# SUSQUEHANNA RIVER WATERSHED ECOLOGICAL FLOW MANAGEMENT STUDY WATERSHED ASSESSMENT DOCUMENTATION REPORT

*Chenango River. Photo credit SRBC*

**2022**

SUSQUEHANNA RIVER BASIN COMMISSION
NY ▪ PA ▪ MD ▪ USA

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# Chapter 1. Introduction

The Susquehanna River Watershed Ecological Flow Management Study is a partnership between the U.S. Army Corps of Engineers (USACE) and the Susquehanna River Watershed Commission (SRBC). Under contract to SRBC, The Nature Conservancy (TNC) provided technical expertise related to ecological flows. The reconnaissance phase of the study began in 2003 and a cost-sharing agreement was signed in 2008 by the two study partners. TNC conducted the ecosystem flow study and facilitated three expert workshops. Federal, state, and local agencies, in concert with non-governmental organizations and academic institutions, participated in the effort. The overarching goal of the study was to clearly establish the volume and timing of flows required to support aquatic species, and to minimize and avoid deleterious ecosystem impacts in the Susquehanna River watershed (SRBC and USACE, 2012).

The study process generally followed the Ecological Limits of Hydrologic Alteration Framework (Poff et al., 2010). Using stream and river classifications to establish ecosystem response relationships to flow alterations across a broad geographic area, the approach enabled environmental flow needs to be assessed when in-depth studies were not possible for an entire watershed. The result was a set of flow recommendations that support ecosystem health; the study results are documented in *Ecosystem Flow Recommendations for the Susquehanna River Basin* (TNC, 2010) and *Susquehanna River Basin Ecological Flow Management Study Phase I Report* (SRBC and USACE, 2012).

Significant low flows, combined with water withdrawals and consumptive water use, may create critical low-flow conditions, impacting natural functions of the ecosystem and the species that depend on these functions and attributes. The complexity of the Susquehanna River system and the potential for changing conditions in the watershed call for a better understanding of how to manage ecosystem flows. It is critical to maintain the current range of unaltered flow variability to sustain the full range of species and ecological processes throughout the watershed.

The Phase I report identified strategies by USACE and SRBC to preserve and restore flows necessary to support ecosystem health and resilience. The variable flows may be supported with reservoir operations by USACE and water resource management actions by SRBC including consumptive use regulation, pass-by flows, water availability studies, and other related actions. Management and regulatory actions can help maintain and restore natural flow regimes that support the natural habitats and characteristic species of the Susquehanna River watershed and also provide benefits for all of the watershed's inhabitants. The study is continuing with SRBC as the non-Federal sponsor. This will allow for the examination of a number of options to protect aquatic ecosystems, particularly during critical low flow conditions.

This report includes information gathered during initial stages of the study process that the report was to document. The study was not completed and this report has not undergone District Quality Control, Agency Technical Review, or other formal review processes. Therefore, the reader is cautioned that the information contained documents study progress and should be used with caution. The work contained in the report was completed in 2017.

## 1.1 PROJECT AUTHORIZATION

As a watershed assessment, this effort was conducted under Section 729 of the Water Resources Development Act (WRDA) of 1986, as amended. Guidance has been provided in USACE memoranda dated 29 May 2001, 7 March 2008, and 15 January 2012 for watershed planning under Section 729 of WRDA 1986, as amended, and other specifically authorized watershed planning authorities.

## 1.2 PROJECT SPONSORS AND PARTNERS

The Federal sponsor is USACE and the non-federal sponsor is SRBC. TNC is also providing ecosystem flows expertise to the study.

## 1.3 STUDY AREA

The Susquehanna River is the longest river located entirely within the U.S. portion of the Atlantic Ocean drainage. Flowing 444 miles from Otsego Lake, New York to the Chesapeake Bay, the watershed drains more than 27,500 square miles, covering half the land area of Pennsylvania and portions of New York and Maryland. There are six major subwatersheds: the Upper Susquehanna, Chemung, Middle Susquehanna, West Branch, Juniata, and Lower Susquehanna (Table 1-1, Figure 1-1). Most of the watershed's headwaters originate on the Appalachian Plateau, and the river crosses the Ridge and Valley and Piedmont provinces before reaching the Bay (Figure 1-1). The watershed encompasses over 43 percent of the Chesapeake Bay's total drainage area and provides about half of its freshwater inflow (SRBC, 2013).

**Table 1-1. Major Subwatersheds**

| *Subwatershed* | *Drainage Area (Sq.Mi.)* |
|---|---|
| ***-Upper Susquehanna*** | ***4,944*** |
| ***-Chemung*** | ***2,594*** |
| ***4-West Branch Susquehanna*** | ***6,978*** |
| ***3-Middle Susquehanna*** | ***3,771*** |
| | |
| ***5-Juniata*** | ***3,404*** |
| ***6-Lower Susquehanna*** | ***5,809*** |
| ***Total Susquehanna River Watershed*** | ***27,500*** |

*SRBC 2013*

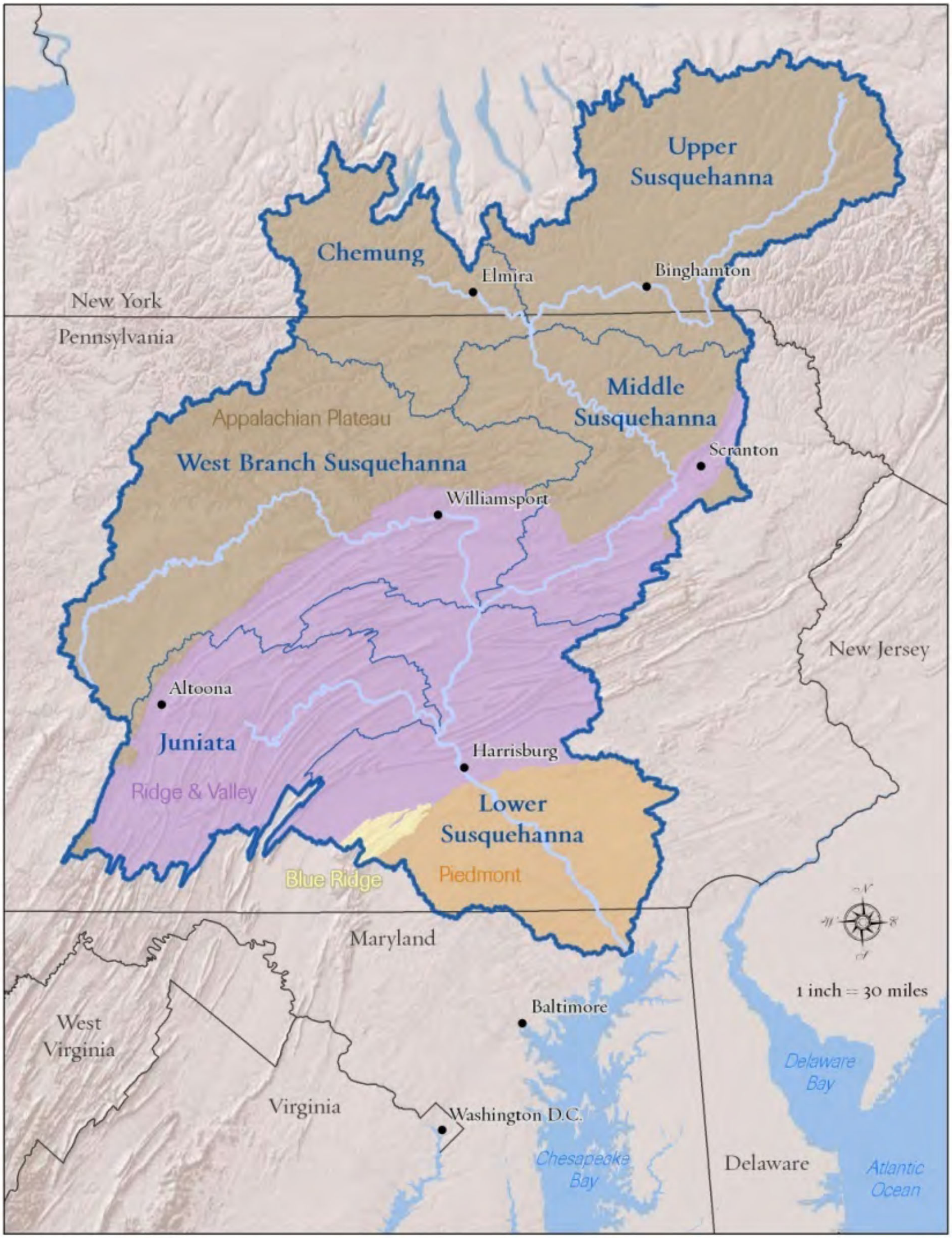



**Figure 1-1. Study Area**

# Chapter 2. Existing Conditions

Some key hydrologic characteristics of the Watershed area are as follows (TNC, 2010):

- Average annual precipitation ranges from approximately 33 to 49 inches.
- Forest covers more than 63 percent of the watershed.
- Evapotranspiration losses account for 52 percent of total precipitation.
- Glaciated regions of the Appalachian Plateau are underlain by thick glacial deposits that result in losing and gaining river reaches.
- Subwatersheds underlain by limestone geology can have baseflows that are two to three times higher than other stream types.
- More than 50 percent of mean annual flow is delivered between March and May.
- Flows are lowest between July and October, when evapotranspiration rates are highest.
- The Susquehanna is one of the most flood-prone watersheds in the United States; historically, flood events have occurred in all seasons.
- Flow conditions can be highly variable from month to month; floods and droughts may occur in the same year.

## 2.1 PHYSIOGRAPHY AND TOPOGRAPHY

Hydrologic characteristics vary with watershed physiography. A physiographic province is an area delineated according to similar terrain that has been shaped by a common geologic history (Fenneman 1938). Physiographic provinces provide the geomorphic context for rivers and streams and influence valley form, elevation, slope, drainage pattern and dominant channel forming processes (Sevon 2000). The watershed spans three major physiographic provinces: the Appalachian Plateau, the Ridge and Valley, and the Piedmont (Figure 2-1).

The Appalachian Plateau underlies most of the watershed, including the Upper Susquehanna, Chemung and northern portion of the West Branch subwatersheds. It has the highest average elevation of all three provinces; its elevations ranges from 440 to 3,210 ft, and is characterized by steep slopes and deeply dissected valleys (Shultz, 1999). Portions of this province were modified by the Pleistocene glaciations, with dominant channel forming processes including fluvial and glacial erosion (Fenneman, 1938; Sevon, 2000). Surficial glacial deposits can be 8 to 15 m thick. These deposits influence surface water hydrology by creating heterogeneous gaining and losing reaches (Cushing et al., 2006).

The Ridge and Valley province consists of a band of parallel ridges created by folded sandstone, shale and limestone ranging in elevation from 140 to 2,775 ft. Depending on the underlying bedrock, dominant channel forming processes include fluvial erosion and solution of carbonate rocks (Fenneman, 1938; Sevon, 2000). More weather-resistant bedrock formations confine valley reaches and floodplains, while limestone valley reaches tend to be broad and less confined. Because of their subsurface water storage capacity, limestone formations also have a significant influence on the hydrology of Pennsylvania streams, yielding higher baseflows and a more stable hydrograph than in non-karstic (a more stable hydrograph than in terrain without underlying limestone) terrain (Stuckey and Reed, 2000; Chaplin, 2005). Trellis and karst drainage patterns are very common[1]. Headwaters and small streams typically flow north or south from the ridge tops to the valleys, then east or west along the valley floor to the mainstem. Subwatersheds within the Ridge and Valley include the southern portion of the West Branch, the Juniata, and portions of the Middle and Lower Susquehanna from the confluence with the Lackawanna River to the Conodoguinet confluence (Shultz, 1999; Sevon, 2000).

The Piedmont transition zone lies between the Appalachian Mountains and the coastal plain. It is characterized by low elevation rolling hills and moderate slopes between the elevations of 20 and 1,355 ft. The Watershed's lowest elevations and most southern latitudes occur within this province, resulting in a concentration of warm headwater streams. While trellis and karst drainage patterns occur, the province is dominated by dendritic drainage patterns, resembling the roots of a tree and channel forming processes are dominated by fluvial erosion (Fenneman, 1938; Sevon, 2000). Portions of the Lower Susquehanna subwatershed fall within this province (Shultz, 1999).

Most of the watershed's headwaters originate on the Appalachian Plateau, and the river crosses the Ridge and Valley and Piedmont physiographic provinces before reaching the Bay. The mainstem Susquehanna River has an average gradient of five feet per mile, but has many areas of locally steeper gradients through riffles and rapids. The width of the Susquehanna River varies greatly along its extent. The Susquehanna river is several hundred feet in width where it enters Pennsylvania from New York, increasing to about a half mile in width in non-dammed sections of the river below Conowingo Dam.

River width is increased greatly in the reservoirs immediately upstream of the York Haven, Safe Harbor, Holtwood, and Conowingo Dams, to as much as a mile (PFBC, 2011).

[1] Trellis patterns, resembling a common garden trellis, and karst patterns, characterized by sinkholes, caves, underground flow and springs, are both common to this province.


**Figure 2-1. Physiographic Provinces**

## 2.2 LAND USE

Land use patterns vary greatly within the Susquehanna River watershed, but range from primarily forested in the upstream portions of the watershed, to either agricultural or urban in the downstream portions of the watershed. These land use patterns specific to the Susquehanna River watershed are illustrated further in Figure 2-2.

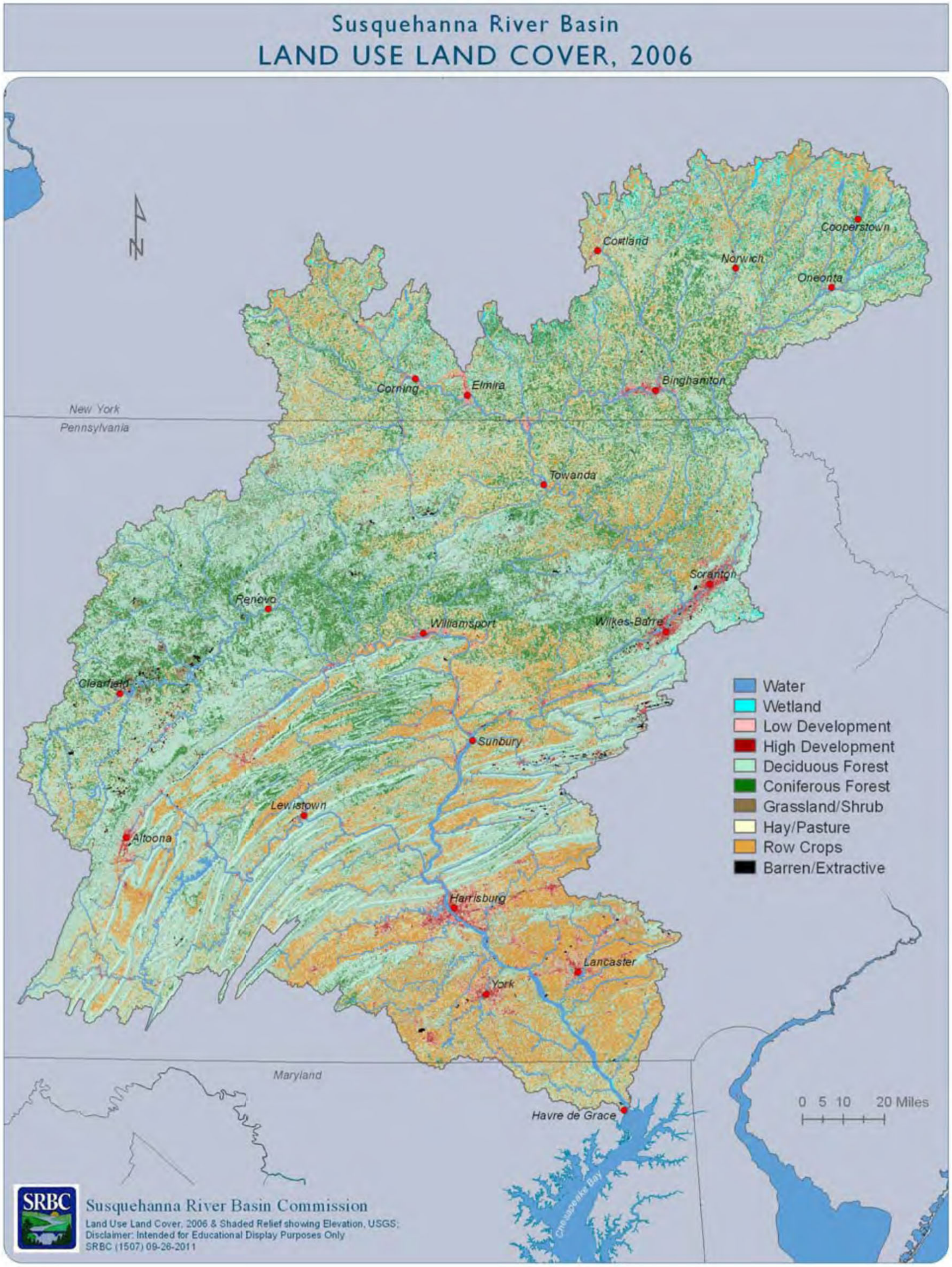



**Figure 2-2. Land Use**

In the central and northeastern Atlantic Slope forest cover plays a major role in governing the distribution and timing of streamflows. Since the region is dominated by deciduous trees, peak evapotranspiration occurs in the late summer and early fall, and is minimal during winter. This pattern is reflected in seasonal baseflow trends.

Changes in forest cover directly influenced historic hydrology. It is estimated that 95 percent of the region was forested before European settlement. Settlement was followed by large-scale deforestation and land use conversion due to increased agriculture, energy demands (charcoal wood), and industrial logging. Conversion and deforestation peaked in the early 1900s when only 30 percent forest cover remained. Since then, forest cover has more than doubled, due to abandonment of agricultural lands and the evolution of silvicultural practices. During periods of low forest cover, streams and rivers had higher baseflows during the summer and fall months. Baseflows were higher because fewer trees resulted in a decrease in evapotranspiration during the growing season. Periods of low forest cover are also associated with flashier hydrographs [2](TNC, 2010).

A significant portion of land cover in the Watershed is agricultural, while a very small percent of the water use in the Susquehanna Watershed is directed towards agricultural use (about 1 percent). The Lower Susquehanna Watershed holds the majority of the agricultural uses, with 36 percent of the land cover in the Lower Susquehanna consisting of crops or pasture. Dairy, cattle, chicken, egg, hog, fruit, feed, and vegetable crop production can all be found within the watershed. Some of the most fertile agricultural land in the United States is located in Lancaster County. At a consumption rate of 120 million gallons a day, agricultural operations are the fastest growing water use sector (PA DCNR, 2003)

## 2.3 GEOLOGY AND SOILS

Soil types in the watershed vary largely within the predominant physiographic provinces. In the glaciated portion of the Appalachian Plateau Province, the deep soils on the sloping uplands are developed in glacial till and are moderately well to poorly drained. Most of the soils contain considerable amounts of coarse fragments, frequently have stones on the surface, and are in woodland. The stream valleys contain deep deposits of glacial valley fill materials and are predominantly deep and well drained (sand and gravel deposits) or poorly drained (finely textured deposits). In the unglaciated part of the plateau, soils formed in materials weathered from sandstone and shale are deep and well to poorly drained (SRBC, 2016).

In the Ridge and Valley Province, soils of the ridges are mostly moderately deep to deep, well drained, and very stony. Soils of the shale valleys are mostly moderately deep to shallow, well to moderately well drained, and feature moderate to steep slopes. Soils of the limestone valleys are predominantly deep, well drained, productive, and often in cropland (SRBC, 2016).

Soils of the Piedmont Province are formed in parent materials weathered from a wide variety of rocks, including red shale, schist, gneiss, quartzite, diabase, and greenstone. The ridge soils are mostly deep,

[2] Displaying high peak drainage flow, and rapidly rising and falling flow patterns

well drained, and very stony. Soils formed over shales and other softer rocks are moderately deep to deep, well to poorly drained, and generally very fertile (SRBC, 2016).

**Mineral Resources**

Coal has been, and continues to be, a significant mineral resource in the Susquehanna watershed. There are nearly 850 active coal mines in the watershed and over 2,100 square miles (surface area) of coal fields. Some of the towns and cities in the watershed were built for the single purpose of coal mining. While coal provided a livelihood for thousands over many decades, the operators worked without regard to environmental impacts until the 1970s. The land was stripped, deep mine wastes were left in enormous piles, and mine drainage flowed into waterways and groundwater. Since the 1970s, many of the previously mined areas have been either abandoned or reclaimed. These abandoned mines may reduce conveyance of flow and increase infiltration also creating sediment traps (Nuttle, et. al. 2015). The SRBC's Comprehensive Plan contains more detailed information on the effects of mine drainage and actions taken to manage and mitigate these effects.

Another very significant mineral resource in the watershed is the natural gas captured in certain shale formations. The SRBC's Comprehensive Plan includes more detailed information on natural gas extraction in the watershed. Large reserves of both coal and natural gas are present in the watershed and will be important sources of energy production for decades.

Other important mineral resources of the watershed include glass sand, lime, clay, trap rock (an aggregate deposit also known as "Diabase" that is a very hard durable material), sand and gravel and stone (SRBC, 2016).

## 2.4 HYDROLOGY

Susquehanna River Watershed hydrology, as with most hydrologic settings, is a function of three primary drivers: underlying geology, land cover, and realized precipitation. These characteristics are fundamental determinants in the amount of water available in both groundwater and surface water systems of the watershed. As discussed previously, the Susquehanna River watershed is comprised of six major subwatersheds, each exhibiting unique features that ultimately translate into water availability. Typical flow patterns across the watershed display the highest annual flows occur in the spring (March/April), associated with the combination of rain and snowmelt, with the lowest flows occurring in early fall (September) following dry hot summer months. Average annual precipitation across the Susquehanna watershed approaches 40 inches in a typical year. Figure 2-3 presents 30-year average rainfall across the watershed from 1981-2010 and displays a spread of 31 to 56 inches. The wettest year recorded, in Harrisburg, since record keeping began in 1889, was 2011 with a total precipitation amount of 73.73". Likewise, the driest year recorded at Harrisburg in 1941 was 25.22" (C. Ross, personal communication, 2015). Prolonged periods of dryness lead to drought with the most significant droughts on record occurring in the 1930's and 1960's. Flooding of some magnitude occurs annually as the steep and varied topography of the watershed facilitates flash flooding associated with heavy thunderstorms while widespread heavy rainfall brings main stem rivers out of their banks.

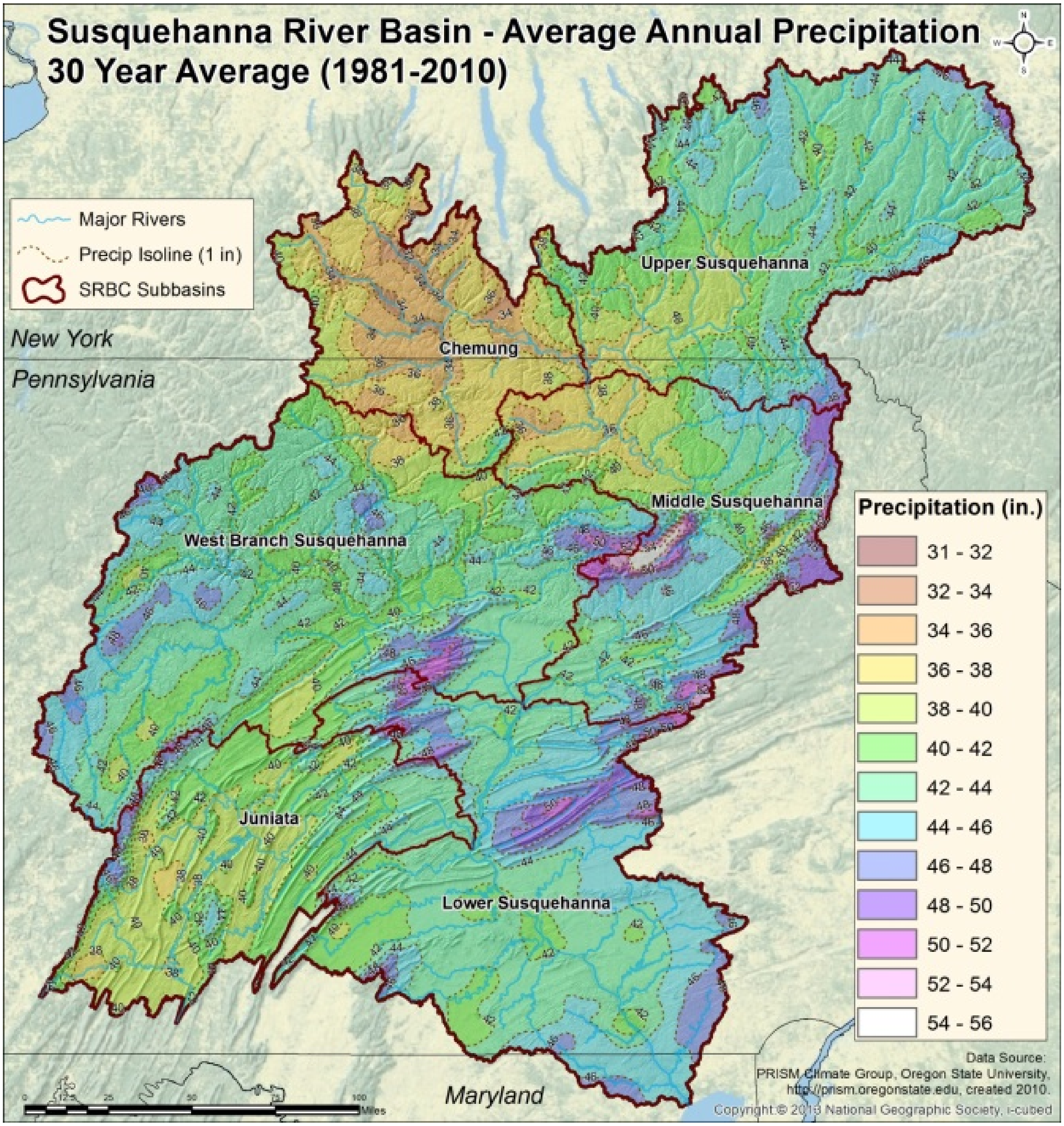



**Figure 2-3. Average Annual Precipitation**

Subwatershed flow conditions were evaluated at six United States Geological Survey (USGS) reference gages (Figure 2-4), selected based on their extended periods of record and overall percentages of drainage area within each subwatershed represented (Figure 2-4). Table 2-1 identifies the watershed reference gages and several of their watershed characteristics. It is important to note that the drainage areas captured by the Susquehanna River at Wilkes-Barre (USGS 01536500) and the Susquehanna River at Harrisburg (01570500) are cumulative encompassing drainage areas of other subwatersheds.

Capturing the drainage area of five upstream subwatersheds allows the Harrisburg gage to be generally representative of current flow conditions across the watershed overall.

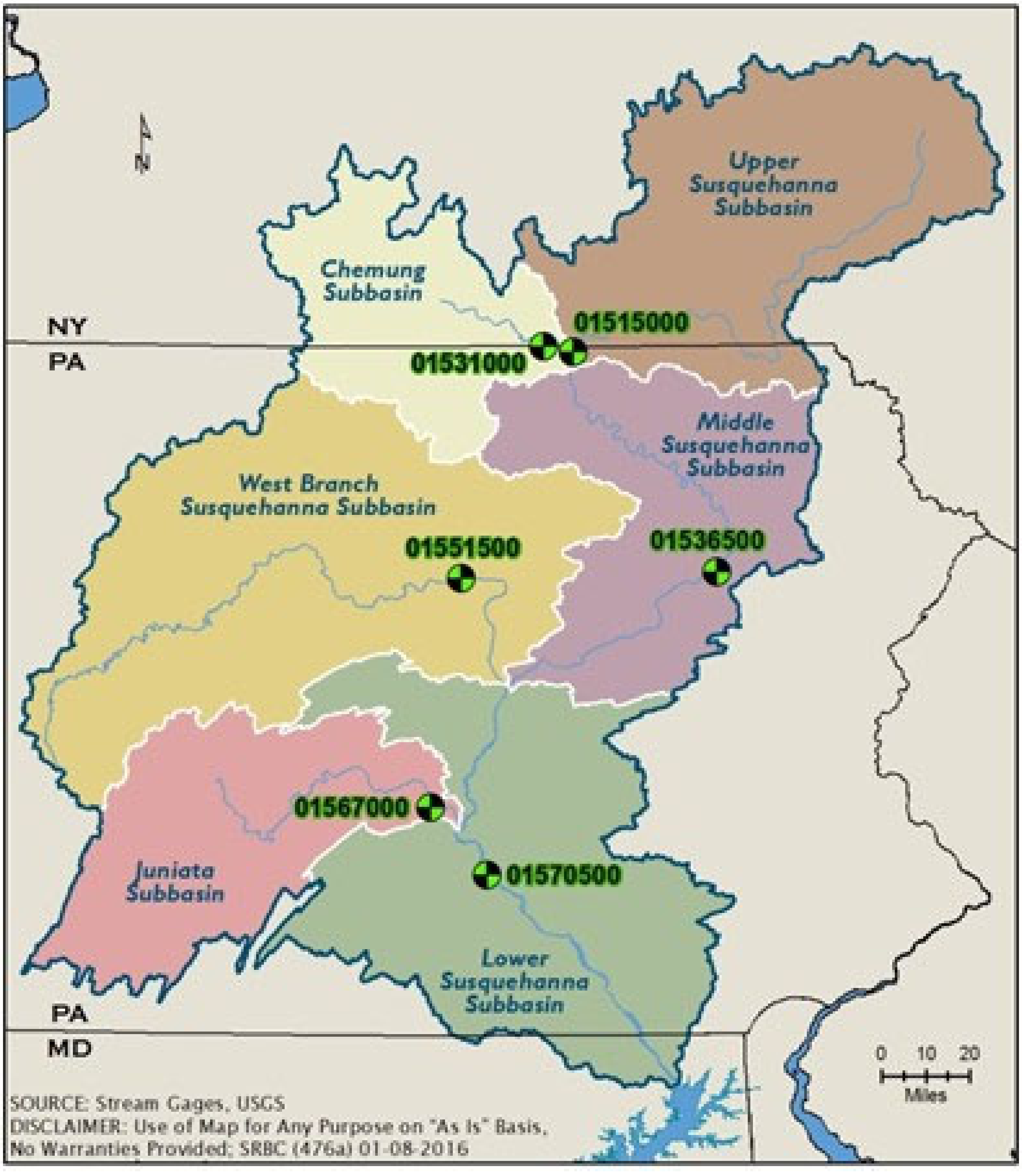



**Figure 2-4. USGS Subwatershed Reference Gages**

**Table 2-1. USGS Subbasin Reference Gage Watershed Characteristics**

| Subwatershed | Reference Gauge | USGS Site Number | Drainage Area (mi²) | Mean Annual Precipitation (in) | Glaciated (%) | Carbonate (%) | Forest (%) | Urban (%) |
|---|---|---|---|---|---|---|---|---|
| Upper Susquehanna | Susquehanna River at Waverly | 01515000 | 4773 | 39.75 | 100 | 2.3 | 70 | 2.2 |
| Chemung | Chemung River at Chemung | 01531000 | 2506 | 33.3 | 99.1 | 0 | 65.1 | 2 |
| West Branch Susquehanna | West Branch Susquehanna at Williamsport | 01551500 | 5682 | 40.7 | 12.9 | 4.7 | 85.1 | 1.4 |
| Middle Susquehanna | Susquehanna River at Wilkes-Barre | 01536500 | 9960 | 38 | 100 | 1.08 | 68 | 2.8 |
| Juniata | Juniata River at Newport | 01567000 | 3354 | 39 | 0 | 16.5 | 69 | 2.1 |
| Lower Susquehanna | Susquehanna River at Harrisburg | 01570500 | 24100 | 39.4 | 49.1 | 5.6 | 70 | 2.5 |
| | | | | | | | | |

Baseflow conditions in the Susquehanna River Watershed occur when realized precipitation has declined to the point that all run-off from recent precipitation events has passed through the streamflow network. Baseflow is typically attributed to groundwater discharge, which can sustain streamflow during extended low flow periods and droughts. Table 2-2 provides baseflow values forvarious recurrence intervals at subwatershed reference gages.

**Table 2-2. USGS Reference Gage Baseflow Statistics**

| USGS Reference Gauge | Average Annual Baseflow (cfs) | 2-Year Recurrence (cfs) | 5-Year Recurrence (cfs) | 10-Year Recurrence (cfs) | 25-Year Recurrence (cfs) | 50-Year Recurrence (cfs) |
|---|---|---|---|---|---|---|
| **Susquehanna River Near Waverly, NY** | 4798 | 4757 | 3840 | 3347 | 3024 | 2989 |
| **Chemung River at Chemung, NY** | 1287 | 1233 | 966 | 851 | 690 | 652 |
| **West Branch Susquehanna River at Williamsport, PA** | 5244 | 5107 | 4316 | 3872 | 3520 | 3219 |
| **Susquehanna River at Wilkes-Barre, PA** | 7446 | 7191 | 5910 | 5367 | 4608 | 4168 |
| **Juniata River at Newport, PA** | 2632 | 2528 | 2016 | 1744 | 1512 | 1453 |
| **Susquehanna River at Harrisburg, PA** | 18700 | 18464 | 15641 | 14123 | 12872 | 10972 |

Low flow conditions in the Susquehanna Watershed are evaluated against the 95th percent exceedance (P95) flow statistic for the period of record at each subwatershed reference gage. The P95 statistic represents the flow value for which 95 percent of the recorded daily flows are greater than the observed value. The P95 flow statistic is the surface water threshold for indicating drought emergency conditions within the watershed. The Ecosystem Flow Recommendations for the Susquehanna River Basin (TNC, 2010) also contain a recommendation of no change to monthly P95 for streams with drainage areas greater than 50 square miles. The P95 flow statistic can be calculated on an annual or monthly basis. Evaluating the P95 flow statistic on a monthly basis (Table 2-3) provides a seasonal perspective of low flow conditions in the Watershed which vary significantly between typical spring high flow and summer low flow periods. The lowest flows in the Watershed typically occur during the months of July, August, September, October, and November (JASON months). Examination of the occurrence of P95 streamflows demonstrates the significance of the 1930's and 1960's droughts. It also underscores the fact that variability in streamflow is persistent from subwatershed to subwatershed and that a P95 streamflow can occur in any subwatershed without occurring in other subwatersheds.
Temporal variations in long-term occurrence of low flows within the watershed were described by Zhang, et. al. (2010). Results from their study concluded that the annual minimum flow for 7 out of 8 unregulated watersheds within the Susquehanna watershed increased abruptly around 1970 and about half the examined watersheds showed abrupt increases in annual median flow. No abrupt change was observed in the magnitude of high flows. From the 1940's through the 1960's large scale reservoirs were constructed by USACE, primarily for flood control. While Zhang et. al (2010) studied unregulated streams, these reservoirs may have additionally increased low flows in the regulated downstream reaches by providing prescribed conservation releases during low flow periods.

In addition to temporal variations in low flow occurrences, spatial variations in the magnitude of low flows were examined for the subwatershed reference gages (Figure 2-5). When comparing the P95 flows, normalized by drainage area, the Chemung subwatershed exhibited the lowest values for each of the JASON months (Figure 2-6). Relatively low mean annual precipitation rate and a largely glaciated drainage are likely contributors to this characteristic. The Middle, Upper, and West Branch Susquehanna subwatersheds produced similar average JASON monthly P95 flow values per square mile for JASON months. Increased values for the Upper and West Branch Susquehanna subwatersheds compared to the Middle Susquehanna Subwatershed, could be attributed to an increase in average annual precipitation, up to 1.75 inches per year. The Juniata and Lower Susquehanna subwatersheds exhibited the highest monthly P95 flow values per square mile for each of the JASON months. When comparing the Juniata Subwatershed to the other tributary subwatersheds (Upper, Chemung, West Branch), the average JASON P95 flow ranged from 19-63 percent greater than the other tributary subwatersheds. This increase is most likely due to a considerable portion of the watershed being underlain by carbonate bedrock.

