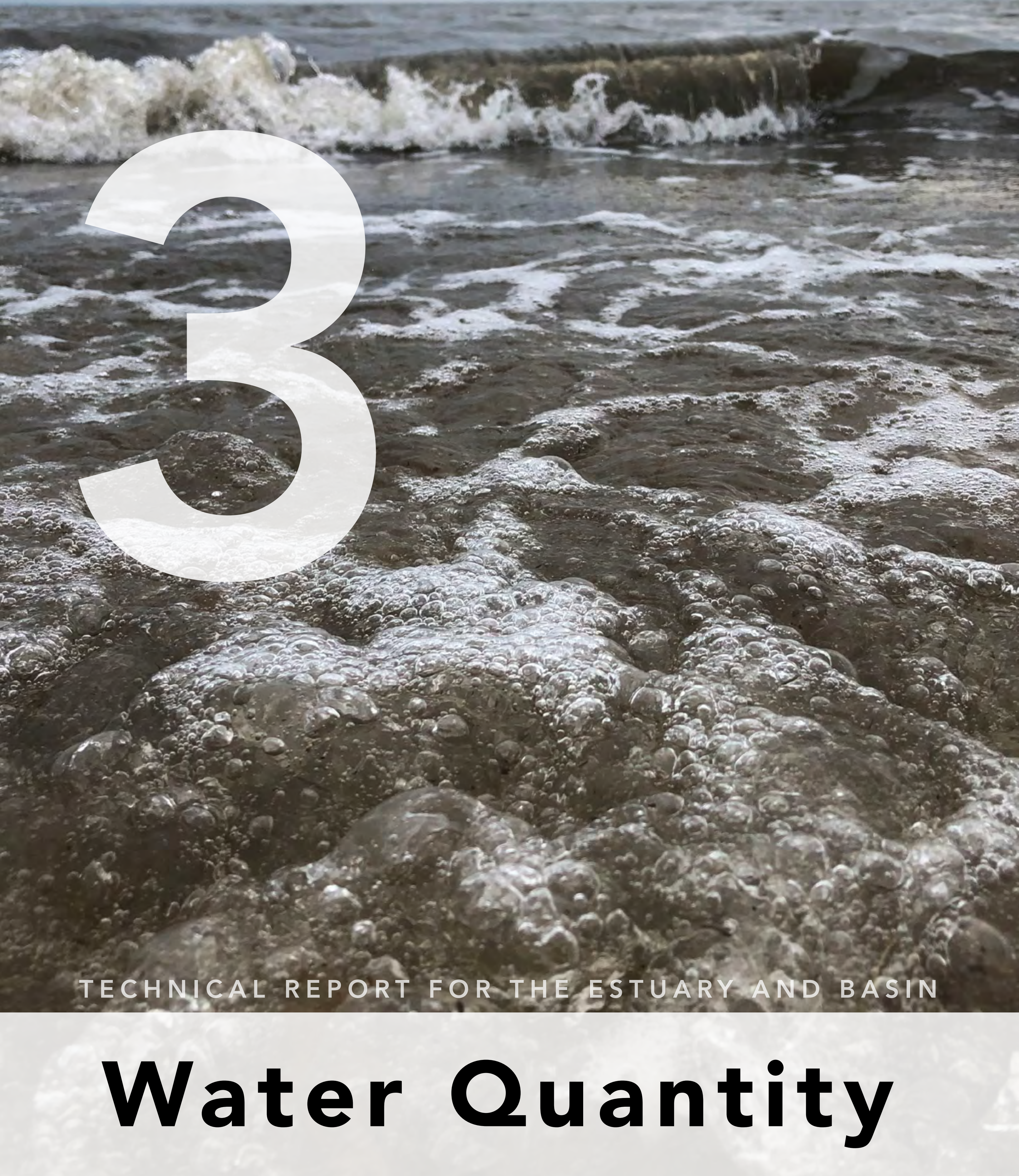

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TECHNICAL REPORT FOR THE ESTUARY AND BASIN

Water Quantity

Partnership for the DELAWARE ESTUARY

December 2022 | Report No.22-05

Partnership for the Delaware Estuary—Host of the Delaware Estuary Program

3

Water Quantity

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Delaware River Basin Commission

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Cover photograph by LeeAnn Haaf

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3. Water Quantity

Abstract

Although the Delaware Estuary and Basin drain only four-tenths of one percent of the total continental United States land area, its water resources provide drinking water for over 13.3 million people in four states—approximately 4 percent of the total population of the United States. Based on 2020 data, ground and surface water withdrawals from the Delaware Estuary and Basin are estimated to total 6,390 million gallons per day (MGD), out-of-Basin diversions total 594 MGD, and in-basin consumptive use is 263 MGD. With such a demand for water, it is essential that humans continue to monitor and plan for these uses–not only to ensure that the demands can be met, but to help maintain a sustainable relationship with the environmental needs of the Basin and the creatures which inhabit it. To this point, several indicators assessing water quantity and hydrology are outlined in this chapter. Aptly captured by a Native American proverb: "The frog does not drink up the pond in which he lives."

Data Sources

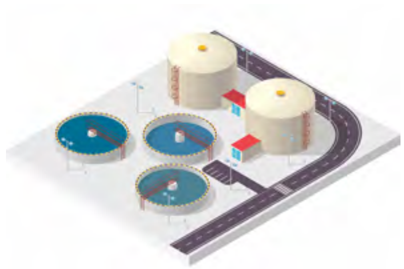
Several of the indicators described in this chapter are based on water withdrawal datasets. These data are typically reported annually by water users (i.e., industrial and public water systems) to the state environmental agencies. As each state has differing requirements, nomenclature, and structure in how data are retained, Delaware River Basin Commission (DRBC) manages its own water use database. This process allows DRBC to compile and assess data on water withdrawals and consumptive use throughout the Delaware Estuary and Basin (also referred to as the Delaware River Basin herein) with some degree of consistency across state boundaries. In some cases, DRBC even supplements data from state agencies with that collected through DRBC programs. This integrated database for the Delaware River Estuary and Basin is typically updated annually and requires a substantial degree of quality assurance/quality control to verify that data are not duplicated or missing.

3.1 Water Withdrawals: Tracking Water Supply & Demand

Description of Indicator

Accurate and comprehensive water use information enables the proper assessment, planning, and management of water resources. As reporting improves, so does our accounting and understanding of the need for water among various water-using sectors. Almost all data are based on withdrawals reported to state agencies. The two exceptions are the self-supplied domestic withdrawal sector (i.e., a private residence utilizing a well that serves a single home, where data is estimated based on population analyses), and the hydroelectric power category within the power generation sector (which has some data estimated based on net electricity generation).

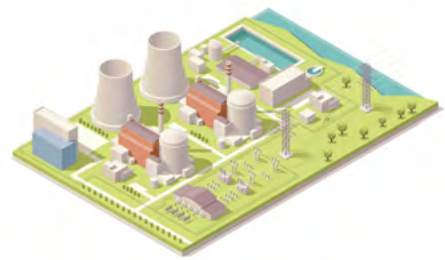
The indicator presented in this section of the report is focused on water withdrawals and discusses the data in terms of withdrawal sectors (which may contain multiple withdrawal categories) (Fig 3.1). As is defined in this section, "water use" may refer to either the withdrawal or end-use of water. This is important when considering public water supply, and how the data are categorized. For example, consider a hypothetical public water supplier operating a withdrawal(s), and then distributing the water to numerous customers (e.g., 60% domestic, 30% industrial, 10% commercial). In this scenario, the withdrawal would be described



(PWS) Public Water Supply
Water withdrawn by a facility meeting the definition of a public water supply system under the Safe Drinking Water Act (Pub. L. No. 93-523, 88 Stat. 1660), or subsequent regulations set forth by signatory parties.

(DIV) Out-of-Basin Diversions
Withdrawals of water for public water supply exported from the Delaware River Basin by the Decree Parties in accordance with a 1954 U.S. Supreme Court Decree (U.S. Supreme Court, 1954).

(SSD) Self-Supplied Domestic
Water withdrawal for domestic use for residents who are not served by a public water supply system; it is assumed in this study that all self-supplied groundwater withdrawals are groundwater.



(PWR) Power Generation
Water withdrawn/diverted by facilities associated with the process of generating electricity. Within the Delaware River Basin, this refers to water withdrawn/diverted by both thermoelectric and hydroelectric facilities.

(IND) Industrial
Water withdrawals by facilities associated with fabrication, processing, washing, and cooling. This includes industries such as chemical production, food, paper and allied products, petroleum refining (i.e., refineries), and steel. Due to the generally close relationship, water withdrawn for groundwater remediation purposes is also included in this sector.

(IRR) Irrigation
Water withdrawals which are applied by an irrigation system to assist crop and pasture growth, or to maintain vegetation on recreational lands such as parks and golf courses. This does not include withdrawals/diversions associated with aquaculture.

(MIN) Mining
Water withdrawals by facilities involved with the extraction of naturally occurring minerals. This includes operations such as mine dewatering, quarrying, milling of mined materials, material washing and processing, material slurry operations (e.g. sand), dust suppression and any other use at such facilities.

(OTH) Other
Facilities not categorized by previous sectors, including but not limited to aquaculture, bottled water, commercial (e.g. hotels, restaurants, office buildings, retail stores), fire suppression, hospital/health, military, parks/recreation, prisons, schools, and ski/snowmaking.

Figure 3.1 Summary of common withdrawal sectors. All images on this page are copyrighted and used by Dreamstime.com, used in accordance with licenses.

by one withdrawal category (public water supply), whereas the end-use would be described by multiple water use categories (domestic, industrial, and commercial).

Present Status

Understanding water withdrawals, consumption, and supply is integral to the management of water resources, which helps provide for a sustainable balance between conservation and utilization. In recent years, our understanding of how water is withdrawn from the system and subsequently used has greatly improved. This increase in knowledge also includes a better understanding of the underlying data management systems, meaning more timely and comprehensive assessments can be made. Figure 3.2 shows the Basin-wide picture of water withdrawals, out-of-Basin diversions, and consumptive use, by sector, based on the 2020 calendar year water use data; the data shown represents daily average withdrawals on an annual basis (DRBC 2022a).

Key Delaware River Basin Water Withdrawal Facts:

- Based on 2016 data, an estimated 13.3 million people rely on water from the Delaware River Basin for their daily water needs (Byun et al. 2019). Approximately 8.3 million people live in the Delaware River Basin, and the volume of diversions to New York City and northeastern New Jersey is sufficient to supply water to an additional 5 million people.
- Based on 2020 data, ground and surface water withdrawals from the Delaware River Basin are estimated to total 6,390 million gallons per day (MGD), out-of-Basin diversions total 594 MGD, and in-basin consumptive use is 263 MGD.
- Approximately 95% of all water used in the Delaware River Basin is obtained from surface waters.
- Three dominant use sectors account for over 68% of total water withdrawals; these sectors are thermoelectric power generation (49%), public water supply (12%), and industrial (7%).

