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Water Withdrawal and Consumptive Use Estimates for the Delaware River Basin (1990-2017) With Projections Through 2060

Report No: 2021-4

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Water Withdrawal and Consumptive Use Estimates for the Delaware River Basin (1990-2017) With Projections Through 2060

DRBC Report No: 2021-4

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AUTHORIZATION

This work is being conducted in accordance with Article 3 Section 3.6.c of the Delaware River Basin Compact (Pub. L. No. 87-328, 75 Stat. 688). More specifically, it is part of a broader project termed "*Water Supply Planning for a Sustainable Water Future 2060",* which has been approved in annual DRBC Water Resources Programs, most recently for FY2022-2024 (DRBC, 2021).

ACKNOWLEDGEMENTS

The Delaware River Basin Commission staff are grateful to the following organizations which are on the forefront of water withdrawal data collection/analysis, who work with the DRBC to share data and help in analyses where possible, and without whom such an analysis would not be possible:

- Delaware Department of Natural Resources and Environmental Control, Division of Water
- New Jersey Department of Environmental Protection, Division of Water Allocation & Well Permitting
- New Jersey Department of Environmental Protection, Division of Water Supply & Geoscience
- New York State Department of Environmental Conservation, Division of Water
- Pennsylvania Department of Environmental Protection, Office of Water Resources Planning
- U.S. Geological Survey, New Jersey Water Science Center

There was much more data used throughout the report beyond water withdrawals, and the DRBC would like to extend its gratitude to anyone who reviewed or commented on the data being used. Many parts of this research were presented at the DRBC Water Management Advisory Committee, and the DRBC would like to thank the committee members for positive words of encouragement and thoughtful insight during the course of this study.

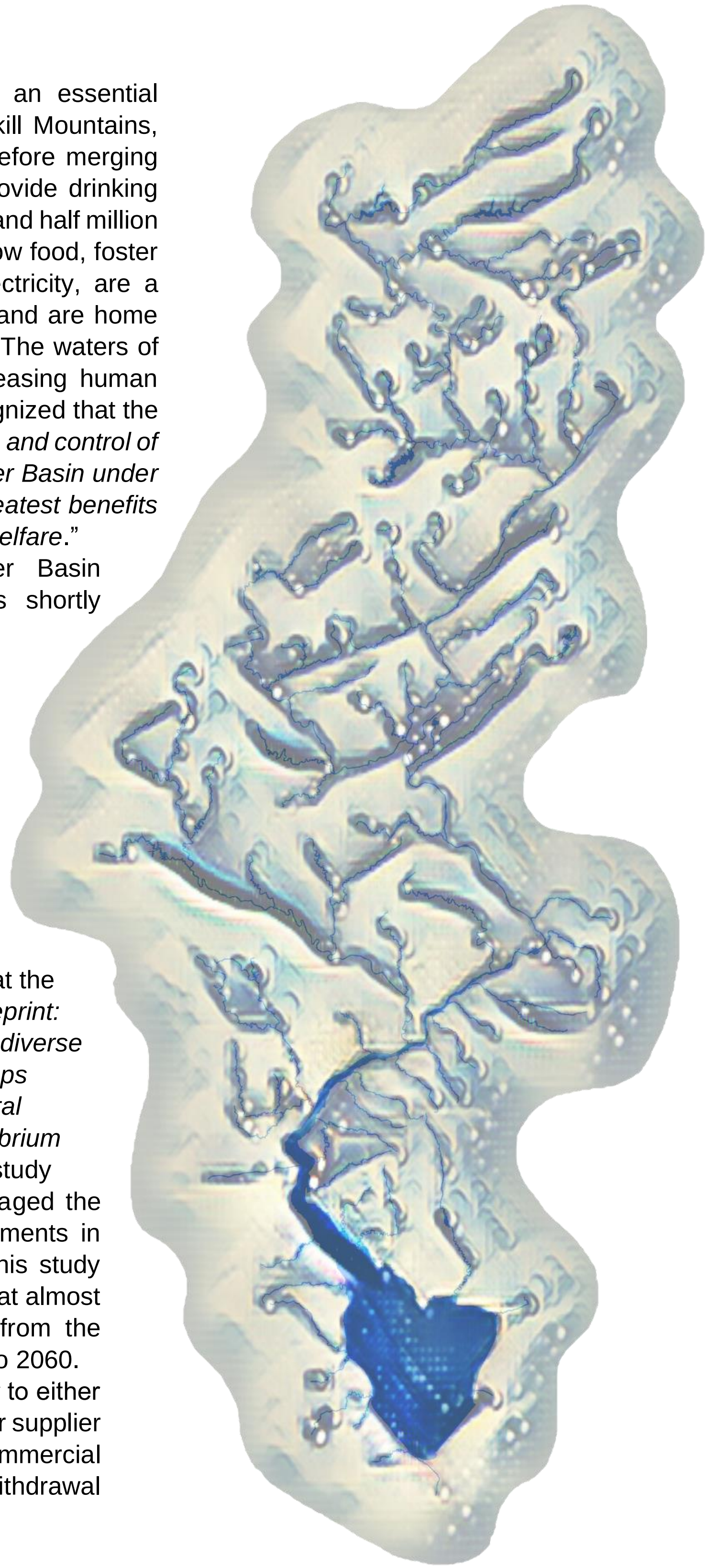
The authors would like to thank fellow co-workers at DRBC for their review of statistical concepts during the development of included methodologies. We are especially grateful to the DRBC Operations group who shared preliminary datasets regarding bias-corrected regional climate model data. Finally, we would like to thank current and former DRBC staff who have contributed directly to this project in varying degrees: Kent Barr, SeungAh Byun, Evan Kwityn, Douglas Rowland, David Sayers and Sara Sayed.

SCOPE AND ORGANIZATION

The purpose of this study is to analyze existing water withdrawal and consumptive use data for the Delaware River Basin and to provide projected water withdrawals through the year 2060 in support of water availability planning. The results of these water withdrawal and consumptive use projections work will be incorporated into a demand/availability assessment of the Delaware River Basin, considering scenarios that will include the drought of record and the effects of climate change. This work fits within the Commission's broader focus on water security – working to ensure sustainable supplies of suitable quality water for the Delaware River Basin.

Delaware Water Gap viewed from
Mount Tammany, New Jersey.
Credit: © Tetyana Ohare

EXECUTIVE SUMMARY



The waters of the Delaware River Basin are an essential component of life. They flow from high in the Catskill Mountains, cascading over cliffs and winding through valleys before merging with the Atlantic Ocean. Along the journey, they provide drinking water to over eight million in-Basin residents and five and half million out-of-Basin residents, irrigate farms and fields to grow food, foster the generation of nearly 100 terawatt-hours of electricity, are a catalyst for commerce, promote healthy recreation, and are home and habitat to countless species of flora and fauna. The waters of the Basin are a priceless resource subject to increasing human population and activities. Sixty years ago it was recognized that the "*conservation, utilization, development, management, and control of the water and related resources of the Delaware River Basin under a comprehensive multipurpose plan will bring the greatest benefits and produce the most efficient service in the public welfare*."

The above quote from the Delaware River Basin Commission (DRBC or Commission) Compact is shortly followed by a charge for the DRBC to "*Conduct and sponsor research on water resources, their planning, use, conservation, management, development, control and protection, and the capacity, adaptability and best utility of each facility thereof, and collect, compile, correlate, analyze, report and interpret data on water resources and uses in the basin...*" As such, these actions have been common practice of the DRBC in attempts to promote sustainable use and planning of the available water resources. It was recognized in Commission planning efforts from the early 1970s that the planning process "…*cannot be a grandiose fixed blueprint: rather it is a process involving continuing inputs from diverse programs, agencies, institutions, individuals and groups representative of every conceivable human and natural interest... The end product sought is a dynamic equilibrium serving the public interest.*" Over the decades, each study assessing and projecting water demands has leveraged the best available data at the time. Following advancements in technology, data collection, sharing and analysis, this study takes the next step to provide a comprehensive look at almost 30 years of historical data on water withdrawals from the Delaware River Basin, and projects these demands to 2060.

As is defined in this report, "water use" may refer to either the withdrawal or end-use of water (e.g., a public water supplier may withdraw water and distribute it for domestic, commercial or industrial end uses). This study is focused on the withdrawal of water; therefore, data are categorized into

(PWS) Public Water Supply

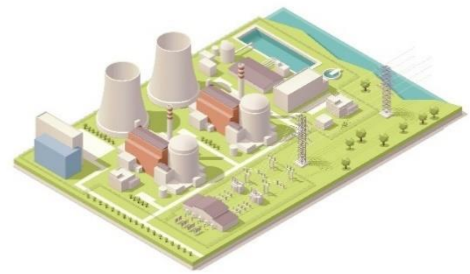
Water withdrawn by a facility meeting the definition of a public water supply system under the Safe Drinking Water Act (Pub. L. No. 93-523, 88 Stat. 1660), or subsequent regulations set forth by signatory parties.

(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 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 are 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.

"withdrawal sectors", and analyses are presented as separate sections throughout the report. The major sectors are highlighted in the graphic to the left which outlines the type of facilities included in each, and what the water may be withdrawn for (full definitions provided in Table 1). In addition to those traditional sectors, an "out-of-Basin diversions" sector is included to describe the water withdrawn from the Basin and exported out of the Basin in accordance with a 1954 U.S. Supreme Court Decree (U.S. Supreme Court, 1954). Furthermore, this report includes a summary of the analyses of the "consumptive use" of the water withdrawals, defined in DRBC regulations 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*."

Beyond gathering data and providing estimates of annual withdrawals from the Delaware River Basin, a key planning component is the ability to provide projections of future withdrawals. The methods and scope of projecting water use data have evolved over time as technology advances, data sharing becomes easier, and cultural priorities shift, changing how we the people of the Basin use and think about the water around us. It has been over a decade since the Delaware River Basin Commission has published a comprehensive projection of water use, and this study has leveraged these advancements to take full benefit of the resources available to us.

This study compiles data on water withdrawals from the Delaware River Basin for the years 1990 through 2017, assumed to represent actual (or observed) conditions. Application of consumptive use ratios in a standardized approach emphasizing self-reported consumptive use data has helped to provide estimates of consumptive use for the years 1990 through 2017. Each sector of withdrawal and consumptive use data is then projected through the year 2060 using methods outlined in respective report sections. The estimates and projections of water withdrawal and consumptive use are provided in Figure ES-1 and Figure ES-2. All historical withdrawal and consumptive use data, as well as projected data are provided as a data release in Appendix A.

The Delaware River viewed from Hawk's Nest
in Sullivan County, New York.
Credit: © Joseph Halliday

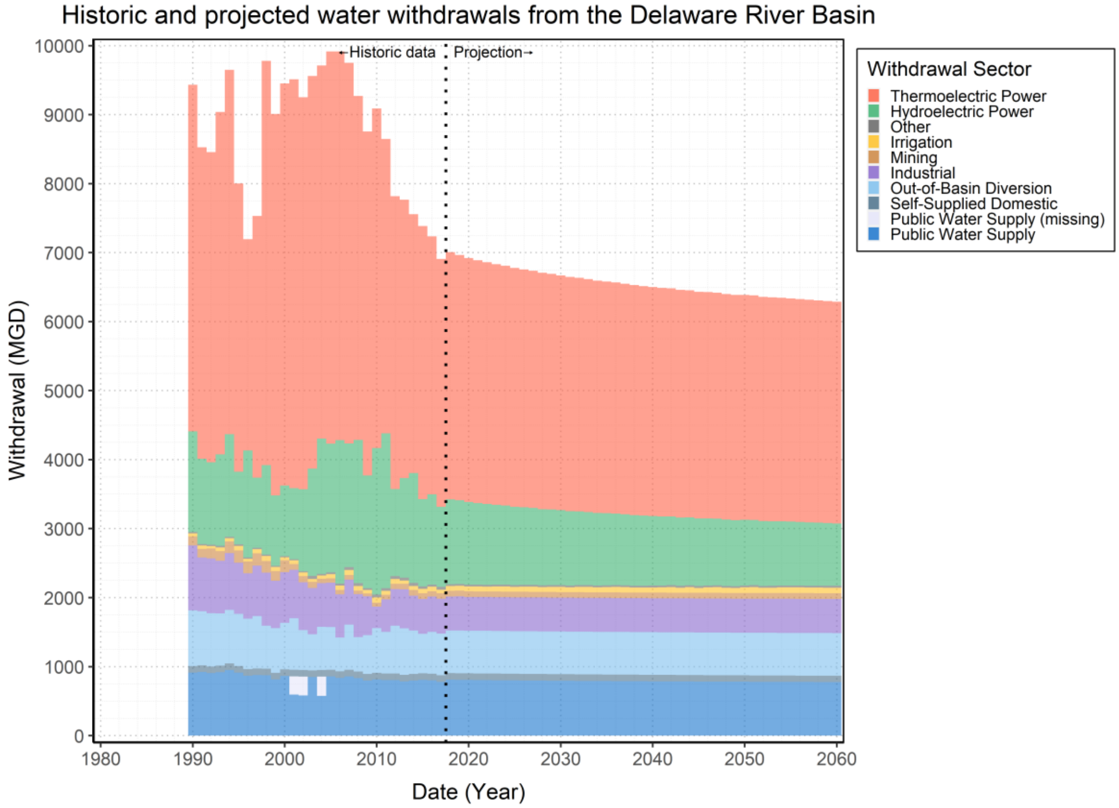


***Figure ES-1: Historical and projected water withdrawals from the Delaware River Basin**. Data in this figure has been provided in data releases corresponding with each sector. The historical data and projection have been color coded by sector to demonstrate the relative magnitude and trends of the expected value.*

Based on the data provided in these two figures (and others in the report), there are multiple summary conclusions which can be made, such as:

1. 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).
2. Historically, on average, water withdrawals from the Basin have been comprised of about 5.4% groundwater and 94.6% surface water, although in 2017 they were 6.3% and 93.7%, respectively.
3. Not considering the out-of-Basin diversions, consumptive use in the Delaware River Basin has remained relatively constant with a historical annual average of about 286 MGD and a coefficient of variation of about 4.5%. Historically, the collective out-of-Basin diversions have added another 500-800 MGD depending upon the time period and is also considered entirely consumptive.
4. The population residing within the Delaware River Basin in 2010 was estimated to be approximately 8.252 million people, of which approximately 86% reside inside public water supply service areas, and 14% reside outside.

To begin projecting data, an algorithm was developed and generated over 600 facility-level reports for staff review. These reports plot data visually, highlight key metrics about the data set, incorporate metadata (e.g., water transfers between systems) and store review information. Each report disaggregates withdrawal

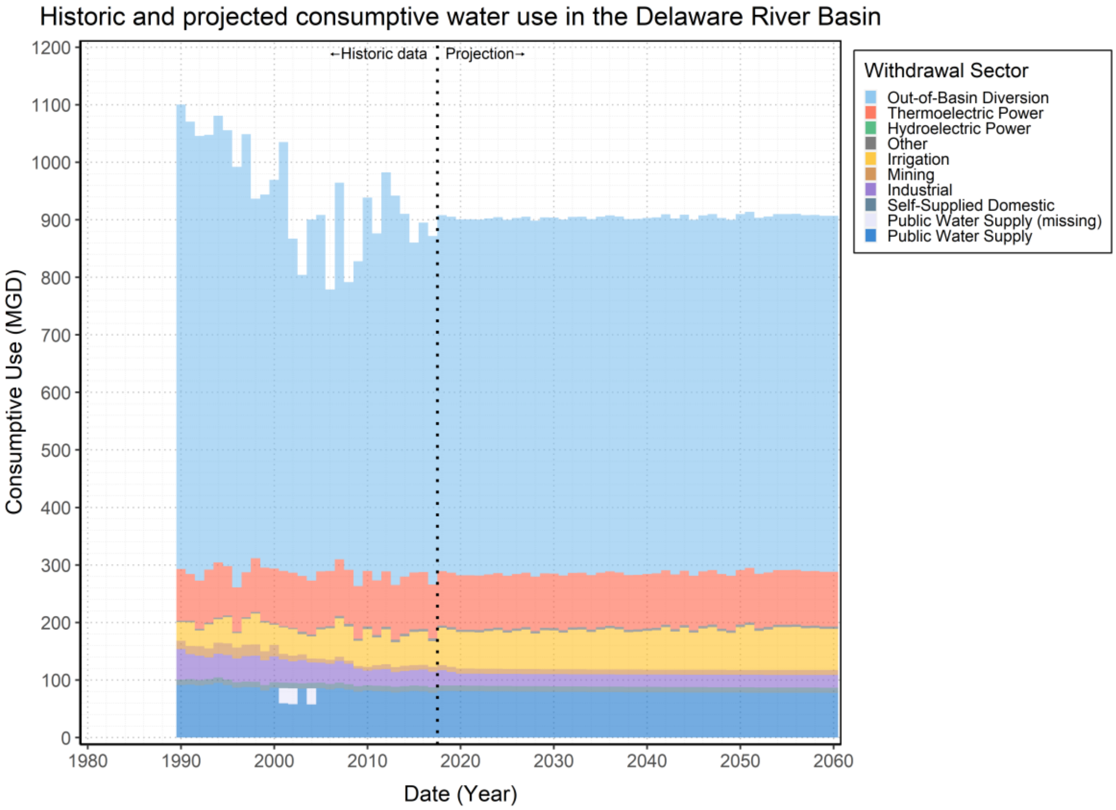


Figure ES-2: Historical and projected consumptive water use in the Delaware River Basin*. Data in this figure has been provided in data releases corresponding with each sector. The historical data and projection have been color coded by sector to demonstrate the relative magnitude and trends of the expected value.*

data and extrapolates it at various scales (i.e. facility, groundwater subbasin, and source), providing a suite of options such that selected projection equations are able to meet specific DRBC planning needs. Specifically, the results must be able to:

1. Represent a Basin-wide assessment of water withdrawals by sector (e.g., public water supply).
2. Present groundwater projections at a planning scale defined for the Basin in 147 subbasins, and for the Southeastern Pennsylvania Groundwater Protected Area's 76 subbasins.
3. Have projections for specific surface water withdrawals that foster future planning initiatives which require point assessments for metrics such as pass-by flow requirements.

An example projection report is provided in Appendix B; however, individual system reports are not published with this study. A complete list of facilities individually considered in this report is included for reference in Appendix C.

This methodology was used for most sectors in the report aside from self-supplied domestic (which used a per-capita based estimation approach) and irrigation (which used a multi-variate regression approach with regional climate model data inputs). With all sectors combined, this study generated about 1,750 projection equations to describe withdrawals from the Delaware River Basin. All equations can be combined together to project water withdrawals from the entire Basin, or in any number of combinations to project water withdrawals from different planning regions. Along with the "expected value" for a projection, 80%

and 95% prediction intervals are also calculated to quantify uncertainty in the extrapolation based on the characteristics of the input data.

This report is organized by withdrawal sector with the projection results presented in detail within each section. The results of all sectors are then combined together to present findings for various planning scales. For full details on the findings, it is appropriate to review the applicable section, but some conclusions on projections can be highlighted as follows:

1. The Basin-wide water withdrawals from the Delaware River Basin are projected to continue decreasing, from about 6,303 MGD in 2020 to about 5,670 MGD in 2060. The largest decreases are projected 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.
2. The Basin-wide consumptive water use is projected to remain relatively constant, with the largest increase attributed to the irrigation sector. There are many sub-dynamics observed throughout the report, such as the portion of consumptive use attributed to thermoelectric facilities has become almost entirely associated with facilities using recirculating cooling.
3. Basin-wide consumptive use has historically been the most commonly projected water use parameter by DRBC (Figure ES-3). Many previous studies relied on indirect projections based on a single estimated year of water use data, and therefore this study provides a new perspective with the ability of viewing and assessing almost three decades of withdrawal data. The current projection of Basin-wide consumptive use suggests the least growth of any previous study, but it is supported by the trends observed in historical data and previous estimates (especially considering trends in the thermoelectric sector post-2007).
4. 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.
5. The population residing within the Delaware River Basin has not only increased historically but is projected to continue increasing as shown in this report. Despite a growing Basin-wide population, public water supply withdrawals have historically decreased (Figure 9) and are projected to continue decreasing. Furthermore, the projected population growth is weighted in areas with municipal water supply and consequently the self-supplied population (and withdrawal) is projected to decrease slightly.
6. Additional analysis shows that while Basin-wide trends may suggest minimal change (e.g., the projection model returned a groundwater withdrawal of 466.739 MGD in 2018 and 465.718 MGD by 2060), there may be sub-trends important for water resources planning. For example, assessing groundwater withdrawals in each of the 147 planning subbasins presents a slightly different finding (Figure 107):
   - Decreasing (Δ < -0.10 MGD) ..... 51 subbasins (-26.500 MGD)
   - Neutral (-0.10 < Δ < 0.10 MGD). 56 subbasins (-1.451 MGD)
   - Increasing (Δ > 0.10 MGD) .... 40 subbasins (+26.930 MGD)

These are just some of the highlighted findings from the CONCLUSIONS section of the report. As with all studies, it is important to also consider the assumptions on which the projections are based (Section 3.4.5.4 and Section 4.4.4). Namely, it is assumed in this projection methodology that the current trends of facilities withdrawing water will carry into the future; external factors such as a thermoelectric facility closure or opening were not considered in this study.

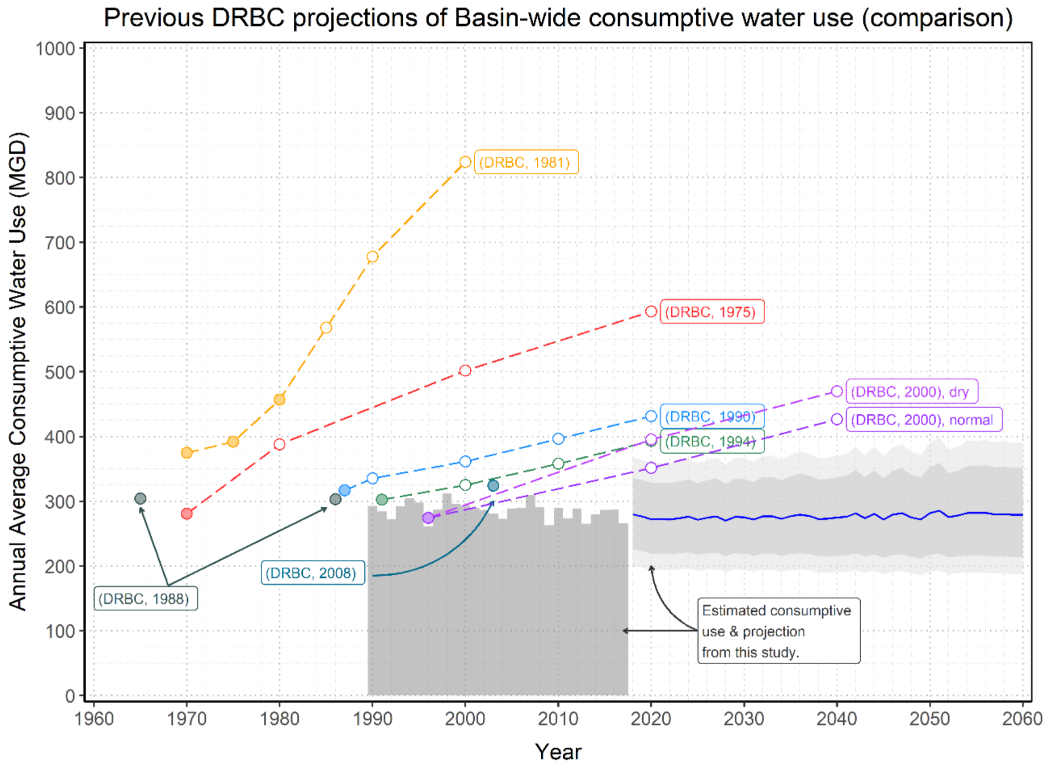


Figure ES-3: Previous DRBC projections of Basin wide consumptive water use (comparison). *Note that this figure is an updated version of the analysis presented as Figure 3. The projection data from previous studies corresponds with the reports outlined in Table 2 (filled circles represent estimates, hollow circles represent projections). Note that out-of-Basin diversions are not included to be consistent with previous studies.*

A significant amount of data which has been collected over decades has been compiled and assessed as part of this study. It provides the most comprehensive and current opportunity to draw conclusions about the history of water withdrawals from the Delaware River Basin, the consumptive use of that water, and how future water withdrawals may unfold given a continuation of the current trends. The narrative of water use in the Delaware River Basin is continually evolving, and newer and expanded data are constantly available. As is mentioned in the report, some data were incorporated in projections extending past 2017 as it was available or necessary; however, historical data were only ever presented through 2017 as it marks the last year of data providing a complete picture. DRBC has compiled the historical data (1990-2017) and the model projections (2018-2060) in a series of data releases supporting this report in the hopes that other organizations may find it an easily accessible and usable dataset for their planning or research needs.

Cape Henlopen, Delaware.
Credit: Delaware State Parks
https://destateparks.com/Beaches/CapeHenlopen

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Wing Dam on The Delaware River
Lambertville New Jersey on the left and
New Hope Pennsylvania on the right.
Credit: © James Loesch
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LIST OF ACRONYMNS/ABBREVIATIONS

AER	annual energy report
AWWA	American Water Works Association
CDL	crop data layer
CFR	Code of Federal Regulations
CIESIN	Center for International Earth Science Information Network
CMIP5	Coupled Model Intercomparison Project 5
CRCM	Canadian Regional Climate Model
CU	consumptive use
CUR	consumptive use ratio
CV	coefficient of variation
CY	calendar year
DE DNREC	Delaware Department of Natural Resources and Environmental Control
DHSS	Delaware Health and Social Services
DIV	Out-of-Basin Diversions
DoR	Drought of Record
DRB	Delaware River Basin
DRBC	Delaware River Basin Commission
ESM2M	Earth System Model 2M
ESRI	Environmental Systems Research Institute
FY	fiscal year
GCM	global climate model
GFDL	Geophysical Fluid Dynamics Laboratory
GIS	geographical information system
GPCD	gallons per capita per day
GW	groundwater
HUC	hydrologic unit code
ICPRB	Interstate Commission on the Potomac River Basin
IND	Industrial (sector)
IRR	Irrigation (sector)
KRA	Key Result Area
MG	million gallons
MGD	million gallons per day
MGM	million gallons per month
MIN	Mining (sector)
MM	million
MPO	Municipal Planning Organization
MW	megawatt
MWh	megawatt-hour
NASS	National Agricultural Statistics Service (USDA)
NGCC	natural-gas combined-cycle
NJDEP	New Jersey Department of Environmental Protection
NLCD	Nation Land Cover Dataset (USGS)
NRC	National Research Council
NWIS	National Water Information System
NWUE	National Water Use Estimate
NYSDEC	New York State Department of Environmental Conservation

NYSDOH	New York State Department of Health
OAID	organization address ID
OLS	ordinary least-squares
OTFW	once-through fresh water
OTH	Other (sector)
PADEP	Pennsylvania Department of Environmental Protection
PDE	Partnership for the Delaware Estuary
PFID	primary facility ID
PI	prediction interval
PIID	program interest ID
PL	Public Law
PWR	Power Generation (sector)
PWS	Public Water Supply (sector)
QAQC	quality assurance / quality control
RCA	Reservoir Catchment Area
RCM	regional climate model
RCP	Representative Concentration Pathway
SEPA-GWPA	Southeastern Pennsylvania Groundwater Protected Area
SFID	sub-facility ID
SIID	subject item ID
SRBC	Susquehanna River Basin Commission
SSD	Self-Supplied Domestic (SSD)
SSP	Shared Socioeconomic Pathway
Stat.	Statute
SW	surface water
TWh	terawatt-hour
USACE	U.S. Army Corps of Engineers
USCB	U.S. Census Bureau
USDA	U.S. Department of Agriculture
USDOI	U.S. Department of the Interior
USEIA (EIA)	U.S. Energy Information Administration
USEPA (EPA)	U.S. Environmental Protection Agency
USGS	U.S. Geologic Survey
WD	withdrawal
WSCC	Water Supply Coordination Council
WSID	water source ID
WUDS	Water-Use Data System
WUTA	Water-use Tabulation Area
ZCTA	Zip Code Tabulation Area

Table of Contents

View of the Delaware River from Bowman's Hill Tower in Bucks County, Pennsylvania. Credit Michael Thompson, DRBC

1 INTRODUCTION

1.1 Study purpose and authority

The purpose of this study is to analyze existing water withdrawal data for the Delaware River Basin and to provide projected water withdrawals through the year 2060 in support of water supply planning. The results of this water withdrawal projection work will then be used to assess water availability. This work is being conducted in accordance with Article 3 Section 3.6.c of the Delaware River Basin Compact (Pub. L. No. 87-328, 75 Stat. 688).

More specifically, this work is related to initiatives set forth in the *Water Resources Plan for the Delaware River Basin*, which was developed over a four-year period through extensive collaboration among many devoted individuals and organizations, henceforth referred to as the "*Basin Plan*" (DRBC, 2004b). The *Basin Plan* was developed in response to a resolution signed by the governors of the four Delaware River Basin states (Delaware, New Jersey, New York and Pennsylvania) on September 29, 1999 which directed the development of a new "*comprehensive water resources plan for the Basin*" (DRBC, 1999) . On September 13, 2004 the governors signed a resolution supporting the implementation of the *Basin Plan* (DRBC, 2004a).

The *Basin Plan* includes five interrelated Key Result Areas (KRA) which were established to outline specific desired results for the Basin. The *Basin Plan* also includes the goals and objectives set as a means of achieving the desired results. The first KRA is "Sustainable Use and Supply", which calls for an adequate and reliable supply of suitable quality water to sustain human and ecological needs. Under this KRA-1, Goal 1.3 is specifically focused on ensuring that there is an adequate and reliable supply of water given the current demands in each water use sector, as well as future demands based on projections of future water use.

This was initially assessed in a joint study performed between the U.S. Army Corps of Engineers (USACE) and the DRBC, termed the "*Multi-jurisdictional Report*" (USACE & DRBC, 2008), in which an estimate of water use in the Delaware River Basin for the year 2003, projections of each water use sector's peak monthly water withdrawal through the year 2030, and comparisons of demand versus availability were provided. However, a limitation of this project is that it did not account for the 1961-1967 drought of record (DoR), which is specified in Section 2.400.1 of the Delaware River Basin Water Code to be "*the basis for determination and planning of dependable Basin water supply"* (DRB Water Code, 2013), incorporated by reference in 18 CFR Part 410.

In the current study, updated projections of water withdrawals by major sectors of the Delaware River Basin through the year 2060 are provided. The results of this study will be incorporated into future withdrawal/availability assessments of the Delaware River Basin, considering scenarios such as reservoir operations, a repeated drought of record and possible effects of climate change. This broader project, "*Water Supply Planning for a Sustainable Water Future 2060",* has been approved in annual DRBC Water Resources Programs, most recently for FY2022-2024 (DRBC, 2021).

1.2 Hydrological setting and study area

The Delaware River Basin, located in the northeastern United States, covers an area of approximately 13,539 square miles, spanning the four Basin States as shown in Figure 1. The headwaters of the Basin originate in the western Catskill Mountains, which reach elevations ranging from 2,500 to over 3,800 feet above mean sea level. The mainstem of the Delaware River officially begins at the confluence of the East and West Branches in Hancock, NY, and flows approximately 330 miles until it joins the Atlantic Ocean. Along the way, the river is fed by 216 major tributaries, draining portions of New York (2395.1 mi^2, 18.6%), Pennsylvania (6454.0 mi^2, 50.2%), New Jersey (3009.5 mi^2, 23.4%) and Delaware (978.7 mi^2, 7.6%). While the mainstem Delaware River is one of the longest free flowing rivers in the country, there are numerous impounded reservoirs throughout the Basin which are located on tributaries. The use of reservoirs may be singular or multi-purpose; some typical uses include water supply, flood control, hydroelectric power and recreation.

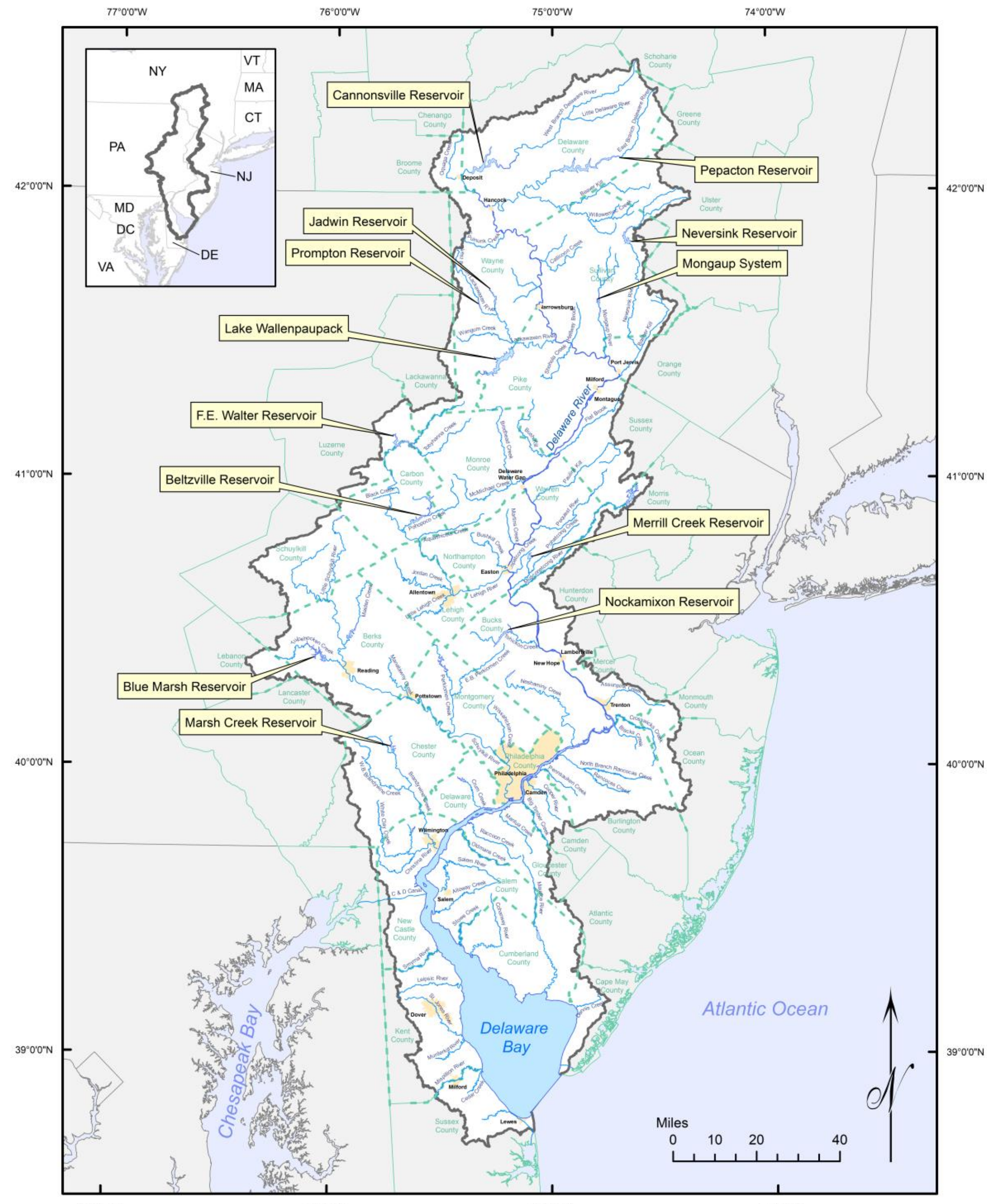

Figure 1: A map of the Delaware River Basin shown with state/county boundaries, cities/towns, major rivers, and reservoirs. *Note that the approximately eight square miles of Maryland are not included in this report.*

Overall, the Delaware River Basin provides a wide array of benefits for those who depend on it. Three quarters of the non-tidal Delaware River are included in the National Wild and Scenic Rivers System, as well as one tributary and portions of many other tributaries (DRBC, 2020). To quote the Wild and Scenic Rivers Act, this means that they are recognized as possessing "*outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values*" (Pub. L. No. 90-542, 82 Stat. 906). Economically, the Basin annually supports billions of dollars in industries such as navigation, agriculture, water supply, fish/wildlife and recreation (Kauffman, 2011). Finally, the Basin is estimated to supply drinking water for an estimated 13.3 million people based on data from 2016. This includes 8.3 million people residing within the Basin, and water exported to New Jersey and New York City, which is estimated to be sufficient for an additional 5 million people (Byun et al., 2019).

1.3 Background

1.3.1 Defining "water use data" and related concepts

In the context of this report, *water use data* refers to data describing either the *withdrawal* of water, or the *end-use* of water (Figure 2). Therefore, it is important to distinguish whether water use data are *withdrawal data* or *end-use data*. While it is ideal to withdraw water close to the point of use in order to minimize pumping energy and potential losses, water is not always used in the same locality as where is it withdrawn. This may cause subtle differences in how the numbers should be considered in a planning analysis. Two examples of where this may be important are:

- Areas of high density where water supply systems are interconnected and transfer water.
- A single facility with withdrawal points which span different planning boundaries (e.g., a single use number at the facility does not tell which aquifer the water came from).

While supply and demand are inherently linked, it is reasonable to conclude that an analysis focused on or intended to be used in assessing available supply must consider withdrawal data or make assumptions to connect end-use data back to the sources of water withdrawal.

Another important distinction to make is in terms of nomenclature when discussing the categorization of data. As shown in Figure 2, categories/sectors can be used to describe either the point of withdrawal/diversion (*withdrawal category*), or the end-use of the water (*water use category*). Two examples of why this distinction is important are:

- 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 by one withdrawal category (public water supply), whereas the end-use would be described by multiple water use categories (domestic, industrial, and commercial).
- Regarding demands, calculating a water demand using a per-capita method may only be describing the end-use demand for residential use. This would likely result in a different conclusion than calculating a water demand based on withdrawals by public water suppliers.

The analyses performed in this report are focused on the points of withdrawal. Therefore, withdrawal data have been grouped into withdrawal sectors as described in Table 1.

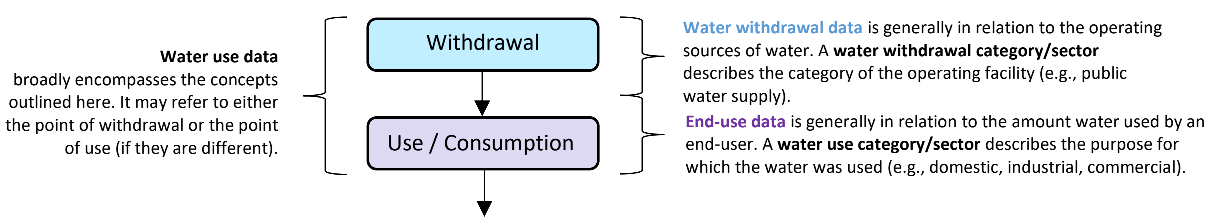

***Figure 2**: A schematic of water use terminology, as referenced in the context of this report.*

***Table 1**: Withdrawal sector descriptions, as defined in the context of this report.*

Withdrawal Sector	Acronym	Description
Public Water Supply	PWS	Water withdrawn by a facility meeting the definition of a public water supply system under the Safe Drinking Water Act (P.L. 93-523, 88 Stat. 1660), or subsequent regulations set forth by signatory parties.
Out-of-Basin Diversions	DIV	Water withdrawn for public water supply which is exported from the Delaware River Basin by the Decree Parties associated with a 1954 U.S. Supreme Court Decree (U.S. Supreme Court, 1954).
Self-Supplied Domestic	SSD	Water withdrawal for domestic use by those who are not served by a public water supply system; it is assumed in this study that all SSD withdrawals are groundwater.
Power Generation	PWR	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 (including cogeneration) and hydroelectric facilities. Thermoelectric withdrawals may include both water and reclaimed wastewater and are typically used for cooling purposes. Hydroelectric facility water diversions are typically used as the primary mover for power generation.
Industrial	IND	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. However, this sector does not include withdrawals associated with commercial, mining, or power generation facilities (including cogeneration facilities).
Mining	MIN	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.
Irrigation	IRR	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. Irrigation includes water that is applied for pre-irrigation, frost protection, chemical application, weed control, field preparation, crop cooling, harvesting, dust suppression, leaching of salts from the root zone, and conveyance losses. This does not include withdrawals/diversions associated with aquaculture.
Other	OTH	This includes all other categories of withdrawals not captured by the industrial, irrigation, mining, public water supply or power generation sectors. This includes facilities which may be classified as aquaculture, bottled water, commercial (e.g., hotels, restaurants, office buildings, retail stores), fire suppression, hospital/health, military, parks/recreation, prisons, schools, and ski/snowmaking.

1.3.2 Methods of estimating and projecting water use (or withdrawals)

Techniques commonly used in estimating water use are described in a 2002 report by the National Research Council (NRC, 2002), and are grouped into two categories: “direct” and “indirect” methods. Direct methodologies include the intuitive complete inventory approach, which attempts to quantify all use in a particular area of interest (e.g., direct measurement or secondary records). When this is not possible due to data availability, data consistency/quality or other constraints, sampling a subset of the complete population can also be used to estimate water use; for example, a stratified random sampling approach. Indirect methodologies include coefficient-based methods (e.g., per-capita estimations), multi-variate regressions of factors affecting water use, and econometric methods. These methods are commonly utilized by agencies such as the United States Geological Survey (USGS), who have reported National Water Use Estimates (NWUE) for the Unites States every five years since 1950 (Dieter et al., 2018). For this report, it is assumed that this same terminology for estimating water use (or withdrawals) is applicable to estimating/projecting future water withdrawals.

The American Water Works Association’s (AWWA) Manual M50 outlines numerous methods for directly or indirectly projecting future water use, and is largely geared specifically for individual water utilities (AWWA, 2016). It highlights that the underlying method of analysis in most forecasts is some form of regression, even though it may not be apparent. Four common examples include a per-capita model based on consumption rates and population projections (an indirect method), extrapolation of historical water use with time (a direct method), multivariate regression models (an indirect method), and disaggregate models which break water use down into categories which are projected individually.

Table 2: Previous DRBC reports which included projections of water use data.

Title	Reference	Year Published	Projection Start	Projection Horizon	W	C	M	S
Delaware River Basin Commission Comprehensive Plan	DRBC, 1962	1962	1965	2010	X			
The Comprehensive Plan (DRAFT)	DRBC, 1973	1973	1970	2020		X	X	
Water Management of the Delaware River Basin	DRBC, 1975	1975	1970	2020		X	X	
The Final Report and Environmental Impact Statement of the Level B Study	DRBC, 1981	1981	1981	2000		X		X
Delaware River Basin Commission Water Resources Program 1990-1991 (Depletive Water Use Inventory)	DRBC, 1990	1990	1987	2020		X		X
Delaware River Basin Commission Water Resources Program 1994-1995 (Depletive Water Use Inventory)	DRBC, 1994	1994	1991	2020		X		X
Preliminary Consumptive Water Use Estimates for the Delaware River Basin For 1996, Including Projections for 2020 and 2040	DRBC, 2000	2000	2000	2040		X		
Enhancing Multi-jurisdictional Use and Management of Water Resources for the Delaware River Basin, NY, NJ, PA, and DE	USACE & DRBC, 2008	2008	2003	2030			X	

Notes:
W = Total withdrawal (annual average)
C = Consumptive/depletive use (annual average)
M = Maximum monthly withdrawal or consumptive/depletive use
S = Seasonal withdrawal or consumptive/depletive use

1.3.3 Delaware River Basin studies (DRBC)

Since the DRBC was established, there have been numerous studies which included evaluation of available data and projections of water withdrawal and/or consumptive use. These studies have been the result of various drivers, but the underlying foundation of water resources planning remained the same. These studies are summarized in Table 2, followed by a brief description of each. An important note on terminology must be made about *depletive water use* and *consumptive water use*. Definitions for both terms are provided in the GLOSSARY; however, for this table they are considered interchangeable as the standard terminology changed over time. Since the most consistently projected parameter has remained as some form of annual average consumptive/depletive use across the entire Delaware River Basin, it is possible to visualize how projections have changed over time in Figure 3.

1. In 1962, the DRBC published its first comprehensive plan, referred to as "*Comprehensive Plan (1962)*", which was developed to "*provide an established framework of commission policy for the immediate and long-range development and use of the water resources of the basin*" (DRBC, 1962). While this document largely focused on planning efforts related to individual projects, it did include projections of total water use in the Basin for 1965, 1980 and 2010. These projections are different from most subsequent studies published by DRBC, in that water use was not reported by water use sector, did not include depletive use, and excluded water withdrawn for thermoelectric cooling.
2. In 1973, the DRBC published a draft of its second comprehensive plan. Although never approved by the Commission, it is referred to as "*Comprehensive Plan (1973)"*, and was a revised long-term planning document for the Delaware River Basin (DRBC, 1973). Profoundly, the authors state that the planning process

   "*…cannot be a grandiose fixed blueprint: rather it is a process involving continuing inputs from diverse programs, agencies, institutions, individuals and groups representative of every conceivable human and natural interest... The end product sought is a dynamic equilibrium serving the public interest.*"

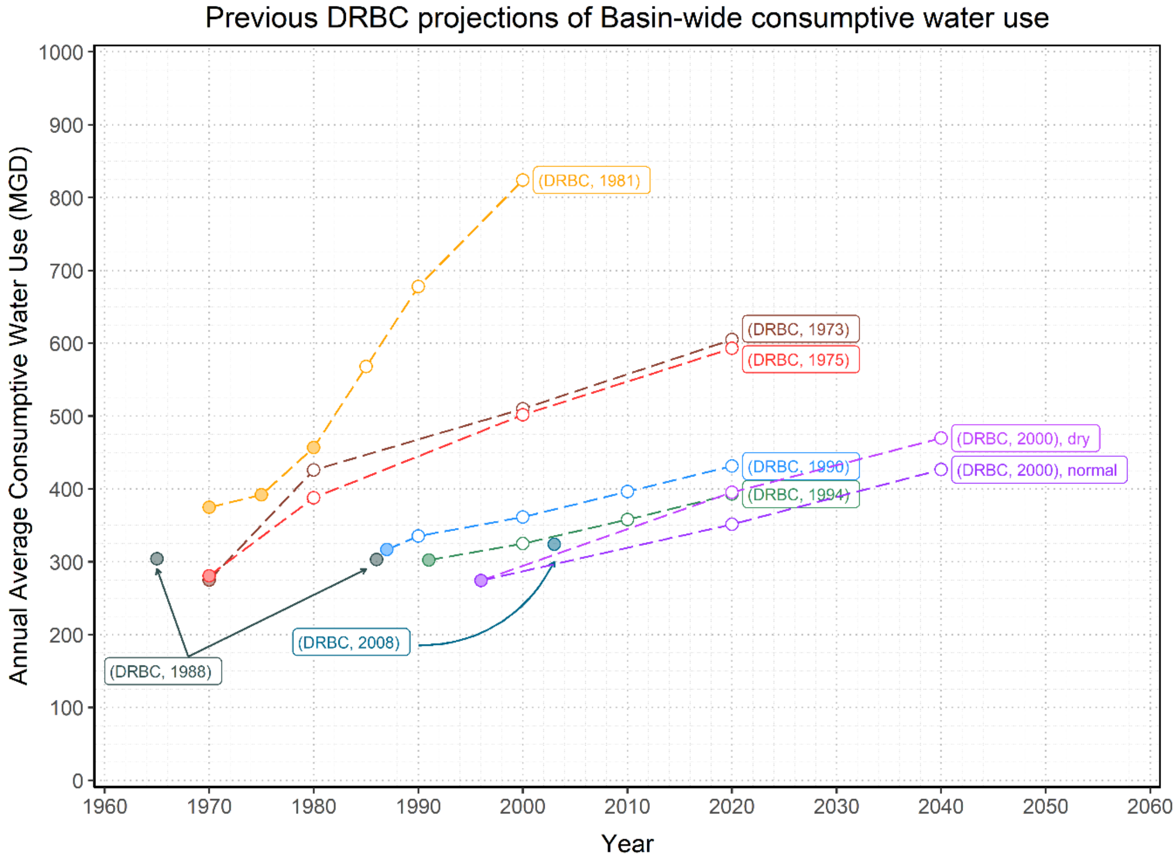

Figure 3: Previous DRBC projections of Basin-wide consumptive water use. *This data corresponds with the reports outlined in Table 2. Filled circles represent estimates, hollow circles represent projections. Note that major out-of-Basin diversions are not included in these estimates and projections.*

Among many things, it includes an evaluation and projection of maximum monthly water use, maximum monthly per-capita rates, maximum monthly depletive use, and annual average depletive use. The projections extended to the year 2020 and are disaggregated among several water use sectors. Notably, the report recognizes that:

> "*Today's long-term projections are not the ones which will be used 10 to 40 years hence. The planning process is continuously building on the best information obtainable and it must correlate with new and amended public laws and Federal-State goals.*"

The projections were performed using a variety of data across sectors; however, the only projection methodology strongly outlined was for the municipal and rural-domestic sectors (combined projected population and projected per-capita rates). Agencies and sources of data involved were referenced for the provided industrial and steam electric generation values, and a report cited for the livestock projection.

3. Shortly after the *Comprehensive Plan (1973)* was published, a report was published in 1975 titled *Water Management of the Delaware River Basin*, which drew from many aspects of the previous comprehensive plan (DRBC, 1975). Of note, it provided slightly revised projections of those provided in *Comprehensive Plan (1973)*.
4. In 1981, the DRBC published a report referred to as the "*Level B Study*" (DRBC, 1981), which addressed a broad objective of identifying and addressing water resources problems. As part of this

study, projections of depletive water use at the Basin-scale were provided for various sectors (municipal, rural, industrial, steam electric, irrigation-agriculture, golf & institutions, livestock, and imports/exports). The results of these projections were based on a compilation of other studies referenced in the report (of specific interest, Table 5). These results were subsequently published by DRBC in the 1983 Water Resources Program (DRBC, 1983).

5. A series of "Good Faith" agreements were formalized in a report in 1982 between the signatory parties regarding interstate water management (SP, 1982). One of the thirteen recommendations was the development of a "depletive use budget." One outcome of this recommendation was the calculation of several "Depletive Water Use Inventories" which were performed by DRBC at different times and presented in Water Resources Programs (DRBC, 1990; DRBC, 1994). These inventories included both estimates and projections of depletive use for the Basin, separated by sector of use. The specific methods behind the projections are not outlined in detail within the reports but often reference external studies.
6. In 2000, the DRBC published a report entitled *Preliminary Consumptive Water Use Estimates for the Delaware River Basin for 1996, Including Projections for 2020 and 2040* (DRBC, 2000). This report provided population and consumptive water use projections for numerous sectors; however, a specific difference from the previous two studies is that this report did not include projections of imports/exports from the Basin. The projections were performed in support of a study entitled *Strategy for Resolution of Interstate Flow Management Issues in the Delaware River Basin* (Hydrologics, Inc., 2004) and were provided to serve as an update to the projections published in 1989, and which were assumed to be in reference to previous Water Resource Programs. Various methods were used to perform projections, and multiple sectors considered a "normal year" and "dry year" scenario.
7. In 2008, DRBC published its most recent study which included projections of water use, referred to as the *Multi-jurisdictional Report* (USACE & DRBC, 2008). The authority as to why this report was developed is discussed in Section 1.1. A notable feature of this report was the incorporation of the methodology outlined in Sloto & Buxton, 2006, which established 147 subbasins for groundwater planning in the Delaware River Basin. Total water use for the Basin is estimated for the year 2003, and projections are provided for "peak" total and consumptive water use under the general assumption that this occurs in July (a significant difference from all previous studies). Projections are performed using various methods, outlined in Table 2.5 of the report. Population projections are used based on a literature review of available data sources and are allocated to 147 established subbasins. This represents the most recent DRBC report comprehensively projecting water use data.