**Table 2-3 USGS Subwatershed Reference Gage Monthly P95 Flow Values.**

| Month | Susquehanna River Near Waverly, NY | Chemung River at Chemung, NY | West Branch Susquehanna River at Williamsport, PA | Susquehanna River At Wilkes-Barre, PA | Juniata River At Newport, PA | Susquehanna River At Harrisburg, PA |
|---|---|---|---|---|---|---|
| **Jan** | 1720 | 320 | 1540 | 2400 | 870 | 7300 |
| **Feb** | 1800 | 350 | 2000 | 2800 | 1200 | 9600 |
| **Mar** | 3000 | 780 | 3650 | 5280 | 2120 | 17300 |
| **Apr** | 5340 | 1320 | 5230 | 8900 | 2240 | 22600 |
| **May** | 2430 | 700 | 3050 | 4330 | 1650 | 13200 |
| **Jun** | 1170 | 315 | 1610 | 2200 | 1020 | 7700 |
| **Jul** | 640 | 170 | 917 | 1280 | 644 | 4420 |
| **Aug** | 468 | 126 | 677 | 970 | 486 | 3510 |
| **Sep** | 432 | 112 | 537 | 860 | 430 | 2990 |
| **Oct** | 537 | 130 | 594 | 982 | 465 | 3160 |
| **Nov** | 906 | 177 | 738 | 1390 | 548 | 4175 |
| **Dec** | 2200 | 234 | 1090 | 2100 | 630 | 6000 |

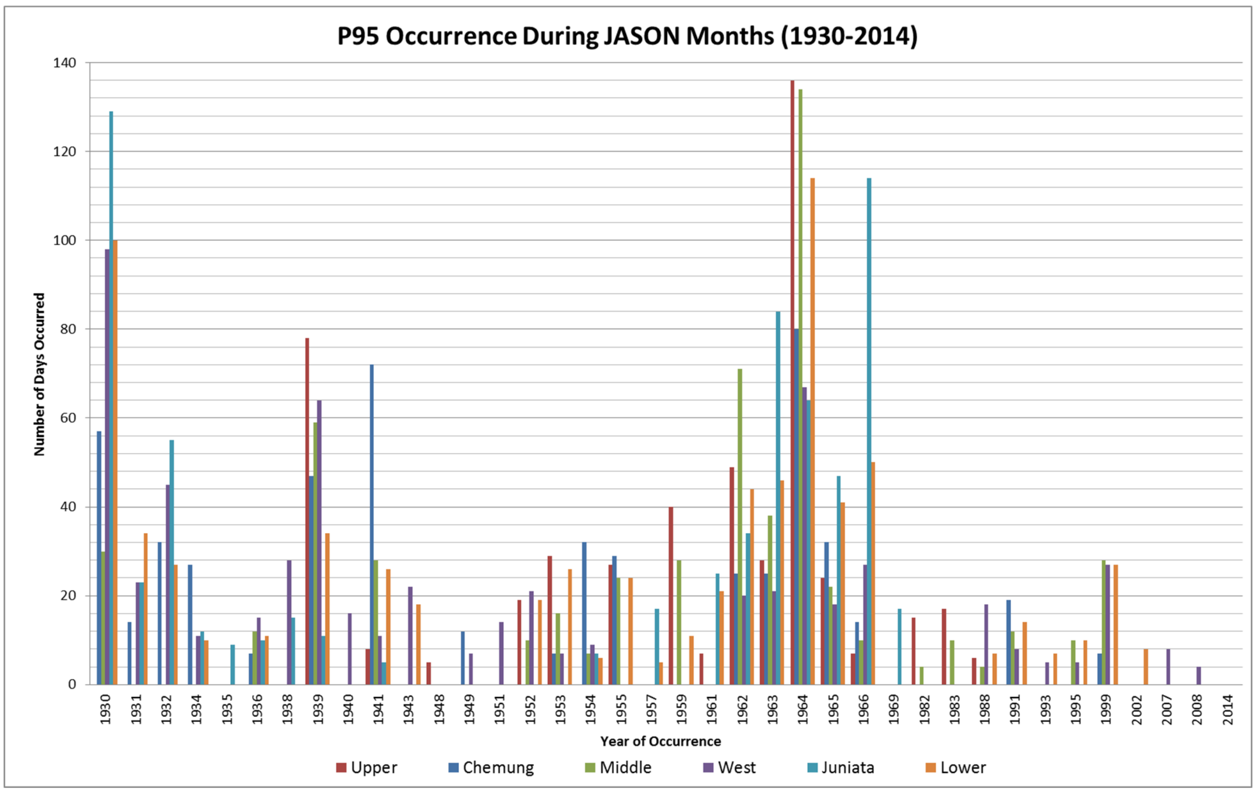
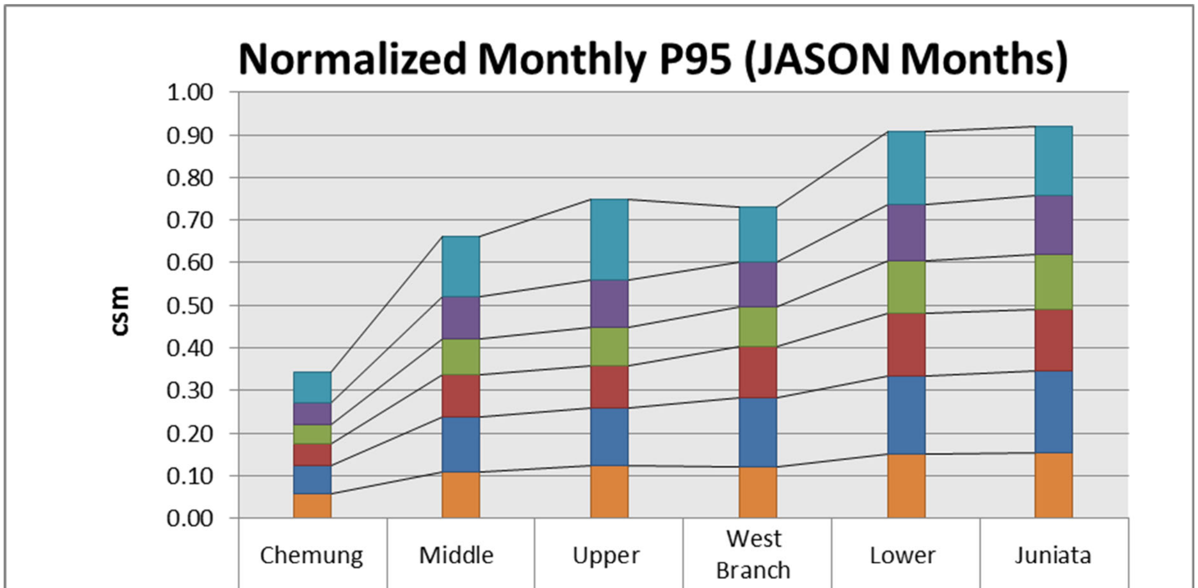



**Figure 2-5. USGS Reference Gage P95 Flow Occurrence During Low Flow Months**
*Note: X-axis reflects only the year in which the P95 flows occurred and not actual months of occurrences.*




| | Chemung | Middle | Upper | West Branch | Lower | Juniata |
|---|---|---|---|---|---|---|
| November | 0.07 | 0.14 | 0.19 | 0.13 | 0.17 | 0.16 |
| October | 0.05 | 0.10 | 0.11 | 0.10 | 0.13 | 0.14 |
| September | 0.04 | 0.09 | 0.09 | 0.09 | 0.12 | 0.13 |
| August | 0.05 | 0.10 | 0.10 | 0.12 | 0.15 | 0.14 |
| July | 0.07 | 0.13 | 0.13 | 0.16 | 0.18 | 0.19 |
| Avg JASON P95 | 0.06 | 0.11 | 0.12 | 0.12 | 0.15 | 0.15 |

**Figure 2-6. USGS Subwatershed Reference Gage Monthly P95 Flow Normalized by Drainage Area**

*Note: CSM is cubic feet per second per square mile.

## 2.5 WATER QUALITY

Similar to hydrologic drivers, water quality is typically a reflection of geology and watershed characteristics, as well as ecoregion. Across the six subwatersheds, water quality ranges from streams so polluted to the extent they are devoid of aquatic life to high quality, pristine streams that support a robust aquatic ecosystem. Major contributors to water quality issues in the Watershed include abandoned mine drainage (AMD), agriculture, urban development, and resource extraction. Maintaining a sufficient volume of water in streams is not only critical to sustaining aquatic life but can also sustain water quality by improving the assimilative capacity and diluting effluent.

The TNC (2010) report describes the key flow needs for water quality which are summarized below:

- Decreased flow magnitudes can increase stream temperature and decrease dissolved oxygen, particularly in shallow margins and backwater habitats important for juvenile fish development.
- High flow pulses during summer flush fine sediments, decrease stream temperature, increase dissolved oxygen and transport and break down coarse particulate organic matter.

- Decreased flow magnitude could reduce assimilative capacity (ability of a body of water to cleanse itself; its capacity to receive waste waters or toxic substances without deleterious effects and without damage to aquatic life or humans who consume the water and decrease effectiveness of wastewater treatment and abandoned mine drainage remediation.

### Upper Susquehanna River Subwatershed

Streams in the Upper Susquehanna subwatershed tend to be unstable due to the dominance of glacial till substrate which is unconsolidated cobble; this substrate moves easily during high flow events and can cause total rearrangement of stream channels in a short period of time. This geology is often reflected in water chemistry and is characterized by elevated aluminum, moderate conductance values and higher baseline turbidity even in heavily forested watersheds. While there are some exceptions, most streams in the Upper Susquehanna subwatershed do not exhibit elevated concentrations of nutrients. Less than five percent of the stream miles in the subwatershed are not meeting their state regulated designated uses (PADEP 2016b, NYDEC 2014). The lower portion of the Upper Susquehanna subwatershed is in the flood prone southern tier of New York and has experienced devastating flooding numerous times over the last decade.

### Chemung River Subwatershed

Six percent of the stream miles in the subwatershed are not meeting their state regulated designated uses and most are located in the Tioga River Watershed, a tributary to the Chemung River. ver. The largest source of impairment in the Pennsylvania portion of the subwatershed is AMD and this is confined to the Tioga River Watershed which has a legacy of AMD. A TMDL and a Watershed Assessment and Remediation Strategy have been completed on the Tioga River Watershed to address the AMD impairments in the watershed. Excess nutrients and sediment are another contributor to impairments in the Chemung subwatershed. Excess nutrients can cause algal blooms and sediment often builds up on the stream substrate, both of which are detrimental to aquatic life.

### West Branch Susquehanna River Subwatershed

The West Branch subwatershed contains some of the most pristine streams in the watershed, with over 50 percent of the stream miles in the subwatershed designated exceptional value or high quality (PADEP 2016a). A large portion of the subwatershed is covered with state forest and provides a large arena for outdoor recreational activities. The subwatershed also contains some of the watershed's most impaired streams. Approximately 18 percent of the stream miles are listed as not meeting their state regulated designated use (PADEP 2016b). AMD is the main source of impairment; there are several streams devoid of aquatic life because of metal concentration and acidic conditions. Numerous TMDLs have been prescribed in the West Branch subwatershed to address the AMD issues and restoration efforts are ongoing in the subwatershed.

### Middle Susquehanna River Subwatershed

Approximately 16 percent of the stream miles in the Middle Susquehanna subwatershed are not meeting their state-regulated designated use (PADEP, 2016b). Three major impairments to the streams in the subwatershed are indicative of the land uses – AMD, development (urban and small residential), and agriculture. The Lackawanna River corridor was extensively mined for anthracite coal beginning in the early 1800's, leaving behind numerous abandoned discharges and seeps. AMD causes excessive metal and sediment loads, acidic (majority of the time) stream conditions and is most commonly identified by orange streams. The high metal concentrations, sediment loads, and low pH have adverse impacts on aquatic life leading to systems with no aquatic organisms or only organisms with high pollution tolerances. Several AMD Total Maximum Daily Loads (TMDL) have been completed by state regulators in coordination with the EPA in the subwatershed to identify pollutant load reductions needed for the streams to meet water quality standards.

Two major population centers are located in the subwatershed – Scranton and Wilkes-Barre. These populated areas increase urban runoff, channelize streams, and have point source dischargers. The northern and south-western regions of the subwatershed are dominated by agriculture and several subwatersheds within these areas are impaired by nutrients and siltation. The middle portion of the subwatershed is mostly forested on the eastern and western edges with several high quality streams.

#### Juniata River Subwatershed

The streams in the Juniata subwatershed generally are the most eutrophic of any of the subwatersheds, which is likely a combination of heavy agriculture and limestone geology that characterize the subwatershed. Some of the highest nitrogen values within the watershed overall have been collected in the Juniata Subwatershed and summer pH values over 9.0 are not uncommon. Nearly ten percent of the streams in the Juniata River subwatershed are not meeting their state regulated designated uses (PADEP, 2016b). Within the Juniata subwatershed there are excellent fishing locations, including the Little Juniata River, which attracts anglers from across the state. Some small pockets of residual impacts from coal mining are also evident within the Juniata subwatershed.

#### Lower Susquehanna River Subwatershed

The Lower Susquehanna subwatershed is home to some of the watershed's most productive agricultural lands, as well as some of the watershed's largest cities. As a result, water quality typically reflects the surrounding land uses, whether elevated nutrient and sediment concentrations from agricultural activities or increased pollutant loads of metals, pathogens, or emergent contaminants from industry and human activity. In the Lower Susquehanna subwatershed, greater than 22 percent of the stream miles are not currently meeting their state-regulated designated uses (PADEP, 2016b). Concentrations of nitrogen and phosphorus are generally higher in the Lower Susquehanna than anywhere else in the Watershed. Carbonate geology also influences water chemistry in many streams in the Lower Susquehanna Subwatershed with naturally high conductivity, alkalinity and a greater buffering capacity.

## 2.6 WATER MANAGEMENT AND USE

### Water Management

Effective management of the water resources of the Susquehanna River Watershed requires a coordinated effort among all stakeholders that seeks to balance the economic value of the resource while protecting the integrity of the resource for generations to come. The watershed states of New York, Pennsylvania, and Maryland all have regulatory authority with regard to both water quality and water quantity. The Maryland Department of Natural Resources, Pennsylvania Department of Conservation and Natural Resources, Pennsylvania Department of Environmental Protection, New York Department of Environmental Conservation and the New York State Department of Health all have authorities related to water quality. Water quantity authorities reside with the Maryland

Department of the Environment, Pennsylvania Department of Environmental Protection, and the New York State Department of Environmental Conservation. Both USACE and SRBC have unique roles in managing the resources of the Watershed.

Within the Susquehanna River Watershed, USACE operates and maintains 13 reservoirs (there is also one state owned and operated reservoir) that provide multiple benefits to both stakeholders and the resource overall. Authorized individually for specific purposes, the reservoirs collectively provide flood damage reduction, water supply, recreation, and water quality management options. During Tropical Storm Lee the reservoirs were responsible for preventing $173.3M in damages (Personal communication, J. Fritz, Chief, Water Resources Section, USACE, 2016). To enhance and protect water quality, the reservoirs have been operated to buffer acidic flows, particularly in the West Branch sub-watershed. Providing economic benefit, USACE utilizes both public and private partnerships to provide contractual operation for recreational facilities at the reservoirs.

SRBC's role is to enhance public welfare through comprehensive planning, water supply allocation, and management of the water resources of the Watershed. SRBC's leadership role in Watershed water resources planning and management is exercised through its regulatory function, which fills regulatory gaps that exist in member states' (New York, Pennsylvania, and Maryland) water management programs. There is an ongoing interface between SRBC and state regulatory programs to ensure each meets its objectives without duplication of work or inconsistencies.

SRBC regulates groundwater and surface water withdrawals of 100,000 gallons per day (gpd) or more (peak 30-day average), consumptive use (CU) and out-of-watershed diversions of 20,000 gpd or more (peak 30-day average), and all in-watershed diversions. The main purposes of the regulations are to avoid conflict among water users, protect public health, safety and welfare, manage and protect water quality, consider economic development factors, protect fisheries and aquatic habitat, and safeguard the Chesapeake Bay. Projects and proposals for development, use and management of the water resources of the Watershed are evaluated in terms of their compatibility with the objectives, goals, standards, and criteria set forth in the SRBC Comprehensive Plan, and on the basis of public input regarding project impacts. Every project, independent of the industry or entity from which the application originates, is evaluated solely upon its technical merits and the scientific and engineering information upon which the application is based.

The SRBC adopted a new Low Flow Protection Policy (LFPP) in December 2012. The LFPP provides guidance for determining pass-by flows and conservation releases associated with approved water withdrawal projects. A pass-by flow is defined as a prescribed streamflow below which withdrawals must cease. A conservation release is defined as a prescribed quantity of flow that must be continuously maintained downstream of an impoundment. The scientific framework for developing the LFPP was a study conducted by TNC which produced a report entitled *Ecosystem Flow Recommendations for the Susquehanna River Watershed* (TNC, 2010). In contrast to the former policy, the LFPP specifies variable monthly low flow protection thresholds as opposed to a constant annual threshold. The SRBC uses pass by flows, conservation releases, and withdrawal limits in conditioning approved water withdrawals to avoid adverse impacts to water quality, competing users, and aquatic resources throughout the Watershed.

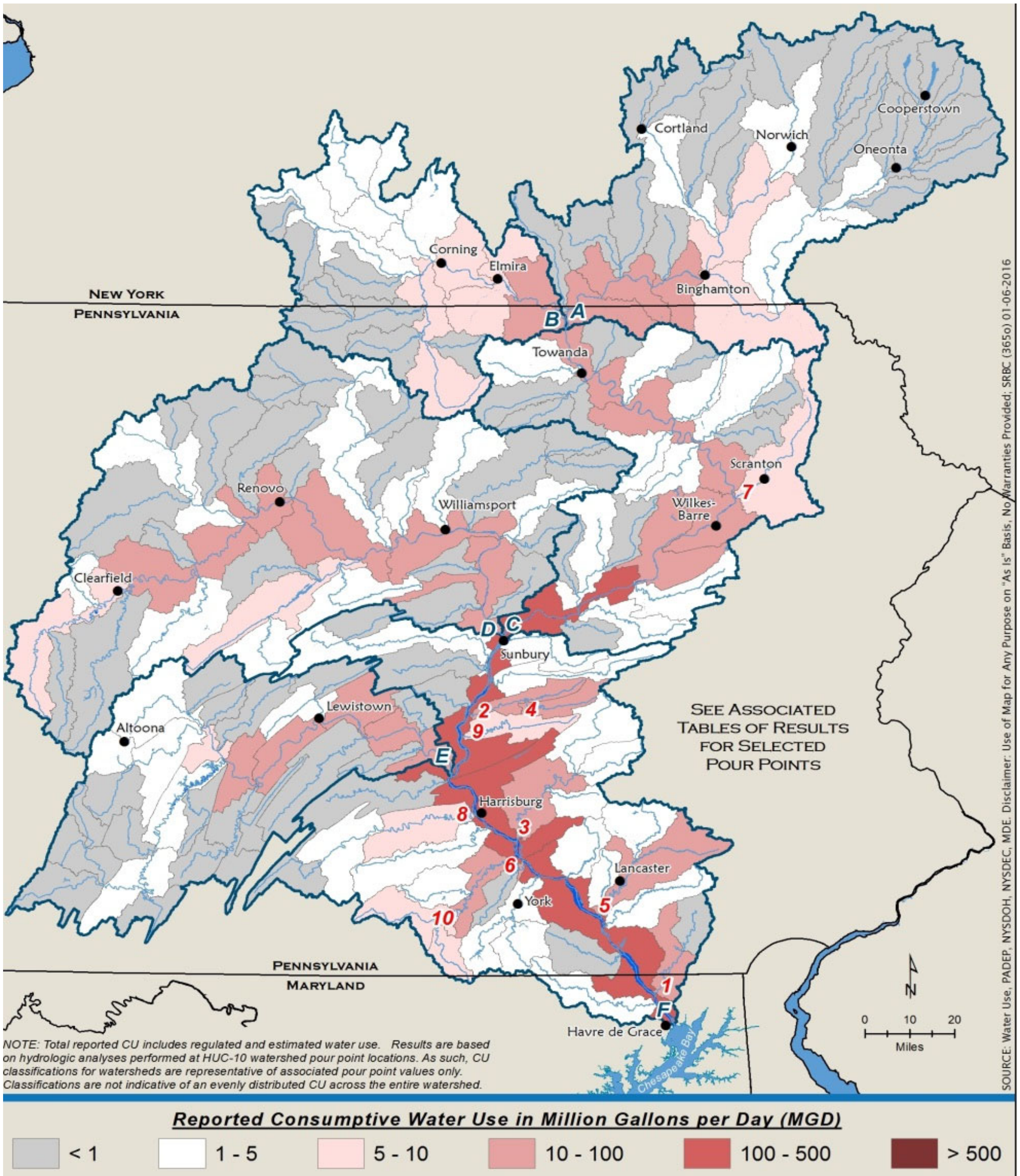



**Figure 2-7. Reported Consumptive Use by HUC-10 Watershed**

The SRBC completed a Cumulative Water Use and Availability Study (CWUAS) in January 2016. The study involved computing existing (Figure 2-7.) and projected CU, determining water capacity at varying spatial scales, developing a Geographic Information System (GIS) -based tool to automate computations of water availability, and evaluating alternatives for mitigating effects of cumulative CU in the watershed. A comprehensive water use database was developed by integrating SRBC and member state water use records. Estimates of unregulated CU by the self-supplied residential and agricultural sectors were generated. Projections of 2030 CU were developed based on trend analysis and published forecast information. Hydrologic analyses were performed for gaged and ungaged watersheds to estimate water capacity sustainably available to support water resources development. Water availability for a given watershed was calculated by subtracting cumulative CU from the selected water capacity threshold. A suite of protection, mitigation, and enhancement (PM&E) measures, including water use reductions, pass-by flows, conservation releases, CU mitigation releases, and water use caps was evaluated with respect to their effect on cumulative water use and availability. A data-driven GIS-based tool was also developed to provide a series of analytical components for automating the quantification of water use, capacity, and availability at user input point locations throughout the watershed.

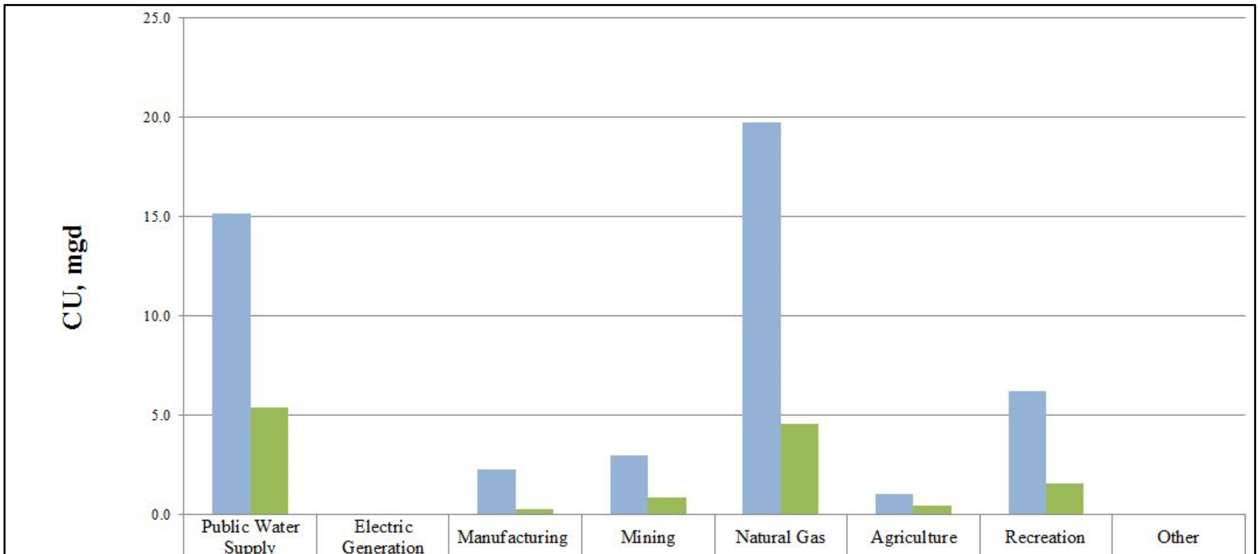
## Water Use

Water use in the Susquehanna River Watershed is attributable to a variety of sectors which include power generation, public water supply, recreation, industrial processes, and agriculture. Withdrawals occur from both groundwater and surface water sources and to the extent the withdrawal is of a quantity that exceeds regulatory thresholds requires appropriate approval to ensure the sustainability of the resources overall. The SRBC regulates both withdrawal and consumptive water use in the Watershed. Consumptive water use (water withdrawn from but not returned to the Watershed) has the greatest potential to impact instream uses and downstream users and, as such, was quantified by subwatershed using SRBC databases. Approved CU represents the total quantity of CU permitted by SRBC dockets while reported CU represents the portion of the permitted CU actually used. Consumptive use for the public water supply sector was calculated based on documented CU factors for public water supply. CU associated with recreation is mostly attributed to golf course irrigation and snowmaking. With regard to CU by the natural gas industry, the entire amount of the withdrawal is considered to be consumptively used and applied at the source of withdrawal regardless of where the water is actually used.

### Upper Susquehanna Subwatershed

Approved CU in the Upper Susquehanna subwatershed totaled 47.4 million gallons per day (mgd) in 2014, however, actual reported CU, averaged by days used, accounted for less than 30 percent of that allocation at 13.1 mgd. Generally, approved CU in the Upper Susquehanna subwatershed was concentrated on the natural gas (See the SRBC 2016 Comprehensive Plan for more detailed information on natural gas extraction in the watershed) and public water supply (PWS) sectors at 42 and 32 percent, respectively, with recreation following at 13 percent (Figure 2-8). Mining (6 percent), manufacturing (5 percent), and agriculture (2 percent) were the only other sectors using detectable amounts of water. Reported CU was slightly different as the PWS sector actually used more water than the natural gas industry by 0.8 mgd.

CU for the natural gas industry included fourteen sources that can withdraw 19.7 mgd. Since the natural gas industry uses water for hydrofracking, water is not returned to the watershed undiminished in quantity, use for this sector was considered 100 percent consumptive. Two withdrawals of three mgd apiece were the highest allocations with both occurring on the main stem Susquehanna River. All natural gas industry withdrawals were located in the Pennsylvania portion of the Upper Susquehanna subwatershed due to a moratorium on natural gas production existing in New York. None of the sources reported more than 0.8 mgd and four sources did not operate in 2014. The PWS sector had the second highest approved CU total (15.2 mgd), but the highest reported CU (5.4 mgd). The top five PWS systems were Binghamton, Johnson City, United Water Nichols/Owego, Endicott, and Norwich. These were the only systems approved for more than one mgd of CU, using a 15 percent CU factor, and accounted for 54 percent of the total approved and 41 percent of the total reported PWS sector use. Twelve golf courses (during warmer months) and four skiing facilities mostly accounted for all recreational CU. Greek Peak Mountain ski resort was the only facility in this sector that could use greater than one mgd. Skiing facilities also reported the most use in this sector, but none were higher than 0.35 mgd (and only during winter months). Significant users in the remaining sectors included Cortland Asphalt Products and Chobani in manufacturing, and Tri City in mining.




| | Public Water Supply | Electric Generation | Manufacturing | Mining | Natural Gas | Agriculture | Recreation | Other |
|---|---|---|---|---|---|---|---|---|
| 2014 Approved CU | 15.2 | 0.0 | 2.3 | 2.9 | 19.7 | 1.0 | 6.2 | 0.0 |
| 2014 Reported CU | 5.4 | 0.0 | 0.3 | 0.9 | 4.6 | 0.4 | 1.6 | 0.0 |

**Figure 2-8. Consumptive Use by Sector in the Upper Susquehanna Subwatershed**

## Chemung Subwatershed

In 2014, the Chemung subwatershed supported 33.7 mgd of approved CU with 8.7 mgd or 26 percent actually reported. Approved CU in this subwatershed was predominantly allocated for the agriculture and natural gas sectors at 34 and 29 percent, respectively, with PWS following at 16 percent (Figure 2-9). Manufacturing (10 percent), mining (6 percent), and recreation (5 percent) were the remaining sectors using significant amounts of water. The agriculture sector also had the highest reported CU at 3.9 mgd, followed by PWS (2.0 mgd), natural gas (1.1 mgd), and manufacturing (1.1 mgd).

Approved CU for agriculture was dominated by three large scale farming operations accounting for 94 percent of the sector total. These same operations were also responsible for 84 percent of the reported CU. The natural gas industry was approved for 9.8 mgd among 17 withdrawal sources. Only one withdrawal, along the Tioga River, was approved for more than one mgd. Seven of the sources operated in 2014 and all reported less than 0.5 mgd. As in the Upper Susquehanna subwatershed, all natural gas industry withdrawals were located in the Pennsylvania portion of the Chemung subwatershed. The PWS sector had the third highest approved CU (5.3 mgd), but the second highest reported CU (2.0 mgd). The top five PWS systems were Hornell, Elmira, Painted Post, Bath, and Erwin. These systems accounted for 55 percent of the total approved CU and 53 percent of the total reported PWS sector use. Eleven manufacturing facilities combined for 3.5 mgd of approved CU. Corning, Inc., with 6 separate facilities, was the only company in this sector that could use greater than one mgd and represented 42 percent of the approved and 35 percent of the reported CU. Significant users in the remaining sectors included Spalina and Hanson Aggregates in mining, and seven golf courses in recreation.

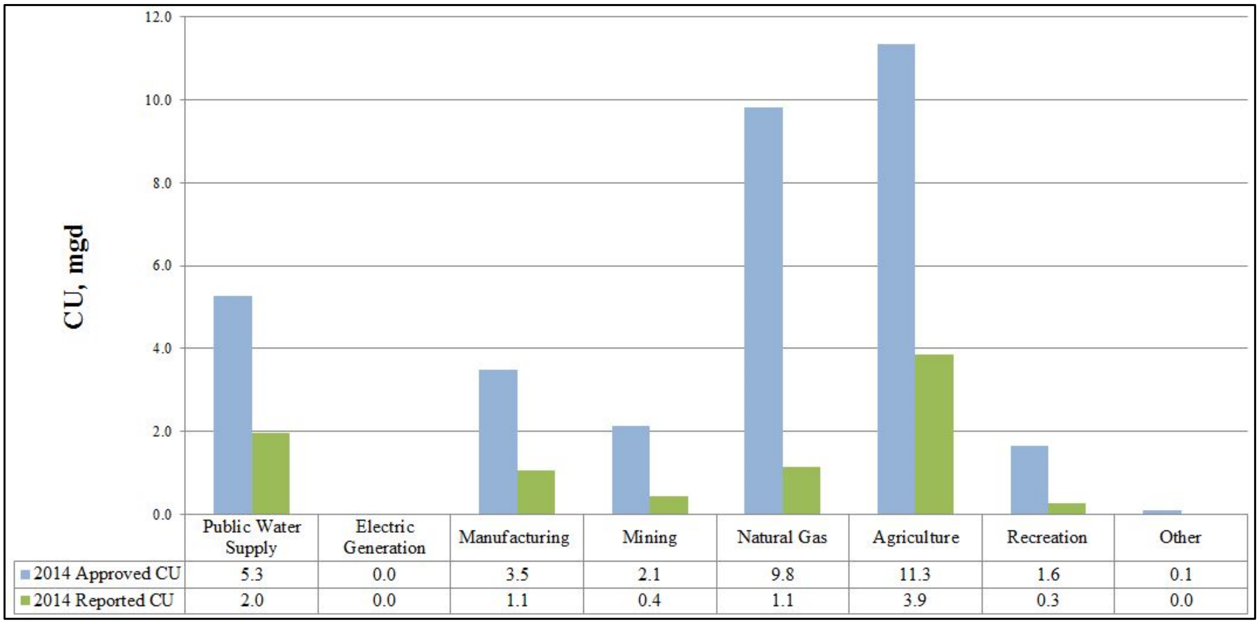
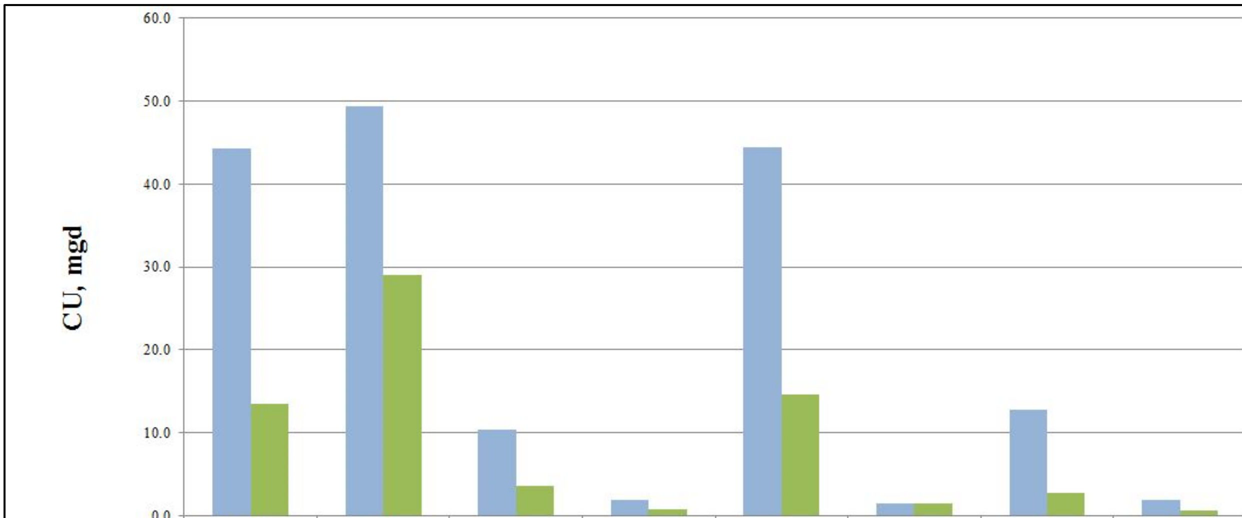



**Figure 2-9. Consumptive Use by Sector in the Chemung Subwatershed**

### Middle Susquehanna Subwatershed

Approved CU in the Middle Susquehanna subwatershed totaled 166.4 mgd in 2014, with actual reported CU accounting for less than 40 percent at 66.3 mgd. The electric generation, natural gas, and PWS sectors far outweighed other classes in this subwatershed combining for 83 percent of the approved CU (Figure 2-10). Recreation (8 percent) and manufacturing (6 percent) were the other sectors using greater than 5 percent of the approved CU. Results for reported CU followed a similar pattern with the same three sectors utilizing 86 percent of the total. Subsequently, manufacturing was the remaining sector using at least five percent of the reported CU.

Three electric generation facilities, Susquehanna Steam Electric Station, UGI Hunlock Creek Energy Center, and PEI Power Corporation, accounted for all 49.4 mgd of approved CU for this sector. Susquehanna, Steam Electric Station, however, was responsible for 97 percent of both the approved and reported CU. The natural gas industry included 50 sources that were able to withdraw 44.4 mgd. Almost a quarter of the withdrawals equaling 40 percent of the approved CU were located along the Susquehanna River. Only 1 source reported more than 1 mgd of CU and 13 sources were not operational. The PWS sector followed closely behind using 44.2 mgd. The top five PWS systems were Pennsylvania America Water Company (PAWC) Scranton, PAWC Springbrook, Hazleton, Aqua America Roaring Creek Division, and United Water Bloomsburg. The PAWC systems were by far the largest users in this sector, being approved for almost 19 mgd each (85 percent) and reporting just under 10 mgd (73 percent). Twenty-nine golf courses and two skiing facilities mostly accounted for all recreational CU. Montage Mountain and Elk Mountain ski resorts were the only facilities in this sector that could use over one mgd. Of the 31 facilities in this sector, none reported higher than 0.65 mgd. Two pharmaceutical companies, Procter & Gamble and Merck Sharp & Dohme Corporation, accounted for 50 percent of the approved and 57 percent of the reported CU for the manufacturing sector. Significant users in the remaining sectors included Cedar Rock Materials Corporation in mining and Furman Foods in agriculture.




| | Public Water Supply | Electric Generation | Manufacturing | Mining | Natural Gas | Agriculture | Recreation | Other |
|---|---|---|---|---|---|---|---|---|
| 2014 Approved CU | 44.2 | 49.4 | 10.3 | 1.9 | 44.4 | 1.5 | 12.7 | 1.9 |
| 2014 Reported CU | 13.4 | 29.0 | 3.6 | 0.8 | 14.6 | 1.5 | 2.8 | 0.6 |

**Figure 2-10. Consumptive Use by Sector in the Middle Susquehanna Subwatershed**

### West Branch Susquehanna Subwatershed

Total approved CU in the West Branch Susquehanna subwatershed in 2014 was 118.3 mgd of which 47.9 mgd or 40 percent was reported. The natural gas industry had the largest amount of approved CU in this subwatershed at 36 percent (Figure 2-11). Electric generation and PWS were next at 26 percent and 16 percent, respectively. Agriculture and manufacturing, both at six percent, were the remaining sectors using greater than five percent of the approved CU. Although the natural gas sector had the most approved CU, it only reported the fourth highest use, while electric generation (34 percent) and PWS (26 percent) used significantly more water.

The natural gas industry was approved for 42.0 mgd among 45 withdrawal sources. Four withdrawals, along the West Branch Susquehanna River, were approved for two or more mgd. Nine sources along the West Branch Susquehanna River (14.6 mgd) and 13 sources in the Pine Creek Watershed (9.3 mgd) accounted for 57 percent of the approved CU. However, withdrawals in the Lycoming Creek Watershed reported the most CU (28 percent). There were 27 sources that did not report CU in 2014. Electric generation, the second highest sector in terms of approved CU, was comprised of three facilities, Montour Steam Electric Station, NRG REMA Shawville Station, and Viking Energy. Montour Steam Electric Station accounted for 85 percent of the approved and 73 percent of the reported CU. The PWS sector had the third highest approved CU (18.5 mgd), but the second highest reported CU (12.2 mgd). The top five PWS systems were DuBois, which included an out-of-watershed diversion, PAWC White Deer, Williamsport, State College, and Bellefonte. These systems accounted for 51 percent of the total approved and 46 percent of the total reported PWS sector use. Forty-one agricultural facilities combined for 7.5 mgd of approved CU. Three facilities reported over one mgd of CU and combined to represent 58 percent of the agricultural use. First Quality Tissue, Pennsylvania Grain Processing, and the Coca-Cola Company together accounted for 81 percent of the manufacturing approved CU. Significant users in the remaining sectors included sixteen golf courses in recreation, Pennsylvania State University in other, and Glenn O. Hawbaker in mining.