Past Trends

DRBC recently published a comprehensive report assessing historical water withdrawals and consumptive use in the Delaware River Basin from 1990-2017, with projections provided through the year 2060 (Thompson & Pindar 2021). For the most part, the study evaluated individual withdrawal systems (i.e., a facility which operates withdrawal sources together) which are associated with DRBC regulatory approvals (excluding the self-supplied domestic and irrigation sectors). The more than 600 systems which were individually reviewed included about 3,700 sources and account for the overwhelming majority of reported water withdrawals by volume (greater than 99%). The remaining withdrawal systems not associated with DRBC regulatory approvals (likely operating below review thresholds) included about 2,450 sources and subsequently account for under 1% of the total average withdrawal. Based on the volumetric proportion of data, subject to the project's review process, it is assumed that the historical time series represents actual (or observed) conditions. The historical water withdrawals from the Delaware River Basin are presented in Figure 3.3, color-coded by withdrawal sector and updated to include data from 2018-2020, which was beyond the scope of Thompson & Pindar (2021).

Future Predictions

In addition to compiling a historical time series of withdrawal data for the Delaware River Basin, Thompson & Pindar (2021) also project future withdrawals through the year 2060. The detailed methodology behind the projections is contained within that report; however, it can be summarized by a few key notes:

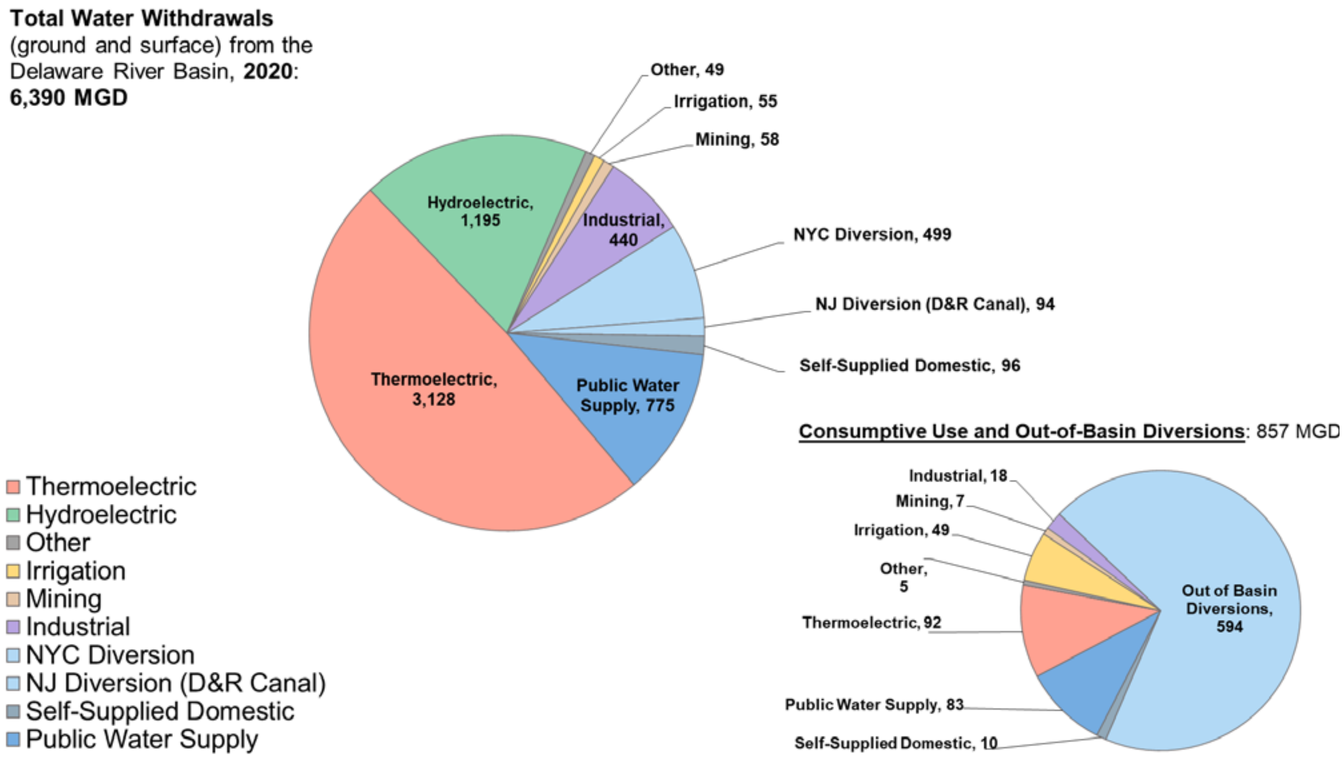


Figure 3.2 Total water withdrawals from the Delaware River Basin, 2020.

- Primary method: The majority of projected sectors (excluding out-of-Basin diversions, self-supplied domestic, and irrigation) relied on the extrapolation of historical withdrawal data. Projections were performed on a system-by-system basis, often at finer scales, allowing results to meet planning objectives. Pertinent metadata was often a consideration in determining the most appropriate regression(s) for each system.
- Out-of-Basin diversions: Due to the complex nature of the operation of these sources, trend extrapolation was not considered an appropriate means for providing a projection of withdrawal. Instead, the last five years of data in this study (2013-2017) were averaged and used as the projected value for each source.
- Self-supplied domestic: Withdrawal estimates for self-supplied domestic water users were based on population distribution in relation to public water supply service areas (considering per-capita water rates). Projections were performed utilizing county-level population projections for 2020-2100 for one of five Shared Socioeconomic Pathways (SSPs), which represent different ways in which the United States may be expected to grow in this century (M. E. Hauer 2019; M. Hauer & CIESIN 2021; O'Neill et al. 2014).
- Irrigation: Due in part to the large number of sources and approvals, irrigation withdrawals were aggregated to and projected at the smallest applicable planning scales, differentiating groundwater from surface water. Projections were performed considering climatic variables from a downscaled regional climate model.

The projections from each of these methods were performed in a way, such that the results may be aggregated to various planning scales (e.g. hydrologic unit codes, state boundaries, Basin-wide, and various combinations of sectors). The Basin-wide projection is presented in Figure 3.3 as the solid blue line, with 80% and 95% predictive intervals in varying shades of gray. Some high-level conclusions from Thompson & Pindar (2021) regarding the projection results are:

- Peak water withdrawal from the Delaware River Basin has likely already occurred (in 2005 and 2006 it was estimated to be approximately 9.917 billion gallons per day).
- The Basin-wide water withdrawals from the Delaware River Basin are projected to continue decreasing, from a projected value of 6,921 MGD in 2020 to about 6,289 MGD in 2060, however, the estimated value based on reported data for 2020 is 6,390 MGD. The largest projected decreases were for thermoelectric power (-322 MGD) and hydroelectric power (-292 MGD), followed by public water supply (-30 MGD) and self-supplied domestic (-5 MGD). The remaining sectors returned mild increases.
- Historical decreases in water withdrawals by thermoelectric facilities are shown to be strongly correlated with decreases in energy generation from coal-fired steam-turbine facilities using once-through cooling. These findings are consistent with other studies at the national level which highlight the closure of many such facilities.
- The population residing within the Delaware River Basin has historically increased and is projected to continue increasing. Despite a growing Basin-wide population, public water supply withdrawals have historically decreased and are projected to continue decreasing. The pattern of increasing population and decreasing withdrawals (Fig 3.4) is assumed to be related to advances in leak detection and water conservation by purveyors, regulatory efforts such as plumbing standards,

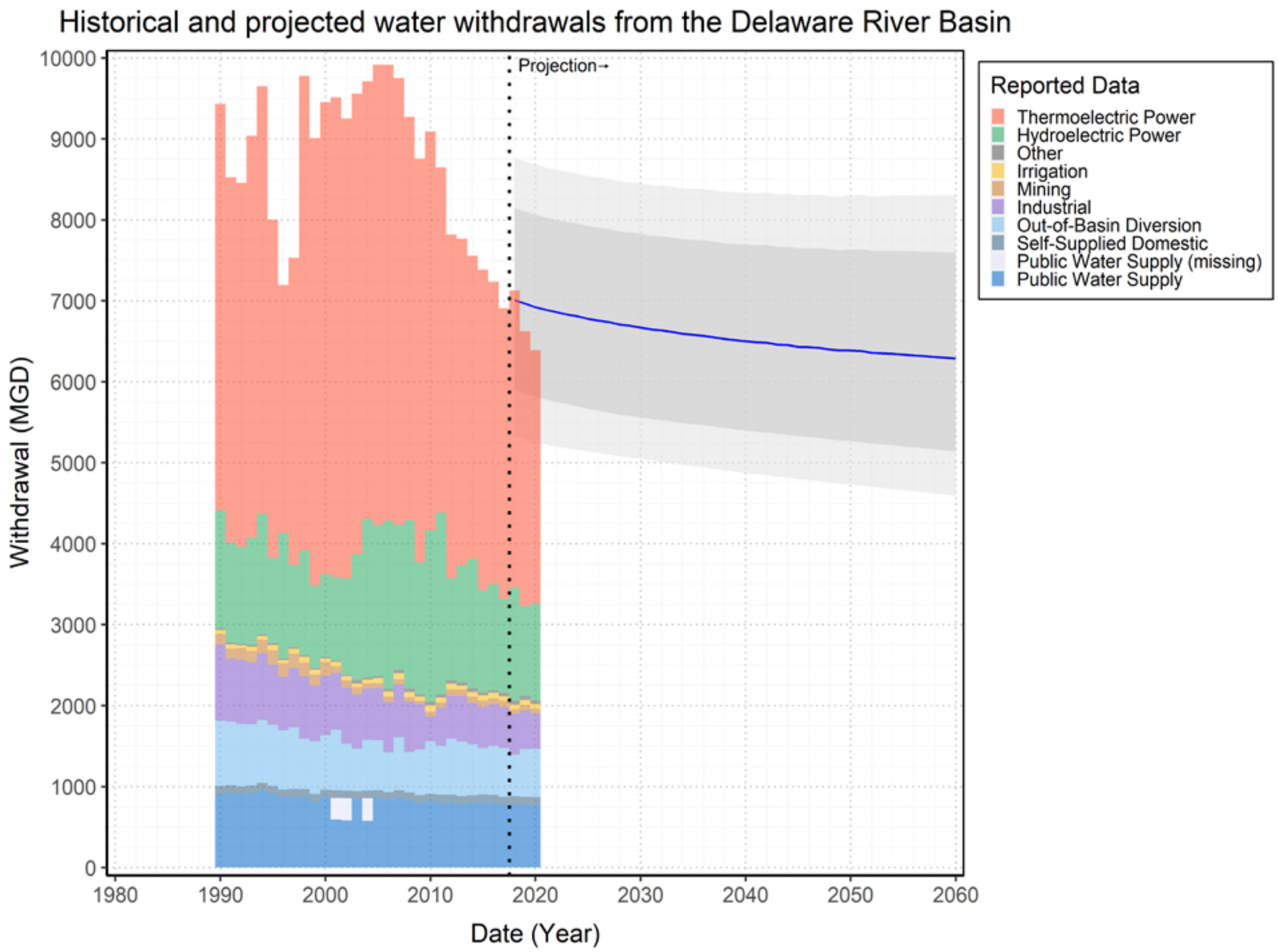


Figure 3.3 Historical and projected water withdrawals from the Delaware River Basin initially published in Thompson & Pindar (2021). The predictive interval shown represents the aggregated predictive intervals for all sectors. The figure has been amended with complete years of data through 2020.

and general public awareness of water conservation. While decreasing in total, withdrawals have increased in several systems where there are population growth regions (i.e., where water conservation practices cannot offset the more rapid increase in population).