1.3.4 Regional watershed studies

One of the challenges in projecting water use data is availability of data, especially when a study area spans multiple regional or political boundaries. The USGS National Water Use Estimates have provided a strong national scale dataset, and consequently there have been several studies projecting water use at the national level. For example, Brown, 1999 projected the water use of major sectors of irrigation, thermoelectric, industrial & commercial, domestic & public and livestock to the year 2040. This study was largely based on population projections and compared the results against six previous major projection studies, which also utilized population projections. In a more recent review, Perrone et al., 2015 expands on the comparison of national projection studies against the USGS national estimates of water use and discusses the limitation of assumptions accurately representing future conditions, the consistency and availability of data, and stresses the importance of explicitly defining the intentions of calculating future water use estimates.

***Table 3**: A summary of recent studies projecting water use on a regional watershed scale, spanning multiple regional and/or political boundaries. This table is showing what sectors of water use may have been projected in a given study and is not intended to suggest that water use projections were the primary focus.*

Study	Study Region	Study Scale[1] (mi²)	Major States	Projection Horizon	Public Water Supply	Self-supplied domestic	Power generation	Industrial/Manufacturing	Mining	Irrigation / Agriculture
(Hutson et al., 2004)	Tennessee River Watershed	40,910	AL, GA, KY, MI, NC, TN, VA	2030	X		X	X		X
(ICPRB, 2012)[2]	Potomac River Basin	14,670	DC, MD, PA, VA, WV	2030	X	X	X	X	X	X
(USDOI-BR, 2012)	Colorado River Basin	246,000	AZ, CA, CO, NM, NV, UT, WY	2060	X		X	X	X	X
(USDOI-BR, 2016)	Klamath River Basin	15,700	CA, OR	2030, 2070	X	X				X
(Balay et al., 2016)	Susquehanna River Basin	27,502	MD, NY, PA	2030	X	X	X	X	X	X
(Robinson, 2019)	Cumberland River Watershed	17,900	KY, TN	2040	X					
(Zamani Sabzi et al., 2019)	Red River Basin	65,595	AK, LA, NM, OK, TX	2050, 2075	X	X	X	X	X	X

Notes:
[1] Does not necessarily correspond to the entire watershed area; values are rounded to the nearest reported square mile.
[2] A more recent study published in 2020 may be referenced regarding demand forecasts by the ICPRB (Ahmed et al., 2020).

Performing an assessment of water withdrawals where the study area spans multiple states inherently brings added challenges in dealing with multiple sets of data, which may have varying degrees of compatibility. A list of some recent regional watershed studies, which have included projections, is summarized in Table 3. This table is not intended to imply that projection of future water use or withdrawal is the main focus of any listed reference, but merely that it was a part of the study. For additional information, it is suggested that the reader reference each report directly. Expanded tables highlighting the methodologies used in each projection sector are reviewed as part of each sector in this report, and can be cross-referenced through the links below:

- Section 3: Public water suppl .... Table 6
- Section 4: Self-supplied domestic .... Table 15
- Section 5: Power generation .... Table 18
- Section 6: Industrial .... Table 28
- Section 7: Mining .... Table 37
- Section 8: Irrigation .... Table 42

1.4 Planning objectives

The purpose of this analysis is to provide projections of future average annual water withdrawals and consumptive water use in the Delaware River Basin, through the year 2060. The results of these projections are intended to be incorporated into future demand/availability assessments of the Delaware River Basin. In order to be incorporated into future models, there are various scales at which the results of this study must be applicable:

- *Basin wide*: The results of the analysis must be able to represent withdrawals and consumptive use in Delaware River Basin as a whole, as well as Basin-wide for each sector and sourcewater.
- *Groundwater* must be coherent at two levels:
    - A review provided in USACE & DRBC, 2008 recommended that the 147 subbasins developed in Sloto & Buxton, 2006 be used for quantification of groundwater availability for the entire Delaware River Basin. These subbasins are represented in Figure 5.
    - The DRBC is contracted to manage the Southeastern Pennsylvania Groundwater Protected Area (SEPA-GWPA) on behalf of the Commonwealth of Pennsylvania. The subbasins used in analyzing groundwater availability in SEPA-GWPA are at a finer scale than the 147 subbasins, as shown in Figure 6. The regulations defining the SEPA-

GWPA became effective beginning in January 1981 (18 CFR Part 430, 1980). Within the SEPA-GWPA, there are 76 subbasins which are used as assessment units based on numerical groundwater withdrawal limits on a subbasin level which were established based on multiple studies (Schreffler, 1996; USGS, 1998).

- *Surface water*: It is expected that many individual surface water withdrawal points will be assessed during the "*Water Supply Planning for a Sustainable Water Future 2060*". Therefore, surface water withdrawal points must be represented at the source level.

1.5 Analysis overview

The analyses used in this study are based upon a disaggregation methodology, separating water withdrawals into sectors and projecting each individually as shown in Figure 4. Descriptions of each withdrawal sector in the context of this study were provided for reference in Table 1. Within each sector, data are disaggregated further in order to capture finer scale trends required to meet planning objectives (described in Section 1.4). This disaggregation approach creates a "hierarchy of time-series" where each time series represents water withdrawals at a specific spatial resolution (e.g., one public water supply system). Projections are then developed in such a manner that they can be aggregated to create coherent projections at higher levels, such as withdrawal sectors, regional watersheds or the entire Delaware River Basin.

In most sectors, the basis of the projection methodology is the extrapolation of historical water withdrawal data. A report-based methodology was developed to analyze withdrawal data and corresponding metadata at a system level (largely corresponding to regulatory approvals) and present multiple forms of analyses to facilitate staff review and selection of the most appropriate projection(s). Rather than outlining this methodology using generic examples, it is first detailed in Section 3.4 using the public water supply sector as a specific example. Any deviations from this "baseline" approach used in the other sectors are then detailed in the corresponding sections of the report.

Two sectors use different methodologies for developing projections. The self-supplied domestic sector uses a dasymetric population assessment combined with per-capita rates to create a single estimate for 2010, which is projected based on county level population projections (discussed in Section 4.4). The irrigation sector uses a multivariate regression based on precipitation and temperature at the 147 subbasin scale and generates projected withdrawal volumes based on two climate change scenarios from a Regional Climate Model (discussed in Section 8.4).

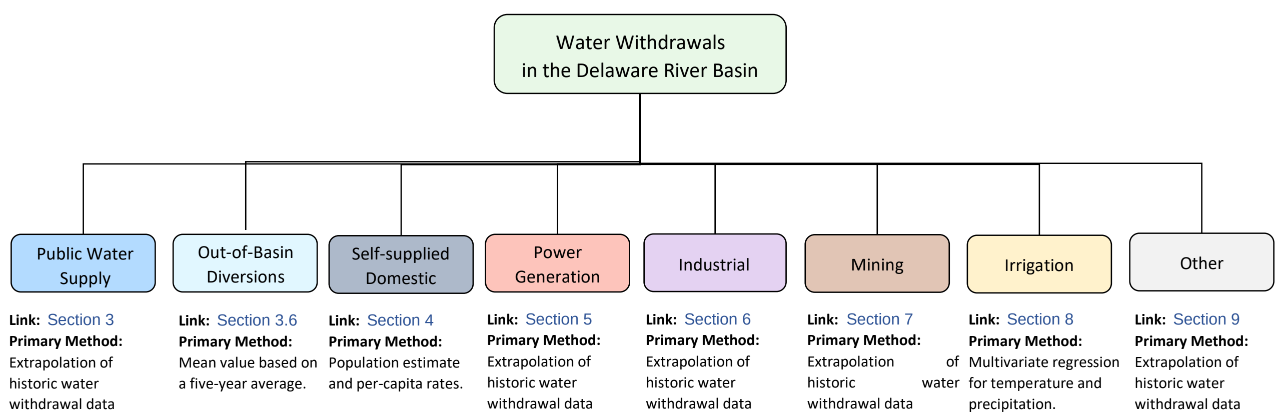

***Figure 4**: A schematic showing the disaggregation structure of water use data within the Delaware River Basin by sector of water use for the purposes of this report. Links included in the figure are directed towards the organization of this report. The example of public water supply's further disaggregation of data to create a hierarchical aggregation structure of related time series is referenced later as Figure 13.*

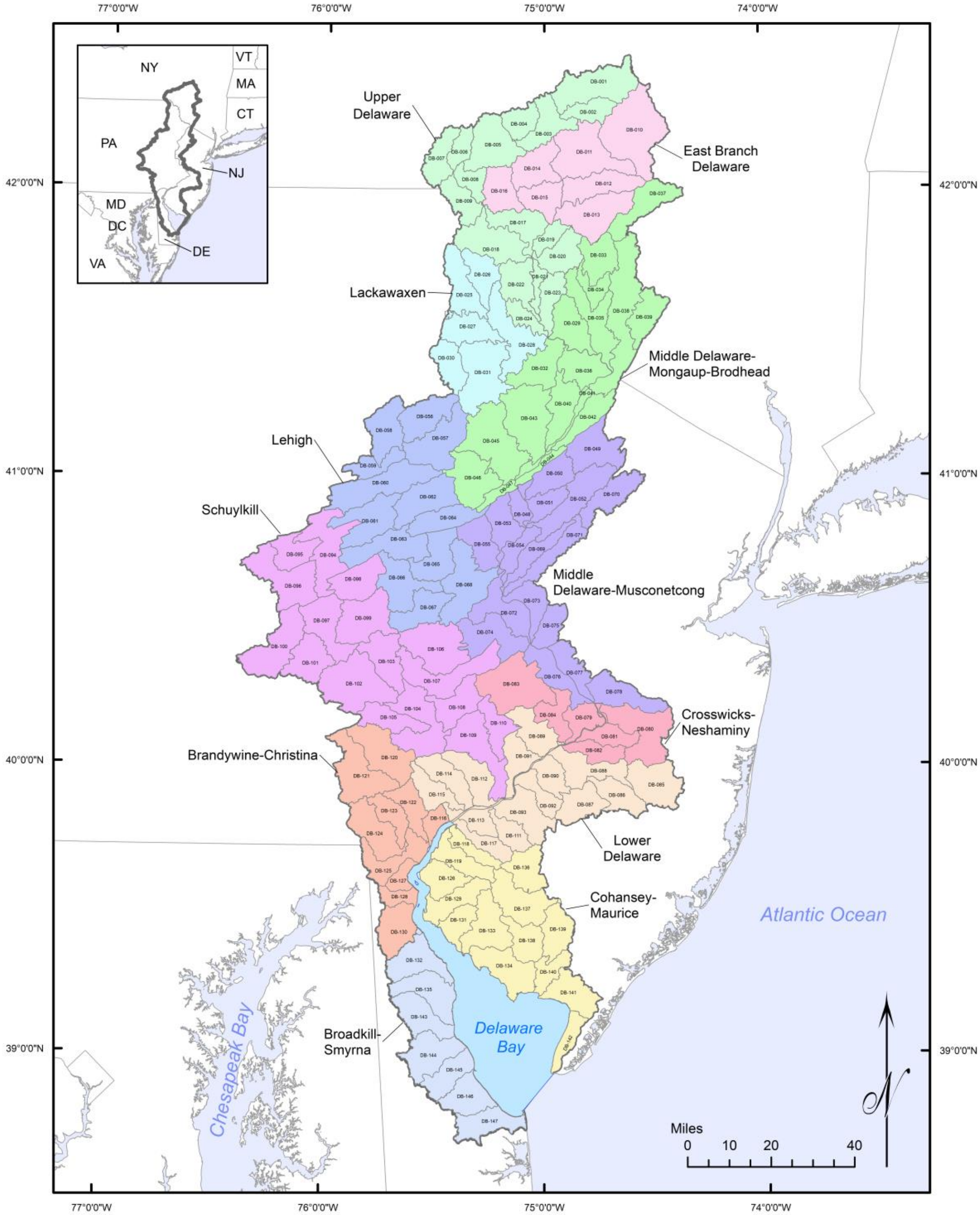

***Figure 5**: A map of the twelve USGS HUC-8 watersheds within the Delaware River Basin, and the 147 modified sub-watersheds representing drainage areas ranging in size from 17.9 to 210 mi^2, as were defined in Sloto & Buxton, 2006.*

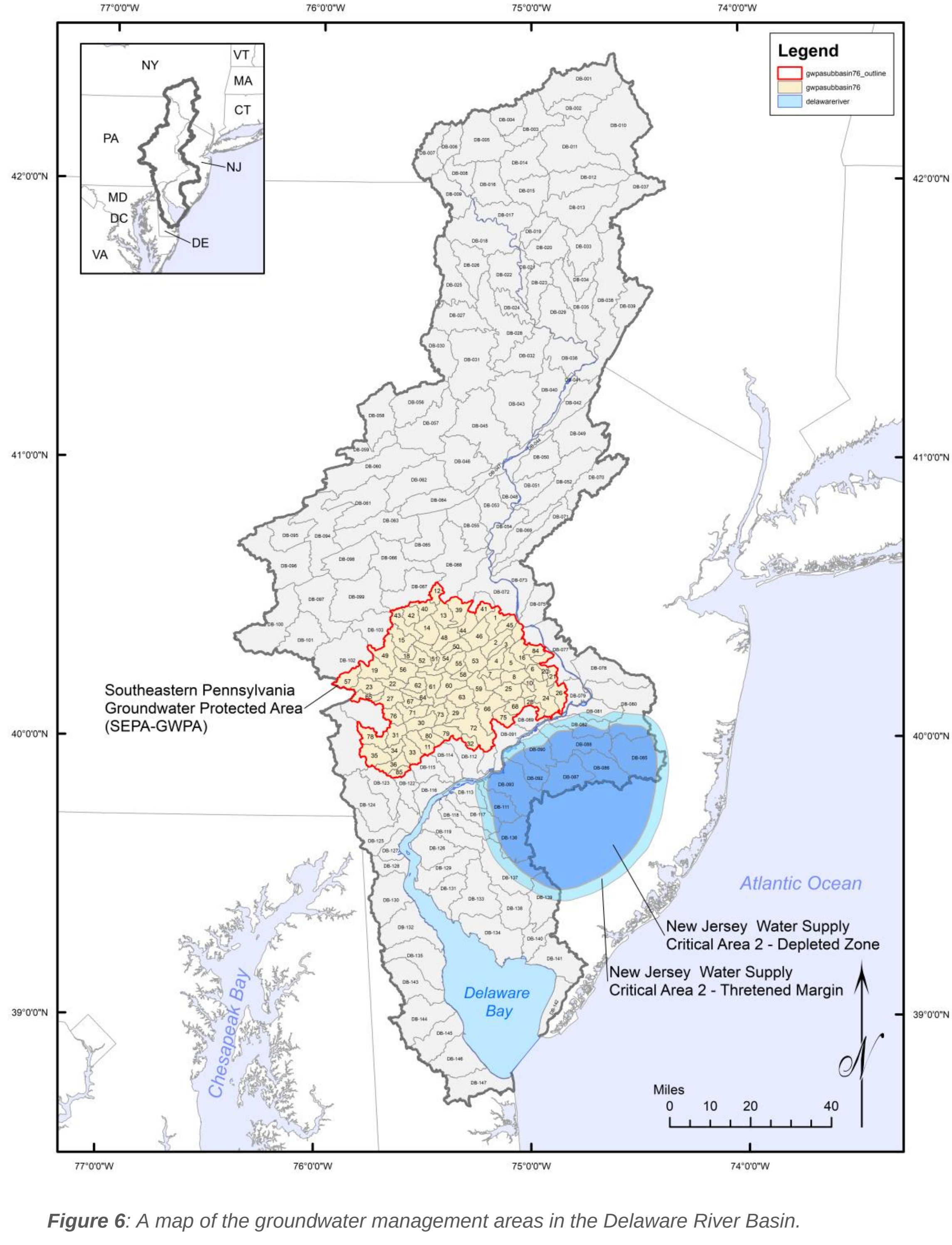

***Figure 6**: A map of the groundwater management areas in the Delaware River Basin.*

Ice forming on the Delaware River
near Bucks County, Pennsylvania.
Credit Michael Thompson, DRBC

2 DATA SOURCES AND MANAGEMENT

The DRBC has regulatory authority with regards to the allocation of ground and surface water withdrawals above certain thresholds within the Delaware River Basin. As highlighted in the *State of the Basin, 2019* report (Byun et al., 2019) and detailed in numerous reports (USACE & DRBC, 2008; Hutson et al., 2016; DRBC, 2021) water withdrawals within the Basin are tracked in detail to identify key water-using sectors and trends in withdrawals and consumptive use. Oftentimes, regional study areas may have additional challenges related to obtaining/maintaining consistent datasets (e.g., different states reporting similar information in different ways). Therefore, it is beneficial to first outline specific details about the data used in this analysis before detailing the methods.

2.1 Water withdrawal data

The DRBC has five signatory parties, of which one is the federal government and the other four are the states within the Basin boundary: Delaware, New Jersey, New York, and Pennsylvania (Figure 1). Water withdrawal data used in this analysis typically originate with state agencies, meaning that data are collected from water users through existing state-run programs/portals. However, certain surface water withdrawal data are collected through a DRBC program which helps supplement state collected data. In 2008, the DRBC created an integrated database to function as a means of binding together the data management styles of the five involved agencies. This entailed an extensive review of existing data sources and coordination with state partners to establish a working framework within DRBC. As technology and data sharing advances, the efficiency and methods of data sharing have also adapted. The five primary sources of withdrawal data are summarized in Table 4.

Specifically, in the context of this report, water withdrawal data refers to four specific pieces of information:

1. the source of the withdrawal,
2. the system that the source is a part of,
3. the time of the withdrawal (e.g., year and month), and
4. the volume of the withdrawal.

Each agency has its own nomenclature when describing water withdrawal data, and therefore pertinent data acronyms are also presented in Table 4. Each agency has a similar method of indexing sources and systems with slight variations; therefore, it was useful for DRBC to create a common source/system index as a parallel to the individual agency methods. This process allows withdrawal data to be combined in the DRBC integrated database on an annual basis using DRBC identifiers, which are in turn linked back to agency identifiers.

***Table 4**: Agencies within the Delaware River Basin and regulatory authority related to water withdrawals. Additionally, the resolution of withdrawal data collected by each agency, and the method of indexing the data.*

Agency	Withdrawal Threshold (gpd)	Data Collection Categories				Source Identifier	System Identifier
		Withdrawals		Cons. Use	Inter.		
		SW	GW				
DRBC	>100,000[1] or >10,000[2]	X	--	X	--	Water Source ID (WSID)	Organization Address ID (OAID)
NYSDEC	>100,000	X	X	--	--	--[3]	--[3]
NJDEP	>100,000	X	X	--	X	Subject Item ID (SIID)	Program Interest ID (PIID)
PADEP	>10,000	X	X	--	X	WUDS Sub-Facility ID (SFID)	WUDS Primary Facility ID (PFID)
DE DNREC	>50,000	X	X	--	--	DNREC ID	--

Notes:
[1] Refers to basin-wide groundwater and/or surface water withdrawals.
[2] Refers to groundwater in Southeastern Pennsylvania Groundwater Protected Area (SEPA-GWPA).
[3] Data provided by New York has typically been listed by organization name; DRBC assigns identifiers for its integrated database.

2.2 Water withdrawal metadata

Metadata is broadly defined as "data about other data." Having described the data required for extrapolating historical water withdrawals (source; system; time; volume), it is easier to understand data which are "describing" or "related to" a particular data point. Some examples of this metadata may include interconnection data (e.g., how much water is transferred to other systems), categorical information (e.g., water withdrawal sector), source construction details (e.g., well depth and pump capacity), allocation limits, geographic information, permits and other forms of administrative or engineering information. While not being projected, this metadata is associated with each projection via the unique identifiers (source; system). This information is valuable because the purpose of projecting water withdrawal data is not simply to extrapolate it but to be able to relate the results back to water resources planning objectives. Beyond typical metadata (such as the name of a source and the operating organization), additional data sets which DRBC considered metadata for the purposes of this analysis are described in the following sections.

2.2.1 System interconnection data

As is shown in Figure 7, there is a high density of population in the middle and lower portions of the Delaware River Basin, which has led to a high density of public water supply systems. Coupled with the region's history of water use in other sectors (such as industrial operations and energy generation), a complex web of relationships between water supply systems has developed, termed "interconnections." Interconnections are where water is sold or purchased in bulk and physically transported to adjacent systems. This is predominantly observed in the public water supply sector. Data related to the volume of water being transferred were not included in the DRBC integrated database but were able to be referenced in this analysis via system identifier relationships (Table 4). These data are only available for New Jersey and Pennsylvania and generally have a more limited time-series than water withdrawal data sets. The specific data included in this analysis focused on four items:

1. which system exported (provided) the water,
2. which system imported (received) the water,
3. the time of the transfer (e.g., year and month), and
4. the volume of water transferred.

2.2.2 AWWA water audit data

In accordance with Sections 2.1.6 and 2.1.8 of the DRB Water Code, water supply systems serving the public (purveyors) in the Delaware River Basin that distribute water supplies in excess of an average of 100,000 gallons per day (gpd) during any 30-day period are required to annually submit a water audit using the AWWA Free Water Audit Software (AWWA, 2021). These reports are linked to DRBC approvals and provide additional system-level data. While this study relies on water withdrawal data from other sources as it is at a finer scale (typically monthly source level data), specific parameters from water audits such as "non-revenue water" and "data validity score" are brought into analyses as metadata for reference during review.

2.2.3 Consumptive use data

Consumptive use 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*." In this report, consumptive use volumes are calculated by multiplying the total withdrawal volume by a percent value, termed a Consumptive Use Ratio (CUR). There are three main sources of information where CURs are obtained, and they are applied to historical water withdrawal data (and projections) in a specific order. Listed from most to least preferred, the sources of data for CURs are as follows:

1. Certain surface water withdrawals are subject to reporting requirements outlined in the DRBC Water Supply Charges Regulations (18 CFR Part 420). For a subset of reporters, both the total water withdrawal and the portion consumptively used are reported. This allows for calculation of annual average CURs and, ultimately, a final average historical CUR to be applied to the withdrawal data and projection.
2. DRBC regulatory approvals (dockets) often contain system specific information such as the portion of total withdrawal consumptively used, estimated by either the docket holder or by DRBC. This CUR can be applied to all sources associated with a specific system.
3. Based on literature review, there are numerous "default values" used by DRBC for CURs which can be applied to data based on the source or system water withdrawal category. The default values used historically by DRBC and in this analysis are provided in Table 5.
    a. If a system is "associated" with a DRBC regulatory approval and individually analyzed, a single default value can be applied to all sources based on the withdrawal sector of the system.
    b. Sources which are "not associated" with a DRBC approval ("unassociated") have no other option than to be assigned an individual default CUR based on the water withdrawal category associated with the source (or sector).

***Table 5**: Default consumptive use ratios used in this analysis, by sector and category. Descriptions of each sector were provided for reference in Table 1.*

Withdrawal sector	Withdrawal category	Default CUR	Reference using the same CUR
Public water supply	Public water supply	0.10	NA
Self-supplied domestic	Self-supplied domestic	0.10	NA
Power Generation	Thermoelectric	0.02	Shaffer & Runkle, 2007
	Hydroelectric	0.00	Shaffer & Runkle, 2007
Industrial	Industrial	0.10	Shaffer & Runkle, 2007
	Refinery	0.10	NA
	Remediation	0.10	Domber & Hoffman, 2004
Mining	Mining	0.12	Domber & Hoffman, 2004
Irrigation	Agriculture	0.90	Domber & Hoffman, 2004
	Cranberry operations	0.00	NA
	Golf/CC	0.90	Domber & Hoffman, 2004
	Non-Agricultural Irrigation	0.90	Domber & Hoffman, 2004
	Nursery	0.90	Domber & Hoffman, 2004
Other	Bottled Water	0.80	Domber & Hoffman, 2004
	Commercial	0.10	Shaffer & Runkle, 2007
	Fire	0.20	Balay et al., 2016
	Fish Hatchery	0.05	Domber & Hoffman, 2004
	Hospital/Health	0.10	Shaffer & Runkle, 2007
	Military	0.10	NA
	Other	0.20	NA
	Parks/Recreation	0.10	Balay et al., 2016
	Prison	0.15	NA
	School	0.15	Shaffer & Runkle, 2007
	Ski/Snowmaking	0.22	DRBC, 1992; Leaf & Wright Water Engineers, 1986

2.2.4 EIA power plant data

Two datasets related to United States Energy Information Administration's (EIA) survey forms were used in this study, specifically for the thermoelectric sector (Section 5). The survey forms are considered mandatory reports for specific facilities, including but not limited to those which have a combined generator nameplate capacity equal to or greater than 1 megawatt (MW) and are connected to a local or regional power grid. The EIA collects certain data at the "Plant Level" tracked under a unique "Plant ID" for each facility. In this study, it was possible to link these Plant IDs to the corresponding water withdrawal time-series. While EIA data are not directly projected, separate analyses of these data help to describe the observed trends in water withdrawals. The three specific datasets used are:

1. **PowerPlants_US_202004.shp**
   A shapefile dataset provided by EIA titled "Power Plants" which was updated in April 2020 (USEIA, 2020c). The dataset contains information compiled from survey forms EIA-860 (*Annual Electric Generator Report*), EIA-860M (*Monthly Update to the Annual Electric Generator Report*) and EIA-923 (*Power Plant Operations Report*). It contains relevant information used to perform a geospatial analysis of the power facilities within the Delaware River Basin by installed capacity and primary fuel type. This analysis is discussed in Section 5.
2. **Form EIA-860 (Annual Electric Generator Report)**
   This is a survey form which collects generator-level specific information and associated environmental equipment at electric power plants with a combined nameplate capacity equal to or greater than 1 megawatt (USEIA, 2020a). The annual report forms were referenced back to 2001 to obtain information on facilities which may have since closed and no longer report data (i.e., would not be in the current *PowerPlants_US_202004.shp*) but have historical data relevant to time-series of the Delaware River Basin.
3. **Form EIA-923 (Power Plant Operations Report)**
   This is the current survey form which collects information on the operation of electric power plants and combined heat and power plants in the Unites States (USEIA, 2020b). Historical time-series of net power generation by primary mover type and fuel type were developed for all power facilities identified as being within the Delaware River Basin. This analysis also made use of a previous version of the survey form, namely data from Form EIA-759, -867, -906 and -920. This analysis is discussed in Section 5.3.1.

It is worth noting that Schedule 8 Part D of Form EIA-923 has been used to collect data on Monthly Cooling System Operations since the year 2008. However, the required respondents are limited to thermoelectric power plants with a total steam-electric capacity of 100 MW or greater. It was determined that these data are predominantly captured at finer resolution by data sources described in Section 2.1, and the data were therefore not included in the projections.

2.3 Population data

Data regarding the population within the Delaware River Basin were used specifically in the estimation of a self-supplied domestic withdrawal volume by subbasin. This dasymetric population data set was obtained from the EPA EnviroAtlas (USEPA, 2016), is presented in Figure 7 and discussed in detail in Section 4. Additional data from the U.S. Census Bureau were used to perform quality control checks on the EPA dataset (USCB, 2010a, 2010b). Data for projected population growth scenarios were obtained from M. E. Hauer, 2019 and M. Hauer & CIESIN, 2021 and are discussed in detail in Section 4.

2.4 Climate data

Climate data were obtained from another project within DRBC (DRBC, Pending). This includes historical observations from 2,141 weather stations with data from the past 70 years (temperature and precipitation), as well as bias-corrected temperature data from a regional climate model (discussed and referenced in Section 8).

2.5 Data analysis tools

The majority of all data analysis was performed in the computing language *R* (R Core Team, 2021). There were numerous supplemental packages used in this analysis, such as: {cowplot}, {data.table}, {dplyr}, {fBasics}, {foreign}, {ggplot2}, {grid}, {gridBase}, {gridExtra}, {gridGraphics}, {gtable}, {investr}, {lemon}, {MASS}, {matrixStats}, {propagate}, {scales}, {stats}, {stringr}, {tidyr}, {timeDate}, {timeSeries}, {TTR}, and {wesanderson}.

Delaware River flowing under the West Trenton Railroad Bridge.
Credit Michael Thompson, DRBC

Swann Memorial Fountain in Logan Square
Philadelphia, Pennsylvania.
Credit: © Lori Newman
Used with permission

3 PUBLIC WATER SUPPLY

This portion of the study is focused on public water supply systems within the Delaware River Basin. Areas within the Basin which are served by public water supply systems (termed "service areas") are shown in Figure 7; note that certain service areas which extend beyond the Basin boundary have been clipped for clarity of presentation. These service areas have been underlain by a population dataset developed by the USEPA, which dasymetrically mapped 2010 census population data to 30x30 meter pixels based on land cover (NLCD 2011) and land slope (USEPA, 2016). By comparing the total population within the Basin boundary to the portion of population distributed in service areas, it is possible to estimate that approximately 86% of the 2010 population residing within the Basin relied on public water supply (detailed analyses are presented in Section 4 concerning estimation of self-supplied domestic withdrawals). Furthermore, the population within current service areas is projected to grow approximately 1.5% by 2060. It is important to note that water withdrawn by public water supply systems may also serve commercial and industrial customers (end-use), as described in Section 3.3.

3.1 Review of regional watershed studies

***Table 6**: An expansion of Table 3 in order to more accurately summarize the specific methods utilized by regional watershed studies which projected public water supply.*

								PWS Method			
Study	**Study Region**	**Projected data**	**Projected data scale**	**Reported Results Scale[1]**	Total water use	Consumptive water use	Variable per-capita rates	Growth rate applied to current water use	Per-capita rates x population projections	Per-capita rates x population projections (multi-scenario)	Extrapolation of historical withdrawal estimates
(Hutson et al., 2004)	Tennessee River Watershed	No. households	County	RCA, WUTA	X	X		X			
(ICPRB, 2012)	Potomac River Basin	Population	County	County	X	X	X			X	
(USDOI-BR, 2012)	Colorado River Basin	Population	*NA*	State		X	X			X	
(USDOI-BR, 2016)	Klamath River Basin	Population	County	County		X				X	
(Balay et al., 2016)	Susquehanna River Basin	Population	County	HUC-10		X		X			
(Robinson, 2019)	Cumberland River Watershed	Population	County	RCA	X	X			X		
(Zamani Sabzi et al., 2019)	Red River Basin	USGS NWUE	County	County		X					X

Notes:
HUC = Hydrologic Unit Code
RCA = Reservoir Catchment Area
WUTA = Water-use Tabulation Area
USGS NWUE = USGS National Water Use Estimates

An expansion of the study descriptions listed in Table 3 is included for reference as Table 6 and provides additional details for each study which included projections of public water supply. A noteworthy observation is that most studies estimated future public water supply using a projection made at a county level, and the results were then re-aggregated to different scales. Four of the studies used indirect methods by applying per-capita rates to population projections. Two of the studies varied the per-capita rate by defined scenarios; one included percent changes to individual state per-capita rates by scenario (USDOI-BR, 2012), and the other varied the annual growth of a basin-wide per-capita rate by scenario (ICPRB, 2012). The only study which reported results at a small sub-watershed scale (HUC-10) applied the ratio of projected county population change to the most recent year of available withdrawal data for individual withdrawal sources (Balay et al., 2016). Only one study directly projected water use data utilizing historical USGS Nation Water Use Estimates, and it applied linear regressions to county level surface water consumptive use estimates, accounting for decreasing trends by setting a lower limit of 20% of the current water use (Zamani Sabzi et al., 2019).

In most of the reference studies, results are generally presented for the specified "projection horizon" as a bar chart, color coded basin map, or table of results. Three studies quantified uncertainty by presenting results of multiple defined scenarios which captured a range of variability in key variables, such as per-capita rates. The remaining four studies did not present variable ranges for estimated future water use.

3.2 Review of studies within the Delaware River Basin

The *Multi-jurisdictional Report* (USACE & DRBC, 2008) provided an estimate of water use in the Delaware River Basin for the year 2003, as well as projected sector trends for peak monthly water withdrawal through the year 2030. Separate data sources were used for public water supply projections in each Basin state, and were primarily based on population projections; however, Pennsylvania's analysis was disaggregated between "residential" and "non-residential" water use, respectively, using population and employment projections. The study also incorporated assumed percent-use reductions based on future water conservation practices. Notably, the *Multi-jurisdictional Report* provided a summary of each Basin states' approach to demand forecasting at the time of the report. Similarly, this report provides a summary of continued efforts by Basin states to project public water supply:

- **Delaware**. The Water Supply Coordinating Council (WSCC) was created in July of 2000. Through numerous reports, the WSCC has projected water use in all counties within Delaware through the year 2030:
  - *Northern New Castle County* was covered in the Thirteenth Report to the Governor and General Assembly (DE DNREC et al., 2018). Two methods of projection were performed: one assessment based on population trends suggests a possible small increase in demand, while a logarithmic extrapolation of withdrawal data suggests a possible slight decrease in withdrawal.
  - *Southern New Castle County* was covered in the Ninth Report to the Governor and General Assembly (DE DNREC et al., 2006). Peak daily public water supply was projected based on percent projected population change. This may change based on a pending draft report being developed by the University of Delaware for New Castle County Department of Land Use projecting use to 2050.
  - *Kent County and Sussex County* were covered in the Twelfth Report to the Governor and General Assembly (DE DNREC et al., 2014). Peak daily public water supply was projected based on percent projected population change, and an additional assessment considered potential added effects of temperature increase due to climate change.
- **New Jersey**. The most recent New Jersey Water Supply Plan (2017-2022) included an analysis of future public water supply demands at the public water system level (NJDEP, 2017). Broadly described, the analysis used Municipal Planning Organization (MPO) population projections at municipal levels and assigned proportions to public water supply systems corresponding to the percent of the existing municipal population served by the system. A standard per-capita rate of 125 gallons of water per person per day was used to assess population water demand. As planned, the study was expanded on at a finer scale by Rutgers University (Van Abs et al., 2018). This more detailed study used a refined method of assigning population projections to service areas (dasymetric analysis), created variable per-capita rates based on multiple factors from the dasymetric analysis and utility surveys, and considered system water-loss reporting. The study provided multiple scenarios but recommended the set of results that applies the modelled percent changes in demand to existing actual demands.

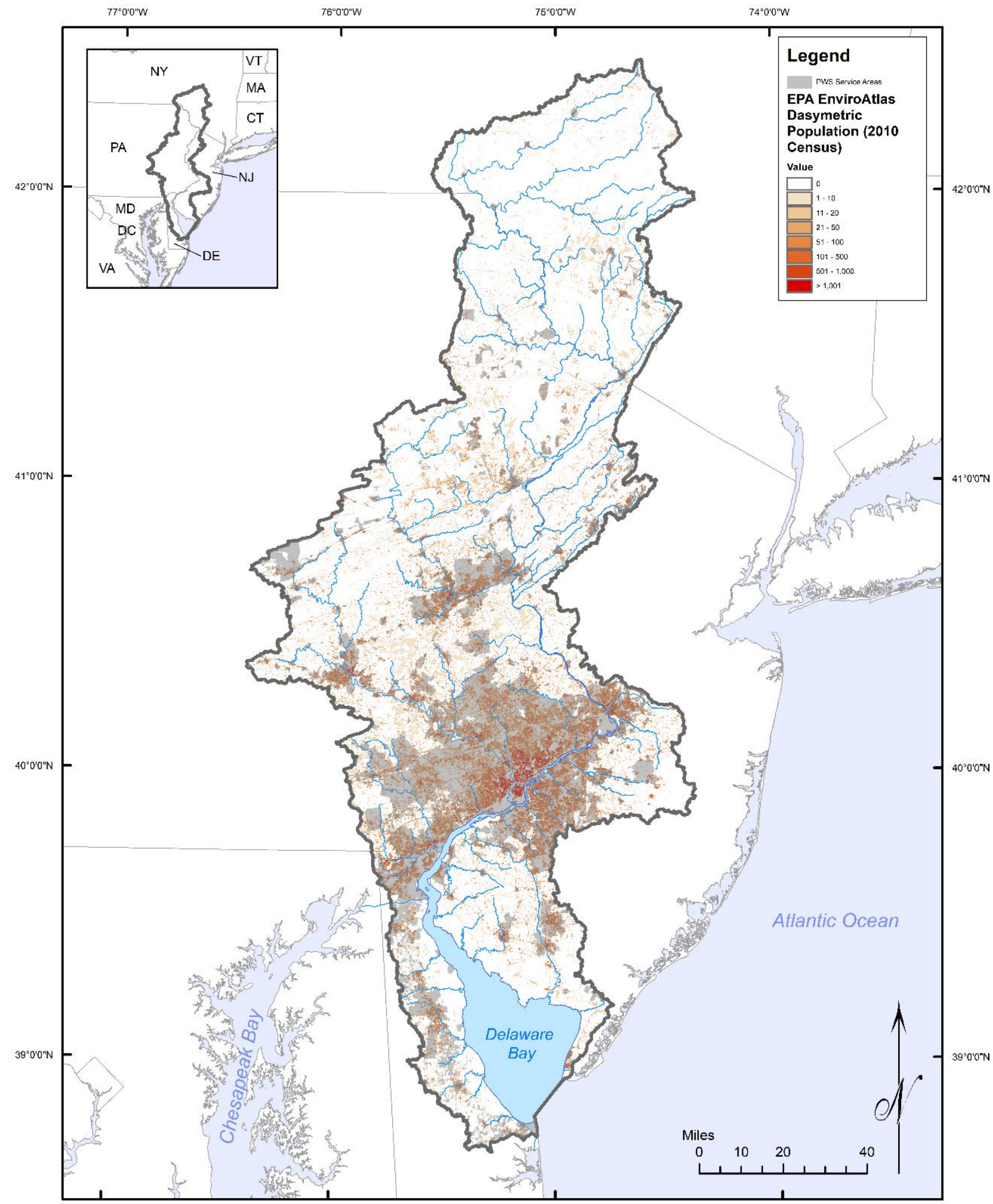

Figure 7: A map comparing population distribution and public water supply service areas in the Delaware River Basin. *The population dataset is from the USEPA EnviroAtlas (USEPA, 2016). The public water supply service areas overlay the population raster in a semi-transparent gray for DE (DE PSC, 2021), NJ (NJDEP, 2019), NY (NYSDOH, 2021), and PA (PADEP, 2020). Population values represent the number of people per 30x30 meter area (pixel), evaluated at an accuracy of 0.01 prior to rounding. An enhanced view of a single census block is presented in Figure 27.*

- **Pennsylvania**. Pennsylvania's Act 220 Water Resources legislation called for the development of a new State Water Plan, which was last updated in 2009 (PADEP, 2009). The plan is currently being reviewed again but has not been updated at the time of this report. The 2009 State Water Plan included the development of a methodology for projecting water demands in a number of water use sectors, called the Water-Analysis Screening Tool (WAST) (Stuckey, 2008). This study drew heavily on the work of Camp, Dresser, and McKee (CDM) which was performed in 2005 as part of a pilot study in the Lehigh River Watershed, directed by DRBC; the final report is included in the State Water Plan as Appendix I (CDM & DRBC, 2005). The methods finalized in Stuckey, 2008 use a per-capita approach, separating public water supply into residential and non-residential, using rates initially developed in CDM & DRBC, 2005 for the Lehigh River watershed. While the WAST developed by Stuckey, 2008 did not provide projections, the CDM & DRBC, 2005 pilot study had performed projections specific for the Lehigh River Basin.

3.3 Water withdrawal data evaluation

As this portion of the analysis is focused on the public water supply sector, it is appropriate to define what public water supply means in the context of this report. The Safe Drinking Water Act of 1974 defined the term public water supply system as "*a system for the provision to the public of piped water for human consumption, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals*" (Pub. L. No. 93-523, 88 Stat. 1660). This definition has largely been adopted by the four state agencies within the Basin:

- PADEP Safe Drinking Water Regulations (25 Pa. Code §109)
- NJDEP Safe Drinking Water Act Rules (N.J.A.C. 7:10)
- DHSS Public Drinking Water Regulations (16 Del. Admin. C §4462)
- NYSDOH Drinking Water Supplied Regulations (N.Y.C.R.R. tit. 10)

This definition was previously used by DRBC in the *Basin Plan* (DRBC, 2004b). It has also been used by the USGS in a separate study on water use within the Delaware River Basin, where it specifically elaborates that the reported public water supply withdrawal data includes water delivered by these systems for domestic, commercial, industrial, other public use purposes and system losses (Hutson et al., 2016).

Whether or not a withdrawal source is used for public water supply is typically determined by the respective state agency at the time of source registration, assigning a water use category or withdrawal category. In broad terms, this analysis includes most withdrawal sources within the Delaware River Basin which have a withdrawal category of public water supply (or derivation), regardless of the actual end use of withdrawn water.

3.3.1 Associated and unassociated systems

Public water supply systems subject to one or both of the following DRBC regulations were included on a list for individual analysis. Based on these criteria at the time of analysis, 335 public water supply systems were individually assessed.

1. A public water supply system within the DRBC subject to water audit reporting requirements (DRB Water Code); this may be a system encompassing multiple active DRBC approvals.
2. A public water supply system not subject to the water audit reporting requirements but which withdrawals water that is either recognized or approved by the DRBC under Section 3.3 of the DRBC Compact (Pub. L. No. 87-328, 75 Stat. 688, 1961), meaning that there is either an active docket, permit or entitlement associated with the withdrawal.

A procedure was established as part of the projection methodology to verify that sources listed in active regulatory approvals are accounted for in the withdrawal data, to the extent possible. As decommissioned or inactive sources which have reported data also help describe a system's historical withdrawal trend, each analysis was not restricted to active sources. Once the list of public water supply systems was defined and

***Table 7**: A summary of the total water withdrawal data for public water suppliers in the Delaware River Basin, categorized by source-type and association with regulatory approvals.*

Data category	Systems (OAIDs)	Water type	Sources (WSIDs)	Average withdrawal (MGD)	Percent total withdrawal
Associated	362*	GW	2,126	234.685	28.6%
		SW	112	580.351	70.6%
Unassociated	548	GW	1,131	6.081	0.7%
		SW	30	0.345	0.0%
Totals:	910	--	3,399	821.463	100.0%

Notes:
*Accounts for 335 public water supply systems. Some systems encompass data assigned under multiple facility IDs in cases where the current system extents have evolved over time, or an approval covers multiple smaller systems operated by a single entity.

sources accounted for; it was then possible to break down the water withdrawals from the Delaware River Basin by public water suppliers into two administrative categories:

1. **Associated**, meaning the withdrawal source is associated with a system meeting the previously defined criteria and is therefore associated with DRBC regulations.
2. **Unassociated**, meaning that the withdrawal source is located within the Delaware River Basin and categorized as public water supply, but it does not meet the previously defined criteria nor is it associated with a facility in another withdrawal sector. These withdrawal sources are grouped together as an aggregate data set and analyzed as one "system" for each state.

For reference, a complete list of the associated facilities assessed in this report is included as Appendix C; some facilities may have been reviewed but not projected, as indicated in the appendix. While all sources of an associated system are considered in the analysis regardless of withdrawal category (e.g., a rare occurrence may be a purveyor that categorizes a well as industrial if it is known to only serve industrial customers), the unassociated data set considers all sources not modelled as part of a system in any withdrawal sector and takes only sources with a category included within the sector as shown in Table 5 (without consideration to a single facility potentially having sources with multiple classifications).

By averaging the public water supply dataset over the entire time-period, it is possible to summarize the average withdrawal in Table 7, indicating which portions of the volume are associated with DRBC approvals, surface water, or groundwater. From this preliminary assessment of reported data, the following conclusions are able to be drawn regarding water withdrawals by public water suppliers in the Delaware River Basin:

- Of water withdrawn by public water suppliers within the Delaware River Basin, about 99% of the volume is associated with some form of active regulatory approval.
- On average, the unassociated volume of water withdrawn is about 6.426 MGD (~1% of the total) and is almost entirely groundwater.

3.3.2 Data exclusions

There are four items worth noting regarding the analysis projecting public water supply withdrawal data:

1. Two major in-Basin withdrawals are not included in this projection analysis for public water supply; they are covered by a 1954 U.S. Supreme Court Decree (U.S. Supreme Court, 1954) and include the exportations of surface water to New York City and New Jersey. These withdrawals are instead accounted for in the out-of-basin diversions sector as presented and discussed in Section 3.6.
2. Self-supplied domestic withdrawals are covered in Section 4.

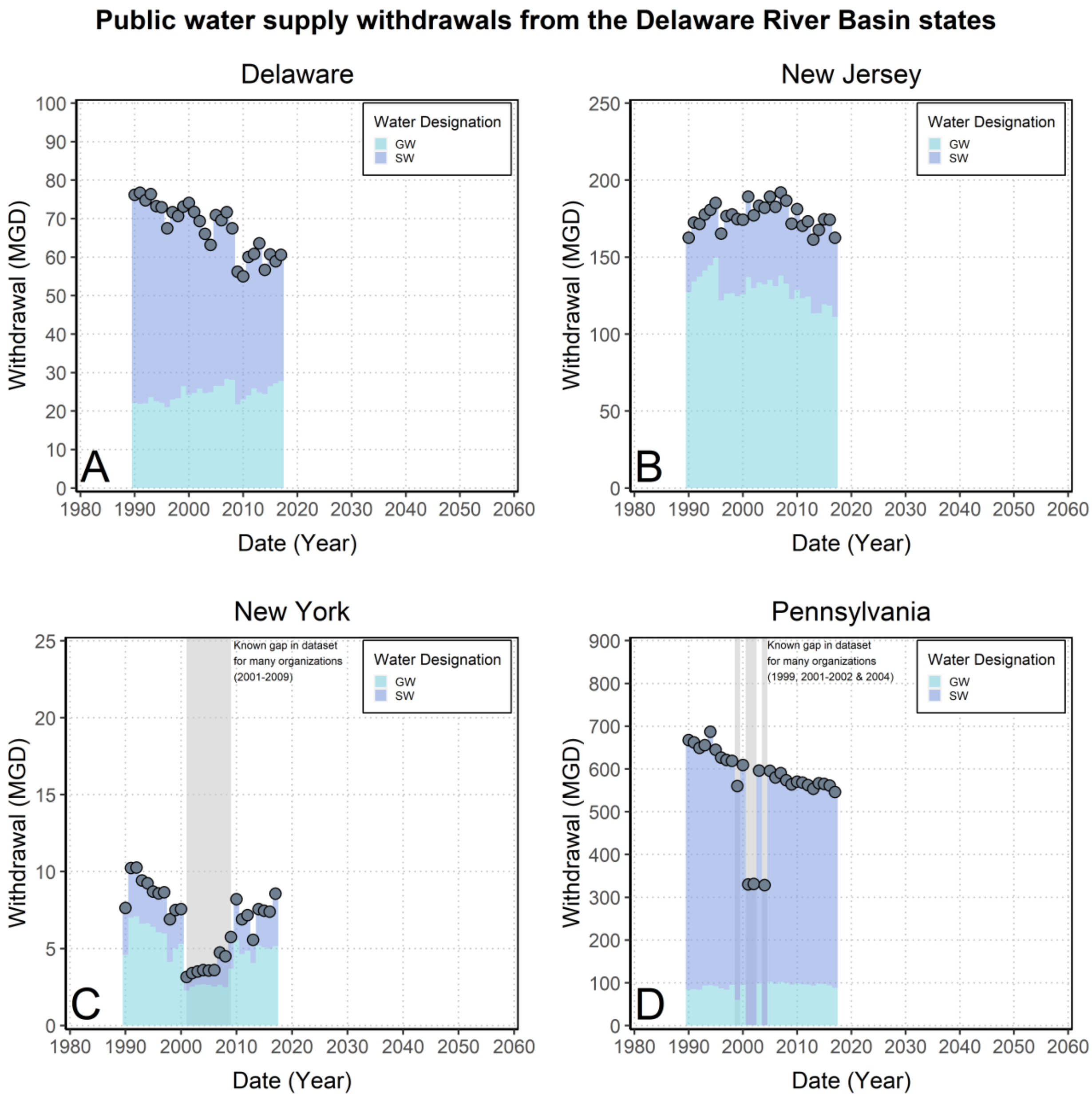

Figure 8: Public water supply withdrawal from the Delaware River Basin states. *The y-axis scale of each plot varies to promote visibility of data. This dataset is aggregated to the Basin scale and presented as Figure 9. Data supporting these figures are provided for reference in Table A-1.*

3. Withdrawals which are strictly inter-basin transfers are not included in this analysis (e.g., water withdrawn from a river which is discharged to a reservoir to support a withdrawal from the reservoir would not be included, whereas the reservoir withdrawal is included).
4. Unassociated surface water is not projected, although the data are presented in figures and corresponding datasets for completeness.

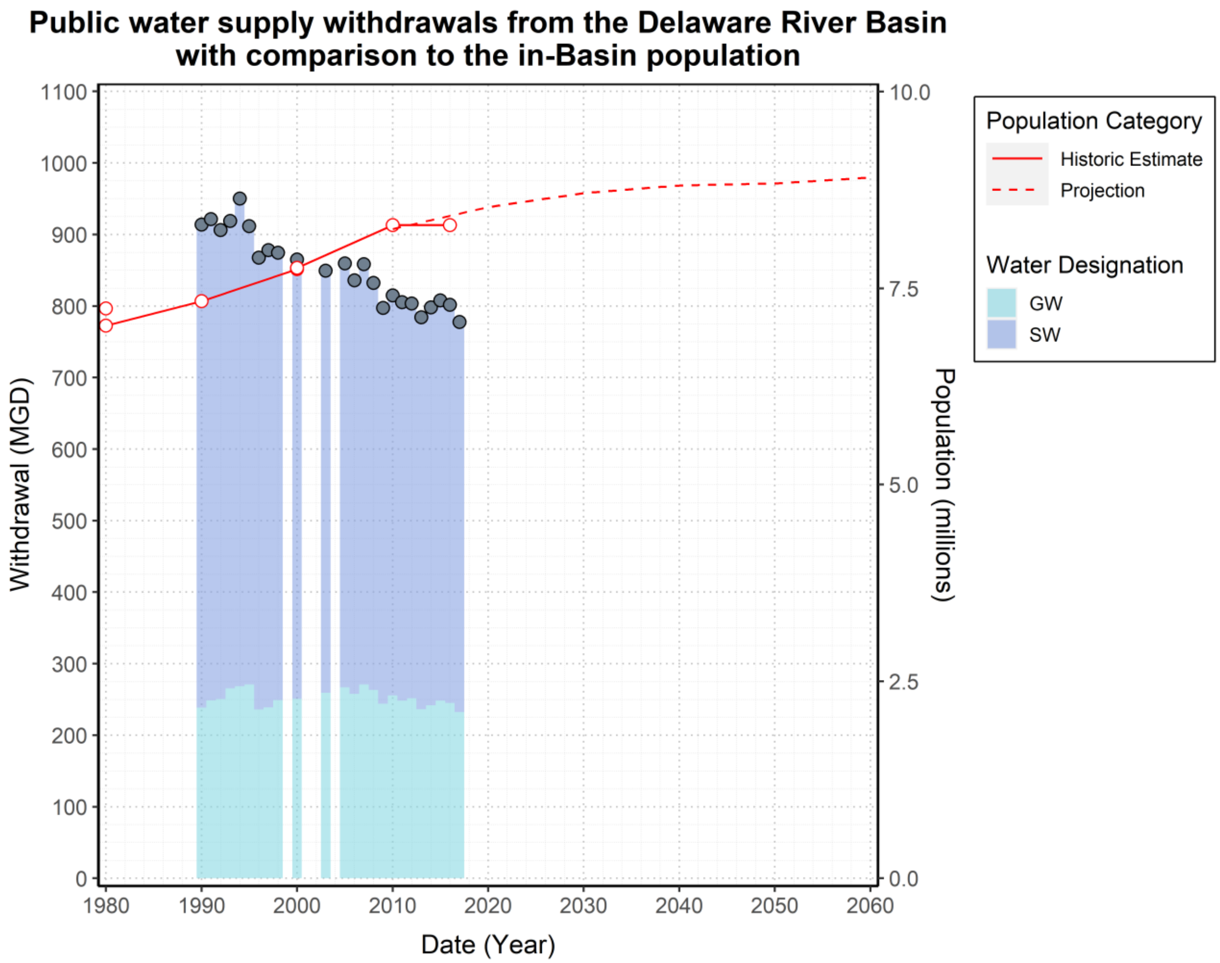

Figure 9: Public water supply withdrawals from the Delaware River Basin. *Average annual withdrawal rates from the Delaware River Basin (MGD) for water supply systems and/or sources meeting the criteria of the public water supply sector. Note that selected years have been omitted from the Basin estimate for clarity; however, system-level data were used for projections if available. This figure represents an aggregation of the data provided in Figure 8. Withdrawal data supporting this figure are provided for reference in Table A-1. Population data supporting this figure are discussed in Section 4).*

3.3.3 Total water withdrawal

Through calendar year 2017, data reflecting water withdrawals by public water suppliers in the DRB portion of each Basin state are summarized in Figure 8 and aggregated to the Basin scale in Figure 9. The data release supporting the analysis in this section is provided in Appendix A as Table A-1. Estimates and projections of in-Basin population are also provided in Figure 9; the details behind the population data are discussed in Section 4 covering self-supplied residential withdrawals.