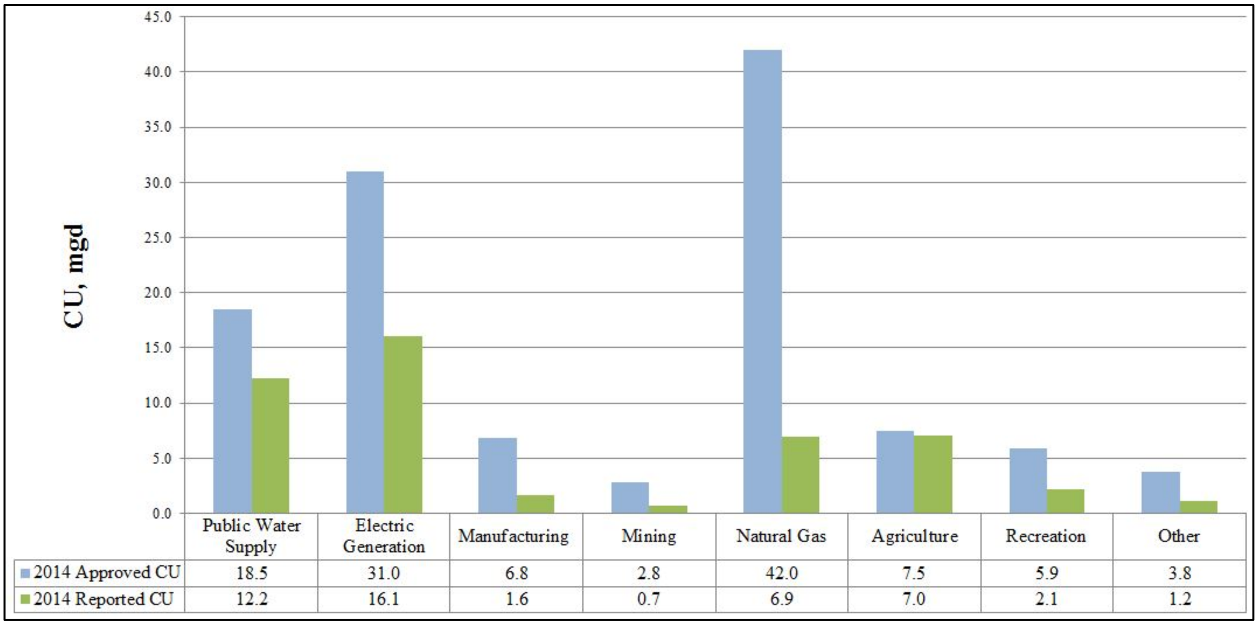
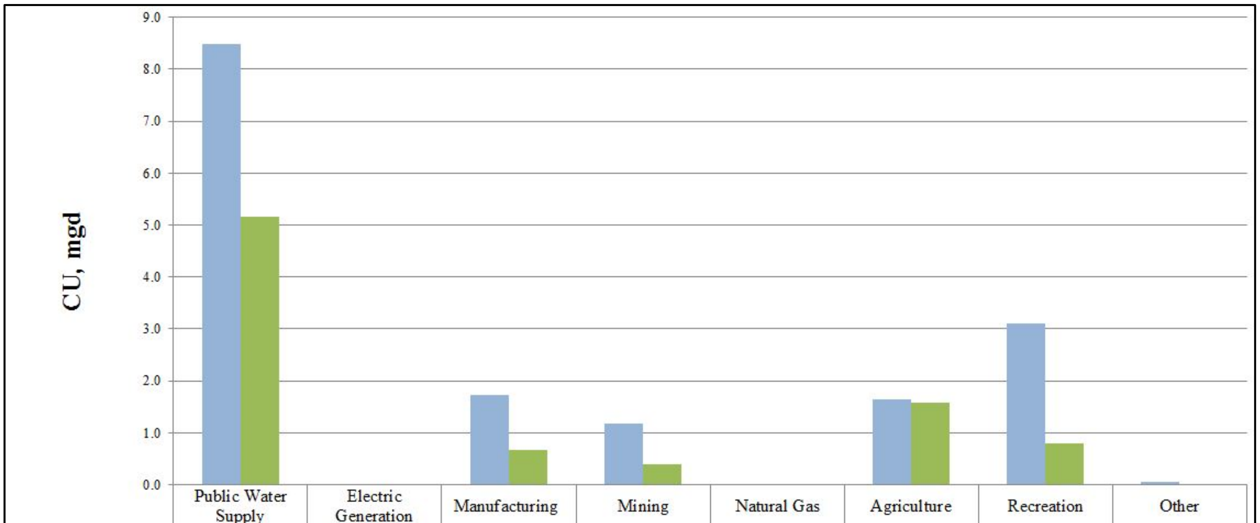



**Figure 2-11. Consumptive Use by Sector in the West Branch Susquehanna Subwatershed**

## Juniata Subwatershed

In 2014, the Juniata subwatershed contained 16.2 mgd of approved CU with 8.6 mgd or 53 percent actually reported. Approved CU in this subwatershed was mostly allocated for the PWS sector (52 percent) with the recreation (19 percent) and manufacturing (11 percent) sectors following (Figure 2-12). Agriculture (10 percent) and mining (7 percent) were the remaining sectors using significant amounts of water. Natural gas and electric generation sectors were not present in this subwatershed. PWS also had the highest reported CU at 5.2 mgd, while agriculture was the only other sector to report more than one mgd.

CU for PWS, although the highest use sector in this subwatershed, was still relatively small compared to other subwatersheds. The top five PWS systems were Altoona, State College (has sources in both Juniata and West Branch subwatersheds), Lewistown, Huntingdon, and Berlin. These 5 municipalities accounted for 67 percent of the approved and 65 percent of the reported CU. Altoona, State College, and Lewistown were the only PWS systems with greater than one mgd of approved CU. Altoona was the only system that reported more than one mgd of CU. The recreation CU was comprised of 11 golf courses. Lewistown Country Club was the only golf course approved to use more than 0.5 mgd and two, Park Hills and Scotch Valley Country Clubs, reported more than 0.1 mgd. Standard Steel and the Coca-Cola Company were the sole manufacturing facilities approved for 0.5 mgd or greater. Standard Steel (0.6 mgd) was the only facility reporting more than 0.1 mgd. The agriculture sector CU included 39 operations, two using more than 0.1 mgd of CU and none using more than 0.5 mgd. However, this sector did report the second most CU throughout the subwatershed. Four mining facilities using nine quarries combined for 1.2 mgd of approved and 0.4 mgd of reported CU. New Enterprise Stone and Lime Company had the most approved and reported CU for this sector at 61 and 43 percent, respectively.



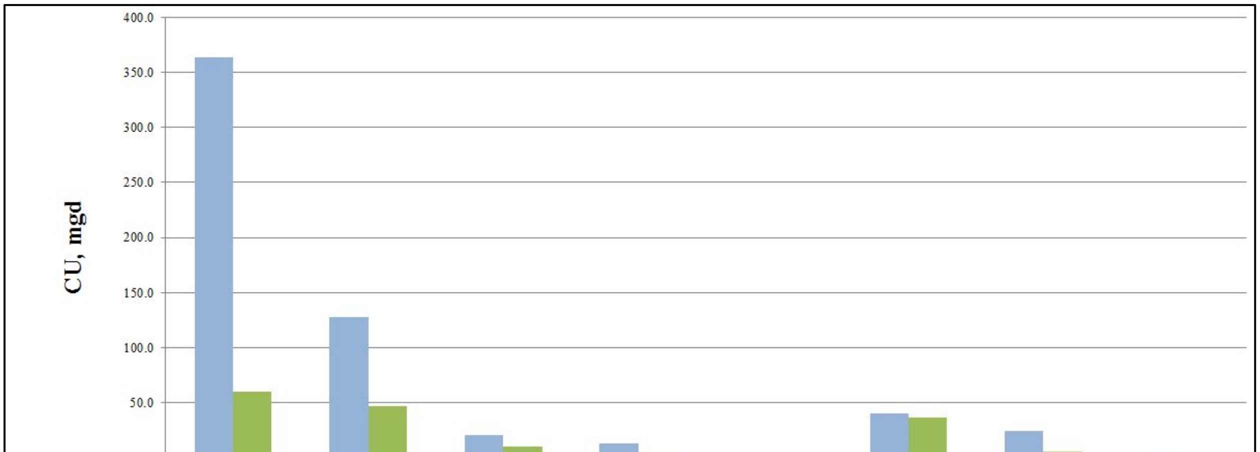

| | Public Water Supply | Electric Generation | Manufacturing | Mining | Natural Gas | Agriculture | Recreation | Other |
|---|---|---|---|---|---|---|---|---|
| 2014 Approved CU | 8.5 | 0.0 | 1.7 | 1.2 | 0.0 | 1.6 | 3.1 | 0.1 |
| 2014 Reported CU | 5.2 | 0.0 | 0.7 | 0.4 | 0.0 | 1.6 | 0.8 | 0.0 |

**Figure 2-12. Consumptive Use by Sector in the Juniata Subwatershed**

### Lower Susquehanna Subwatershed

Approved CU in the Lower Susquehanna subwatershed totaled 593.1 mgd in 2014, with reported CU accounting for less than 30 percent at 163.8 mgd. The PWS and electric generation sectors far outweighed other classes combining for 83 percent of the approved CU (Figure 2-13). It is important to note that a 250 mgd diversion for the City of Baltimore was included in the approved CU results for PWS, however, it did not operate in 2014 explaining the large disparity between approved and reported quantities. Agriculture (7 percent) was the only other sector using greater than five percent of the approved CU. Overall results for reported CU were much lower, but PWS (36 percent) and electric generation (29 percent) remained the top two categories followed by agriculture (22 percent) and manufacturing (6 percent).

With the City of Baltimore diversion included, PWS was by far the largest sector in terms of approved CU. Chester (60 mgd), York (8.1 mgd), Lancaster (7.4 mgd), and United Water Harrisburg (3.3 mgd) rounded out the top five systems. These 5 systems accounted for 90 percent of the approved and 71 percent of the reported CU. Electric generation had the second highest approved and reported CU total. Sixteen electric generation facilities accounted for all approved CU in this sector. Exelon Generation's Peach Bottom (49 mgd) and Three Mile Island (19.2 mgd) nuclear power plants, coupled with Brunner Island Steam Electric Station (23.1 mgd) were responsible for 72 percent of the approved and 81 percent of the reported CU. Agriculture, comprised of 165 facilities, had the third highest CU. Sterman Masser and Huntsinger Farms were responsible for 50 percent of the agricultural CU. Although recreation, manufacturing, and mining did not account for more than five percent of the CU in this subwatershed, results were significant when compared to other subwatersheds. Forty-five percent of watershed wide approved CU for recreation and manufacturing was allocated in this subwatershed. A total of 71 golf courses made up 90 percent of the approved and nearly all of the reported recreational CU. Close to 90 different manufacturing facilities contributed to the 20.5 mgd total in this sector with the Hershey Company, Arcelormittal Steelton, and P.H. Glatfelter being the largest users. Mining in this subwatershed was more than all of the other subwatershed totals combined. In all, there were 21 companies utilizing over 30 quarries with Old Castle Materials and WMPI PTY approved for over three mgd each. Only the Continental Mine and Hempt Brothers reported over one mgd of CU.




| | Public Water Supply | Electric Generation | Manufacturing | Mining | Natural Gas | Agriculture | Recreation | Other |
|---|---|---|---|---|---|---|---|---|
| 2014 Approved CU | 363.5 | 127.6 | 20.5 | 13.1 | 0.1 | 40.1 | 24.1 | 4.1 |
| 2014 Reported CU | 59.4 | 47.0 | 9.6 | 4.7 | 0.0 | 36.6 | 5.4 | 1.0 |

**Figure 2-13. Consumptive Use by Sector in the Lower Susquehanna Subwatershed**

## 2.7 ANIMAL LIFE

### Benthic Invertebrates

Benthos are the community of organisms that live within the water column or on the bottom sediment of water bodies. Benthos includes mobile and immobile organisms. Benthic invertebrates are often used as indicators of water quality and ecological health due to their abundance, known pollution tolerances, and limited mobility. A healthy benthic community includes species characteristic of unstressed communities. In a polluted environment, these species would be replaced by species more tolerant of pollution. Most degraded communities would also tend to have fewer species, fewer large organisms deep in the sediment, and a lower total mass of organisms (Versar, 2013).

At least a dozen native mussel species occur in the Susquehanna River watershed. Native mussels have a variety of traits related to habitat and velocity preference, body size, longevity, length of brooding, timing of spawning, glochidia (larval) release, and use of host fish. In general, mussel species have been undersampled in the Susquehanna River watershed compared to other watersheds, and as a result, little is known about them. Extreme low flow events increase the risk of exposure and predation of mussel beds. Significantly reduced flows may cause local extirpation or reduced growth. Changes to the timing and amount of high flows can lead to habitat degradation and may reduce opportunities for mussel species to interact with migrating fish, which disperse mussel larva and eggs throughout the watershed. Mussels were grouped into three categories to define their flow needs: primarily riverine species, facultative riverine species, and primarily lentic species.

Key flow needs for selected species are described in the TNC (2010) technical report and summarized below:

- Extreme low flows increase risk of exposure and predation of mussel beds.
- Significantly reduced flow magnitudes may cause local extirpation or reduced growth.
- Drought can reduce individual fitness of mussels, even though some mussel species may be drought tolerant.
- Increased magnitude and frequency of high flow events can lead to habitat instability, reduced recruitment, and reduced carrying capacity of mussel habitat.
- Decreased magnitude or frequency of high flows can lead to habitat degradation, including embeddedness, lack of appropriate substrate size, and aggrading channel morphology.
- During spawning season and glochidia release, flows are needed to facilitate host fish interaction and glochidia distribution.
- Increased high flows in spring or decreased low flows in summer may reduce host fish availability.
- Natural flow regimes can reduce risk of establishment of non-native mussel species.

### Aquatic Insects

Aquatic insects are key indicators of ecosystem health. The chemistry and temperature of streams control macroinvertebrate functions such as ion regulation, growth, and reproduction. Flows also help to control food availability. Healthy streams have diverse, well-balanced, and functioning insect communities. Quantitative and qualitative responses of species that share functional traits and/or assemblage metrics in other river systems were used to set expectations about flow needs for aquatic insects. Functional traits used to help set ecosystem flow needs included: life history, mobility, morphology, and ecology. The expected or reported response of assemblage metrics to changes in flow were also used to set ecosystem flow needs. Assemblage metrics used to define ecosystem flow needs included: abundance, species richness, Hilsenhoff Biotic Index (HBI), and EPT richness (Ephemeroptera, Plecoptera, and Trichoptera).

Key flow needs for aquatic insect species are outlined in the technical report (TNC 2010) and are summarized below:

- Groundwater flow through hyporheic zones provides refugia for aquatic insects.
- Winter baseflows need to be maintained for winter emerging species.
  Flow depletion can reduce macroinvertebrate density and richness, abundance of sessile, rheophilic, large-bodied, filter feeding and grazing taxa, and shift communities to tolerant taxa.
- Rapid wetting and drying leads to loss of benthic biomass.

- Summer baseflows provide thermal refuge for cold-water dependent taxa (stenothermal).

**Finfish**

Surveys and collection records dating to the 1800s indicate that nearly 120 fish species in 26 families occur within the watershed. Two species are thought to be extirpated from the watershed.

Migratory fish include both anadromous and catadromous species. Anadromous fish, such as American and hickory shad, blueback herring, and alewife, spawn in fresh water, with the juveniles migrating to brackish or salt water to grow and mature into adults. American eel, the only catadromous species in the watershed, spawns in deep waters of the Sargasso Sea near Bermuda (people have identified eel larvae in the Sargasso Sea; so their spawning areas have long been inferred, but no adult eel has ever been observed migrating in the open sea or on the presumed spawning grounds). Young American eels ride the Gulf Stream north and enter rivers on the east coast of North America, where they grow and mature into adults (SRBC, 2016).

The four dams (York Haven, Safe Harbor, Holtwood and Conowingo) on the lower Susquehanna River form manmade fish blockages which are probably the most important in the Chesapeake Bay watershed, having essentially eliminated access to the Susquehanna River watershed for migratory fish ascending or descending the river to the Bay. Migratory fish species affected include various species of shad and river herring, as well as American eel (*Anguilla rostrata*). The Pennsylvania Fish and Boat Commission (PFBC) (2011) report provides a full species list.

Construction of the dams contributed to regional declines of the populations of the migratory fish that formerly made use of upstream river habitat in much greater numbers than today. All three dams have fish passage projects in place to reduce the impacts of the dams to fish migration patterns. Improving passage of migratory fish through the dams is a topic of ongoing concern in relicensing of the Conowingo Dam hydropower (CBP, 2013).

Key flow needs for finfish species are described in the TNC (2010) technical report and are summarized below:

- Extreme low flows reduce availability of high velocity habitats and may decrease abundance of riffle-dwelling fishes and species with small home ranges.
- Seasonal flows maintain connectivity among stream habitats, especially during spring and fall spawning periods, and provide access to thermal refugia during summer.
- A decrease in summer and early fall flows may reduce access to shallow, slow velocity nursery habitats in margins and backwaters.
- High seasonal flows are needed to maintain habitat, and keep redds (fish spawning nests) sediment-free, but flows cannot be so high that they scour and flush eggs from redds.
- Winter baseflows are needed to provide thermal refuge and fall high flow pulses to cue adult eel out-migration and summer baseflows provide lower velocities conducive to elver upstream migration.

- High seasonal flows are needed to provide velocities sufficient for shad migration and spawning in the spring and to facilitate juvenile out-migration in the fall; flows that are too high can inhibit migration.

### Amphibians and Reptiles

At least 35 species of reptiles and amphibians, including 12 species of salamanders, 2 toads, 9 frogs, 8 turtles, and 4 snakes use riverine and riparian habitats in the watershed during various life stages. Fourteen species were selected to represent reptile and amphibian life history traits, and these species can be organized into five groups: aquatic-lotic species; semi-aquatic lotic species; riparian species; floodplain-terrestrial species; and vernal habitat species. Aquatic-lotic species are expected to be the most sensitive to changes in flow regime because they depend on flowing waters for all of their life stages (TNC, 2010).

Key flow needs for amphibians and reptiles are described in the TNC (2010) technical report and are summarized below:

- Winter and spring high flows fill vernal pools and intermittent streambeds used for amphibian breeding and egg and larval development.
- Several species are particularly sensitive to increased frequency and duration of low flow events, which can increase temperature and sediment concentrations, and decrease dissolved oxygen.
- Decreases in winter flows and/or increased flashiness could expose or destabilize stream beds, banks, and channel margins that several turtles and amphibians use for overwinter habitat.
- Flood events are required to maintain floodplain habitats (sediment texture and vegetation) for turtle nesting and amphibian and reptile burrowing sites.

### Birds and Mammals

Birds and mammals rely on floodplains and riparian forests maintained by seasonal flooding for food and habitat. Many of the bird species found throughout the Susquehanna River watershed use these areas for nesting and breeding. As such, these species may respond directly or indirectly to the availability of food sources or vegetation caused by streamflow changes. For example, several species depend on seasonal high flows to reduce predator access to dens or nest sites, and flow changes could allow predator access (e.g. muskrat). Seasonal high flows are needed to limit connectivity or land bridges between mainland and island habitats to avoid predatory introduction to bird rookeries. Many bird and mammal species also rely on seasonal riparian and floodplain inundation to maintain their habitats, and flow changes could affect their normal reproduction, development, and survival. For example birds and mammals need access to aquatic food resources, including macroinvertebrates, small fishes, and vegetation (TNC, 2010).

## 2.8 VEGETATION

The distribution and structure of aquatic, riparian, and floodplain vegetation are driven by river flows and associated geomorphology, soil and water chemistry. Other factors affected by streamflows include seed dispersal and soil moisture. Juvenile fish and macroinvertebrates depend on submerged aquatic vegetation as nursery sites, for refuge and a food source. High flow pulses help to maintain wetland vegetation in headwaters and small streams, while decreased flow can desiccate plants. Ice scour associated with high winter flows can promote early succession of vegetation, and spring high flows can control encroachment of woody vegetation.

Wetland and riparian plant communities can be impacted by lowered groundwater levels and reduced flow. Riparian vegetation provides shade to help moderate daily fluctuations in water temperature. Leaf litter and other detritus from riparian vegetation serve as important food sources for aquatic insects and other organisms that fish utilize as a food source. Both wetland and riparian vegetation help regulate biogeochemical cycles, influence water quality, help moderate the duration and magnitude of flooding, and provide food, cover, nesting sites, and migration corridors for a variety of fish and wildlife species (SRBC, 2016).

Vegetation grouped as: submerged and emergent bed, herbaceous, scrub-shrub, and floodplain forest and their ecosystem flow needs are depicted in (Figure 2-14).

Key flow needs for selected communities are outlined in the technical report (TNC 2010) and summarized below:
.

- Increases or decreased in duration of inundation may encourage community transition along the inundation gradient.
- Juvenile fish and many macroinvertebrate species depend on submerged and emergent aquatic vegetation.
- High flow pulses maintain wetland vegetation in headwaters and small streams.
- Decreased flow magnitude can lead to desiccation of submerged, emergent, and riparian vegetation.
- During winter, high flow events and associated ice scour promote early successional vegetation.
- Small and large floods maintain habitat structure and diversity.
- Spring high flows reduce encroachment of woody vegetation.

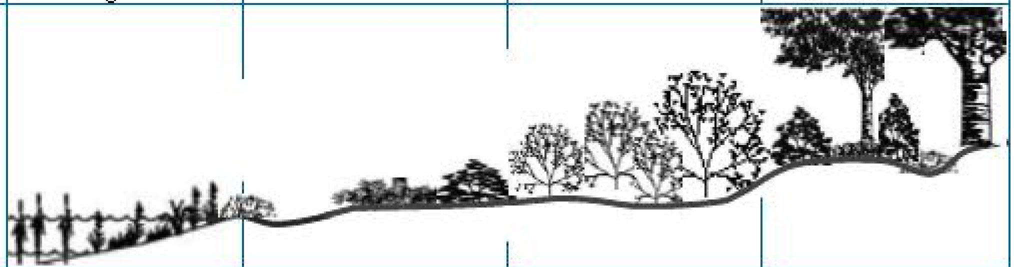
| | Submerged and Emergent Bed | Herbaceous Community | Scrub-Shrub Community | Floodplain Forest |
|---|---|---|---|---|
| **Elevation Gradient** Lateral Position and Distance from Active Channel |  | | | |
| | | | | |
| **Disturbance Gradient** Severity of Flood and Ice Scour | **Severe** | **Severe to Moderate** | **Moderate** | **Moderate to Low** |
| | | | | |
| **Inundation Gradient** Inundation Duration | **Semi-permanent** | **Seasonal to Temporary Flooding** | **Seasonal to Temporary Flooding** | **Temporary Flooding** |
| | | | | |
| **Example Communities** | River weed (*Podostemum ceratophyllum*) | Indian grass (willow) riverine shrubland (*Sorghastrum nutans*) | Speckled alder – dogwood riverine shrubland (*Alnus rugosa, Cornus florida*) | Sycamore floodplain forest (*Platanus occidentalis*) |
| | Water willow emergent bed (*Justicia americana*) | Sedge-spotted joe-pye weed riverine herbaceous vegetation | Mixed hardwood riverine shrubland (*Platanus* spp., *Acer* spp., *Betula* spp.) | Sycamore mixed hardwood floodplain forest (*Betula nigra*) |
| | Lizard's tail emergent bed (*Saururus cernuus*) | Riverside scour vegetation | Black willow slackwater shrubland (*Salix nigra*) | Silver maple floodplain forest (*Acer saccharinum*) |

**Figure 2-14. Examples of Aquatic, Riparian, and Floodplain Communities Along Elevation, Disturbance, and Inundation Gradients.**

## 2.9 CLIMATE

The Susquehanna River watershed possesses a sub-temperate and humid climate. Continental weather conditions include cold winters with snow events and warm to hot summers. Within the watershed, precipitation and temperature are largely influenced by latitude and elevation. Both precipitation and temperature increase from north to south and from west to east. Average annual air temperatures are approximately 44°F in the northern portion of the watershed and 53°F in the southern portion. Average annual precipitation in Susquehanna River watershed ranges from approximately 33 to 49 inches. An estimated 52 percent of this total precipitation is lost by evapotranspiration; the remaining 48 percent infiltrates to groundwater or results in overland flow and streamflow runoff (SRBC, 2013a).

Across the Susquehanna River watershed, precipitation events can be severe, ranging from localized thunderstorms to regional hurricanes. Storms that generate flooding in the study area include northeasters and tropical storms. Northeasters can produce precipitation for a duration of up to several days, and occur most frequently between December and April. Tropical storms produce intense runoff over a shorter period of time, usually occurring between July and October.

Climate trends in the last two decades have shown wetter conditions on average, than in previous decades. Increased precipitation has produced higher annual minimum flows and slightly higher median flows during summer and fall (Najjar et al., 2010).

Long-term climate analysis indicates that overall, temperatures in the region are increasing and will continue to do so. Future impacts of various climate events are uncertain, especially on a regional scale, but temperatures in the region are widely expected to warm throughout the 21st Century. Annual precipitation is also likely to increase, as will winter precipitation, with less precipitation in the form of snow. With warming temperatures, more precipitation may be rain on snow, which will cause snow to melt faster, potentially changing stormwater regimes in the watershed. By the late 21st Century, the region should see a 3 to 5 week longer growing season, with increased evapotranspiration. Weather in the watershed may become more extreme, with longer dry periods and more intense storms. Research also suggests there will be fewer, more intense tropical storms (Shortle et al., 2009). Projected increases in air temperature and alteration to hydrologic systems due to climate change and other anthropogenic sources are expected to have a significant impact on stream temperature (O'Neil, 2013).

Changes to any of the significant variables (air temperature, groundwater, shading, travel time, and urban area) in a watershed are likely to result in alteration of the stream temperature regime. Climate change, logging, land development, and streamflow regulation are just some of the possible anthropogenic influences that target these vulnerabilities (O'Neil, 2013).

## 2.10 THREATENED, AND ENDANGERED SPECIES

Endangered species are animals and plants that are in danger of becoming extinct. Threatened species are those that are likely to become endangered in the foreseeable future. Table 2-4 provides a list of state and federally listed threatened and endangered species in the Susquehanna River watershed. This is based on a web search of the U.S. Fish and Wildlife Service (USFWS), PAFBC and the New York State Department of Environmental Conservation (NYSDEC) websites:

http://www.fws.gov/ /pafo/endangered_species_list.html
http://www.pgc.pa.gov/Wildlife/EndangeredandThreatened/Pages/default.aspxhttp://www.dec.ny.gov/animals/7494.html

**Table 2-4. State and Federally Listed Endangered Species**

| Species (Common Name | Scientific Name | Endangered (E) or Threatened (T) Designation | Federally listed? | State Listed? |
|---|---|---|---|---|
| Indiana Bat | *Myotis sodalist* | E | Yes | No |
| Bog Turtle | *Clemmys muhlenbergii* | T | Yes | No |
| Northern Long Eared Bat | *Myotis septentrionalis* | T | Yes | No |
| Atlantic Sturgeon, | *Acipenser oxyrhynchus* | E | Yes | No |
| Northern Redbelly Dace, | *Chrosomus eos* | E | No | Yes, PA |
| Bald Eagle | *Haliaeetus leucocephalus* | T | No | Yes, NY |
| Tadpole Madtom | *Noturus gyrinus* | E | No | Yes, PA |

## 2.11 RECREATION

Public lands and boat access points are found throughout the watershed, with the greatest concentration of state forest land being found in the West Branch Susquehanna Subwatershed, as well as in areas to the north. Additional maps depicting public lands, boat access points, water trails, and other watershed features are included in the Map and Data Atlas on SRBC's web site http://srbc.net/atlas/. Additional water use information is also included on the web site, along with SRBC's 2013 State of the Susquehanna Report (SRBC, 2016).

The watershed's resources provide residents and visitors with excellent opportunities for outdoor, water-based or oriented recreation. Fishing, waterfowl hunting, boating, swimming, hiking, camping, and bird watching are among the activities that can be enjoyed. Recreational features include 79 state parks available for use on approximately 181 square miles (115,562 acres) of public lands, having an estimated 397 miles of streams.

More than 522 public boat launches along the Susquehanna River and its major tributaries offer excellent access to the waterways. There are 12 designated "Water Trails" in the watershed, totaling a length of 984 miles. Forty-two moderate to large lakes in the watershed offer nearly 57,000 acres of surface area. In addition to parks, waterway access and lakes, there are 154 public forests and 154 game lands in the watershed, encompassing a total of almost 4,500 square miles of land, respectively. There is an estimated 6,500 miles of streams within the public forests and game lands (SRBC, 2016).

The 54 mile Susquehanna River trail flows from Sunbury to Harrisburg, incorporating 22 campsites on 20 islands designated for day use and primitive camping. Access sites are trail heads with enticing, naturalistic signage welcoming visitors to the River Trail. Canoeing and kayaking are promoted as great ways to experience this unique wilderness. The River Trail is managed as a partnership of the PA

Department of Conservation & Natural Resources, the PA Fish & Boat Commission, and the nonprofit Susquehanna River Trail Association, Inc. (SRTA).

The National Park Service developed a Chesapeake Watershed Public Access Plan, prepared in 2013. This plan reflects public access to significant streams, rivers, and bays in the entire Chesapeake Bay watershed, including the Susquehanna River. The plan recognizes and documents a series of planning and policy considerations that will influence a strategic approach to expanding public access. In addition, it sets out a series of actions for moving access development forward. The evaluation includes access improvement opportunities in the Susquehanna River watershed (NPS, 2013).

Designated water trails throughout the Susquehanna Watershed can be looked at in more detail in the websites below:

http://findyourchesapeake.com/places/chemung-watershed-river-trail

http://findyourchesapeake.com/places/juniata-river-water-trail

http://findyourchesapeake.com/places/susquehanna-river-water-trail-lower-section

http://findyourchesapeake.com/places/susquehanna-river-water-trail-middle-section

http://findyourchesapeake.com/places/susquehanna-river-water-trail-north-branch

http://findyourchesapeake.com/places/susquehanna-river-water-trail-west-branch

http://findyourchesapeake.com/places/swatara-creek-water-trail

http://www.fish.state.pa.us/watertrails/trailindex.htm

Ultimately recreation is an important consideration when planning any flow augmentation in the watershed. Low flow conditions can lead to elevated water temperatures and increased algal growth that also can impact recreational use (SRBC, 2016).

## 2.12 ENERGY

The Susquehanna watershed is home to multiple energy sources, including: nuclear power plants, fossil-fuel plants, hydroelectric facilities, pumped storage facilities, as well as green energy facilities (solar, wind). Nuclear and fossil fuel facilities account for 79 percent of the power generated in the watershed and have the highest associated CU. The remaining 21 percent of power produced is from facilities that have little or no associated CU, including hydroelectric and pumped storage facilities. While hydroelectric facilities typically have little or no CU associated with their operation, they do have significance to water resources given their potential to impede fish migration and manipulate and modify natural flow regimes.

According to United States Energy Information Administration database (USEIA, 2014) 96 operating electric generation facilities exist within the Susquehanna watershed. Of the 96, 26 have associated water use approvals and account for 75 percent of the total power production in the Watershed. The maximum electric generation output that could be sourced from within the Watershed is 16,362 megawatts (MW) (USEIA, 2014).

The Lower Susquehanna subwatershed accounts for 63 percent of the total electric generation capacity and 59 percent (121 mgd) of the total approved water use for electric generation (EIA 2014). Nuclear (30 percent), natural gas (22 percent), and coal (21 percent) make up the majority of power production within this subwatershed. A total of 8 facilities within the Lower Susquehanna subwatershed have generating capacities that exceed 500 MW. Two of these facilities, Exelon's Peach Bottom and Three Mile Island Nuclear facilities, have a combined capacity to generate up to 3,056 MW. The third highest power producing facility in the Lower Susquehanna subwatershed is Exelon's Muddy Run pumped storage facility. The pumped storage facility is unique as water is pumped from Conowingo Reservoir during non-peak hours into Muddy Run reservoir and is released, turning turbines for power, during peak power demand. Four hydroelectric facilities, with a combined capacity of 1,306 MW are located in the Lower Susquehanna subwatershed; and include Conowingo, Holtwood, Safe Harbor, and York Haven facilities. In total, 12% of the power production in the Lower Susquehanna is sourced from hydroelectric power.

The Middle Susquehanna subwatershed provides 20% of the Watersheds generating capacity and accounts for 25 percent (52mgd) of the approved water use. Within the Middle Susquehanna subwatershed, Susquehanna Steam Electric Station is responsible for 77% of the electric generation; the remainder is comprised of 5 natural gas facilities, and a combination of small scale petroleum, wind, solar, and biomass fueled facilities. The West Branch Susquehanna subwatershed contains less electric generation capacity and approved water use than the Middle Susquehanna subwatershed at 14% and 15% (31 mgd) respectively. Approximately 92% of the electric capacity within the West Branch Susquehanna subwatershed is generated from NRG REMA LLC's Shawville plant and Montour Steam Electric Station.

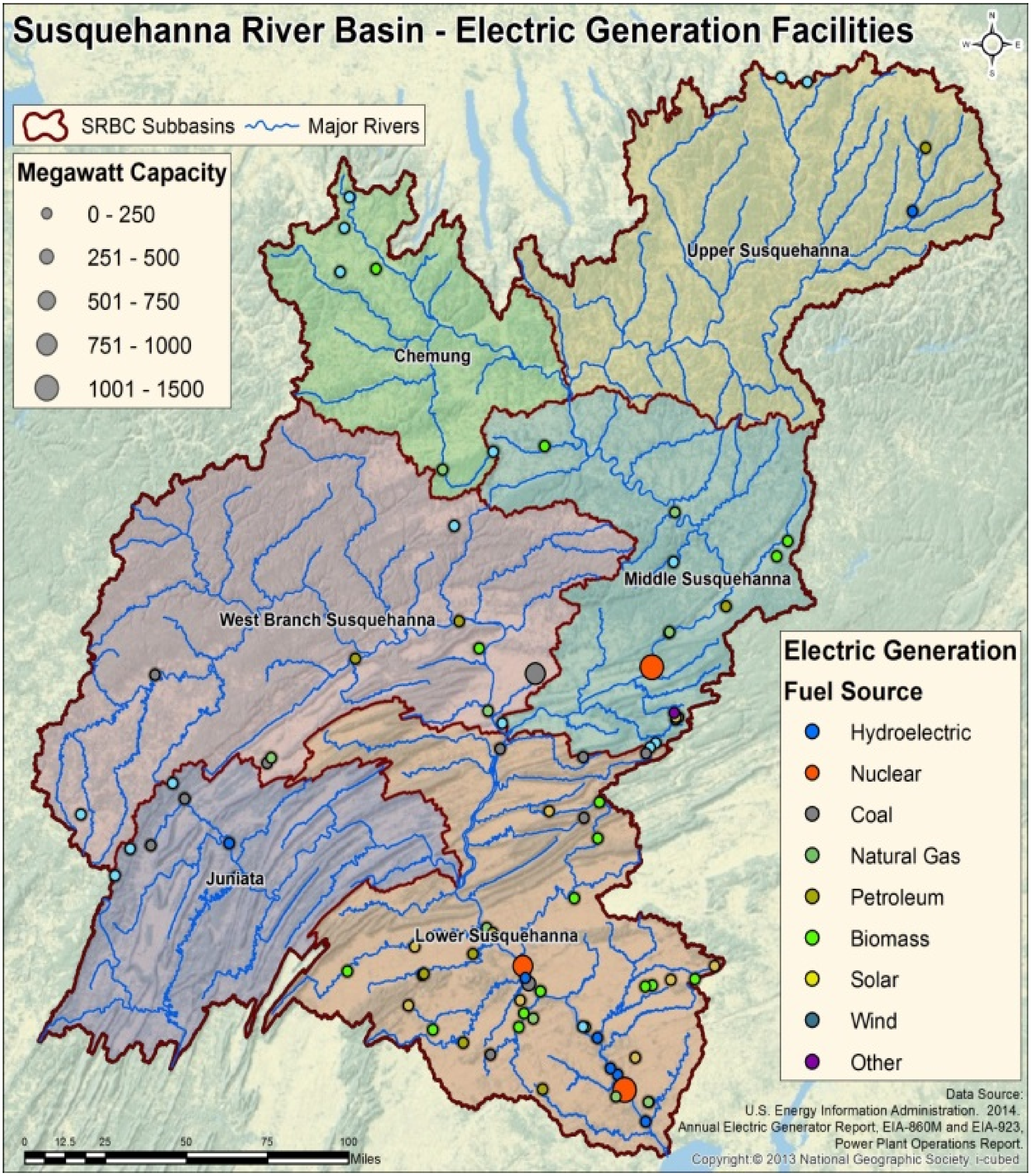



**Figure 2-15. Electric Generation Facilities by Fuel Source.**

The lowest quantities of generating capacity, at less than two percent of the Watershed total, are found within the Chemung, Juniata, and Upper Susquehanna subwatersheds. Electric generation facilities existing within these subwatersheds are generally small scale (less than 100 MW) wind powered facilities. Up to 90 percent of the watersheds' wind power exists here. Other than wind power, a total of three hydroelectric facilities are located within these subwatersheds. The Warrior Ridge Dam and Hydroelectric Plant and William F. Matson facilities are located on the Juniata River and Raystown Branch of the Juniata River respectively, with a combined generating capacity of 10.4 MW. Although, not a significant power producer, Goodyear Lake (Colliersville) hydroelectric facility is located in the Upper Susquehanna watershed on the Susquehanna River at the outlet of Goodyear Lake.

