most other parameters; and system-wide increases in chloride and specific conductance concentrations. The assessment was the first effort of its kind, and was demonstrated to be effective in achieving its objective: to determine whether or not water quality degradation occurred. The assessment revealed dozens of stories to be told about different watersheds and their water quality, and this document will provide the foundation for assessment of the whole Special Protection Waters region from Hancock to Trenton in the future.

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