From the trends observed at the state-level, it is possible to conclude that peak water withdrawal has already occurred in the DRB portion of each state. The peak withdrawals for Delaware, New York and Pennsylvania likely occurred before the start of the time series (pre-1990), and therefore a peak annual average withdrawal rate cannot be definitively stated. The peak withdrawal in New Jersey appears to have occurred around 2007 at an average of about 190 MGD.

Some individual years of data have been omitted from the Basin-wide estimate for clarity (Figure 9), largely due to known data gaps in Pennsylvania data for the years 1999, 2001, 2002 and 2004. While omitted from this figure, the data were used in projections at the system level where available. This analysis has presented differing estimated values of total withdrawal as compared to previous studies (DRBC, 2004b; USACE & DRBC, 2008; Hutson et al., 2016; Byun et al., 2019). However, it should be noted that this study has included a significant amount of data validation at the individual system level to avoid inclusion of potential duplicate data, and does not include the specific data exemptions noted in Section 3.3.2 which may have been included in other studies.

An interesting observation at the Basin scale is the difference in trends between withdrawals by public water suppliers and in-Basin population. While withdrawals have decreased by over 100 MGD on average since 1990, the in-Basin population has increased an estimated 965,000 people and is projected to continue increasing (refer to Section 4 for discussion on population data). This pattern is assumed to be attributed to multiple factors, including but not limited to, advances in leak detection and water conservation by purveyors, regulatory efforts such as plumbing standards, and general public awareness of water conservation.

Another important planning scale for this study specific to Pennsylvania is the Southeastern Pennsylvania Groundwater Protected Area (SEPA-GWPA). Groundwater data which are applicable to the 76 subbasins highlighted in Figure 6 are presented in Figure 10. Note that while the data only extends back to 1990, the regulations defining SEPA-GWPA became effective beginning in January 1981 (18 CFR Part 430, 1980). Withdrawals have remained relatively constant for the period of reported data, in the range of about 45 MGD on average.

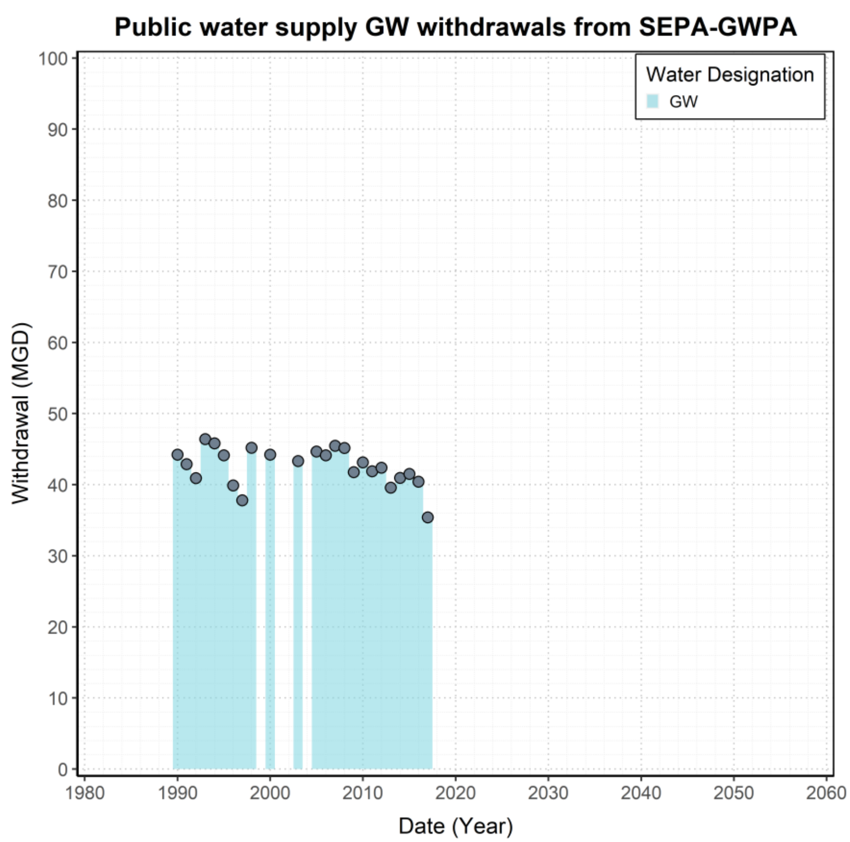

Figure 10: Public water supply GW withdrawal from the Southeastern Pennsylvania Groundwater Protected Area. *This data only represents withdrawal volumes from sources which plotted within the boundary of SEPA-GWPA as shown in Figure 6. Data supporting this figure are provided for reference in Table A-1.*

3.3.4 Consumptive water use

For the public water supply sector, consumptive use is calculated using the default CUR listed in Table 5. Therefore, the trends observed will mirror those presented in Figure 8 and Figure 9, and separate figures have not been presented. However, corresponding consumptive use data are included as part of the data release provided in Appendix A as Table A-1.

3.4 Methods

The methods outlined for this sector are similar to the projection methods used for many of the sectors analyzed in this report (power generation, industrial, mining, and the other sector). It was determined that explaining the methodology using the public water supply sector as an example would be the most efficient means, rather than using hypothetical examples. The portions of this report which cover other sectors each have a “Methods” section but will focus mainly on the differences from the methods outlined for public water supply. Only two sectors use entirely different methods, which are outlined in the respective sections of this report: self-supplied domestic and irrigation.

3.4.1 Concept

The overall concept of this analysis is to estimate future public water supply withdrawal needs by extrapolating historical withdrawal data at either the water supply system and/or sub-system levels. The extrapolations are done in a manner such that a “bottom-up” approach can be used to re-aggregate the projections. While withdrawal data are available at a monthly resolution, this study aggregates and projects data on an annual timescale for the purposes of assessing future average demand. This analysis takes a detailed look at the public water supply sector by disaggregating withdrawal data into numerous levels of spatial resolution related to source coordinates (i.e., system-level, subbasin-level, and source-level). A report-based methodology was developed to extrapolate data at each spatial scale, pulling in pertinent metadata from additional sources of information. The selected projections for each system were indexed in a manner such that they may be re-aggregated in a variety of ways to support different planning objectives.

3.4.2 Rationale supporting data extrapolation

As was highlighted in the introduction, many previous public water supply projection studies are based largely on population projections, while a few more recent studies have assessed source-level withdrawal data. While it may be related in-part to data accessibility, extrapolating historical withdrawal data provides an advantage over some population-based studies for the following reasons. As with all methods, there are inherent assumptions which accompany the extrapolation method as are outlined later in Section 3.4.5.4.

1. Extrapolating withdrawal data has as a direct link between the projection and the point of withdrawal, rather than the point of consumption (e.g., residential demand estimates or per-capita estimates). As water may not always be consumed where it is withdrawn, using data from the point of withdrawal poses an advantage when considering natural resource availability.
2. If per-capita rates were developed using purveyor data (and therefore result in a population-based factor accounting for commercial and other end-uses), increasing population projections would not result in decreased purveyor withdrawal unless a projection of the calculated per-capita rate was also accounted for (which goes back to the issue of data availability).
3. Given the current availability of self-reported withdrawal data, extrapolating the most recent operational trends of systems may provide insight to findings otherwise unnoticed (e.g., metadata such as interconnections revealing changes in where water is being withdrawn spatially, while demands stay constant).

3.4.3 Rationale supporting a system-level approach

As this study focuses on the extrapolation of historical data, it is worth highlighting why a system-level approach was selected, rather than aggregating data at larger scales (e.g., HUC-8 watershed or Basin-wide). There are three primary factors driving this decision:

1. Firstly, projecting water withdrawal for a specific public water supply system inherently ties it to metadata (as described in Section 2.2). While a projection is based solely on the extrapolation of historical withdrawal data, the link to associated metadata provides additional insight during the analysis which can help determine if a proposed projection is logical. Additionally, after a projection is completed, it provides key water resources planning tools such as the ability to compare projected withdrawals against metadata such as an approved allocation or natural resource availability estimates.

   This concept is demonstrated via withdrawal data for an example public water supply system presented in Figure 11. Not only are the annual withdrawal data able to be reviewed, but additional information such as interconnection data, a forecasted estimate provided by the docket/permit holder, and allocation limits are all able to be graphically displayed. This additional information helps identify/justify that extrapolating the entire dataset would be flawed, and that a projection should not start until around the year 2010 due to changes in the system operation. Furthermore, calculated variables such as the total service area demand can also be considered to more accurately identify if a projection is logical (in this specific case, projected withdrawal should not exceed projected service area demand).

2. Secondly, while the record of public water supply withdrawals in the Delaware River Basin extends back to the early 1990s, it is understood that data reporting and sharing has evolved over time. All public water supply systems do not have the same starting year for the respective time-series (even within individual states). Therefore, extrapolating at a larger scale may mistakenly capture data reporting issues as influences on withdrawal trends. Using a bottom-up approach and re-aggregating system projections to a Basin scale in this analysis can help account for the differences in time-series completeness and therefore may offer increased accuracy over higher-level projections.

3. Lastly, the decision was based on the concept that sources operated together as a system have a high likelihood of demonstrating some form of cause-and-effect relationship. As summarized in a recent comprehensive literature review which analyzed 107 publications on optimization of water distribution systems, pump operation was determined to be a primary focus (included as an area of application in 82% of papers). Furthermore, it concluded that explicit pump scheduling is the most frequently used control for optimization, meaning pumps are turned on/off based on certain criteria (Mala-Jetmarova et al., 2017). Specific to groundwater systems, if the full capacity of a well field is not required, the decision to turn pumps on/off may be based on a variety of factors. For example, in order of decreasing capacity, in order of decreasing efficiency, to equalize operational time, based on operator decision, or based on the cost of water pumped (S. Pezeshk et al., 1994).

   With these concepts in mind, and considering all withdrawal sources for a given system, it was often observed in this analysis that source-level data returns poor or indistinguishable trends, whereas aggregating the withdrawals at the system-level yields a stronger relationship between volume and time. A pronounced example of this concept is shown in Figure 12. It was therefore determined that the highest level of data aggregation (i.e., system) should be prioritized for extrapolation, while ensuring that the results will remain useful in meeting planning objectives (for example, verifying that all sources plot within the same planning subbasin).

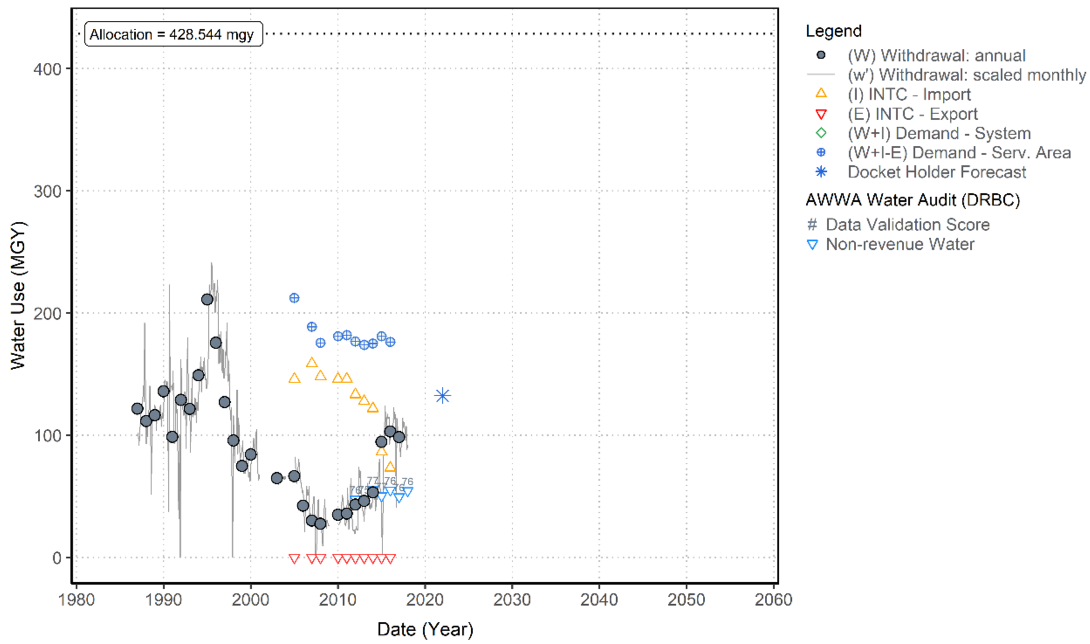

***Figure 11**: An example public water supply system's annual withdrawal data.* *Additional metadata for the system can be referenced graphically. For example, interconnection data can be used to calculate other information such as total service area demand. As may otherwise not be discernable, an operational shift is apparent around the year 2010 where bulk purchases begin to be replaced by source withdrawals. This suggests that an attempt to extrapolate the entire data set or ignoring the calculated total system demand would not be appropriate in reflecting the current operational trend. Note that the interconnection likely predates the available data. An example of this data being projected is provided in Figure 18.*

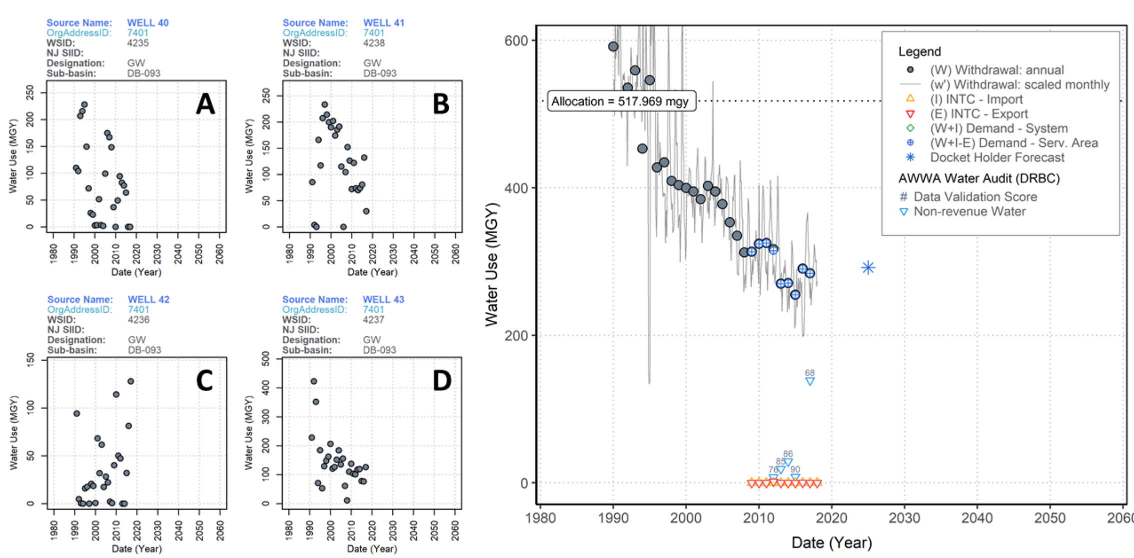

***Figure 12**: An example of water withdrawal data associated with a public water supply system, comprised of four groundwater sources.* *These figures are representative of graphical outputs from the developed projection methodology. (A-D) The data associated with the four groundwater sources which comprise the system, all visibly having poor relationships between time and withdrawal volume. (E) The same data aggregated together to represent water withdrawal at the system level, demonstrating a strong relationship between time and withdrawal volume. An example of this data being projected is provided in Figure 15.*

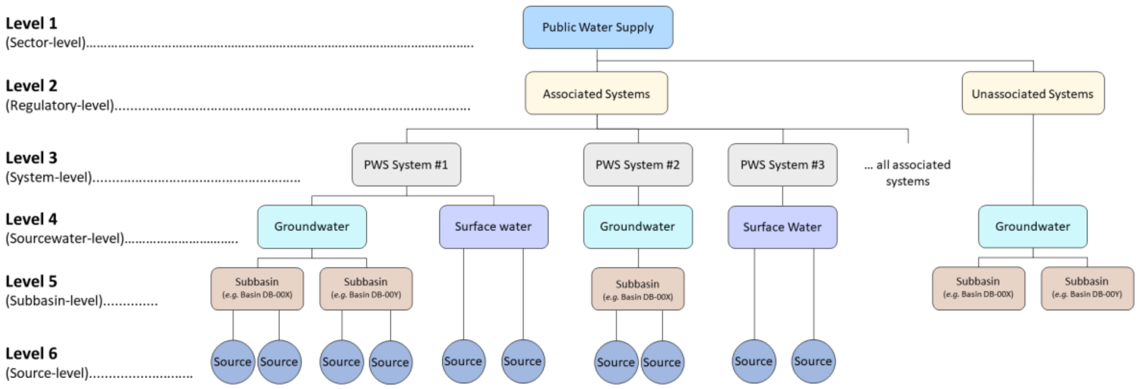

***Figure 13**: **The hierarchical aggregation structure resulting from the disaggregation of public water supply withdrawal data, as performed in this study.** Associated systems (level 3) are considered on an individual basis; while not all possibilities are presented, three example system structures are depicted. Unassociated systems, accounting for about 1% of the Basin's public water supply withdrawal, were included in a single analysis for each state. The way in which public water supply fits into the overall analysis was highlighted in Figure 4.*

3.4.4 Data disaggregation and time-series hierarchy

As has been discussed, the public water supply withdrawal estimates presented in Figure 9 were disaggregated by public water supply system (largely as a link to regulatory metadata), but also to further levels such that projections can support specific planning objectives. As described in Hyndman & Athanasopoulos, 2018, this creates a hierarchical aggregation structure of related time series. For this study, six levels are used as depicted in Figure 13 which will continue to be referenced throughout this report.

The withdrawal data was described in Section 2.1 as having four main parts and being reported at the source-level. Therefore, this disaggregated hierarchy is actually formed by aggregating withdrawal data based on common metadata (e.g., create a system level time-series by aggregating all sources together for a particular system). As withdrawal data has been integrated into the DRBC database over time, it has led to about 3,400 unique public water supply sources with reported withdrawal data (WSIDs), which are associated with approximately 910 unique system level identifiers (OAIDs). The following describes how each of the levels were created:

- ***Level 6*** – raw data are reported at the source level (i.e., WSID; OAID; time; volume).
- ***Level 5*** – coordinates associated with each source were used in a desktop GIS analysis to extract a "Basin-ID" related to which Sloto & Buxton, 2006 subbasin each source plots within. Withdrawal data for a particular system can then be aggregated by Basin-ID to the subbasin level.
- ***Level 4*** – the sourcewater designation (i.e., SW or GW) is standard metadata associated with each source; therefore, data can be aggregated by this metadata.
- ***Level 3*** – the associated OAID is part of each unique data point's metadata, and therefore withdrawal volumes can be aggregated easily. The OAID is closely related to a "system-level," and only in a few circumstances does a system include multiple OAIDs.
- ***Level 2*** – this was outlined in Section 3.3.4.
- ***Level 1*** – this was outlined in Section 1.5.

3.4.5 Projecting withdrawal data

Withdrawal data were primarily used for the years 1990-2017 which is the date range within which the data represent a "complete" Basin-wide picture. In certain circumstances where data were available and beneficial, withdrawals beyond 2017 may have been incorporated into system-level projections on a case-by-case basis. These post-2017 withdrawals are not shown in figures throughout the report, nor used for comparison against aggregated models, as it would not represent a complete picture of the data.

3.4.5.1 Report-based methodology

The general concept was to develop a single analytical process which was able to be applied to the entire dataset in a consistent manner. Due to the complexity of each system, the desire to weight external influences such as metadata without creating a more complicated extrapolation model, and the possible levels of projections and multiple regressions per level, it was determined that a report-based format would be the most appropriate means of summarizing all possible results and relevant metadata. This was accomplished in the following steps:

1. Required data from the DRBC integrated database and external databases were saved as static input files.
2. A program was developed using the computer language *R* (R Core Team, 2021). Given a specific system, data are aggregated to different levels and multiple least-squares regressions are calculated for all sub datasets within each level. Figures, tables of results and tables of metadata are generated and saved as output files.
3. A program was developed using the computer language *Visual Basic for Applications* (*VBA*) in *Microsoft Excel* to combine all output files (figures and tables) into a six-section PDF report. An example report is provided for reference in Appendix B. The six sections are:
    a. Cover sheet (results)
    b. Data summary
    c. System-level analysis
    d. Subbasin-level analysis (Sloto & Buxton, 2006 defined 147 subbasins)
    e. Subbasin-level analysis (SEPA-GWPA defined 76 subbasins)
    f. Source-level analysis

Most aspects of the analysis were automated through this report generation process; however, it was determined that the final selection of specific projection equations should not be automated. At some point external factors affecting withdrawal data required review which was beyond the scope of programming logic for this study. Therefore, the report format was created to give DRBC staff the tools necessary to review the analysis, modify parameters as appropriate, and make sound judgements on which proposed projection equation(s) were best suited to describe the system withdrawal trends. Once a decision was finalized, results were saved in a master metadata file and the results included on the cover page in subsequent report runs.

3.4.5.2 Projected hierarchy levels

Technically, only two hierarchy levels are projected (although this study includes a third category by nomenclature). The two lowest levels of data aggregation are the only datasets which get projected (source-level and subbasin-level). However, there are circumstances where these levels provide the same data as the system-level, in which case it may be referred to as a "system-level" equation/projection. Two specific examples are:

1. As depicted in Figure 13 (example PWS System #2), this is a system comprised only of groundwater sources within the same subbasin. In this scenario, the subbasin-level and system-level provide the same data.
2. A system comprised of only one source (e.g., surface water intake) has the same data at all levels.

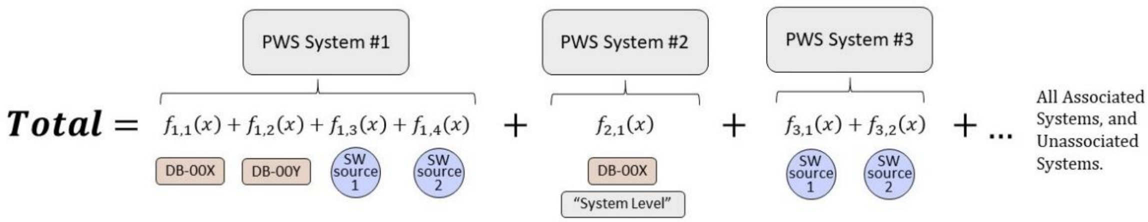

***Figure 14**: **Conceptualization of the bottom-up approach, based on the example associated public water supply systems provided in Figure 13.** Note that number of projections $f_{i,j}(x)$ for each system is based on the hierarchy and structured to meet planning objectives. In each system, the shape under the equation indicates what hypothetical sub-dataset the projection would be for.*

The report generated for each system provides an analysis for all three levels of data aggregation (system, subbasin and source) regardless of the scenarios described above, assuming data are available (e.g., subbasin-levels are only assessed for groundwater).

3.4.5.3 Bottom-up projection approach

As described in Section 3.2, there were many reasons for projecting the withdrawal data of individual public water supply systems, a primary reason being the increase in projection accuracy. Based on the discussion in Section 3.4.5.2, projections for each system were generally performed at the two lowest levels in the disaggregation hierarchy. The concept of the bottom-up approach is that the summation of these more accurate sub-level projections will create a coherent top-level projection.

It was discussed previously that the dataset for each system may not start at the same year for various reasons; therefore, the independent variable x is defined such that equations may add up regardless of the dataset's starting date (i.e., $x = Year - StartYear + 1$). For each dataset, this creates a normalized sequence, $x = 1,2,3 \ldots n$, where n is the total number of datapoints. Considering the example associated public water supply systems outlined in Figure 13, a conceptualization of the bottom-up approach is provided in Figure 14. This schematic is intended to not only help explain which projection equations would be associated with each hypothetical system, but how these projections can re-aggregate at the Basin scale. It is also clear from this schematic that projection equations can be re-aggregated to sub-levels such as source-type or sub-watershed.

3.4.5.4 Assumptions

There are multiple assumptions which are necessary to state in a study of this scale and detail. Primary assumptions of importance are outlined here:

1. As was stated in CDM & DRBC, 2005, trend extrapolation inherently assumes that "*the rate of change in water use over the recent past is assumed to continue into the future at the same rate of change.*" Consequently, while this analysis may account for phenomena in historical data such as structural breaks (one-time offsets) and operational changes (e.g., trend reversal), this study does not attempt to forecast future structural breaks or operational changes.

2. It was also stated in CDM & DRBC, 2005 that underlying assumptions of trend extrapolation are either "*(a) there is no correlation between time and factors that affect water use, or that (b) time and factors that affect water use are perfectly correlated*". This study does not ignore that there are many factors which affect water use, such as those which are commonly used for indirect projections. It is understood that while option (b) is not the best assumption, it is necessary in this application. However, the authors of this study suggest that this assumption has been mitigated to some degree

through the inclusion of metadata in a review process which compares multiple trend extrapolation scenarios against the metadata.

3. Pump capacities are not considered in selecting projections because it is assumed that if the projected withdrawal were to exceed the aggregated pump capacity, additional sources would be added in the same planning area to meet the demand (e.g., installation of a new well).

4. While uncommon, projected equations will sometimes return a trend towards zero withdrawal; however, more often the calculated predictive interval (e.g., 95% probability) will extend below zero. In these instances, negative values are replaced with zeros as a lower limit because it is not logical that a facility once requiring water for operation would have a net negative withdrawal in the future (i.e., inject water into the ground).

3.4.5.5 Projection Equations

Monthly withdrawal data were aggregated and projected at the annual timescale for this analysis in order to accommodate planning objectives focused on average annual demand. The primary method of extrapolating data was an ordinary least squares (OLS) regression. If none of the OLS models were sufficient in projecting the withdrawal trends, other methods of projection were utilized which include mean-value projections, top-down projections, and projections with structural break offsets. Each of these projection methods is described in the subsequent sections. Of the 600 projection equations resulting from this analysis of public water supply, a summary of the equation distributions is provided in Table 8.

***Table 8**: Summary of methods used in projecting withdrawal data. The corresponding value for the average withdrawal volume modeled by the equations from 2013-2017 is also presented as reference.*

Model class	Model group	Number of equations	Model average 2013-2017 (MGD)	Percent MGD
Associated	OLS	333	570.871	70.1%
	Mean-value	138	197.55	24.3%
	Top-down	11	5.886	0.7%
	Structural break	21	32.592	4.0%
Unassociated	OLS	32	3.074	0.4%
	Mean-value	65	3.978	0.5%
	Top-down	0	0	0.0%
	Structural break	0	0	0.0%

Ontelaunee Reservoir Dam
near Reading, Pennsylvania.
Credit: © Melissa Kopf
Used with permission

***Table 9**: Ordinary least squares regression forms. The Y and X variables represent the transformed data, while the table entries represent how the data was transformed.*

Name	Linear Form: $\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x$		Simplified form
	Y	*X*	
Linear	$\hat{y}$	x	$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x$
Logarithmic	$\hat{y}$	$ln(x)$	$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 ln(x)$
Exponential	$ln(\hat{y})$	x	$\hat{y} = e^{\hat{\beta}_0} e^{\hat{\beta}_1 * x}$

where,

x = (Year – Start Year + 1) i.e. x=1,2,3…n
$\hat{y}$ = the projected withdrawal volume (MGY)
$\hat{\beta}_0$ & $\hat{\beta}_1$ = coefficients from the least-square regression

3.4.5.5.1 Ordinary Least Squares

The preferred method for extrapolation was an OLS regression applied to historical withdrawal data. Three forms of an OLS regression were calculated at each hierarchal level dataset as a potential best-fit to the data, as indicated in Table 9. Each regression was developed as a linear model in the general form $\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x$. The logarithmic and exponential regressions were calculated using natural log-transformed *x* and *y* data, respectively, initially yielding linear equations of transformed data. Once each equation is un-transformed, the models can be simplified as expressed in Table 9.

The following statistical parameters were considered in determining which regression provided the best extrapolation of historical data. The general way in which each was considered is indicated as follows:

- *Adjusted coefficient of determination ($\bar{R}^2$)* was calculated for each OLS regression and used as a reference for the goodness of fit. While the number of predictors in this analysis does not change (*k=1*, time), the $\bar{R}^2$ was used over the un-adjusted value because it also accounts for the number of observations; this was considered essential as each projected public water supply system does not have the same length time-series. As indicated in Hyndman & Athanasopoulos, 2018, there are no set rules for what defines a "good" $\bar{R}^2$ value. It was standard practice during the review of a dataset to favor regression models with higher $\bar{R}^2$ values; however, influences of metadata on withdrawal projections were also considered during reviews. Therefore, the form of OLS regression returning the highest $\bar{R}^2$ for a given dataset was not automatically selected as the most appropriate model. This concept is demonstrated by overlaying the three possible OLS regressions to the same example public water supply data in Figure 12, shown now as Figure 15. The three possible OLS regressions all have similar $\bar{R}^2$ values; however, considering the plausibility that the system will not reach zero withdrawal and considering the docket holder's own projection, the logarithmic regression returning the lowest $\bar{R}^2$ is considered to be the most appropriate extrapolation.
- *probability value (p-value)* was also obtained for each regression. A *p-value* threshold of *p-value<0.05* was used in this study as a reference point when comparing different forms of OLS regressions applied to the same dataset, due to its historical use in suggesting whether or not a relationship may be considered significant.

3.4.5.5.2 Mean-value projections

In some cases, the least-squares regression returned poor statistical indicators; however, the data visually appeared to be consistent with time. In these instances, an interpretation of a high *p-value* may be that there is not a significant correlation between the data for withdrawal volume and time. Additionally, very low or even negative $\bar{R}^2$ values would suggest that a horizontal line (or mean value) would be a better statistical fit. In these instances, the *coefficient of variation (CV)* of the dataset was also considered, and a determination was made as to whether or not a historical mean withdrawal volume was an adequate projection.

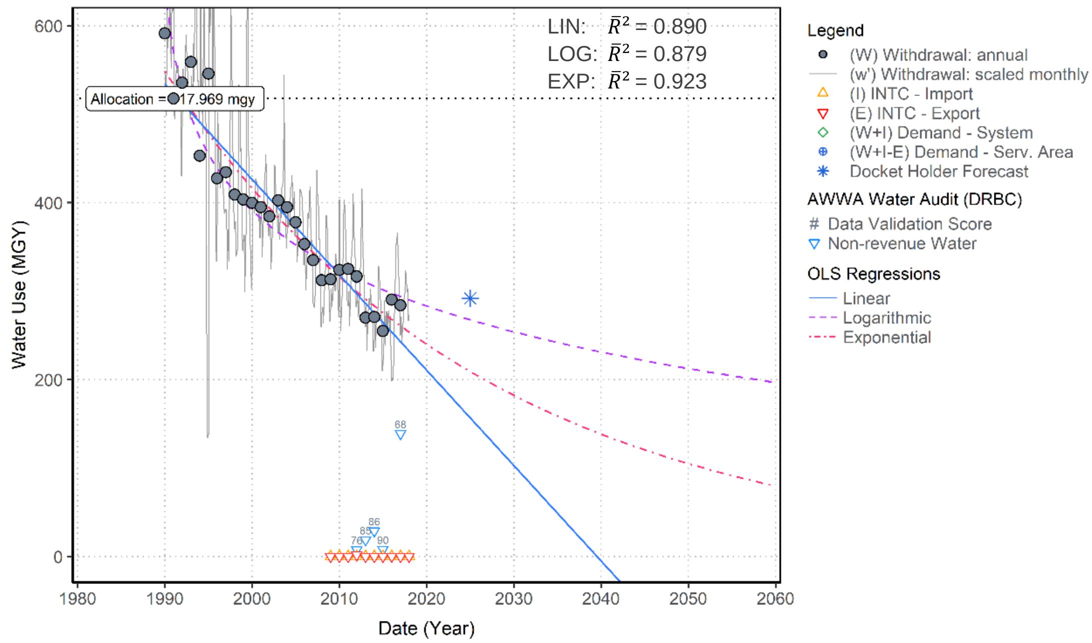

Figure 15: The same example of water withdrawal data as presented in Figure 12, showing three possible projection regressions. *As all four sources were within the same subbasin, the projection was performed at the subbasin (or system) level. The three methods of OLS extrapolation are presented with corresponding $\bar{R}^2$. With similar statistical parameters, it is evident how metadata (i.e. a docket holder's projection provided with a docket application) might influence the selection of an appropriate model.*

3.4.5.5.3 Top-down projections

In a few cases it was observed that a system which required multiple sub-level projections only had some or no statistically adequate results; however, the system-level data returned an adequate least-squares projection. Based on the established hierarchy in Section 4, two general formats of "top-down" methods can be utilized.

1. **Average historical proportions**: As described in Hyndman & Athanasopoulos, 2018, this method disaggregates the high-level projection equation to sub-levels through the application of coefficients based on the sub-level proportions of historical data. It was noted in Gross & Sohl, 1990 that the applicability of such a top-down method is a function of three generalized factors: (1) high-level projection accuracy, (2) sub-level proportion accuracy, and (3) the sub-level projection accuracy. In this study, an emphasis was placed on (3), in that this top-down approach was used out of necessity when sub-level projections were not good, assuming that (1) the system-level projection was adequate.
2. **Difference-based projections**: Similar to the method of average historical proportions, scenarios were also observed where the system-level projection was adequate and all but one sub-level projection were adequate. In this instance, the poor sub-level dataset may have been estimated as the difference between the system-level and the other sub-level projections.

3.4.5.5.4 Structural break offset projections

It was observed that certain public water supply systems may encounter external influences which drastically alter the operational capabilities of the system within a short timeframe (i.e., the time-series undergoes a structural break). Examples of such influences may include the passing of water management regulations or contamination of the water sources which temporarily requires a partial or full shutdown of the system. Instances of this phenomenon were identified visually rather than using a quantified test or algorithm. Two types of structural breaks were observed:

1. A clear change in the operational trend of the system with time (e.g., decreasing withdrawal changing to increasing). This is addressed in Section 3.4.5.8.3.
2. A single structural break causing a clear one-time offset in the time-series.

Regarding this second type, in certain datasets the withdrawal trends prior to the event causing the offset could be modeled and a Heaviside step function applied to the regression around the year of the structural break. A specific example is shown in Figure 16 where the system has temporarily experienced a full shutdown of sourcewater withdrawal. The sudden decrease in withdrawal is observed to be met by an increase in water imports, and therefore the calculated service area demand logically remains at the same order of magnitude.

It is not the scope of this study to make attempts at estimating when a possible resolution of external influences will occur and what resumed withdrawal patterns may look like; therefore, the projection in Figure **16** was left at zero moving into the future. The benefit of using the Heaviside step function is largely for the purpose of checking aggregated model accuracy (i.e., a sudden drop in withdrawal is not unaccounted for in the model), as opposed to simply not projecting this system's data. There were other instances observed where, rather than a full shutdown, the Heaviside step function was used as a partial offset, and the projected trend continues as an adjusted magnitude.

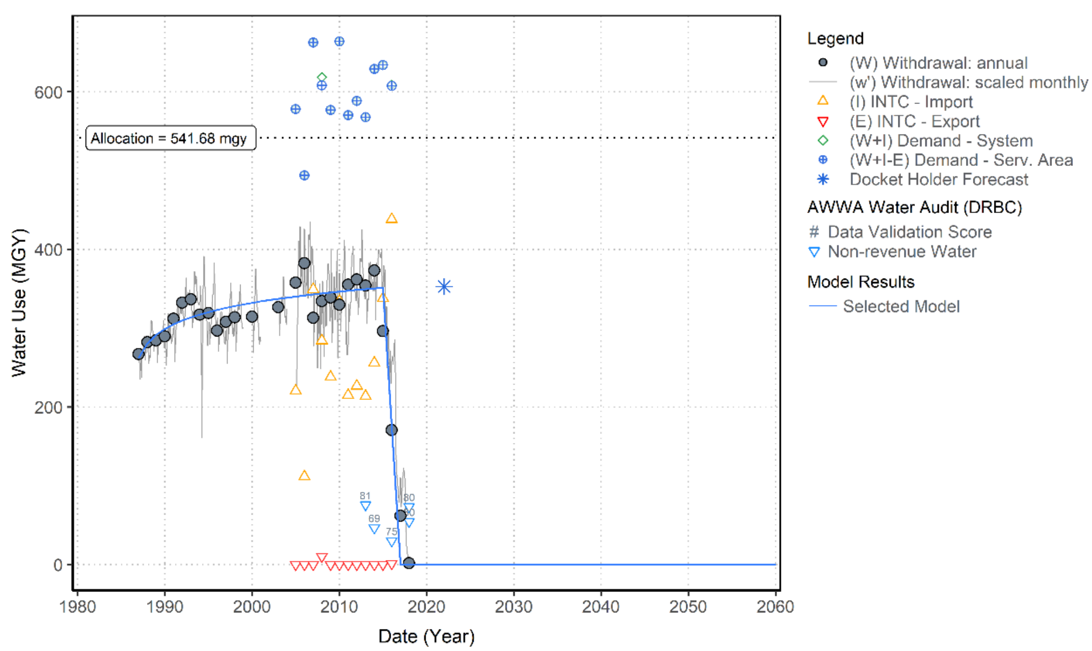

Figure 16: An example of a public water supply system where all groundwater sources are in one subbasin and the system has experienced a temporary shutdown of water withdrawal. *It is evident that there has been a subsequent increase in water imports, resulting in a consistent service area demand. Excluding the last four withdrawal points, it is observed that the system trend prior to the external influence was well represented by a logarithmic function. The logarithmic regression was then corrected through the addition of a Heaviside step function to give the equation plotted in blue.*

3.4.5.6 Prediction Intervals

3.4.5.6.1 OLS and mean-value model classes

In this analysis, a mean-value projection is considered as a linear projection with a slope of zero; therefore, OLS equations and mean-value equations are both included in this discussion. Referring to Table **8**, these two model classes account for about 92.2% of the equations describing public water supply and correspond to approximately 95.2% of the average modelled volume (MGD) between 2013-2017. To quantify uncertainty in the analysis, an 80% and 95% prediction interval were calculated for each projection ($t_{\alpha,v}$ = 1.28 and 1.96, respectively). As indicated in Hyndman & Athanasopoulos, 2018, the prediction interval was taken to follow the form:

$$\hat{y} \pm t_{\alpha,v} * \hat{\sigma}_e \sqrt{1 + \frac{1}{n} + \frac{(x-\bar{x})^2}{(n-1)s_x^2}}$$

where,

- $\hat{y}$ = the projected withdrawal volume (mgy)
- x = (Year – Start Year + 1) i.e. *x*=1,2,3…*n*
- $\bar{x}$ = mean of the observed *x* values
- $t_{\alpha,v}$ = Student t-statistic
- $\hat{\sigma}_e$ = residual standard error
- *n* = total number of observations
- s_x^2 = standard deviation of observed *x* values

The use of this prediction interval equation for each individual projection is based upon three assumptions, which were addressed as described below:

1. *The model follows the general form* $\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x$. Therefore, the prediction intervals were calculated based upon the transformed-linear forms of the equations, and the prediction interval results were un-transformed to the original scale.
2. *The residual errors are normally distributed*. The residuals $(y - \hat{y})$ of the transformed-linear regressions were assessed using a formal Shapiro-Wilk normality test. A passing result of the test suggests that the residual errors are normally distributed.
3. *The residual errors are independent of each other (i.e., "uncorrelated").* The residuals of the transformed-linear regressions were tested using the Ljung-Box test for autocorrelation. A passing result of the test suggests that the residual errors are uncorrelated.

The results of the statistical tests for normality and autocorrelation are summarized in Table 10. While assessments were also performed for normality considering thresholds placed on skewness and excess kurtosis, and for autocorrelation using the Box-Pierce test, the tests included in Table 10 reflect the more conservative results. It is apparent that the majority of equations likely have normally distributed residual errors and that this corresponds with about 88.4% of the average modelled withdrawal from 2013-2017. Not surprising as is commonly found in time-series, the test for autocorrelation has a higher percentage of failing results. Roughly 44.4% of the average modelled withdrawal from 2013-2017 have uncorrelated residuals. Considering the results of Table 10 in conjunction with the scope and application of this study, it was determined that the test results are good enough to apply for the entire sector, providing the benefit of a consistent methodology. However, this discussion was considered important to keep the limits of the assessment in perspective while dealing with real-world data.

***Table 10**: A summary of the analysis performed to test assumptions associated with the prediction interval calculation for the OLS and mean-value projections.*

Shapiro-Wilk (Normality)	Ljung-Box (Uncorrelated)	Number of Equations	Modelled Avg. 2013-2017 (MGD)	Percent MGD
PASS	PASS	300	287.826	37.4%
PASS	FAIL	138	362.146	47.0%
FAIL	PASS	68	54.74	7.1%
FAIL	FAIL	37	65.496	8.5%
	Summary Totals:	543	770.208	100.0%

3.4.5.6.2 Other equation model classes

Prediction intervals for equations in other model classes accounted for only 7.8% of the equations describing public water supply and corresponded to approximately 4.8% of the average modelled volume (MGD) between 2013-2017. Based on a review of available literature, no available options for explicitly calculating a predictive interval could be located for these various forms of models. Therefore, a standard approach was taken as:

$$\hat{y} \pm t_{\alpha,v} * \hat{\sigma}_e$$

3.4.5.7 Consumptive use

In order to calculate a projection for consumptive use, each equation has a CUR assigned to it from one of the various datasets described in Section 2.2.3. For public water supply, it was assumed that only the default value provided in Table 5 would be used. Therefore, each projection equation (and associated prediction intervals) is multiplied by the CUR to obtain another set of equations describing consumptive water use.

Specific to unassociated data (depending on the withdrawal sector), a single projection equation may be compromised of sources with multiple individual consumptive use categories (e.g., industrial). As this dataset is typically small and not analyzed on a system-by-system basis, all unassociated equations are assigned the withdrawal sector default CUR.

3.4.5.8 Data quality

Data quality assurance and quality control (QA/QC) were performed in three general categories throughout the analysis and may have resulted in data being excluded from a particular projection: source verification, an algorithm to assess the “completeness” of each annual withdrawal datapoint, and a combination of visual data review and best professional judgement. The QA/QC procedures were essential in helping to produce the most logical projections from the available data and were implemented in the order listed.

3.4.5.8.1 Source verification

It was discussed in Section 3.3.4 that the verification of sources against existing regulatory approvals was a part of the analysis methodology. There are four general cases where data associated with a withdrawal source may have been removed from the projection analysis:

1. The withdrawal source could not be verified as either an active or decommissioned source against active regulatory approvals.
2. The data were determined to represent duplicate data reported under another source.

3. The singular data source represented “combined data sources” (e.g., an old method of reporting), and it could not be verified that this did not overlap with individual source data (e.g., a new method of reporting) therefore causing duplication of reported water withdrawals.
4. The system is located near the Basin boundary, and it is determined that a source is not located within the Basin.

3.4.5.8.2 Annual withdrawal completeness

The planning objectives of this analysis are focused on average annual withdrawal demand, so monthly withdrawal data were aggregated to project annual withdrawal volumes. Therefore, it was necessary to check that each annual point accurately reflects an entire year of system operation. A partial year of operation may result in an artificially low aggregated annual withdrawal volume which skews the projection. An algorithm was developed to check the completeness of each annual datapoint at each projection level. For each year, it counts the number of months which were either not reported, reported zero withdrawal volume, or reported volumes below a defined “low-limit” (e.g., data reported as 0.000001 instead of zero). Default thresholds were established for an annual datapoint to be considered “acceptable,” as shown in Table 11. As an example, a system with three or more monthly datapoints missing, equal to zero, and/or below the low-limit threshold within a given year were omitted from the analysis. An example of data being removed by the algorithm is shown in Figure 17. While almost all analyses used the default QA/QC values in Table 11, it was determined that they may be overridden (ignored) depending upon the specific system. Two examples justifying the removal of such an algorithm is a system which is inherently seasonal, or a system which regularly withdrawals volumes close to the low-limit threshold.

***Table 11**: Default QAQC values for determining annual datapoint completeness.*

Projection level	Number of months not reported, zero or below threshold	Low-limit threshold (MGM)
System	3	0.010
Subbasin	6	0.001
Source	6	0.001

3.4.5.8.3 Visual review and best professional judgement

There are two situations in which visual review of the data may have resulted in manual removal of data from the projection.

1. **Removal of a specific year of data.**
Advanced tests and algorithms assessing the distribution of monthly data were considered; however, it was ultimately determined that staff review of the dataset would be a more effective tool. If an individual year(s) of data were specified to be removed from a dataset, the year(s) were removed from all projection levels of the analysis. Rationale for the removal of a point may include arbitrarily high monthly datapoints indicating a possible data entry error, low monthly data above the low-limit threshold which is uncharacteristic for a high-volume system, external knowledge of system impacts such as water quality impairments, and best professional judgement to capture the best representation of the system’s withdrawal trend. An example of data being manually removed based on visual inspection is shown in Figure 17.

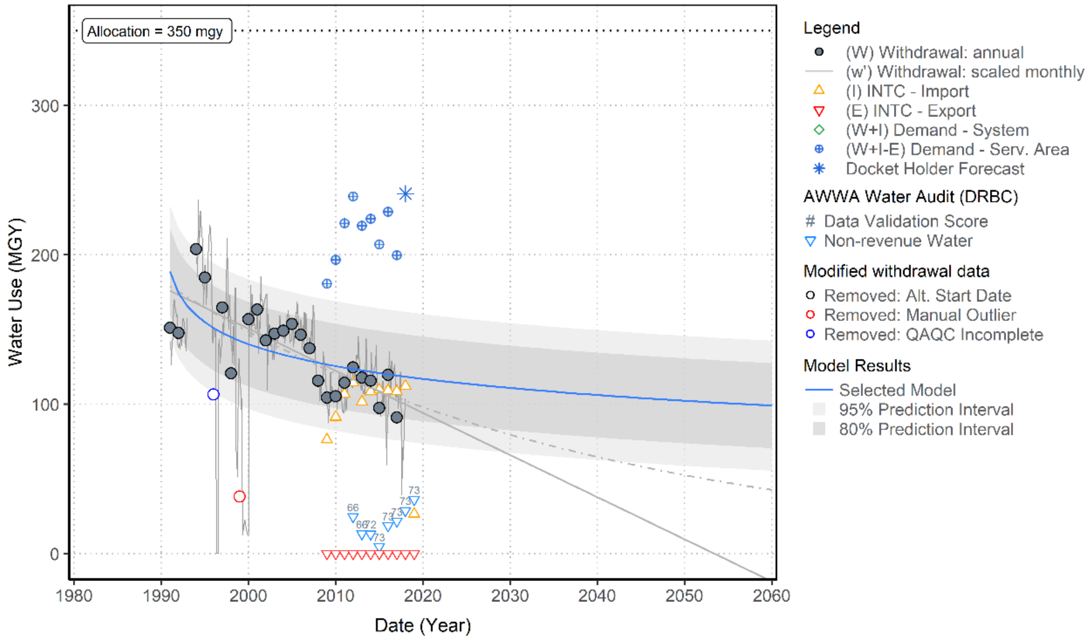

Figure 17: An example projection for a public water supply system where specific years of data have been removed from the analysis. *The datapoint manually removed is the most obvious outlier; however, the low monthly data were above the low-limit threshold, and they were not captured by the QA/QC algorithm. The other datapoint was removed by the QA/QC algorithm as it had at least three months of zero or non-reported data. Removal of these two points helps clarify a logical average annual withdrawal trend for the system.*

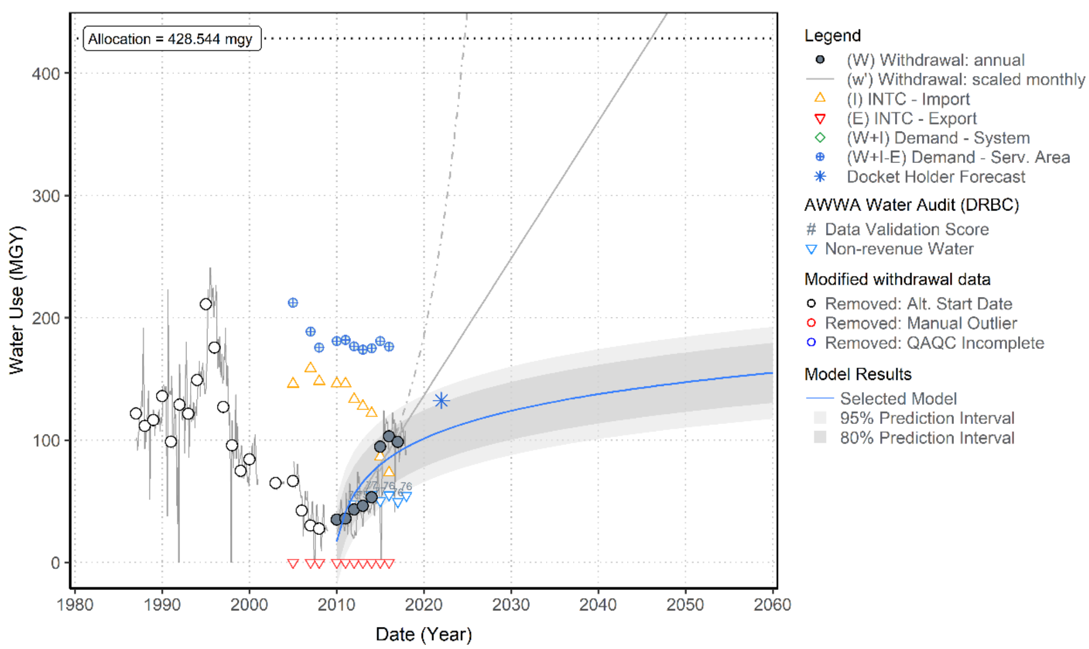

Figure 18: A projection of water withdrawal data for the example system initially presented in Figure 11. *As was previously described, it is apparent that the system's source withdrawals begin to replace bulk purchases. Therefore, the current trend can be projected by forcing the dataset to start in the year 2010. Of three possible regressions, the logarithmic form is the most logical considering not only the Docket Holder's own projection, but the visual trend of the service area demand calculated data.*

2. **Adjusting the starting year of a projection.**
   One intent of this study is to capture *current* withdrawal trends for extrapolation. While system withdrawals change with time, the changes are influenced by external determinants. Population is a common predictor of water use, but other factors such as the owner of the system, the specific person operating the system, infrastructure repairs, weather and the economy may all influence withdrawals to some degree. As stated in Section 3.4.5.5.4, withdrawal trend reversal was a common observation in this study. Therefore, the analysis was setup such that the starting year of the projection for any given dataset could be adjusted as a means of capturing the current trend. An example of this concept is depicted in Figure 18.