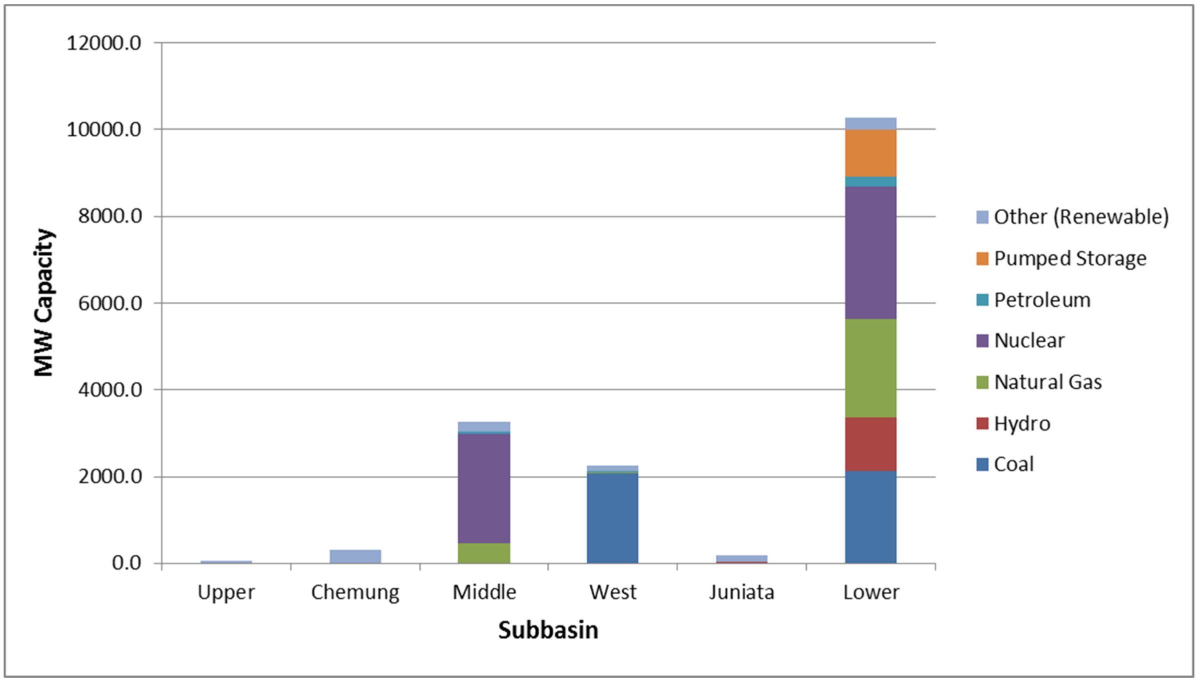



**Figure 2-16. Electric Generation Fuel Sources by Watershed.**

The natural gas industry relies on watershed resources primarily in the extraction of natural gas using unconventional hydraulic fracturing techniques. The average amount of water withdrawn for hydraulic fracturing processes has ranged from approximately 2,040 million gallons (MGal) in 2010 to approximately 4,065 Mgal in 2014. Currently natural gas is predominantly produced in the Upper, Chemung, Middle and West Branch Susquehanna subwatersheds. Industry withdrawals are typically intermittent and short-term which reflect seasonally available water, hydrofracturing schedules, and hydrofracking water volume needs to insure enough storage is built up for a hydrofracturing job. From 2010-2014, reported withdrawals occurred, on average, 93-150 days a year (Table 2-5.)

**Table 2-5. Reported Natural Gas Water Use and Well Fracturing Rates: 2010-2014**

| Year | Wells Fractured Annually | Reported Use (mg) | Average Days Withdrawal Occurred | Reported Use (mgd) [1] | Reported Use (mgd) [2] |
|---|---|---|---|---|---|
| 2010 | 449 | 2071.6 | 150 | 12.500 | 5.591 |
| 2011 | 793 | 3218.7 | 138 | 19.100 | 7.972 |
| 2012 | 812 | 2711.7 | 112 | 25.200 | 7.429 |
| 2013 | 631 | 2800.3 | 93 | 24.500 | 7.669 |
| 2014 | 568 | 4065.0 | 131 | 27.200 | 11.071 |

[1] Reported use (mgd) rate calculated by average days individual sources were used per year. [2] Reported use rate calculated as an annual rate (averaged over 365 days per year).

# Chapter 3. Examination of Ecological Flow Management Options

This section will identify and assess options to provide ecological flow augmentation to improve ecosystem health during low flow periods in the Susquehanna River. Options include ecological flow augmentation in Federal, state and private reservoirs, acid mine drainage pools, structural options, programmatic options, operational options, and regulatory options.

## 3.1 FEDERAL RESERVOIRS

There are 14[3] USACE-constructed reservoirs and one state-constructed reservoir (15 total) within the Susquehanna River Watershed portion of the Baltimore District (See Figure 3-1 for locations and 3-2 for photos of each). Appendix A provides more description of each of these reservoirs. These reservoirs provide a total storage capacity of about 1.5 million acre-feet (488 billion gallons) (total storage at the spillway). These reservoirs are operated primarily for flood risk management, although several projects are also authorized for other purposes such as water supply, low flow augmentation, water quality control, recreation, and non-Federal hydroelectric power generation. Releases from some reservoirs are also made to dilute abandoned mine drainage (AMD) during low flow periods.

The cumulative hydrologic impact on the magnitude of floods and droughts is tempered by the location of these dams on small to medium-sized streams throughout the watershed. About half of these reservoirs are on headwater and small streams, with upstream watersheds ranging from 6 to about 125 square miles. Most of the other reservoirs are located on medium-sized tributaries with drainage areas ranging from about 200 to 400 square miles. The largest reservoir (Raystown Lake) has a tributary drainage area of 960 square miles. The collective drainage upstream of these reservoirs is about 3,306 square miles or roughly 12 percent of the entire Susquehanna River Watershed that drains a total of 27,510 square miles.

During low flow periods, reservoir operating procedures sometimes dictate the production of outflows that are equal to or larger than inflows. There may be additional low flow augmentation opportunities at some of these reservoirs. Provided that authorized project purposes are not compromised and the effects of altered releases are thoroughly understood, optimally managed reservoir releases can be a component of an ecologically sensitive water management plan.

The following sections furnish brief descriptions of the federally managed reservoirs along with assessments of potential opportunities to provide flow augmentation during low flow conditions

[3] Tioga-Hammond are separate dams/reservoirs but the reservoirs are joined by a connecting channel through a ridge. Due to proximity they are discussed together and are enumerated as "13a and 13b."

(Table 3-1). Appendix A provides a matrix displaying detailed physical and operational data about each of the reservoirs in more detail.

## Upper Susquehanna River Subwatershed

The Upper Susquehanna River Subwatershed covers about 4,900 square miles lying mostly in southcentral New York and northeastern Pennsylvania. Major tributaries include the Chenango, Tioughnioga, and Unadilla Rivers. Most of the subwatershed is steeply sloped with hills and ridges dominated by forest land. The Binghamton/Vestal/Endicott/Johnson City metropolitan complex straddles the Upper Susquehanna River and is prone to repeated flooding. Other major communities include Cortland and Oneonta. About 500,000 people reside in the Upper Susquehanna River Subwatershed. There are two Federal reservoirs (East Sidney Lake and Whitney Point Lake) within this subwatershed as well as numerous Federally-constructed local flood risk management projects (levees and floodwalls).

### (1) East Sidney Lake (#1 on Figure 3-1):

**Authority and Purpose:** East Sidney Lake is a unit of the comprehensive flood risk management plan for the protection of communities in southern New York and northeastern Pennsylvania. The project was authorized by the Flood Control Act of June 22, 1936, as amended by the Flood Control Act of June 28, 1938, and is described in House Document No. 702, 77th Congress, 2nd session. The primary project purpose is flood risk management; recreation was added later as a secondary or incidental project purpose.

**Existing Features and Operations:** East Sidney Dam is located on Ouleout Creek about six miles upstream from Unadilla in Delaware County, New York. The dam controls a drainage area of 102 square miles. It consists of a concrete gravity structure with earth and rockfill wings, rising about 130 feet above the streambed. The project was operationally complete in April 1950. At spillway crest elevation 1,203.0 feet project construction datum (PCD), East Sidney Lake contains a storage volume of 33,013 acre-feet and covers 1,110 acres. The project is currently managed to provide a summer conservation pool for recreation at elevation 1,150.0 feet PCD', with a winter drawdown of 10 feet to elevation 1,140.0 feet PCD' for additional flood control storage. At summer conservation pool levels, the lake contains a storage volume of 2,836 acre-feet and covers 203 acres. The outlet works consists of five gate-controlled conduits through the concrete section of the dam. The project is normally operated for a minimum outflow target of at least 10 cubic feet per second (cfs).

**Recreation:** Recreational facilities were first made available in May 1965. The Town of Sidney currently operates and maintains the East Sidney Recreation Area. Recreational facilities include a swimming beach, picnic area, pavilion, playground, campground, and boat launch. The park is open from Memorial Day to Labor Day. In 2012, approximately 8,400 people visited East Sidney Lake.

**Limitations and Opportunities for Low Flow Augmentation/Management:** Flood storage reallocation is not a feasible alternative at East Sidney Lake due to limits imposed by criteria for passing the Probable Maximum Flood (PMF).

There is, however, a very minor potential for an operational change to provide low flow augmentation. This would be achieved by advancing the 10-foot December drawdown to earlier fall months when flows in the Susquehanna River sometimes approach critical low levels. This potential, however, is extremely limited because there is only about 1,600 acre-feet of storage that is available between the summer and winter conservation pools. For this reason, the overall potential for the existing conservation pool at East Sidney Lake to provide low flow augmentation was judged to be low.

**(2) Whitney Point Lake (#2 on Figure 3-1):**

**Authority and Purposes:** Whitney Point Lake is a unit of the comprehensive flood risk management plan for the protection of communities in southern New York and northeastern Pennsylvania. The project was authorized by the Flood Control Act of June 22, 1936, as amended by the Flood Control Act of June 28, 1938, and is described in House Document No. 702, 77th Congress, 2nd session. As originally authorized, the primary project purpose was flood risk management. In the mid-1960's, recreation was added as a secondary or incidental project purpose. In 2009, the project was further modified to provide flow augmentation releases to improve in-stream aquatic resources downstream of Whitney Point Lake.

**Existing Features and Operations:** Whitney Point Lake is located on the Otselic River in Broome County, New York, about ¾ mile upstream of Whitney Point Village. The dam controls a drainage area of 257 square miles and consists of a rolled earthfill embankment rising 92 feet above the streambed. The project was operationally completed in 1942. At spillway crest elevation 1,010.0 feet PCD', the lake contains a storage volume 84,233 acre-feet and covers 3,231 acres. The project is currently managed to provide a year-round conservation pool at elevation 973.0 feet PCD', with a storage volume of 11,688 acre-feet and a surface area of 1,183 acres. The outlet works consist of an outlet tower and three service gates leading into a single tunnel conduit discharging into the Otselic River. Prior to 2009 and the addition of the flow augmentation purpose, the project was regulated to provide a summer conservation pool at elevation 973.0 feet PCD', with a seasonal drawdown of 7 feet to a winter conservation pool at elevation 966.0 feet PCD'. The project is normally operated for a minimum outflow target of at least 10 cfs.

**Recreation:** The recreational facility is Dorchester Park, operated by the Broome County Department of Parks. Dorchester Park is a day-use facility with no entrance fee. The park has picnic facilities, restrooms, 3 100-person picnic shelters, playground equipment, a 2 mile walking/biking trail, a boat launch, and a swimming beach with certified lifeguards and changing areas. The park also offers group camping for organized youth groups (i.e. church youth groups, schools, YMCA, YWCA, Boys Scouts, and Girl Scouts). Boats are allowed on the lake, but they are limited to a 25 horsepower motor and a maximum speed of 10 m.p.h. Dorchester Park rents canoes, rowboats, paddleboats, sailboats and kayaks. Most recreational activities are offered annually from Memorial Day to Labor Day. The beach is open through October. The boat launch remains open until the lake freezes and then access for ice fishing is allowed during winter months. In 2012, approximately 81,400 people visited Whitney Point Lake.

**Limitations and Opportunities for Low Flow Augmentation/Management:** Flood storage reallocation for the purpose of low flow augmentation is not a feasible alternative at Whitney Point Lake due to limits imposed by criteria for passing the PMF.

The potential for low flow augmentation from within the existing conservation pool at Whitney Point Lake was investigated jointly by USACE and the SRBC in 2001 (USACE and SRBC, 2001). The investigation determined that changes to the project could be made that would improve both the in-lake and downstream aquatic environment. These changes included: elimination of the annual winter drawdown, placement of fish habitat structures, creation of additional wetlands, and dedication of approximately 8,000 acre-feet of conservation storage for making flow augmentation releases when established low flow triggers were observed at either Chenango Forks or Waverly. The changes were implemented in 2009 under the Section 1135 programmatic authority of the Water Resources Development Act of 1986 that allows USACE to modify its projects to restore and enhance environmental quality. No further changes to create additional low flow augmentation opportunities are envisioned at this time.

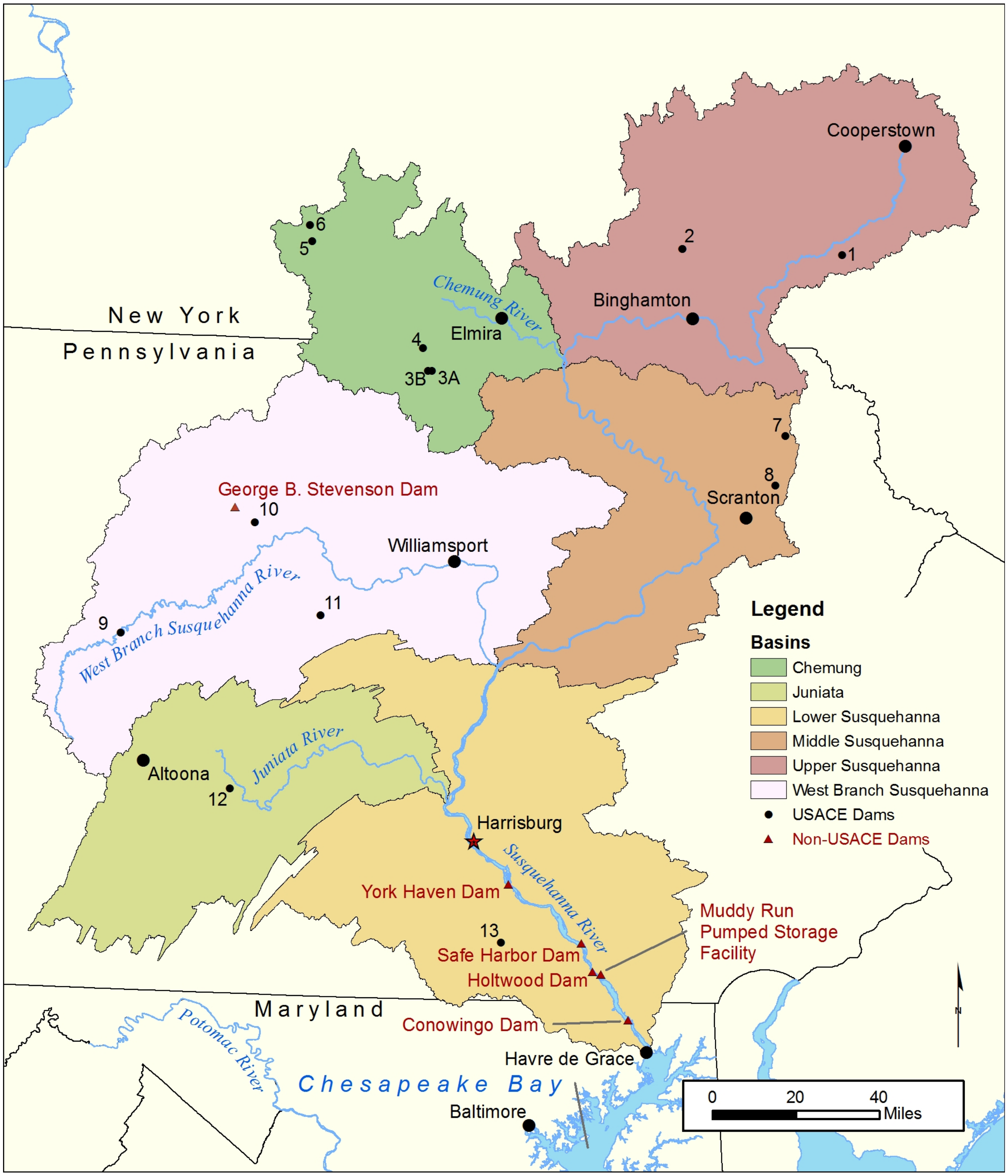



**Figure 3-1. Major nonfederal Flood Control and Hydroelectric Dams.**

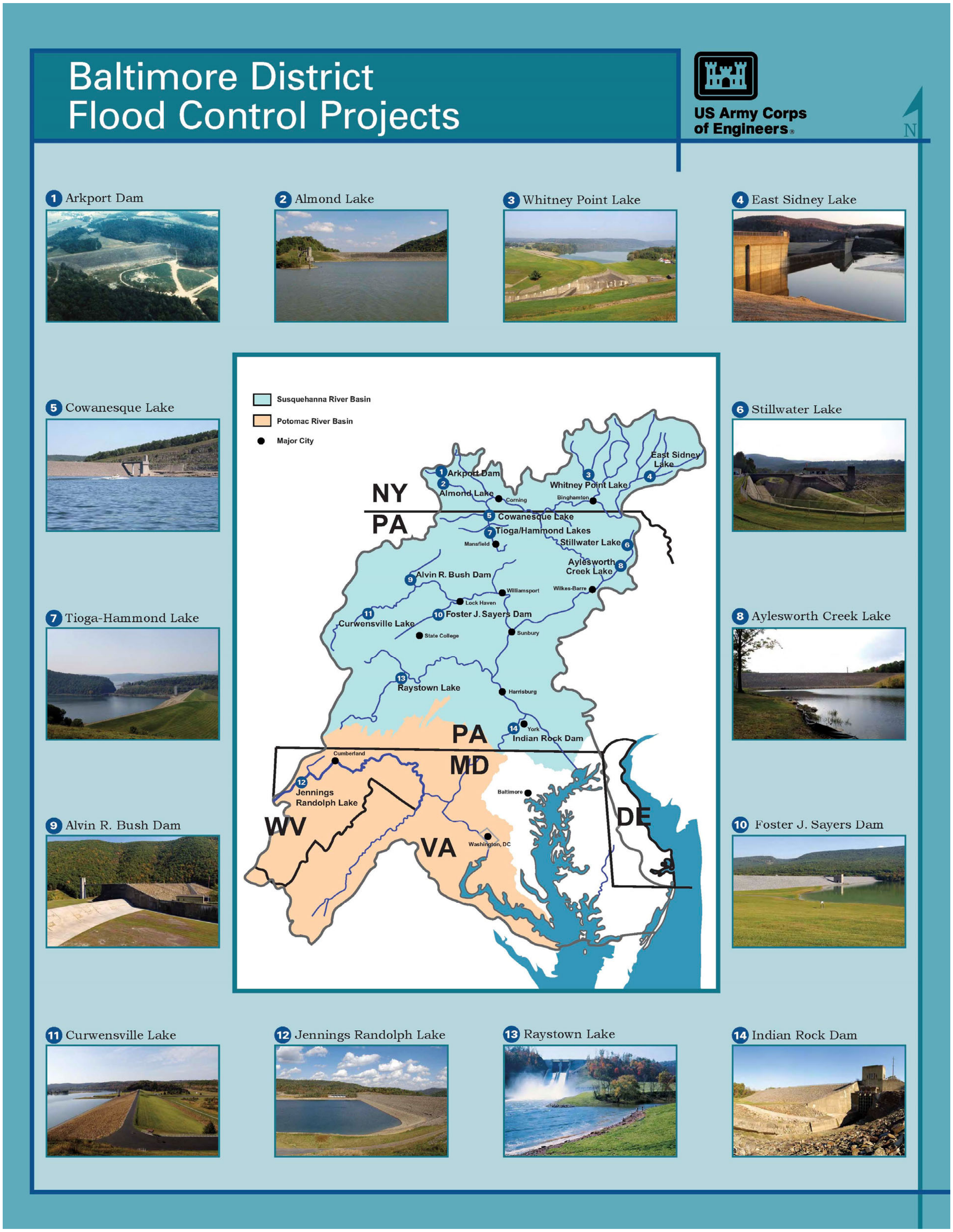



**Figure 3-2. Federal Flood Control Reservoirs.**

**Table 3-1. Federal Reservoir Analysis**

| Subwatershed (Project) | Flood Storage Reallocation Potential | Environmental Improvements Permanent Operational Change Potential | Identified Constraints | Ecological Flow Augmentation Potential |
|---|---|---|---|---|
| **UPPER SUSQUEHANNA RIVER** | | | | |
| (1) East Sidney Lake | None | Low (Advance fall drawdown) | a) PMF concerns for storage reallocation<br>b) Only 1600 AF of conservation storage | Low |
| (2) Whitney Point Lake | None | None-Sec 1135 study complete | a) PMF concerns for storage reallocation | None |
| **CHEMUNG RIVER** | | | | |
| (3A) Tioga Lake | Moderate | Moderate | a) Concerns with managing Tioga water quality for either storage reallocation or operational change options | Moderate |
| (3B) Hammond Lake<br><br>(4) Cowanesque Lake | Moderate<br><br>None (Flood storage already reallocated to water supply) | Moderate<br><br>None<br><br>(C2 Cowanesque study[4] resulted in changes to low flow release triggers) | b) Flood storage reallocation – significant adverse impact to recreation facilities<br>Reallocation and operational changes have already been implemented for the project. | Moderate<br><br>None |
| (5) Almond Lake | Low | Low | a) Cost -effectiveness<br>b) Only 840 AF of conservation storage | Low |
| (6) Arkport Dam | None | None | a) PMF concerns for storage reallocation<br>b) Small drainage area, no permanent pool, restricted outlet | None |
| MIDDLE SUSQUEHANNA RIVER | | | | |
| (7) Stillwater Lake | Low | Low | a) Cost -effectiveness<br>b) Only 209 AF of conservation storage | Low |
| (8) Aylesworth Creek Lake | None | None | a) Small drainage area<br>b) No conservation storage | None |

| Subwatershed (Project) | Flood Storage Reallocation Potential | Environmental Improvements Permanent Operational Change Potential | Identified Constraints | Ecological Flow Augmentation Potential |
|---|---|---|---|---|
| **WEST BRANCH SUSQUEHANNA RIVER** | | | | |
| (9) Curwensville Lake | Low | None (C2 Curwensville[5] study is currently evaluating potential changes to low flow release triggers) | a) Previous study resulted in reallocation of flood control storage to water supply (winter pool eliminated)<br>b) Possible concerns with recreation relocation if additional flood storage is reallocated | Low |
| (10) Alvin R. Bush Dam | None | None | a) PMF concerns for storage reallocation<br>b) Only 1864 AF of conservation storage | None |
| (11) Foster Joseph Sayers Dam | None | Moderate Advance fall drawdown - Section 1135 proposed | a) Flood storage reallocation not feasible due to already limited storage | Moderate |
| **JUNIATA RIVER** | | | | |
| (12) Raystown Lake | None | Moderate (Change flow rate/timing of summer and winter releases, or 'presubscribe' existing releases | a) Very high cost to relocate recreation facilities should flood storage be reallocated | Moderate |
| **LOWER (MAIN STEM) SUSQUEHANNA RIVER** | | | | |
| (13) York Indian Rock Dam | None | None | a) No conservation storage<br>b) Substantial costs to operate with a seasonal/permanent pool<br>c) In-lake water quality could be a major concern with any permanent or seasonal pool | None |

[4] The C2 Cowanesque study, Final Environmental Assessment, Cowanesque Lake Water Supply Releases to Cowanesque, Tioga, Chemung, and Susquehanna Rivers, approved in October 2013, is discussed further in Chapter 3.1.

[5] The C2 Curwensville study, Draft Environmental Assessment, Curwensville Lake Water Supply Releases to West Branch Susquehanna and Lower Susquehanna Rivers, Pennsylvania; USACE, July 2016, is currently under review by the North Atlantic Division, USACE. The study is discussed further in Chapter 3.1.

## CHEMUNG RIVER SUBWATERSHED

The Chemung River Subwatershed covers about 2,600 square miles lying mostly in southcentral New York and northcentral Pennsylvania. Major tributaries include the Cowanesque, Tioga, Canisteo, and Cohocton Rivers. Much of the subwatershed is dominated by glaciated watersheds composed of rolling to flat-topped uplands with steep-sided alluvial valleys. Metropolitan areas include Elmira, Corning, and Hornell, New York. About 225,000 people reside in the Chemung River Subwatershed. There are five Federal reservoirs (Tioga Lake, Hammond Lake, Cowanesque Lake, Almond Lake, and Arkport Dam) within this subwatershed as well as numerous Federally-constructed local flood risk management projects.

### Tioga-Hammond Lake (#3A and #3B on Figure 3-1):

**Authority and Purposes:** The Tioga-Hammond Lakes project is a unit of the flood risk management plan for protecting communities in New York and Pennsylvania within the Susquehanna River Watershed. The project, along with the nearby Cowanesque Lake, was authorized by the Flood Control Act of July 3, 1958 (Public Law 85-500, 85th Congress) in accordance with the recommendations of the Chief of Engineers in House Document No. 394, 84th congress, dated February 24 1955. The primary purpose of Tioga-Hammond Lakes is flood risk management. Recreation was subsequently added as a secondary purpose with the passage of the Federal Water Project Recreation Act of 1965 (Public Law 89-72, as amended). This act allows for recreational development on Federal project lands, provided non-Federal beneficiaries agree to bear part of the cost of constructing, operating, and maintaining the recreational facilities. The project also provides water quality control by mixing the alkaline waters of Hammond Lake with the acidic waters of Tioga Lake to produce a more neutral release from the project.

**Existing Features and Operations:** Hammond Dam is located on Crooked Creek about 2.5 miles upstream of its confluence with the Tioga River near Tioga in Tioga County, Pennsylvania. Hammond Dam controls a drainage area of 122 square miles and consists of a zoned earth and rockfill dam rising 122 feet above the streambed. Tioga Lake is located on the Tioga River just downstream of Mansfield, Pennsylvania and just upstream of Tioga, Pennsylvania. Tioga Dam controls a drainage area of 280 square miles and also consists of a zoned earth and earthfill dam rising 140 feet above the streambed. The project also includes a levee along the Tioga River protecting Mansfield from reservoir backwater effects when Tioga Lake approaches spillway elevation 1,131.0 feet PCD'. The overall project was operationally complete in 1980.

The two lakes are joined by a connecting channel through a ridge separating the two watersheds. A weir (crest elevation = 1,101.0 feet PCD') in the connecting channel keeps the lakes separate, except during times when the projects are storing excess flood runoff. The Hammond conservation pool usually contains water of good quality and is maintained year-round at an elevation of 1,086.0 feet PCD' (storage capacity = 8,785 acre-feet, surface area = 679 acres). The Tioga conservation pool is typically degraded by acid mine drainage and is maintained 5 feet lower year-round at elevation 1,081.0 feet PCD' (storage capacity = 9,951 acre-feet, surface area = 493 acres). Under most conditions, the operating objective is to release water from Hammond Lake into Tioga Lake through two gates in the connecting channel weir to help improve the water quality in Tioga Lake prior to making releases to the Tioga River. During high water events when excess runoff is being stored to reduce downstream flooding, reservoir levels in either project may rise above the connecting channel weir and spill into the other reservoir. Usually, though, Tioga Lake spills into Hammond Lake first because of topographic differences in the two watersheds and the relative size of the two impoundments. Coordinated winter operations are needed at both lakes when the surfaces are ice-covered to help minimize the accumulation of acid layers within Tioga Lake.

Hammond Lake has an uncontrolled spillway serving both lakes. At spillway crest elevation 1,131.0 feet PCD', the combined storage capacity of the two lakes is 125,622 acre-feet and the surface area is 3,349 acres. In addition to the two connecting channel gates, there is also one small gate discharging water to Crooked Creek downstream of Hammond Dam. The purpose of this outlet is to provide a small continuous flow (5 to 10 cfs) within the original Crooked Creek channel prior to joining the Tioga River further downstream.

The outlet works at Tioga Lake consist of an outlet tower, two main service gates, and two low flow/quality control gates all connecting to a single tunnel conduit discharging into the Tioga River. The low flow/quality control system is capable of withdrawing water from four different lake elevations and is used to mix water of differing qualities that may have stratified in different zones or layers within Tioga Lake. The minimum outflow target downstream of Tioga Dam is 35 cfs.

**Recreation:** Hammond Lake has 679 surface acres of water. The project includes the Ives Run Recreation Area with a campground, boat launches and overnight mooring for campers. Fishing, picnicking, swimming, various sport fields, and a volleyball court are close by.

The Lambs Creek Recreation Area is a day use facility on Tioga Lake, with 493 surface acres of water, located just a few miles north of Mansfield, Pennsylvania. Its secluded location offers a boater's paradise and great water-skiing opportunities. Picnic sites with horseshoe pits and a hiking/biking trail are close by. In 2012, approximately 179,400 people visited Tioga-Hammond Lakes.

**Limitations and Opportunities for Low Flow Augmentation/Management:** The layout and operational procedures at Tioga-Hammond Lakes create complex conditions. Any proposal to reallocate flood storage would likely have to consider the impact to recreational features at both lakes, but especially at Hammond Lake containing the majority of the lakeside recreation facilities. Likewise, any flood storage reallocation proposal would have to carefully consider the balance of flow and storage between the two lakes so as to retain the existing neutralization capabilities. Future water quality improvements throughout the Tioga watershed may open additional opportunities.

### (4) Cowanesque Lake (#4 on Figure 3-1):

**Authority and Purposes:** Cowanesque Lake is a unit of the flood risk management plan for protecting communities in New York and Pennsylvania within the Susquehanna River Watershed. The project, along with the nearby Tioga-Hammond Lakes project, was authorized by the Flood Control Act of July 3, 1958 (Public Law 85-500, 85th Congress) in accordance with the recommendations of the Chief of Engineers in House Document No. 394, 84th congress, dated February 24 1955. The primary purpose of Cowanesque Lake is flood risk management. Recreation was subsequently added as a secondary purpose with the passage of the Federal Water Project Recreation Act of 1965 (Public Law 89-72, as amended). This act allows for recreational development on Federal project lands, provided non-Federal beneficiaries agree to bear part of the cost of constructing, operating, and maintaining the recreational facilities. The project can also provide some incidental water quality control if alkaline releases from Cowanesque Lake are needed to help neutralize acidic releases from nearby Tioga-Hammond Lakes.

Shortly after project completion, a reformulation study was conducted to investigate the possibility of adding water supply storage at Cowanesque Lake. In a Record of Decision dated March 1983, the Chief of Engineers approved the necessary project modifications. The Supplemental Appropriations Act of 1985 (Public Law 99-88, 15 August 1985) authorized the addition of water supply storage space as a project purpose at Cowanesque Lake.

**Existing Features and Operations:** Cowanesque Lake is located on the Cowanesque River about two miles upstream of its confluence with the Tioga River near Lawrenceville in Tioga County, Pennsylvania. The dam controls a drainage area of 298 square miles and consists of a zoned earth and earthfill dam rising 151 feet above the streambed. The project was operationally complete in 1980. At spillway crest elevation 1,117.0 feet PCD, the lake contains a storage capacity of 84,747 acre-feet and has a surface area of 2,020 acres. The project is currently managed to provide a year-round conservation pool at elevation 1,080.0 feet PCD, with a storage capacity of 29,876 acre-feet and a surface area of 1,050 acres. The outlet works consist of an outlet tower, two main service gates, and two low flow/quality control gates all connecting to a single tunnel conduit discharging into the Cowanesque River. The low flow/quality control system is capable of withdrawing water through any of six ports positioned at four different lake elevations; this low flow/quality control system is used mostly during the summer months to withdraw the warmer surface water. The minimum outflow target is 25 cfs as long as the lake elevation is higher than 1,080.0 feet PCD; should the lake elevation drop below that level, then the minimum outflow target is 15 cfs. If the government's conservation storage should become depleted, then the minimum outflow target is set at the inflow rate.

The lake was originally maintained at elevation 1,045.0 feet PCD, but was raised to elevation 1080.0 feet PCD when water supply storage was added as a project purpose. SRBC purchased the water supply storage space (presently estimated to contain 23,494 acre-feet) to provide compensation for downstream consumptive water uses at several large electric generating utilities. The change was implemented in 1990 with modifications to the outlet tower along with relocation and expansion of existing recreation facilities.

**Recreation:** The recreation opportunities the project offers include boating, fishing, hunting, water-skiing, camping, picnicking, hiking, and amphitheater programs. The Tompkins Recreation Area and Campground is located along the north shore of Cowanesque Lake, three miles west of Lawrenceville on Bliss Road. The campground has 83 campsites, 16 hike-in sites, a 24-site group camp and a boat launch and beach for camper use. The South Shore and Lawrence Day Use Areas are located on the south side of the lake west of Lawrenceville along State Route 49. The South Shore Recreation Area has boat launching, picnicking and swimming facilities. The Lawrence Recreation Area has picnicking facilities. There are, also, two overlooks at Cowanesque Lake and two downstream fishing access sites. In 2012, approximately 97,600 people visited Cowanesque Lake.

**Limitations and Opportunities for Low Flow Augmentation/Management:** Flood control storage has already been reallocated to water supply storage at Cowanesque Lake. Additional flood storage reallocation is not a viable option for two reasons. First, Cowanesque Lake provides the least amount of flood runoff control of any Federal reservoir in the Susquehanna River Watershed (about 3.5 inches at Cowanesque Lake as compared to more than 5 inches at most of the other reservoirs). Further sacrifice of flood control storage at Cowanesque Lake is not considered to be prudent. Second, USACE and SRBC have already invested extensively in water-oriented recreational facilities that have been relocated and constructed to take maximum advantage of the lake at its new elevation 1,080.0 feet. Raising the lake elevation by means of further flood storage reallocation would require additional major expenditures to replace the existing facilities.

With regard to operational changes for providing additional low flow augmentation opportunities, the SRBC has requested that the trigger for making water supply releases from Cowanesque Lake be changed from a single annual Q7-10 value to multiple monthly P95 values. These monthly P95 values reflect SRBC's revised low flow protection policies that are now based on instream ecological needs. The operational changes were approved with the signing of the Environmental Assessment (EA) and Finding of No Significant Impact (FONSI), *Final Environmental Assessment, Cowanesque Lake Water Supply Releases to Cowanesque, Tioga, Chemung, and Susquehanna Rivers; USACE, August 2013 (Revised October 2013).* Changes went into effect in November 2015 with the approval of the revised Cowanesque Lake Reservoir Regulation Manual. No further changes to create additional low flow augmentation opportunities are envisioned at this time.

### (5) Almond Lake (#5 on Figure 3-1):

**Authority and Purposes:** Almond Lake is a unit of the comprehensive flood risk management plan for the protection of communities in southern New York and northeastern Pennsylvania authorized by the Flood Control Act of June 22, 1936 as amended by the Flood Control Act of June 28, 1938, and as described in House Document No. 702, 77$^{th}$ Congress, 2nd session. The primary project purpose is flood risk management; recreation was added later as a secondary or incidental project purpose.

**Existing Features and Operations:** Almond Lake is located on Canacadea Creek in Steuben County, New York, about two miles upstream of Hornell. The dam controls a drainage area of 56 square miles, and consists of a rolled earthfill embankment rising about 90 feet above the streambed. The project was operationally complete in 1942. At spillway elevation 1,300.0 feet PCD, the lake contains a storage volume of 13,397 acre-feet and covers a surface area of 492 acres. The project is currently managed to provide a year-round conservation pool at elevation 1,260.0 feet PCD, with a storage capacity of 840 acre-feet and a surface area of 135 acres. The outlet works consist of an outlet tower and three service gates leading into a single tunnel conduit discharging into Canacadea Creek. Prior to 1987, the conservation pool was maintained at lower elevations (1,255 feet/1,250 feet, summer/winter), but was raised to the present elevation because sedimentation was causing a significant loss of usable lake surface for recreation. The minimum outflow target at Almond Lake is about 5 cfs.

**Recreation:** Steuben County operates and maintains the Kanakadea Recreation Area at Almond Lake. Recreation facilities include a boat launch, picnic area, four picnic pavilions, playgrounds, a softball field, basketball courts, a sand volleyball court, hiking trails, and a campground with cabins. The camping season at Kanakadea Park runs from April 15 to December 1. In 2012, approximately 31,600 people visited the Kanakadea Recreation Area at Almond Lake.

**Limitations and Opportunities for Low Flow Augmentation/Management:** The potential for storage reallocation from flood control to flow augmentation at Almond Lake is low because of limited cost-effectiveness. The opportunity to provide low flow augmentation using the existing conservation pool at Almond Lake is also very low; the conservation pool contains only 840 acre-feet of storage.

**(6) Arkport Dam (#6 on Figure 3-1):**

**Authority and Purposes:** Arkport Dam is a unit of the comprehensive flood risk management plan for the protection of communities in southern New York and northeastern Pennsylvania. The project was authorized by the Flood Control Act of June 22, 1936, as amended by the Flood Control Act of June 28, 1938, and as described in House Document No. 702, 77th Congress, 2nd session. The primary purpose is flood risk management.

**Existing Features and Operations:** Arkport Dam is located on the Canisteo River in Steuben County, New York, about five miles upstream of Hornell. The dam controls a drainage area of 31 square miles and consists of a rolled earthfill embankment rising 113 feet above the streambed. The dam was operationally complete in 1939. At spillway crest elevation 1,304.0 feet PCD, the lake contains a storage volume of 7,000 acre feet and covers a surface area of 191 acres. Normally, the project is operated as a "dry" dam, meaning that no water is impounded unless a high water event is occurring and inflow exceeds the capacity of the outlet structure. The outlet structure consists of single tunnel conduit containing a 4.3 foot diameter nozzle that throttles outflow. Arkport Dam is an unmanned facility, with maintenance activities provided by personnel stationed at nearby Almond Lake. There is no minimum outflow target.