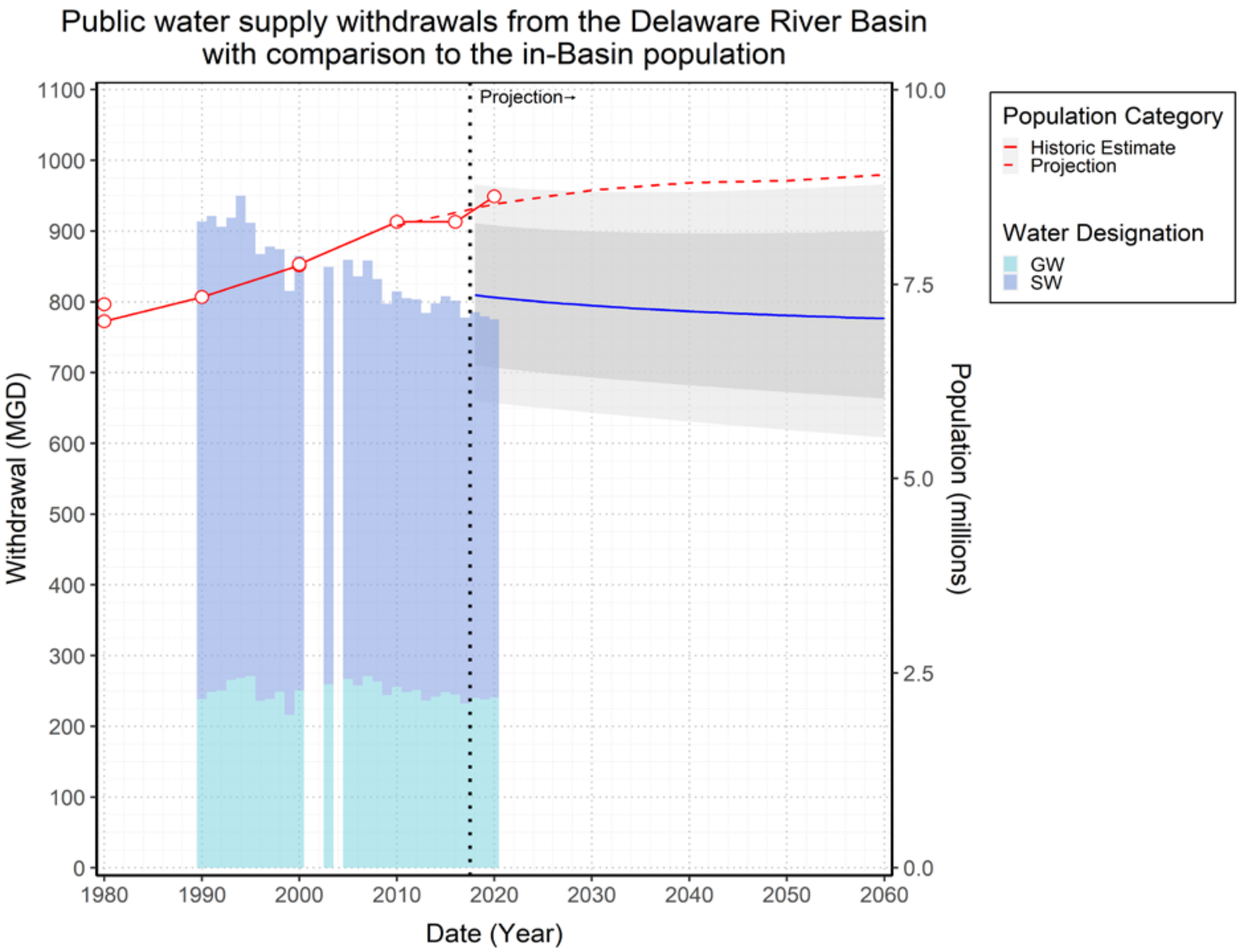


Figure 3.4 Average annual withdrawal rates from the Delaware River Basin (MGD) by public water supply systems, categorized by source water type. Additionally, previous population estimates for in-Basin population as performed by DRBC are graphed as red circles. Data through 2017 and data on projections for both public water supply withdrawals and in-Basin population are adopted from Thompson & Pindar (2021). This graphic has been updated with withdrawal data through 2020, as well as the U.S. Census Bureau data for 2020 as part of the FY2023-2025 Water Resources Program (DRBC 2022a). Years of significant data gaps in withdrawal data have been omitted.

Actions and Needs

The quality and completeness of water withdrawal data are continuously advancing due to the progression of state reporting programs, electronic web-based reporting, and advancements in data sharing, such as online portals and reports. It is likely that advancements in data sharing and availability will continue into the future. Known data gaps exist in certain sectors (mining) where electronic reporting and data sharing are assumed to be not on par with other sectors, which is a possible area for future improvement. There is continuous improvement in reporting compliance and accuracy within the irrigation sector. Improvements in obtaining and sharing the most recent data related to water withdrawals and use within the Delaware River Basin will continue to support advances in quantifying the instream needs of aquatic ecosystems, which are necessary for achieving a balance between instream and off-stream (withdrawal) water needs.

Summary

Advances in the collection and reporting of water withdrawals, primarily by state agencies, have improved our understanding of water use in the Delaware River Basin and its watersheds. A recent comprehensive study performed by DRBC assessed historical water withdrawals and consumptive use in the Delaware River Basin from 1990-2017, with projections provided through the year 2060 (Thompson & Pindar 2021); data on historical withdrawals and projections have been made publicly available on the DRBC website. This dataset has helped DRBC support many important findings, such as that peak water withdrawal from the Delaware River Basin has likely occurred (around 2006 it was estimated to be approximately 9.917 billion gallons per day). Withdrawals by public water supply systems have decreased over time and are projected to continue decreasing despite growing populations in the Basin. Withdrawal by thermoelectric facilities decreased by almost 2,500 MGD since 2007 due largely to reduced operation and/or closure of coal-fired facilities using once-through cooling technology; consumptive use by this sector has been and is projected to remain relatively constant as more evaporative cooling is utilized. Overall, Basin-wide water withdrawals are projected to continue decreasing, from a projected value of 6,921 MGD in 2020 to about 5,670 MGD in 2060; the estimated value based on reported data for 2020 is 6,390 MGD.

3.2 Consumptive Use

Description of Indicator

The previous section largely focused on total withdrawals of water from the Delaware River Basin; however, another important planning metric considers how much of that withdrawn water is actually returned to the immediate environment (or consequently how much of the withdrawal is consumed). For the DRBC, consumptive use of water is defined in 18 CFR Part 420 as:

> *"...the water lost due to transpiration from vegetation in the building of plant tissue, incorporated into products during their manufacture, lost to the atmosphere from cooling devices, evaporated from water surfaces, exported from the Delaware River Basin, or any other water use for which the water withdrawn is not returned to the surface waters of the basin undiminished in quantity."*

Generally, the consumptive use of water is calculated by applying a percentage to the total withdrawal of water (that percentage can vary significantly between withdrawal sectors). For example, Thompson & Pindar (2021) provide a table of the default consumptive use ratios for each sector and the category used in that report (along with cited literature as applicable). Irrigation is highly consumptive (an estimate of 90% or greater is often used) as the water is absorbed by plants, soil, or lost to evaporation. Public water supplies are typically considered to have a consumptive use of 10%, as only a small portion of the water used in homes and cities is evaporated, and the majority is returned to the hydrologic system via sewerage systems. Thompson & Pindar (2021) exclusively applied default consumptive use ratios in all but two sectors for the study (and consequently this analysis); thermoelectric power generation and self-supplied industrial. For these two sectors, under certain circumstances, consumptive use data are reported annually, and wherever possible calculated historical average consumptive use rates were applied.

Present Status

Understanding the consumptive use of water is an integral component of adequate water resource planning. Figure 3.2 shows the Basin-wide picture of water withdrawals, out-of-Basin diversions, and in-

Basin consumptive use, based on the 2020 calendar year water use data; the data shown represents daily average rates on the annual basis (DRBC 2022a).

Key Delaware River Basin Water Consumptive Use Facts:

- The largest component of consumptive use for the Basin are out-of-Basin diversions, which were established as part of the 1954 Supreme Court Decree and are managed separately from other withdrawals and discharges in the Basin.
- Of the remaining 263 MGD of in-Basin consumptive use, the four major components are thermoelectric facilities (92 MGD, 35%), public water supply (83 MGD, 32%), irrigation (49 MGD, 19%), and industrial (17 MGD, 6.7%).

Past Trends

DRBC recently published a comprehensive report assessing historical water withdrawals and consumptive use in the Delaware River Basin from 1990-2017, with projections provided through the year 2060 (Thompson & Pindar 2021). The historical water withdrawals from the Delaware River Basin were presented in Figure 3.3. From these data, it is possible to calculate the portion of withdrawals, which is consumptively used. The corresponding historical consumptive water use in the Delaware River Basin is presented in Figure 3.5. As the out-of-Basin diversions are such a significant portion of Figure 3.5, it is sometimes beneficial to assess each of the other four sectors individually, as shown in Figure 3.6. From these two figures, and considering the previous conclusions on total withdrawals, additional findings can be summarized:

- Public water supply: The trends shown in consumptive use by the public water supply sector mirror the withdrawal trends because this sector's consumptive use is calculated with a default consumptive use rate of 10%. Therefore, findings of declining consumptive use contrary to increasing populations are expected.
- Irrigation: The irrigation sector is comprised of multiple uses, of which the primary is agricultural irrigation (other examples: golf courses, tree nurseries, sports fields). These withdrawals were determined to be strongly correlated with climatic variables and were projected using Regional Climate Model data (Thompson & Pindar 2021). Withdrawal reporting compliance and accuracy appear to be increasing. Consumptive use for this sector is also calculated using a default rate of 90%.
- Industrial: The industrial sector has most of the consumptive use data calculated using reported facility-specific consumptive use rates, or adopted from regulatory approvals; Thompson & Pindar (2021) provides a graphic showing the proportions of data by a calculation method. Overall, the industrial sector has shown significant declines in both withdrawals and consumptive use, often attributed to declines in production at specific facilities (e.g., the U.S. Steel Fairless Plant stopped iron and steel production in 1991, Bethlehem Steel ceased production in 1995, there was a temporary shutdown of Delaware City Refinery in 2010, and Philadelphia Energy Solutions closed in 2019). Despite these historical declines, the projection for industrial withdrawals and consumptive use suggests a lower plateau and continuation at a relatively constant rate.
- Thermoelectric: Water withdrawn for thermoelectric power generation is most commonly used for cooling (e.g., non-contact cooling water). The specific technology used for cooling at a given facility drastically affects the amount of water used. For example, recirculating cooling systems withdraw less water than once-through systems but generally have much higher rates of evaporation and therefore consumptive use. Historical decreases in water withdrawals by thermoelectric facilities were shown to be strongly correlated with decreases in energy net generation from coal-fired

steam-turbine facilities using once-through cooling (Thompson & Pindar 2021). The decrease in withdrawals by thermoelectric facilities between 2007-2017 was around 1,920 MGD, of which about 1,850 MGD was attributable to facilities using once-through cooling. Therefore, it is not surprising that the decreases in total withdrawals have not translated into reduced consumptive use, as shown in Figure 3.6A. To further investigate this concept, consumptive use data can be categorized by each facility's cooling system type, as shown in Figure 3.7. This graphic quantifies that an increasing proportion of overall consumptive use is attributed to facilities with recirculating cooling towers, which comparatively withdraw less water but operate at higher rates of consumptive use than facilities with once-through cooling. The Commission manages the replacement of consumptive use from electric generating and cogenerating facilities during critical hydrologic conditions in accordance with Resolution 2018-5, which accounts for a facility's location in the basin and its impact on the salt front.