3.4.5.9 Limitations

A common practice in forecasting is to divide a given dataset into a "training set" and a "test set." The model is only developed using the training set, whereas the test set is used to help evaluate the model's accuracy. As noted in Hyndman & Athanasopoulos, 2018, the test set may typically be as much as 20% of the total data set; additionally, the maximum forecast horizon should only be as long as the test set. These concepts pose challenges for this analysis, as the datasets available are limited. Projections are made using annual datapoints to capture the annual average demands and at best extend back only to the late 1980's (Figure 19). Furthermore, it becomes more complicated by the concept of extrapolating "current trends," which may reduce the size of some datasets (e.g. Figure 18). As time continues and additional data becomes available, it is the authors' hope that these limitations will become less constraining. For the time being, these issues are addressed in two ways:

1. Due to the limited size of datasets for individual systems, projections were developed using the entire available time-series. However, once the individual projections are aggregated together to represent broader trends, it is possible to determine a year at which the model is considered 99% complete. This is demonstrated for the Basin-wide assessment in Figure 19. For each of the 600 projection equations, the Calendar Year 2017 (CY2017) modelled withdrawal is considered as a running percentage of the total modelled CY2017 withdrawal, calculated based on the starting year of each equation. Therefore, a specific year can be determined when the equations included in the aggregated model account for 99% of the modelled 2017 volume. In this scenario, the aggregated Basin-wide model results may be compared against the aggregated Basin-wide data for the years 2010-2017. The results and comparison of the Basin-wide scenario are presented later in Figure 21 and Table 13, but this concept is applied throughout the study.
2. The forecast horizon for this study is through the year 2060 based on planning objectives of the Delaware River Basin Commission. By indicating a year at which point a model is considered complete by the method above, the same timespan can be visually identified extending beyond the dataset as necessary.

Example of testing at a groundwater well for public water supply.
Credit: Bob Damiani, DRBC

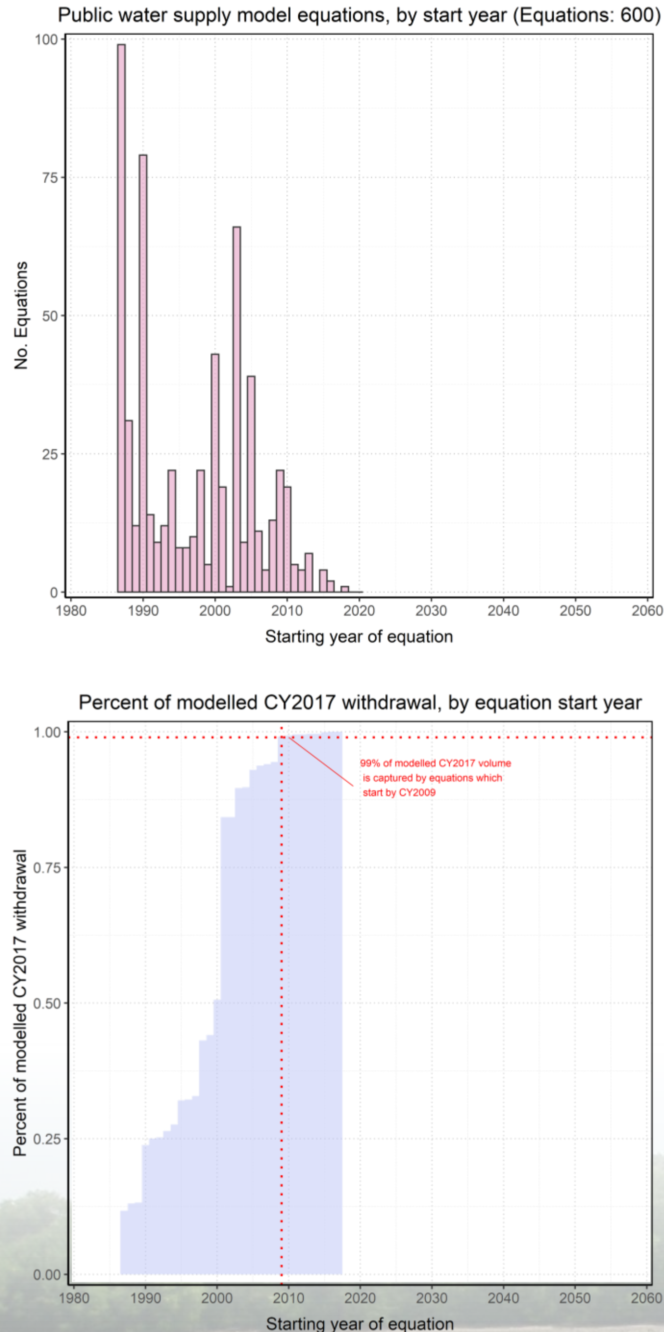

***Figure 19**: (Top) A summary of the starting year for projection equations in the public water supply sector. (Bottom) The representative CY2017 modelled volume corresponding to the equations, as a running total percentage.*

A water filtration plant near the Delaware River in Bucks County, Pennsylvania. Credit: Chad Pindar, DRBC

3.5 Results

3.5.1 Total water withdrawal

The projected withdrawals from the Delaware River Basin by the public water supply sector in each state are presented in Figure 20, and a summary of the state-level model results are provided in Table 12. The results are then aggregated to provide a Basin-level projection in Figure 21, and a summary of the Basin-level model results are provided in Table 13. The data release supporting this model is provided in Appendix A as Table A-2. Considering the results provided in these two figures, there are multiple conclusions which can be summarized:

1. These projections broadly represent the rate/volume of water projected to be withdrawn by public water suppliers in order to meet the demands of all end-users (residential, commercial, industrial, etc.).
2. **Basin states:** Building on the initial conclusion that peak water withdrawal has already occurred in each state, it is evident from Figure 20 that continued decreases are projected for New York, New Jersey and Pennsylvania. However, it is worth noting that the projected withdrawals in Delaware increase very slightly over time. As the scale of data is vastly different between state models, it is important to distinguish between the y-axis scales of each plot.
3. **Basin-wide:** Overall, the average annual water withdrawal from the Delaware River Basin by public water suppliers is projected to continue decreasing, as shown in Figure 21. The model decrease from 2017 to 2060 is approximately 34.610 MGD, which is a 4.3% reduction. It was determined that 2010 is the year when projections represent over 99% of the modelled 2017 withdrawal, highlighted in Figure 21 by the red dashed line. From this analysis, there is relative agreement between the aggregated projections and historical data from 2010-2017, suggesting a coherent model which is comprised of 600 projection equations. The prediction interval shown with the Basin-wide projection is the aggregation of prediction intervals for each individual projection. The general order of magnitude of the 95% prediction interval ranges from about (-18.5)/(+19.4)% in 2020 to about (-21.6)/(+24.5)% in 2060, whereas the 80% prediction interval ranges from about (-12.3)/(+12.6)% in 2020 to about (-14.5)/(+16.0)% in 2060. While conservative, these values are important to consider as they provide a means of quantifying uncertainty in the projection, stemming from the quality of data used at the system- and sub-system levels.

In many cases, a water supply system lies within the same Sloto & Buxton, 2006 147-subbasin and SEPA-GWPA subbasin; therefore, the groundwater projection equation will be the same for each model. However, there are instances where a system is within the same 147-subbasin but spans multiple SEPA-GWPA subbasins. This complicating factor is what drives the need for a second model specific to the SEPA-GWPA subbasins. The projected withdrawal from the SEPA-GWPA by the public water supply sector is presented in Figure 22, and a summary of the model results is provided Table 14. The data release supporting this model is provided in Appendix A as Table A-3. The resulting projection indicates very slight continued decrease in total withdrawal volume, nearing a constant value projection.

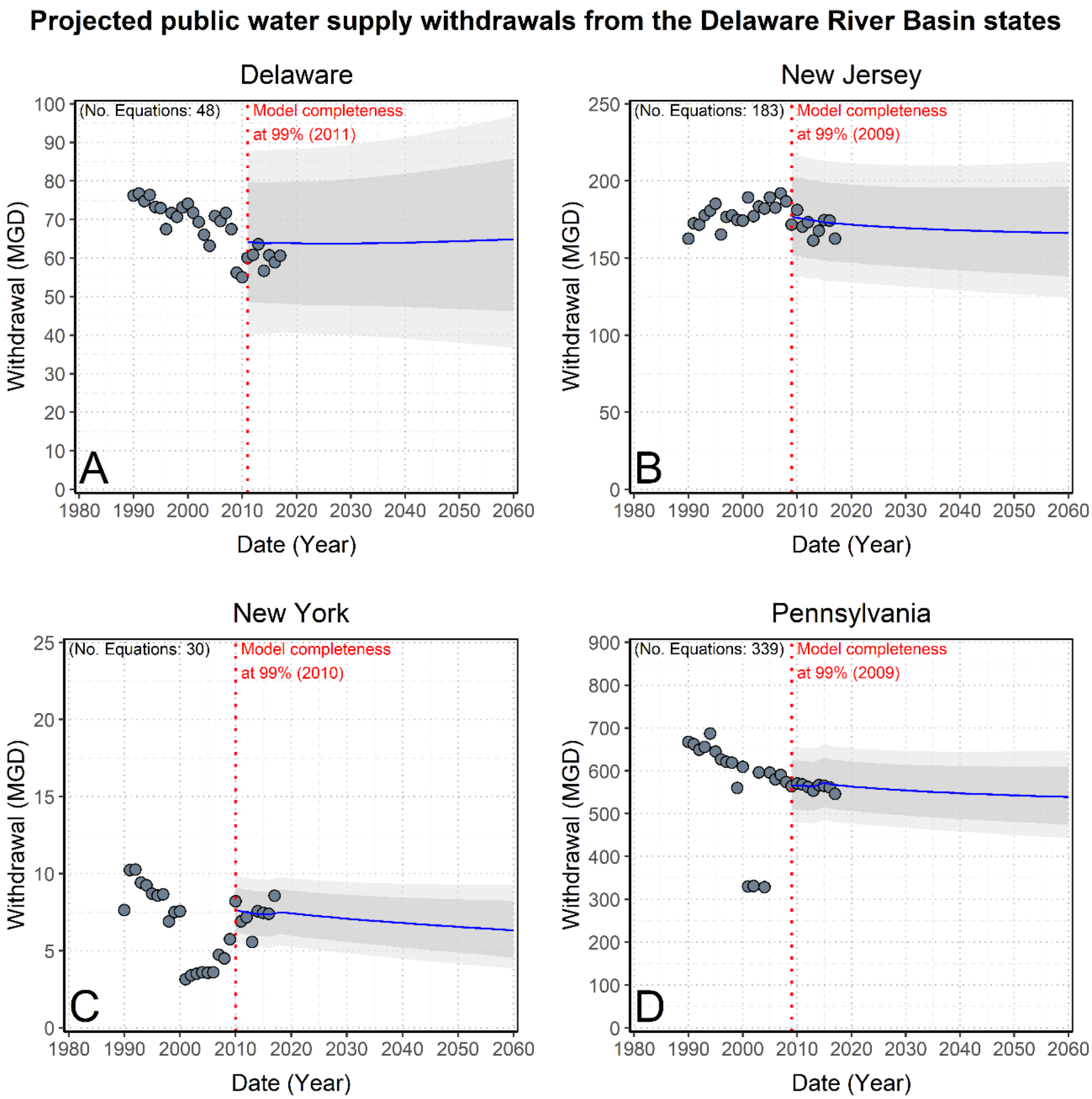

Figure 20: Projected public water supply withdrawals from the Delaware River Basin states. *The historical data for each state is the same as was presented in Figure 8. In these plots, the red line indicates the year at which models are considered 99% complete (by withdrawal volume) based on the starting year of individual projections. Prediction intervals were aggregated in the same manner as projection equations. The results supporting these figures are summarized in Table 12. Data supporting these projection figures are provided for reference in Table A-2.*

__Table 12__: Summary of results supporting Figure 20 for a basin-state projection of total water withdrawals by the public water supply sector of the Delaware River Basin.

State	Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
					lwr80	upr80	lwr95	upr95
Delaware	2013	63.565	63.994	0.670	48.430	79.642	40.330	87.955
	2014	56.693	63.908	12.730	48.322	79.580	40.297	87.907
	2015	60.682	63.837	5.200	48.222	79.541	40.310	87.884
	2016	58.922	64.016	8.650	48.356	79.767	40.542	88.134
	2017	60.573	63.961	5.590	48.262	79.752	40.542	88.141
	2020	*NA*	63.841	*NA*	47.995	79.785	40.502	88.256
	2030	*NA*	63.769	*NA*	47.673	80.525	39.984	89.427
	2040	*NA*	63.995	*NA*	47.307	81.914	39.061	91.433
	2050	*NA*	64.394	*NA*	46.775	83.715	38.037	93.980
	2060	*NA*	64.911	*NA*	46.170	85.799	36.814	96.897
New Jersey	2013	161.315	174.380	8.100	149.565	200.294	136.631	214.359
	2014	167.605	173.957	3.790	149.154	199.842	136.255	213.819
	2015	174.574	173.113	0.840	148.317	198.978	135.475	212.933
	2016	174.184	172.739	0.830	147.956	198.702	135.173	212.700
	2017	162.588	172.588	6.150	147.808	198.545	135.065	212.531
	2020	*NA*	171.668	*NA*	146.894	197.661	134.218	211.642
	2030	*NA*	169.509	*NA*	144.253	195.969	131.580	210.189
	2040	*NA*	168.051	*NA*	142.027	195.481	129.092	210.189
	2050	*NA*	166.995	*NA*	140.008	195.720	126.695	211.069
	2060	*NA*	166.213	*NA*	138.166	196.419	124.551	212.546
New York	2013	5.566	7.438	33.630	6.016	8.897	5.306	9.672
	2014	7.558	7.383	2.320	5.962	8.843	5.252	9.619
	2015	7.462	7.391	0.950	5.957	8.867	5.240	9.651
	2016	7.402	7.343	0.800	5.909	8.821	5.191	9.606
	2017	8.569	7.423	13.370	5.989	8.904	5.270	9.691
	2020	*NA*	7.427	*NA*	5.982	8.915	5.260	9.708
	2030	*NA*	7.085	*NA*	5.577	8.634	4.854	9.468
	2040	*NA*	6.802	*NA*	5.214	8.450	4.485	9.343
	2050	*NA*	6.554	*NA*	4.881	8.330	4.153	9.285
	2060	*NA*	6.328	*NA*	4.561	8.248	3.848	9.271
Pennsylvania	2013	553.821	563.165	1.690	506.461	620.971	477.603	652.024
	2014	566.293	567.732	0.250	511.163	625.433	482.333	656.425
	2015	565.094	573.066	1.410	515.641	631.590	486.331	663.029
	2016	561.155	569.337	1.460	512.299	627.765	483.173	659.164
	2017	545.986	567.143	3.880	510.190	625.505	481.098	656.885
	2020	*NA*	563.573	*NA*	506.481	621.941	477.312	653.383
	2030	*NA*	554.414	*NA*	495.837	614.553	467.050	646.822
	2040	*NA*	547.905	*NA*	487.752	611.068	458.342	644.812
	2050	*NA*	542.968	*NA*	480.874	609.738	450.483	645.416
	2060	*NA*	539.053	*NA*	474.722	609.874	443.352	647.661

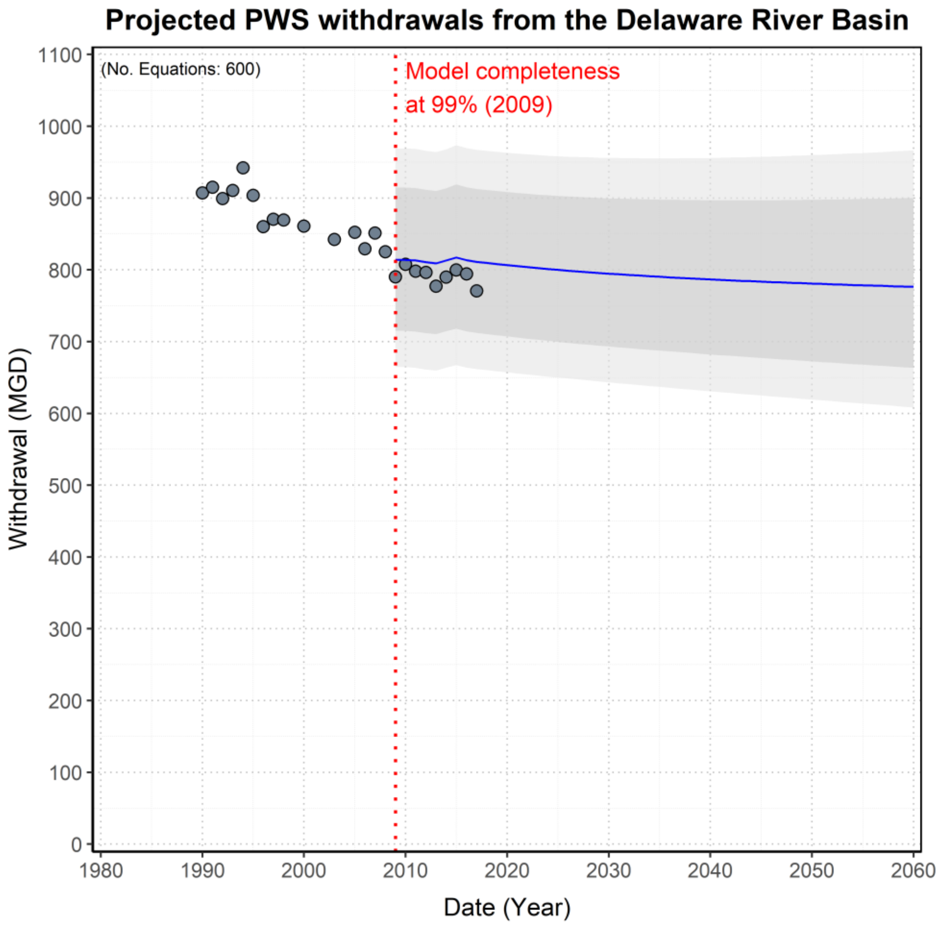

Figure 21: Projected public water supply withdrawals from the Delaware River Basin. *Aggregated projection results indicating a Basin-wide projection for water withdrawals needed to meet the public water supply demand. The results supporting this figure are summarized in Table 13. Data supporting this projection, including a breakdown by sourcewater, is provided for reference in Table A-2.*

Table 13*: Summary of the aggregated projection results providing a Basin-wide projection for water withdrawals needed to meet the public water supply demand.*

Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
				lwr80	upr80	lwr95	upr95
2013	784.267	808.976	3.15	710.472	909.804	659.870	964.011
2014	798.149	812.980	1.86	714.600	913.698	664.137	967.769
2015	807.811	817.407	1.19	718.137	918.976	667.356	973.497
2016	801.663	813.436	1.47	714.519	915.055	664.078	969.604
2017	777.716	811.115	4.29	712.249	912.706	661.975	967.247
2020	NA	806.509	NA	707.353	908.301	657.292	962.988
2030	NA	794.777	NA	693.340	899.681	643.468	955.907
2040	NA	786.754	NA	682.299	896.913	630.980	955.777
2050	NA	780.910	NA	672.538	897.504	619.367	959.750
2060	NA	776.505	NA	663.619	900.340	608.564	966.375

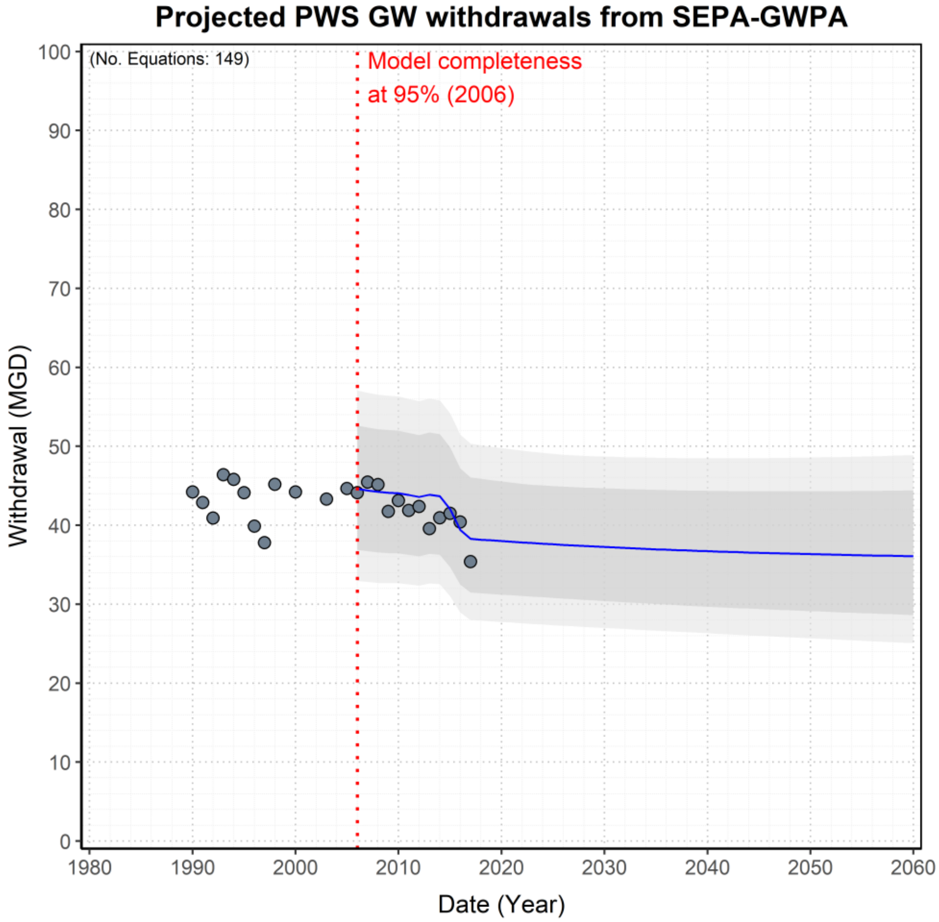

Figure 22: Projected public water supply groundwater withdrawals from the Southeastern Pennsylvania Groundwater Protected Area. *The results supporting this figure are summarized in Table 14. Data supporting this projection, including a breakdown by sourcewater, is provided for reference in Table A-3.*

Table 14*: Summary of results supporting Figure 22 for the projection of annual average water withdrawal by public water supply facilities within SEPA-GWPA.*

Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
				lwr80	upr80	lwr95	upr95
2013	39.582	43.870	10.83	36.372	51.757	32.648	56.065
2014	40.934	43.667	6.68	36.268	51.530	32.558	55.820
2015	41.498	42.026	1.27	34.715	49.868	31.013	54.143
2016	40.399	39.397	2.48	32.476	47.210	28.953	51.472
2017	35.398	38.292	8.18	31.488	46.058	28.013	50.315
2020	NA	37.998	NA	31.226	45.539	27.765	49.773
2030	NA	37.250	NA	30.405	44.682	27.002	48.697
2040	NA	36.717	NA	29.691	44.361	26.334	48.476
2050	NA	36.342	NA	29.132	44.297	25.687	48.572
2060	NA	36.084	NA	28.636	44.420	25.089	48.893

3.5.2 Consumptive water use

As was discussed in Section 3.3.4, consumptive use is calculated for the public water supply sector using the default CUR listed in Table 5. The same method of calculation is used to generate projections of consumptive use; therefore, the trends observed will mirror those presented in the previous section, and separate figures have not been presented. However, results for the consumptive use model is provided in data releases in Appendix A as a part of Table A-2 and Table A-3.

3.5.3 Comparison against other studies

3.5.3.1 Delaware

As was discussed in Section 3.2, there have been three finalized reports from the Delaware Water Supply Coordinating Council (WSCC) which have collectively projected public water supply for the three counties in Delaware. In general, these studies were largely based on population projections applied to an established benchmark of water use (e.g. a specific year of historical data). This assessment attempts to normalize the results from the studies such that a comprehensive projection can be referenced. The units used in each study are not directly comparable to each other, nor to those used in this study. Therefore, two methods were used to convert units:

1. The studies for southern New Castle County (DE DNREC et al., 2006) and Kent County and Sussex County (DE DNREC et al., 2014) performed projections for each water purveyor in units of peak daily demand (MGD) which was generally defined as the peak daily recorded withdrawal in a given timespan (e.g. annual). However, the base estimates used in each projection also provided the corresponding average annual demand (MGD) and calculated peaking factor. Therefore, the projections presented in the reports were converted to units of average annual demand (MGD) using the provided peaking factor.
2. The study for northern New Castle County performed projections in units of maximum monthly water demand (MGD) (DE DNREC et al., 2018); this was taken as the recorded peak monthly water demand (June-August) for the year 2011. DRBC datasets for each purveyor were used to calculate a "monthly peaking factor", taken as the ratio of the peak monthly water record to the annual average record for the year 2011. The peaking factor was then applied to the projections to convert the (DE DNREC et al., 2018) results into average annual demands. The same method was used to convert the historical time-series of maximum monthly water demands in (DE DNREC et al., 2018) such that the extrapolated trend could be represented as an average annual demand.

The projection results in each WSCC study were presented by purveyor, which this study then associated with corresponding approvals within the Delaware River Basin. However, it was noted that larger purveyors may operate multiple systems both within and outside the Delaware River Basin (specifically Kent and Sussex counties). The projections for two purveyors in Kent County were included (8/10 systems within the Basin), while two purveyors in Sussex County were excluded (2/15 systems within the Basin). All other purveyors were reasonably placed inside or outside the Basin boundary.

The two earlier WSCC studies both included 2010 within the projection - either within the projection, or as the starting year. The most recent study for Northern New Castle County included data through 2015; however, data from 2011 was selected as the base year for the projection. Therefore, all three studies are reasonably able to portray data for ~2010, 2020 and 2030. While not consistent between WSCC studies, two provided alternate projection "scenarios". As such, it is possible to also present three different scenarios for comparison (all with converted units):

1. The standard population-projection based models.
2. Accounting for the DE DNREC et al., 2014 study which included climate change effects as percent increases (applied to all WSCC studies).

3. The same as the standard models above (1.) but replacing the northern New Castle County population-projection model with the extrapolation of historical data trends.

The results of the WSCC projections aggregated for the Delaware River Basin are presented in Figure 23, overlaying the projection provided by this study.

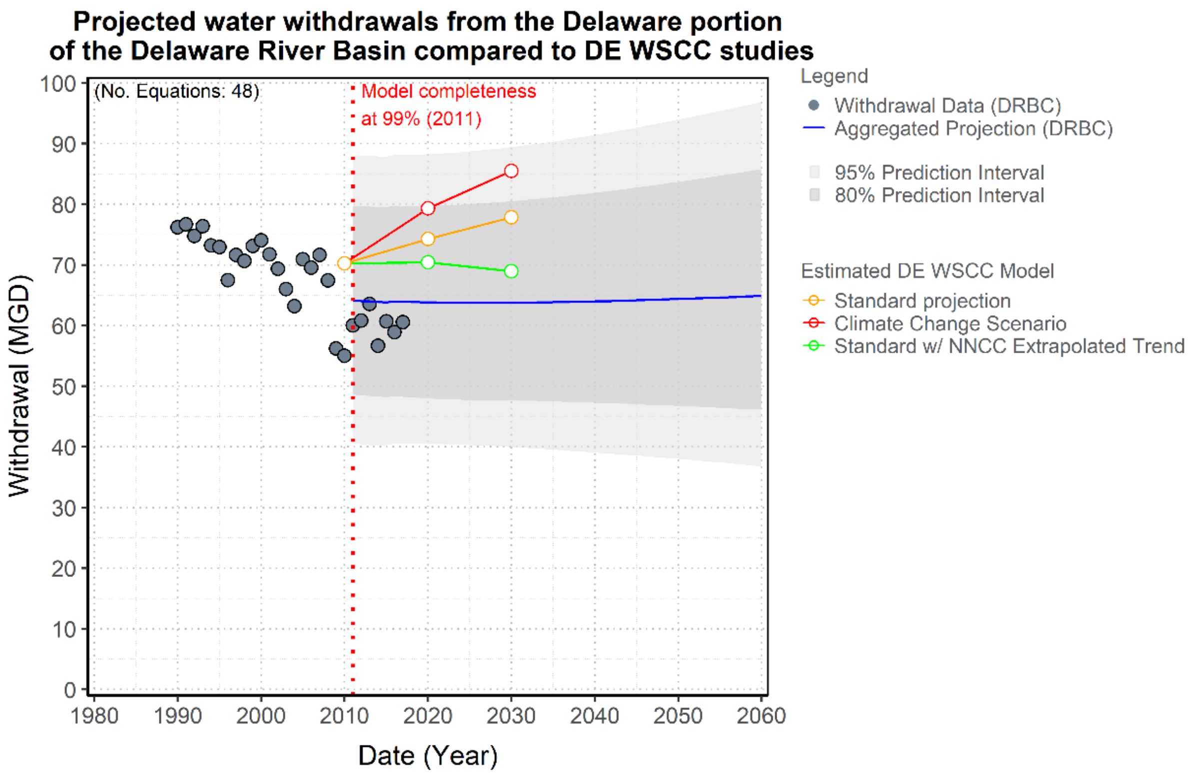

Figure 23: Projected water withdrawals from the Delaware portion of the Delaware River Basin compared to DE WSCC studies. *Three scenarios were estimated from the various data provided in the DE WSCC reports.*

Hoopes Reservoir in
New Castle County, Delaware.
Credit: © Michael Gatti
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3.5.3.2 New Jersey

As was discussed in Section 3.2, the most recent New Jersey Water Supply Plan (2017-2022) included a supply demand analysis at the public water system level, and was expanded by a recent study at Rutgers University (Van Abs et al., 2018). In that study, Van Abs et al., 2018 performed numerous evaluations which were summarized into five sets of results based on scenarios of water loss options and methods for calculating demand scenarios. The study ultimately recommended the results from "Set 5" for planning use, which considers:

1. The current calculated peak and average demands of specific public water supply service areas from the NJDEP NJ Water Tracking (NJWaTr) database, averaged during the period 2008 through 2015.
2. A modelled percent change in service area demand from 2010-2040 for two scenarios including "No Water Conservation" (i.e. constant per capita rates) and "Water Conservation" (i.e. decreasing per capita rates).
3. Two scenarios of water loss which were defined as "Nominal Rate" (the current median water loss rate) or the more aggressive "Optimal Rate" (the current 25th percentile water loss rate). Water loss rates were calculated based on water audit data collected by DRBC for the year 2014, as it was the available data at the time of analysis.

The results from Van Abs et al., 2018 were filtered to public water suppliers within in the Delaware River Basin by comparing New Jersey Program Interest IDs (NJPIIDs) and Public Water Supplier IDs (PWSIDs) for individual systems based on the IDs included in this study. While complicated to detail nuances of the comparison, there were ultimately 99 unique NJPIIDs included in the comparison. Demands were calculated with data in this study using the following equation, and averaged to the same time period (2008-2015):

$$Demand = Withdrawal + Import - Export$$

Two conclusions from this analysis are:

1. Based on data in this analysis averaged to the period from 2008-2015, withdrawals from the New Jersey portion of the Delaware River Basin were approximately 171.972 MGD. There were 31 systems which imported water totaling an average of 12.031 MGD, and 21 systems which exported water totaling and average of 16.900 MGD. While water is moving between systems to meet demand, the majority of water withdrawn from the Delaware River Basin remains within the Basin boundary.
2. Comparing the average demands calculated by Van Abs et al., 2018 against demands calculated in this study, there are nine systems which have an average annual difference of 0.5 MGD or greater, all reported as higher volumes by Van Abs et al., 2018. Of these systems, six have service areas located on the boundary of the Delaware River Basin and may include sources outside the Basin. To more accurately compare the results, an offset was applied to the aggregated results from Van Abs et al., 2018 equal to the magnitude of error from these six systems on the Basin boundary.

A comparison between this study's projection of withdrawal from the Delaware River Basin for public water supply is comparable to Van Abs et al., 2018 study on demand, as long as it is assessed at the Basin-wide scale because the volume of export/import from the Basin is relatively small; therefore, a comparison is shown in Figure 24. Each of the four average demand scenarios presented by Van Abs et al., 2018 within the Set 5 results is shown as a separate line extending to the 2040 aggregated result, corrected by the calculated offset. The results of this study indicate that the trends of water use in the New Jersey portion of the Delaware River Basin are most representative of a scenario considering water conservation practices and reductions in water losses. Furthermore, the range of the four average demand scenarios within Set 5 are observed to span a large portion of the calculated 80% prediction interval for the results of this study, which indicate that while conservative, the prediction interval magnitudes are likely appropriate.

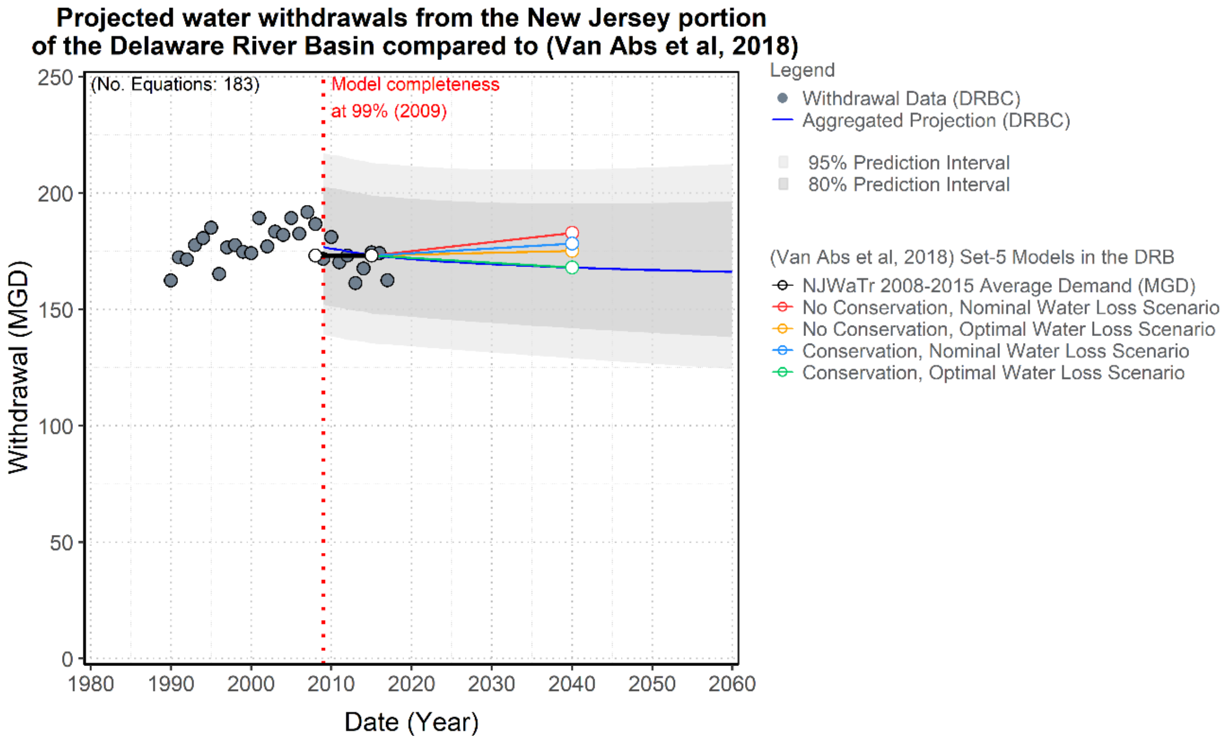
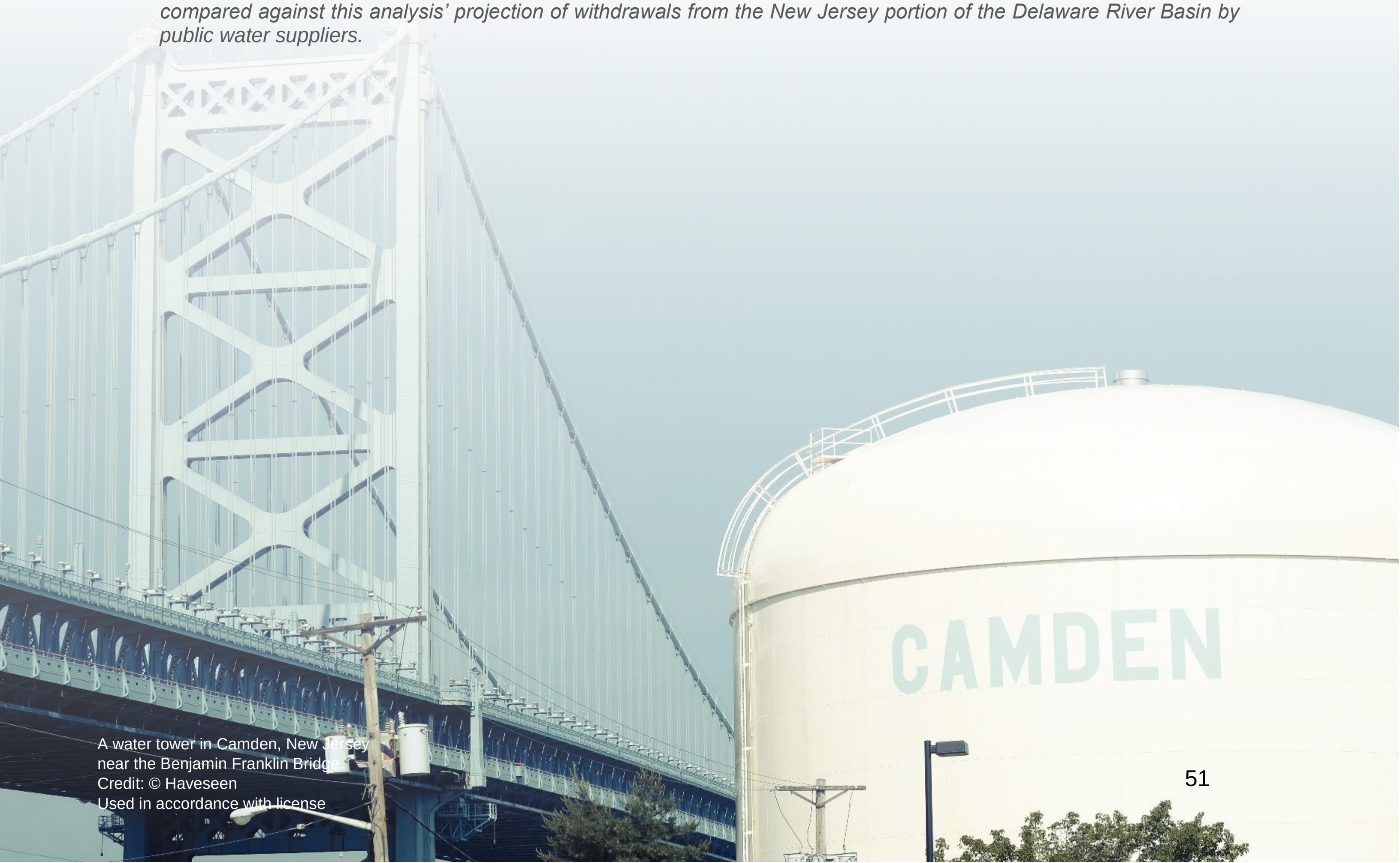


Figure 24: Projected water withdrawals from the New Jersey portion of the Delaware River Basin compared to (Van Abs et al, 2018). *The results for public water supply demand as modelled by Van Abs et al., 2018 restricted to facilities within the Delaware River Basin and corrected by a small offset based on service areas on the Basin boundary, compared against this analysis' projection of withdrawals from the New Jersey portion of the Delaware River Basin by public water suppliers.*



A water tower in Camden, New Jersey
near the Benjamin Franklin Bridge
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3.6 Out-of-Basin Diversions

In addition to water withdrawals for public water supply serving populations largely within the Delaware River Basin, there are significant withdrawals for export by two of the Decree Parties associated with a 1954 U.S. Supreme Court Decree (U.S. Supreme Court, 1954). This decision allows for:

1. The withdrawal of up to 100 MGD from the Delaware and Raritan Canal and export for northern New Jersey water purveyors.
2. The withdrawal of up to 800 MGD from three reservoirs in New York (Cannonsville, Neversink and Pepacton) and export to New York City.

These two withdrawals fully comprise a separate out-of-basin diversions sector. Historical data for each of these two major exports are provided in Figure 25 and Figure 26. 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. This method does not attempt to capture or model the drivers behind withdrawal operations, and merely represents a current snapshot in time. The benefit of providing such a projection for out-of-Basin diversions is that Basin-wide withdrawal projections can present a complete picture (as opposed to omitting the major diversions).

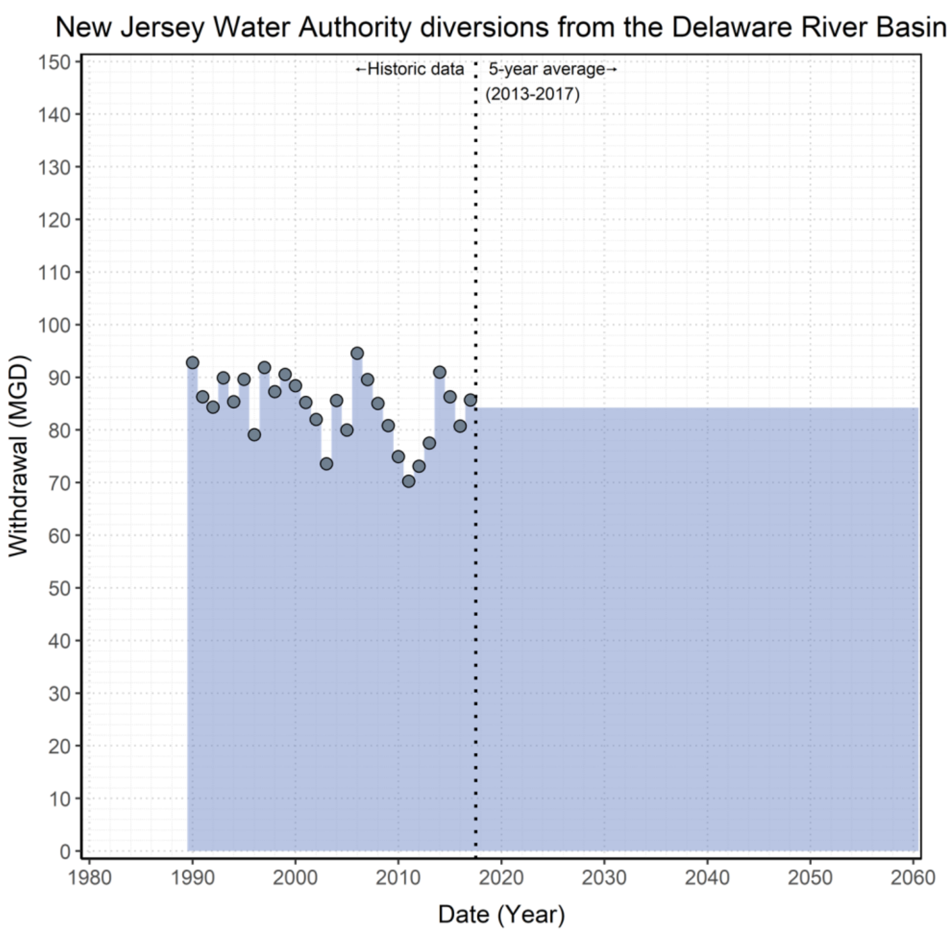

Figure 25: New Jersey Water Authority diversions from the Delaware River Basin. *This withdrawal is a single source from the Delaware and Raritan Canal. Data can be accessed through the NJDEP Dataminer website (NJDEP, 2021).*

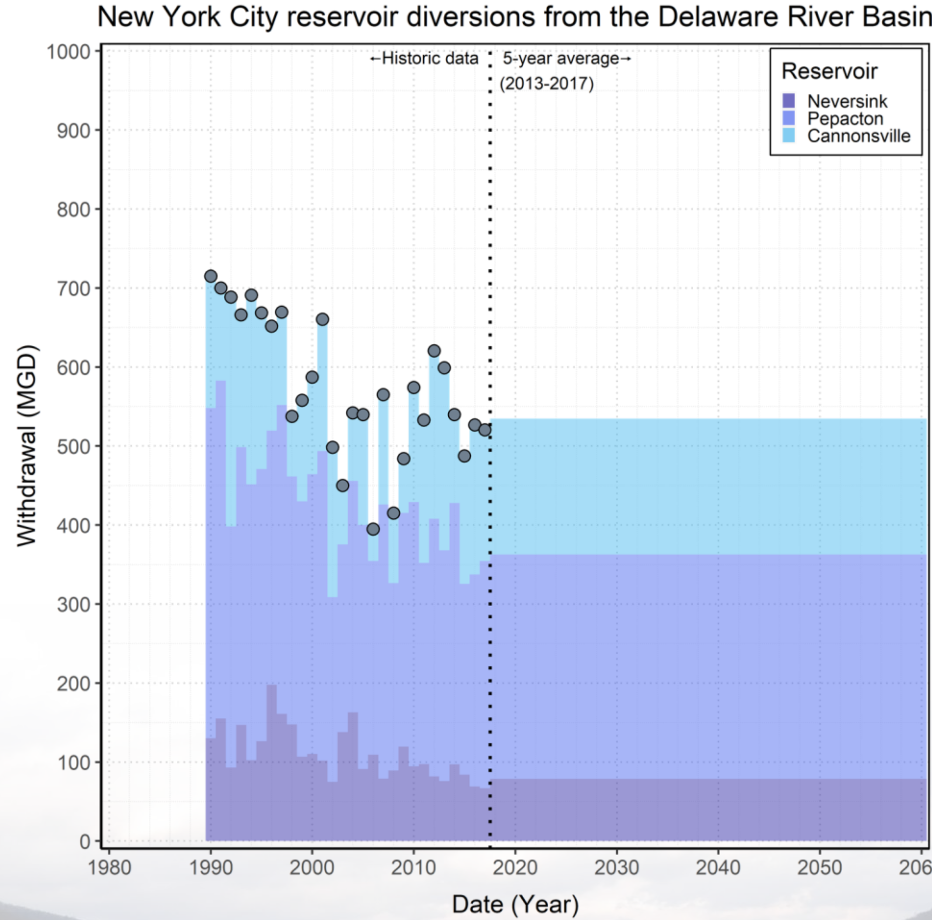

Figure 26: New York City reservoir diversions from the Delaware River Basin. *Historical water withdrawal data as reported by NYSDEC; withdrawal data from individual reservoirs were only available starting in 1998. Data can be accessed through a web application run by the USGS Office of the Delaware River Master (USGS, 2021a).*

Pepacton Reservoir
in Delaware County, New York
Credit: Steven Walsh, DRBC

3.7 Climate change

The effects of climate change on projections of public water supply withdrawals were not addressed quantitatively in this study; however, system operational responses to changes in climate over the past 30 years are assumed to be inherently captured by modelling trends in reported withdrawal data. That said, numerous studies reviewed did consider climate change with a consensus that a driver of increasing temperature may result in increased water demands. It was suggested in DE DNREC et al., 2014 that overall water demand in New Castle, Kent and Sussex counties would increase by 3% for every 1% increase in maximum air temperature; furthermore, the report highlights two other studies on the same topic. Frederick & Major, 1997 reviewed 13 studies which examined the effects of climatic variables on residential/municipal water use, and found that effects vary widely based on region, season, indoor/outdoor, urban/suburban; ultimately, suggesting that a 1% rise in temperature could increase residential water use by 0.02 to 3.8%. Dziegielewski & Chowdhury, 2008 performed a study in northern Illinois which estimated that by 2050, an increase in 6°F in air temperature would increase total public-supply withdrawals by 8.4% relative to unchanged normal weather demand (or about 1.4% increase in withdrawal per 1°F).

Based on studies such as these, broad percent change increases could be applied to the entire projection for the Delaware River Basin or could even be applied at a more regional scale (e.g. 147 subbasin) if the work was done to refine percentage estimates by factors such as those assessed in Van Abs et al., 2018 which influenced variable per-capita rates. However, based on the data from DRBC, Pending (discussed in Section 8), and on GCM projected trends, the Basin-average maximum daily temperature (°F) for the season May-September may increase about +2°F (RCP 4.5) and +3°F (RCP 8.5) by 2060, based on a 5-year moving average (Figure 80). Considering a rate on the order of 1.5% per degree Fahrenheit would suggest withdrawal increases on the order of 3.0% - 4.5% by 2060 due to increased temperature. However, the prediction intervals calculated at the Basin scale for 2060 are (-14.5)/(+16.0)% [PI-80] and (-21.6)/(+24.5)% [PI-95]. It seems likely that this range would include the resulting climate change scenario, similar to Figure 23.

3.8 Summary

Water withdrawals from the Delaware River Basin by public water purveyors were presented for 1990-2017 based on self-reported withdrawal data. It was estimated that withdrawals have decreased approximately 100 MGD on average over this timeframe, whereas the in-Basin population has increased by an estimated 965,000 people and is projected to continue increasing (Figure 9). Furthermore, is possible to estimate that approximately 86% of the 2010 population residing within the Basin relied on public water supply (detailed in Section 4) and that the population within current service areas is projected to increase about 1.5% by 2060. The pattern of increasing population and decreasing withdrawals is assumed to be related to advances in leak detection and water conservation by purveyors, regulatory efforts such as plumbing standards, and general public awareness of water conservation.

Withdrawals were projected at the system level based on the extrapolation of historical data, considering the most recent operation trends and available metadata. Data for the major Basin exports to New York City and New Jersey were presented, but not projected. The results from 335 individually assessed systems (and projected unassociated data) indicate continued decreases in modelled withdrawals from the Delaware River Basin of approximately 34.610 MGD by 2060, which is a 4.3% reduction. Regionally, decreases are projected for New York, New Jersey and Pennsylvania whereas withdrawals in Delaware are projected to increase very slightly over time, almost appearing to remain constant. The results presented at various scales appear coherent, and two comparisons were presented for New Jersey and Delaware and demonstrated general agreement.

Fairmount Water Works
in Philadelphia, Pennsylvania.
Credit: Partnership for the Delaware Estuary
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The Delaware Water Gap
Credit: © Hop On Air LLC
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4 SELF-SUPPLIED DOMESTIC

A separate sector often related to public water supply is water withdrawn for the self-supplied residential population. As outlined in Table 1, this covers water withdrawals by the portion of the population within the Delaware River Basin who are not served by public water supply systems, and account for both residential indoor and outdoor uses. It is assumed in this analysis that all of this self-supplied population is served by groundwater sources, similar to other studies (Hutson et al., 2016). A method is established to estimate the population of the Delaware River Basin at various spatial resolutions, such that the population residing outside of public water supply service areas may be estimated. The populations are then projected based on recent county-level population projections, and self-supplied domestic withdrawals calculated based on per-capita rates.