**Recreation:** The project does not have any recreational features.

**Limitations and Opportunities for Low Flow Augmentation/Management:** Flood storage reallocation for the purpose of low flow augmentation is not a feasible alternative at Arkport Dam due to limits imposed by criteria for passing the PMF. Due to its lack of a permanent pool, its small drainage area, and its type of outlet structure, Arkport Dam offers no potential for low flow augmentation.

## MIDDLE SUSQUEHANNA RIVER SUBWATERSHED

The Middle Susquehanna River Subwatershed covers about 3,800 square miles lying in northeastern Pennsylvania. Major tributaries include the Lackawanna River and Meshoppen, Towanda, and Fishing Creeks. The northern part of the subwatershed is characterized by high, flat-topped plateaus separated by steep-sided valleys. The southern part is characterized by northeast/southwest tending ridges and valleys. The subwatershed contains several major metropolitan areas (Scranton, Wilkes-Barre, Kingston, Plymouth, Nanticoke, Berwick, Bloomsburg, and Danville), and these communities are located throughout the Wyoming Valley along the Susquehanna and Lackawanna Rivers. About 700,000 people reside in the Middle Susquehanna River Subwatershed. There are two small Federal reservoirs (Stillwater Lake and Aylesworth Creek Lake) within this subwatershed as well as several large Federally-constructed local flood risk management projects. The Wyoming Valley communities receive significant benefits from upstream reservoirs located in the Upper Susquehanna and Chemung River Subwatersheds.

### (7) Stillwater Lake (#7 on Figure 3-1):

**Authority and Purposes:** Stillwater Lake is a unit of the comprehensive flood risk management plan for the protection of communities in northeastern Pennsylvania. The project was authorized by the Flood Control Act of August 18, 1941 as a modification of the earlier Flood Control Act of June 22, 1936, and is described in House Document No. 702, 77th Congress, 2nd session. The primary project purpose is flood risk management; a secondary project purpose is water supply that was "grandfathered" into Stillwater Lake as a result of a small pre-existing facility at the project site.

**Existing Features and Operations:** Stillwater Dam is located on the Lackawanna River in Susquehanna County, Pennsylvania, about 4 miles upstream of Forest City and 25 miles upstream from Scranton. The dam controls a drainage area of 37 square miles and consists of an earthfill embankment rising 73 feet above the streambed. The project was operationally complete in 1960. At spillway crest elevation 1,621.0 feet PCD, the lake contains a storage capacity of 11,558 acre-feet and has a surface area of 416 acres. The project is managed to provide a year-round conservation pool at elevation 1,572.0 feet PCD, with a storage capacity of 247 acre-feet and a surface area of 66 acres. The outlet works consist of one gate leading to a tunnel conduit discharging into the Lackawanna River. PAWC utilizes releases from Stillwater Lake as a source of water supply for the Forest City Water Purification Plant. The intake facility is located immediately downstream of the reservoir on the Lackawanna River. The minimum outflow target for Stillwater Lake is merely the inflow rate.

**Recreation:** Under a USACE real estate agreement, the Pennsylvania Fish and Boat Commission operates and maintains a boat launch at Stillwater Lake. Swimming and gasoline powered boat motors are prohibited in the lake since releases from the lake are used as a water supply source for downstream communities. Visitation numbers are not calculated for Stillwater Lake.

**Limitations and Opportunities for Low Flow Augmentation/Management:** Flood control storage reallocation for the purpose of low flow augmentation offers very minor potential due to limited cost-effectiveness. Due to its small tributary drainage area and its small conservation pool, Stillwater Lake offers no potential for low flow augmentation using the existing conservation storage.

### (8) Aylesworth Creek Lake (#8 on Figure 3-1):

**Authority and Purposes:** Aylesworth Creek Lake is part of a flood risk management plan for the Lackawanna River Watershed in northeastern Pennsylvania. The project was authorized by Flood Control Act of October 23, 1962 (Public Law 87-874) and is described in Senate Document No. 141, 87th Congress, 2nd session. The primary project purpose is flood risk management, with recreation and water quality control as secondary or incidental project purposes.

**Existing Features and Operations:** Aylesworth Creek Lake is located on Aylesworth Creek in Lackawanna County, Pennsylvania about ten miles northeast of Scranton. The dam controls a drainage area of about 6 square miles and consists of a zoned earth and rockfill embankment rising 80 feet above the streambed. The project was operationally complete in 1970. At spillway crest elevation 1,150.0 feet PCD, the lake contains a storage volume of 1,842 acre-feet and has a surface area of 89 acres. The project is currently managed to provide a year-round conservation pool at elevation 1,108.0 feet PCD with a storage capacity of 62 acre-feet and a surface area of 8 acres. The outlet works consist of an overflow weir at elevation 1,108.0 feet PCD leading to a three-foot diameter outlet conduit. Normally, inflow and outflow at Aylesworth Creek Lake are equivalent, unless a high water event is occurring and inflow exceeds the capacity of the outlet conduit. Aylesworth Creek Lake is an unmanned facility, with maintenance activities provided by personnel stationed at nearby Stillwater Lake. There is no minimum outflow target for Aylesworth Creek Lake. The project also includes a small dike near Mayfield, Pennsylvania to prevent stored flood waters from spilling into an adjacent creek.

**Recreation:** The recreation area at Aylesworth Creek Lake is operated and maintained by Lackawanna County as Aylesworth Park. The 8 acre lake features a swimming beach with certified lifeguards, 150-person pavilion, picnic area, playground equipment, multipurpose/soccer and softball fields, volleyball court, and hiking trails. The park is located near East Jermyn, in

Lackawanna County, about ten miles upstream from Scranton on US 6. The park is open year-round. In 2012, approximately 21,000 people visited Aylesworth Park.

**Limitations and Opportunities for Low Flow Augmentation/Management:** Flood control storage reallocation for the purpose of low flow augmentation offers extremely limited potential due to the very small flood control pool. Likewise, there is no potential for low flow augmentation using the existing conservation pool because of the small tributary drainage area and very small conservation pool.

## WEST BRANCH SUSQUEHANNA RIVER SUBWATERSHED

The West Branch Susquehanna River Subwatershed covers about 7,000 square miles lying in central Pennsylvania. Major tributaries include Clearfield, Anderson, Moshannon, Sinnemahoning, Kettle, Bald Eagle, Pine, Lycoming, and Loyalsock Creeks. The subwatershed includes the steep hillsides of the Allegheny Plateau and the broad valleys and long high ridges of the Allegheny Front. Much of the western and northern part of the subwatershed is dominated by forest lands, while the southern and eastern section is devoted to agriculture and urban land uses. Major metropolitan areas include Clearfield, State College, Lock Haven, Williamsport, and Lewisburg. About 500,000 people reside in the West Branch Susquehanna River Watershed. There are three Federal reservoirs (Curwensville Lake, Alvin R. Bush Dam, and Joseph Foster Sayers Dam) in the subwatershed as well as one large state-owned reservoir (Stevenson Dam). The four reservoirs are operated together as a system during high water events. There are two Federally-constructed local flood risk management projects.

### (9) Curwensville Lake (#9 on Figure 3-1):

**Authority and Purposes:** Curwensville Lake is a unit, along with Alvin R. Bush Dam Lake and Foster Joseph Sayers Dam, of the comprehensive flood risk management plan for the protection of communities in the West Branch Susquehanna River Watershed. The state-owned George B. Stevenson Dam is also part of this comprehensive plan. The three Federal projects were authorized by the Flood Control Act approved September 3, 1954 and are described in House Document No. 29, 84th Congress, and 1st session. Originally, the primary purpose of Curwensville Lake was flood risk management. An incidental project purpose was water quality control, especially for minimizing the impact of downstream acid mine drainage discharges and for managing downstream water temperature for a healthy warm water fishery. Subsequently, recreation was added as a secondary purpose with the passage of the Federal Water Project Recreation Act of 1965 (Public Law 89-72, as amended). This act allows for recreational development on Federal project lands, provided non-Federal beneficiaries agree to bear part of the cost of constructing, operating, and maintaining the recreational facilities. In 1994, municipal and industrial water supply for downstream users was added as another project purpose as described below.

**Existing Features and Operations:** Curwensville Lake is located on the West Branch Susquehanna River approximately 13 miles southwest of Clearfield in Clearfield County, PA. The dam controls a drainage area of 365 square miles and consists of a rolled earthfill dam rising about 145 feet above the streambed. The project was operationally complete in 1965. At spillway crest elevation 1,228.0 feet PCD, the lake contains a volume of 119,467 acre-feet and has a surface area of 2,877 acres. The project is currently managed to provide a year-round conservation pool at elevation 1,162.0 feet PCD, with a storage capacity of 7,483 acre-feet and a surface area of 770 acres. The outlet works consist of an outlet tower, three main service gates, and two low flow bypass gates all connecting to a single tunnel conduit discharging into the West Branch Susquehanna River. The low flow bypass system is used mostly during the summer months to withdraw the warmer surface water. The minimum outflow target is 50 cfs, plus the pass-through amount described below (usually about 10 cfs). Should all of the Government's conservation storage be used, then the minimum outflow target is set at the inflow rate.

An investigation in the mid-1990's concluded that some flood storage space within Curwensville Lake could be reallocated to water supply storage space. SRBC subsequently purchased the water supply storage space (presently estimated to contain 4,240 acre-feet) to provide compensation for downstream consumptive water uses. The change was implemented in 1997 with minor modifications to some existing recreation facilities and the elimination of the previous seven-foot winter drawdown.

A further modification to project regulation occurred in about 2011. A discharge point for an acid mine drainage treatment plant was transferred from the Ohio River Watershed to the West Branch Susquehanna River Subwatershed upstream of Curwensville Lake. SRBC requested that this "new" water be allowed to pass through Curwensville Lake undiminished in quantity so that it might be available to compensate for downstream agricultural consumptive uses.

**Recreation:** Clearfield County operates and maintains the recreation area adjacent to Curwensville Lake. The recreation facilities include a beach, boat launch, picnic areas, hiking trails, athletic fields, playgrounds, five picnic pavilions, a dog park, and a campground with three cabins and approximately 115 campsites. The park offers boating with no horsepower restrictions. Recreation is offered from Memorial Day to Labor Day, with the boat ramp usually open through October, depending on the lake levels. The campground is not open during hunting season. In 2012, approximately 35,600 people visited Curwensville Lake.

**Limitations and Opportunities for Low Flow Augmentation/Management:** Opportunities for flood storage reallocation at Curwensville Lake to provide storage for flow augmentation is low, primarily due to potential concerns about major relocations of existing recreation facilities. At the request of SRBC, possible operational changes to provide low flow augmentation and compensation for downstream consumptive uses are currently being investigated as part of the C2-Curwensville study. SRBC has requested that the trigger for making water supply releases from Curwensville Lake be changed from a single annual Q7-10 value to multiple monthly P95 values. These monthly P95 values reflect SRBC's revised low flow protection policies that are now based on instream ecological needs. A draft EA/FONSI, *Draft Environmental Assessment, Curwensville Lake Water Supply Releases to West Branch Susquehanna and Lower Susquehanna Rivers, Pennsylvania; USACE, July 2016,* has been prepared and is currently under review by the North Atlantic Division, USACE. Besides those alternatives evaluated in the C2-Curwensville study, no additional opportunities for operational changes are available. Therefore, the overall potential to provide additional low flow augmentation from Curwensville Lake, beyond those that may be implemented through the C2-Curwensville study, is low.

### (10) Alvin R. Bush Dam (#10 on Figure 3-1):

**Authority and Purposes:** Alvin R. Bush Dam, originally named Kettle Creek Reservoir, is a unit, along with Curwensville Lake and Foster Joseph Sayers Dam, of the comprehensive flood risk management plan for the protection of communities in the West Branch Susquehanna River Watershed. The state-owned George B. Stevenson Dam is also part of this comprehensive plan. The three Federal projects were authorized by the Flood Control Act approved September 3, 1954 and are described in House Document No. 29, 84th Congress, 1st session. The primary purpose of Bush Dam is flood risk management. Subsequently, recreation was added as a secondary purpose with the passage of the Federal Water Project Recreation Act of 1965 (Public Law 89-72, as amended). This act allows for recreational development on Federal project lands, provided non-Federal beneficiaries agree to bear part of the cost of constructing, operating, and maintaining the recreational facilities.

**Existing Features and Operations:** Alvin R. Bush Dam is located on Kettle Creek approximately 8 miles above its confluence with the West Branch Susquehanna River and about 15 miles above Renovo, PA, in Clinton County. The dam controls a drainage area of about 226 square miles and consists of a rolled earthfill dam rising about 165 feet above the streambed. The project was operationally complete in 1962. At spillway crest elevation 937.0 feet PCD, the lake contains a volume of 74,941 acre-feet and has a surface area of 1,437 acres. The project is currently managed to provide a year-round conservation pool at elevation 841.0 feet PCD, with a storage capacity of 1,864 acre-feet and a surface area of 159 acres. The outlet works consist of an outlet tower, three main service gates and a low flow bypass system all connecting to a single tunnel conduit discharging into Kettle Creek. The low flow bypass system is used mostly during the warm summer months.

It contains two weirs (each with a corresponding two-foot diameter gate) that can release warm water off of the lake surface and a one-foot diameter gate that can release cool water off of the lake bottom. The minimum outflow target is 10 cfs.

**Recreation:** The recreational facilities are operated and maintained by the Department of Conservation and Natural Resources of the Commonwealth of Pennsylvania (DCNR) as Kettle Creek State Park. Recreation facilities include a 1,800 acre park with a boat launch, picnic areas, hiking and horseback riding trails, and campgrounds. In 2012, approximately 66,900 people visited Kettle Creek State Park.

**Limitations and Opportunities for Low Flow Augmentation/Management:** Flood storage reallocation for the purpose of low flow augmentation is not a feasible alternative at Bush Dam due to limits imposed by criteria for passing the PMF. The opportunity to provide low flow augmentation using the existing conservation pool at Bush Dam is very low, considering that the conservation pool contains only 1,864 acre-feet of storage.

### (11) Foster Joseph Sayers Dam (#11 on Figure 3-1):

**Authority and Purposes:** Foster Joseph Sayers Dam, originally named Blanchard Reservoir, is a unit, along with Curwensville Lake and Bush Dam, of the comprehensive flood risk management plan for the protection of communities in the West Branch Susquehanna River Watershed. The state-owned George B. Stevenson Dam is also part of this comprehensive plan. The three Federal projects were authorized by the Flood Control Act approved September 3, 1954 and are described in House Document No. 29, 84th Congress, 1st session. The primary purpose of Sayers Dam is flood risk management. Subsequently, recreation was added with the passage of the Federal Water Project Recreation Act of 1965 (Public Law 89-72, as amended). This act allows for recreational development on Federal project lands, provided non-Federal beneficiaries agree to bear part of the cost of constructing, operating, and maintaining the recreational facilities.

**Existing Features and Operations:** Sayers Dam is located on Bald Eagle Creek in Centre County, PA about 15 miles above its confluence with the West Branch Susquehanna River near Lock Haven, PA. The dam controls a drainage area of about 339 square miles and consists of a rolled earthfill dam rising 97 feet above the streambed. The project was operationally complete in 1969. At spillway crest elevation 657.0 feet PCD, the lake contains a volume of 100,505 acre-feet and has a surface area of 3,500 acres. The project is currently managed to provide a seasonal conservation pool for recreation at elevation 630.0 feet PCD between May and November, with a storage capacity of 29,215 acre-feet and a surface area of 1,823 acres. The outlet works consist of an outlet tower with two main service gates connecting to a single tunnel conduit discharging into Bald Eagle Creek. When the project was first constructed, there was also a leaf gate system that allowed water to be withdrawn from different lake elevations, but this system no longer functions. The minimum outflow target is usually set between 120 and 140 cfs. The project also includes a levee at Howard, PA to protect the community from backwater when the reservoir level rises into the flood pool.

The lake is partially drawn down to elevation 625.0 feet PCD from early December to mid-February to provide some additional flood control storage while keeping most of the lakebed upstream of Howard Borough submerged. Beginning in mid-February, the lake is drawn down further to elevation 610 feet PCD for late February and March when the potential for heavy snowmelt runoff is the greatest. The purpose of this phased drawdown over the winter is to minimize the potential for dust storms that can result from high velocity winds sweeping over an exposed lakebed.

A portion of the watershed upstream of Sayers Dam is located in limestone terrain, and the water impounded in the reservoir is usually alkaline. Occasionally, supplemental releases are made from this alkaline pool behind Sayers Dam to dilute or buffer Beech Creek acidic flows that enter Bald Eagle Creek about 2.5 miles downstream of the dam. Supplemental releases from Sayers Dam have also been made in the past to help dilute concentrated acid slugs that formed along the main channel of the upper West Branch Susquehanna River and moved downstream past Lock Haven.

**Recreation:** Recreation facilities are operated and maintained by the DCNR as Bald Eagle State Park. DCNR leases 5,900 acres with the following facilities: swimming beach with changing rooms, marina, picnic areas, hiking trails, athletic fields, volleyball courts, playgrounds, six boat launches (unlimited horsepower motors permitted), and camping that includes three cabins and two yurts. The Nature Inn, located at Bald Eagle State Park, is a 16-room inn that overlooks the lake. Howard Borough also leases, operates, and maintains a five-acre community park. Recreation is available year round. The marina closes on Oct. 31 annually. One boat launch is open until mid-February (weather permitting). Campgrounds are open through hunting season (mid-December) and winter sports are available. In 2012, approximately 504,500 people visited Bald Eagle State Park.

**Limitations and Opportunities for Low Flow Augmentation/Management:** Flood storage reallocation to create low flow augmentation opportunities at Sayers Dam is not a viable option for two reasons. First, Sayers Dam provides the least amount of flood runoff control of the four large reservoirs comprising the West Branch Susquehanna flood risk management system (less than 4 inches at Sayers Dam as compared to 6.1 inches at Bush Dam, 5.8 inches at Curwensville, and 5.7 inches at Stevenson). Further sacrifice of flood control storage at Sayers Dam is not considered to be prudent. Second, PA DCNR has invested extensively in water-oriented recreational facilities that have been constructed to take maximum advantage of the lake at elevation 630.0'. Raising the lake elevation by means of flood storage reallocation would require major expenditures to replace the existing facilities.

Operational changes to provide additional opportunities for low flow augmentation might be possible. SRBC and USACE are undertaking a separate Section 1135 effort that will investigate whether the late fall drawdown (from elevation 630.0 to 625.0 feet PCD) could occur earlier and over a longer period during extended low flow conditions. The feasibility phase of the Section 1135 study is in the preliminary stages. It is anticipated that the feasibility study will be completed in 2018.

## JUNIATA RIVER SUBWATERSHED

The Juniata River Subwatershed covers about 3,400 square miles lying in southcentral Pennsylvania. Major tributaries include the Little Juniata River and the Frankstown and Raystown Branches of the Juniata River. Much of the terrain is characterized by parallel mountains separated by long narrow valleys. Major urban areas include Altoona, Hollidaysburg, Bedford, Huntingdon, and Lewistown. About 325,000 people reside in the Juniata River Subwatershed. There is one large Federal reservoir (Raystown Lake) within this subwatershed, but no Federally-constructed local flood risk management projects.

### (12) Raystown Lake (#12 on Figure 3-1):

**Authority and Purposes:** Raystown Lake was authorized by the Flood Control Act of 1962 (Public Law 87-874, October 23, 1962) and is described in House Document No. 565, 87th Congress, 2nd session. The primary purpose of Raystown Lake is flood risk management along the Juniata and Susquehanna Rivers in central and southern Pennsylvania. Additional purposes include recreation and flow maintenance for a downstream warm water fishery. A non-Federal hydroelectric generating facility was added in 1988.

**Existing Features and Operations:** Raystown Lake is located on the Raystown Branch of the Juniata River approximately six miles upstream of its confluence with the Juniata River near Huntingdon in Huntingdon County, PA. The dam controls a drainage area of about 960 square miles and consists of a zoned earth and rockfill dam rising 225 feet above the streambed. The project was operationally complete in 1973. At spillway crest elevation 812.0 feet PCD, the lake contains a storage volume of 762,000 acre-feet and has a surface area of 10,800 acres. The project is currently managed to provide a year-round conservation pool at elevation 786.0 feet PCD, with a storage capacity of 513,090 acre-feet and a surface area of 8,300 acres. Raystown Lake has several outlets: two bottom service gates connecting to a tunnel, a gated spillway controlled by two large tainter gates and one small quality control gate, one non-Federal hydroelectric intake and penstock connecting to two turbines, and an uncontrolled spillway fuseplug. The project also includes a small dike near Hesston, PA to prevent stored flood waters from spilling into an adjacent creek.

Under most conditions, the project is operated to maintain a steady lake surface near elevation 786.0 feet PCD to support the extensive shoreline recreational facilities located around Raystown Lake. Outflow normally passes through the non-Federal hydroelectric plant unless lake inflow exceeds the plant capacity of 1,800 cfs. If inflow exceeds this amount, then the Corps outlet gates (service gates, tainter gates, or quality control gate) are activated. Minimum outflow targets for the downstream fishery are 200 cfs between mid-May and mid-November, and 480 cfs between mid-November and mid-May. Operation to satisfy these seasonal targets sometimes causes the lake surface to fall below the desired elevation at 786.0 feet PCD with corresponding adverse impacts to recreation.

**Recreation:** USACE operates and maintains 12 public access areas. Facilities include beaches, 10 boat launches, 5 campgrounds managed or leased by the Corps, 68.5 miles of hiking and mountain bike trails, playgrounds, ten picnic shelters and other picnic areas, an amphitheater with sound, light and video capabilities, and excellent opportunities for hunting and fishing. The Seven Points Recreation Area is the top grossing park in all of the 4,000+ recreation areas operated by USACE. In 2012, approximately 894,000 people visited Raystown Lake.

Four concessions currently exist at the project:

1. Lake Raystown Resort: the concessionaire operates a campground (including 64 cabins), marina, lodge/motel, conference center, water park complex, miniature golf, boat rentals, and other amenities.
2. Seven Points Marina: the concessionaire operates a marina with both wet and dry slips, boat rentals, and a restaurant facility.
3. Branch Camp: located 2 miles below the dam on the Juniata River and includes a 31 site campground.
4. The Lighthouse: The Lighthouse concession is located at Seven Points Beach. The facility offers a variety of snacks, fast food items, and water trampolines for the visitors to the beach area.

**Limitations and Opportunities for Low Flow Augmentation/Management:** Flood storage reallocation to create additional low flow augmentation opportunities at Raystown [6]Lake is not a

[6] Section 410 of the Water Resources Development Act of 1990 (PL 101-640) is legislation specifically for Raystown Lake, indicating that any changes in the allocation of storage for this project, resulting

viable option. There are numerous and extensive recreation facilities (beaches, boat launches, marinas, and campgrounds) situated immediately adjacent to the lake at elevation 786.0 feet PCD', and any rise would necessitate very costly relocations.

There are, however, several potential opportunities associated with operational changes using the existing conservation pool. One option might be to alter the discharge rate for the current seasonal minimum outflow targets (480 and 200 cfs). A related option might be to adjust the timing/duration of the minimum targets from the current November and May schedules. Such options might be appropriate items for a Section 1135 investigation. A third possibility might be to 'resubscribe' how the flows comprising the minimum outflow targets are accounted; for instance, a condition when lake inflow is 80 cfs and lake outflow is 200 cfs might be considered as providing flow augmentation of 120 cfs. Resubscription might be an appropriate mechanism for SRBC to consider when accounting for releases that compensate for consumptive uses.

## LOWER (MAIN STEM) SUSQUEHANNA RIVER SUBWATERSHED

The Lower (or Main Stem) Susquehanna River Subwatershed covers about 5,800 square miles lying mostly in southern and eastern Pennsylvania. Major tributaries include Conestoga, Conodoguinet, Swatara, Conewago, Codorus, and Penn's Creek. The northern section of the subwatershed consists of a series of ridges and valleys transitioning to rolling hills and broader valleys in the central section. This subwatershed is the most intensely developed of all of the Susquehanna River subwatersheds. Major metropolitan areas include Harrisburg, York, Lebanon, Carlisle, and Lancaster. About 1,900,000 people reside in the Lower Susquehanna River Subwatershed. There is one Federal reservoir (York Indian Rock Dam) and one Federally-constructed local flood risk management There are, however, four sizable hydroelectric dams (York Haven, Safe Harbor, Holtwood, and Conowingo) located on the Lower Susquehanna River downstream of Harrisburg. All of these hydroelectric facilities are owned and operated by utility companies.

### (13) York Indian Rock Dam (#13 on Figure 3-1):

**Authority and Purposes:** York Indian Rock Dam was authorized by the Flood Control Act of June 22, 1936, as amended by the Flood Control Act of June 28, 1938, and is described in House Document No. 702, 77th Congress, 2nd session. The primary project purpose is flood risk management.

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from the "on-going Raystown Lake reallocation study" must be submitted to and approved by Congress. The specific Raystown Lake reallocation study mentioned was terminated in the 1980's, however, USACE legal would need to be engaged to determine if this language would be applicable to a future Raystown Lake reallocation study.

**Existing Features and Operations:** York Indian Rock Dam is located on the Main Branch of Codorus Creek about three miles upstream of the City of York in York County, Pennsylvania. The dam controls a drainage area of about 94 square miles and consists of an earthfill embankment rising about 83 feet above the streambed. The project was operationally complete in 1942. At spillway elevation 435.0 feet PCD', the lake contains a storage volume of 27,657 acre-feet and has a surface area of 1,454 acres. The project is operated as a "dry" dam, meaning that no water is impounded unless a high water event is occurring. The outlet works consist of an outlet tower and three service gates leading into a single tunnel conduit discharging into Codorus Creek. During normal flow conditions, the three gates remain in partially open positions, and reservoir inflow and outflow are equivalent. There is no minimum outflow target.

**Recreation:** Recreation is not a project purpose at York Indian Rock Dam.

**Limitations and Opportunities for Low Flow Augmentation/Management:** Any proposal to provide low flow augmentation from York Indian Rock Dam would require that a permanent, or at least seasonal, pool be maintained at the project. Observed inflow data indicate that poor water quality may pose a significant concern for a permanent or seasonal pool. Additionally, there would be substantial annual maintenance costs to regulate the project with a permanent or seasonal pool. For these reasons, there appear to be no opportunities for low flow augmentation from York Indian Rock Dam.

## 3.2 STATE AND PRIVATE RESERVOIRS

An iterative GIS based analysis was performed on the most recent dam permitting data furnished by New York, Pennsylvania, and Maryland. There are approximately 2,300 permitted impoundments within the watershed, and subsequent screenings based on water surface area show that there are 159 facilities with a surface area of 50 acres or greater, with 74 of those having a surface area of 100 acres or greater. The potential for low flow augmentation without significant adverse impacts to other reservoir uses is directly related to reservoir size. Therefore, in order to minimize impacts to the greatest extent possible and to accommodate multiple use facilities, only those impoundments with a surface area of 100 acres or greater were selected for further analysis. That screening identified the number of facilities, along with the aggregated total surface area. The results, grouped by subwatershed, are shown in Table 3-2.

**Table 3-2. State and Private Reservoirs, 100 acres**

| Watershed | Facilities | Total Acreage |
|---|---|---|
| Upper Susquehanna | 17 | 8,927 |
| Chemung | 4 | 2,545 |
| Middle Susquehanna | 25 | 5,613 |

| | | |
|---|---|---|
| West Branch Susquehanna | 12 | 3,938 |
| Juniata | 2 | 605 |
| Lower Susquehanna* | 14 | 7,193 |

* Hydroelectric dams not included

To assess the potential for these facilities to provide low flow augmentation, each facility was individually investigated by looking at all the pertinent information in the respective dam safety databases. Additional identification keys focusing on SRBC subwatershed, 10 digit Hydrologic Unit Code (HUC) watershed, ownership and usage were created and assigned to each facility so that a more in-depth analysis of augmentation potential could be accomplished. With regards to ownership, two general categories were created: government affiliated and private ownership. The government ownership category was further broken down into ownership by state, county, local or public utility entities. The private ownership category included "for profit" water purveyors, industry / private utility, associations, and private individuals. The usage category was broken down into public water supply, recreation, industrial, flood control / storm water management, navigation, and conservation / natural resource uses.

The first step in the assessment process was to eliminate from consideration all 23 of the impoundments who's sole or primary (in the case of multi-use facilities) purpose was public water supply. These impoundments, and the water they store, would need to be conserved during times of low flow for public health and safety purposes. The remaining 51 facilities were further divided by the subwatershed in which they are located, and that summary is shown in Table 3-3.

**Table 3-3. Non-Public Water Supply State and Private Reservoirs Greater Than 100 Acres**

| **Subwatershed** | **Government Ownership** | | **Private Ownership** | |
|---|---|---|---|---|
| | Number of Facilities | Surface Area (acres) | Number of Facilities | Surface Area (acres) |
| Upper Susquehanna | 10 | 5,725 | 6 | 2,942 |
| Chemung | 3 | 2,428 | 1 | 117 |
| Middle Susquehanna | 5 | 909 | 7 | 1,525 |
| West Branch Susquehanna | 5 | 2,483 | 4 | 456 |
| Juniata | 2 | 605 | 0 | 0 |
| Lower Susquehanna | 5 | 1,192 | 3 | 1,623 |

An analysis of the low flow augmentation potential that may be present in each subwatershed is discussed in the following sections. Table 3-4 shows select details for all 51 facilities discussed in the following sections, along with an estimate of the low flow augmentation release potential assuming a low flow period of 30, 60 and 90 days.

## Upper Susquehanna Subwatershed

There are 16 impoundments in the Upper Susquehanna Subwatershed with a surface area of 100 acres or greater. The largest government owned facility is Otsego Lake at 4,225 acres, which is owned by the Village of Cooperstown. Otsego Lake is primarily a recreational lake having water supply as a secondary use. The largest privately owned facility is Canadarago Lake at 1,902 acres, which is a recreation use facility owned by the Canadarago Lake Association. It cannot be determined from the dam safety database what type of outlet works may be present at each facility, making a determination of low flow augmentation feasibility difficult. However, if a 2 foot drawdown could be implemented at these two facilities, a total of just over 12,200 acre feet of water could be made available for low flow augmentation. The details for these two impoundments, along with the data for the remaining 14 facilities in the Upper Susquehanna Subwatershed, are shown in Table 3-4. If every facility in the subwatershed could be drawn down two feet, just over 17,000 acre feet of low flow augmentation could be realized.

### Chemung Subwatershed

There are 4 impoundments in the Chemung Subwatershed with a surface area of 100 acres or greater. The largest facility is Bradford Dam, a public utility hydroelectric facility in Steuben County with a surface area of 2,200 acres. The only privately owned facility in the subwatershed is known as the Tyrone Power Company Dam which has an area of 117 acres and is listed as a flood control / surface water management facility. If a 2 foot drawdown could be implemented at each of these two facilities, a total of just over 4,300 acre feet of water could be made available for low flow augmentation. The details for these two impoundments, along with the data for the remaining two facilities in the Chemung Subwatershed, are shown in Table 3-4. If all facilities in the subwatershed could be drawn down 2 feet, just over 5,000 acre feet of low flow augmentation could be realized.

**Table 3-4. Pertinent Attributes of Shortlisted State and Private Reservoirs**

| Dam Name | Stream | Owner Type | Permittee | Purpose | Drainage Area (Sq mi) | Surface Area (acres) | 2-Foot Drawdown (ac-ft) | 30-Day Release (cfs) | 60-Day Release (cfs) | 90-Day Release (cfs) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Upper Susquehanna Subwatershed** | | | | | | | | | | |
| Otsego Lake Dam | SUSQUEHANNA RIVER | Local | VILLAGE OF COOPERSTOWN | Recreation, Water Supply - Secondary | 68.34 | 4225 | 8450 | 142.0 | 71.0 | 47.3 |
| Eaton Brook Reservoir Dam | EATON BROOK | State | NYS CANAL CORP - SYRACUSE DIVISION | Navigation, Recreation | 7.96 | 275 | 550 | 9.2 | 4.6 | 3.1 |
| Lake Moraine Dam | PAYNE BROOK | State | NYS CANAL CORP - SYRACUSE DIVISION | Navigation, Other, Recreation | 8.21 | 260 | 520 | 8.7 | 4.4 | 2.9 |
| New York State Electric & Gas Dam | SUSQUEHANNA RIVER | Public Utility | NEW YORK STATE ELECTRIC & GAS | Hydroelectric | 3880 | 151 | 302 | 5.1 | 2.5 | 1.7 |
| Little York Dam | WEST BR TIOUGHNIOGA RIVER | Local | CORTLAND COUNTY | Recreation | 32.6 | 150 | 300 | 5.0 | 2.5 | 1.7 |
| Chenango Lake Dam | CHENANGO LAKE OUTLET | Local | CITY OF NORWICH | Recreation, Water Supply - Secondary | 0.8 | 150 | 300 | 5.0 | 2.5 | 1.7 |
| Bradley Brook Reservoir Dam | BRADLEY BROOK | State | NYS CANAL CORP - SYRACUSE DIVISION | Navigation, Recreation | 0 | 141 | 282 | 4.7 | 2.4 | 1.6 |
| Hatch Lake Dam | BRADLEY BROOK | State | NYS CANAL CORP - SYRACUSE DIVISION | Recreation | 11.46 | 134 | 268 | 4.5 | 2.3 | 1.5 |
| Balsam Swamp Dam | BALSAM CREEK | State | NYS DEC | Other | 2.13 | 121 | 242 | 4.1 | 2.0 | 1.4 |
| Long Pond Dam | POND BROOK | State | NYS DEC | Recreation | 0 | 118 | 236 | 4.0 | 2.0 | 1.3 |
| Canadarago Lake Dam | OAKS CREEK | Private | CANADARAGO LAKE ASSOCIATION | Recreation | 67.56 | 1902 | 3804 | 63.9 | 32.0 | 21.3 |
| Colliersville Dam | SUSQUEHANNA RIVER | Private | ENEL GREEN POWER NORTH AMERICA | Hydroelectric, Recreation | 351 | 369 | 738 | 12.4 | 6.2 | 4.1 |
| Cayuta Lake Property Owners Dam | CAYUTA CREEK | Private | CAYUTA LAKE PROPERTY OWNERS ASSN | Other | 16.49 | 366 | 732 | 12.3 | 6.2 | 4.1 |
| Genegantslet Lake Dam | TR-GENEGANTSLET CREEK | Private | GENEGANTSLET LAKE ASSOC. | Recreation | 5.4 | 105 | 210 | 3.5 | 1.8 | 1.2 |
| Lake Ludlow Club Dam | LUDLOW CREEK | Private | LAKE LUDLOW CLUB INC | Recreation | 6.34 | 100 | 200 | 3.4 | 1.7 | 1.1 |
| PAGE LAKE | SALT LICK CREEK | Private | RUSSELL PEPE | Recreation | 4.78 | 100 | 200 | 3.4 | 1.7 | 1.1 |
| **Chemung Subwatershed** | | | | | | | | | | |
| Bradford Dam | MUD CREEK | Public Utility | NEW YORK STATE ELECTRIC & GAS | Hydroelectric | 44.8 | 2200 | 4400 | 73.9 | 37.0 | 24.6 |
| HILLS CREEK | HILLS CREEK | State | PA DCNR | Recreation | 3.7 | 128 | 256 | 4.3 | 2.2 | 1.4 |
| Newtown Hoffman Site 3a Dam | NEWTOWN CREEK | Local | CHEMUNG COUNTY SOIL & WATER | Flood Control / SW Mgmt, Recreation | 2.67 | 100 | 200 | 3.4 | 1.7 | 1.1 |
| Tyrone Power Company Dam | TOBEHANNA CREEK | Private | MARIANNE AARONS | Flood Control / SW Mgmt, Recreation | 11.8 | 117 | 234 | 3.9 | 2.0 | 1.3 |
| **Middle Susquehanna Subwatershed** | | | | | | | | | | |
| LAKE JEAN | TR KITCHEN CREEK | State | PA DCNR | Recreation | 3 | 245 | 490 | 8.2 | 4.1 | 2.7 |
| LACKAWANNA | S BRANCH TUNKHANNOCK CRK | State | PA DCNR | Recreation | 44.9 | 202 | 404 | 6.8 | 3.4 | 2.3 |
| LAKE WINOLA | TR BEAVER CREEK | State | PA FISH & BOAT COMMISSION | Recreation | 2.4 | 190 | 380 | 6.4 | 3.2 | 2.1 |
| FRANCES SLOCUM | ABRAHAMS CREEK | State | PA DCNR | Recreation | 6.1 | 164 | 328 | 5.5 | 2.8 | 1.8 |
| LILY LAKE | TR LITTLE WAPWALLOPEN CRK | State | PA FISH & BOAT COMMISSION | Recreation | 2.2 | 108 | 216 | 3.6 | 1.8 | 1.2 |
| HARVEYS LAKE OUTLET | HARVEY CREEK | Private | JOSEPHINE MORETTI | Recreation | 6.72 | 646 | 1292 | 21.7 | 10.9 | 7.2 |
| LAKE CAREY | BILLINGS MILL BROOK | Private | LAKE CAREY WELFARE ASSOCIATION | Recreation | 7 | 263 | 526 | 8.8 | 4.4 | 2.9 |
| BEECH MOUNTAIN LAKE | OLEY CREEK | Private | BEECH MOUNTAIN LAKES ASSN | Recreation | 8.47 | 154 | 308 | 5.2 | 2.6 | 1.7 |
| NO 5 | S BRANCH ROARING CREEK | Business | AQUA PENNSYLVANIA, INC. | Recreation | 9.2 | 127 | 254 | 4.3 | 2.1 | 1.4 |
| SHICKSHINNY LAKE | SHICKSHINNY CREEK | Private | JERRY FTORKOWSKI | Recreation | 5.95 | 117 | 234 | 3.9 | 2.0 | 1.3 |
| LAKE CATALPA | FALLS CREEK | Private | GERALDINE NESBITT | Recreation | 2.1 | 115 | 230 | 3.9 | 1.9 | 1.3 |
| BAYLORS LAKE | SHIEK CREEK | Private | BAYLOR LAKE ASSOCIATION | Recreation | 2.2 | 102 | 204 | 3.4 | 1.7 | 1.1 |
| **W Branch Susquehanna Subwatershed** | | | | | | | | | | |
| GLENDALE | BEAVERDAM RUN | State | PA DCNR | Flood Control | 41.9 | 1600 | 3200 | 53.8 | 26.9 | 17.9 |
| ROSE VALLEY LAKE | MILL CREEK | State | PA FISH & BOAT COMMISSION | Recreation | 3.4 | 389 | 778 | 13.1 | 6.5 | 4.4 |
| KEPHART | BLACK MOSHANNON CREEK | State | PA DCNR | Recreation | 15.4 | 235 | 470 | 7.9 | 3.9 | 2.6 |
| GEORGE B STEVENSON | FIRST FORK SINNEMAHONING CRK | State | PA DCNR | Flood Control | 243 | 142 | 284 | 4.8 | 2.4 | 1.6 |
| HUNTERS LAKE | TROUT RUN | State | PA FISH & BOAT COMMISSION | Recreation | 1.3 | 117 | 234 | 3.9 | 2.0 | 1.3 |
| MONTOUR ASH WATERSHED NO 1 | WTRSHD CHILLISQUAQUE CREEK | Business | MONTOUR, LLC | Ash Watershed | 0.2 | 117 | 234 | 3.9 | 2.0 | 1.3 |
| EAGLES MERE | EAGLES MERE OUTLET | Business | EAGLES-MERE LAND COMPANY | Unpopulated | 0.5 | 116 | 232 | 3.9 | 1.9 | 1.3 |
| LAKE CHILLISQUAQUE | CHILLISQUAQUE CREEK | Business | MONTOUR, LLC | Mill Operation | 5.6 | 113 | 226 | 3.8 | 1.9 | 1.3 |
| LAKE MOKOMA | MILL CREEK | Private | LAKE MOKOMA ASSOCIATION | Recreation | 3.2 | 110 | 220 | 3.7 | 1.8 | 1.2 |
| **Juniata Subwatershed** | | | | | | | | | | |
| SHAWNEE LAKE | TR RAYSTOWN BR JUNIATA RVR | State | PA DCNR | Flood Control | 37.5 | 450 | 900 | 15.1 | 7.6 | 5.0 |
| CANOE CREEK | CANOE CREEK | State | PA DCNR | Recreation | 16.4 | 155 | 310 | 5.2 | 2.6 | 1.7 |
| **Lower Susquehanna Subwatershed** | | | | | | | | | | |
| MIDDLE CREEK | MIDDLE CREEK | State | PA GAME COMMISSION | Recreation | 7.4 | 365 | 730 | 12.3 | 6.1 | 4.1 |
| PINCHOT LAKE | BEAVER CREEK | State | PA DCNR | Recreation | 17.5 | 342 | 684 | 11.5 | 5.7 | 3.8 |
| WALKER LAKE (PA-637) | NORTH BRANCH MIDDLE CRK | State | PA FISH & BOAT COMMISSION | Recreation | 17.6 | 239 | 478 | 8.0 | 4.0 | 2.7 |

| Dam Name | Stream | Owner Type | Permittee | Purpose | Drainage Area (Sq mi) | Surface Area (acres) | 2-Foot Drawdown (ac-ft) | 30-Day Release (cfs) | 60-Day Release (cfs) | 90-Day Release (cfs) |
|---|---|---|---|---|---|---|---|---|---|---|
| FAYLOR LAKE (PA-636) | MIDDLE CREEK | County | COMMISSIONERS OF SNYDER COUNTY | Recreation | 33.2 | 140 | 280 | 4.7 | 2.4 | 1.6 |
| SPEEDWELL FORGE | HAMMER CREEK | State | PA FISH & BOAT COMMISSION | Recreation | 24.1 | 106 | 212 | 3.6 | 1.8 | 1.2 |
| LAKE MARBURG | WEST BRANCH CODORUS CREEK | Business | P.H. GLATFELTER COMPANY | Mill Operation | 23.2 | 1275 | 2550 | 42.9 | 21.4 | 14.3 |
| LAKE MEADE | MUD RUN | Private | LAKE MEADE POA INC. | Recreation | 8.8 | 211 | 422 | 7.1 | 3.5 | 2.4 |
| LAKE PAHAGACO | FIRST FORK OF BUNCH CREEK | Business | P.H. GLATFELTER COMPANY | Recreation | 2.33 | 137 | 274 | 4.6 | 2.3 | 1.5 |