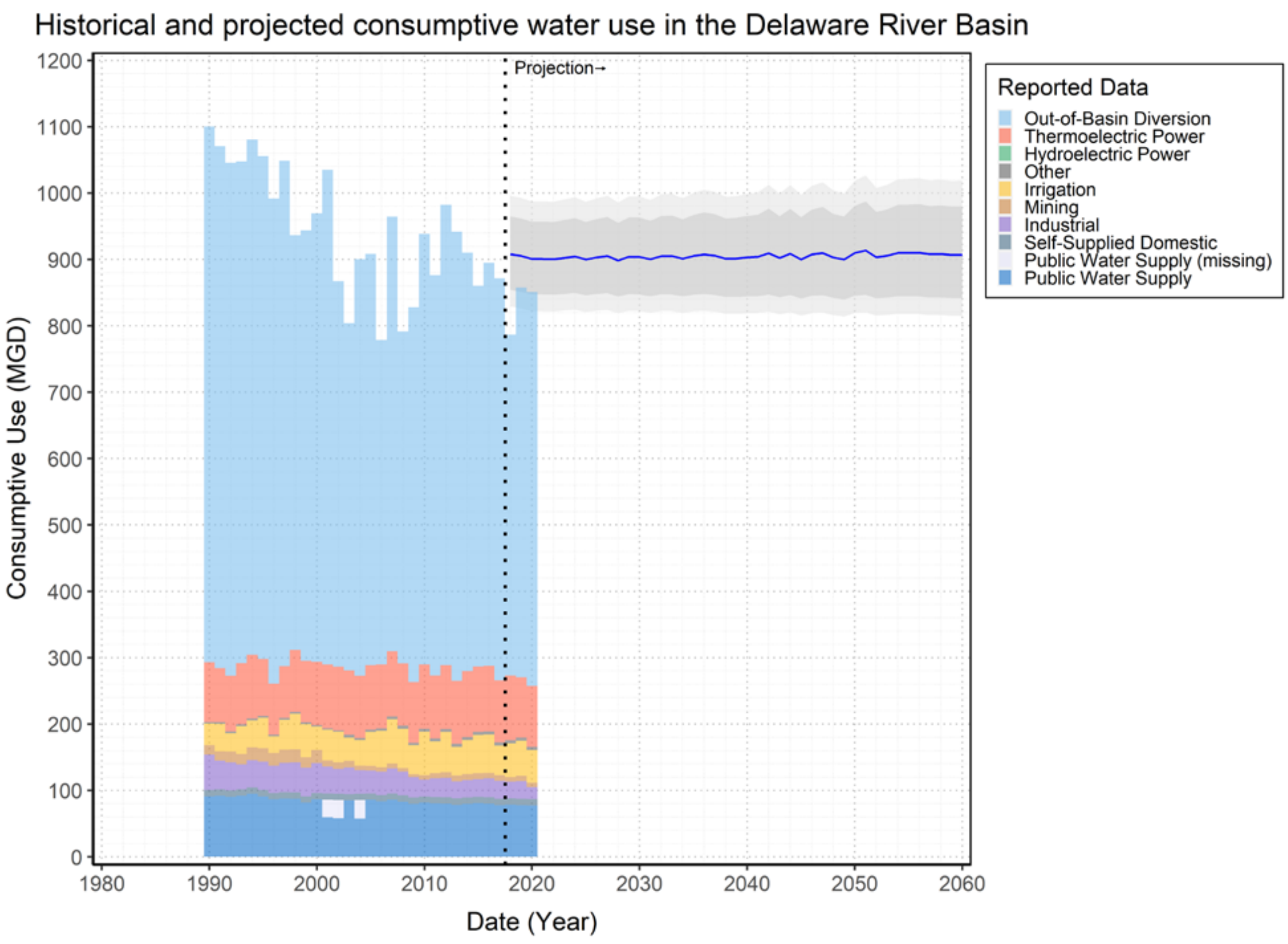


Figure 3.5 Historical and projected consumptive water use in the Delaware River Basin initially published in Thompson & Pindar (2021). The predictive interval shown represents the aggregated predictive intervals for all sectors, excluding the out-of-Basin diversions which did not have a calculated predictive interval. The figure has been amended with complete years of data through 2020.

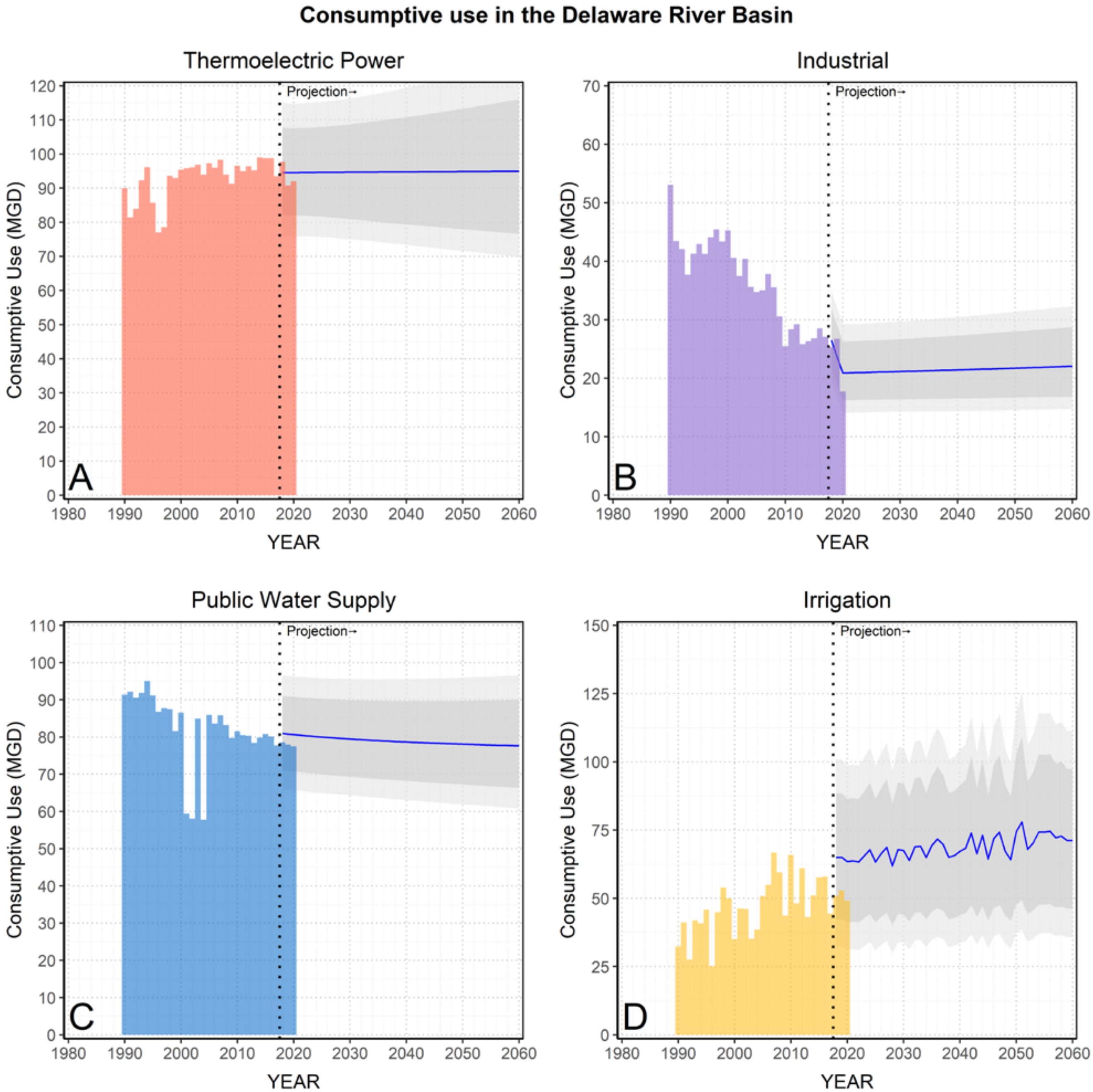


Figure 3.6 Historical and projected consumptive water use in the Delaware River Basin for major sectors.

Future Predictions

Consumptive use trends over the past three decades were shown in Figure 3.5, as well as a Basin-wide projection as determined in Thompson & Pindar (2021); individual sectors trends and projections were shown in Figure 3.6. At the Basin-scale, consumptive use was projected to remain relatively stable. Considering the four highlighted sectors:

- Public Water Supply (PWS): Projections show continued decreases in consumptive use, consistent with the projections of overall withdrawal, based on the same drivers previously discussed. This is due to the method of calculating consumptive use for public water supply.

- Irrigation: Consumptive use was projected using a multivariate model developed based on climate data from a regional climate model for the Delaware River Basin area. Irrigation volumes were shown to share a direct relationship with temperature; therefore, increasing temperatures in the regional climate model helped drive a projection of increasing irrigation withdrawals and consumptive use.
- Industrial: Projections accounted for one major facility shutdown, as the event occurred during model development. However, barring additional circumstances such as the major facility shifts discussed previously, the projection shows a relatively stable and even slightly increasing projection of consumptive use.