4.1 Review of regional watershed studies

Table 15: *An expansion of Table 3 in order to more accurately summarize the specific methods utilized by regional watershed studies which projected self-supplied domestic water use.*

Study	Study Region	Projected data	Projected data scale	Reported Results Scale	Total water use	Consumptive water use	Variable per-capita rates	Self-supplied Domestic: Included within the assessment for PWS	Self-supplied Domestic: Per-capita rates x population projections	Self-supplied Domestic: Extrapolation of historical withdrawal estimates
(Hutson et al., 2004)	Tennessee River Watershed	No. households	County	RCA, WUTA						
(ICPRB, 2012)	Potomac River Basin	Population	County	County	X	X	X	X		
(USDOI-BR, 2012)	Colorado River Basin	Population	*NA*	State						
(USDOI-BR, 2016)	Klamath River Basin	Population	County	County		X			X	
(Balay et al., 2016)	Susquehanna River Basin	Population	County	HUC-10		X			X	
(Robinson, 2019)	Cumberland River Watershed	Population	County	RCA						
(Zamani Sabzi et al., 2019)	Red River Basin	USGS NWUE	County	County		X				X

Notes:
HUC = Hydrologic Unit Code
RCA = Reservoir Catchment Area
WUTA = Water-use Tabulation Area
USGS NWUE = USGS National Water Use Estimates

An expansion of the studies listed in Table 3 is provided for reference as Table 15 and gives additional details for each study which included projections of self-supplied domestic water use. The study performed in the Potomac River basin captures domestic water supply in the same category as public water supply, and projected them together based on projections of population (ICPRB, 2012). Two other studies also used per-capita methods combined with population projections; however, only the study in the Susquehanna River Basin outlined details on how the self-supplied population was estimated. Balay et al., 2016 performed a GIS analysis using 2010 U.S. Census Bureau (USCB) block groups and their spatial relationship to public water supply service areas. Populations outside public water supply service areas were considered to be self-supplied and projected as such. Lastly, the study performed by Zamani Sabzi et al., 2019 used the same methodology for all sectors, directly projecting water use data uses historical USGS National Water Use Estimates.

4.2 Review of studies within the Delaware River Basin

There have been numerous studies which have provided estimates of self-supplied domestic water use/withdrawal in the Delaware River Basin, summarized in Table 16. While not capturing the assumptions and calculations of each study, a small discussion is provided to highlight some background on the history of these numbers.

***Table 16**: Summary of studies providing self-supplied domestic estimates for the Delaware River Basin.*

Study	Most-recent year of population data referenced		Served by PWS		Self-supplied		Per capita rate (GPCD)	Estimated domestic withdrawal (MGD)	Smallest resolution presented	Note
	Data	Pop.	%	Pop.	%	Pop.				
(Byun et al., 2019)	USCB, 2016	8.300	NA	NA	NA	NA	NA	117	Basin	1
(PDE, 2017)	ACS, 2015	8.338	NA	NA	NA	NA	112	101	Basin	
(Hutson et al., 2016)	USCB, 2010	8.260	81	6.691	19	1.569	75	117	12-digit HUC	
(DRBC, 2013)	USCB, 2010	8.300	NA	NA	NA	NA	NA	114	Basin	2
(PDE, 2012)	USCB, 2010	8.256	82	6.770	18	1.486	NA	114	Basin	2
(DRBC, 2008)	USCB, 2000	7.759	NA	NA	NA	NA	NA	103	Basin	
(USACE & DRBC, 2008)	USCB, 2000	7.742	NA	NA	NA	NA	NA	105	Basin	3
(Sloto & Buxton, 2006)	USCB, 2000	NA	NA	NA	NA	NA	65, 75	105	147-subbasin	

Notes:
[1] Uses the estimate provided by Hutson et al., 2016
[2] Use estimates from the same analysis performed by DRBC
[3] Uses estimate provided by Sloto & Buxton, 2006

The DRBC has reported a single Basin-wide value for self-supplied domestic water withdrawals in previous reports (e.g. Byun et al., 2019; DRBC, 2021). The number of 117 MGD (annual average) was initially obtained from the analysis published in the USGS report *Estimated Use of Water in the Delaware River Basin in Delaware, New Jersey, New York, and Pennsylvania, 2010* (Hutson et al., 2016). In that analysis, data from the USCB for population and housing unit counts at the block group and block levels (the smallest geographical units available) were used in conjunction with county wide estimates of total population served from public supply in the USGS National Water Information System (NWIS). A method was developed to rank the populations within the census blocks served by public water supply and match the population totals to the county wide estimates of population served by public water supply through NWIS. Census blocks were then assigned either self-supplied or public water supplied for calculation, and the centroids of census blocks could be compared to watershed boundaries. The resulting estimates of basin-wide population were 8.260 million persons, 81% served by public water supply (6.700 million persons) and therefore 19% in the category of self-supplied domestic (1.560 million persons), resulting in a self-supplied domestic groundwater withdrawal of approximately 117 MGD based on a per capita rate of 75 gallons per person per day (the 2005 average self-supplied domestic use per capita of the four states from Kenny et al., 2009).

Prior to using this number, the DRBC had reported a single Basin-wide annual average value for self-supplied domestic water withdrawals in 2008 (105 MGD, USACE & DRBC, 2008), which was adopted from the USGS study *Estimated Ground-water Availability in the Delaware River Basin, 1997-2000* (Sloto & Buxton, 2006). In this USGS study the analysis was performed using USCB data, applying the percentage of households on domestic wells in 1990 to the population in 2000 to determine the self-supplied domestic population in each census block. The populations were multiplied by 65 gallons per capita per day (GPCD) (PA) and 75 GPCD (DE, NJ, NY). This report provides self-supplied domestic withdrawals broken into the 147 subbasins, although the methodology was not outlined explicitly.

Two additional values have been reported by DRBC, although the background to their development is limited. In the 2008 State of the Basin (DRBC, 2008), the DRBC has reported 103 MGD which is assumed to be based on data provided by the USACE. In the 2012 State of the Basin (DRBC, 2013), the DRBC reported a value of 114 MGD based on an analysis that was performed in conjunction with work for another report which published the same value (PDE, 2012).

Currently a study is ongoing by the USGS in cooperation with the NJDEP to meter private domestic wells which will help improve estimates of domestic water use, which is not listed in Table 16 (USGS, 2021b). Using clamp-on ultrasonic meters coupled with data collection platforms and transmitters, individual self-supplied household water lines can be metered to better understand water use patterns and help refine self-supplied domestic per-capita estimates.

4.3 Data evaluation

Unlike every other withdrawal sector in this report, there is no data reported by water users for self-supplied domestic use; therefore, like other previous studies it must be estimated and is discussed in the subsequent section outlining the methods.

4.4 Methods

4.4.1 Data sources

The estimation method used in this analysis is a per-capita method based on the population estimated to be living in the Delaware River Basin, but outside of reported public water supply service areas. The projection is then performed using county-level population projection data (as a percent change) applied to planning areas within each county. This approach is similar to the methods used by Balay et al., 2016 and DRBC, 2013 which made use of block level census data to perform such an analysis. However, this study uses a slightly different approach which requires three key data inputs:

1. **Population data (for 2010 estimate)**. The data available for this analysis is different from that of previous studies because of the spatial resolution. As was shown in Figure 7, the USEPA has analyzed 2010 census population data by dasymetrically mapping it based on land cover (NLCD 2011) and land slope (USEPA, 2016). This algorithm enhances spatial population data by removing areas from a census block which are uninhabitable (such as open water and slopes greater than 25 percent) and re-distributes census population data to a 30x30 meter grid. This form of population data is easier to spatially manipulate in terms of aggregations to unique boundaries (such as the Delaware River Basin, 147 subbasins, or public water supply service areas).
2. **Population data (for projections).** A recent study calculated county-level population projections for 2020-2100 for 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). The population projection from SSP2 was selected for use in this study because it represents a "middle of the road" scenario. County level populations were compared against U.S. Census Bureau 2010 county level population estimates to obtain decadal population percent change values (USCB, 2019). A linear interpolation was used to fill gaps between data points to create a continuous population estimate by county from 2010 to 2060.
3. **Per-capita rates.** The most recent USGS National Water Use Estimates for 2015 included per-capita domestic water use estimates by state (Dieter et al., 2018). These rates were reported as 80 GPCD (DE), 94 GPCD (NJ), 75 GPCD (NY) and 60 GPCD (PA). All values were used except the value for Pennsylvania, which was replaced by the value 80 GPCD based on discussion with PADEP, initially determined by CDM & DRBC, 2005 and adopted by Stuckey,

2008. It should also be noted that NJDEP has adopted the methodology developed in Van Abs et al., 2018 to apply variable per-capita rates based on housing density and physiographic province. However, incorporation of such variable rates to one Basin-state are not suited for this study; future studies may build on the research of NJDEP and apply the methodology to the entire Basin.

4.4.2 Data validation

A comparison was run between USCB 2010 Census data and the USEPA EnviroAtlas dataset to confirm accuracy. The dasymetrically mapped population data was aggregated to 192,280 census blocks which plot entirely within the Basin boundary, and 33,120 zip code tabulation areas (ZCTAs) completely within the Basin boundary. Increasing the accuracy of the dasymetric population raster file to 0.01 before rounding is a key step in data verification. Cumulative population count error between the EnviroAtlas dataset and USCB block data was -0.17% error, and cumulative error compared to the ZCTAs was -0.20% error. An additional analysis was run for ZCTAs increasing accuracy of the dasymetric population data to 0.001 before rounding, which decreased error to -0.01% error. This analysis clearly demonstrated to the authors that as rounding is eliminated, error between the datasets likely approaches machine precision. The accuracy level of 0.01 before rounding was used for this analysis as errors associated with assumptions made in this analysis will greatly outweigh the error saved by increasing accuracy to 0.001, compared to the required computational effort.

4.4.3 Procedure

A GIS analysis was used to restrict the dasymetrically mapped 2010 population data to the boundary of the Delaware River Basin to serve as a working dataset for the remainder of the analysis. The three basic steps in this analysis include:

1. The population data within the Basin was tabulated to a complex boundary set allowing population planning areas to be re-aggregated by state, county, HUC-147 subbasin, SEPA-GWPA subbasin and each states' public water supply service areas. This offers a potential improvement over methods which must split census block populations evenly by percent area, or even assign an entire census block population to a region based on the block centroid. An example of this method focusing on a single USCB 2010 census block is provided in Figure 27. This one example clearly indicates how the dasymetric mapping can affect population distributions being aggregated to subbasins and service areas, as compared to other methods such as centroid or percent area.
2. Projected populations were calculated by applying the county-level annual percent change determined from M. Hauer & CIESIN, 2021 evenly to all planning areas within each county.
3. Each states' per-capita rates were applied to respective population planning areas to determine an average annual self-supplied domestic water withdrawal value in million gallons per day.

4.4.4 Limitations and assumptions

This approach inherently has limitations and assumptions associated with it, but none that seem any more unreasonable than those made by approaches using census block level data. Five primary assumptions being made in this method include:

1. All population dasymetrically mapped into public water supply service areas are served by the public water supply system.
2. Public water supply service areas will remain constant (i.e., not expand or contract).
3. All water withdrawn for self-supplied domestic purposes is from groundwater sources.
4. Population growth in each county is applied evenly across the county, matching the dasymetrically mapped distribution.
5. Per-capita rates do not change with time and are only variable by state.

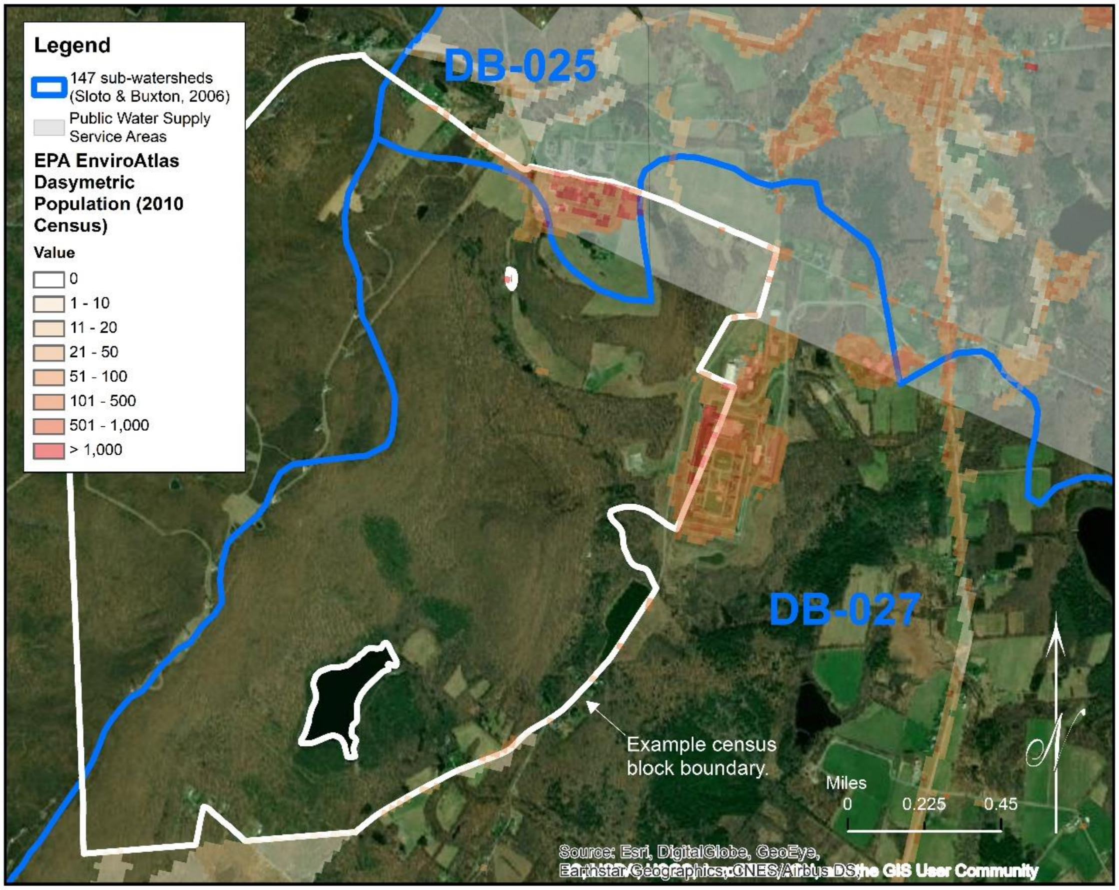


Figure 27: Map showing an example USCB 2010 census block, dasymetrically mapped population data, and subbasin boundaries. *Data was evaluated at an accuracy of 0.01 prior to creating a 32-bit signed integer raster. It is evident that the dasymetrically mapped population likely provides a higher estimate for DB-025 than would be obtained by either a percent area or centroid method; additionally, the census block has been separated by the Basin divide. Small errors associated with pixels falling outside service area boundaries are also evident. The corresponding map for the entire Basin is presented as Figure 7.*

Furthermore, a specific limitation of note is that the analysis is highly dependent on the alignment and assumed agreement between the dasymetrically mapped population and purveyor developed service area shapefiles. A specific example of where this assumption does not hold true is shown in Figure 27 near the subbasin divide – there are a few high-density population grid cells plotting just outside the service area boundary, whereas it seems likely they should be included. This form of error likely only represents marginal changes in the overall Basin-wide analysis, and adjustment of shapefiles on a system-level basis is not in the scope of this study. Across the entire basin, this method is assumed to be sufficient.

4.5 Results

The population analysis has provided a 2010 in-Basin population estimate for the Delaware River Basin of approximately 8.252 million people, of which approximately 86% reside within public water supply service areas (7.106MM) and approximately 14% reside outside of public water supply service areas (1.146MM). This initial 2010 population estimate and projected population estimates (based on M. Hauer & CIESIN, 2021 scenario SSP2) are provided for graphical reference in Figure 28 at the Basin scale, along with previous Basin population estimates performed by DRBC. While many previous DRBC studies also included projections, they are not portrayed graphically. A summary table presenting the Basin-wide population and

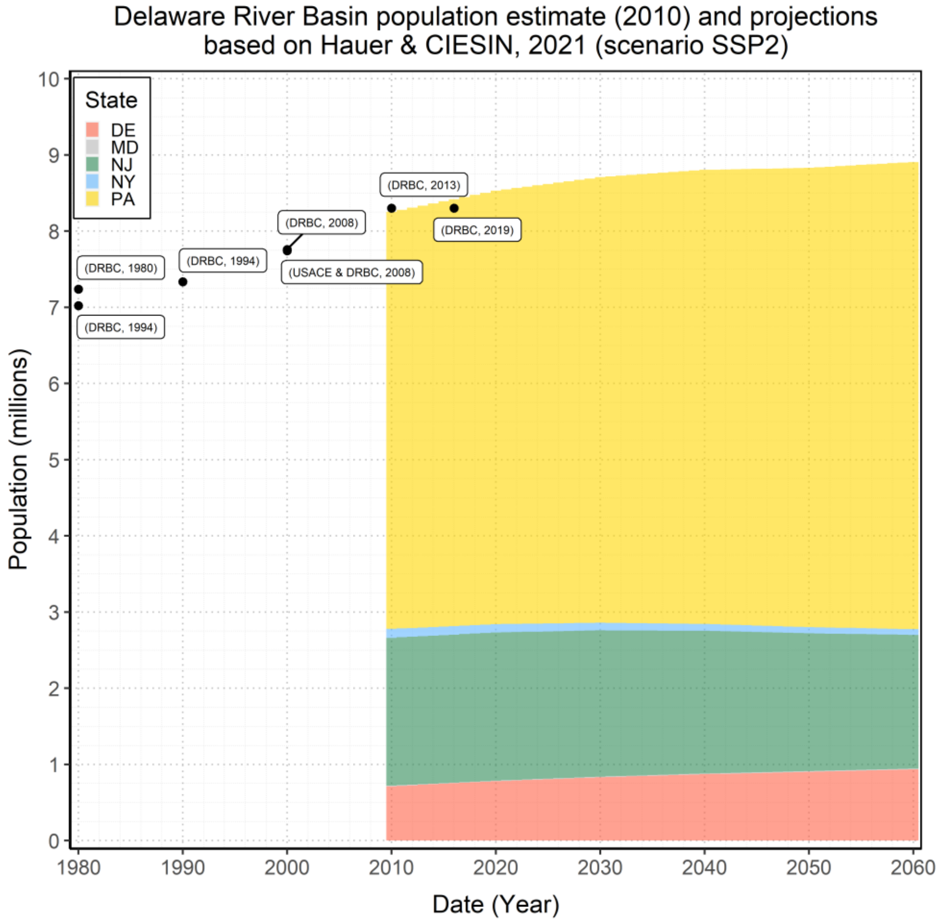


Figure 28: Delaware River Basin population estimate (2010) and projections based on M. Hauer & CIESIN, 2021 (scenario SSP2). *Previous Basin-wide estimates of population are plotted as black circles, labelled with the corresponding DRBC study. The results supporting this figure are summarized in Table 17. Data supporting this figure are provided for reference in Table A-4.*

***Table 17**: Summary of results supporting Figure 28 for water withdrawals and consumptive use by the populations of the Delaware River Basin living outside of public water supply service areas (self-supplied).*

Year	Delaware River Basin Population (estimate)	Inside public water supply service areas		Outside public water supply service areas		Self-supplied domestic withdrawal (MGD)	Self-supplied domestic consumptive use (MGD)
		Population	%	Population	%		
2010	8,251,815	7,105,813	86.1%	1,146,002	13.9%	95.224	9.522
2020	8,530,210	7,371,663	86.4%	1,158,547	13.6%	96.159	9.616
2030	8,708,203	7,551,844	86.7%	1,156,359	13.3%	95.865	9.586
2040	8,804,505	7,664,729	87.1%	1,139,776	12.9%	94.387	9.439
2050	8,830,378	7,715,283	87.4%	1,115,095	12.6%	92.242	9.224
2060	8,907,241	7,803,099	87.6%	1,104,142	12.4%	91.238	9.124

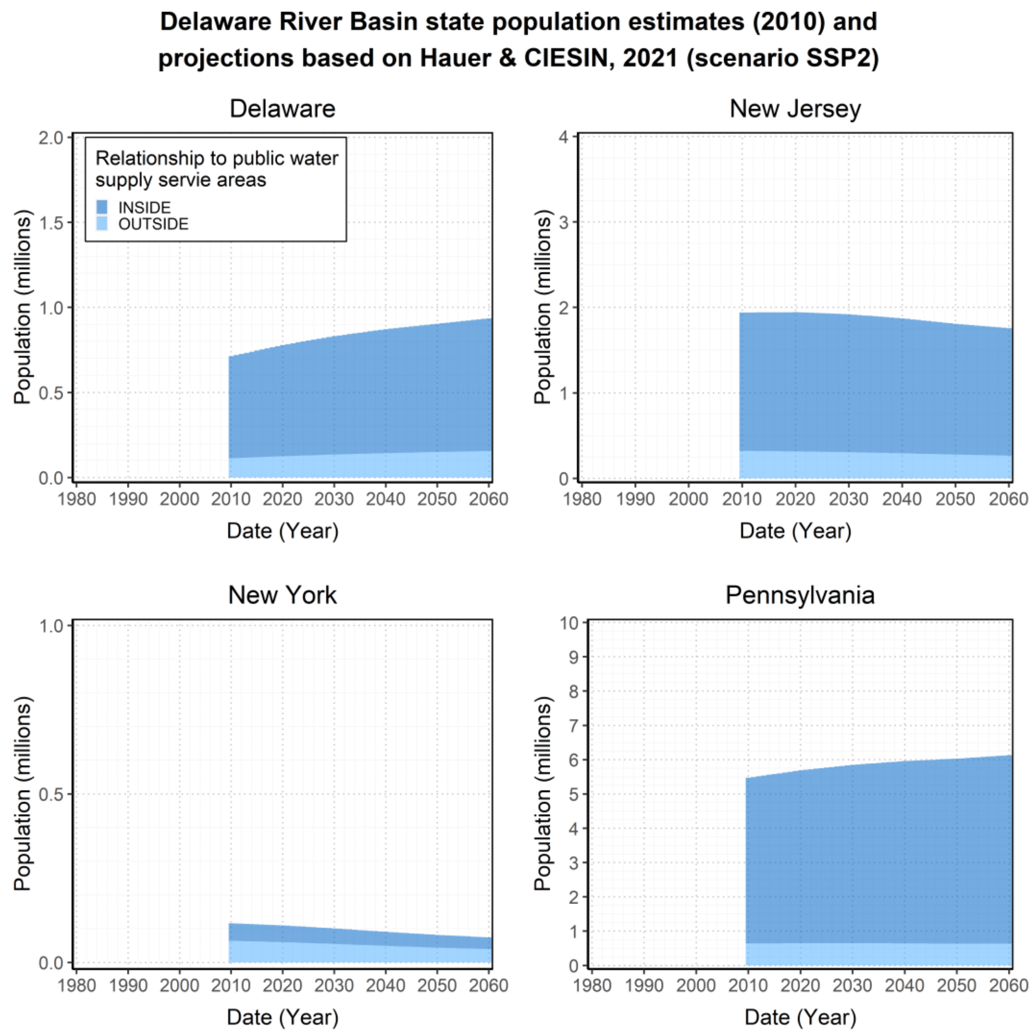


Figure 29: Delaware River Basin state population estimates (2010) and projections based on (M. Hauer & CIESIN, 2021) (scenario SSP2). The data have been presented by state, and therefore y-axes have been adjusted to scale data. Data supporting this figure are provided for reference in Table A-4.

corresponding self-supplied withdrawal estimates are presented for select years in Table 17. The data for each state is then shown in Figure 29, graphically indicating the portion of population inside/outside public water supply service areas over time. The data release supporting this model is provided in Appendix A as Table A-4.

4.6 Climate change

The effects of climate change on self-supplied domestic withdrawal projections were not addressed quantitatively in the projections of water withdrawal; however, it is assumed that the major effects will be that of temperature on a per-capita rate, and that the effects will disproportionally affect the rates with respect to variables such as housing density and physiographic province. This study uses fixed per-capita rates as outlined in Section 4.4.1. If a study is undertaken (as suggested in Section 4.4.1) which applies the methodology developed in Van Abs et al., 2018 to the entire Delaware River Basin, it would be an appropriate study for including the impacts of climate change on self-supplied per-capita rates.

4.7 Summary

The 2010 population residing in the Delaware River Basin estimated in this study (8.252MM) is based on the USEPA EnviroAtlas dasymetrically mapped population dataset (USEPA, 2016), and is very close to other estimates for 2010, highlighted in Table 16. The main advancement which comes from this analysis is based on population distribution within census blocks, which likely resulted in a higher estimate of approximately 86% of people residing within public water supply service areas (as compared to the two studies which reported 81% and 82%). A second advancement of this study is the ability to easily split the population between planning areas which do not align with USCB census areas.

Referencing county-level population projections estimated in M. E. Hauer, 2019; M. Hauer & CIESIN, 2021 under a "moderate" scenario SSP2, linearly interpolated county-level population growth rates were applied to all planning areas in each county evenly. The resulting population of the Delaware River Basin was estimated to increase to approximately 8.907MM people by 2060. This is a slightly different estimate than was recently published by DRBC (Byun et al., 2019) which indicated the Basin may reach 8.9MM people by 2030. However, if this study had considered the most extreme shared socioeconomic pathway (SSP5) using the same methodology, it may be estimated that the Basin population would reach 9.2MM people by 2030 and over 10.9MM people by 2060. Using the more moderate SSP2 therefore seems appropriate to the authors in the context of this study.

The projected populations estimated in this study indicate that while the entire Basin population is increasing, the distribution of people outside public water supply service areas will decrease. This is reflected by the initial estimate of 13.9% of people outside public water supply service areas decreasing to approximately 12.4% in 2060. Counterintuitively to an increasing Basin-wide population, this results in a decreasing withdrawal volume by self-supplied domestic populations from 95.224 MGD in 2010 to 91.238 MGD in 2060.

5 POWER GENERATION

This portion of the study focuses on water withdrawals associated with the process of power generation. Within the Delaware River Basin there are a significant number of power facilities with a combined nameplate capacity of 1-megawatt or greater. These facilities are required to report various data to the United States Energy Information Administration (EIA) through Forms EIA-923 (USEIA, 2020b) and EIA-860 (USEIA, 2020a). At the time of publication, the most recent data representing the installed capacity (in megawatts) and primary fuel type is presented for the northeastern Unites States in Figure 30, then enhanced to show more details specific to the Delaware River Basin in Figure 32. This information was obtained as a shapefile from the EIA (USEIA, 2020c). There are two broad categories of power facilities which require consistent use of water within the Delaware River Basin: thermoelectric (typically for cooling) and hydroelectric (typically as the primary fuel).

The Delaware River Basin consists of two 6-digit Hydrologic Unit Codes (HUC), HUC 020401 (Upper Delaware) and HUC 020402 (Lower Delaware). This is the largest scale USGS hydrologic unit which can be restricted to the boundary of the Delaware River Basin. From the most recent Watershed Boundary Dataset available from the USGS, there are 388 6-digit hydrologic units which cover the United States, with an average area size of 10,541 square miles (USGS, 2020); hydrologic units which lie completely in Canada, Mexico, Puerto Rico, Guam, Virgin Islands and minor islands were excluded. A GIS analysis was performed to aggregate the installed capacity of all power facilities in the United States to the 6-digit hydrologic unit scale. This analysis indicated that 360 of the 388 6-digit hydrologic units have a combined installed capacity greater than zero. A map showing the HUC-6 watersheds color coded and ranked by installed capacity is shown in Figure 31, overlaid by the boundaries of the Delaware River Basin and PJM Interconnection grid. The facilities within the Lower Delaware (020402) have a combined installed capacity of approximately 19,818 MW, which ranks 5th in the nation; however, net generation data indicates that the Lower Delaware ranked 2nd in the nation for 2017-2019, each year behind HUC 030902 (Southern Florida). The Upper Delaware has fewer facilities and reports a combined installed capacity of approximately 5,490 MW, which ranks 77th nationwide. This analysis has demonstrated that the Delaware River Basin is a significant resource in terms of power generation capability, and consequently, the waters of the Basin play an important role in generating that power.

Hope Creek and Salem Generating Stations
in Salem County, New Jersey.
Credit: © John Beatty
Used with permission.

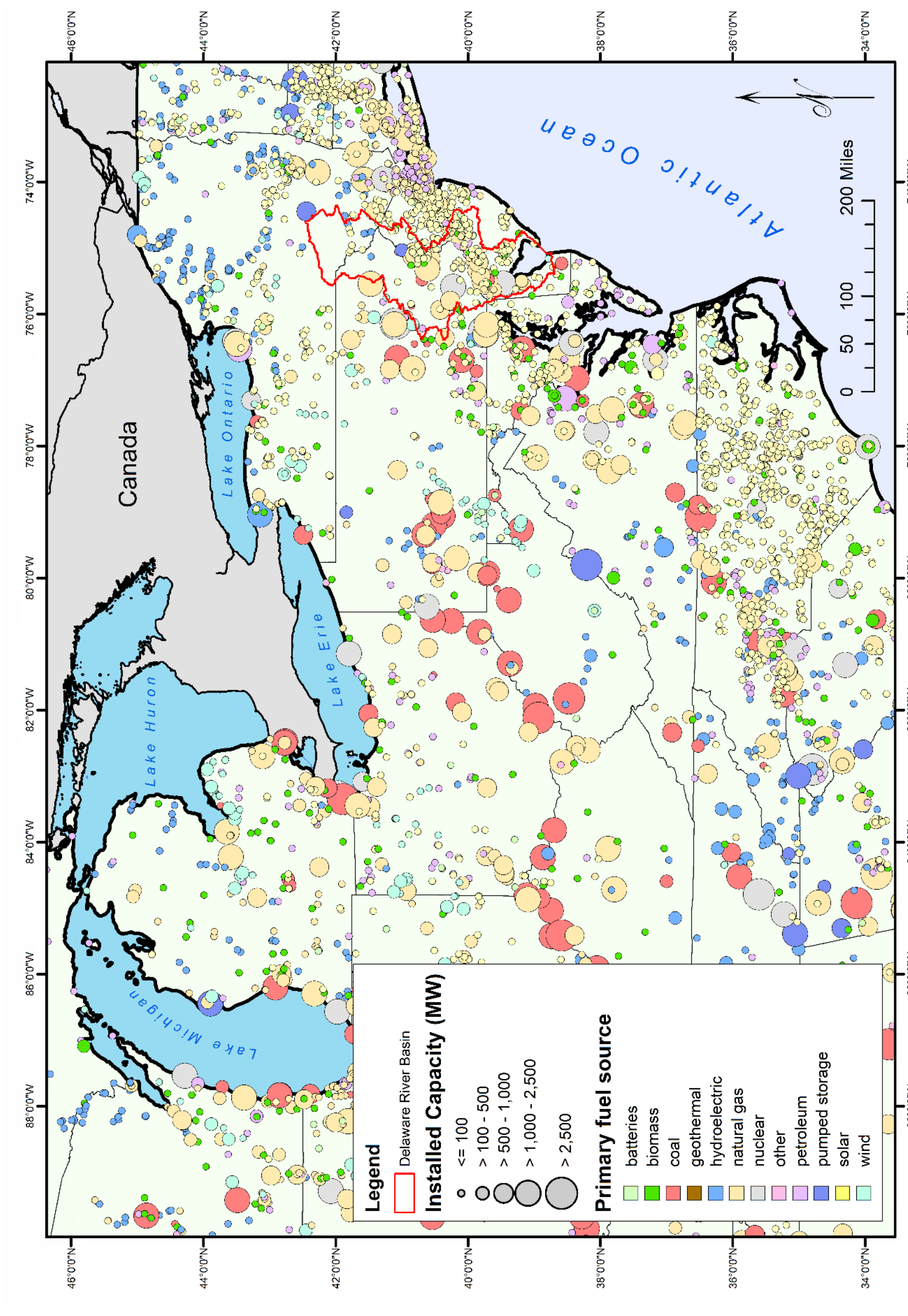


Figure 30: A map of the current installed capacity and primary fuel type for power facilities in the NE United States. *Data obtained from the EIA (USEIA, 2020c). It is important to emphasize that the nameplate capacity and the primary fuel type reflect current conditions, and do not account for operational changes (e.g., switching fuel from coal to natural gas).*

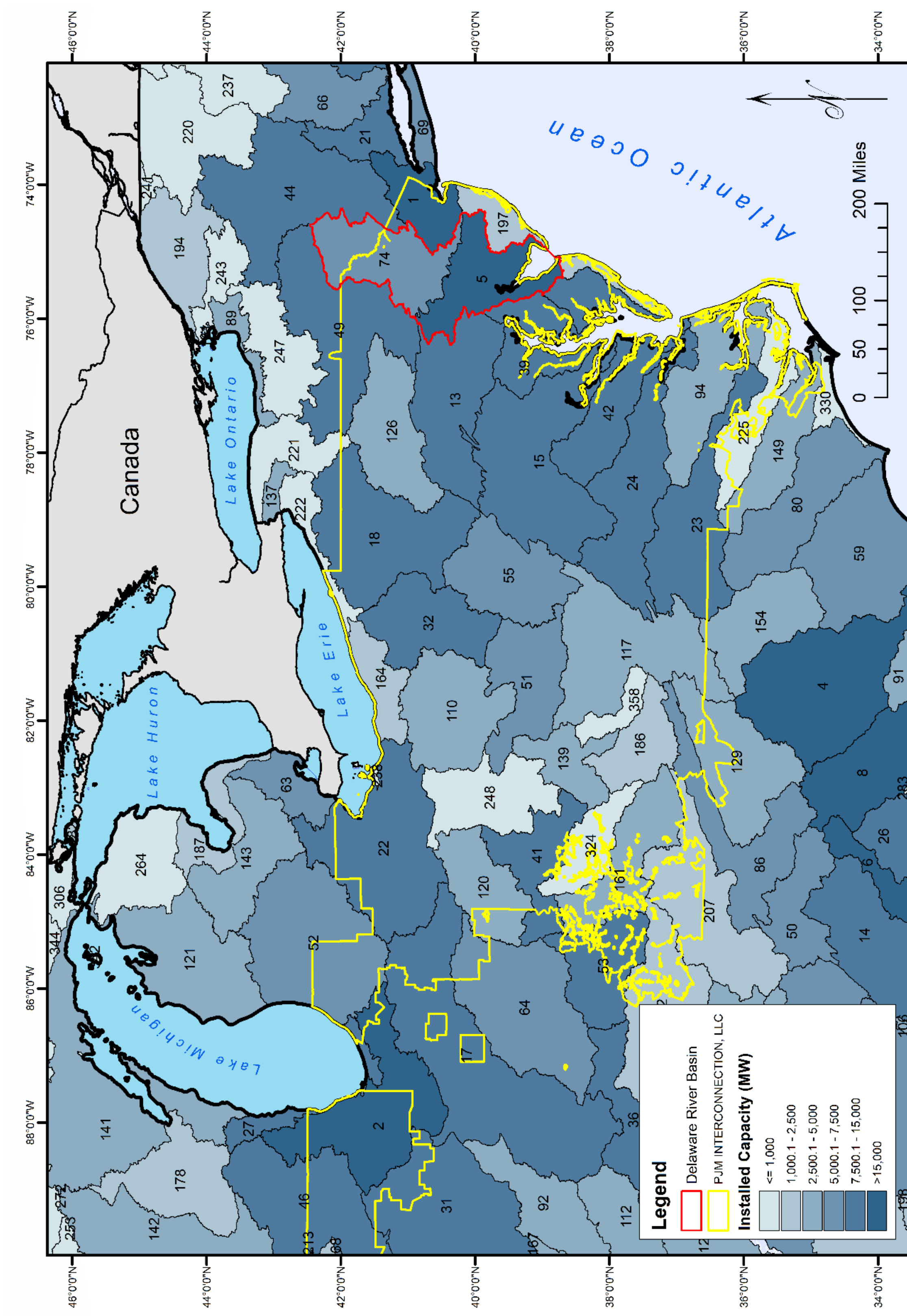


Figure 31: A map of the aggregated power generation facility installed capacities at the HUC-6 level. *The Delaware River Basin and PJM Interconnection are highlighted for reference. There are 388 6-digit hydrologic units which cover the United States, with an average area of 10,541 square miles (excluding hydrologic units which lie completely in CA, MX, PR, GM, VI, and minor islands).*

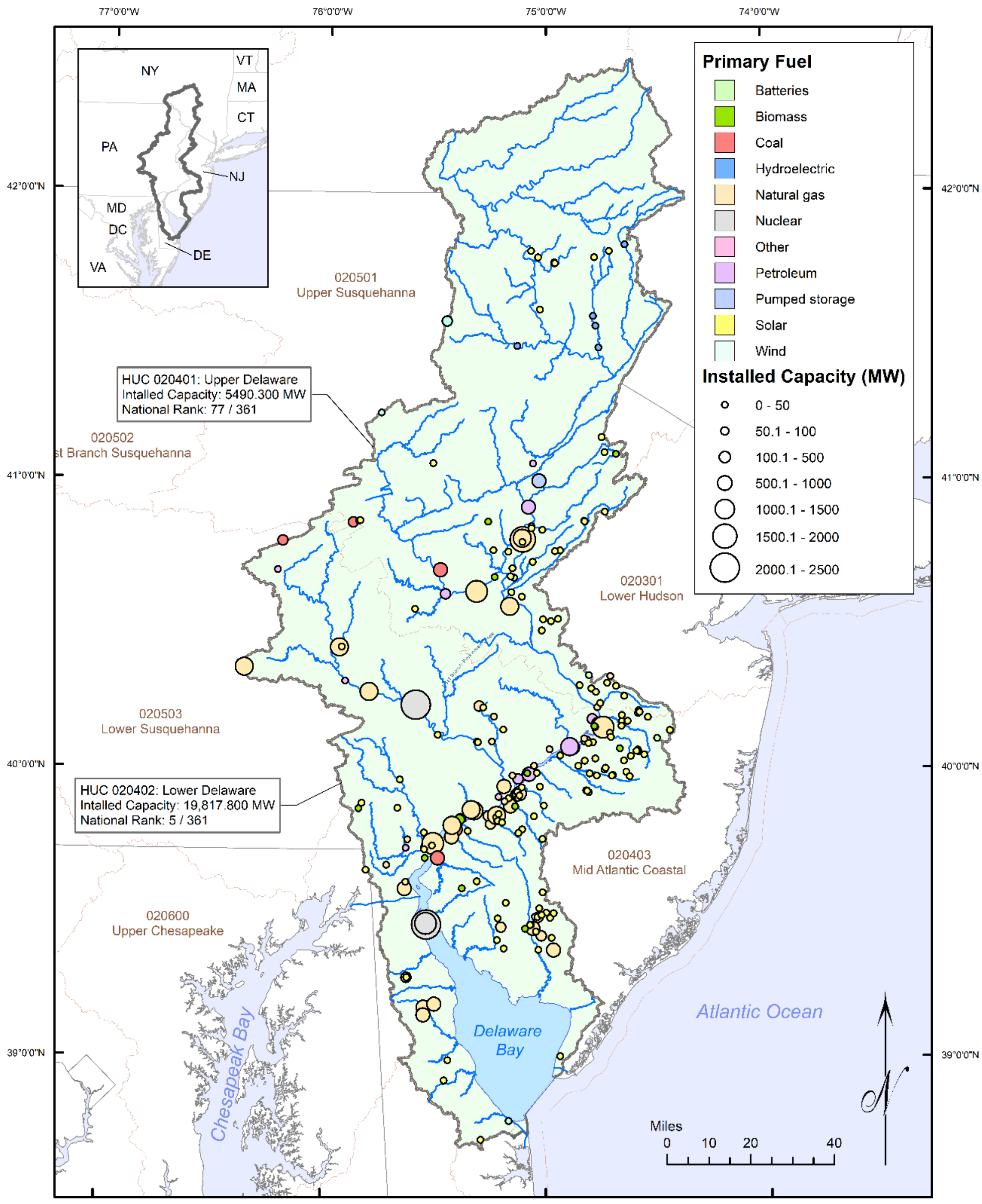


Figure 32: A map of the current installed capacity and primary fuel type of the 234 generating plants within the Delaware River Basin. *Data obtained from the EIA (USEIA, 2020c). It is important to emphasize that the nameplate capacity and the primary fuel type reflect current conditions and do not account for operational changes such (e.g., switching fuel from coal to natural gas).*

***Table 18**: An expansion of Table 3 in order to more accurately summarize the specific methods utilized by regional watershed studies which projected water use in the power generation sector.*

Study	Study Region	Projected data	Projected data scale	Reported Results Scale[1]	Total water use	Consumptive water use	Thermoelectric	Non-thermoelectric	Power Generation: Provided by other agency	Power Generation: Growth rate applied to current water use	Power Generation: Per capita energy-water use factor	Power Generation: Extrapolation of historical withdrawal estimates
(Hutson et al., 2004)	Tennessee River Watershed	*NA*	*NA*	RCA, WUTA	X		X		X			
(ICPRB, 2012)	Potomac River Basin	EIA projection	County	County	X	X	X			X		
(USDOI-BR, 2012)	Colorado River Basin	*NA*	*NA*	State		X	X	X			X	
(USDOI-BR, 2016)	Klamath River Basin	*NA*	*NA*	*NA*								
(Balay et al., 2016)	Susquehanna River Basin	EIA projection	County	HUC-10		X	X			X		
(Robinson, 2019)	Cumberland River Watershed	*NA*	*NA*	*NA*								
(Zamani Sabzi et al., 2019)	Red River Basin	USGS NWUE	County	County		X	X					X

Notes:
HUC = Hydrologic Unit Code
RCA = Reservoir Catchment Area
WUTA = Water-use Tabulation Area
USGS NWUE = USGS National Water Use Estimates

5.1 Review of regional watershed studies

An expansion of the studies listed in Table 3 is provided for reference as Table 18 which gives additional details for each study that included projections for the power sector. Only five of the seven included the power sector in the study, and only one study considered generation technology other than thermoelectric. The methodologies for the projections varied almost exclusively, aside for two studies which used a similar approach based on application of a percent-change value to water use, determined from EIA energy projections (ICPRB, 2012; Balay et al., 2016). The one study which included multiple generation technologies captured thermoelectric, solar, geothermal and oil shale and used either known plans for future facility development, or calculated per-capita energy water use factors (USDOI-BR, 2012). The only study which directly projected water use data uses historical USGS National Water Use Estimates, and applies linear regressions to county level surface water consumptive use estimates, accounting for decreasing trends by setting a lower limit of 20% of the current water use (Zamani Sabzi et al., 2019).

5.2 Review of studies within the Delaware River Basin

As previously referenced, the *Multi-jurisdictional Report* (USACE & DRBC, 2008) provides an estimate of water use in the Delaware River Basin for the year 2003, as well as projected sector trends for peak monthly water withdrawal through the year 2030. Both the thermoelectric and hydroelectric sectors were projected through the year 2030.

- **Thermoelectric** projections were based on trend extrapolation of peak monthly water use data from 1994-2003. The result yielded growth rates consistent with EIA forecasts of MW demand growth for the Mid-Atlantic Region. Consumptive use information was obtained on a site-specific basis from DRBC dockets.
- **Hydroelectric** projections were based on available water use data and held constant.

The *Multi-jurisdictional Report* also provides a summary of each Basin states' approach to demand forecasting at the time of the report, but only Pennsylvania was stated to have addressed power generation. To the authors' knowledge, there have been no additional focused studies at the state level on projecting water withdrawals and consumptive water use for power generation, although many states have published recent “energy plans” which outline goals for energy production. To this end, additional details regarding the projections for Pennsylvania are summarized below:

- **Pennsylvania**. As was discussed in Section 3.2, Pennsylvania’s Act 220 Water Resources legislation led to the development of a State Water Plan, which included a pilot study of water use projection methodology for the Lehigh River Basin in Appendix I (CDM & DRBC, 2005). This pilot study included projections of water use for both thermoelectric and hydroelectric power generation.
  - **Thermoelectric** projections were based largely on a projection by PJM (the regional transmission organization for much of Pennsylvania), which estimated (at the time of the report) that power demand was projected to grow 1.7 percent annually through 2015 for the PJM Mid-Atlantic Region, which was extended to 2030 for the pilot study. The projection methodology assumed no new or retired facilities, and no import-export of generated power. Therefore, water demand at each facility within the region (based on 2004 production data) was assumed to grow at the same rate as power demand, until the power generation of a specific facility reached 85% of the operating capacity.
  - **Hydroelectric** facilities were assumed to operate at capacity, meaning that reported withdrawals are equal to the amount of water available, and that power demand has no impact on the withdrawals. Variation in water withdrawals from year to year was assumed to be a function of water availability. An inventory of water use data was taken for each facility in the pilot study, and a constant rate applied to future projections.

5.3 Energy generation data evaluation

The data provided by (USEIA, 2020c) was updated in April 2020 and indicates that there were 234 operable electric generating plants within the Delaware River Basin, as presented in Figure 32. However, in order to more accurately capture a time-series of energy generation data, an additional 27 power facilities were included within the dataset from an analysis of all available geospatial data provided by Form EIA-860 datasets (USEIA, 2020a); this includes facilities which are known to be decommissioned or retired. Therefore, the time-series analysis for energy generation within the Delaware River Basin includes 261 facilities with unique EIA Plant IDs.

5.3.1 EIA energy generation data

Historical data related to energy generation of the 261 Delaware River Basin facilities was compiled from datasets maintained by the EIA, summarized into four groups:

Utility & Non-utility (2001-2019): .... Monthly data from Forms EIA-906/920/923

Non-utility (1999-2000): .... Monthly data from Form EIA-906 (format differs from 2001)

Non-utility (1990-1998): .... Annual data from Form EIA-867

Utility (1990-2000): .... Monthly data from Form EIA-759

Definitions provided by the EIA for the parameters of interest to this report are:

Electric Utility...............*A corporation, person, agency, authority, or other legal entity or instrumentality aligned with distribution facilities for delivery of electric energy for use primarily by the public.*

Electric Nonutility ....*A corporation, person, agency, authority, or other legal entity or instrumentality that owns or operates facilities for electric generation and is not an electric utility.*

Net Generation ....*The amount of gross generation less the electrical energy consumed at the generating station(s) for station service or auxiliaries.*

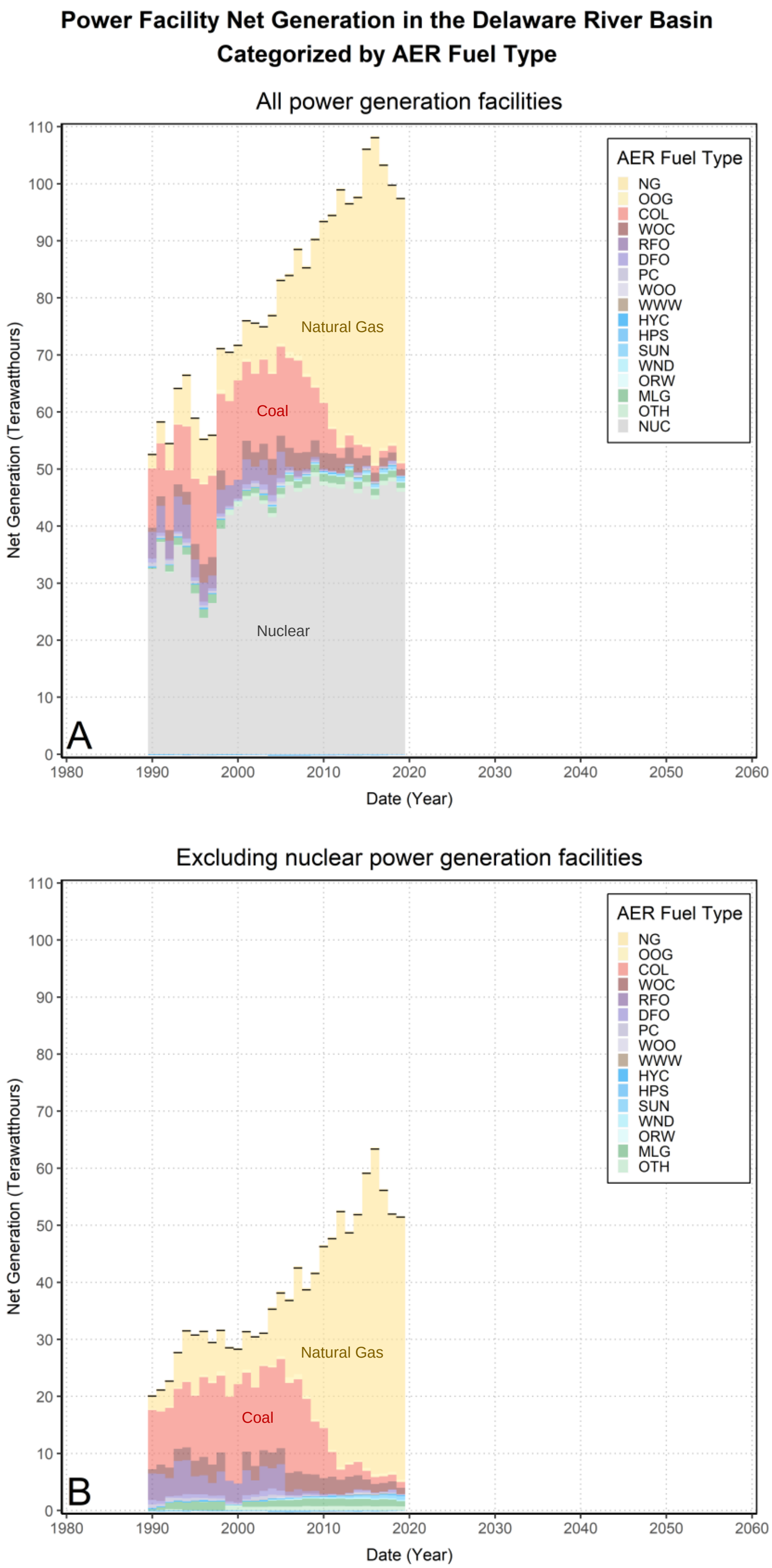
AER Fuel Type ....*This represents a partial aggregation of the reported fuel type codes into larger categories used by EIA in, for example, the Annual Energy Review (AER).*

Primary Mover Type.....*The engine, turbine, water wheel, or similar machine that drives an electric generator; or, for reporting purposes, a device that converts energy to electricity directly (e.g. steam turbine [ST]).*

There are inherent challenges when attempting to present multiple datasets in a normalized fashion, which was primarily encountered while analyzing the AER fuel type code. For data from Form EIA-759 (1990-2000, utilities) and Form EIA-906 (1999-2000, non-utilities), reported fuel type codes were manually categorized into an AER fuel type code. Additionally, data on the primary mover type was not available from Form EIA-867 (1990-1998, non-utilities) and Form EIA-906 (2000-2001, utilities and non-utilities).