### Middle Susquehanna Subwatershed

There are 12 impoundments in the Middle Susquehanna Subwatershed with a surface area of 100 acres or greater. The largest government entity owned facility is Lake Jean, a state park facility in Luzerne County with a surface area of 245 acres. The largest privately owned facility in the subwatershed is Harvey's Lake, also located in Luzerne County, which has an area of 646 acres. The primary purpose of both facilities is recreational usage. In fact, the primary purpose of all 12 facilities in the subwatershed is recreation. The details for these two impoundments, along with the data for the remaining 10 facilities in the Middle Susquehanna Subwatershed, are shown in Table 3-4. If a 2 foot drawdown could be implemented at all 12 facilities in the subwatershed, just under 5,000 acre feet of low flow augmentation could be realized.

### West Branch Susquehanna Subwatershed

There are 9 impoundments in the West Branch Susquehanna Subwatershed with a surface area of 100 acres or greater. The largest facility is Glendale Lake, a state park facility in Cambria County with a surface area of 1,600 acres. The largest privately owned facility in the subwatershed is an industrial ash disposal watershed, located in Montour County near the Montour power plant, which has an area of 117 acres. It cannot be determined from the dam safety database what type of outlet works may be present at each facility. In fact, it is highly unlikely that an ash watershed facility would have any type of control structure at all. However, if a 2 foot drawdown could be implemented at each of these 2 facilities, a total of just over 3,400 acre feet of water could be made available for low flow augmentation. The details for these two impoundments, along with the data for the remaining seven facilities in the West Branch Susquehanna Subwatershed, are shown in Table 3-4. If all 9 facilities in the subwatershed could be drawn down 2 feet, just under 5,900 acre feet of low flow augmentation could be realized.

### Juniata Subwatershed

There are only 2 impoundments in the Juniata Subwatershed with a surface area 100 acres or greater. The largest facility is Shawnee Lake, a state park facility in Bedford County with a surface area of 450 acres. The only other facility is also a state park lake (Canoe Creek Lake) which has an area of 155 acres. There are no privately owned facilities with a water surface area greater than 100 acres. If a 2 foot drawdown could be implemented at both facilities, a total of just over 1,100 acre feet of water could be made available for low flow augmentation. The details for these two impoundments are shown in Table 3-4.

### Lower Susquehanna Subwatershed

There are 8 impoundments in the Lower Susquehanna Subwatershed with a surface area 100 acres or greater. The largest government entity owned facility is Middle Creek Lake, a Pennsylvania Game Commission facility in Lancaster County with a surface area of 365 acres. The largest privately owned facility in the subwatershed is Lake Marburg which has an area of 1,275 acres. If a two foot drawdown could be implemented at each of these two facilities, a total of just over 3,200 acre feet of water could be made available for low flow augmentation. The details for these two impoundments, along with the data for the remaining six facilities in the Lower Susquehanna Subwatershed, are shown in Table

3-4. If all 8 facilities in the subwatershed could be drawn down two feet, just over 5,600 acre feet of low flow augmentation could be realized.

In summary, if all 51 facilities could be drawn down 2 feet, a total of approximately 40,000 acre feet of water would be available for low flow augmentation. However, utilizing all that potential for low flow augmentation releases is unlikely. First and foremost, it cannot be determined, with the information in the databases provided, if there is the infrastructure in place that would allow drawdown releases to be made. In the Upper Susquehanna Subwatershed, as a result of several internet searches, the two largest facilities (Otsego Lake and Canadarago Lake) appear to be small, uncontrolled overflow spillway type structures that may have flashboards installed to increase impounded water levels. The presence of an auxiliary method for releasing water may not be present, which would necessitate some type of siphon or pumping arrangement to tap into these resources. Additionally, any privately owned facility devoted solely to recreation may be hesitant to agree to a two foot drawdown during the prime water borne recreation time of July, August and early September. Post recreation season drawdowns of shorter durations may be a possibility. These 2 facilities alone make up over 12,000 acre feet of the 40,000 acre foot potential figure cited above.

Another facility where the potential may be difficult to obtain is the 2,200 acre Bradford Dam hydroelectric facility in Steuben County New York. This facility is located on the Susquehanna Watershed divide, and may very well be transferring water into the Great Lakes Watershed through the hydropower facility, rather than having the water available for low flow augmentation. Thus, the 4,400 acre feet of potential storage may not be able to be utilized.

The ten PA DCNR facilities that appear in Table 3-4 have a total surface area of 3,663, resulting in a potential low flow augmentation volume of 7,326 acre feet of water. However, any proposed low flow augmentation releases from PA DCNR lakes would need to not be in conflict with the authorized purposes of the facilities. An agreement is currently in place between the SRBC and PA DCNR regarding coordination of planned drawdowns at facilities within the Susquehanna Watershed, so that the timing of associated releases could be optimized to provide flow augmentation during low flow periods.

The largest privately owned facility in the Lower Susquehanna Subwatershed, Lake Marburg, is identified as being used for mill operations (PH Glatfelter paper mill). However, it also supports a robust recreation purpose at Codorus State Park, which was constructed surrounding the privately owned impoundment. It would require further planning and coordination to add a low flow augmentation release to the existing uses of this water body. An in-depth investigation into the infrastructure specifics of almost all of the facilities listed in Table 3-4, along with "feasibility" discussions with the individual owners, would have to be made in order to determine a realistic estimate of low flow augmentation potential.

### 3.3 <u>ABANDONED MINE STORAGE (AMS) S</u>

There are numerous abandoned mines located within the Susquehanna River Watershed. This includes the bituminous coal fields, the anthracite coal fields and non-coal surface and subsurface mines. Some abandoned mine pools have the potential to augment low flows in streams and rivers located within the Watershed. The following sections provide an overview of AMS within each subwatershed and estimate potential volumes for low flow augmentation, in an effort to prioritize mine pools for low flow management.

Criteria used to assess the low flow augmentation potential of mine pools included storage volume, mine pool water quality, receiving stream classification, drainage area, and engineering concerns. Storage volumes were estimated based on available data for the anthracite and bituminous mine pools, while the non-coal mines were estimated using surface area and an estimated usable water depth of 20 feet. The drainage areas of the mine pools were determined based on estimated discharge locations. In the case of the anthracite and bituminous mine pools, multiple discharges could emanate from the same mine pool, and the discharges may not accurately reflect drainage areas. Mine pool water quality was assumed to generally be poor for all the anthracite and bituminous mine pools, and to require an active treatment plant to treat and discharge the water. Non-coal mine pool water quality was assumed not to require treatment unless the receiving stream was of exceptional value. Exceptional quality trout supporting streams have stricter water quality standards and could pose a challenge for discharging water from non-coal mine pools. Engineering concerns include known challenges for treating anthracite and bituminous mine discharges such as volume, chemistry, and location. Non-coal mines were evaluated by comparing the potential flow augmentation rate with the receiving stream using the estimated 90 day flow augmentation rates and the September 95 percent exceedance flow rate at the discharge point. This was completed using regional regression equations or drainage area ratios. Comparing the September P95 flow rate with the estimated flow augmentation rate provides an understanding of the receiving streams ability to accept low flow augmentation volumes Small volumes of low flow augmentation that is delivered to a large receiving stream may not have an impact to the stream, and conversely, large discharges to a small stream may have a negative impact.

The availability of data for mine pools varies greatly within the Watershed. Consequently, many mine pools cannot be adequately prioritized because there are no data on mine pool extent, storage potential, water quality, or other important metrics. Modern mine regulations were not standardized until the 1977 Federal Surface Mining Control and Reclamation Act (SMCRA). Datasets for post-1977 surface mines were used for non-coal mine pools, and USGS, Pennsylvania Department of Environmental Protection (PADEP), and SRBC publications were used for mine pools in the anthracite and bituminous regions. A GIS review of available permits was conducted to locate and identify existing abandoned mine pools. The GIS dataset used for this analysis were the PADEP active and inactive mine data base as well as the inactive mine reclamation dataset provided by NYSDEC. Historic mine pools (prior to 1977) were included where data were available to supplement the SMCRA data. Only mine pools with an estimated potential of 1 mgd for a 90 day period or greater were included in this analysis.

A total of 38 anthracite and bituminous mine pools, and 38 non-coal mine pools, were identified as having the potential for low flow augmentation based upon the above listed criteria within the Susquehanna River Watershed. Table 3-5 below summarizes all of the identified mine pools with augmentation potential greater than 1 mgd for a 90 day duration by subwatershed.

**Table 3-5. Mine Pools Types and Yields**

| Subwatershed | Non-Coal Mine Pools | Coal Mine Pools | Total 90 Day Yield (mgd) | 90 Day Yield of Largest Mine Pool (mgd) |
|---|---|---|---|---|
| Chemung | 6 | 3 | 31.0 | 7 |
| Upper Susquehanna | 9 | 0 | 36.4 | 10 |
| West Branch Susquehanna* | 9 | 4 | 76.6 | 19 |
| Middle Susquehanna | 1 | 11 | 4,828.2 | 2,674 |
| Juniata | 1 | 1 | 9.1 | 7.1 |
| Lower Susquehanna | 12 | 19 | 59.7 | 21.5 |

* Excludes underground mines of unknown extent or volume

A complete list of mine pools identified during the review is presented below. These mine pools still have the potential for low flow augmentation, but may have criteria that are not as attractive as those listed above. Additional information is provided in the following sections by subwatershed.

### Upper Susquehanna Subwatershed

There are 9 mine pools in the Upper Susquehanna River Subwatershed with an estimated 36.4 mgd flow potential for a 90-day duration. The water quality of these mines is anticipated to mimic local stream and groundwater conditions and not require treatment. All of the mines identified are sand and gravel mines. Only 2 of the receiving streams for these mine pools are designated as exceptional quality or trout supporting streams including the largest facility, South Homer quarry.

The largest facility not located on a high quality receiving stream is the Polkville quarry located along the Tioughnioga River with a drainage area of 342.4 square miles, a low flow September P95 of 25.8 mgd, and an estimated low flow augmentation of 7.5 mgd. This mine pool was prioritized and placed in the final mine pool list due to its size, location, and receiving stream designation. There are no known coal mine pools within the Upper Susquehanna River subwatershed. If all the identified mine pools were developed, a total of 36.4 mgd of potential low flow augmentation could be realized. Table 3-6 summarizes the mine pools identified in the Upper Susquehanna subwatershed during the desktop review.

**Table 3-6. Mine Pools in Upper Susquehanna Subwatershed**

| Subwatershed | Mine Type | Name | Volume (Mgal) | 90 Day Yield (mgd) | Receiving Stream & Use Designation* | Discharge Water Quality |
|---|---|---|---|---|---|---|
| **UPPER** | NON-COAL | South Homer | 968 | 10 | West Branch Tioughnioga [C(T)] | Fair |
| | | Polkville | 688 | 7.5 | Tioughnioga [B] | Fair |
| | | Kilmer | 411 | 4.5 | Meylert Creek [HQ-CWF] | Fair |
| | | Freuhan | 352 | 3.9 | Trib. Rhiney Creek [CWF] | Fair |
| | | Whitney Point | 326 | 3.6 | Tioughnioga [B] | Fair |
| | | Gorick | 224 | 2.5 | Chenango River [B] | Fair |
| | | Barton #1 | 182 | 2 | Susquehanna River [B] | Fair |
| | | Boland | 105 | 1.2 | Chenango River [B] | Fair |
| | | Vann Gravel Pit | 104 | 1.2 | Thomas Creek [C] | Fair |

*NY – NYCRR 6 § 800
*PA – PA Code 25 § 93.9
C- Class C – Waters are suitable for fish, shellfish and wildlife propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.
T- Trout Waters - Any water quality standard, guidance value, or thermal criterion that specifically refers to trout or trout waters applies.
B-Class B - Waters are a source of primary and secondary contact recreation and fishing. These waters shall be suitable for fish, shellfish and wildlife propagation and survival.
CWF-Cold Water Fishes—Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat.

## Chemung Subwatershed

There are a total of nine 9 mine pools in the Chemung subwatershed with an estimated 31 mgd of flow potential for a 90 day period. The water quality of these mines is anticipated to mimic local stream and groundwater conditions and not require treatment, except for the coal mines which require a treatment plant... Only one of the receiving streams was identified as exceptional quality. The largest facility, the Rhinehart quarry, is located along the Chemung River with a drainage area of 2,060 square miles, a P95 flow of 93.9 mgd, and an estimated low flow augmentation potential of 7 mgd. This mine pool was prioritized and placed in the final mine pool list due to its volume potential, receiving stream water quality, and capacity of the receiving stream to accept the augmentation water.

The Tioga River watershed is the only coal-containing watershed in the Chemung subwatershed with all of the identified discharges located in the Upper Tioga River Watershed, which is severely impacted by AMD. In 1979, the U.S. Environmental Protection Agency (USEPA) completed a study in the Morris Run portion of the watershed and found that the down dip method of mining precluded the storage of any significant volume of water. Down dip mining involves mining the coal from a lower elevation to a higher elevation in order to allow any infiltrated water to drain down slope from the active workings. Only three coal mines were found to have potential for flow augmentation. None were included in the prioritized list, but were included in Table 3-7 which summarizes the identified mine pools within the Chemung subwatershed.

**Table 3-7. Mine Pools in the Chemung Subwatershed**

| Subwatershed | Mine Type | Name | Volume (Mgal) | 90 Day Yield (mgd) | Receiving Stream & Use Designation* | Discharge Water Quality |
|---|---|---|---|---|---|---|
| CHEMUNG | NON-COAL | Rhinehart | 619 | 7.0 | Chemung River [C] | Fair |
| | | Dalrymple | 489 | 5.4 | Chemung River [WWF] | Fair |
| | | Rosark Farm | 365 | 4.0 | Newton Creek [C] | Fair |
| | | Cold Spring | 220 | 2.4 | Trib. to Tioga [C] | Fair |
| | | Coopers Plain | 209 | 2.3 | Cohocton River [C] | Fair |
| | | Pall/Buch Pit | 127 | 1.4 | Newton Creek [C(T)] | Fair |
| | COAL | Coal Creek 5 | 324 | 3.6 | Coal Creek [CWF-Imp] | Poor |
| | | Johnson Creek 900 | 297 | 3.3 | Johnson Creek [CWF-Imp] | Poor |
| | | Morris Run 4 | 143 | 1.6 | Morris Run [CWF-Imp] | Poor |

*NY – NYCRR 6 § 800*PA – PA Code 25 § 93.9

C- Class C – Waters are suitable for fish, shellfish and wildlife propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes.

WWF- Warm Water Fishes—Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.

T- Trout Waters - Any water quality standard, guidance value, or thermal criterion that specifically refers to trout or trout waters applies.

CWF-Cold Water Fishes—Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat.

As described in Section 3.5, in addition to providing flood control and recreation, the Tioga-Hammond Lakes project also affords water quality control by mixing the alkaline waters of Hammond Lake with the acidic waters of Tioga Lake to produce a more neutral release from the project. Future water quality improvements throughout the Tioga River Watershed may result in a reduced need to operate the project for water quality control, which could afford greater flexibility for future low flow management. If all the identified mine pools in the Chemung subwatershed were developed for low flow augmentation, a total of 31.0 mgd could be realized.

## Middle Susquehanna Subwatershed

There are 12 mine pools in the Middle Susquehanna subwatershed with an estimated low flow augmentation potential of 4,828.2 mgd. Eleven of the mines are coal mines located within the anthracite coal region, while only one mine was non-coal. Anthracite coal mines are generally deeper compared to bituminous coal mines and thus provide more storage potential than the laterally extensive bituminous mines. A majority of mine pools were not prioritized due to their location beneath major metropolitan areas. Notably, the Scranton-Metro mine pool ostensibly provides a very large estimated mine pool volume (133,790 million gallons) but is entirely underlain by residential and commercial properties. Mine pools with minimal development above the target mine are preferred for flow augmentation. The Jermyn mine pool was identified as having the largest potential for flow augmentation, while having minimal development above the mine pool. The Jermyn mine pool discharges to the Lackawanna River [CWF-Imp] near Jermyn, PA, where the Lackawanna River has a drainage area of 100 square miles. The estimated September P95 is 12.6 mgd with the mine pool having a potential 90 day flow augmentation rate of 45 mgd. A stream capacity assessment would be needed to determine appropriate flow rates to the Lackawanna River due to the fact that the Jermyn mine pool can provide 3.5 times the September P95 flows. All mine pools within the anthracite region would require some sort of water quality treatment prior to providing flow augmentation, and the Jermyn mine pool is no different. Table 3-8 below summarizes all the identified mine pools within the Middle Susquehanna subwatershed.

**Table 3-8. Mine Pools in Middle Susquehanna Subwatershed**

| Subwatershed | Mine Type | Name | Volume (Mgal) | 90 Day Yield (mgd) | Receiving Stream & Use Designation * | Discharge Water Quality |
|---|---|---|---|---|---|---|
| **MIDDLE** | NON-COAL | Beaver | 201 | 2.2 mgd | Catawissa Creek [CWF] | Fair |
| | COAL | Northwestern/Loomis/Inman | 240,661 | 2,674 | Solomon Creek [CWF-Imp] | Poor |
| | | Scranton Metro | 133,790 | 1,487 | Susquehanna River [WWF] | Poor |
| | | Susquehanna #7 | 17,770 | 197 | Newport Creek [CWF-Imp] | Poor |
| | | Wanamie/Sterns | 12,930 | 144 | Newport Creek [CWF-Imp] | Poor |
| | | Duryea | 8,620 | 96 | Lackawanna River [CWF-Imp] | Poor |
| | | Coalbrook | 5,920 | 66 | Coal Brook [CWF-Imp] | Poor |
| | | Jermyn | 4,020 | 45 | Lackawanna River [CWF-Imp] | Fair |

| Subwatershed | Mine Type | Name | Volume (Mgal) | 90 Day Yield (mgd) | Receiving Stream & Use Designation * | Discharge Water Quality |
|---|---|---|---|---|---|---|
| | | Forest City | 3,700 | 41 | Lackawanna River [CWF-Imp] | Poor |
| | | Gravity Slope | 2,860 | 32 | Lackawanna River [CWF-Imp] | Poor |
| | | Glen Lyon | 2,480 | 28 | Newport Creek [CWF-Imp] | Poor |
| | | East Side | 1,590 | 18 | Lackawanna River [CWF-Imp] | Poor |

*NY – NYCRR 6 § 800
*PA – PA Code 25 § 93.9
CWF-Cold Water Fishes—Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat.
Imp- Impaired - Streams and bodies of water not attaining designated and existing uses as part of 305(b) and 303(d) of the Clean Water Act (CWA)

### West Branch Susquehanna Subwatershed

There are 13 mine pools in the West Branch Susquehanna subwatershed with an estimated flow augmentation potential of 76.6 mgd. Nine of the mines are non-coal and are a mix of surface and underground mines. Volumes for the underground mines could not be assessed with the available data at hand; however, historically, these mines have been excavated several hundred feet in depth based on PADEP historic mining reports and have the potential for significant low flow augmentation. A few of these underground mines are currently active; however, deeper portions of the mines no longer being mined may be flooded and could provide augmentation flows. These active and abandoned mines should be investigated further. The remaining non-coal mines are comprised of sand and gravel mines and dimension stone quarries. The only non-coal surface mine prioritized was the Hanson 2 quarry. Although it has a smaller augmentation yield when compared to other mine pools, the quarry may be deeper than the 20 feet of depth used for this assessment due to the type of mining. The Hanson 2 mine quarried dimension stone from solid rock. Modern mining procedures require a bench cut of 50 feet, and it is anticipated that the Hanson 2 mine would have similar benches.

The West Branch subwatershed is located within the bituminous coal field of western Pennsylvania. Due to the same down dip mining method employed in the Chemung, the majority of mine pools have minimal storage. In 2006, PADEP investigated ten mine pools in the West Branch subwatershed; their primary focus was water quality enhancement and stream restoration rather than low flow augmentation. Of the ten mines investigated, three were rejected for various reasons, two are under construction/investigation, and one is in the Juniata subwatershed. Four remain viable candidates and were retained for this evaluation. The largest of these coal mines is Moss Creek with a drainage of 3.7 square miles from its main discharge. The estimated 90 day rate provided by PADEP was 21.7 mgd. It should be noted that a second discharge from the mine pool is used as source water for a public water supply. Due to the small watershed size, accurate low flow statistics could not be calculated. It is anticipated that a review of Moss Creek's capacity to accept augmentation flows up to the estimated 21.7 mgd rate will be needed. The use of the mine pool as a public water supply will also need to be evaluated for impacts. The Moss Creek mine pool was selected for prioritization due to its water quality, existing data, and potential volume. Table 3-9 summarizes identified mine pools in this subwatershed.

**Table 3-9. Mine Pools in West Branch Susquehanna Subwatershed**

| Subwatershed | Mine Type | Name | Volume (Mgal) | 90 Day Yield (mgd) | Receiving Stream & Use Designation* | Discharge Water Quality |
|---|---|---|---|---|---|---|
| **WEST BRANCH** | NON-COAL | Hawbaker Valley Mine | UNDGR | >1 + | Gap Run [CWF] | Fair |
| | | Graymont Pleasant Gap | UNDGR | >1+ | Gap Run [CWF] | Fair |
| | | Centre Lime | UNDGR | >1+ | Gap Run | Fair |
| | | Bell/Con Lime | UNDGR | >1+ | Buffalo Run [HQ-CWF] | Fair |
| | | Hanson | 1,733 | 19 | West Branch Susquehanna [WWF] | Fair |
| | | Pleasant Gap Aggregate | 202 | 2.2 | Gap Run [CWF] | Fair |
| | | North Star | 195 | 2.2 | Bennett Branch Sinnemahoning Creek [CWF] | Fair |
| | | Winfield Lime | 172 | 1.9 | Winfield Creek [WWF] | Fair |
| | | Hanson | 137 | 1.5 | Muncy Creek [TSF] | Fair |
| | COAL | Moss Creek | 1,960 | 21.7 | Moss Creek [WWF-Imp] | Fair |
| | | Hughes | 1,540 | 17.1 | Little Conemaugh River [Imp] | Poor |
| | | Eureka 29 | 440 | 4.9 | Muddy Run [Imp] | Poor |
| | | Bark Camp | 190 | 2.1 | Matley Run [Imp] | Poor |

*NY – NYCRR 6 § 800
*PA – PA Code 25 § 93.9
+ Due to unknown volumes, rates were assumed to be greater than 1 mgd over a 90 day period
WWF- Warm Water Fishes—Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
CWF-Cold Water Fishes—Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat.

TSF- Trout Stocking—Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
HQ- High Quality Waters
Imp- Impaired - Streams and bodies of water not attaining designated and existing uses as part of 305(b) and 303(d) of the Clean Water Act (CWA)

## Juniata Subwatershed

There are only two mine pools in the Juniata subwatershed with low flow augmentation potential of 1 mgd or greater. The largest facility is Broad Top mine within the western bituminous coal region. The Broad Top mine is located along Shoup Run, with a drainage area of 21.4 square miles, a September P95 flow of 1.9 mgd, and an estimated low flow augmentation potential of 7.1 mgd. Shoup Run and Great Trough Creek watersheds are both underlain by the Broad Top Coal mine and provide recharge to the mine pool. Further analysis would be needed to determine the ability of Shoup Run to assimilate augmentation flows of 7.1 mgd during low flow conditions. A treatment plant would be needed in order to treat and discharge mine pool water due to poor water quality. The Broad Top mine was included in the prioritized mine pool list since it has the highest potential for low flow augmentation in the Juniata Subwatershed. Table 3-10 below summarizes the identified mine pools in the Juniata subwatershed.

**Table 3-10. Mine Pools in Juniata Subwatershed**

| Subwatershed | Mine Type | Name | Volume (Mgal) | 90 Day Yield (mgd) | Receiving Stream & Use Designation* | Discharge Water Quality |
|---|---|---|---|---|---|---|
| JUNIATA | NON-COAL | Center Valley | 101 | 2.0 | Trib. to Honey Creek [HQ-CWF] | Fair |
| | COAL | Broad Top | 645 | 7.1 | Shoup Run [WWF-Imp] | Poor |

*NY – NYCRR 6 § 800
*PA – PA Code 25 § 93.9
WWF- Warm Water Fishes—Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
CWF-Cold Water Fishes—Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat.
HQ- High Quality Waters
Imp- Impaired - Streams and bodies of water not attaining designated and existing uses as part of 305(b) and 303(d) of the Clean Water Act (CWA)

## Lower Susquehanna Subwatershed

There are 31 mine pools in the Lower Susquehanna subwatershed with an estimated low flow augmentation potential of 59.7 mgd. Nineteen of the mines are coal mines located within the anthracite coal region. The remaining 12 non-coal mines are comprised of sand and gravel quarries, limestone quarries, and dimension stone quarries that have estimated augmentation flow rates that range from 1.1 to 4.7 mgd. The Pennsy-Hershey and the Bainbridge quarries were prioritized due to their volume potential, proximity to receiving streams, and anticipated water quality due to the carbonate bedrock. The water quality in the mine pool is anticipated to be equal or better than the quarries' respective receiving stream and therefore water quality is not anticipated to be a concern. In general, non-coal mine pools do not require water quality treatment which reduces implementation costs.

The majority of low flow augmentation potential in the Lower Susquehanna subwatershed is located within the anthracite mine pools. The anthracite coal mines located within the Lower Susquehanna are among the most geologically complex mine pools in the Susquehanna River Watershed and can be difficult to characterize. The Brookside mine pool is located in the Rausch Creek watershed and has a drainage area of approximately 9.4 square miles and a low flow augmentation potential of 22 mgd for a 90-day period. Brookside was prioritized because there is an existing treatment plant located near the confluence of Rausch Creek and Pine Creek. This existing infrastructure, as well as the volume potential and minimal development above the mine pool, warrants future investigations. Table 3-11 below summarizes the identified mine pools within the Lower Susquehanna subwatershed.

**Table 3-11. Mine Pools in Lower Susquehanna Subwatershed**

| Subwatershed | Mine Type | Name | Volume (Mgal) | 90 Day Yield (mgd) | Receiving Stream & Use Designation* | Discharge Water Quality |
|---|---|---|---|---|---|---|
| **LOWER** | NON-COAL | Vulcan 2 | 423 | 4.7 | South Branch Conewago Creek [WWF] | Fair |
| | | Cornwall | 417 | 4.6 | Snitz Creek [TSF] | Poor |
| | | Pennsy Hershey | 345 | 3.8 | Swatara Creek [WWF] | Fair |
| | | Cedar | 312 | 3.5 | Yellow Breeches [CWF] | Fair |
| | | Manchester | 260 | 2.9 | Codorus Creek [WWF] | Fair |
| | | Mundis Road | 247 | 2.7 | Codorus Creek [WWF] | Fair |
| | | Regents Glen | 202 | 2.2 | Codorus Creek [WWF] | Fair |
| | | Bainbridge | 189 | 2.1 | Susquehanna River [WWF] | Fair |
| | | Fontana Quarry | 110 | 1.2 | Bachman Run [TSF] | Fair |
| | | Silver Spring | 110 | 1.2 | Conodoguinet [WWF] | Fair |
| | | Peach Bottom | 110 | 1.2 | Michael Run [WWF] | Fair |

| Subwatershed | Mine Type | Name | Volume (Mgal) | 90 Day Yield (mgd) | Receiving Stream & Use Designation* | Discharge Water Quality |
|---|---|---|---|---|---|---|
| | | Glen-Gery | 97 | 1.1 | South Branch Conewago Creek [WWF] | Fair |
| | COAL | Packer | 3,873 | 43 | Mahanoy Creek Watershed [Imp] | Poor |
| | | Scott | 3,081 | 34.2 | Shamokin Creek Watershed [Imp] | Poor |
| | | Maysville-Corbin | 2,504 | 27.8 | Shamokin Creek Watershed [Imp] | Poor |
| | | Cameron | 2,415 | 26.8 | Shamokin Creek Watershed [Imp] | Poor |
| | | Sterling | 2,368 | 26.3 | Shamokin Creek Watershed [Imp] | Poor |
| | | Brookside | 1,935 | 22 | Rausch Creek [Imp] | Poor |
| | | Potts-Tunnel | 1,460 | 16.2 | Mahanoy Creek Watershed [Imp] | Poor |
| | | Gilberton | 1,176 | 13.1 | Mahanoy Creek Watershed [Imp] | Poor |
| | | Locust Gap | 1,031 | 11.5 | Mahanoy Creek Watershed [Imp] | Poor |
| | | Bast | 870 | 9.7 | Mahanoy Creek Watershed [Imp] | Poor |

| Subwatershed | Mine Type | Name | Volume (Mgal) | 90 Day Yield (mgd) | Receiving Stream & Use Designation* | Discharge Water Quality |
|---|---|---|---|---|---|---|
| | | North Franklin | 781 | 8.6 | Mahanoy Creek Watershed [Imp] | Poor |
| | | Vulcan | 672 | 7.5 | Mahanoy Creek Watershed [Imp] | Poor |
| | | Girard | 420 | 4.7 | Mahanoy Creek Watershed [Imp] | Poor |
| | | Donaldson | 388 | 4.3 | Rausch Creek [Imp] | Poor |
| | | Mid Valley | 355 | 3.9 | Mahanoy Creek Watershed [Imp] | Poor |
| | | Big Mountain | 332 | 3.7 | Shamokin Creek Watershed [Imp] | Poor |
| | | Preston | 276 | 3.1 | Mahanoy Creek Watershed [Imp] | Poor |
| | | Markson | 239 | 2.6 | Rausch Creek [Imp] | Poor |
| | | Centralia | 103 | 1.1 | Mahanoy Creek Watershed [Imp] | Poor |

*NY – NYCRR 6 § 800
*PA – PA Code 25 § 93.9
WWF- Warm Water Fishes—Maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.
CWF-Cold Water Fishes—Maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat.
HQ- High Quality Waters
Imp- Impaired - Streams and bodies of water not attaining designated and existing uses as part of 305(b) and 303(d) of the Clean Water Act (CWA)
Trout Stocking-Maintenance of stocked trout from February 15 to July 31 and maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat.

In summary, if all 31 facilities presented above could be developed at the estimated volumes, a total of approximately 5,282 mgd of low flow augmentation could be made available for a 90-day period. However, utilizing all that potential for low flow augmentation releases is unlikely. The potential volumes and rates are estimated and would need further investigation to verify actual yields. Additionally, underground mine pools may have subterranean structural issues that require more infrastructure than a standard treatment plant. Lastly, existing water use and land ownership may prevent the full development of identified mine pools.

In general, anthracite and bituminous mine pools provide the largest potential for low flow augmentation, but require the most in terms of additional investigation costs, construction costs, and potential for environmental liability (spills/subsidence/habitat impact). The non-coal quarries and mines generally have less water storage than coal mines, but typically have better water quality, and often have existing infrastructure (right of way/pumps/intakes) that can be used to develop augmentation water. After reviewing the available data for the above-mentioned mines, a total of 4 coal mines with an estimated potential of 96 mgd, and 6 non-coal mines with an estimated potential of 37.8 mgd for a 90 day period, were prioritized. It should be noted that within the non-coal mines, four underground mines with unknown volume were included but not tabulated in the total estimated volume. These underground mines could provide significant additional low flow augmentation based on historic mining records. Table 3-12 below summarizes the ten mine pools prioritized for low flow augmentation. A location map of the prioritized mine pools is also provided (Figure 3-3).