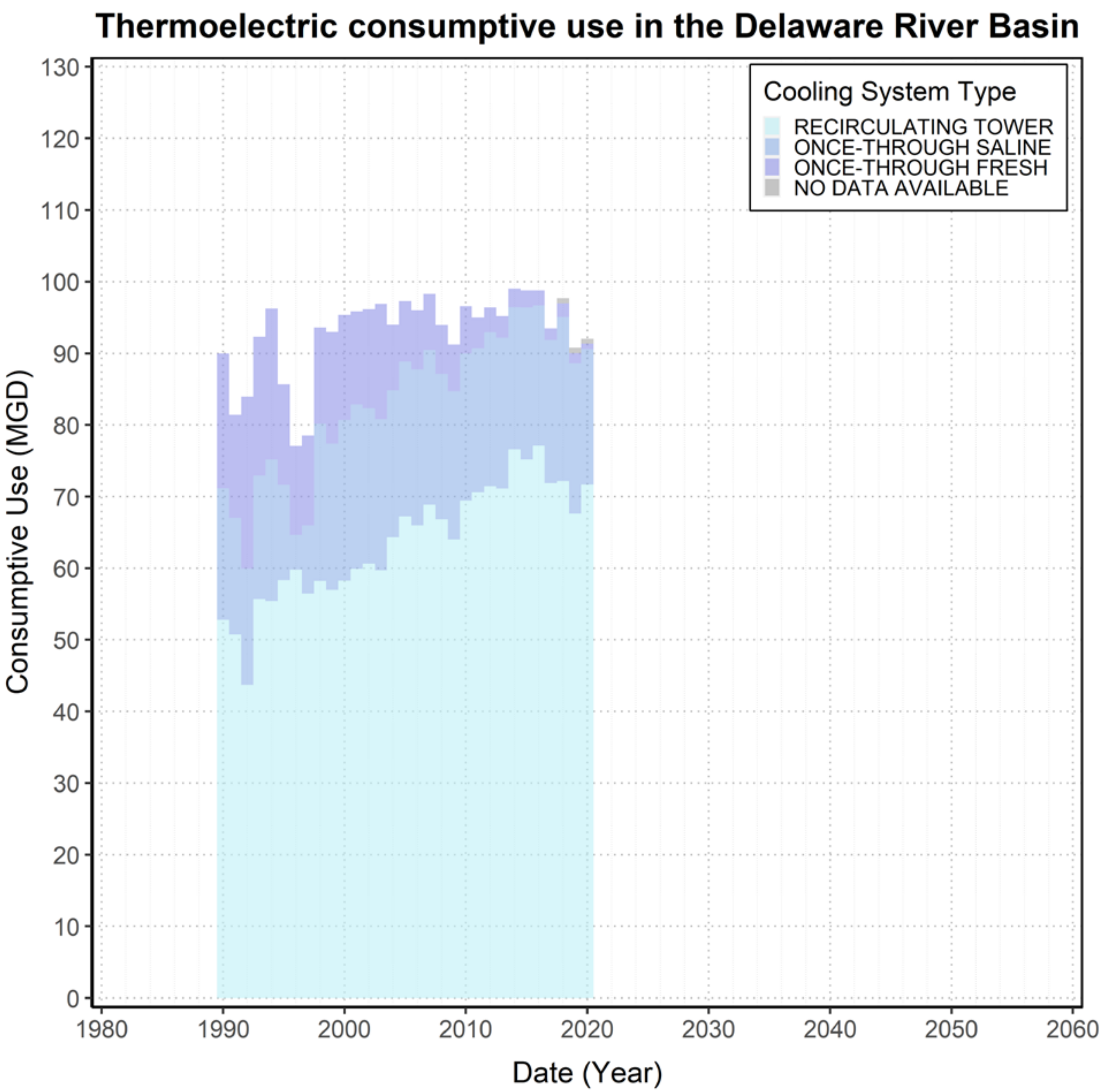


Figure 3.7 Historical consumptive water use in the Delaware River Basin by thermoelectric facilities (same data as Figure 3.6A) color-coded by cooling system type, initially published in Thompson & Pindar (2021). This graphic has been updated with withdrawal data through 2020.

- Thermoelectric: Projections of consumptive water use at thermoelectric facilities were almost constant; it is important to note that the projection methodology did not consider the potential for developing new power generation facilities and is only projecting existing water use patterns given a continuation of the current trends, outlined in the assumptions of Thompson & Pindar (2021). If new facilities were to be constructed, it is likely that they would rely on cooling towers, and potentially increase the overall consumptive use without greatly affecting tends in total withdrawals.

Actions and Needs

An accurate consumptive use characterization for a watershed requires a detailed analysis of each water use sector to determine consumptive use factors representing site-specific conditions. For example, at a small watershed scale, the simple assumption of 10% consumptive use for a PWS system that withdraws from the watershed but discharges wastewater outside the watershed would be inaccurate. This would need to be modeled as 100% consumptive or as an export from the sending watershed and an import of wastewater (minus the 10% consumptive use) to the receiving watershed. More detailed tracking models that link withdrawal volumes more explicitly to discharge volumes are being applied in the Delaware River Basin, such as by New Jersey Geological Survey's Water Transfer Data System.

Summary

An understanding of consumptive water use provides additional insight into water use patterns and is an important indicator in the management of water resources. Within the Delaware River Basin, the largest consumptive uses are the out-of-Basin diversions. Beyond these diversions, the four major components are thermoelectric facilities, public water supply, irrigation, and industrial facilities (constituting approximately 92% of the in-Basin consumptive use). Slightly downward consumptive use trends are expected to continue in the public water supply sector, while neutral trends may continue in the thermoelectric and industrial sectors. Irrigation withdrawals were shown to be correlated with climatic variables, and projections suggest the possibility for mild increases in consumptive use, due primarily to the projected increase in ambient air temperature.

3.3 Groundwater Availability

Description of Indicator

Stress on a groundwater resource system can occur when withdrawals exceed natural recharge. Withdrawal of groundwater through wells is stress superimposed on a previously balanced groundwater system. The response of an aquifer to pumping stress may result in modifications to recharge of the aquifer, a decrease in the natural discharge to streams, a loss of storage within the aquifer, or a combination of these effects. Additionally, impacts may extend beyond the limits of the aquifer being monitored. Therefore, it is important to monitor and assess groundwater withdrawals on various planning scales to better understand where areas of potential stress might exist within the Delaware River Basin. One such tool is a groundwater availability screening method developed in 2006 by the USGS in cooperation with the DRBC (Sloto & Buxton 2006). The methodology assesses the Delaware River Basin as 147 separate sub-basins (Fig 3.8), each of which has stream baseflow from groundwater characterized based on the underlying geology. These baseflows are presented as recurrence intervals (for example, a 25-year recurrence interval is the groundwater baseflow to a particular stream that is expected to occur once in 25 years, abbreviated as RI-25). The method then looks at the net groundwater withdrawals as a percentage of the groundwater baseflow for each sub-basin to assess levels of stress. This method has limited applicability in the Coastal Plain portion of the Basin, which has a complex confined aquifer network; the method is only suited to evaluate withdrawals from unconfined aquifers.

Two major areas, primarily within the watersheds of the Upper Estuary and Schuylkill Valley, have shown signs of potential stress and are recognized as critical or protected areas. These groundwater management areas are shown in Figure 3.8, and are referred to as:

- The Southeastern Pennsylvania Groundwater Protected Area (SEPA-GWPA), which is largely underlain by fractured bedrock, and
- Critical Area 2 in south-central New Jersey, which is underlain by unconsolidated sediments.

DRBC assesses groundwater availability in the SEPA-GWPA using a similar methodology as Sloto & Buxton (2006). The SEPA-GWPA is divided into 76 different sub-basins and groundwater baseflow values were calculated in previous USGS studies in cooperation with DRBC (Schreffler 1996; USGS 1998). The New Jersey Department of Environmental Protection (NJDEP) is the agency responsible for the management and monitoring of Critical Area 2, which is focused on the confined aquifer network in the Atlantic Coastal Plain. New and/or expanded withdrawals in both critical areas are limited and managed, subject to specific regulations that allocate the resource on the basis of a sustainable long-term yield.

Present Status

DRBC has calculated groundwater availability in the Delaware River Basin and for the Southeastern Pennsylvania Groundwater Protected Area (SEPA-GWPA) based on net groundwater withdrawal data from 2020 (Figures 3.9 and 3.10). The present status of groundwater availability in the Basin and in the SEPA-GWPA are summarized below.

Basin-wide: Withdrawal data was adjusted to represent "net" groundwater withdrawals, which is assumed to be the difference between the total groundwater withdrawal from a sub-basin and water recharge occurring within the same sub-basin. Figure 3.9 indicates that one sub-basin is currently between 50.1% and 75% of its 25-year annual baseflow, and two sub-basins are between 25.1% - 50% of its 25-year annual baseflow. The 26 grayed-out basins in Figure 3.9 represent areas where DRBC determined that the methods developed by Sloto & Buxton (2006) are not applicable because groundwater withdrawals in those areas are predominately from confined aquifers in the Coastal Plain (DRBC 2022b). A primary assumption made in Sloto & Buxton (2006) assumes that groundwater withdrawals from the Coastal Plain are from unconsolidated sediments only, as confined aquifer networks may have regional influences which extend beyond sub-basin boundaries.

SEPA-GWPA: The Southeastern Pennsylvania Groundwater Protected Area is an area of 1,200 square miles that includes 127 municipalities, primarily in Bucks, Chester, and Montgomery counties. As municipal boundaries are not defined based on hydrologic parameters, 76 hydrologic sub-basins were delineated to cover all municipalities within SEPA-GWPA (Fig 3.10). DRBC monitors these sub-basins regarding groundwater withdrawals, well interferences, and municipal water supply planning; furthermore, withdrawal limits have been established for each based on previous work by USGS in cooperation with DRBC (Schreffler, 1996; USGS, 1998). The following summary of conditions is based on an analysis using groundwater withdrawal data reported to the Pennsylvania Department of Environmental Protection (PADEP) adjusted to represent net groundwater withdrawals. DRBC will continue to update Delaware River Basin usage with current PADEP water withdrawal data.

- In Figure 3.10, the 2020 net groundwater withdrawal in three of the sub-basins is currently between 50.1% and 75% of the respective annual sub-basin withdrawal limit, and one sub-basin is above the respective withdrawal limit. Sub-basin SP-29 (Schuylkill-Crow Creek) has historically

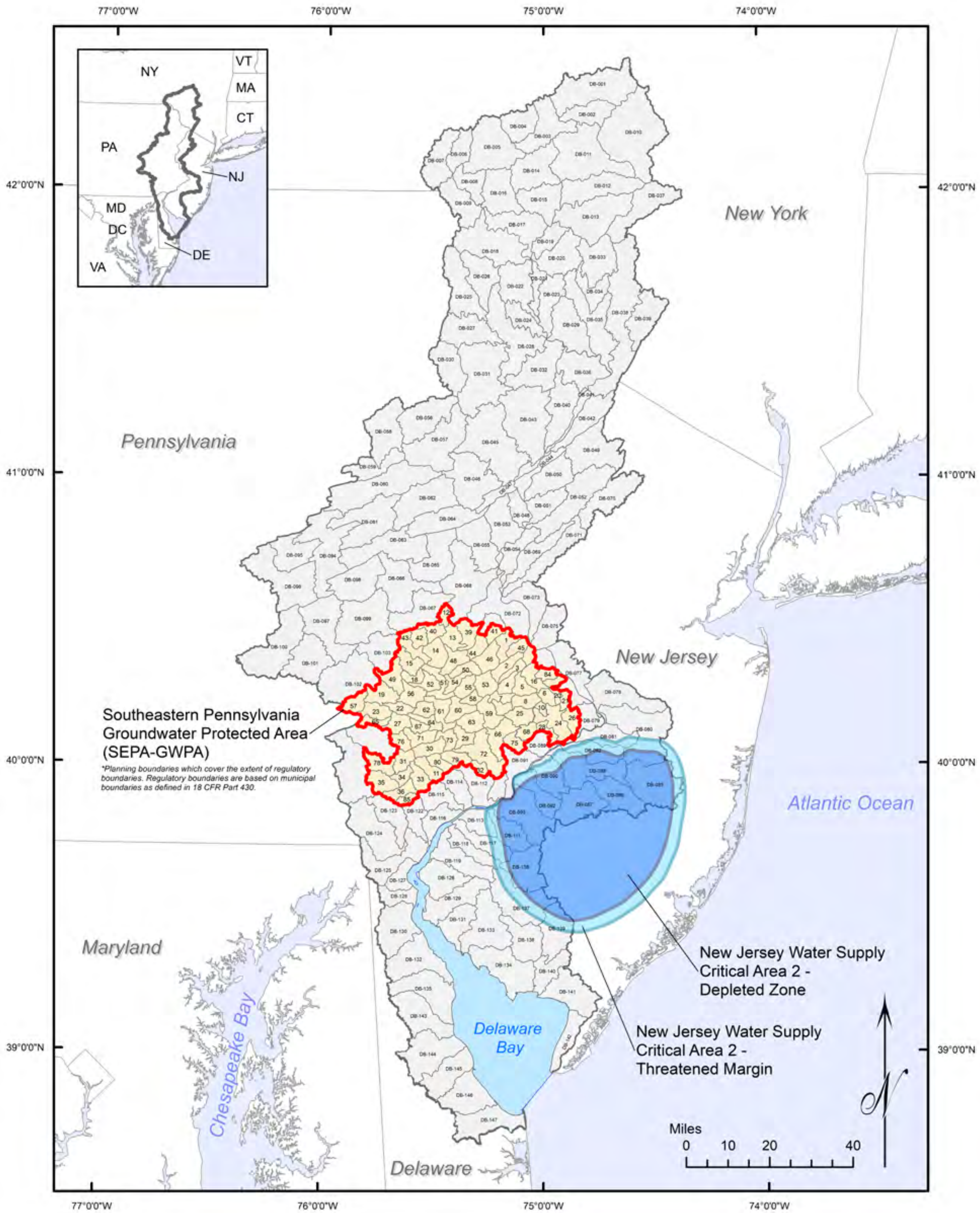


Figure 3.8 Groundwater management areas in the Delaware River Basin.