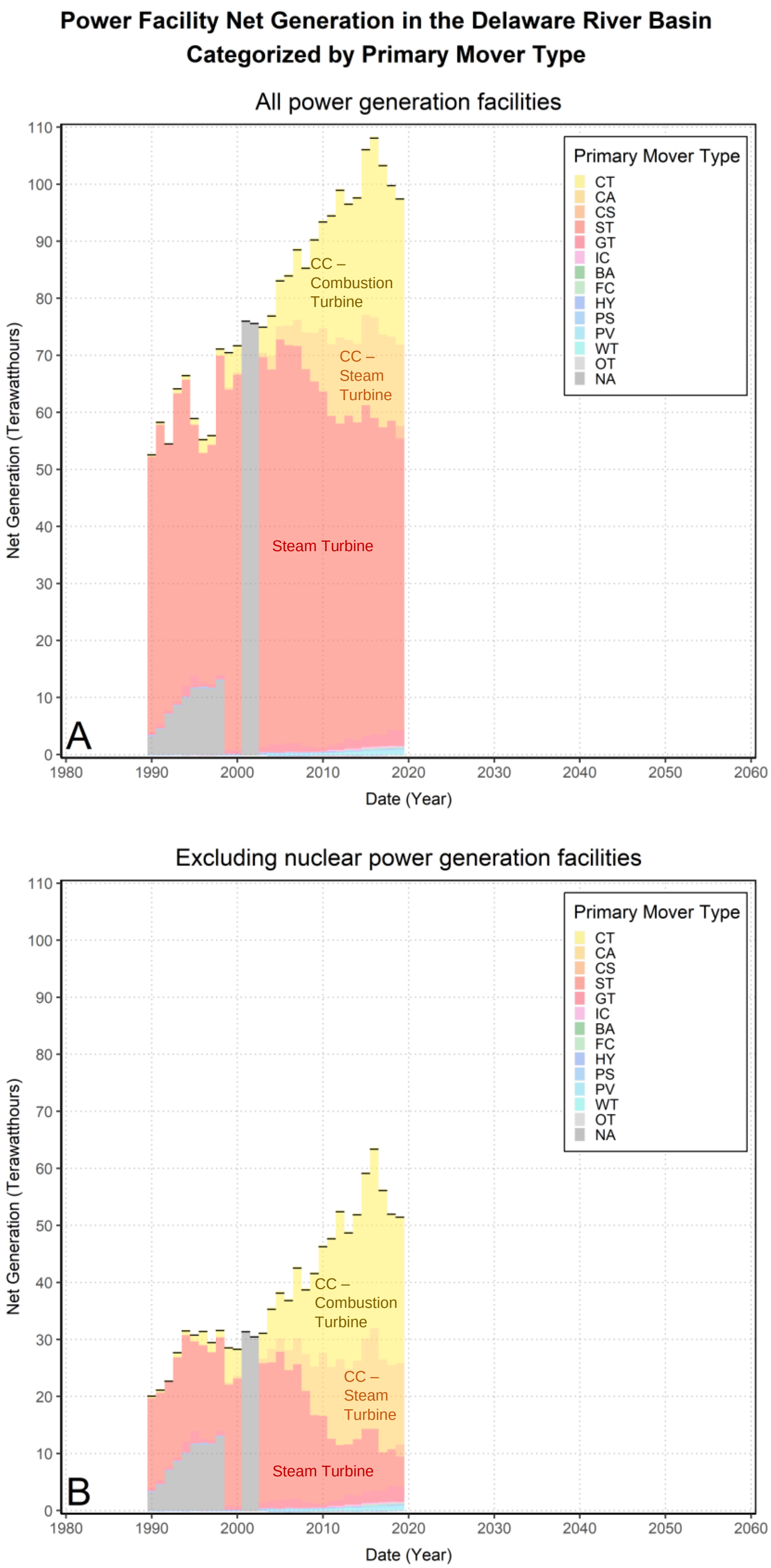
A time-series of net generation for the Basin is presented in Figure 33 (categorized by AER fuel type) and Figure 34 (categorized by primary mover type). A drop in nuclear power generation is evident in the mid-1990s and corresponds with the temporary shut-down of a major generating unit with the Basin. As nuclear power generation has historically accounted for a large percentage of the total net generation, it is helpful to provide an additional graphic in each figure providing the same data without nuclear power facilities. The data release supporting this analysis is provided in Appendix A as Table A-5.

A view of the pipeline leaving the
Lake Wallenpaupack Hydroelectric Dam
in Pike & Wayne counties, Pennsylvania.
Credit: https://www.brookfield.com/



Code	AER Fuel Type Description
NG	Natural Gas
OOG	Other Gases
COL	Coal
WOC	Waste Coal
RFO	Residual Petroleum
DFO	Distillate Petroleum
PC	Petroleum Coke
WOO	Waste Oil
WWW	Wood and Wood Waste
HYC	Hydroelectric Conventional
HPS	Hydroelectric Pumped Storage
SUN	Solar PV and thermal
GEO	Geothermal
WND	Wind
ORW	Other Renewables
MLG	Biogenic Municipal Solid Waste and Landfill Gas
OTH	Other (including nonbiogenic MSW)
NUC	Nuclear

Figure 33: Power facility net generation in the Delaware River Basin, categorized by AER fuel type. *The annual net energy generation of power facilities identified within the Delaware River Basin, categorized by AER fuel type. The graphics represent (A) all power facilities within the Basin, and (B) the same data excluding nuclear power facilities. The data presented in these figures were obtained from the Energy Information Administration, as discussed in Section 5.3.1. Data supporting this figure are provided for reference in Table A-5.*



Code	Primary Mover Type Description
CT	Combined-Cycle Combustion Turbine Part
CA	Combined-Cycle -- Steam Part
CS	Combined-Cycle Single-Shaft Combustion Turbine and Steam Turbine share of single generator
ST	Steam Turbine. Including Nuclear, Geothermal, and Solar Steam (does not include Combined Cycle)
GT	Combustion (Gas) Turbine. Including Jet Engine design
IC	Internal Combustion (diesel, piston, reciprocating) Engine
BA	Energy Storage, Battery
FC	Fuel Cell
HY	Hydraulic Turbine. Including turbines associated with delivery of water by pipeline
PS	Energy Storage, Reversible Hydraulic Turbine (Pumped Storage)
PV	Photovoltaic
WT	Wind Turbine, Onshore
OT	Other

***Figure 34**: **Power facility net generation in the Delaware River Basin, categorized by primary mover type.** The same net energy generation data presented in Figure 33, categorized by the primary mover type. The data presented in these figures were obtained from the Energy Information Administration, as discussed in Section 5.3.1. Data supporting this figure are provided for reference in Table A-5.*

5.3.2 USGS cooling system data

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. The EIA collects data on cooling system types through Form EIA-923 Schedule 8D, but only requires reporting from power plants with a total steam capacity of 100 MW or greater. A 2013 USGS study focused on developing a method for estimating water consumption at thermoelectric power plants included a review of facilities above and below the 100 MW threshold to verify cooling-system types (Diehl et al., 2013). The methods developed were used in a more recent 2019 USGS study estimating the withdrawal and consumption of water by thermoelectric power plants in the United States for the year 2015 (Harris & Diehl, 2019). This more recent study evaluated 1,122 power plants and placed cooling systems into five categories; the cooling system dataset was made publicly available as part of the publication.

This DRBC study applies the cooling-system data classifications from Harris & Diehl, 2019 to the net generation time-series for the Delaware River Basin, and makes the assumption that the current cooling system technology is unchanged from historical operations. Of the five cooling system categories, only three were applicable to power facilities within the Delaware River Basin (Recirculating Tower, Once-Through Saline and Once-Through Fresh). As all power generation within the Delaware River Basin was considered in this analysis (not restricted to thermoelectric), three additional categories were added:

Hydroelectric............ Applied net generation from facilities with primary movers or AER fuel types attributed to hydroelectric power.

No Water Source...... Applied to power facilities which did not report a primary water source to Form EIA-860 between 2012-2019 and is therefore assumed to not use water for cooling.

No Data Available .... Applied to power facilities which reported a primary water source, did not have a classified cooling system from Harris & Diehl, 2019, and did not have a cooling system type identified by DRBC.

There were 38 facilities included in this analysis which were not included in the data set provided by Harris & Diehl, 2019, summarized as follows:

(13) facilities were found to have current and/or former DRBC water withdrawal approvals; cooling system types were populated based on research.

(25) facilities have water sources reported through the EIA, but cooling system information was not available and they remained classified as “No Data Available”.

Once complete, this analysis allows the same net-generation data presented in Figure 33 and Figure 34 to be categorized by facility cooling system, as shown in Figure 35. The information for this analysis is also captured in the data release provided in Appendix A as Table A-5.

5.3.3 Summary

The net energy generation in the Delaware River Basin has increased steadily since 1990 until a peak around 2016. Nuclear power net energy generation has remained relatively stable since 2005, and there are no major changes reported in primary mover or cooling system type. Conversely, the thermoelectric sector has reported major shifts in the primary fuel type, mover type and cooling system type. It is evident that the net energy generation from coal-fired steam turbine power facilities using once-through cooling has drastically decreased since about 2007. Furthermore, the demand for power production has seemingly been made up by natural gas combined-cycle facilities using recirculating cooling towers. Projections of peak summer energy load are routinely updated by PJM, the most recent indicating slight growth for the Mid-Atlantic region (0.3% in 15 years) and the Eastern Mid-Atlantic region (0.4% in 15 years), both of which cover large portions of the Delaware River Basin (PJM, 2021) and represent smaller growth projections than the previous year.

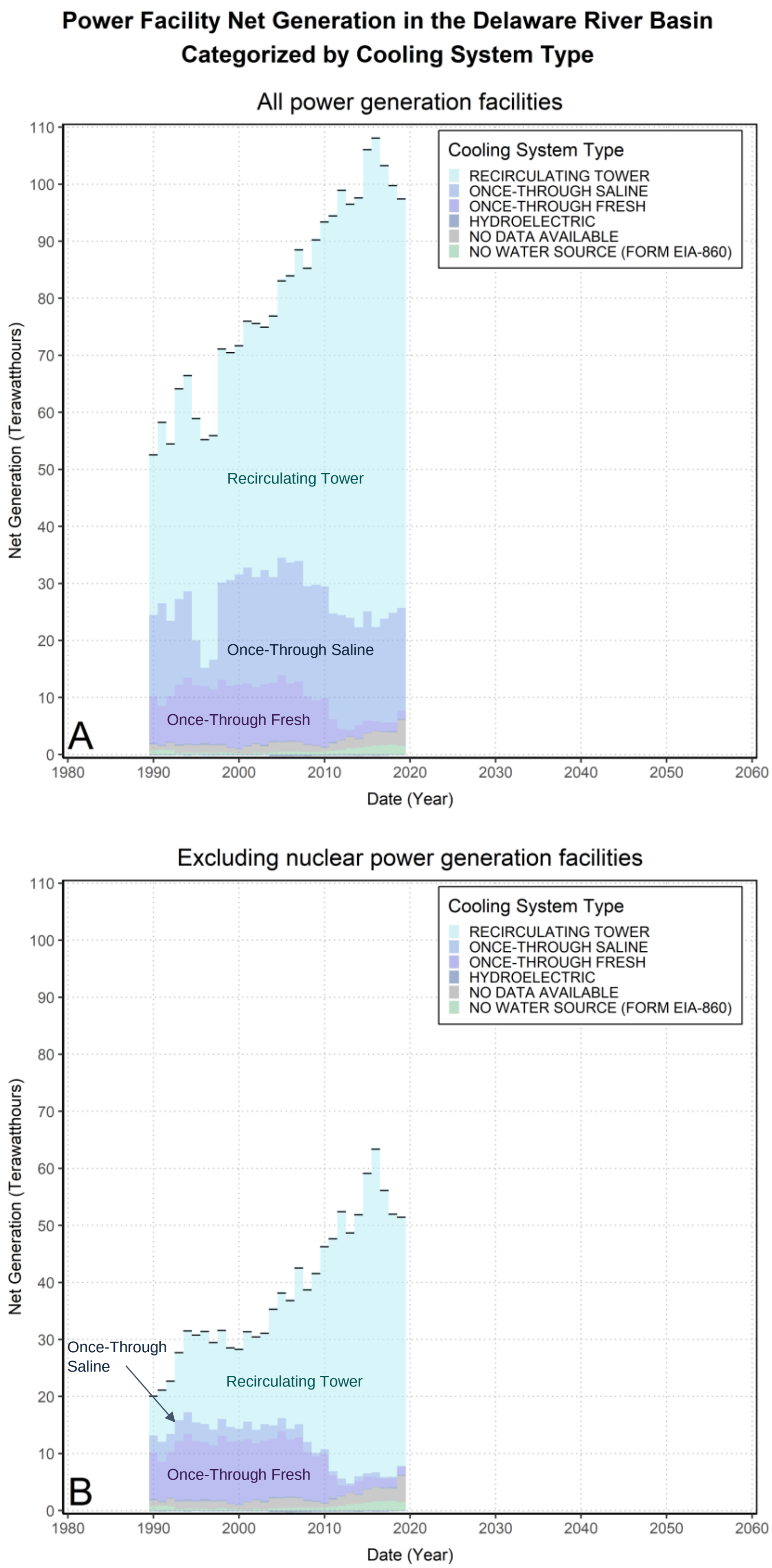


***Figure 35**: **Power facility net generation in the Delaware River Basin, categorized by cooling system type.** The same data presented in Figure 33 and Figure 34 for (A) all facilities within the Delaware River Basin and (B) excluding nuclear power facilities, categorized by cooling system type adapted from Harris & Diehl, 2019. Data supporting this figure are provided for reference in Table A-5.*

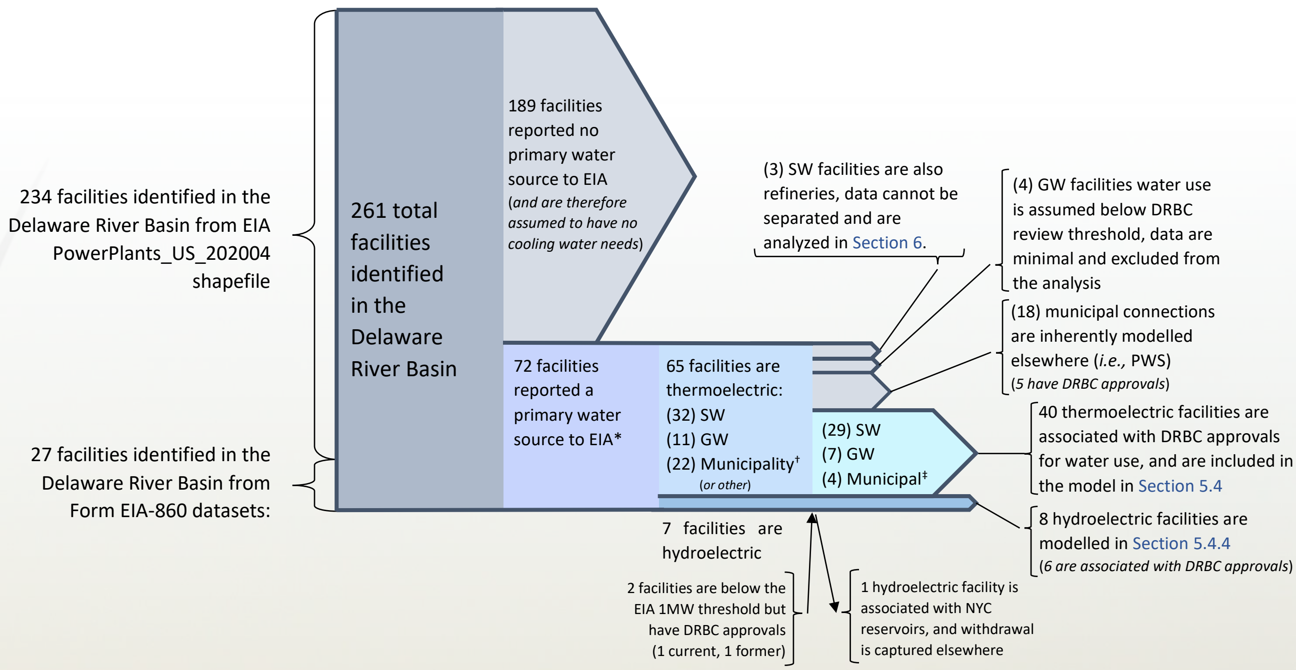
On a national scale, Harris & Diehl, 2019 noted that net electricity generation decreased approximately seven percent between 2010 and 2015; however, declines were not consistent across facilities with different cooling technology. In fact, they report that there was an average increase of nine percent for facilities using recirculating cooling towers, and most notably, an average increase of 54 percent at natural-gas combined-cycle (NGCC) facilities.

Counter to the national trend reported in Harris & Diehl, 2019, this analysis shows that net generation for all facilities in the Delaware River Basin has increased 12.660 TWh between 2010 and 2015, which is equivalent to approximately 13.6%. However, the observed basin wide increase is attributed to sub-trends (which are consistent with Harris & Diehl, 2019), generally attributed to two primary variables in each data category:

- Primary mover type: an increase in net generation from combined-cycle facilities (+15.019 TWh, or 50.1%) and a decrease from steam-turbine facilities (-4.516 TWh, or -7.2%).
- Primary fuel type: an increase in generation using natural gas (+19.946 TWh, or 62.5%) and a decrease in generation using coal (-7.272 TWh, or 82.8%).
- Cooling system type: an increase in generation using recirculating towers (+18.061 TWh, or 28.8%) and a decrease from once-through freshwater systems (-4.227 TWh, or 70.5%).

As additionally noted in Harris & Diehl, 2019, more than half of the plants which became operational from 2010-2015 were NGCC facilities, and all but one had recirculation cooling systems. As energy generation migrates from facilities with less efficient per-volume water cooling systems (once-through) to those with more efficient systems (recirculating), a decrease in total water withdrawals related to thermoelectric power generation is expected (this notion is confirmed in Section 5.4.1.3). However, evaporative cooling techniques (e.g., recirculating towers) generally have higher rates of consumptive use; therefore, the trend of total water withdrawal and the trend of consumptive water use can be different (as is shown in Section 5.4.1.4).

Regarding total withdrawal and consumptive water use, Form EIA-860 requires facilities to report the primary water source used for cooling or hydroelectric energy generation. Therefore, it is clear that not all of the 261 facilities included in the energy generation analysis will be included in the water use analysis. The only facilities within the Basin captured in the water use analysis are thermoelectric and hydroelectric facilities; however, because they are so different in nature the analysis of water use for each has been broken into broken into Section 5.4 and 5.5, respectively. A Sankey diagram summarizing how many facilities are included in each section is provided in Figure 36. Of the 261 facilities, 189 did not report data and are assumed (per reporting instructions) to not require water cooling (72.4%), 22 reported municipal water sources (8.4%), and 50 reported groundwater or surface water sources (19.2%). Excluding certain facilities for the various reasons shown on Figure 36, 48 facilities are included in the analysis on water withdrawal and consumptive use. In general, the 48 facilities included in the analysis have historically accounted for about 94.9% of the net generation for the Basin.



Notes:
- * *One facility reports "No Water Use" which is likely a result of interconnected refinery operations. It is known through docket research that it uses water for cooling and has been included in the total.*
- † *One facility reports a SW primary water source but is assumed to be connected to a municipality.*
- ‡ *Modelled facilities reporting a municipal water source are withdrawals and not interconnections (e.g., withdrawal of a municipal effluent stream).*

***Figure 36**: Sankey diagram summarizing how many power generation facilities are included in each water use analysis, considering the total number of power facilities included in the energy generation analysis for the Delaware River Basin. This chart includes both active and retired facilities, as all contribute to the time-series analysis.*

A wind turbine near Canary Creek
In Sussex County, Delaware.
Credit: Khairil Junos
Used in accordance with license

5.4 Thermoelectric

5.4.1 Water withdrawal data evaluation

5.4.1.1 Associated and unassociated systems

As detailed in Figure 36, there are 40 thermoelectric facilities which have been included in this analysis, all of which are associated with DRBC approvals. A summary of average total withdrawal volume over the entire dataset time-series is presented in Table 19, indicating which portions of the volume are associated with DRBC approvals, surface water, or groundwater. From this assessment, it is possible to conclude that more than 99% of the water withdrawn for thermoelectric power generation in the Delaware River Basin is surface water and associated with some form of regulatory approval. As was indicated in Figure 36, the groundwater withdrawals from the 4 unassociated facilities (assumed to withdrawal below regulatory review threshold) are not modelled. For reference, a complete list of the associated facilities assessed in this report is included as Appendix C; some facilities may have been reviewed but not projected, as indicated in the appendix.

***Table 19**: A Summary of the total water withdrawal data for thermoelectric power generation, categorized by source-type and association with regulatory approvals.*

Data category	Systems (OAIDs)*	Water type	Sources (WSIDs)	Average withdrawal (MGD)	Percent total withdrawal
Associated	46	SW	41	4803.077	99.9%
		GW	41	1.976	0.0%
Unassociated	9	SW	5	0.853	0.0%
		GW	14	0.063	0.0%
Totals:	55	--	101	4805.970	100.0%

* Recall that OAIDs are identifiers, and not necessarily synonymous with number of facilities.

5.4.1.2 Data exclusions

The dataset for unassociated withdrawals is very small compared to the universe of associated data; it is assumed that the withdrawals fall below thresholds for DRBC regulatory review, and datasets are limited. Therefore, unassociated data are excluded from figures, summations, projections and data deliverables.

5.4.1.3 Total water withdrawal

The water withdrawal data for the 40 associated thermoelectric facilities in the Delaware River Basin are presented for each Basin state in Figure 37. These data are then aggregated to represent the entire Delaware River Basin in Figure 38, and plotted again in Figure 39 excluding data from nuclear power facilities. At the Basin scale, the dataset is not substantially complete until the year 1990, and therefore years before that date have been omitted from figures as a standard practice. The data release supporting the analysis in this section is provided in Appendix A as Table A-6.

From the state-level data shown in Figure 37, it is possible to conclude that peak water withdrawal has already occurred in each state. Of particular note shown in Figure 37B, withdrawals in New Jersey showed a significant decrease in the mid-1990s which is consistent with the drop in net generation described in Section 5.3.1, attributed to the temporary shutdown of a nuclear powered generation facility. The separation of cooling system types between the states is logical when also considering each states' proximity to the Delaware Bay. It is worth noting that the y-axis scale on each plot in Figure 37 is independent, and there were no facilities present in the New York portion of the Basin.

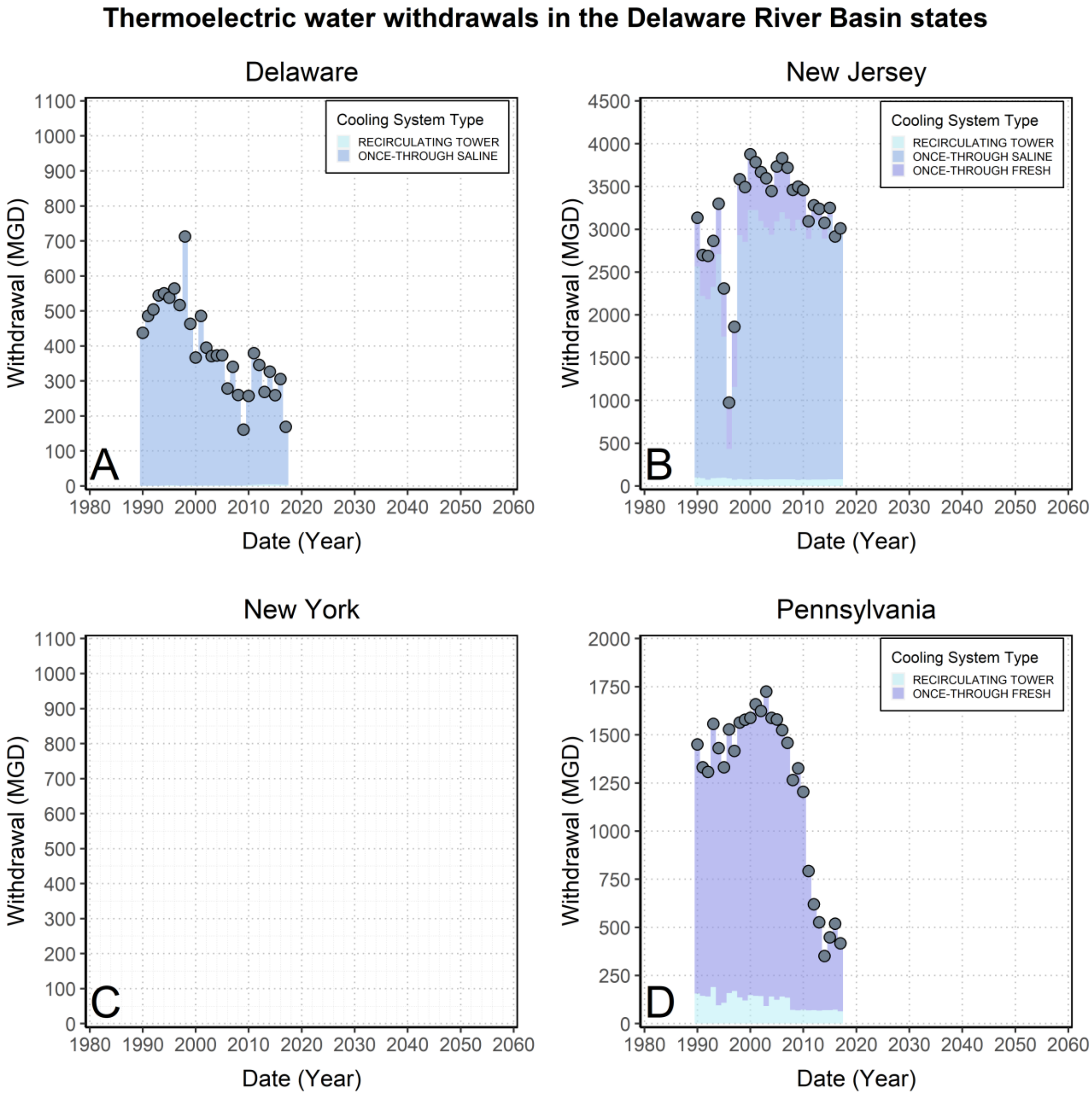


***Figure 37: Thermoelectric water withdrawals from the Delaware River Basin states.** Annual average water withdrawal by the 40 thermoelectric facilities which are included in this study of the Delaware River Basin. Withdrawals are presented for each of the Basin states, categorized by individual facility cooling system types. The projections results for this figure are presented in Figure 43. Data supporting these figures are provided for reference in Table A-6.*

Looking at the aggregated data for the Basin presented in Figure 38, overall thermoelectric water withdrawals appear to have peaked in 2001 at about 5,900 MGD. However, removing nuclear power data from the analysis provides a slightly clearer picture, as shown in Figure 39. This analysis confirms that there have been significant changes in the withdrawal patterns of non-nuclear-powered thermoelectric facilities in the Delaware River Basin. The primary findings are:

1. An approximately 81.2% decrease in withdrawals by facilities using freshwater once-through cooling since 2007, which is equivalent to an average daily withdrawal of about 1,560 MGD.

2. An approximately 60.6% decrease in withdrawals by facilities using saline once-through cooling since 2007, which is equivalent to an average daily withdrawal of about 250 MGD.

These conclusions about total water withdrawal are generally consistent with findings at the national scale published in Harris & Diehl, 2019, which indicated that federally reported thermoelectric withdrawal totals decreased between 2005 and 2015. It concludes that decreases in withdrawals were mostly due to decreased production at, and closure of, coal-fired power facilities using once-through cooling systems. Other drivers of the changes were cited as environmental regulations constraining once-through cooling systems, conversion of once-through cooling systems to recirculating cooling systems, and more natural gas combined cycle plants coming online. These conclusions were supported by a national statistic published by the EIA in 2018 which indicated that 47% of utility-scale power plant retirements between 2008-2017 were coal power plants (USEIA, 2018). From the analysis presented thus far, it is evident that trends regarding water withdrawals in the Delaware River Basin are consistent with those observed at the national scale.

There is one facility which withdrawals groundwater from SEPA-GWPA as a secondary use, and only reports a historical average of about 0.032 MGD. These data are included in the release and are projected; however, separate figures have not been prepared related to SEPA-GWPA.

5.4.1.4 Consumptive water use

Consumptive use ratios were applied to the historical total water withdrawal dataset to calculate a historical consumptive water use dataset for each state, as presented in Figure 40. These data are then aggregated to represent the entire Delaware River Basin in Figure 41, and plotted again in Figure 42 excluding data from nuclear power facilities. The data release supporting the analysis in this section is provided in Appendix A as Table A-6.

As discussed in Section 2.2.3, data reported as a result of the DRBC Water Supply Charges Regulations have resulted in a dataset for certain surface water withdrawals which includes both the total amount of water withdrawn, as well as the portion consumptively used. A summary of data applied to each source of water follows:

Surface water: All but 3 modelled surface water withdrawals have CURs calculated based on historical data. Of the three without calculated CURs, one has a number adopted from the regulatory approval, and two abandoned intakes use default values as indicated in Table 5.

Groundwater: While 7 modelled facilities have a primary source of groundwater, 15 facilities withdrawal groundwater. Of these 15 facilities, 7 have CURs applied to groundwater data based on data obtained from regulatory approvals; the remaining 8 facilities have sector default values applied as indicated in Table 5.

Based on the figures presented in this section of the report, specific conclusions can be drawn regarding consumptive use over the last two decades:

1. Consumptive use has remained relatively constant, excluding the portion of time when one nuclear facility was offline. For all facilities, it has hovered around 96 MGD, whereas non-nuclear facilities account for about 30 MGD.
2. For non-nuclear facilities, the portion of consumptive use attributed to facilities using recirculating cooling towers has accounted for an increasing percentage of the total (from an average of about 38.9% before 2000, to about 88.6% between 2013-2017). This corresponds to an increase in consumptive use by facilities of this type by around 14.659 MGD.

It was reported in Harris & Diehl, 2019 that model-estimated thermoelectric water consumption decreased about 21% between 2010 and 2015 at the national scale, and that decreases were observed in every category of cooling system. The Delaware River Basin differs in that consumptive use has remained relatively consistent, but it is the same in that total consumption was the largest for plants with recirculating cooling systems.

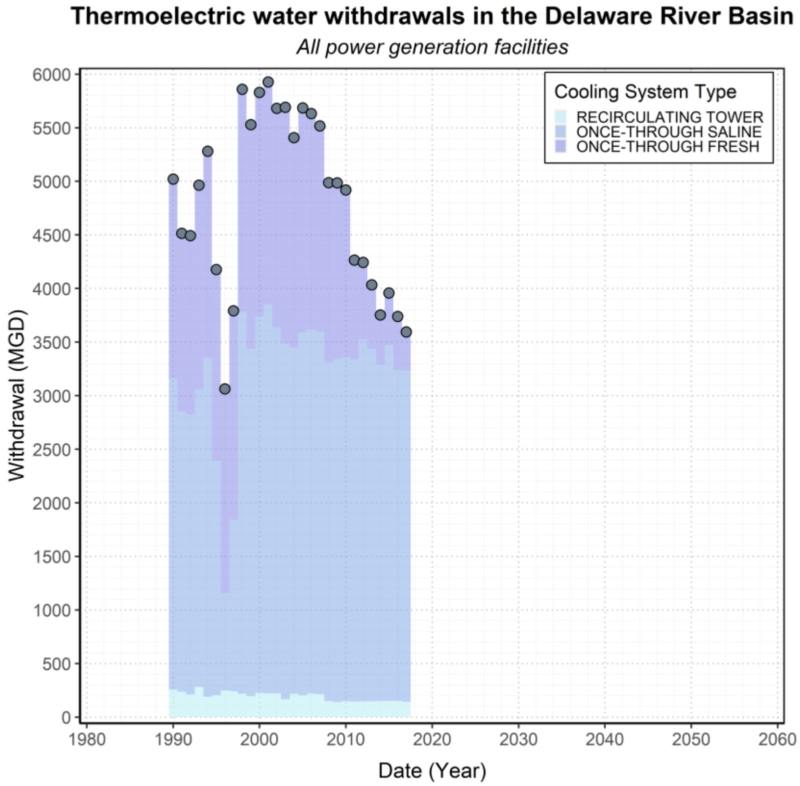


Figure 38: Thermoelectric water withdrawals from the Delaware River Basin (all power generation facilities). *Annual average water withdrawal by the 40 thermoelectric facilities which are included in this study of the Delaware River Basin. This represents the same data presented in Figure 37, aggregated to the Basin scale. The large decrease in the mid-1990s is attributed to a temporary shutdown of a nuclear power generation facility. The projections results for this figure are presented in Figure 44. Data supporting this figure are provided for reference in Table A-6.*

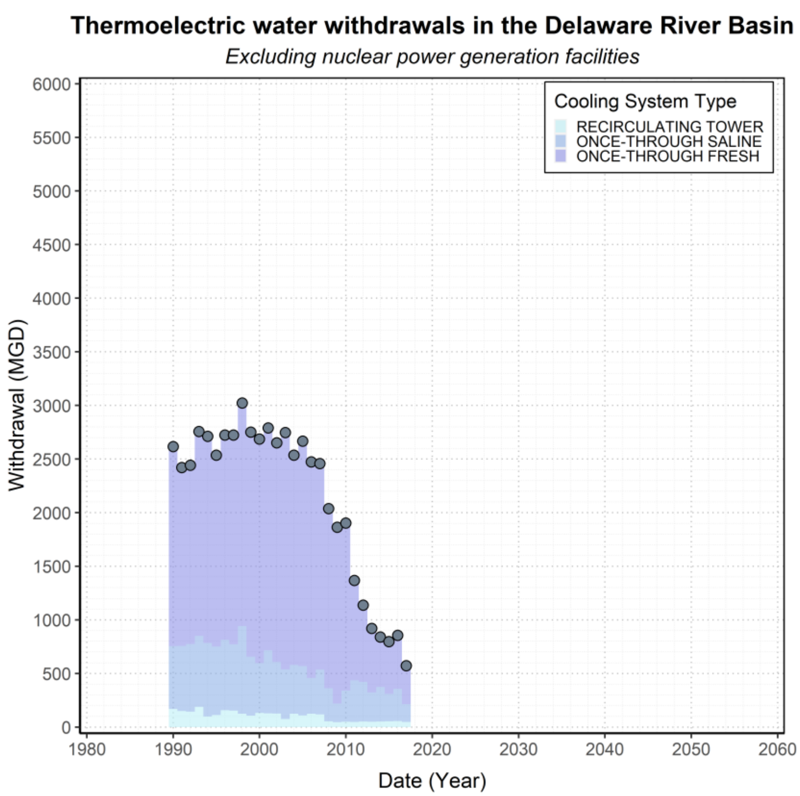


Figure 39**: **Thermoelectric water withdrawals from the Delaware River Basin (excluding nuclear power generation facilities). *Annual average water withdrawal from the 37 non-nuclear powered thermoelectric facilities included in this study of the Delaware River Basin. The projections results for this figure are presented in Figure 45. Data supporting this figure are provided for reference in Table A-6.*

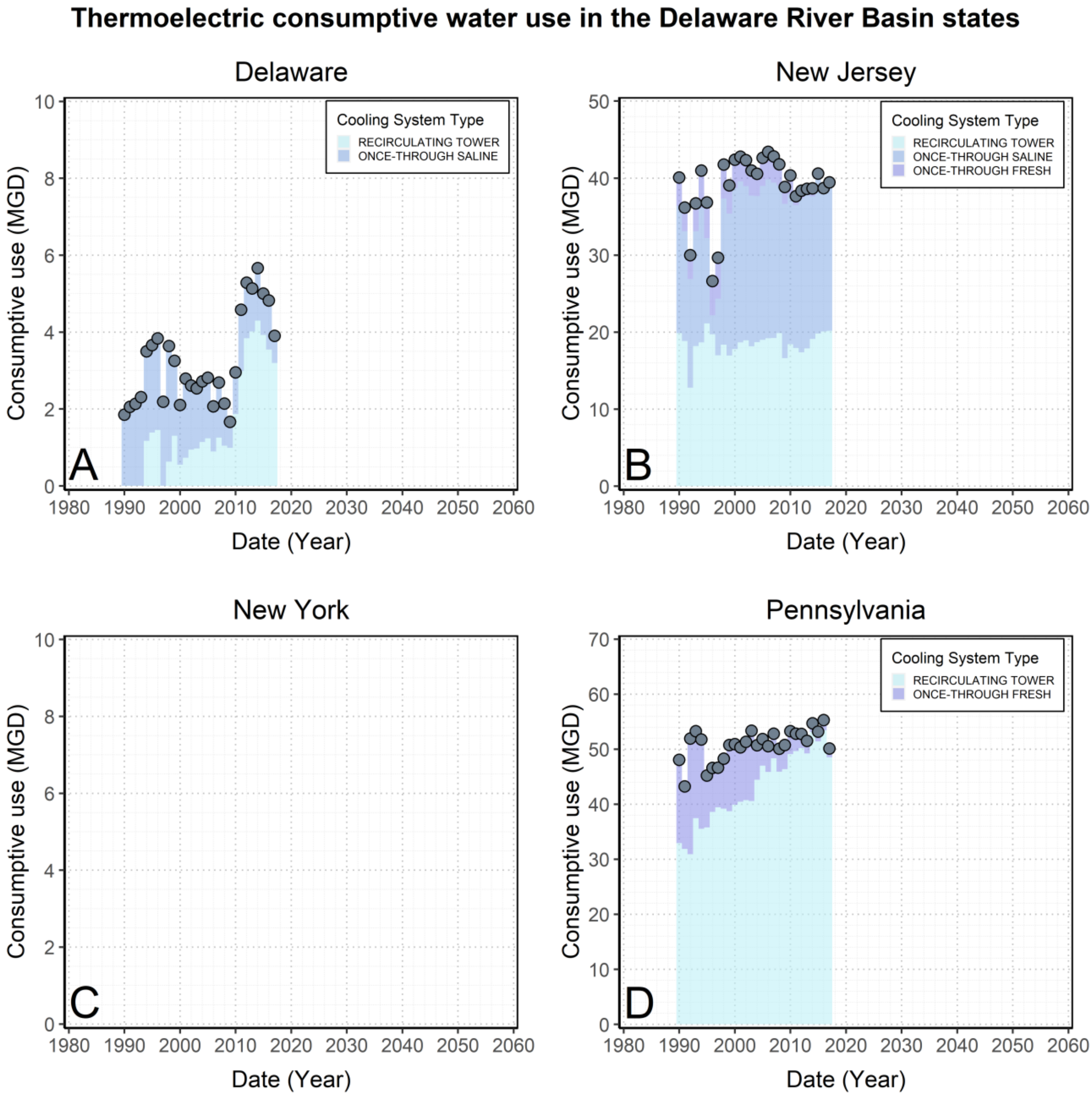


Figure 40: Thermoelectric consumptive water use in the Delaware River Basin states. *Annual average consumptive water use by the 40 thermoelectric facilities included in this study of the Delaware River Basin. These data were calculated using the withdrawal data presented in Figure 37, multiplied by specific consumptive use ratios (calculated or referenced). Note different y-axis scales. The projections results for this figure are presented in Figure 46. Data supporting these figures are provided for reference in Table A-6.*

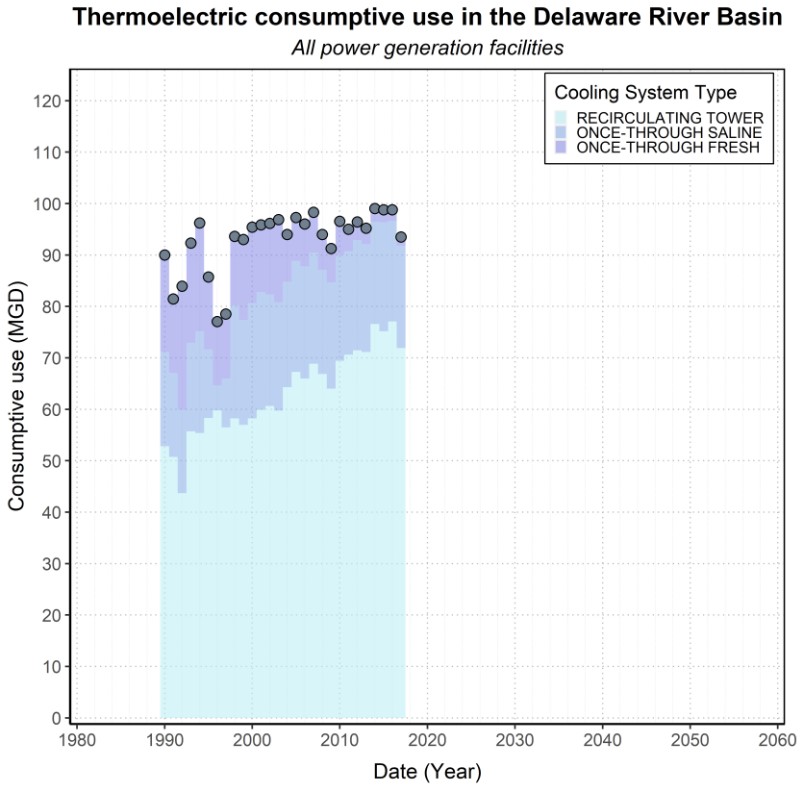


***Figure 41**: Thermoelectric consumptive water use the Delaware River Basin (all power generation facilities).* *Annual average consumptive water use by the 40 thermoelectric facilities which are included in this study of the Delaware River Basin. This represents the same data presented in Figure 40, aggregated to the basin scale. The corresponding figure showing total water withdrawal is Figure 38. The projections results for this figure are presented in Figure 47. Data supporting this figure are provided for reference in Table A-6.*

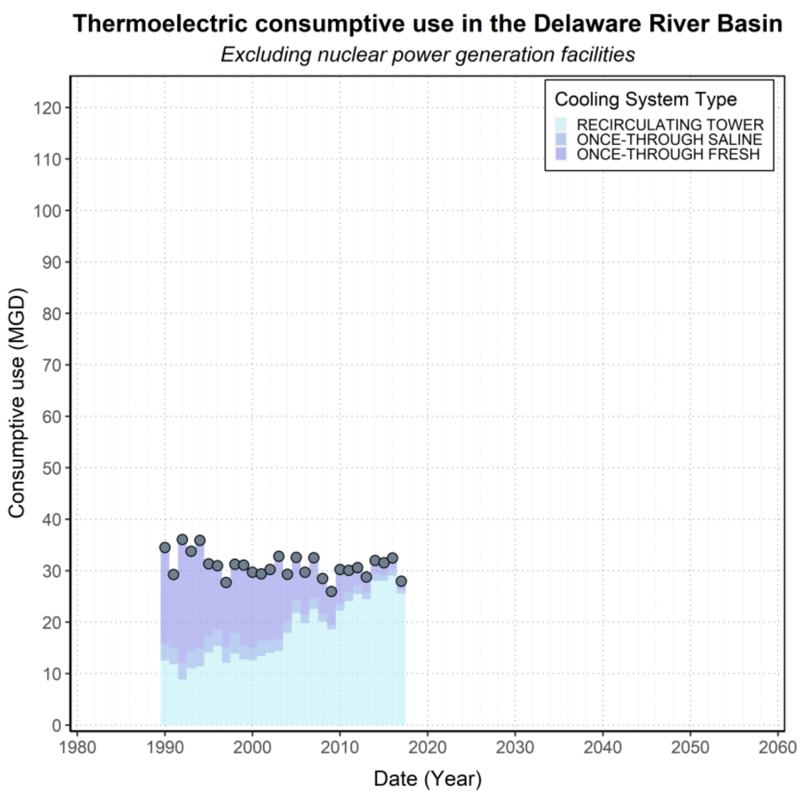


***Figure 42**: Thermoelectric consumptive water use the Delaware River Basin (excluding nuclear power generation facilities).* *Annual average water withdrawal from the 37 non-nuclear powered thermoelectric facilities included in this study of the Delaware River Basin. The corresponding figure showing total water withdrawal is Figure 40. The projections results for this figure are presented in Figure 48. Data supporting this figure are provided for reference in Table A-6.*

5.4.2 Methods

The methods used in this analysis for projecting water withdrawals for use in the power generation sector are the same as described for the public water supply sector, outlined in Section 3.4. To reiterate, the overall concept of this analysis is to estimate future water demands by extrapolating historical withdrawal data at the water supply system and/or sub-system levels in a manner such that a “bottom-up” approach can be used to re-aggregate the projections. The methods inherently assume that the rate of change in water use over the recent past will continue into the future at the same rate of change, among other assumptions (e.g., Section 3.4.5.4). This analysis is not intended to capture changes due to potential new/emerging technology or regulations, nor is it intended to project or capture possible future withdrawal changes as the result of new or closing power facilities. The results of this analysis are focused on water demand and are intended to be used for water resource planning purposes.

5.4.3 Results

5.4.3.1 Total water withdrawal

The data release supporting the model presented in this section is provided in Appendix A as Table A-7. The projected water withdrawals for the 40 associated thermoelectric facilities in the Delaware River Basin are presented for each Basin state in Figure 43. From these projections, two conclusions are apparent:

1. When performing individual projections which attempt to capture the *current* trend in water withdrawals, the dramatic shifts observed in withdrawal patterns often resulted in much smaller usable datasets (i.e., adjusting the starting year of a projection, as discussed in Section 3.4.5.8.3). This is particularly evident in the projection for Pennsylvania, where the model is not substantially representative until after the significant decline in total withdrawals.
2. Non-symmetric prediction intervals are the result of Assumption #4 in Section 3.4.5.4, specifically, that projection equations and prediction intervals will not become negative and instead be replaced with a zero value. As there were substantial decreasing trends in this water use sector, this assumption becomes apparent in the asymmetry of the aggregated predictive intervals.

The aggregated projection result for all thermoelectric facilities within the Delaware River Basin is shown in Figure 44 and indicates a plateauing decline in overall water withdrawal. Consistent with the method outlined in Section 3.4.5.9, it was determined that the model is substantially complete starting in 2011. The annual percent error and model results for select years through 2060 are provided for reference in Table 21.

As all nuclear-powered facilities yielded mean-value projections (or zero-slope linear models), a more specific aggregation of models for non-nuclear powered facilities is provided in Figure 45. This aggregation more clearly shows why the decline in total water withdrawal plateaus, reaching a modelled value in 2060 similar in magnitude to historical water withdrawals by facilities using recirculating cooling systems. Consistent with the method outlined in Section 3.4.5.9, it was determined that the model is substantially complete starting in 2011. The annual percent error and model results for select years through 2060 are provided for reference in Table 22.

As was referenced in Section 5.4.3.1, there is a very small groundwater withdrawal component for one facility in the SEPA-GWPA. While no figures have been prepared, the withdrawal was projected for completeness, and the data release providing results is available in Appendix A as Table A-8.