**Table 3-12. Shortlisted Mine Pools and Quarries Options**

| Subwatershed | Mine Type | Name | Volume (Mgal) | 90 Day Yield (mgd) | Receiving Stream & Use Designation* | Discharge Water Quality |
|---|---|---|---|---|---|---|
| Middle | Coal Mine | Jermyn | 4,020 | 45 | Lackawanna River [CWF-Imp] | Fair |
| West Branch | Coal Mine | Moss Creek | 1,960 | 22 | Moss Creek [CWF-Imp] | Fair |
| Lower | Coal Mine | Brookside | 1,936 | 22 | Rausch Creek [CWF-Imp] | Poor |
| West Branch | Sand and Gravel | Hansen | 1,733 | 19 | West Branch Susquehanna River [WWF] | Fair |
| Upper | Sand and Gravel | Polkville | 688 | 7.5 | Tioughnioga [B] | Fair |
| Juniata | Coal Mine | Broad Top | 645 | 7 | Great Trough Creek [CWF - Imp] | Poor |
| Chemung | Sand and Gravel | Dalrymple | 489 | 5.4 | Chemung River [WWF] | Fair |
| Lower | Limestone | Pennsy Hershey | 345 | 3.8 | Swatara Creek [WWF] | Good |
| Lower | Dolomite | Bainbridge | 189 | 2.1 | Susquehanna River [WWF] | Good |
| Middle | Non-coal | Hawbaker/ Graymont+ | N/A | N/A | Numerous[HQ-CWF] | Good |

*NY – NYCRR 6 § 800
*PA – PA Code 25 § 93.9

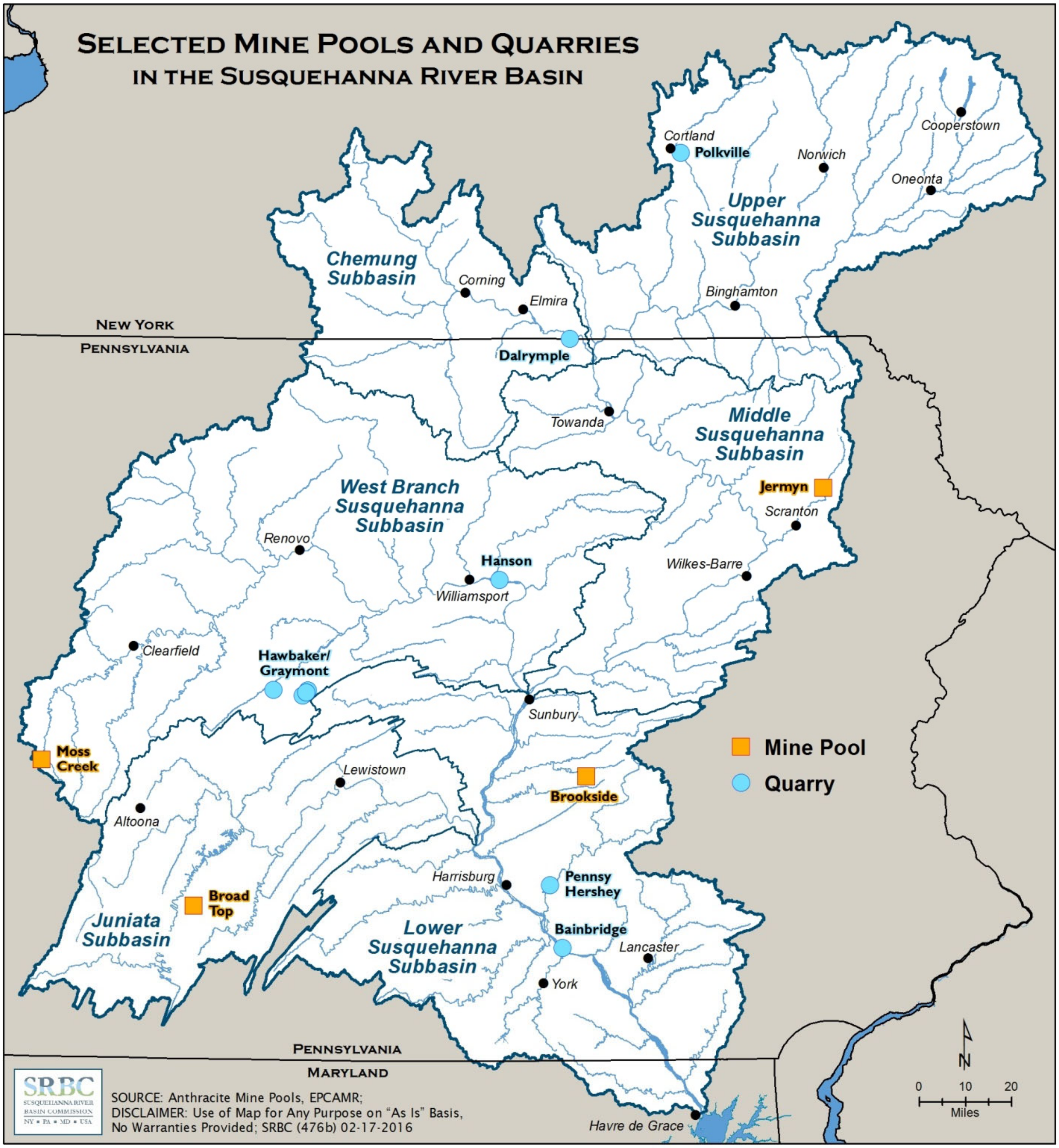


**Figure 3-3. Shortlisted Mine Pools and Quarries.**

# Chapter 4. Ecosystem Flow Needs and Benefits

Section 4.1 will discuss the hydro-geomorphic characteristics for each of the subwatersheds as they relate to low-flow conditions and ecosystem needs. The focus is on those habitats that may be influenced by low flow management alternatives which include streams with greater than 200 square mile contributing watershed. In Section 4.2, the stream type characterization is followed by a subwatershed-by-subwatershed description of biological characteristics and potential risks to ecosystem flow needs from hydrologic alteration. The discussion concludes in Section 4.3 with an overview of the potential qualitative benefits and impacts of low flow management alternatives on ecosystem needs.

## 4.1 HYDRO-GEOMORPHIC CHARACTERISTICS

This analysis includes the major tributary and mainstem habitats discussed in the Ecosystem Flow Recommendations for the Susquehanna River Watershed (TNC, 2010). Major tributaries and mainstem habitats are refined using a recent stream classification system developed by TNC for the Appalachian Landscape (Olivero et al., 2015) that includes updated temperature, floodplain confinement and gradient classifications, in order to distinguish between unique hydro-geomorphic habitats in each of the subwatersheds. Watershed-scale maps for each characteristic are included in Figure 4.1 and Appendix B.

### Stream size

The physical size of a stream relates to major changes in the habitat template and trophic assemblages supported by a stream (Vannote, 1980). In the Susquehanna, stream size, as described by contributing watershed area, has been shown to be a significant predictor of fish and aquatic insect assemblages (Olivero et al. 2015). This study focuses on two size classes: 200-1,000 square miles (tributaries); and greater than 1,000 square miles (Mainstem Rivers).

*

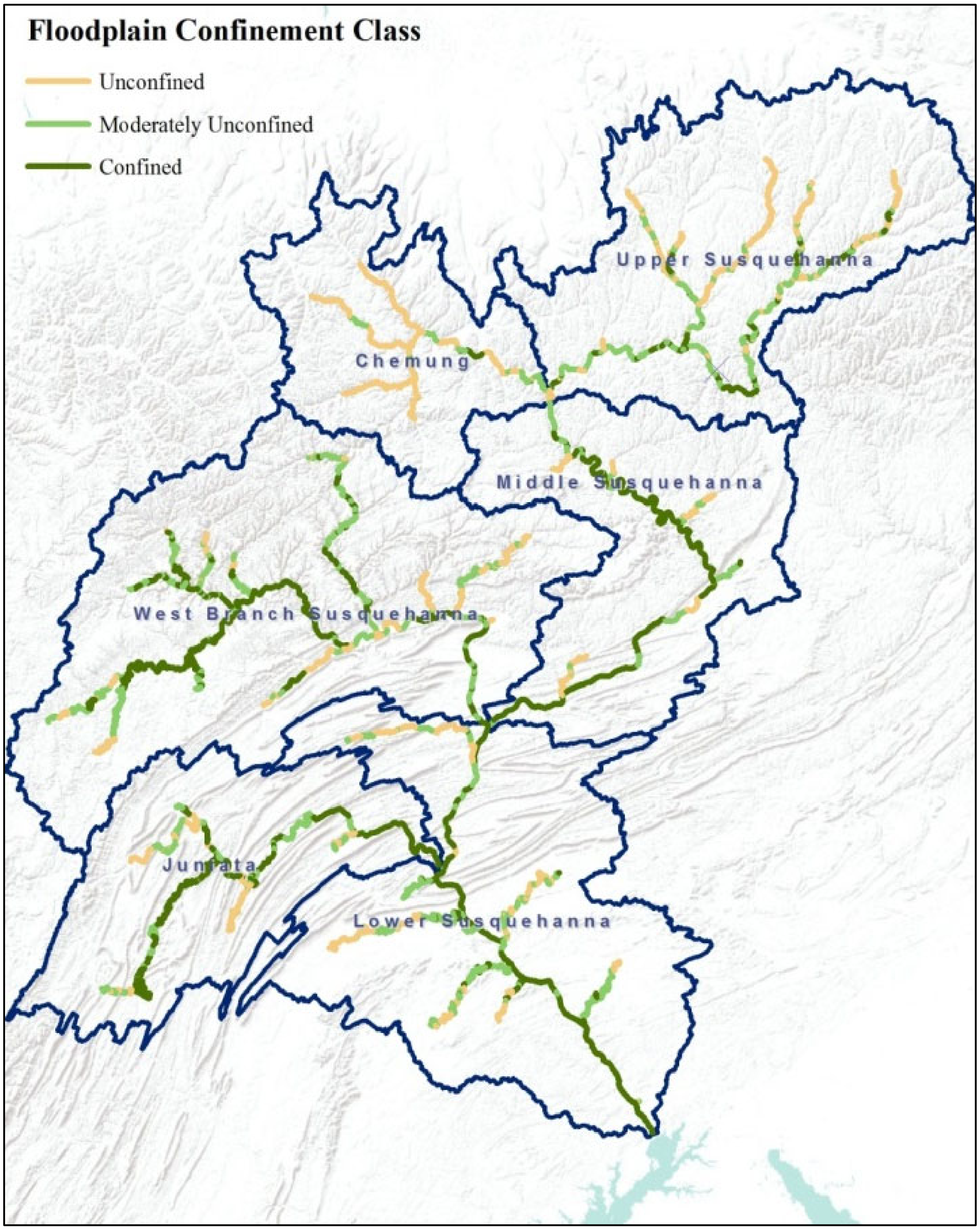


**Figure 4-1. Example Subbasin map illustrating the distribution of floodplain confinement classes.**

***For a complete set of classification maps, see Appendix B.**

### Temperature

Within stream size classes, there are two temperature classes; transitional cool and warm. Each species is adapted to a range of temperatures suited to meet its physiological needs. Therefore, different species inhabit streams based on their temperature range. Transitional cool tributaries have a mean summer temperature of 64.4-71.6°F (18-22°C) and support species like mottled sculpin, blacknose dace, and creek chub. Warm tributaries and large rivers have a mean summer temperature of ≥ 71.6° F (22°C) and support species like longear sunfish, smallmouth bass and shorthead redhorse.

### Confinement and gradient

A stream's underlying and surrounding geology influences the gradient of the streambed textures and confinement of the floodplain. Confinement can be described as the proximity of bounding topographic features that influence a river's space for migration and meandering (Nagel et al., 2014). In turn, gradient and confinement influence the stream's physical and hydraulic habitat including substrate size and distribution, velocity, wetted width, hyporheic zone and extent of the active river area. An unconfined, lower gradient stream will have slower velocities, a large active river area, and likely a greater extent of the hyporheic zone and flood-dependent forests and wetlands. A confined, moderate gradient stream will have greater velocities and likely a narrow active river area with limited hyporheic zone and flood-dependent forests and wetlands. Confinement for tributaries and large rivers is defined in three classes based on the ratio of active river area to bankfull width; confined (0-2), moderately confined (3-6) and unconfined (≥7) (Olivero et al., 2015).

**Table 4-1. Stream Classification by Size, Temperature, Confinement and Gradient**

| Subwatershed | Size | Temperature | Confinement and gradient |
|---|---|---|---|
| Upper Susquehanna | Tributaries | Transitional cool | Unconfined, low gradient |
| | Mainstem river | Warm | Moderately unconfined |
| Chemung | Tributaries | Transitional cool | Unconfined, moderate-low gradient |
| | Mainstem river | Warm | Unconfined-moderately unconfined, low gradient |
| Middle Susquehanna | Tributaries | Transitional cool | Unconfined-moderately unconfined, moderate gradient |
| | Mainstem river | Warm | Confined, low gradient |
| West Branch Susquehanna | Tributaries | Transitional cool | Unconfined to confined, moderate-low gradient |
| | Mainstem river | Warm | Unconfined to confined, low gradient |
| Juniata | Tributaries | Warm | Unconfined to confined, low gradient |
| | Mainstem river | Warm | Unconfined to confined, low gradient |
| Lower Susquehanna | Tributaries | Warm | Moderately confined, low gradient |
| | Mainstem river | Warm | Confined, very low gradient |

*Subwatershed maps are included in Appendix A (Olivero et al. 2015).

## 4.2 ECOLGICAL FLOW NEEDS AND HYDROLOGIC ALTERATION

### 4.2.1 Ecological conditions flow related needs assessment

Products from the TNC (2010) study included a set of flow-ecology diagrams that outline flow-sensitive taxa groups, the timing of key life stages for major habitat types and a series of species distribution tables associating each flow-sensitive taxa group with the major habitat types. Those resources were the foundation of a discrete set of ecosystem flow needs for each habitat type (Figure 4-2).

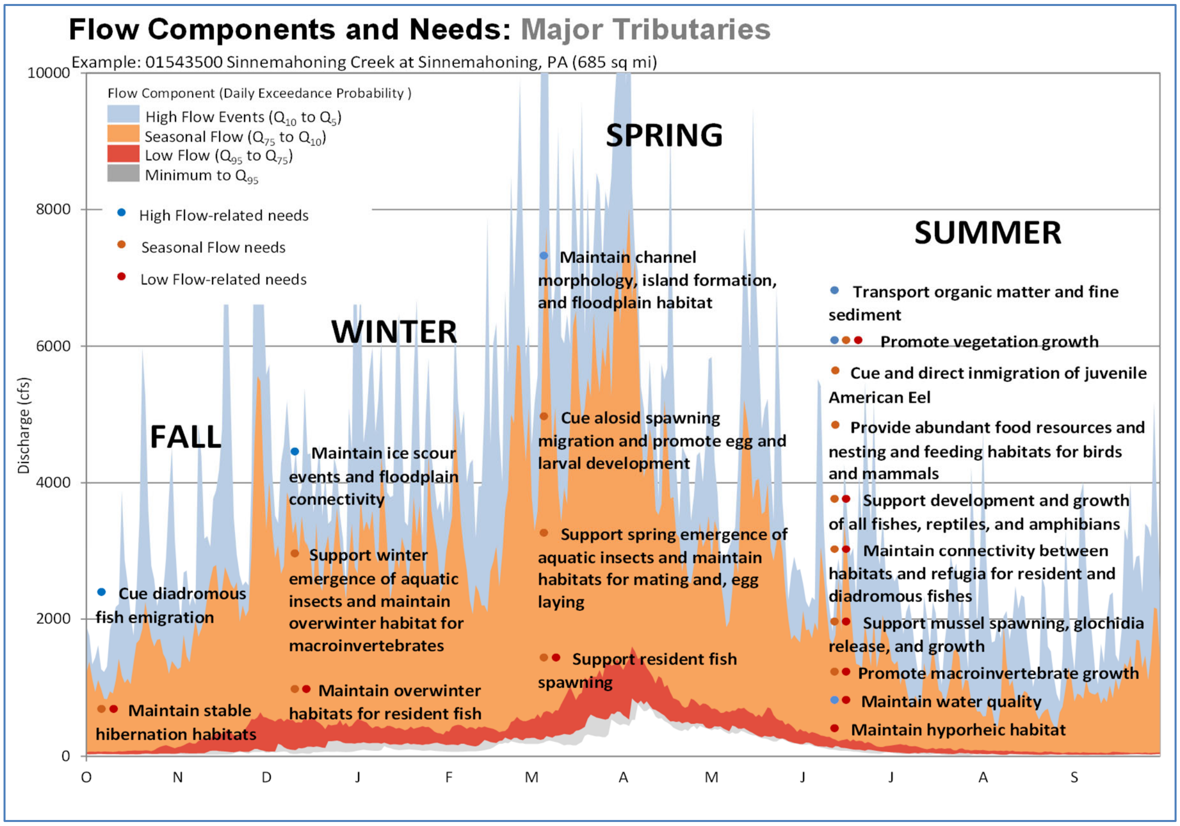


**Figure 4-2. Ecosystem Flow Needs for Major Tributaries.**

The TNC (2010) framework was used to link the presence of specific flow-sensitive taxa groups for tributary and the mainstem river habitats in each of the six subwatersheds to low-flow related ecosystem flow needs (Table 4-2). For each subwatershed, biological characteristics are summarized by reviewing state biological databases, species occurrence data from the natural heritage program and regional literature including the Pennsylvania Aquatic Community Classification, to document which of the flow-sensitive taxa groups identified in the 2010 study are represented (PFBC, 2008; PNHP, 2014; Walsh et al., 2008). This is generally a contemporary summary of species distribution, however, it also includes the diadromous fishes that were historically ubiquitous throughout the watershed but have been restricted by the presence of four dams on the lower Susquehanna River (ASMFC, 2010). There are restoration actions taking place to restore the historic distribution of these species, therefore they are represented here.

**Table 4-2. Ecological Flow Needs by Season for Major Tributaries and Mainstem**

Red shading refers to monthly low flow conditions; Orange shading refers to monthly seasonal flow conditions.

| Flow Need | Summer | | | Fall | | | Winter | | | Spring | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | J | J | A | S | O | N | D | J | F | M | A | M |
| **Fish** | | | | | | | | | | | | |
| Maintain connectivity between habitats and refugia for resident and diadromous fishes | | | | | | | | | | | | |
| Cue immigration of juvenile American eel | | | | | | | | | | | | |
| Maintain overwinter habitats for resident fish | | | | | | | | | | | | |
| Support resident fish spawning | | | | | | | | | | | | |
| Cue alosid migration, spawning and egg and larval development | | | | | | | | | | | | |
| **Mussels** | | | | | | | | | | | | |
| Supports mussel spawning, glochidia release and growth | | | | | | | | | | | | |
| Support winter emergence of aquatic insects and maintain overwinter habitat | | | | | | | | | | | | |
| **Reptiles and Amphibians** | | | | | | | | | | | | |
| Promote/support development and growth of reptiles and amphibians | | | | | | | | | | | | |
| Maintain stable hibernation habitats | | | | | | | | | | | | |
| **Vegetation** | | | | | | | | | | | | |
| Promote vegetation growth | | | | | | | | | | | | |
| **Birds and Mammals** | | | | | | | | | | | | |
| Provide abundant food sources and maintain nesting habitat for birds and mammals | | | | | | | | | | | | |
| **Water Quality, Temperature and Geomorphology** | | | | | | | | | | | | |
| Maintain water quality | | | | | | | | | | | | |
| Transport organic matter and fine sediment | | | | | | | | | | | | |

* Each ecosystem flow need is linked to relevant flow components (TNC, 2010).

### 4.2.2 Hydrologic Alteration Assessment

#### Background

As discussed previously in tributary and mainstem habitats, flows peak in April with snowmelt and spring rains and resume to base flows in the late summer and early fall. Hydrologic conditions can vary significantly from year to year. Even within a year, drought and flood conditions can occur. Hundreds of species have evolved to sync their life stages with these annual and inter annual hydrologic patterns (TNC, 2010). Built on the Ecological Limits of Hydrologic Alteration (ELOHA) methodology, ecosystem flow recommendations were developed to limit change to ecologically-relevant flow components in order to support ecosystem needs in tributary and mainstem habitats (Poff et al., 2010; TNC, 2010).

#### Methods

The purpose of this portion of the analysis is to summarize whether hydrologic alteration to low flow components has occurred over the period of record and how much can be attributed to reservoir operations and CU. A three step process was used to investigate whether a statistically significant change can be detected, and if so, whether the change is outside of ecosystem flow recommendations and may pose a risk to ecosystem flow needs.

1. **Comparing baseline (unregulated) and current (regulated) conditions through a Mann-Kendall test** - First, a non-parametric statistical trend test was employed to examine any significant changes in ecologically-relevant low-flow components over time. The Mann-Kendall test (Mann, 1945; Kendall, 1975; Gilbert, 1987) was used to detect upward or downward trends in streamflow parameters over long period of records in both regulated and unregulated locations, which may indicate that hydrology has or hasn't been altered. For this assessment monthly percent exceedance flow values were calculated for 3-year time steps (i.e. 1895-1930, 1895-1933, 1895-1936, 1895-2014) and 7-day minimum flows were calculated annually for subwatershed reference gages and proximal unregulated gages. Both of the statistics were used as inputs for the Mann-Kendall tests. The test allows us to track changes in low flow statistics throughout early development and industrialization of the 1930's, periods of prominent reservoir development and regulation in the 1950-60's, and assess present-day conditions. The trend itself could be attributed to a multitude of factors, including climate change, reservoir operations, changes in water use rates, policy development and consequent regulation of low flows, changes in land use/land cover, mining, and others. To isolate the impact of reservoir operation and CU from other anthropogenic and climate influences on hydrology, Mann-Kendall tests were completed for a nearby, long-term, unregulated reference gage record within each subwatershed and were compared to the trends observed from subwatershed gage records. Reference stream gages selected for this analysis were minimally altered by regulation, diversion, or mining, and other anthropogenic activities, and had periods of record comparable to subwatershed reference gages (Stuckey et al., 2012; Gazoorian, 2015). The comparison of trends from unregulated and subwatershed locations may provide insight on whether the reservoir operations and consumptive use are contributing to hydrologic alteration, if detected. In the results section below, the Mann-Kendall test results are presented for

each low-flow statistic at both unregulated and subwatershed gages. To help visualize the trend analysis result, upward/downward trends with 95 percent confidence are symbolized by ▲/▼ and upward/downward trends with 90 percent confidence are symbolized by △/▽.

2. **Comparing baseline (unregulated) and current (regulated) conditions in Indicators of Hydrologic Alteration (IHA) –** In order to assess hydrologic alteration at the source where it is presumably occurring, it was determined that a baseline (unregulated) record is needed in order to compare records. Several methods have been proposed to characterize baseline (unregulated) conditions although many challenges have been incurred while trying to replicate a baseline streamflow time series that excludes manmade activities, particularly in a large watershed setting. Four specific methods were explored to best estimate baseline conditions and minimize estimation errors and biases, these are described in detail within Appendix C. Of these methods, daily inflow time series from SRBC's OASIS hydrologic model was determined to be the most appropriate approximation of baseline conditions. In the OASIS model, baseline conditions are synthesized by adding part of the impairments caused by reservoir operations and historic consumptive water use back into the gaged records. Current conditions reflect water use, regulation, and reservoir operations and are represented using USGS daily streamflow data from select subwatershed gages (referenced in the tables below). Baseline conditions are compared to current conditions using IHA. IHA calculates a suite of ecologically-relevant flow statistics and assigns daily flows to various flow components. A common period of record of 1960 through 2014 was used to compare all baseline and current condition records. This includes the drought of the 1960's and recent flood events.

   Specific limitations to the OASIS/IHA approach that should be considered when interpreting and applying the results include estimation errors associated with water use estimation, back interpolation of (monthly to daily) reservoir operations and assumptions in OASIS inflow generation. For OASIS inflow time series, end-of-month reservoir elevations and storage-area-elevation curves were used for computing reservoir impairments on a monthly basis. By disaggregating monthly impairments into a daily flow time series, the daily reservoir storage volumes or releases may not be truly reflected in the synthesized daily inflow time series. Additional methods that were considered for estimating baseline conditions and their limitations are described in Appendix C.

3. **Using hydrologic alteration to estimate ecological risk -** Consistent with the Ecosystem Flow Recommendations for the Susquehanna River Watershed (TNC, 2010), and within the scope of this analysis, various components of the flow regime associated with ecosystem needs under low flow conditions were assessed. These include:
   - Low flow seasons (Summer and Fall Monthly Q50)
   - Seasonal low flow magnitude (Spring, Summer, Fall and Winter Monthly Q95);

- Seasonal low flow range (the change, in area, between the baseline and current flow duration curves from the monthly Q75 - Q99); and
- Extreme low flow conditions (1 in 5 year drought, 1 in 10 year drought and drought of record (DOR), all measured by the 7-day low flow during that event).

Estimated changes between current and baseline condition are compared to the ecosystem flow recommendations and the Phase I Low Flow Management Study in order to estimate the level of ecological risk posed by the degree of hydrologic alteration (TNC, 2010; USACE, 2012). Three categories are used to characterize estimated risk (Table 4-3). For each subwatershed there is a summary table of baseline and current low flow conditions, followed by a percent change and defined risk category. For those statistics where alteration has resulted in a lower magnitude of low flow conditions, or a decrease, risk category thresholds are linked to the 2010 recommendations. For those statistics where alteration has resulted in a greater magnitude of low flow conditions, or an increase, the approach was supplemented. The vast majority of flow-ecology publications have documented the negative effects of exacerbating low flow conditions and drought. Only a few studies have documented the ecological benefits of extreme low flow conditions. Fewer document the ecological risks of augmenting extreme low flow or drought conditions. The TNC (2010) recommendations reflect these study biases and generally focused on the risks of low flow reductions (e.g. water withdrawals or reservoir storage) as opposed to risks of increasing the magnitude of low flow events (e.g. augmentation). For this analysis recent literature was reviewed and related to the ecological risks of flow augmentation. These studies indicate that the ecological risk of reduced flow magnitudes may be greater than the ecological risk of increased flow magnitudes, and that a 'moderate' risk may be imposed when flow components are increased by more than 20 percent (Zimmerman and Poff, 2010; Richter et al., 2011; TNC 2013) (Appendix C).

### Limitations and opportunities to improve future analyses.

In addition to the limitations described above for describing baseline conditions, there are several data and model limitations summarized below to consider when interpreting and applying the results.

- A continuous period of analysis (1960-2014) was utilized. Refining this period into isolated years that represent specific changes in water management including new water use projects, new reservoirs or modified reservoir regulation, and new regulations or policies could improve the granularity of interpretation.
- For each subwatershed, a single point was utilized at the subwatershed reference gage, to represent changes to low flow conditions in that subwatershed. This does not account for the changes to low flow conditions in headwaters, creeks and small rivers in those subwatersheds.
- As discussed in Appendix C, a future comparative analysis may help to quantify the estimation errors associated with each approach to estimating baseline conditions and lend itself to a composite analysis.

- Higher resolution water use and availability data could improve the ability to isolate and communicate hydrologic alteration in response to consumptive use and reservoir operations.
- There are several landscape-scale and local factors that influence hydrology, perhaps most significantly, land use change. Further assessment could focus on isolating the influence of these factors from those of water storage, release and allocation.

**Table 4-3. Ecological Flow Risk Categories Based on Degree of Hydrologic Alteration**

| Risk Category | | Definition of Risk Category |
|---|---|---|
| ● (green) | Low Risk | Hydrologic alteration for a given statistic is between **-10 and +20% of the recommended limits of alteration** |
| ● (yellow) | Moderate Risk | Hydrologic alteration for a given statistic is less than – 10 to +20% greater than recommended limits, but < **+/- 50% alteration** from the baseline condition. |
| ● (orange) | High Risk | Hydrologic alteration for a given statistic is ≥ **+/- 50% alteration** from the baseline condition. |

*TNC 2010, Zimmerman and Poff 2010, Richter et al. 2011, TNC 2013.

### 4.2.3 Hydrologic Alteration Risks

#### Upper Susquehanna

The Upper Susquehanna subwatershed contains transitional cool, unconfined tributaries and warm, moderately unconfined large rivers (mainstem). These habitats support a range of flow-sensitive species groups (Table 4-4), both in the channel bed and in the floodplain. Here, there are unique high quality hyporheic and floodplain indicators like the Clubtail family.

All flow-sensitive taxa groups of mussels represented, representing a range of velocity and substrate preferences are seen as well. These taxa have low desiccation tolerances and benefit by stable low flow conditions. This subwatershed also supports a complex and healthy vegetation structure ranging from submerged aquatic vegetation (SAV) like Podostemum, which require high quality flowing waters, to Indian grass and river birch shrub lands which depend on intermittent flood and drought disturbance.

In assessing long term trends, the Mann-Kendall test (Table 4-5), illustrates that there is a general upward trend in both the unregulated and regulated gages for all low flow statistics with the exception of April, where there is a decreasing trend for P75 flows and P75-P99 flow range. Although the trend in low flows is generally increasing for both settings over time, the regulated low flows observed in summer, fall and winter are increasing than the baseline low flows when impacts from estimated CU and modeled reservoir operation are excluded. Given that the IHA analysis shows a decrease in the majority of low flow statistics from baseline conditions, it is assumed that the increasing trends in low flows over time (from the Mann-Kendall results) are influenced more-so by external factors than reservoir operations and/or CU.

Hydrologic alteration for low flow seasons (summer and fall), seasonal low flows and extreme low flows, falls within the category of low risk to ecosystem needs (Table 4-5). Typical flow magnitudes during low flow seasons vary by less than five percent. Seasonal low flow conditions are slightly lower than the baseline condition (up to 15 percent lower), with the exception of April (3 percent increase). Estimated changes to flow magnitude under extreme low flow events, including the 1-in-5, 1-in-10 and drought of record, are also low risk.

**Table 4-4. Taxa Groups Sensitive to Low Flow Alteration in the Upper Susquehanna Subwatershed**

**Fish**
- Riffle obligates (margined madtom, longnose dace, central stoneroller, fantail darter)
- Riffle associates (white sucker, northern hogsucker)
- Nest builders (creek chub, river chub)
- Migratory (American shad (h), alewife (h), American eel)

**Aquatic Insects and Mussels**
- Primarily riverine (Green floater (t), Elktoe)
- Facultative riverine (Yellow lampmussel, Triangle floater)
- Primarily lentic (Eastern floater, Clubtail Odonates (Lilypad, Spine-crowned, Cobra))

**Reptiles and Amphibians**
- Aquatic (Northern water snake)

**Vegetation**
- Emergent bed (Water willow emergent bed, Grassy pondweed, Illinois pondweed (Podostemum))
- Herbaceous community (Mountain wood fern, Torrey's bulrush)
- Scrub/shrub ( Indian grass riverine shrubland, Silvermaple-river birch mixed hardwood shrubland)

**Birds and Mammals**
- Fish eating birds (Bald eagle, Osprey)
- Wading colony birds (Great Blue Heron)

* Historic presence is denoted by an (h), presence in the tributaries is denoted by (t).

**Table 4-5. Low-Flow Trends for an Unregulated and Regulated USGS Gage in the Upper Susquehanna subwatershed.**

| Flow Statistics | Trend at Unregulated Gage | Trend at Subwatershed Gage |
|---|---|---|
| Jul P50 | ▲ | ▲ |
| Oct P50 | ▲ | ▲ |
| Jan P95 | ▲ | ▲ |
| Apr P95 | - | ▲ |
| Jul P95 | ▲ | ▲ |
| Oct P95 | ▲ | ▲ |
| Jan P75 | ▲ | ▲ |
| Apr P75 | ▼ | ▼ |
| Jul P75 | ▲ | ▲ |
| Oct P75 | ▲ | ▲ |
| Jan P75-P99 | ▲ | - |
| Apr P75-P99 | ▼ | ▼ |
| Jul P75-P99 | ▲ | ▲ |
| Oct P75-P99 | ▲ | ▲ |
| Annual 7-day minimum flow | ▲ | ▲ |

**Table 4-6. Low Flow Alteration and Ecological Risk in the Upper Susquehanna subwatershed.**

| Flow Component | Flow statistic | Baseline (cfs) | Current (cfs) | Percent Change | Ecological Risk |
|---|---|---|---|---|---|
| **Low flow seasons** | | | | | |
| Summer (July) | Monthly Q50 | 2,108 | 1,995 | **-5** | 🟢 |
| Fall (Oct) | Monthly Q50 | 2,420 | 2,320 | **-4** | 🟢 |
| **Seasonal low flows** | | | | | |
| Spring (Apr) | Monthly range - Q75 to Q99 | | | **2** | 🟢 |
| | Monthly Q95 | 5,128 | 5,270 | **3** | 🟢 |
| Summer (July) | Monthly range - Q75 to Q99 | | | **-6** | 🟢 |
| | Monthly Q95 | 692 | 668 | **-3** | 🟢 |
| Fall (Oct) | Monthly range - Q75 to Q99 | | | **-3** | 🟢 |
| | Monthly Q95 | 551 | 538 | **-2** | 🟢 |
| Winter (Jan) | Monthly range - Q75 to Q99 | | | **-8** | 🟢 |
| | Monthly Q95 | 2,109 | 1,800 | **-15** | 🟡 |
| **Extreme low flows** | | | | | |
| | 1 in 5 year, 7 day low flow | 558 | 500 | **-10** | 🟢 |
| | 1 in 10 year, 7 day low flow | 449 | 455 | **1** | 🟢 |
| | 1964 DOR, 7 day low flow | 259 | 248 | **-4** | 🟢 |

## Chemung

Similar to the Upper Susquehanna, the Chemung subwatershed also contains transitional cool, unconfined tributaries and a warm, moderately unconfined mainstem river. These habitats also support the range of flow-sensitive species identified in the TNC (2010) Ecosystem Flow study (Table 4-7). Also similar to the Upper Susquehanna, the geomorphology supports dynamic hyporheic zone, riparian corridors and floodplains. This range of niches is dependent on intermittent disturbance regimes of floods and droughts. Transitional cool fish species like the margined madtom, northern hogsucker and creek chub, occupy the range of hydraulic habitat niches for some portion of their life history, including riffles, runs and stream margins, respectively. Similarly, all flow-sensitive mussel groups are present in the watershed.

Similar to the Upper Susquehanna, in assessing long term trends, the Mann-Kendall test (Table 5-8), illustrates that there is either a statistically significant upward or neutral trend in both the unregulated and regulated gages for all low flow statistics. One exception is the decreasing trend in April P95 flows at the unregulated gage. The trend results generally agree with the hydrologic alteration quantified from the comparison of baseline and current conditions. The observed flows are greater than the baseline low flows when impacts from estimated CU and modeled reservoir operation are excluded.

During low flow seasons, hydrologic alteration is estimated to be low risk (Table 4-9). Seasonal low flow conditions during the fall have increased by more than 20 percent, posing a moderate risk to ecosystem flow needs in these months (Table 4-9). This increase may be the result of spring reservoir releases mimicking inflow and a decrease in cumulative consumptive water use. Extreme low flows have increased by 93 percent. This increase may be the result of summer, and drought low flow augmentation. Differences are expected to be a function of cumulative consumptive water use and reservoir regulation (particularly Cowanesque and Tioga-Hammond Lakes). While augmentation likely benefits water quality conditions and reduces exacerbating chronic temperature and dissolved oxygen effects on fish and mussels, it may inhibit those communities that depend on drought disturbance for competitive advantage.

**Table 4-7. Taxa Groups Sensitive to Low Flow Alteration in the Chemung Subwatershed.**

**Fish**
- Riffle obligates (margined madtom, longnose dace, central stoneroller, fantail darter)
- Riffle associates (white sucker, shorthead redhorse, northern hogsucker)
- Nest builders (fallfish, creek chub, river chub)
- Migratory (American shad (h), alewife (h), American eel)

**Mussels**
- Primarily riverine (Elktoe)
- Facultative riverine (Yellow lampmussel)
- Primarily lentic (Eastern floater)

**Reptiles and Amphibians**
- Aquatic (Northern water snake)

**Vegetation**
- Emergent bed (Water willow emergent bed)
- Herbaceous community (Drooping bluegrass, Wild-pea, Lupine)
- Scrub/shrub (Indian grass riverine shrubland, Blackwillow slackwater shrubland)

**Birds and Mammals**

- Fish-eating raptors (Bald eagle, Osprey)
- Wading colony birds (Great blue heron

*Historic presence is denoted by an (h), presence in the tributaries is denoted by (t)

**Table 4-8. Low-Flow Trends for an Unregulated and Regulated USGS Gage in the Chemung Subwatershed.**

| Flow Statistics | Trend at Unregulated | Trend at Subwatershed |
|---|---|---|
| Jul P50 | - | ▲ |
| Oct P50 | - | - |
| Jan P95 | ▲ | ▲ |
| Apr P95 | ▼ | ▲ |
| Jul P95 | ▲ | ▲ |
| Oct P95 | ▲ | ▲ |
| Jan P75 | ▲ | ▲ |
| Apr P75 | ▲ | ▲ |
| Jul P75 | - | ▲ |
| Oct P75 | - | - |
| Jan P75-P99 | ▲ | ▲ |
| Apr P75-P99 | ▲ | - |
| Jul P75-P99 | ▲ | - |
| Oct P75-P99 | - | - |
| Annual 7-day minimum flow | ▲ | ▲ |

**Table 4-9. Low Flow Alteration and Ecological Risk in the Chemung Subwatershed.**

| Flow Component | Flow statistic | Baseline (cfs) | Current (cfs) | Percent Change | Ecological Risk |
|---|---|---|---|---|---|
| **Low flow seasons** | | | | | |
| Summer (July) | Monthly Q50 | 551 | 557 | **1** | ● |
| Fall (Oct) | Monthly Q50 | 466 | 456 | **-2** | ● |
| **Seasonal low flows** | | | | | |
| Spring (Apr) | Monthly range - Q75 to Q99 | | | **2** | ● |
| | Monthly Q95 | 1,359 | 1,370 | **1** | ● |
| Summer (July) | Monthly range - Q75 to Q99 | | | **11** | ● |
| | Monthly Q95 | 160 | 191 | **19** | ● |
| Fall (Oct) | Monthly range - Q75 to Q99 | | | **24** | ● |
| | Monthly Q95 | 120 | 160 | **33** | ● |
| Winter (Jan) | Monthly range - Q75 to Q99 | | | **11** | ● |
| | Monthly Q95 | 366 | 410 | **12** | ● |
| **Extreme low flows** | | | | | |
| | 1 in 5 year, 7 day low flow | 91 | 158 | **74** | ● |
| | 1 in 10 year, 7 day low flow | 67 | 129 | **93** | ● |
| | 1962 Drought of Record | 97 | 93 | **-4** | ● |

## West Branch

Of all the subwatersheds, the West Branch has the most diverse range of riverine habitats spanning a wide range of temperature and elevation gradients, as well as the range of valley formations from confined to unconfined. Here you see the complex floodplain communities ranging from those that thrive in dynamic river margins and floodplains, like speckled alder shrubland to those that thrive in confined valley reaches, like riverine scour. These communities sustain niche diversity through recurring disturbances like floods and droughts. This watershed has the most abundant and diverse group of reptiles and amphibians from the Eastern hellbender, that thrives in highly oxygenated transitional cool waters to the eastern spadefoot toad, which relies on well-mixed floodplain substrate (Table 4-10).