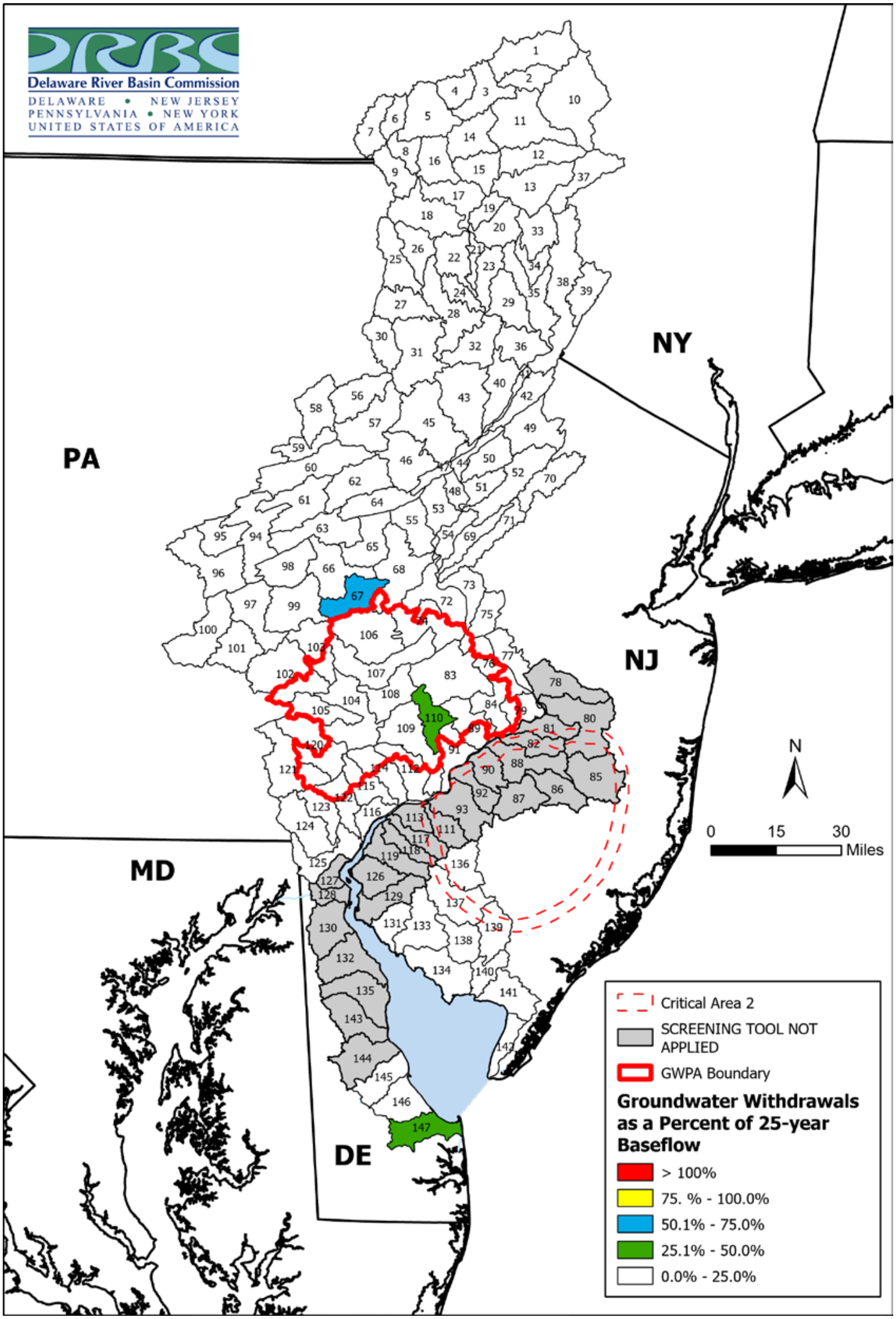


Figure 3.9 Net groundwater withdrawals from the Delaware River Basin for CY2020. Greyed-out sub-basins denote areas where the screening tool was not applied.

been above its withdrawal limit because a large withdrawal from a quarry reservoir is counted as a groundwater withdrawal.

- Reductions in total annual net groundwater withdrawals have been observed over the past two decades. "Conjunctive use" strategies (i.e., adaptive use of both ground and surface water) and regional alternatives to the local supplies are strategies being employed within the SEPA-GWPA.

Critical Area 2: The New Jersey Water Supply Critical Area 2 was designated on July 20, 1993, by administrative order (NJAC 7:19-8.5). This area includes the Potomac-Raritan-Magothy (PRM) aquifer system, with extents based on findings from Eckel & Walker, 1986. The New Jersey Department of Environmental Protection (NJDEP) and the United States Geological Survey (USGS) regularly monitor groundwater levels in the affected aquifers of Critical Area 2 in southern New Jersey, and assessments indicate that withdrawals have significantly decreased beginning with the program's inception in 1996. Data provided by NJDEP for 2019 show that there were about 17,434 million gallons withdrawn from the "Depleted Zone," and about 5,377 million gallons withdrawn from the "Threatened Margin" of the PRM aquifer.

Past Trends

DRBC recently published a comprehensive report assessing historical water withdrawals and consumptive use in the Delaware River Basin from 1990-2017, with projections provided through the year 2060 (Thompson & Pindar 2021). Using data provided as part of that study, a time series of historical net withdrawals for the Delaware River Basin and for the SEPA-GWPA were compiled and updated through 2020 (Figures 3.11 and 3.12). The 30 years of data show that net groundwater withdrawals have changed at both the Basin scale and within the SEPA-GWPA, and this knowledge can help make better planning decisions.

Basin-wide: Groundwater withdrawals in the Basin have varied between about 340 MGD to 400 MGD for the past 30 years (Fig 3.11). More recently annual net groundwater withdrawals hover around 330 MGD with a slight decrease in the past few years. Net withdrawals by sector have shifted with a decrease in industrial withdrawals in the past thirty years.

SEPA-GWPA: As shown in Figure 3.12, the reduction in net groundwater withdrawals in the SEPA-GWPA is largely perceived to be due to the adoption of sub-basin withdrawal limits by DRBC in 1999 and increased reliance on surface water derived from the Delaware River. Over the period from 2000 to 2020, cumulative net groundwater withdrawals from the SEPA GWPA have steadily decreased (Fig 3.12). Groundwater pumping stress in several sub-basins has been alleviated by the Point Pleasant diversion in Pennsylvania, which transfers surface water from the Delaware River to serve populations in several SEPA-GWPA municipalities. This diversion has provided a conjunctive use solution that has reduced the reliance on groundwater in several sub-basins. Other aspects of the management program administered by the DRBC in this area include a water conservation program and a lower withdrawal threshold triggering regulatory review (10,000 gallons/month, as compared to 100,000 gallons/month elsewhere in the Delaware River Basin).

Critical Area 2: The New Jersey Water Supply Critical Area 2 was established by the State of New Jersey in 1993 and has resulted in reduced withdrawals from the Potomac-Raritan-Magothy (PRM) aquifer system. Many of the municipalities are now served by surface water diverted from the Delaware River near Delran, NJ. Strategies such as this have led to decreasing withdrawal volumes from both the Depleted Zone and the Threatened Margin of Critical Area 2 (Fig 3.13A). Consequently, aquifer levels have risen and an example is shown in the graph from USGS Elm Tree 3 Observation well (Fig 3.13B), which is located more than 700 ft below the land surface in the Middle PRM aquifer in Camden, NJ.

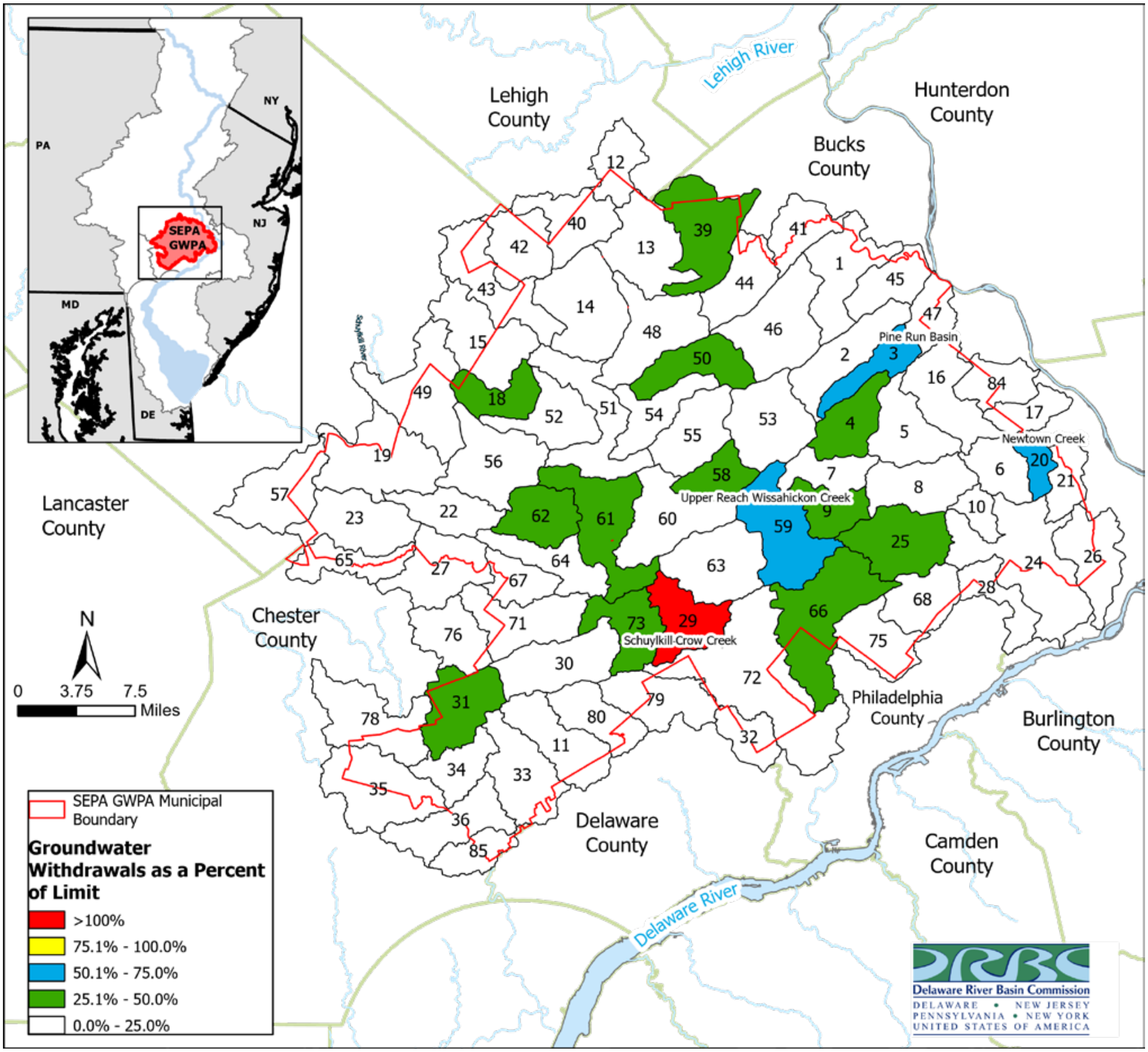


Figure 3.10 Net groundwater withdrawals from the Southeastern Pennsylvania Groundwater Protected Area for CY2020.