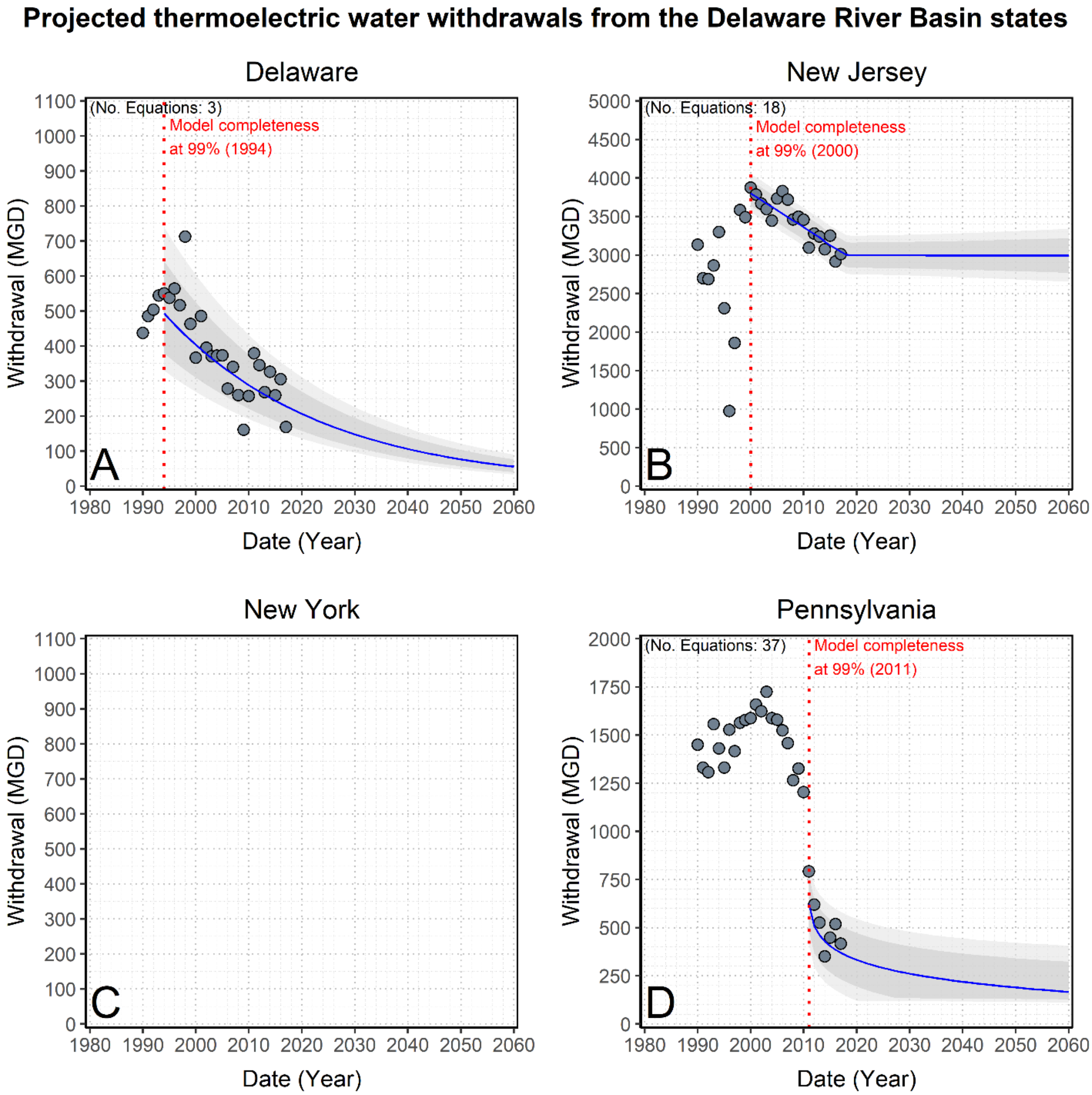


Figure 43: Projected thermoelectric water withdrawals from the Delaware River Basin states. *Aggregated projection results of average annual water withdrawal by the 40 thermoelectric facilities which are included in this study of the Delaware River Basin. Results of the model for select years are presented in Table 20. This projection corresponds with the data initially presented as Figure 37. Data supporting these figures are provided for reference in Table A-7.*

***Table 20**: Summary of results supporting Figure 43 for a basin-state projection of total water withdrawals used in thermoelectric power generation.*

State	Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
					lwr80	upr80	lwr95	upr95
Delaware	2013	268.195	260.917	2.710	199.791	339.885	173.162	390.869
	2014	326.486	252.315	22.720	193.107	328.819	167.323	378.220
	2015	259.096	243.999	5.830	186.641	318.129	161.674	366.005
	2016	305.201	235.962	22.690	180.387	307.802	156.207	354.210
	2017	168.862	228.192	35.140	174.338	297.826	150.919	342.820
	2020	NA	206.404	NA	157.374	269.882	136.067	310.931
	2030	NA	147.912	NA	111.761	195.027	96.091	225.618
	2040	NA	106.279	NA	79.311	141.763	67.661	164.939
	2050	NA	76.701	NA	56.331	103.717	47.579	121.525
	2060	NA	55.668	NA	40.123	76.441	33.483	90.289
New Jersey	2013	3,239.378	3,229.493	0.310	3,071.611	3,392.898	2,987.881	3,479.809
	2014	3,075.501	3,172.649	3.160	3,014.497	3,336.322	2,930.645	3,423.373
	2015	3,250.737	3,124.449	3.880	2,965.689	3,288.728	2,881.532	3,376.100
	2016	2,915.362	3,084.956	5.820	2,925.813	3,249.617	2,841.470	3,337.192
	2017	3,009.667	3,045.466	1.190	2,885.878	3,210.570	2,801.317	3,298.379
	2020	NA	2,996.349	NA	2,835.459	3,162.749	2,750.254	3,251.244
	2030	NA	2,994.949	NA	2,824.883	3,170.595	2,734.807	3,263.998
	2040	NA	2,993.723	NA	2,809.775	3,183.343	2,712.335	3,284.169
	2050	NA	2,992.640	NA	2,791.116	3,199.913	2,684.593	3,310.119
	2060	NA	2,991.679	NA	2,769.914	3,219.392	2,652.715	3,340.458
Pennsylvania	2013	526.264	460.662	12.470	323.013	598.830	250.357	672.445
	2014	350.331	428.201	22.230	290.554	566.401	217.863	640.021
	2015	447.913	404.913	9.600	267.373	543.042	194.714	616.615
	2016	518.649	385.966	25.580	248.359	524.236	175.678	597.886
	2017	416.755	369.946	11.230	232.219	508.279	159.484	581.981
	2020	NA	332.939	NA	194.570	471.733	121.589	545.734
	2030	NA	261.163	NA	133.324	403.343	118.788	478.978
	2040	NA	219.240	NA	131.453	366.011	116.720	444.058
	2050	NA	189.525	NA	129.516	341.379	114.332	422.107
	2060	NA	166.496	NA	127.806	323.676	111.342	407.222

Retired Delaware Generating Station in Philadelphia, Pennsylvania.
Credit: Jonathan Haeber (CC BY-NC 2.0)

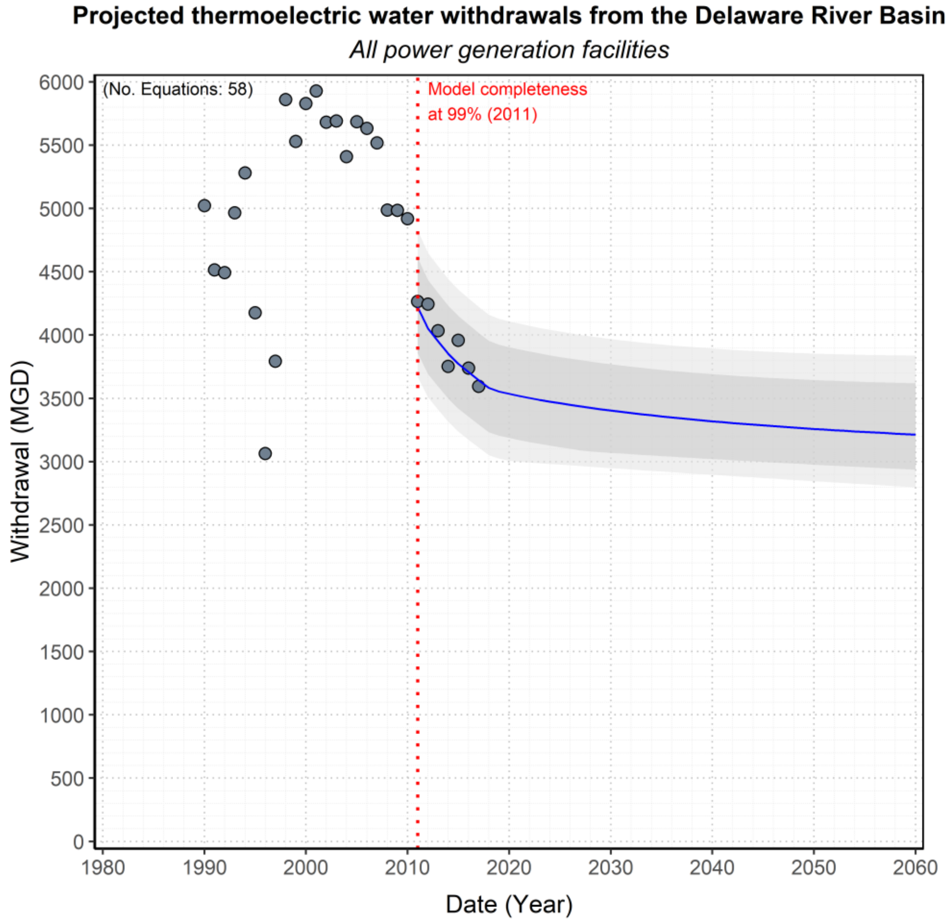


***Figure 44**: **Projected thermoelectric water withdrawals from the Delaware River Basin (all power generation facilities).** Aggregated projection results of annual average water withdrawal by the 40 thermoelectric facilities included in this study of the Delaware River Basin. Results of the model for select years are presented in Table 21. This projection corresponds with the data initially presented as Figure 38. Data supporting this figure are provided for reference in Table A-7.*

***Table 21**: Summary of results supporting Figure 44 for the Basin-wide projection of annual average water withdrawal by the 40 thermoelectric facilities included in this study.*

Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
				lwr80	upr80	lwr95	upr95
2013	4,033.729	3,951.072	2.05	3,594.415	4,331.613	3,411.401	4,543.123
2014	3,752.236	3,853.165	2.69	3,498.158	4,231.541	3,315.831	4,441.614
2015	3,957.651	3,773.361	4.66	3,419.704	4,149.898	3,237.920	4,358.720
2016	3,739.112	3,706.884	0.86	3,354.559	4,081.655	3,173.355	4,289.288
2017	3,594.840	3,643.605	1.36	3,292.435	4,016.675	3,111.719	4,223.179
2020	NA	3,535.692	NA	3,187.404	3,904.365	3,007.910	4,107.910
2030	NA	3,404.024	NA	3,069.968	3,768.964	2,949.686	3,968.593
2040	NA	3,319.242	NA	3,020.540	3,691.117	2,896.716	3,893.165
2050	NA	3,258.866	NA	2,976.963	3,645.009	2,846.504	3,853.751
2060	NA	3,213.843	NA	2,937.843	3,619.509	2,797.539	3,837.970

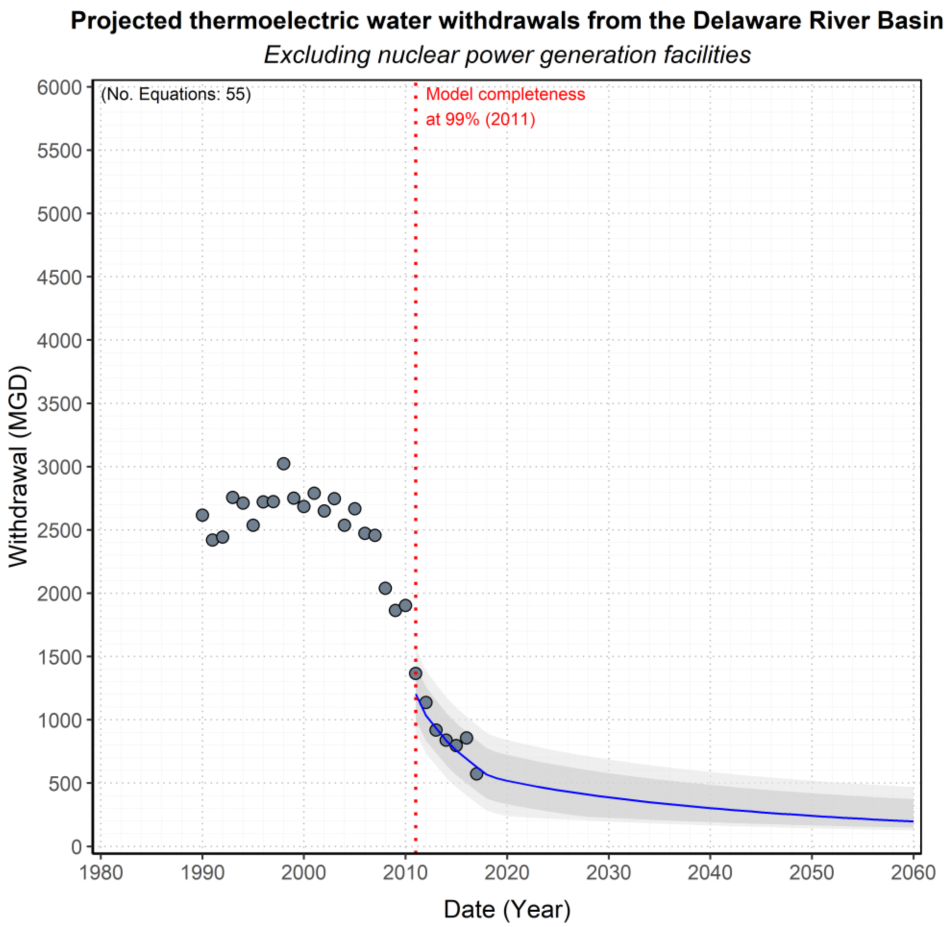


Figure 45: Projected thermoelectric water withdrawals from the Delaware River Basin (excluding nuclear power generation facilities). *Aggregated projection results of annual daily average water withdrawal from the 37 non-nuclear powered thermoelectric facilities included in this study of the Delaware River Basin. Results of the model for select years are presented in Table 22. This projection corresponds with the data initially presented as Figure 39. Data supporting this figure are provided for reference in Table A-7.*

Table 22*: Summary of results supporting Figure 45 for a Basin-wide projection of annual average water withdrawal by the 37 non-nuclear powered thermoelectric facilities included in this study.*

Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
				lwr80	upr80	lwr95	upr95
2013	919.476	934.678	1.65	737.837	1,155.403	639.398	1,282.010
2014	840.115	836.770	0.4	641.857	1,055.053	544.261	1,180.077
2015	795.818	756.967	4.88	563.748	973.066	466.878	1,096.655
2016	855.766	690.490	19.31	499.016	904.410	402.936	1,026.592
2017	572.826	627.211	9.49	437.370	838.952	342.016	959.750
2020	NA	519.298	NA	334.169	724.811	240.909	841.679
2030	NA	387.629	NA	226.786	579.359	197.292	686.969
2040	NA	302.848	NA	192.175	486.336	166.305	588.304
2050	NA	242.472	NA	166.702	421.152	143.801	519.681
2060	NA	197.448	NA	148.502	373.675	126.866	470.245

5.4.3.2 Consumptive water use

The aggregated projection results for all thermoelectric facilities within the Delaware River Basin are shown for each Basin state in Figure 46. It is important to reiterate that these projections are the same equations shown in Figure 43; however, each projection equation has been adjusted by its corresponding CUR. Therefore, equations with higher consumptive use ratios contribute proportionally more to the overall aggregations. It is apparent that decreasing total withdrawal trends in Delaware and Pennsylvania are converted to essentially average value projections of consumptive use, once accounting for CURs.

The aggregated consumptive use projection result for all thermoelectric facilities within the Delaware River Basin is shown in Figure 47, and the projection excluding nuclear-powered facilities is presented in Figure 48. Both aggregations show relatively coherent and stable projections. Consistent with the method outlined in Section 3.4.5.9, it was determined that the models are substantially complete starting in 2015. The annual percent error and model results for select years through 2060 are provided for reference in Table 24 and Table 25, respectively. The data supporting the model presented in this section are provided in Appendix A, in Table A-7.

Merrill Creek Reservoir.
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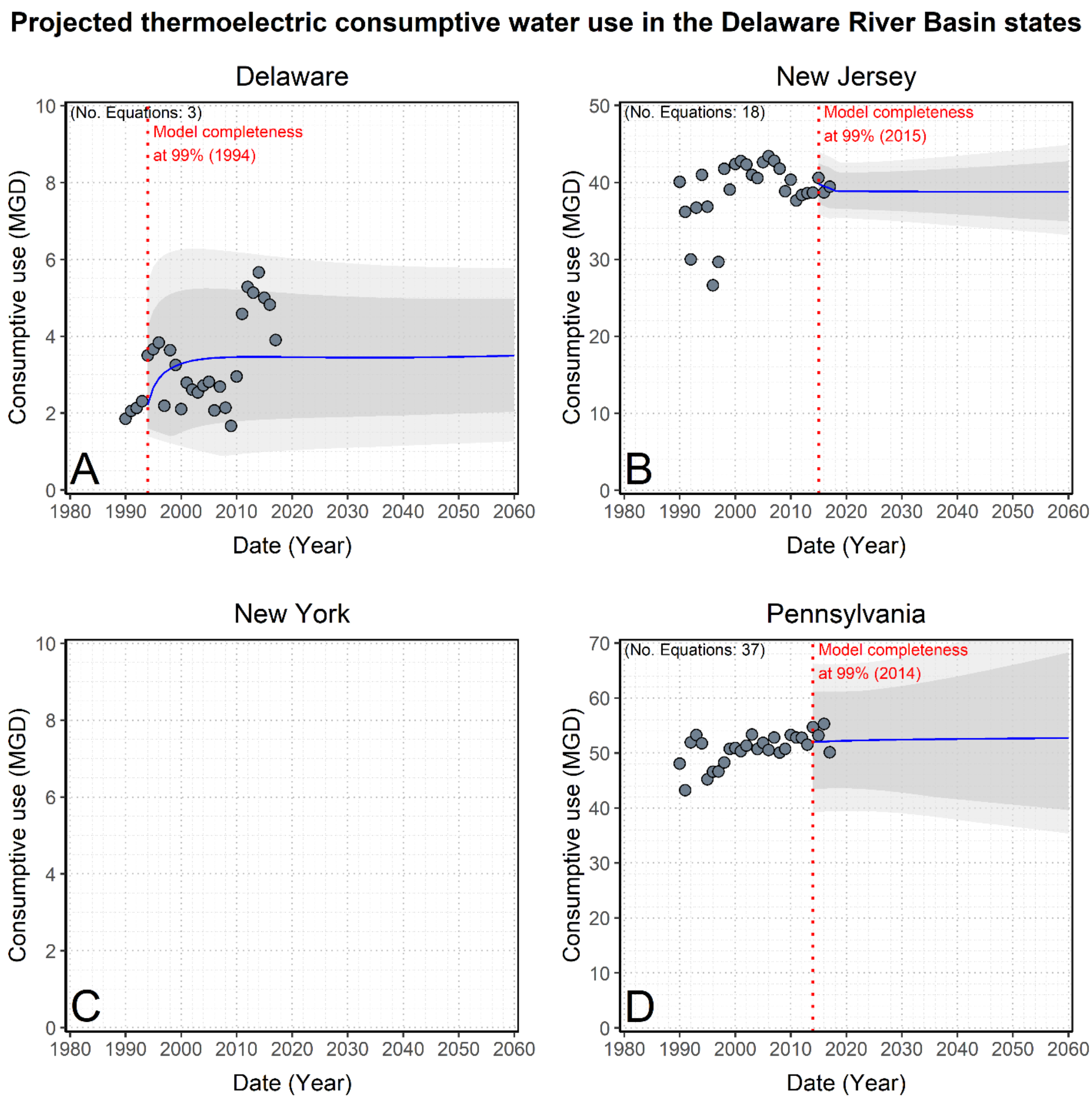

***Figure 46**: **Projected thermoelectric consumptive water use in the Delaware River Basin states.** Aggregated projection results of average annual consumptive water use by the 40 thermoelectric facilities which are included in this study of the Delaware River Basin. Results of the model for select years are presented in Table 23. This projection corresponds with the data initially presented as Figure 40. Data supporting these figures are provided for reference in Table A-7.*

__Table 23__: Summary of results supporting Figure 46 for a Basin-state projection of total water withdrawals used in thermoelectric power generation.

State	Year	Historical Consumptive Use (MGD)	Modelled Consumptive Use (MGD)	Percent Error (%)	Modelled CU prediction intervals			
					upr80	upr95	lwr80	lwr95
Delaware	2013	5.133	3.466	32.480	1.819	5.189	0.969	6.142
	2014	5.661	3.466	38.770	1.827	5.178	0.981	6.125
	2015	5.002	3.465	30.730	1.834	5.168	0.991	6.108
	2016	4.823	3.465	28.160	1.840	5.157	1.001	6.092
	2017	3.900	3.463	11.210	1.846	5.147	1.010	6.075
	2020	NA	3.459	NA	1.862	5.117	1.035	6.029
	2030	NA	3.445	NA	1.903	5.036	1.099	5.904
	2040	NA	3.447	NA	1.943	4.989	1.155	5.827
	2050	NA	3.466	NA	1.988	4.973	1.212	5.788
	2060	NA	3.497	NA	2.039	4.978	1.271	5.778
New Jersey	2015	40.581	39.801	1.920	37.216	42.497	35.862	43.932
	2016	38.688	39.511	2.130	36.924	42.209	35.572	43.644
	2017	39.457	39.221	0.600	36.629	41.924	35.278	43.361
	2020	NA	38.851	NA	36.542	41.270	35.349	42.557
	2030	NA	38.811	NA	36.260	41.485	34.940	42.907
	2040	NA	38.782	NA	35.857	41.845	34.361	43.473
	2050	NA	38.759	NA	35.387	42.281	33.798	44.153
	2060	NA	38.740	NA	34.945	42.763	33.182	44.901
Pennsylvania	2014	54.697	52.009	4.910	43.384	61.167	39.182	66.235
	2015	53.201	52.032	2.200	43.474	61.156	39.285	66.194
	2016	55.270	52.067	5.800	43.542	61.150	39.361	66.169
	2017	50.136	52.115	3.950	43.587	61.145	39.414	66.153
	2020	NA	52.229	NA	43.604	61.186	39.457	66.203
	2030	NA	52.424	NA	42.805	62.207	39.049	67.506
	2040	NA	52.534	NA	41.599	63.955	37.876	70.096
	2050	NA	52.629	NA	40.616	66.036	36.638	73.215
	2060	NA	52.718	NA	39.631	68.297	35.353	76.617

Martins Creek Power Plant
in Bangor, Pennsylvania.
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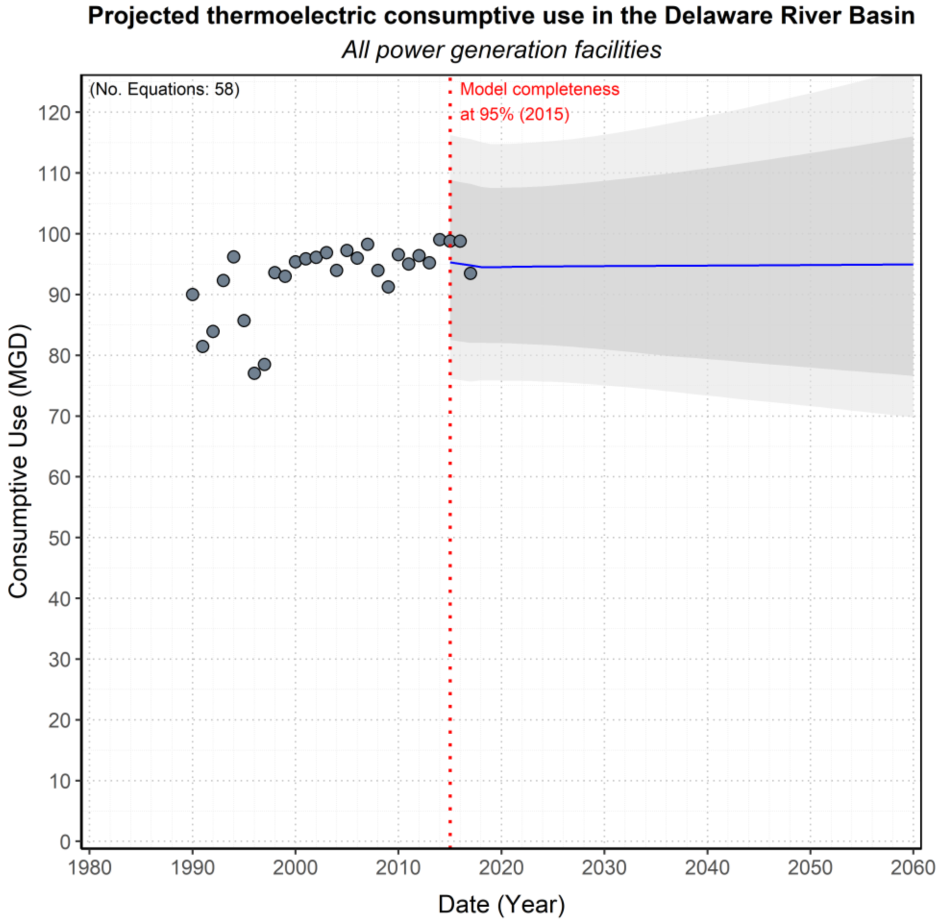


***Figure 47**: **Projected thermoelectric consumptive water use in the Delaware River Basin (all power generation facilities).** Aggregated projection results of annual average consumptive water use by the 40 thermoelectric facilities included in this study of the Delaware River Basin. Results of the model for select years are presented in Table 24. This projection corresponds with the data initially presented as Figure 41. Data supporting this figure are provided for reference in Table A-7.*

***Table 24**: Summary of results supporting Figure 47 for a Basin-wide projection of water consumptively used in thermoelectric power generation.*

Year	Historical Consumptive Use (MGD)	Modelled Consumptive Use (MGD)	Percent Error (%)	Modelled CU prediction intervals			
				lwr80	upr80	lwr95	upr95
2015	98.782	95.299	3.53	82.523	108.821	76.137	116.234
2016	98.779	95.043	3.78	82.306	108.516	75.934	115.905
2017	93.484	94.799	1.41	82.062	108.216	75.703	115.590
2020	*NA*	94.539	*NA*	82.008	107.573	75.842	114.788
2030	*NA*	94.681	*NA*	80.968	108.728	75.087	116.316
2040	*NA*	94.763	*NA*	79.398	110.789	73.392	119.396
2050	*NA*	94.853	*NA*	77.991	113.289	71.648	123.156
2060	*NA*	94.956	*NA*	76.615	116.038	69.806	127.296

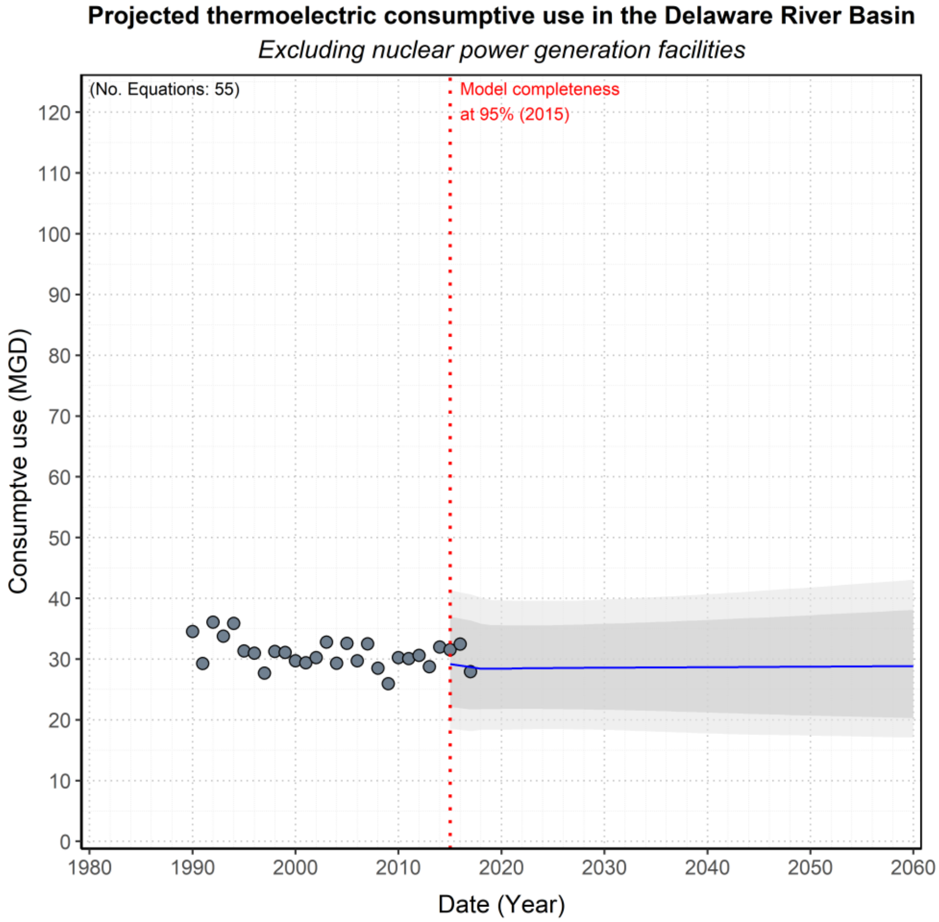


***Figure 48**: Projected thermoelectric consumptive water use in the Delaware River Basin (excluding nuclear power generation facilities). Aggregated projection results of annual daily average consumptive water use from the 37 non-nuclear powered thermoelectric facilities included in this study of the Delaware River Basin. Results of the model for select years are presented in Table 25. This projection corresponds with the data initially presented as Figure 42. Data supporting this figure are provided for reference in Table A-7.*

***Table 25**: Summary of results supporting Figure 48 for a Basin-wide projection of water consumptively used in non-nuclear thermoelectric power generation.*

Year	Historical Consumptive Use (MGD)	Modelled Consumptive Use (MGD)	Percent Error (%)	Modelled CU prediction intervals			
				upr80	upr95	lwr80	lwr95
2015	31.538	29.194	7.43	22.157	36.978	18.550	41.342
2016	32.448	28.938	10.82	21.953	36.660	18.359	40.994
2017	27.933	28.695	2.73	21.731	36.338	18.146	40.645
2020	*NA*	28.435	*NA*	21.797	35.575	18.385	39.659
2030	*NA*	28.576	*NA*	21.666	35.821	18.357	39.796
2040	*NA*	28.658	*NA*	21.230	36.445	17.802	40.676
2050	*NA*	28.748	*NA*	20.720	37.226	17.431	41.802
2060	*NA*	28.851	*NA*	20.326	38.100	17.093	43.071

5.4.4 Climate change

The effects of climate change on projections of water withdrawals by thermoelectric facilities were not addressed quantitatively in this study. However, there are broad concepts which are outlined below:

1. It appears possible that given increased temperatures and varying conditions of humidity, rates of evaporation may be affected. If the rates of evaporation were to increase as a result of climate change, this would specifically affect the consumptive use ratios of facilities which use recirculating cooling towers (assuming that technology does not advance to counteract a changing climate's effect on evaporation).
2. If temperature increases result in an increased use of appliances such as air conditioners, there may be subsequent increases in seasonal energy demand. As the Delaware River Basin is an integral component of the PJM grid, it may be assumed that an increased energy need may increase water demands for cooling. Projections of peak summer energy load are routinely updated by PJM, and those developed in 2021 represent smaller growth projections than those developed in 2020 (PJM, 2021), showing about 0.3% in 15 years (Mid-Atlantic Region) and 0.4% in 15 years (Eastern Mid-Atlantic Region).
3. It is clear that the effects of climate change and research showing possible effects have changed how people think and act, which is also affecting how power is being generated. Ultimately it begins with planning, and such examples include:
    a. The New Jersey Offshore Wind Strategic Plan: targets 7,500 MW from offshore wind technology by 2035 (Ramboll U.S., 2020).
    b. The New Jersey Renewable Portfolio Standard: 50% of the energy sold in the state to come from qualifying energy sources by 2030 (NJBPU, 2020).
    c. The Delaware Renewable Energy Portfolio Standards: 40% of the energy from Delaware's utilities to come from renewable sources such as wind or solar by 2035 (26 Del.C. § 351 – § 364).

Goals such as those outlined above will undoubtably affect the way in which energy is generated in the Delaware River Basin, which will in turn have an effect on the use of water related to energy generation. It is important to reiterate that the scope of this study does not include projections considering new or retiring facilities, or new/emerging technologies that may reduce or eliminate water use related to energy generation. Other considerations, such as subsidies to facilities which are dependent on external factors, are not considered and also have the potential to drastically alter the landscape of energy generation (and resulting water withdrawal) in the Delaware River Basin.

5.4.5 Summary

Water withdrawals from the Delaware River Basin by thermoelectric facilities were presented for 1990-2017 based on self-reported withdrawal data. It was demonstrated that net energy generation from coal-fired steam turbine power facilities using once-through cooling has drastically decreased since 2007. This was shown to be directly reflected in the withdrawal data categorized by cooling system type (Figure 38 and Figure 39), indicating an 81.2% decrease in withdrawals by facilities using freshwater once-through cooling for 2007-2017 (~1,560 MGD) and a 60.6% decrease in withdrawals by facilities using saline once-through cooling for 2007-2017 (~250 MGD). Consumptive use was shown to have remained relatively stable, but an increasing proportion is attributed to facilities with recirculating cooling systems. Projections of thermoelectric withdrawals continue to decrease slightly, but they drastically plateau as withdrawals by non-nuclear facilities approach a lower limit. Projections of consumptive use show relatively coherent and stable projections. Effects of climate change were discussed, but not addressed quantitatively. A very important caveat of this study is that it assumes the continuation of trends at operating facilities and does not consider effects due to possible new/retiring facilities or emerging technologies.

5.5 Hydroelectric

5.5.1 Water withdrawal data evaluation

5.5.1.1 Associated and unassociated systems

As detailed in Figure 36, there are eight hydroelectric facilities which have been included in this analysis, seven of which are associated with DRBC approvals. As there were no additional data identified beyond these eight facilities, each one was individually assessed.

5.5.1.2 Data exclusions

As referenced in Figure 36, one hydroelectric facility which reports to the EIA was excluded from the analysis as it is related to the New York City reservoir diversions. Through the process of diverting water for public water supply, a secondary use is power generation. This water use is accounted for as public water supply, as that is the purpose for the withdrawal.

5.5.1.3 Total water withdrawal

The water use data for the eight associated hydroelectric facilities in the Delaware River Basin is presented for each Basin state in Figure 49, and aggregated to the Basin scale in Figure 50. The data release supporting the analysis in this section is provided in Appendix A as Table A-9. Data were separated by generation type as defined by the EIA's online glossary; there are seven conventional facilities and one pumped storage facility included in the analysis.

Conventional Hydroelectric: *A plant in which all the power is produced from natural streamflow as regulated by available storage.*

Pumped-storage hydroelectric plant: *A plant that usually generates electric energy during peak load periods by using water previously pumped into an elevated storage reservoir during off-peak periods when excess generating capacity is available to do so. When additional generating capacity is needed, the water can be released from the reservoir through a conduit to turbine generators located in a power plant at a lower level.*

Water use records for all facilities were not available for all years; in fact only one facility had a complete dataset from 1990 until it was decommissioned in 2015. This makes it challenging to represent a historical Basin-wide picture of hydroelectric water use. Therefore, historical water use data was estimated by DRBC (as shown in Figure 50). The following two methods were used to estimate missing water use data for seven of the systems:

1. (Five systems) A linear regression was created between available water use data and net generation data on an annual basis. In all cases the trends were developed with at least *n*=13 annual data points and yielded almost perfect coefficients of variation (R^2>0.98) after adjusting for outliers. The linear regressions were then used to calculate water use based on available net generation data from the EIA.
2. (Two systems) Estimated annual water use values were calculated based on information provided by the current facility operations team (e.g., turbine specifications, physical characteristics of installation) and available net generation data.

As has been noted in other studies, the overall water use in this sector is highly variable. For example, it was assumed in CDM & DRBC, 2005 that conventional hydroelectric facilities operate at capacity, meaning that the withdrawals they report are reflective of the amount of water available at the time; therefore, it

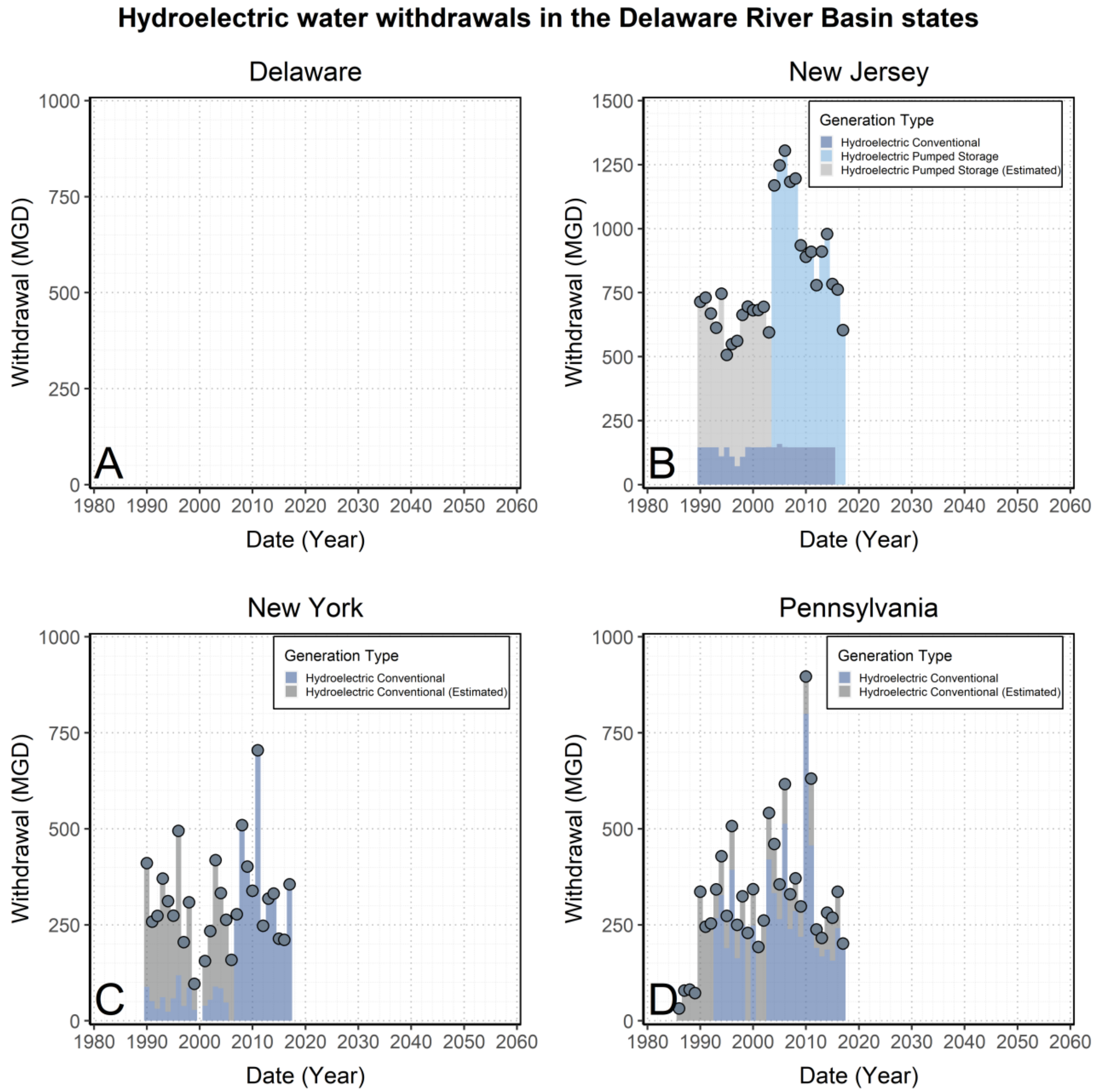


Figure 49: Hydroelectric water withdrawals in the Delaware River Basin states. *Annual average water withdrawal by the eight hydroelectric facilities which are included in this study of the Delaware River Basin. Withdrawals are presented for each of the Basin states, categorized by generation type and whether the data were reported to, or estimated by, DRBC. These data are aggregated to the Basin scale in Figure 50. The projections results for this figure are presented in Figure 51. Data supporting these figures are provided for reference in Table A-9.*

concluded that variations in conventional hydroelectric withdrawal data would be reflective of available supplies. Considering the Delaware River Basin as a whole, this is likely mostly true with some caveats listed below:

1. A pumped storage hydroelectric facility has the potential to operate as necessary based on grid needs, and typically has negative net generation annually.
2. Releases from certain reservoirs (e.g., Mongaup and Wallenpaupack) require coordination with the office of the Delaware River Master and the Montague, NJ, flow target.

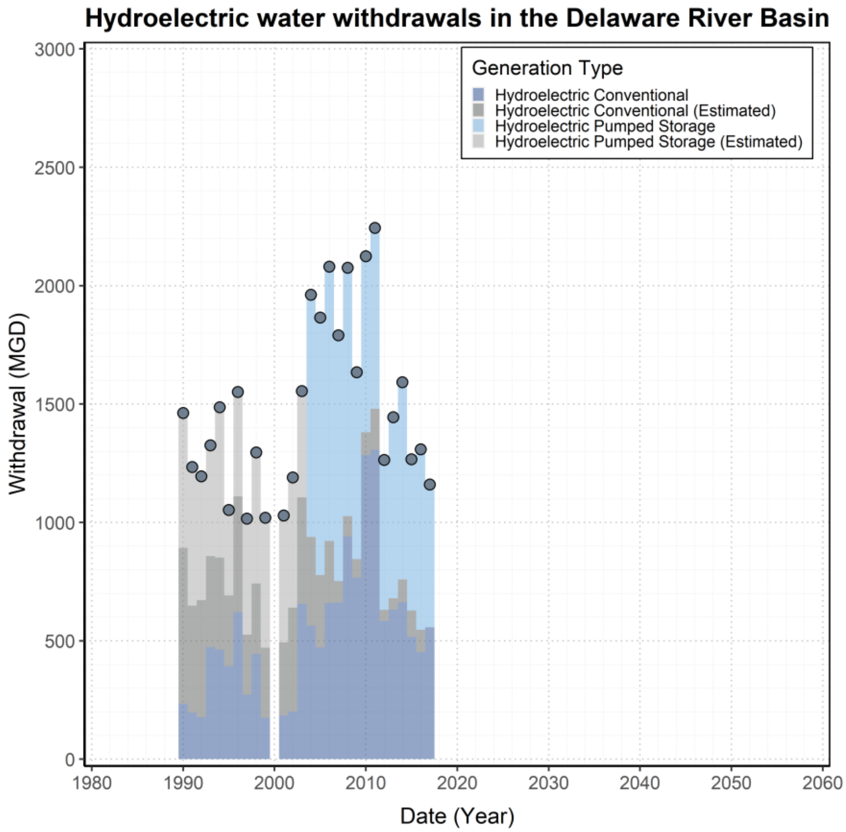


Figure 50: Hydroelectric water withdrawals in the Delaware River Basin. *Annual daily average water withdrawal use by the eight hydroelectric facilities included in this analysis of the Delaware River Basin. Withdrawals have been separated by generation type, including conventional (seven facilities) and pumped storage (one facility). The data are also categorized by whether the data were reported to, or estimated by, DRBC. This represents the same data presented in Figure 49, aggregated to the Basin scale. The projections results for this figure are presented in Figure 52. Data supporting this figure are provided for reference in Table A-9.*

Based on the overall picture provided by Figure 50, two general conclusions may be made. Firstly, there is a large amount of variation in the historical data, and trends are difficult to visually discern. Secondly, there appears to be a small increase in pumped storage operation around the mid 2000's, similar in time to other major power generation changes.

5.5.1.4 Consumptive water use

This analysis does not consider evaporative losses behind impoundments, and per Table 5 the default consumptive use ratio for hydropower is assumed to be zero.

5.5.2 Methods

The methods used in this analysis for projecting water withdrawals for use in the power generation sector are the same as described for the public water supply sector, outlined in Section 3.4. To reiterate, the overall concept of this analysis is to estimate future water demands by extrapolating historical withdrawal data at the water supply system and/or sub-system levels in a manner such that a "bottom-up" approach can be used to re-aggregate the projections. The methods inherently assume that the rates of change in water use over the recent past will continue into the future and are the same rates of change, among other assumptions (e.g., Section 3.4.5.4). This analysis is not intended to capture changes due to potential new/emerging technology or regulations, nor is it intended to project or capture possible future changes as the result of new or closing power facilities. The results of this analysis are focused on water demand and are intended to be used for water resource planning purposes.

5.5.3 Results

The projected water withdrawals for the eight hydroelectric facilities in this study are presented for each Basin state in Figure 51. The projection results are then aggregated to the Basin scale, presented in Figure 52. The annual percent error and model results for select years through 2060 are provided for reference in Table 26 and Table 27, respectively. The data release supporting the model presented in this section is provided in Appendix A as Table A-10. All conventional hydropower facilities were modelled with average value equations given the nature of their operation and variability in the datasets. This variability in data was inherently reflected in the magnitude of each prediction interval. The single facility to not be modelled as an average value was the pumped storage facility which showed some statistical correlation in recent operational trends.

5.5.4 Climate change

The effects of climate change on projections of water withdrawals by hydroelectric facilities were not addressed quantitatively in this study. However, there are broad concepts which are outlined below:

- Oftentimes hydroelectric power is used to supplement the energy grid at times of peak energy demand (or in the case of pumped storage, use energy during low energy demand). As the energy portfolio of the Delaware River Basin changes (e.g., discussion in Section 5.4.4), it may affect how hydroelectric facilities operate, provided the availability of water for power generation.
- While it was not considered in this study, evaporation from water behind impoundments may be considered consumptive use (loss) attributed to hydroelectric energy generation. Given the possible increased temperatures and varying conditions of humidity anticipated, rates of evaporation may be affected. In turn, this will have an effect on future studies which may incorporate or assess the potential consumptive use/loss attributed to water behind impoundments.

5.5.5 Summary

There are eight hydroelectric facilities in the Delaware River Basin, including seven conventional and one pumped storage; all were individually assessed in this study. Water use records for all facilities were not available for all years so some data was estimated by DRBC using either a correlation between energy generation and historical withdrawal data, or calculation from energy generation based on turbine specifications (Figure 50). The dataset shows a large amount of variation between years, and withdrawal trends are difficult to visually discern. Historical average withdrawal volumes range between states: 313 MGD (NY), 358 MGD (PA) and 812 MGD (NJ). The only pumped storage facility is in New Jersey, historically accounting for the majority of the withdrawal, and it is the only remaining active facility. All conventional hydroelectric facility withdrawals were projected with mean-value equations based on the scatter in historical data and considering the operational nature of the facilities. The overall Basin projection therefore largely reflects the recent trend in pumped storage, and the predictive intervals are significant given the scatter in historical data (Figure 52).

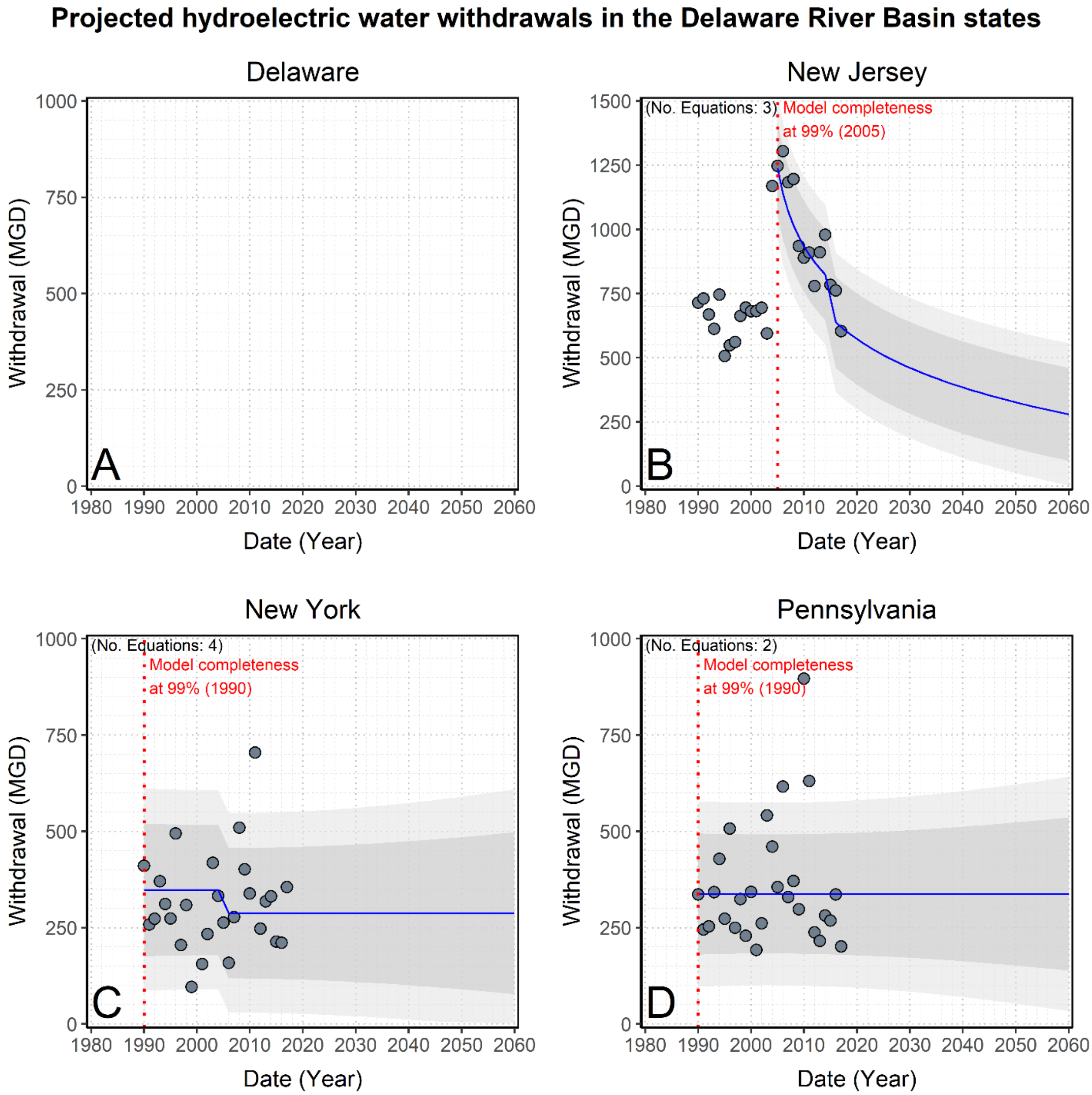
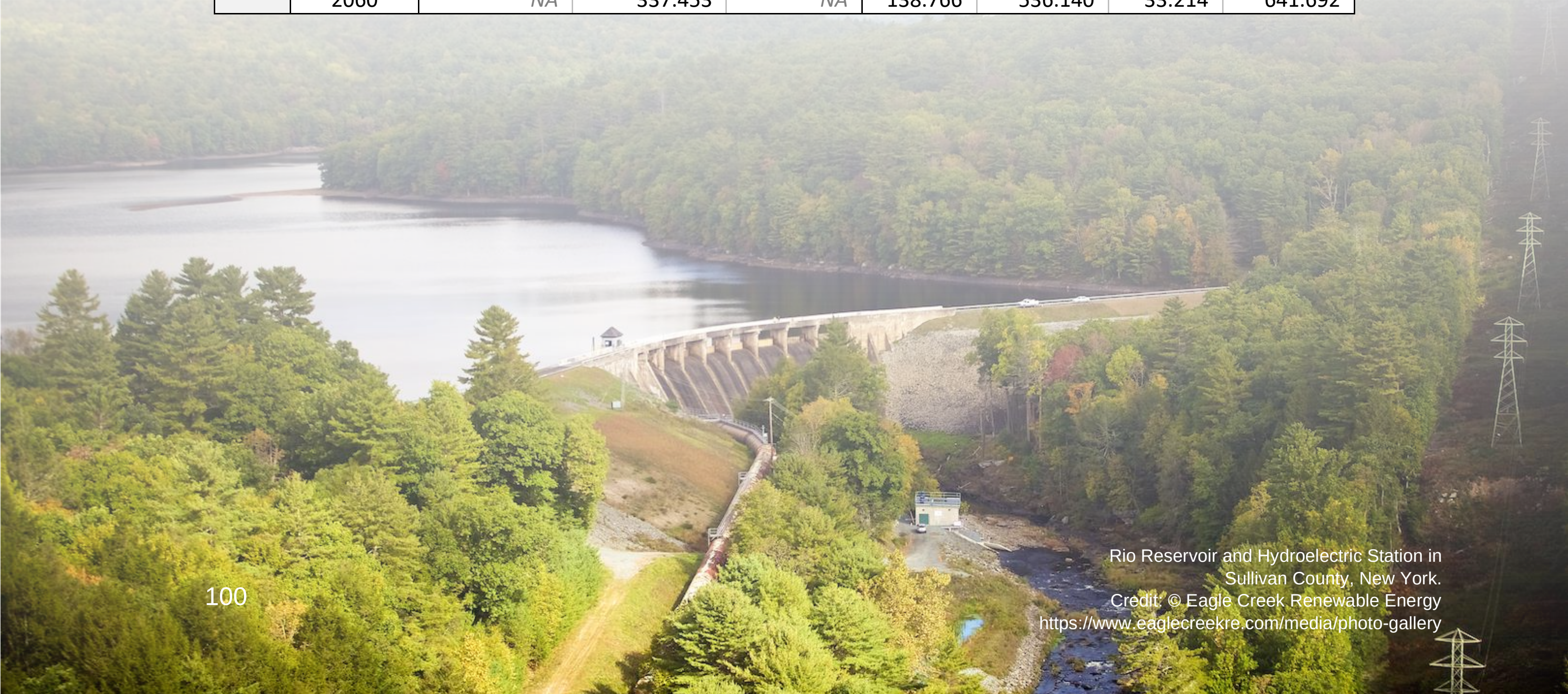


***Figure 51**: **Projected hydroelectric water withdrawals in the Delaware River Basin states.** Aggregated projection results of average annual water withdrawals by the eight hydroelectric facilities which are included in this study of the Delaware River Basin. Results of the model for select years are presented in Table 26. Data supporting these figures are provided for reference in Table A-10.*

***Table 26**: Summary of results supporting Figure 51 for basin-state projections of total water withdrawals by the hydroelectric facilities of the Delaware River Basin.*

State	Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
					lwr80	upr80	lwr95	upr95
New Jersey	2013	910.493	847.089	6.960	669.625	1024.553	575.347	1118.831
	2014	978.959	824.007	15.830	646.515	1001.499	552.223	1095.792
	2015	783.890	730.078	6.860	552.550	907.607	458.237	1001.919
	2016	761.918	637.837	16.290	460.264	815.410	365.928	909.746
	2017	603.562	619.890	2.710	442.267	797.513	347.905	891.875
	2020	NA	572.870	NA	395.072	750.667	300.618	845.122
	2030	NA	460.833	NA	282.320	639.346	187.485	734.182
	2040	NA	384.528	NA	205.214	563.842	109.953	659.102
	2050	NA	326.592	NA	146.447	506.737	50.745	602.439
	2060	NA	279.875	NA	98.892	460.859	4.135	557.006
New York	2013	317.856	287.588	9.520	117.401	457.775	28.746	548.187
	2014	331.327	287.588	13.200	117.134	458.043	28.466	548.597
	2015	213.847	287.588	34.480	116.837	458.339	28.156	549.050
	2016	210.705	287.588	36.490	116.512	458.664	27.816	549.549
	2017	355.503	287.588	19.100	116.158	459.018	27.446	550.091
	2020	NA	287.588	NA	114.925	460.251	26.160	551.978
	2030	NA	287.588	NA	109.037	466.139	20.033	560.994
	2040	NA	287.588	NA	100.627	474.549	11.293	573.872
	2050	NA	287.588	NA	90.016	485.160	4.772	590.121
	2060	NA	287.588	NA	77.537	497.639	0.681	609.228
Pennsylvania	2013	215.652	337.453	56.480	181.300	493.606	98.344	576.562
	2014	281.688	337.453	19.800	180.977	493.929	97.849	577.057
	2015	268.453	337.453	25.700	180.624	494.282	97.308	577.598
	2016	336.087	337.453	0.410	180.241	494.665	96.722	578.184
	2017	201.073	337.453	67.830	179.829	495.077	96.091	578.815
	2020	NA	337.453	NA	178.418	496.488	93.931	580.975
	2030	NA	337.453	NA	171.914	502.991	83.972	590.934
	2040	NA	337.453	NA	162.894	512.012	70.159	604.747
	2050	NA	337.453	NA	151.724	523.182	53.055	621.851
	2060	NA	337.453	NA	138.766	536.140	33.214	641.692



Rio Reservoir and Hydroelectric Station in Sullivan County, New York.
Credit: © Eagle Creek Renewable Energy
https://www.eaglecreekre.com/media/photo-gallery

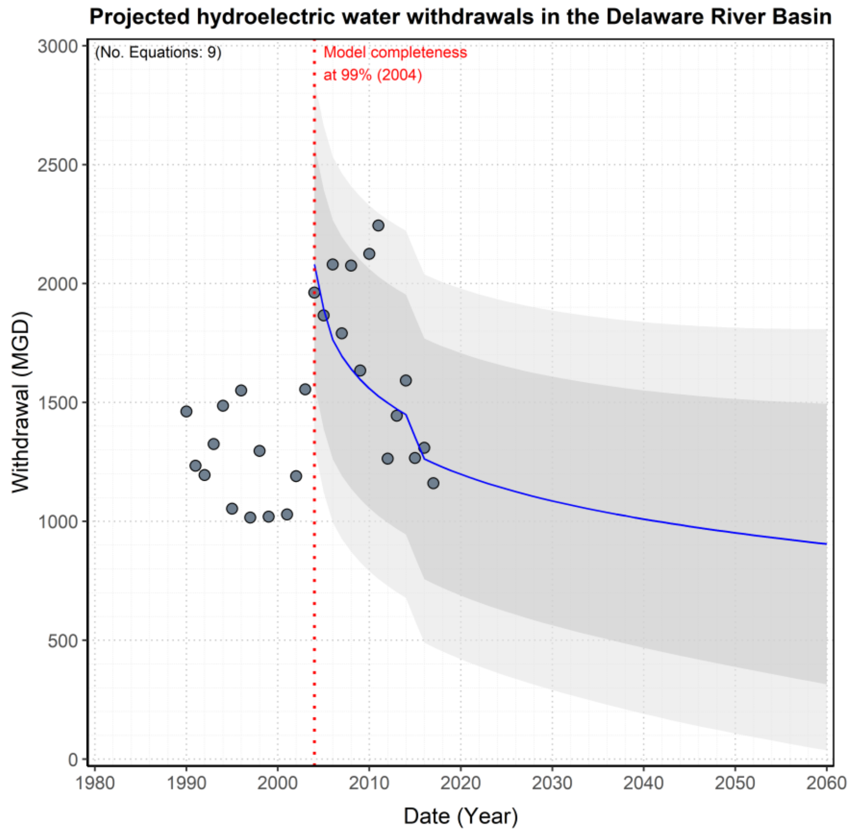


***Figure 52**: **Projected hydroelectric water withdrawals in the Delaware River Basin.** Aggregated projection results of annual average water withdrawals by the eight hydroelectric facilities included in this study of the Delaware River Basin. Results of the model for select years are presented in Table 27. This projection corresponds with the data initially presented as Figure 50. Data supporting this figure are provided for reference in Table A-10.*

***Table 27**: Summary of results supporting Figure 52 for the Basin-wide projection of annual average water withdrawal by the eight hydroelectric facilities included in this study.*

Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
				lwr80	upr80	lwr95	upr95
2013	1,444	1,472	1.95	968	1,976	702	2,244
2014	1,592	1,449	8.98	945	1,953	679	2,221
2015	1,266	1,355	7.02	850	1,860	584	2,129
2016	1,309	1,263	3.50	757	1,769	490	2,037
2017	1,160	1,245	7.31	738	1,752	471	2,021
2020	*NA*	1,198	*NA*	688	1,707	421	1,978
2030	*NA*	1,086	*NA*	563	1,608	291	1,886
2040	*NA*	1,010	*NA*	469	1,550	191	1,838
2050	*NA*	952	*NA*	388	1,515	109	1,814
2060	*NA*	905	*NA*	315	1,495	38	1,808

6 INDUSTRIAL

This portion of the study focuses on industry owned/operated water withdrawals which are associated with industrial processes (such as fabrication, processing, washing and cooling), refinery operations (such as petroleum refining) and groundwater remediation. Collectively, as defined in Table 1, withdrawals meeting these descriptions constitute the "industrial sector." The industrial withdrawal sector *does not* include water withdrawn for the following purposes:

- **Thermoelectric power generation**. Water withdrawals for thermoelectric power generation are covered in Section 5.4 of this report. Typically, refineries may be associated or interconnected with thermoelectric cogeneration facilities (which produce both energy and steam). The steam may typically be used in refinery operations (e.g., powering pumps or steam tracing for pipes), whereas energy may be supplied to a local power grid (or used at the refinery). In most instances in this report, it was possible to separate withdrawals between refinery operations and cogeneration facilities. For three facilities, it was not possible to separate the data, and the portion of the withdrawal used at the cogeneration facility is included in this section. One of these three facilities is no longer operational, and the other two confirmed that water used for cogeneration cooling is small compared to water used for refinery cooling/processes.
- **Mining**. Water withdrawals for mining operations which meet the definition outlined in Table 1 are covered in Section 7 of this report.
- **Commercial**: Water withdrawals for commercial operations include those for self-supplied restaurants, office buildings, hotels, motels, military and nonmilitary institutions, but also include facilities such as amusement parks and casinos (consistent with Dieter et al., 2018), and are covered in Section 8.6 of this report. However, discrepant with Dieter et al., 2018, commercial water withdrawals in this study *only* include self-supplied withdrawals; water used by commercial facilities connected to public water suppliers is inherently captured in Section 3 (Public Water Supply).