In assessing long term hydrologic trends, the Mann-Kendall test (Table 4-11), illustrates that there is a statistically significant decrease in April P95 flows and P75-99 flow ranges at the unregulated gage, while conditions during all other times of year have had an increasing or neutral trend. There is also a statistically significant decrease in January P75 and P75-99 flow ranges at the regulated gage, while no such trends were observed for the unregulated gage. This may be a result of potential changes in consumptive water uses, landscape changes, and/or presence of reservoir flood control within the regulated and unregulated watersheds. An increasing trend was detected for the annual seven-day low flow at both unregulated and subwatershed reference gage settings and is consistent with the percent increases observed for the seven day low flow statistics from baseline conditions observed from the IHA analysis.

In the subwatershed, hydrologic alteration during low flow seasons poses a low risk to ecosystem needs (Table 4-12). Seasonal low flow magnitude has increased under current conditions, however all increases are estimated to be within the low risk category. Extreme low flows have also increased, with the 1 in 10 year drought increasing by an estimated 100 cfs, or 23 percent. Flow magnitude under the drought of record, was an estimated 32 percent higher under current conditions, posing a potential risk to those communities depended on drought disturbance for population maintenance and growth. Differences are expected to be a function of cumulative consumptive water use and modeled reservoir regulation (including Curwensville and Sayers).

**Table 4-10. Taxa Groups Sensitive to Low Flow Alteration in the West Branch Subwatershed.**

**Fish**
- Riffle obligates (margined madtom, longnose dace, central stoneroller, fantail darter)
- Riffle associates (white sucker, northern hogsucker)
- Nest builders (fallfish, creek chub, river chub)
- Migratory (American shad (h), alewife (h), American eel)

**Mussels**
- Primarily riverine (Green floater (t), Elktoe, Brook floater)
- Facultative riverine (Yellow lampmussel, Triangle floater, Eastern lampmussel )
- Primarily lentic (Eastern floater)

**Reptiles and Amphibians**
- Aquatic (Eastern hellbender)
- Semi-aquatic ( Northern leopard frog)
- Riparian and floodplain (Eastern hognose snake, Eastern spadefoot, Fowler's toad)

**Vegetation**
- Emergent bed (Water willow emergent bed, Perfolate pondweed, Red-head pondweed)
- Herbaceous community (River ice scour community, Big bluestem, Cattail sedge, Canadian milkvetch, White trout-lily, Lupine)
- Scrub/shrub (Bulrush marsh, Indian grass riverine shrubland , Speckled alder riverine shrubland)

**Birds and Mammals**
- Fish-eating raptors (Bald eagle, Peregrine falcon)
- Wading colony birds (Great blue heron)

*Historic presence is denoted by an (h), presence in the tributaries is denoted by (t)

**Table 4-11. Low Flow Trends for an Unregulated and Regulated USGS Gage in the West Branch Subwatershed.**

| Flow Statistics | Trend at Unregulated Gage | Trend at Subwatershed Gage |
|---|---|---|
| Jul P50 | ▲ | ▲ |
| Oct P50 | - | ▲ |
| Jan P95 | ▲ | ▲ |
| Apr P95 | ▼ | ▲ |
| Jul P95 | - | ▼ |
| Oct P95 | ▲ | ▲ |
| Jan P75 | - | ▼ |
| Apr P75 | - | ▲ |
| Jul P75 | - | - |
| Oct P75 | ▲ | ▲ |
| Jan P75-P99 | - | ▼ |
| Apr P75-P99 | ▼ | - |
| Jul P75-P99 | - | - |
| Oct P75-P99 | ▲ | ▲ |
| Annual 7-day minimum | ▲ | ▲ |

**Table 4-12. Low Flow Alteration and Ecological Risk in the West Branch Subwatershed.**

| Flow Component | Flow statistic | Baseline (cfs) | Current (cfs) | Percent Change | Ecological Risk |
|---|---|---|---|---|---|
| **Low flow seasons** | | | | | |
| Summer (July) | Monthly Q50 | 2,609 | 2,710 | **4** | 🟢 |
| Fall (Oct) | Monthly Q50 | 2,132 | 2,300 | **8** | 🟢 |
| **Seasonal low flows** | | | | | |
| Spring (Apr) | Monthly range - Q75 to Q99 | | | **3** | 🟢 |
| | Monthly Q95 | 4,950 | 5,080 | **3** | 🟢 |
| Summer (July) | Monthly range - Q75 to Q99 | | | **5** | 🟢 |
| | Monthly Q95 | 842 | 901 | **7** | 🟢 |
| Fall (Oct) | Monthly range - Q75 to Q99 | | | **11** | 🟢 |
| | Monthly Q95 | 626 | 675 | **8** | 🟢 |
| Winter (Jan) | Monthly range - Q75 to Q99 | | | **10** | 🟢 |
| | Monthly Q95 | 1,823 | 1,900 | **4** | 🟢 |
| **Extreme low flows** | | | | | |
| | 1 in 5 year, 7 day low flow | 543 | 662 | **22** | 🟡 |
| | 1 in 10 year, 7 day low flow | 464 | 573 | **23** | 🟡 |
| | 1962 Drought of Record | 335 | 442 | **32** | 🟠 |

## Middle Susquehanna

The Upper Susquehanna and Chemung rivers join to form the Middle Susquehanna. The tributaries in this reach of the mainstem are similar to those in the Chemung and Upper Susquehanna with transitional cool temperatures and moderately confined to unconfined floodplains. The Mainstem River is warm, with a low gradient and confined valley. Confinement results in unique hydraulic habitats including shoreline scour communities conducive to rare vegetation, like the eastern sand cherry (Table 4-13). The river here also transitions into a great river, supporting island complexes and all trophic levels including mammals like the North American river otter. Presence of higher order predators, like the North American river otter, Bald eagles and Osprey, indicates the potential abundance of prey (fish and mussels).

In assessing long term hydrologic trends, the Mann-Kendall test (Table 4-14), illustrates that all regulated and unregulated trends are either neutral or increasing, with the exception of unregulated October low flows which had a statistically significant decrease. The October low flows at subwatershed gages show a neutral or increasing trend, counter to the unregulated gage, which suggests that reservoir releases made in October may have augmented the low flows and neutralized the decreasing trend. Increased trends in the July P50 and P75, and October P75 and P75-P99 were observed at the regulated subwatershed gage but were not observed at the unregulated gage. Such increases could be attributable to many factors, although, the results of OASIS baseline and gaged record comparison suggest reservoir operations or decreases in water use are potential drivers as the October P95 and P75-P99 are also increased. Similar to the Upper Susquehanna, the trend in low flows is generally increasing for the regulated setting, but, low-flows in the spring, summer, winter are lower than what would be observed if impacts from estimated CU and reservoir operations were excluded.

The magnitude of median flows during the low flow season has been reduced by 6 percent or less, resulting in a relatively low risk to ecosystem needs (Table 4-15). The magnitude of the low flow component (Q75-Q99) has been reduced in most seasons. Reductions in winter may pose a moderate risk to ecosystem needs. Winter flows are estimated to be about 500 cfs lower under current conditions (2,950 cfs) as compared to baseline conditions (3,528 cfs). Reductions during spring and winter may be caused, in part, by upstream reservoir storage by increasing reservoir storage elevations for recreation in the summer. Extreme low flow magnitudes are estimated to have increased under current conditions. A portion of this augmentation may be attributed to low flow releases from upstream reservoirs.

**Table 4-13. Taxa Groups Sensitive to Low Flow Alteration in the Middle Susquehanna Subwatershed.**

**Fish**
- Riffle obligates (margined madtom, longnose dace, central stoneroller, fantail darter)
- Riffle associates (white sucker, shorthead redhorse, northern hogsucker)
- Nest builders (fallfish, redbreast sunfish, smallmouth bass)
- Migratory (American shad (h), alewife (h), American eel)

**Mussels**
- Primarily riverine (Green floater, Elktoe)
- Facultative riverine (Yellow lampmussel, Triangle floater)
- Primarily lentic (Eastern floater)

**Reptiles and Amphibians**
- Aquatic (Northern water snake)
- Semi-aquatic (Wood turtle, spotted turtle)
- Riparian and floodplain (Eastern hognose snake)

**Vegetation**
- Emergent bed (Water willow emergent bed, (Podostemum) Illinois pondweed)
- Herbaceous community (Big bluestem indian grass, Sand cherry, Wild-pea, Lupine, White trout lily)

**Birds and Mammals**
- Fish eating raptors (Bald eagle, Osprey, Peregrine falcon)
- Wading colony birds (Great blue heron)
- Mammals (North American River otter)

*Historic presence is denoted by an (h), presence in the tributaries is denoted by (t).

**Table 4-14. Low Flow Trends in an Unregulated and Regulated USGS Gage in the Upper Susquehanna Subwatershed.**

| Flow Statistics | Trend at Unregulated Gage | Trend at Subwatershed Gage |
|---|---|---|
| Jul P50 | - | ▲ |
| Oct P50 | - | - |
| Jan P95 | ▲ | ▲ |
| Apr P95 | ▲ | ▲ |
| Jul P95 | - | - |
| Oct P95 | ▼ | - |
| Jan P75 | ▲ | ▲ |
| Apr P75 | - | - |
| Jul P75 | - | ▲ |
| Oct P75 | - | ▲ |
| Jan P75-P99 | ▲ | - |
| Apr P75-P99 | - | - |
| Jul P75-P99 | ▲ | ▲ |
| Oct P75-P99 | - | ▲ |
| Annual 7-day minimum flow | ▲ | ▲ |

**Table 4-15. Hydrologic Alteration and Ecological Risk in the Middle Susquehanna Subwatershed.**

| Flow Component | Flow statistic | Baseline (cfs) | Current (cfs) | Percent Change | Ecological Risk |
|---|---|---|---|---|---|
| **Low flow seasons** | | | | | |
| Summer (July) | Monthly Q50 | 3,751 | 3,650 | **-3** | 🟢 |
| Fall (Oct) | Monthly Q50 | 4,233 | 3,960 | **-6** | 🟢 |
| **Seasonal low flows** | | | | | |
| Spring (Apr) | Monthly range - Q75 to Q99 | | | **-2** | 🟢 |
| | Monthly Q95 | 9,143 | 8,790 | **-4** | 🟢 |
| Summer (July) | Monthly range - Q75 to Q99 | | | **-2** | 🟢 |
| | Monthly Q95 | 1,324 | 1,290 | **-3** | 🟢 |
| Fall (Oct) | Monthly range - Q75 to Q99 | | | **4** | 🟢 |
| | Monthly Q95 | 1,014 | 1,120 | **10** | 🟢 |
| Winter (Jan) | Monthly range - Q75 to Q99 | | | **-7** | 🟢 |
| | Monthly Q95 | 3,528 | 2,950 | **-16** | 🟡 |
| **Extreme low flows** | | | | | |
| | 1 in 5 year, 7 day low flow | 961 | 1,059 | **10** | 🟢 |
| | 1 in 10 year, 7 day low flow | 749 | 836 | **12** | 🟡 |
| | 1962 Drought of Record | 546 | 511 | **-6** | 🟢 |

## Juniata

Moving further south in the watershed and to lower elevations, both the tributaries and the mainstem of the Juniata subwatershed are classified as warm water. Floodplain confinement varies by reach as rivers cut between the lower gradients of the ridge and valley. In addition to all of the flow-sensitive fish and mussel groups being represented, the Juniata also supports robust populations of warm water taxa including mussels and aquatic turtles (Northern map turtle and common musk turtle). It also supports semi-aquatic mammals, like the Northern river otter (Table 4-16). In assessing long term hydrologic trends, the Mann-Kendall test (Table 4-17), illustrates that for most months, unregulated and regulated flows have exhibited a statistically significant decreases. The exception to this is April, which flows increased at the unregulated gage and either increased or decreased at the regulated gage, depending on the flow statistic. April results should be interpreted with caution. Even though both unregulated and regulated settings show most low flow trends decreasing over time, current impacts from reservoir operations, such as Raystown, appear to neutralize or increase January, July and October P95 flows at the subwatershed gage. An increased trend was also observed for the annual 7-day low flow at subwatershed reference gage, which is consistent with the percent increases observed for the 7 day low flow statistics from baseline conditions observed from the IHA analysis.

Seasonal and inter annual low flow conditions have increased in the Juniata under current conditions (Table 4-18). These increases are estimated to be within the range of low ecological risk for all seasons, with the exception of winter. Seasonally, winter low flows have increased by up to 50 percent, or from about 680 cfs to 1,000 cfs. This may pose a high risk to ecosystem flow needs dependent on stable winter flows. In part, winter flow alteration may be caused by upstream releases from Raystown Reservoir. Extreme low flow events have also increased in magnitude under current conditions, which may pose a moderate risk to those communities and processes that depend on intermediate low flow disturbance to prevent competitive exclusion (Table 4-18). This increase may, in part, be caused by upstream reservoir releases.

**Table 4-16. Taxa Groups Sensitive to Low Flow Alteration in the Juniata Subwatershed.**

**Fish**
- Riffle obligates (margined madtom, longnose dace, central stoneroller, fantail darter)
- Riffle associates (white sucker, shorthead redhorse, northern hogsucker)
- Nest builders (fallfish, redbreast sunfish, smallmouth bass)
- Migratory (American shad (h), alewife (h), American eel)

**Mussels**
- Primarily riverine (Green floater, Elktoe)
- Facultative riverine (Yellow lampmussel, Triangle floater)
- Primarily lentic (Eastern floater)

**Reptiles and Amphibians**
- Aquatic (Northern water snake)
- Semi-aquatic (Wood turtle, spotted turtle)
- Riparian and floodplain (Eastern hognose snake)

**Vegetation**
- Emergent bed (Water willow emergent bed, (Podostemum) Illinois pondweed)
- Herbaceous community (Big bluestem indian grass, Sand cherry, Wild-pea, Lupine, White trout lily)

**Birds and Mammals**
- Fish eating raptors (Bald eagle, Osprey, Peregrine falcon)
- Wading colony birds (Great blue heron)
- Mammals (North American River otter)

*Historic presence is denoted by an (h), presence in the tributaries is denoted by (t).

**Table 4-17. Low Flow Trends for an Unregulated USGS Gage and Regulated s in the Upper Susquehanna Subwatershed.**

| Flow Statistics | Trend at Unregulated Gage | Trend at Subwatershed Gage |
|---|---|---|
| Jul P50 | ▼ | ▼ |
| Oct P50 | ▼ | ▼ |
| Jul P50 | ▼ | ▼ |
| Oct P50 | ▼ | ▼ |
| Jan P95 | ▼ | ▲ |
| Apr P95 | ▲ | ▲ |
| Jul P95 | ▼ | - |
| Oct P95 | - | - |
| Jan P75 | ▼ | ▼ |
| Apr P75 | ▲ | - |
| Jul P75 | ▼ | ▼ |
| Oct P75 | ▼ | - |
| Jan P75-P99 | ▼ | ▼ |
| Apr P75-P99 | ▲ | ▼ |
| Jul P75-P99 | - | ▲ |
| Oct P75-P99 | ▼ | - |
| Annual 7-day minimum | - | ▲ |

**Table 4-18. Low Flow Alteration and Ecological Risk in the Juniata subwatershed.**

| Flow Component | Flow statistic | Baseline (cfs) | Current (cfs) | Percent Change | Ecological Risk |
|---|---|---|---|---|---|
| **Low flow seasons** | | | | | |
| Summer (July) | Monthly Q50 | 1,273 | 1,350 | **6** | 🟢 |
| Fall (Oct) | Monthly Q50 | 872 | 991 | **14** | 🟢 |
| **Seasonal low flows** | | | | | |
| Spring (Apr) | Monthly range - Q75 to Q99 | | | **12** | 🟢 |
| | Monthly Q95 | 1,970 | 2,240 | **14** | 🟢 |
| Summer (July) | Monthly range - Q75 to Q99 | | | **18** | 🟢 |
| | Monthly Q95 | 525 | 600 | **14** | 🟢 |
| Fall (Oct) | Monthly range - Q75 to Q99 | | | **16** | 🟢 |
| | Monthly Q95 | 425 | 455 | **7** | 🟢 |
| Winter (Jan) | Monthly range - Q75 to Q99 | | | **20** | 🟢 |
| | Monthly Q95 | 683 | 1,000 | **46** | 🟡 |
| **Extreme low flows** | | | | | |
| | 1 in 5 year, 7 day low flow | 397 | 499 | **26** | 🟡 |
| | 1 in 10 year, 7 day low flow | 318.1 | 383.3 | **20** | 🟢 |
| | 1962 Drought of Record | 197 | 269 | **37** | 🟡 |

*Historic presence is denoted by an (h), presence in the tributaries is denoted by (t).

### Lower Susquehanna

The Juniata River meets the Middle Susquehanna to form the Lower Susquehanna River and subwatershed. Both the tributaries and mainstem river are classified as warm water, low gradient rivers, with moderately confined to confined floodplains, respectively. The river channel of the mainstem can be more than 1 mile-wide in this section of river, hosting an abundant group of island complexes, which in turn support a two of the region's largest colony bird populations, specifically the Great egret and the Black-crowned night heron. The presence and abundance of these birds can be an indicator for a healthy trophic dynamic, as they depend on a diet of minnows, small fish and large macroinvertebrates and thrive in wadable foraging conditions. The subwatershed also supports all flow-sensitive taxa groups of fish and mussels (Table 4-19).

In assessing long term hydrologic trends, the Mann-Kendall test (Table 5420), illustrates a statistically significant decrease in unregulated P95 low flows for January, April and July. Similarly, the subwatershed reference gage also shows decreases in the July P95. Increased trends were detected for the annual seven day low flow at both unregulated and subwatershed reference gage and is consistent with the percent increase of the seven day low flow statistics from baseline conditions observed from the IHA analysis. Opposite trends were observed for the January P95, July P75, and January P75-99 low flows at unregulated gages. Less emphasis and/or confidence should be placed on these conflicting low flow trends result due to considerable differences in drainage areas and lack of comparable climate physical watershed and characteristics between the unregulated gage and encompassing subwatershed reference gage.

Seasonal and inter annual flow conditions have generally increased, with the exception of winter flows which have decreased. All alterations to seasonal low flow conditions are estimated to be within the category of low ecological risk (Table 4-21). Similarly, the 1-in-5, and 1-in-10 year low flow conditions have increased under current conditions. That increase is estimated to be within a low level of ecological risk. Flow magnitude under the drought of record increased by an estimated 36 percent, or from about 2,040 to 2,780 cfs. This may pose a moderate risk to ecosystem needs to those communities and processes that depend on intermediate low flow disturbance to prevent competitive exclusion. This increase may, in part, be caused by upstream reservoir releases to augment low flow conditions. This assessment focuses on the Lower Susquehanna subwatershed above Harrisburg. The four hydroelectric dams on the Lower River have a significant impact on low flow releases to the Upper Bay. While this is outside of the geographic scope of this report, alteration, ecosystem impacts and recommendations are reflected in TNC (2014) and could inform future low flow management priorities in the Watershed.

**Table 4-19. Taxa Groups Sensitive to Low Flow Alteration in the Lower Susquehanna subwatershed.**

**Fish**
- Riffle obligates (margined madtom, fantail darter)
- Riffle associates (white sucker, shorthead redhorse)
- Nest builders (creek chub, redbreast sunfish, smallmouth bass)
- Migratory (American shad (h), alewife (h), American eel)

**Mussels**
- Primarily riverine ( Elktoe (t))
- Facultative riverine (Yellow lampmussel)
- Primarily lentic (Eastern floater)

**Reptiles and Amphibians**
- Aquatic (Northern map turtle, Common musk turtle, Northern water snake)
- Semi-aquatic (Eastern ribbon snake)

**Vegetation**
- Emergent bed (Water willow emergent bed)
- Herbaceous community (Wild pea, Lupine, Drooping bluegrass)
- Scrub/shrub (Black willow shrub community)

**Birds and Mammals**
- Fish-eating raptors (Bald eagle, Osprey)
- Wading colony birds (Great blue heron, Great egret, Black-crowned night heron)

*Historic presence is denoted by an (h), presence in the tributaries is denoted by (t).

**Table 4-20. Low Flow Trends for an Unregulated and Regulated USGS Gage in the Upper Susquehanna subwatershed.**

| Flow Statistics | Trend at Unregulated Gage | Trend at Subwatershed Gage |
|---|---|---|
| Jul P50 | - | - |
| Oct P50 | - | ▽ |
| Jan P95 | ▼ | ▲ |
| Apr P95 | ▼ | - |
| Jul P95 | ▼ | ▼ |
| Oct P95 | ▲ | △ |
| Jan P75 | - | - |
| Apr P75 | - | - |
| Jul P75 | ▲ | ▼ |
| Oct P75 | ▲ | - |
| Jan P75-P99 | ▲ | ▼ |
| Apr P75-P99 | - | - |
| Jul P75-P99 | ▲ | ▲ |
| Oct P75-P99 | ▲ | - |
| Annual 7-day minimum flow | ▲ | ▲ |

**Table 4-21. Low Flow Alteration and Ecological Risk in the Lower Susquehanna River Subwatershed.**

| Flow Component | Flow statistic | Baseline(cfs) | Current (cfs) | Percent Change | Ecological Risk |
|---|---|---|---|---|---|
| **Low flow seasons** | | | | | |
| Summer (July) | Monthly Q50 | 10,866 | 11,200 | **3** | 🟢 |
| Fall (Oct) | Monthly Q50 | 9,896 | 10,000 | **1** | 🟢 |
| **Seasonal low flows** | | | | | |
| Spring (Apr) | Monthly range - Q75 to Q99 | | | **-1** | 🟢 |
| | Monthly Q95 | 21,746 | 21,100 | **-3** | 🟢 |
| Summer (July) | Monthly range - Q75 to Q99 | | | **4** | 🟢 |
| | Monthly Q95 | 3,719 | 3,880 | **4** | 🟢 |
| Fall (Oct) | Monthly range - Q75 to Q99 | | | **3** | 🟢 |
| | Monthly Q95 | 3,079 | 3,400 | **10** | 🟢 |
| Winter (Jan) | Monthly range - Q75 to Q99 | | | **5** | 🟢 |
| | Monthly Q95 | 8,571 | 8,500 | **-1** | 🟢 |
| **Extreme low flows** | | | | | |
| | 1 in 5 year, 7 day low flow | 3,000 | 3,528 | **18** | 🟢 |
| | 1 in 10 year, 7 day low flow | 2,194 | 2,708 | **23** | 🟡 |
| | 1962 Drought of Record | 1,674 | 1,786 | **7** | 🟢 |

## 4.3 BENEFITS AND IMPACTS TO ECOSYSTEM FLOW NEEDS

This section provides an overview of the potential qualitative benefits and impacts of low flow management alternatives on ecosystem needs.

**Table 4-22. Ecosystem Low Flow Needs and Ecological Risk.**

| Flow Need | Subwatershed | | | | | |
|---|---|---|---|---|---|---|
| | Upper | Chemung | West Branch | Middle | Juniata | Lower |
| **Fish** | | | | | | |
| Maintain connectivity between habitats and refugia for resident and diadromous fishes | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 |
| Cue inmigration of juvenile American eel | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 |
| Maintain overwinter habitats for resident fish | 🟢 | 🟢 | 🟢 | 🟡/- | 🟡/+ | 🟢 |
| Support resident fish spawning | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 |
| Cue alosid migration, spawning and egg and larval development | 🟢 | 🟢 | 🟢 | 🟢 - | 🟢 | 🟢 |
| **Mussels** | | | | | | |
| Supports mussel spawning, glochidia release and growth | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 |
| Support winter emergence of aquatic insects and maintain overwinter habitat | 🟡/- | 🟢 | 🟢 | 🟡/- | 🟡/+ | 🟢 |
| **Reptiles and Amphibians** | | | | | | |
| Promote/support development and growth of reptiles and amphibians | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 |
| Maintain stable hibernation habitats | 🟢 | 🟡/+ | 🟢 | 🟡/- | 🟡/+ | 🟢 |
| **Vegetation** | | | | | | |
| Promote vegetation growth | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 |
| **Birds and Mammals** | | | | | | |
| Provide abundant food sources and maintain nesting habitat for birds and mammals | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 |
| **Water Quality, Temperature and Geomorphology** | | | | | | |
| Maintain water quality | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 |
| Transport organic matter and fine sediment | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 | 🟢 |
| **Disturbance-based population dynamics**** | | | | | | |
| Intermediate disturbance-dependent communities and processes | 🟢 | 🟠/+ | 🟡/+ | 🟡/+ | 🟡/+ | 🟡/+ |
| Communities and river processes that benefit from extreme drought disturbance | 🟢 | 🟢 | 🟠/+ | 🟢 | 🟡/+ | 🟢 |

### Discussion of benefits and potential impacts to ecosystem needs

For this discussion, the information presented in Sections 4.1 and 4.2 is synthesized to discuss the potential benefits and impacts of alteration to low flow conditions on meeting ecosystem flow needs by season. The focus is on the ecosystem needs in each subwatershed that were estimated to have a moderate (•) or high (•) level of risk based on hydrologic alteration (Table 4-14). Risk to a specific ecosystem need is discussed by referencing specific hypotheses from TNC (2010) and within the context of the potential benefits to potentially contradictory needs, if identified.

As described in the method limitations section, the difference between the baseline and current conditions is a combination of reservoir regulation, consumptive water use, and OASIS unimpaired inflow methodology. SRBC is currently assessing the estimation error associated with the OASIS unimpaired inflow and outflow methodology. When that error is quantified, the following risk levels could be re-visited to incorporate modeling efficiency. In the interim, the following risk levels may reflect some portion of that estimation error, but that given the alternatives for best available data, represent the best approximation of unimpaired flows to represent the influence of both reservoir operations and consumptive use across the subwatersheds. Table 4-23 summarizes the potential benefits and impacts of alteration to low flow conditions on meeting ecosystem flow needs by season.

**Table 4-23. Seasonal Ecosystem Low Flow Needs, Benefits and Impacts.**

| Season | Ecosystem Flow Needs | Benefits | Impacts & Contradictory Needs |
|---|---|---|---|
| Spring | -Maintain connectivity between habitats and refugia for resident and diadromous fish.<br>-Support resident fish spawning<br>-Cue alosid migration, spawning and egg and larval development. | -It is estimated that these needs are being supported by flow conditions in all subwatersheds. | None identified. |
| Summer | -Support mussel spawning, glochidia release and growth.<br>-Promote/support development and growth of reptiles and amphibians.<br>-Promote vegetation growth.<br>-Provide abundant food sources and maintain nesting habitat for birds and mammals.<br>-Maintain water quality.<br>-Transport organic matter and fine sediment. | -It is estimated that these needs are being supported by current flow conditions in all subwatersheds.<br>-Relative to the Spring, summer flows are much lower in magnitude. Therefore, even slight decreases in current flow conditions could result in ecosystem needs not being met. Specifically, summer is typically the 'bottleneck' season for fish, mussels and aquatic invertebrates. Lower base flows and higher temperatures during this season, often define the riverine habitat niche (Zorn et al. 2007). Keeping this in mind, it is critical to continue to refine and improve hydraulic habitat during this season.<br>-An assessment of low flow conditions under a range of climate scenarios would help to identify future opportunities to support ecosystem needs dependent on seasonal low flow conditions in the subwatersheds. | None identified. |
| Fall and Winter | -Maintain overwinter habitats for resident fish.<br>-Support winter emergence of aquatic insects and maintain overwinter habitat.<br>-Maintain stable hibernation habitats for reptiles and amphibians. | -It is estimated that these needs are being supported by current low flow-related conditions in the Upper Susquehanna, Chemung, and West Branch and Lower Susquehanna subwatersheds. | -Low flow reductions in the Middle Susquehanna pose a moderate risk to these needs. Reduced low flows during the fall and winter months may:<br>-Dewater hibernation habitats for reptiles and amphibians<br>-Expose brooding mussels<br>-Reduce temperatures in overwinter fish habitats, thereby increasing bioenergetic costs<br>-Reduce the diversity or abundance of emerging insects like the winter stonefly<br>-Increase the frequency or intensity of anchor ice formation and associated disturbance to fish, mussels and aquatic insects. |

| Season | Ecosystem Flow Needs | Benefits | Impacts & Contradictory Needs |
|---|---|---|---|
| | | | -Increases to low flow magnitudes on the Juniata watershed may pose a moderate risk to these needs. This risk is higher if the change in flow magnitude is coupled with a higher frequency of sub-daily changes or increased rate of rise, or recession. If this is the case, this may:<br>-Dewater hibernation habitats for reptiles and amphibians<br>-Expose brooding mussels<br>-Opportunities to ensure the long-term Fall and Winter Q95 is maintain could increase ecosystem benefits of reservoir storage and release operations. |
| Inter-Annual | -Support communities and processes that benefit from intermediate or extreme drought disturbance. | It is estimated that this need is being supported by current low flow related conditions in the Upper Susquehanna subwatershed. | -Increases to low flow in the Chemung, West Branch, Juniata, Middle and Lower Susquehanna may pose moderate to high risk to this need.<br>-Contradictory needs during these conditions (1 in 5, 1 in 10, and record drought), include maintenance of water quality and maintenance of flow refugia for fish, mussels, reptiles and amphibians and aquatic insects. |

# Chapter 5. References

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# Chapter 6. Acronyms

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|---|---|
| AMS | Abandoned mine storage |
| CFS | Cubic Feet per Second |
| CU | Consumptive Use |
| CUMP | Consumptive Use Mitigation Plan |
| CWUAS | Cumulative Water Use and Availability Study |
| DCNR | Department of Conservation and Natural Resources of the Commonwealth of Pennsylvania |
| DOR | Drought of Record |
| ELOHA | Ecological Limits of Hydrologic Alteration |
| EPT | Ephemeroptera, Plecoptera, and Trichoptera |
| GIS | Geographic Information System |
| GPD | Gallons per day |
| HBI | Hilsenhoff Biotic Index |
| HUC | Hydrologic Unit Code |
| IHA | Indicators of Hydrologic Alteration |
| JASON | July, August, September, October, and November |
| LFPP | Low Flow Protection Policy |
| MGD | Millions of Gallons per Day |
| MW | Megawatt |
| NYSDEC | New York State Department of Environmental Conservation |
| OASIS | |
| PADEP | Pennsylvania Department of Environmental Protection |
| PAWC | Pennsylvania America Water Company |
| PCD | Project Construction Datum |
| PFBC | Pennsylvania Fish and Boat Commission |
| PM&E | Protection, Mitigation, and Enhancement |
| PMF | Probable Maximum Flood |
| PWS | Public Water Supply |
| SAV | Submerged Aquatic Vegetation |
| SMCRA | Surface Mining Control Reclamation Act |
| SRBC | Susquehanna River Watershed Commission |
| SRTA | Susquehanna River Trail Association |
| TMDL | Total Maximum Daily Loads |
| TNC | The Nature Conservancy |
| USACE | United States Army Corps of Engineers |
| USEPA | United States Environmental Protection Agency |
| USFWS | United States Fish and Wildlife Service |
| USGS | United States Geological Survey |
| WRDA | Water Resources Development Act |

# Chapter 7. Glossary of Terms

| Term | Definition |
|---|---|
| Algal | Any of numerous groups of chlorophyll-containing, mainly aquatic eukaryotic organisms ranging from microscopic single-celled forms to multicellular forms 100 feet (30 meters) or more long, distinguished from plants by the absence of true roots, stems, and leaves and by a lack of no reproductive cells in the reproductive structures: classified into the six phyla – Euglenophyta, Crysophyta, Pyrrophyta, Chlorophyta, Phaeophyta, and Rhodophyta. |
| Alluvial deposits | Detrital material which is transported by a river and deposited – usually temporarily – at points along the flood plain of a river. Commonly composed of sands and gravels. |
| Anadromous | The migration of fish from salt water to spawn in fresh water |
| Anthropogenic | Related to the influence of human beings or their ancestors on natural objects. Wastewater is any water that has been adversely affected in quality by anthropogenic influence. |
| Base flow | Normally refers to the stream levels associated primarily with groundwater or subsurface contributions, as opposed to storm flow which corresponds to stream levels associated with recent precipitation and surface runoff. |
| BasinWatershed | A depressed area with no surface outlet, such as a lake watershed or an enclosed sea. |
| Bedrock | The solid rock that underlies gravel, soil, and other superficial material. Bedrock may be exposed at the surface (an outcrop) or it may be buried under a few centimeters to thousands of meters of unconsolidated material. |
| Benthic | Pertaining to the sub-aquatic bottom. |
| Benthic invertebrates | Aquatic animals without backbones that dwell on or in the bottom sediment of fresh or salt water. Examples: clams, crayfish, and a wide variety of worms. |
| Benthos | Those animals that live on the sediment of the sea floor, including both mobile and non-mobile forms. |
| Biomass | In ecology, organic material that makes up living organisms; the collective mass of living matter in a given place and time. In energy, organic material derived from living or recent living organisms, containing chemical energy that originated with photosynthesis. |
| Brackish | Having a somewhat salty taste, especially from containing a mixture of seawater and fresh water. |
| Clay | A fine grained, plastic, sediment with a typical grain size less than 0.004 mm. Possesses electromagnetic properties which bind the grains together to give a bulk strength or cohesion; - Substrate particles that are smaller than silt and generally less than 0.003 mm in diameter. |

| Term | Definition |
|---|---|
| Confluence | The junction of two or more river reaches or channels (the opposite of a bifurcation). |
| Dam | Structure built in rivers or estuaries, basically to separate water at both sides and/or to retain water at one side. |
| Deforestation | The clearing and loss of forests. |
| Degradation | The geologic process by means of which various parts of the surface of the earth are worn away and their general level lowered, by the action of wind and water. |
| Discharge(s) | The volume of water per unit of time flowing along a pipe or channel. |
| Dynamic equilibrium | Used in this report to describe the reservoir sediment storage condition. In this condition, little to no sediment storage remains; however, scour events will increase sediment storage for a short period of time, resulting in a reduction in sediment load in the upper Chesapeake Bay for a short time. In the long-term, sediment will continue to deposit in the reservoirs and be removed with scour-producing flow events. |
| Elevation | The vertical distance from mean sea level or other established datum plane to a point on the earth's surface; height above sea level. Although sea floor elevation below mean sea level should be marked as a negative value, many charts show positive numerals for water depth. |
| Erosion | The wearing a way of land by the action of natural forces. On a beach, the carrying away of beach material by wave action, tidal currents, littoral currents, or by deflation. |
| Estuary | (1) The part of a river that is affected by tides. (2) The region near a river mouth in which the fresh water of the river mixes with the salt water of the sea and which received both fluvial and littoral sediment influx. |
| Eutrophic | Usually refers to a nutrient-enriched, highly productive body of water. |
| Evapotranspiration | The quantity of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces. Quantitatively, it is usually expressed in terms of depth of water per unit area during a specified period of time. |
| Hydrograph | A curve showing stream discharge over time. |
| Hydrography | (1) The description and study of seas, lakes, rivers and other waters. (2) The science of locating aids and dangers to navigation. (3) The description of physical properties of the waters of a region. |
| Hydrology | The scientific study of the water of the earth, its occurrence, circulation and distribution, its chemical and physical properties, and its interaction with its environment, including its relationship to living things. |
| Hydropower | The generation of electricity using the kinetic energy of moving water. |
| Land use | Land use is defined as the human use of land – the natural and built environment features covering the earth's surface that comprise land cover. |
| Macroinvertebrate | Invertebrates visible to the naked eye, such as insect larvae and crayfish. |
| Morphology | River/estuary/lake/seabed form and its change with time. |

| Term | Definition |
|---|---|
| Nutrient | An element or compound that organisms consume and require for survival. |
| Reservoir | An artificial lake, watershed or tank in which a large quantity of water can be stored. |
| Riverine | Relating to, formed by, or resembling a river including tributaries, streams, brooks, etc. |
| Runoff | Water that flows over the ground and reaches a stream as a result of rainfall or snowmelt. |
| Scour/scouring | Removal of underwater material by waves and/or currents, especially at the base or toe of a shore structure. |
| Sediment | (1) Loose, fragments of rocks, minerals or organic material which are transported from their source for varying distances and deposited by air, wind, ice and water. Other sediment is precipitated from the overlying water or form chemically, in place. Sediment includes all the unconsolidated materials on the sea floor. (2) The fine grained material deposited by water or wind. |
| Sedimentation | (1) The combined processes of soil erosion, entrainment, transport, deposition, and consolidation. (2) Deposition of sediment. |
| Silt | Sediment particles with a grain size between 0.004 mm and 0.062 mm, i.e., coarser than clay particles but finer than sand. |
| Spawning | To produce or lay eggs in water. |
| Stratification | Formation or deposition of layers, as of rock or sediment. |
| Substrate | (1) The composition of a streambed, including either mineral or organic materials. (2) Material that forms an attachment medium for organisms. |
| Topography | The configuration of a surface, including its relief and the positions of its streams, roads, building, etc. |
| Tributary | A stream that flows into a larger stream or river or into a lake. |
| Waterfowl | A water bird, especially a swimming bird. |
| Watersheds | The area of land that includes a particular river or lake and all the rivers, streams, etc. that flow into it. |
| Wetlands | Land that has a wet and spongy soil, as a marsh, swamp, or bog. |