Future Predictions

In addition to compiling a historical time series of withdrawal data for the Delaware River Basin, Thompson & Pindar (2021) also provide projections of groundwater withdrawals through the year 2060. These data were published with the report and have been converted to net groundwater withdrawals for the purposes of this study. The detailed methodology behind the projections is contained within the report, but it can be summarized both Basin-wide and for the specially protected areas in the Basin:

Basin-wide: It is projected that net groundwater withdrawals will remain relatively stable with a slight decrease over time (Fig 3.11). At the time of this report, no sub-basins are expected to exceed the RI-25 baseflow determined by Sloto & Buxton (2006).

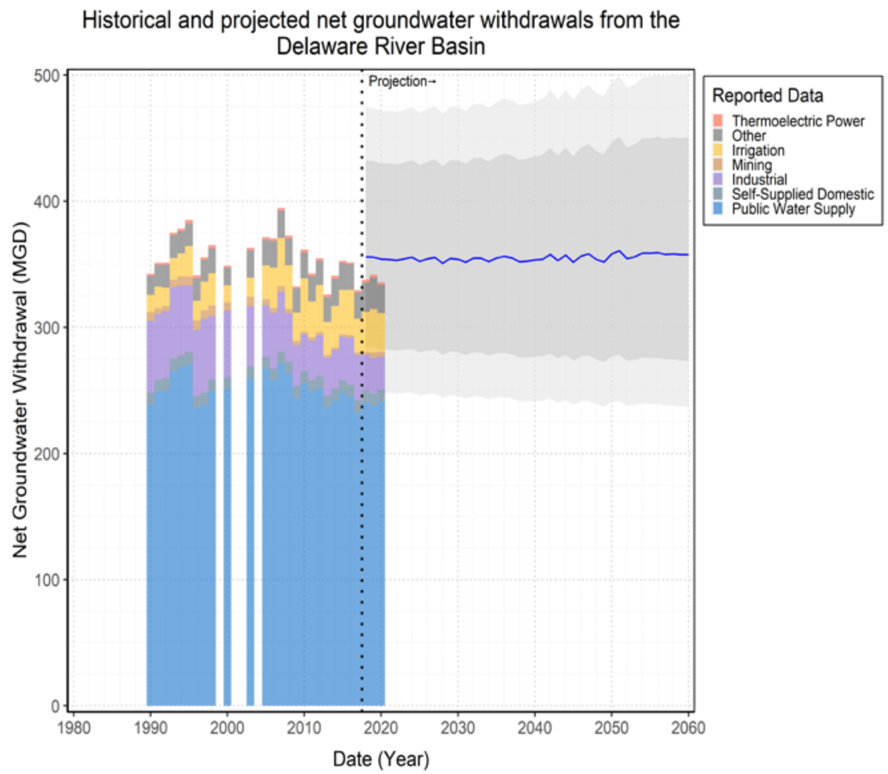


Figure 3.11 Net groundwater withdrawals in the Delaware River Basin 1990-2020. There are known data gaps present for 2001, 2002, and 2004.

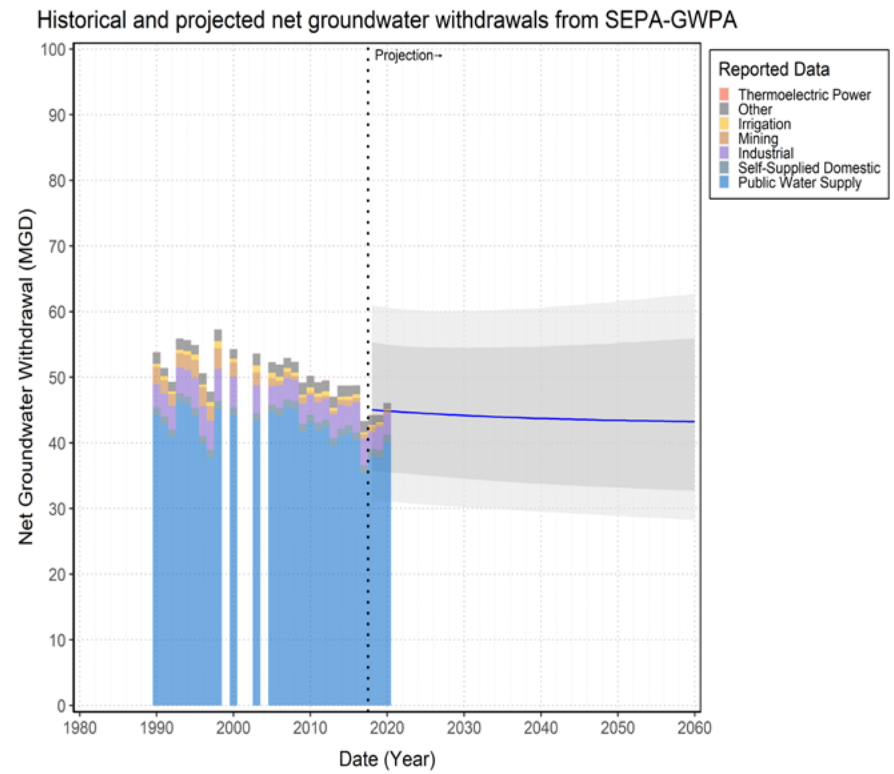


Figure 3.12 Net groundwater withdrawals in the Southeastern Pennsylvania Groundwater Protected Area 1990-2020. There are known data gaps present for 2001, 2002, and 2004.

SEPA- GWPA & Critical Area 2: Groundwater conditions in the SEPA-GWPA and NJ Critical Area 2 are expected to continue to improve over time due to management strategies of the DRBC, Pennsylvania, and New Jersey (Figures 3.12 and 3.13).

Actions and Needs

In recent years, progress has been made to improve water use reporting and these improvements should be continued in order to provide necessary data to monitor and assess conditions in sensitive areas such as the SEPA-GWPA and the New Jersey Water Supply Critical Area 2. In addition, improvements can be made in our understanding of the dynamics distinguishing the confined and unconfined aquifers in the coastal plain. The current Sloto & Buxton (2006) method does not apply to the coastal plain portion of the Basin and an improved understanding would help DRBC and other resource agencies better assess and manage groundwater availability in the region.

Finally, assessing the seasonality of both natural groundwater baseflow and net groundwater withdrawals would allow for a better understanding of seasonal trends and potential stresses in groundwater availability. Certain water use sectors tend to withdraw groundwater more during the summer months, likely resulting in the current annual depiction of availability as an underestimate for certain months of the year. A better understanding of these trends could help with DRBC's and other agencies' availability assessments.

Summary

Overall, the increase in data availability and advancement in data quality have made it possible to better understand historical trends and make future projections for net groundwater withdrawals. Paired with assessments of groundwater baseflows to surface water streams, this net groundwater withdrawal data is used to determine groundwater availability. Historical trends in groundwater withdrawals showed potential stresses in certain sub-basins in Southeastern Pennsylvania and in the Coastal Plain of New Jersey. This led to the development of two groundwater management areas: SEPA-GWPA and Critical Area 2.

Groundwater availability screening tools are used to assess groundwater availability on the Basin wide scale (Sloto & Buxton 2006) and for SEPA-GWPA (Schreffler 1996; USGS 1998). In an analysis of calendar year 2020 Basin-wide groundwater availability indicates that it is generally stable. Analyses of both groundwater management areas show a continued decrease in groundwater withdrawals.

Basin-wide net withdrawals are projected to remain stable with a slight decrease in the next forty years. In the groundwater management areas, groundwater withdrawals are expected to continue to decrease as management strategies continue to be implemented. The two management areas described in this section are examples of successful, proactive management strategies that could be applied to other areas undergoing stress due to the withdrawal of groundwater.

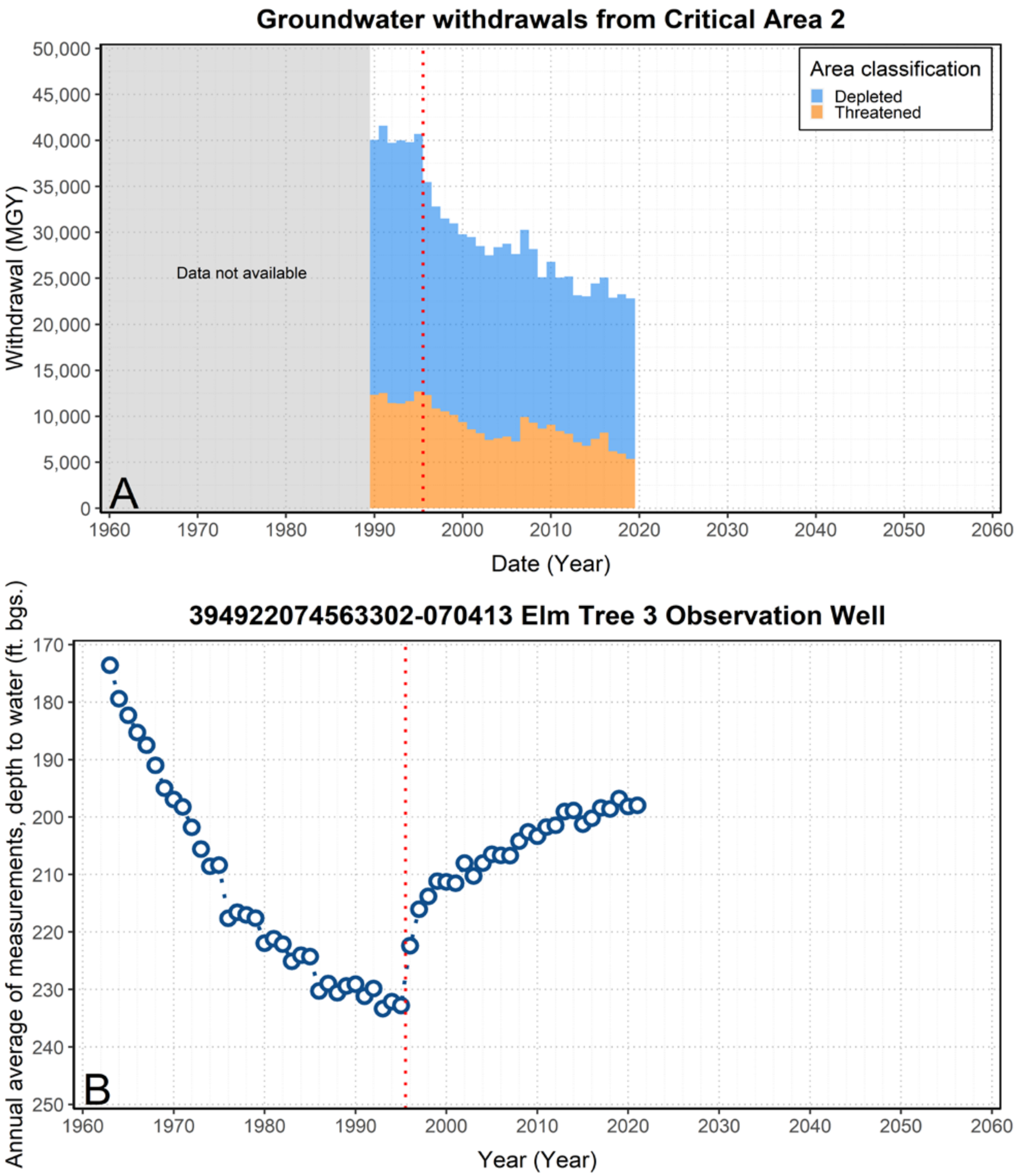


Figure 3.13 (A) Withdrawals from the PRM from 1990-2020 show significant reductions since the inception of Critical Area 2 in the early 1990s. Source: I. Snook, NJDEP, February 2022. (B) Example of rebounding groundwater levels in the upper PRM of NJ Critical Area 2, measured in feet below ground surface (ft. bgs.). Elm Tree 3 observation well, Camden Co., NJ. Period of records shown (02/22/1963 – 12/27/2021), data presented as an annual average of measurements. Source: USGS, February 2022.

3.4 Salt Front Location & Movement

Description of Indicator

The salt front is an estimation of where the seven-day average chloride concentration equals 250 ppm (parts per million) along the tidal Delaware River. The location of the salt front plays an important role in the Delaware River Basin water quality and drought management programs because upstream migration of brackish water from the Delaware Bay during low-flow and drought conditions could increase sodium concentrations in public water supplies, presenting a health concern. Critical intakes on the Delaware River that could be adversely affected by salinity moving upstream are the Philadelphia Water Department's Baxter intake and the New Jersey American Water Company's Delran intake (Fig 3.14). Both intakes are located at approximately river mile 110 (river km 176). In addition, upstream migration of the salt front may have adverse impacts on the PRM aquifer, as high rates of pumping in the PRM draw tidal river water into the aquifer. If the salt front moves too far upstream for an extended period, the presence of sodium could reduce the quality of water in the aquifer.

Present Status

Good: Drinking water intakes in the tidal river are protected by the reservoir releases to meet flow objectives. The water quality in the PRM aquifer remains good.

Past Trends

The salt front moves upstream and downstream with each tidal cycle and seasonal variations in freshwater flow. For most of the year, the location of the salt front is between the Commodore Barry Bridge (RM 82/KM 131) and Artificial Island (RM 54/KM86). During droughts and periods of low inflow to the Estuary, water is released from reservoirs, in accordance with normal and drought operating plans, to augment flows to meet a daily flow objective of 3,000 CFS (84.9 CMS) in the Delaware River at the Trenton, NJ gage. The program has been effective and, since the 1970s, the salt front has remained more than 18 miles below the drinking water intakes, protecting drinking water supplies in the most urbanized area of the Estuary (Figures 3.14 and 3.15).

Future Predictions

Sea level rise and potential changes to the variability and seasonality of flow from anticipated increases in temperature and precipitation may create additional challenges for the management of the salt front in the future. Additional challenges may be the availability of water for releases from storage due to the need to rehabilitate aging infrastructure and increased demands.

Actions and Needs

An evaluation is needed to determine the ability of the existing drought management plan to impede the upstream movement of the salt front, considering factors such as sea level rise and changes in hydrology resulting from an anticipated increase in temperature and precipitation. An investigation into the contribution of additional sources of chlorides, such as road salts, on the estuary salinity and associated impacts, is appropriate.

Summary

Flow management strategies have been successful in impeding the upstream movement of the salt front and have effectively protected drinking water intakes in the most densely populated area of the Basin.

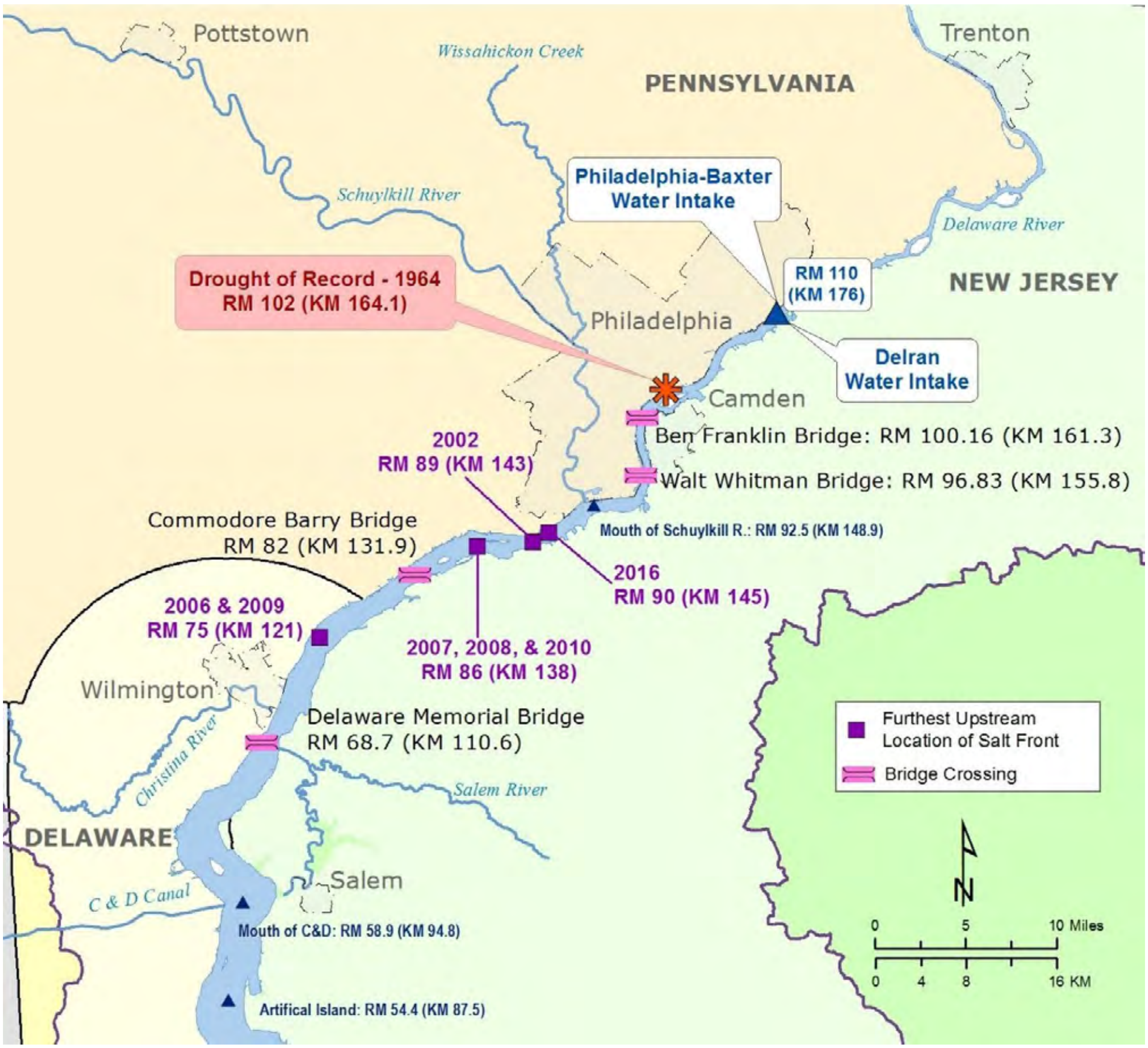


Figure 3.14 Map of historic salt front locations.

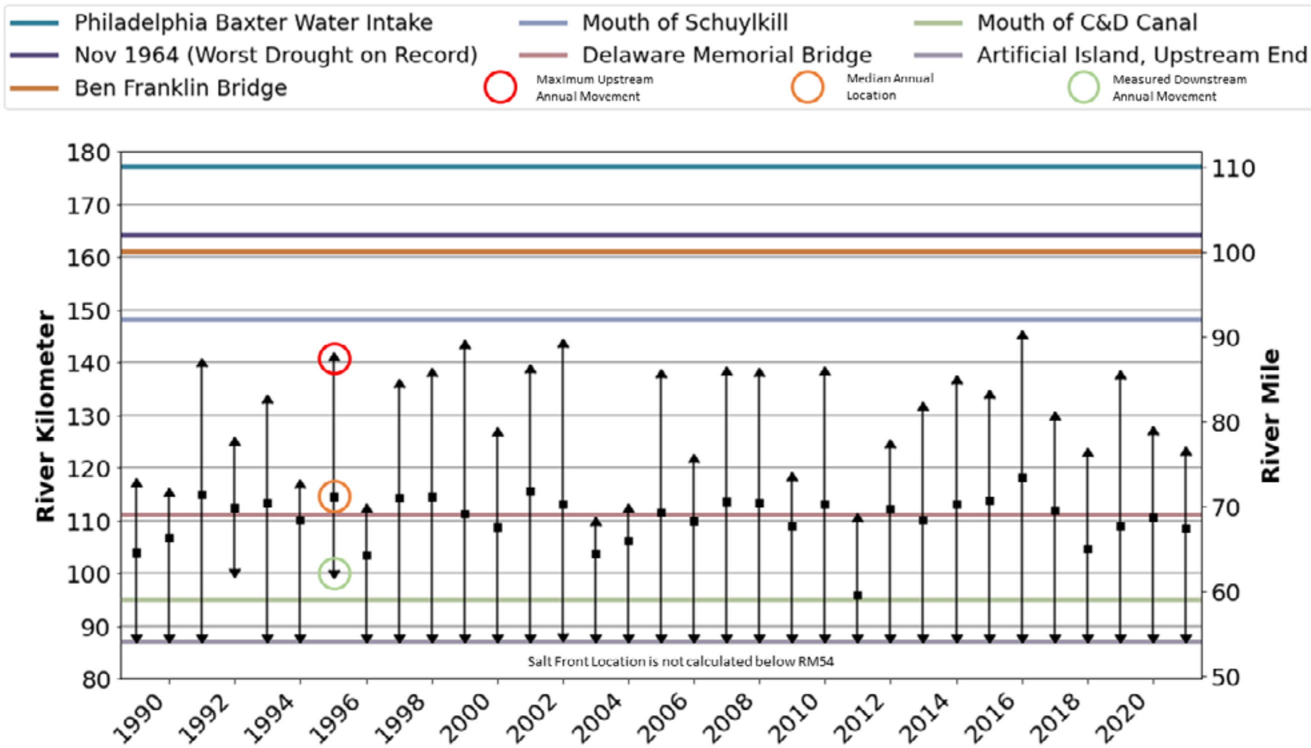


Figure 3.15 Range of Annual Salt Front Locations From 1989-2021. The salt front river mile location is estimated by DRBC using data from the USGS water quality measurements.

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