The Walt Whitman Bridge over the Delaware River
Philadelphia in the background.
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6.1 Review of regional watershed studies

***Table 28**: An expansion of Table 3 in order to more accurately summarize the specific methods utilized by regional watershed studies which projected water use in the industrial and refinery sector.*

Study	Study Region	Projected data	Projected data scale	Reported Results Scale	Total water use	Consumptive water use	Industrial: Growth rate applied to current water use estimate	Industrial: Growth rate applied to current water use (*multi-scenario*)	Industrial: Extrapolation of historical withdrawal estimates
(Hutson et al., 2004)	Tennessee River Watershed	Earnings	County	RCA, WUTA	X	X	X		
(ICPRB, 2012)	Potomac River Basin	EIA projection	County	County	X	X		X	
(USDOI-BR, 2012)	Colorado River Basin	Population	*NA*	State		X		X	
(USDOI-BR, 2016)	Klamath River Basin	*NA*	*NA*	*NA*					
(Balay et al., 2016)	Susquehanna River Basin	Population	County	HUC-10		X	X		
(Robinson, 2019)	Cumberland River Watershed	*NA*	*NA*	*NA*					
Zamani Sabzi et al., 2019	Red River Basin	USGS NWUE	County	County		X			X

Notes:
HUC = Hydrologic Unit Code
RCA = Reservoir Catchment Area
WUTA = Water-use Tabulation Area
USGS NWUE = USGS National Water Use Estimates

An expansion of the studies listed in Table 3 is provided for reference as Table 28 which gives additional details for each study that included projections for this sector. Only five of the seven studies included an assessment of the industrial sector, two of which had the assessments combined with other water use sectors (USDOI-BR, 2012; Balay et al., 2016). Overwhelmingly, the approach for projecting water use appears to be determination of a growth rate based on the correlated variable being projected and applying that growth rate to the estimated water use of a particular year. While ICPRB, 2012 considered multiple projection scenarios, none of the scenarios affected the results for the industrial sector. While USDOI-BR, 2012 considered multiple projection scenarios, industrial water use was combined with municipal use and makes it difficult to see the scenario effects specific to self-supplied industrial. The only study which directly projected water use data uses historical USGS Nation Water Use Estimates, and applies linear regressions to county level surface water consumptive use estimates, accounting for decreasing trends by setting a lower limit of 20% of the current water use (Zamani Sabzi et al., 2019).

6.2 Review of studies within the Delaware River Basin

As previously referenced, the *Multi-jurisdictional Report* (USACE & DRBC, 2008) provides an estimate of water use in the Delaware River Basin for the year 2003, as well as projected sector trends for peak monthly water withdrawal through the year 2030. Separate data sources were used to project industrial water use in each Basin state, including manufacturing employment projections (NJ and PA), trend extrapolation of manufacturing employment data (DE), and average historical water use (NY). The study also incorporated assumed percent-use reductions based on future water conservation practices in the industrial sector.

The *Multi-jurisdictional Report* also provides a summary of each Basin states' approach to demand forecasting at the time of the report, but only Pennsylvania was stated to have addressed the industrial sector. The summary below is intended to provide an overview of additional activities performed by the states since the *Multi-jurisdictional Report* was published:

- **Delaware**. As discussed in Section 3.2, the Water Supply Coordinating Council (WSCC) was created in July of 2000 and released three reports regarding water use in Delaware state counties. However, only the report covering Kent & Sussex counties addressed self-supplied industrial water use (DE DNREC et al., 2014). Historical use was estimated based on reported groundwater data from 2004-2008. The Delaware Geological Survey estimated a peak industrial water demand of 1.3 MGD in Kent County and 7.0 MGD in Sussex County. It was projected that the industrial sector would grow 50% and 100% in 10 and 20 years, respectively, based on siting of new industries which may have moved to the counties.
- **New Jersey**. As discussed in Section 3.2, the most recent New Jersey Water Supply Plan (2017-2022) included an analysis of future public water supply demands at the public water system level (NJDEP, 2017), and was expanded on at a finer scale by Rutgers University (Van Abs et al., 2018). This study by Rutgers University accounted for the percentage of water a public water purveyor may attribute to industrial sources based on reported data, and where not available, based on land use percentages. Self-supplied industrial withdrawals were not within the scope of the study.
- **Pennsylvania**. As mentioned in Section 3.2, in coordination with the state water plan (PADEP, 2009), a report was published developing a methodology for projecting water demands in a number of water use sectors called the Water-Analysis Screening Tool (WAST) (Stuckey, 2008), which uses the methods developed by (CDM & DRBC, 2005) for estimating industrial withdrawals. Water use factors were developed for industrial (438 gal/d per employee) and commercial (42 gal/d per employee) sites, based on data from 12 and 21 public water suppliers, respectively (plus self-supplied facilities within the service areas). These values are then applied to areas inside or outside of public water supply service areas based on employment statistics.

6.3 Water withdrawal data evaluation

6.3.1 Associated and unassociated systems

A summary of average total withdrawal volume over the entire dataset time-series is presented in Table 29, indicating which portions of the volume are associated (or not) with DRBC approvals, and whether the withdrawals are surface water or groundwater. From this assessment it is possible to conclude that more than 99% of the reported water withdrawn for industrial purposes in the Delaware River Basin is associated with some form of regulatory approval. Furthermore, it may be concluded that withdrawals have historically been split about 93% surface water and 7% groundwater. For reference, a complete list of the associated facilities assessed in this report is included as Appendix C; some facilities may have been reviewed but not projected, as indicated in the appendix.

***Table 29**: A summary of the total water withdrawal data for the industrial sector in the Delaware River Basin, categorized by source-type and associated with regulatory approvals. These statistics were calculated for the entire basin, corresponding to the data presented in Figure 54.*

Data category	Systems (OAIDs)	Water type	Sources (WSIDs)	Average withdrawal (MGD)	Percent total withdrawal
Associated	164*	SW	97	603.844	93.3%
		GW	855	37.579	5.8%
Unassociated	215	SW	23	0.287	0.0%
		GW	509	5.611	0.9%
Totals:	379	--	1,484	647.320	100.0%

* *This number represents system/facility identifiers (Organization Address ID; OAID). The same system may have multiple identifiers as ownership changes overtime. The number of unique associated systems in this analysis is 153.*

6.3.2 Data exclusions

The unassociated dataset for surface water withdrawals is presented in figures and summations but is not projected based on the small comparative size of the dataset.

6.3.3 Total water withdrawal

The water withdrawal data for self-supplied industrial facilities in the Delaware River Basin are presented for each Basin state in Figure 53; the data have been broadly grouped into industrial, refinery or remediation categories. This dataset is then aggregated to represent the entire Delaware River Basin in Figure 54.The data release supporting the analysis in this section is provided in Appendix A as Table A-11.

From the state-level data, it is possible to conclude that peak industrial water withdrawal has already occurred in each state reporting major withdrawals (DE, NJ and PA). Table 30 provides average values of withdrawal by category for each state over two timeframes, the early 1990s and recent years. It is clear that the most pronounced shifts have been decreases in industrial category withdrawals (e.g., the closure of Bethlehem Steel in 1998 in Pennsylvania which had large intakes on the Lehigh River), whereas refinery withdrawals have remained relatively consistent as a whole. Three additional notes are worth highlighting regarding the data:

1. A significant drop in withdrawal for the state of Delaware is attributed to a particular refinery which correlates with a temporary shut-down, change of ownership and subsequent restart of operations.
2. There are only two facilities reporting withdrawal data in the New York portion of the Delaware River Basin. The apparent increase in withdrawal is associated with differing start dates for data reporting.
3. It is likely that there are more withdrawal data associated with remediation systems which are not being reported to state agencies as they may be associated with federal programs (e.g., EPA's Superfund program).

At the Basin scale, the peak year of withdrawal was 1990 at about 930 MGD; however, it is not clear that this is the historical peak as there may have been larger withdrawals by facilities in this sector in the 1980s. Since 1990, there has been a dramatic decrease in total withdrawal (~300 MGD) between the two averaged periods in Table 30, primarily attributed to industrial facilities. From a review of the system level data, it was apparent that historically about 90% of the withdrawal in this sector was attributed to about 20 facilities, the remaining 9% of associated withdrawals to about 130 facilities, and the 1% of unassociated withdrawals from about 200 facilities (or more). Three significant events at large facilities are highlighted on Figure 54 to demonstrate how impactful they can be to Basin-wide trends.

Another important planning scale for this study specific to Pennsylvania is the SEPA-GWPA. Groundwater data which are applicable to the 76 subbasins highlighted in Figure 6 are presented in Figure 55. Note that while the data only extends back to 1990, the regulations defining SEPA-GWPA became effective beginning in January 1981 (18 CFR Part 430, 1980). Withdrawals of groundwater from the region have historically fluctuated between 3-5 MGD.

***Table 30**: Summarized industrial sector withdrawal data for each Basin state, corresponding to Figure 53. Average values provided for a period in the early 1990s ('90-'94) and recent years ('13-'17).*

State	Refinery		Industrial		Remediation	
	'90-'94	'13-'17	'90-'94	'13-'17	'90-'94	'13-'17
Delaware	312.146	293.453	41.322	5.913	0.855	0.066
New Jersey	18.352	7.963	80.470	26.847	0.937	1.878
New York	NA	NA	NA	1.586	NA	NA
Pennsylvania	96.676	109.693	267.840	68.948	1.487	1.160
Total	427.173	411.109	389.633	103.294	3.279	3.104

('90-'94) All Categories Subtotal: 820.085 MGD
('13-'17) All Categories Subtotal: 517.507 MGD

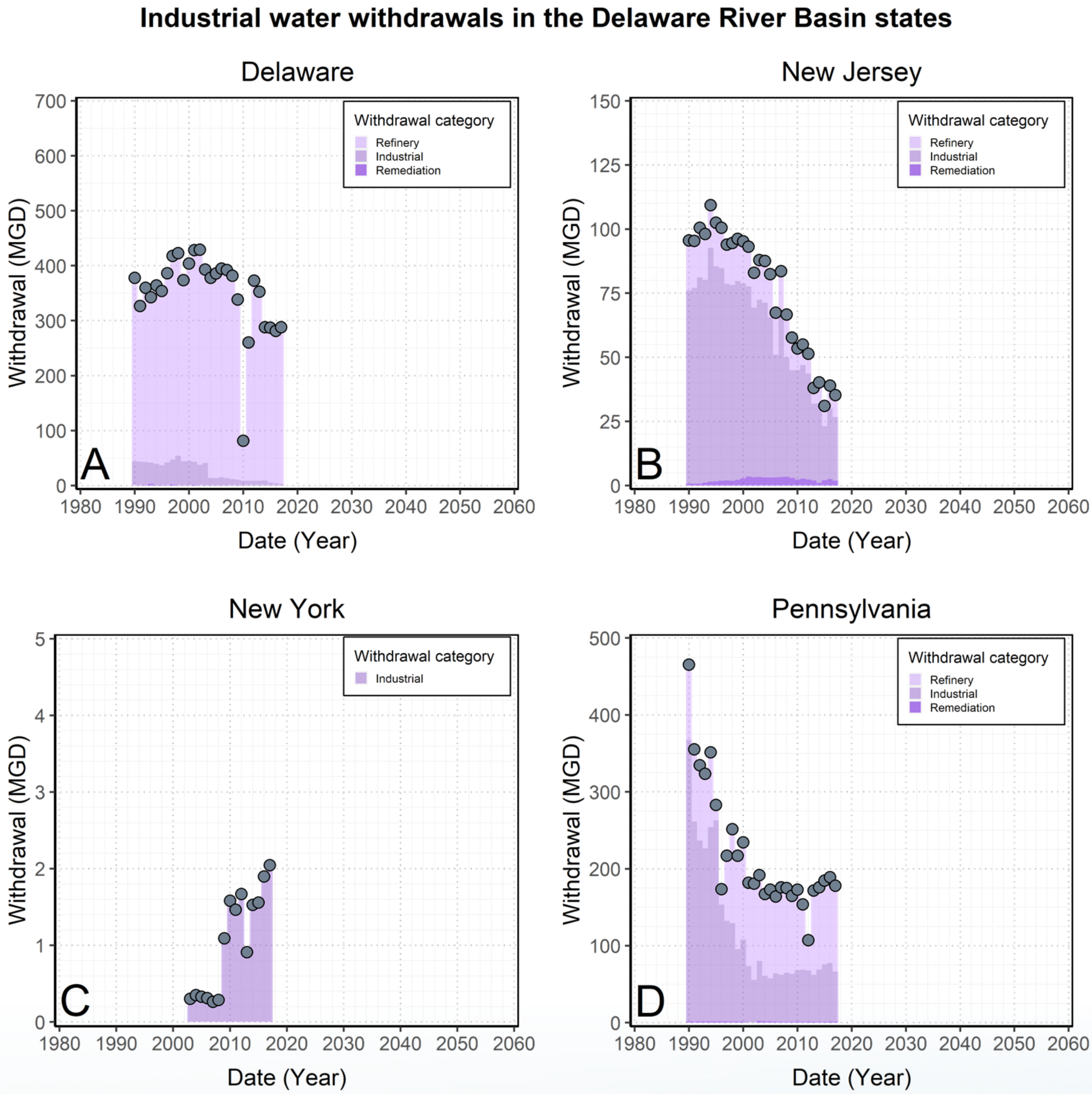
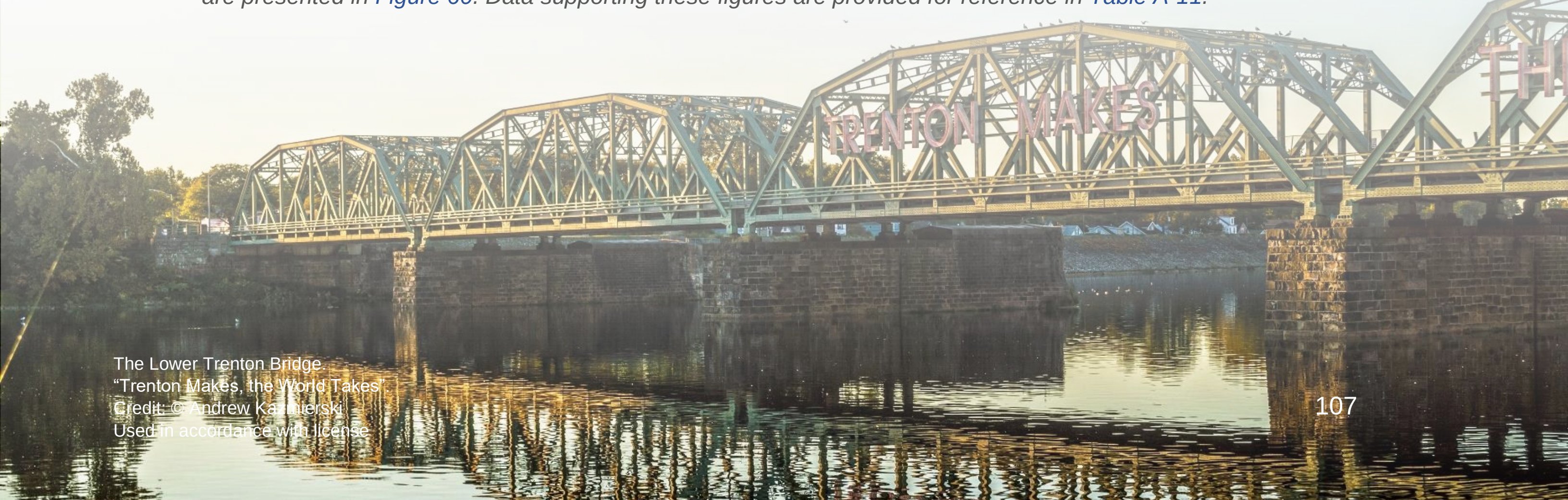


Figure 53: Industrial water withdrawals from the Delaware River Basin states. *Annual average water withdrawal by each state in the Delaware River Basin, grouped by industrial sector category (Refinery, Industrial and Remediation). This dataset is aggregated to the Basin scale in Figure 54. The projections results for this figure are presented in Figure 60. Data supporting these figures are provided for reference in Table A-11.*



The Lower Trenton Bridge
"Trenton Makes, the World Takes"
Credit: © Andrew Kazmierski
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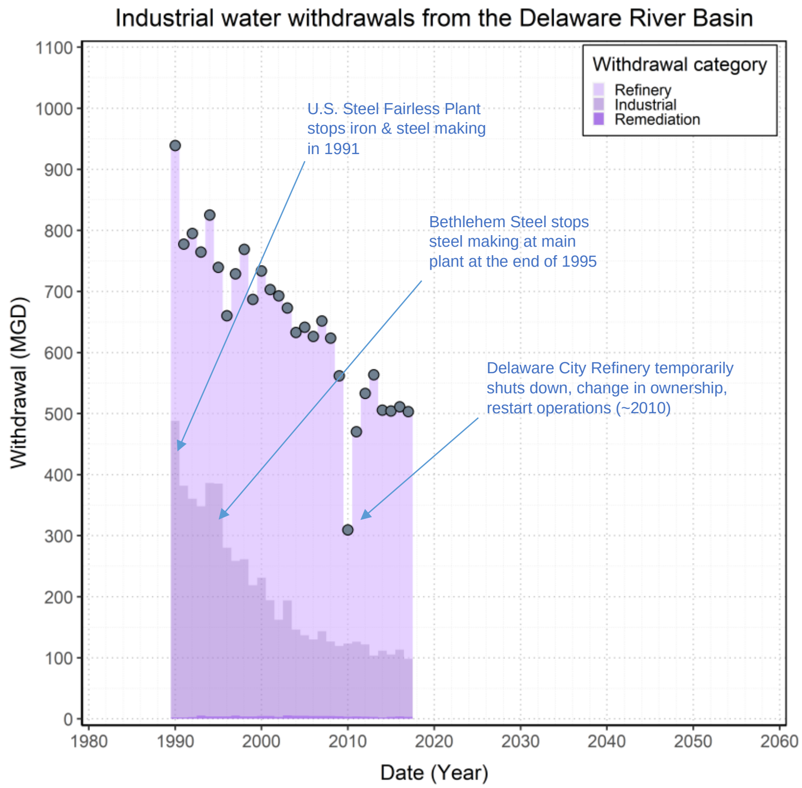

Figure 54: Industrial water withdrawals from the Delaware River Basin. *Annual average water withdrawals from the Delaware River Basin, grouped by industrial sector category (Refinery, Industrial and Remediation). This represents the same data presented in Figure 53, aggregated to the Basin scale. The projections results for this figure are presented in Figure 61. Data supporting this figure are provided for reference in Table A-11.*

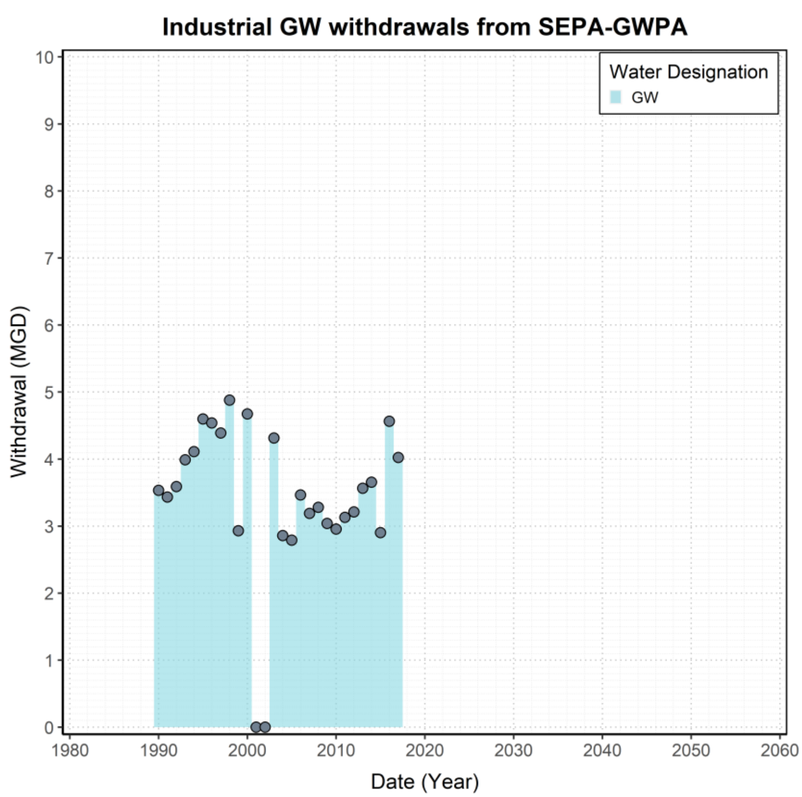

Figure 55: Industrial groundwater withdrawals from the Southeastern Pennsylvania Groundwater Protected Area. *These data only represent withdrawal volumes from sources which plotted within the boundary of SEPA-GWPA as shown in Figure 6. The projections results for this figure are presented in Figure 62. Data supporting this figure are provided for reference as part of Table A-11.*

6.3.4 Consumptive water use

Consumptive use ratios were applied to the historical water withdrawal data in order to calculate a historical consumptive water use dataset for each Basin state, as presented in Figure 56. This consumptive use dataset is then aggregated to represent the entire Delaware River Basin in Figure 57; the same data are then presented in Figure 58 color coded by the method used to calculate the consumptive use value. A final analysis in Figure 59 presents the consumptive use of groundwater withdrawals from SEPA-GWPA. The data release supporting the analysis in this section is provided in Appendix A as Table A-11.

Consumptive use ratios were applied to industrial withdrawal data in the specific preferential order outlined in Section 2.2.3. Because each of the different methods were used in calculating consumptive use, Figure 58 was developed to show specific proportions of data related to the respective methods of calculation. Some notes on each method of calculation are as follows:

1. **Historic reported data (source level)**: Directly using the ratios from the DRBC Water Supply Charges Regulations was the preferred method for surface water sources, and on average is associated with about 54% of the data in Figure 58.
2. **Referenced information (system level)**: Dockets and/or other regulatory approvals were reviewed for information relating to reported system-specific consumptive use ratios, which on average is associated with about 42% of the data in Figure 58.
3. **Default (system)**: If neither method detailed above were viable for an associated system, the default CUR from Table 5 was applied to all sources in the system. On average this method is associated with about 2% of the data in Figure 58.
4. **Default (source)**: Unassociated data were brought into the analysis at the source level, and therefore default CURs from Table 5 were applied at the source level based on source categorizations. On average this method is associated with about 2 % of the data in Figure 58.

Based on a review of Figure 56 and Figure 57, it is apparent that the patterns of consumptive use are strongly reflective of the overall withdrawal. The Basin-wide consumptive use had a maximum calculated rate of about 53.057 MGD in 1990, followed by steady declines until around 2010. Since this time, the Basin-wide average consumptive use has been around 27.206 MGD (2010-2017). Converse to this trend, the industrial consumptive use in SEPA-GWPA has shown a slight increase from an average of about 0.718 MGD (1990-1994) to 1.047 (2013-2017).

Industrial facility in
New Castle County, Delaware.
Credit: © Joe Sohm
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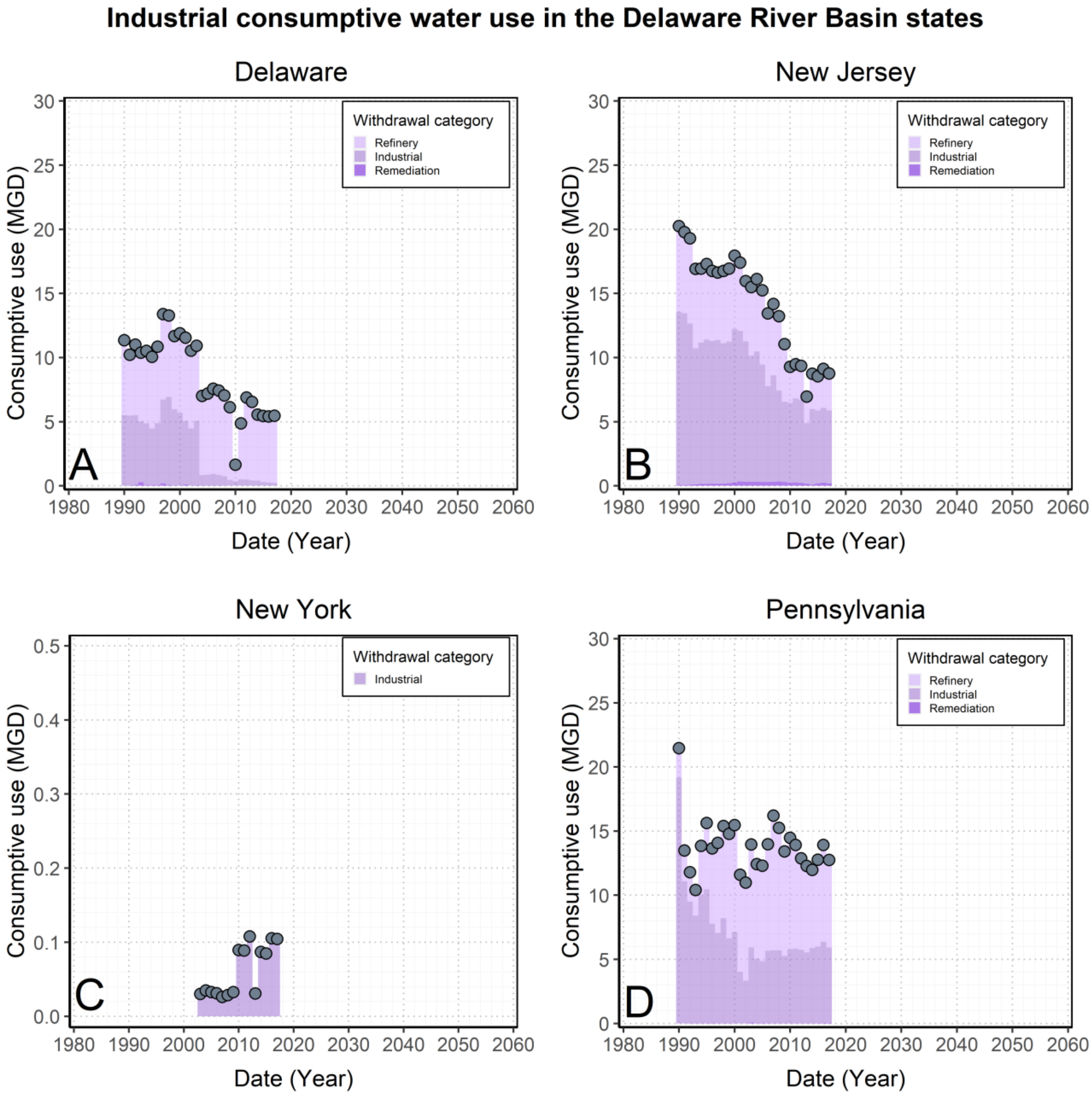

Figure 56: Industrial consumptive water use in the Delaware River Basin states. *Annual average consumptive water use for each state in the Delaware River Basin, grouped by industrial sector category (Refinery, Industrial and Remediation). These data were calculated using the withdrawal data presented in Figure 53, multiplied by specific consumptive use ratios (calculated, referenced or default). Note different y-axis scales. This dataset is aggregated to the Basin scale in Figure 57. The projections results for this figure are presented in Figure 63. Data supporting this figure are provided for reference as part of Table A-11.*

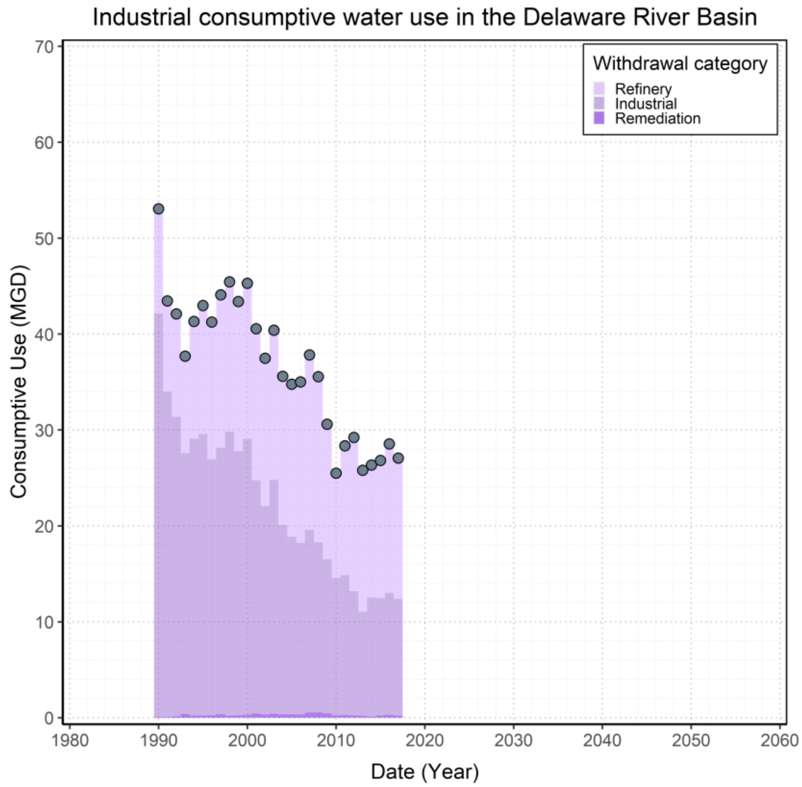

***Figure 57**: **Industrial consumptive water use in the Delaware River Basin, by withdrawal category.** Annual average consumptive water use for the Delaware River Basin, grouped by industrial sector category (Refinery, Industrial and Remediation). This represents the same data presented in Figure 56, aggregated to the basin scale. The corresponding figure showing total water withdrawal is Figure 54. The projections results for this figure are presented in Figure 64. Data supporting this figure are provided for reference as part of Table A-11.*

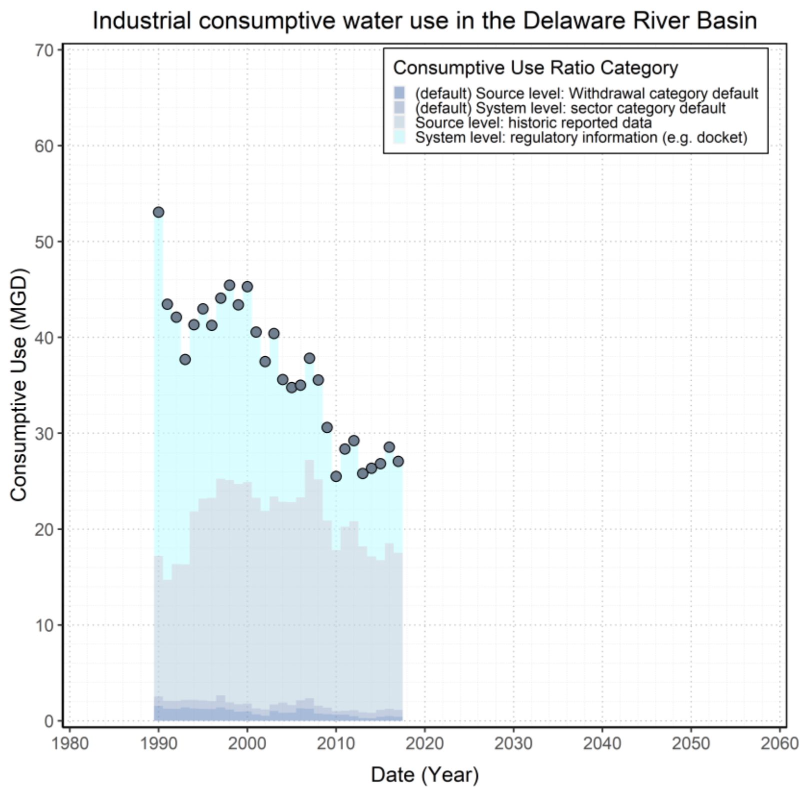

***Figure 58: Industrial consumptive water use in the Delaware River Basin, by consumptive use ratio category.** Annual average consumptive water use for the Delaware River Basin, grouped by method of consumptive use calculation. These are the same values presented in Figure 57, categorized to show proportions of calculation methods.*

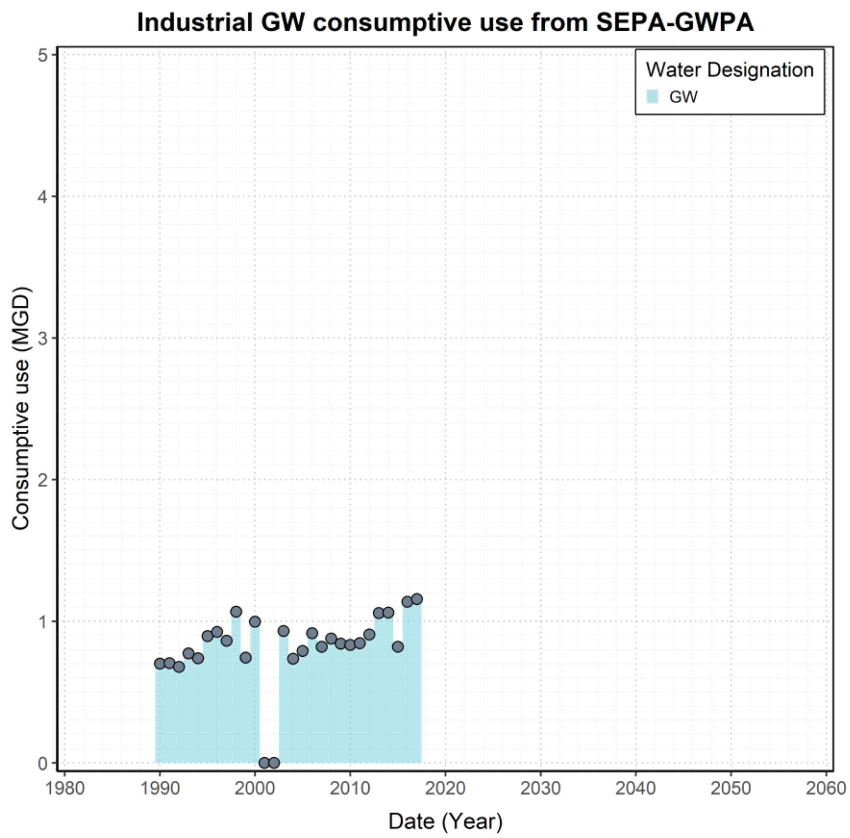

Figure 59: Industrial consumptive water use in the Southeastern Pennsylvania Groundwater Protected Area. *The corresponding figure showing total water withdrawal is Figure 55. The projections results for this figure are presented in Figure 65. Data supporting this figure is provided for reference as part of Table A-11.*

6.4 Methods

The methods used in this analysis for projecting water withdrawals for use in the industrial sector are the same as described for the public water supply sector, outlined in Section 3.4. To reiterate, the overall concept of this analysis is to estimate future water demands by extrapolating historical withdrawal data at the water supply system and/or sub-system levels in a manner such that a “bottom-up” approach can be used to re-aggregate the projections. The methods inherently assume that the rate of change in water use over the recent past will continue into the future at the same rate of change, among other assumptions (e.g., Section 3.4.5.4). This analysis is not intended to capture changes due to potential new/emerging technology or regulations, nor is it intended to project or capture possible future withdrawal changes as the result of new or closing facilities. The results of this analysis are focused on water demand and are intended to be used for water resource planning purposes.

As the public water supply sector only has one withdrawal category (Table 5), and there were no unassociated data for the power generation sector, this is the first sector addressing an unassociated dataset where sources may have multiple withdrawal categories (i.e., industrial, refinery, remediation). It is worth re-iterating that historical unassociated consumptive use data are presented based on calculations using the source-level withdrawal category and default CUR. However, in order to use a standard method of applying one CUR to a projection equation, the default *sector* CUR was applied to projection equations which may or may not represent sources of multiple withdrawal categories. In this instance, all default values are equal to 0.10 and therefore are consistent (unlike the other sector, presented in Section 8.6).

6.5 Results

6.5.1 Total water withdrawal

The projected withdrawals from the Delaware River Basin by the industrial sector in each state are presented in Figure 60, and a summary of the state-level model results are provided in Table 31. The results are then aggregated to provide a Basin-level projection in Figure 61, and a summary of the Basin-level model results are provided in Table 32. The data release supporting this model is provided in Appendix A as Table A-12.

Considering the results provided in these two figures, a primary conclusion can be drawn that even though the historical data shows marked decreases over the last two decades, the projected results suggest a stabilization or even slight increase in the future withdrawal volumes by industrial facilities. The Basin-wide withdrawals by industrial facilities are projected to increase about 5 MGD over approximately 40 years, representing an increase of only about 1%. Considering the average associated 80% predictive interval of (-18.6%)/(+20.4%) and 95% predictive interval of (-27.8%)/(+31.3%), it can be concluded that the projection is most accurately described as a stabilization with predictive intervals skewed slightly towards increased withdraws.

The projected withdrawals from the SEPA-GWPA by the industrial sector are presented in Figure 62, and a summary of the state-level model results are provided Table 33. The data release supporting this model is provided in Appendix A as Table A-13. Similar to the Basin-scale, this model suggests that there will be a continued stable trend for industrial withdrawals from SEPA-GWPA; however, the prediction interval is more dramatically skewed towards suggesting increased withdrawals in the future.

6.5.2 Consumptive water use

The projected consumptive use from the Delaware River Basin by the industrial sector in each state are presented in Figure 63, and a summary of the state-level model results are provided in Table 34. The results are then aggregated to provide a Basin-level projection in Figure 64, and a summary of the Basin-level model results are provided in Table 35. The data release supporting this model is provided in Appendix A as Table A-12. Considering both analyses, there are a few conclusions which may be summarized:

1. There is a significant decrease in Pennsylvania which appears as an offset around the year 2019 due to the closure of a refinery. This was accounted for in the model, given the magnitude of the facility and potential influence on the overall projection. The offset is included in the withdrawal projection, but is more noticeable in the projection of consumptive use given that the operation historically had a high CUR.
2. The overall trend in projected consumptive use largely reflects that of the Basin-scale, suggesting only a minor increase of about 1.15 MGD over 40 years and representing an increase of about 5.5%. The predictive intervals are proportionately larger but skewed in the same manner; the average 80% predictive interval is (-22.9%)/(+27.7%) and the average 95% predictive interval is (-32.8%)/(+42.6%).

The projected consumptive use from the Southeastern Pennsylvania Groundwater Protected Area is presented in Figure 65, and a summary of the model results are provided in Table 36. The results show a relatively constant projection with an uneven predictive interval skewed towards higher values.

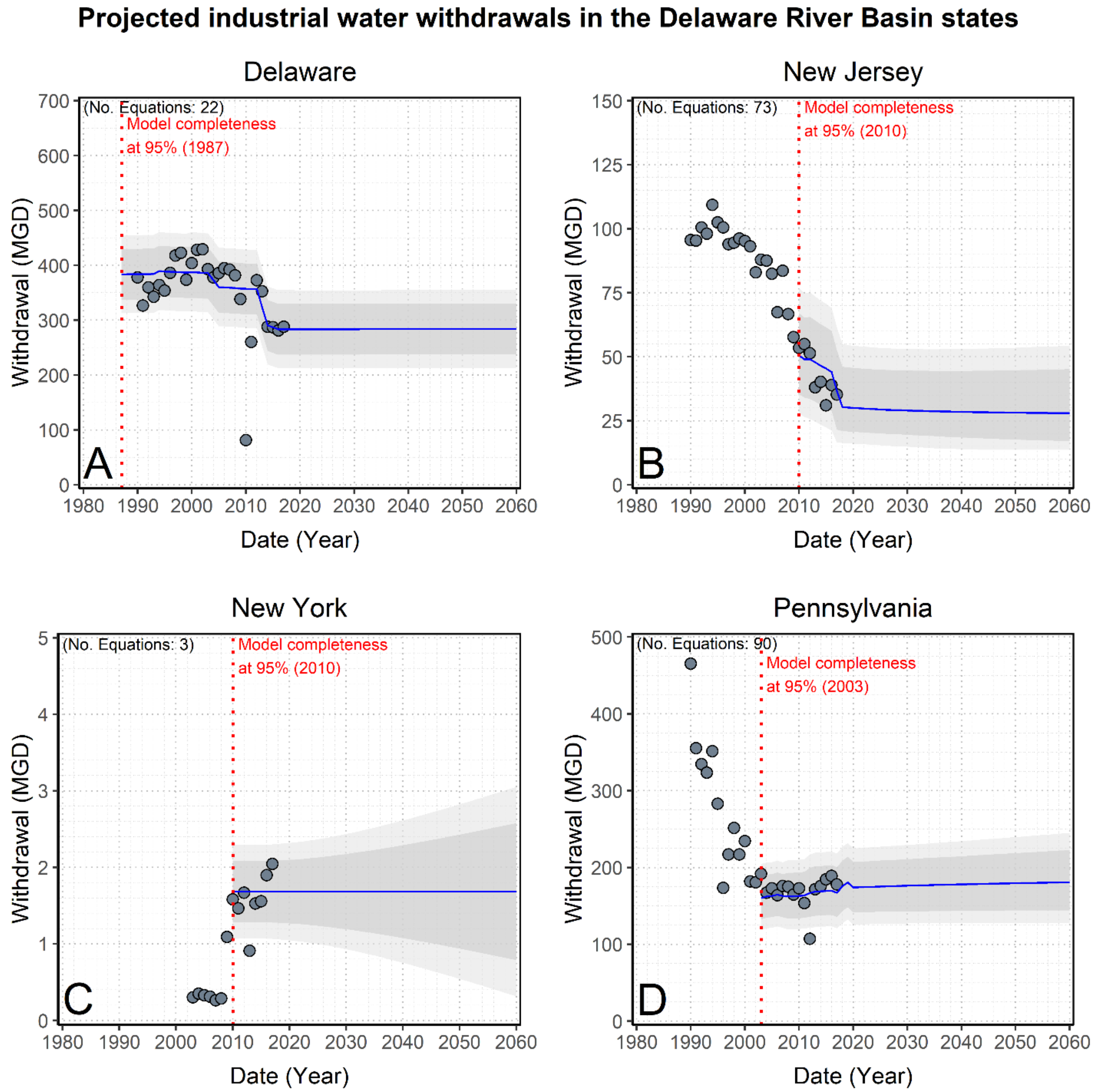

Figure 60: Projected industrial water withdrawals from the Delaware River Basin states. *Aggregated projection results of industrial sector annual average water withdrawals from each state in the Delaware River Basin. This projection corresponds with the data initially presented as Figure 53. Results of the model for select years are presented in Table 31. Data supporting these figures are provided for reference in Table A-12.*

The Port of Philadelphia
on the Delaware River.
Credit: © Brian Kushner

***Table 31**: Summary of results supporting Figure 60 for Basin-state projections of total water withdrawals by the industrial sector of the Delaware River Basin.*

State	Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
					lwr80	upr80	lwr95	upr95
Delaware	2013	352.746	323.588	8.27	277.305	370.042	252.850	394.833
	2014	288.060	290.471	0.84	244.206	336.895	219.755	361.660
	2015	287.229	286.999	0.08	240.747	333.399	216.299	358.142
	2016	281.305	283.525	0.79	237.288	329.903	212.842	354.626
	2017	287.818	283.569	1.48	237.335	329.935	212.887	354.645
	2020	*NA*	283.551	*NA*	237.345	329.875	212.899	354.542
	2030	*NA*	283.587	*NA*	237.394	329.880	212.929	354.498
	2040	*NA*	283.691	*NA*	237.442	330.045	212.931	354.683
	2050	*NA*	283.815	*NA*	237.473	330.277	212.905	354.966
	2060	*NA*	283.946	*NA*	237.484	330.542	212.868	355.299
New Jersey	2013	38.034	47.810	25.70	32.423	64.174	24.682	73.555
	2014	40.215	46.474	15.56	31.165	62.670	23.448	71.892
	2015	31.004	45.456	46.61	30.156	61.569	22.478	70.688
	2016	38.985	44.061	13.02	28.905	60.049	21.245	69.047
	2017	35.207	36.646	4.09	21.534	52.529	16.587	61.424
	2020	*NA*	30.043	*NA*	20.713	45.712	16.118	54.375
	2030	*NA*	29.020	*NA*	19.535	44.622	14.876	53.044
	2040	*NA*	28.474	*NA*	18.542	44.465	13.942	53.021
	2050	*NA*	28.152	*NA*	17.662	44.713	13.647	53.543
	2060	*NA*	27.956	*NA*	17.124	45.177	13.625	54.344
New York	2013	0.908	1.684	85.46	1.284	2.083	1.072	2.295
	2014	1.526	1.684	10.35	1.284	2.083	1.072	2.295
	2015	1.556	1.684	8.23	1.283	2.084	1.071	2.296
	2016	1.897	1.684	11.23	1.282	2.085	1.068	2.299
	2017	2.044	1.684	17.61	1.280	2.087	1.065	2.302
	2020	*NA*	1.684	*NA*	1.269	2.099	1.048	2.319
	2030	*NA*	1.684	*NA*	1.192	2.175	0.931	2.436
	2040	*NA*	1.684	*NA*	1.076	2.291	0.754	2.614
	2050	*NA*	1.684	*NA*	0.939	2.428	0.543	2.824
	2060	*NA*	1.684	*NA*	0.790	2.577	0.316	3.051
Pennsylvania	2013	171.773	168.647	1.82	137.244	201.615	122.558	219.321
	2014	175.770	169.079	3.81	137.679	202.035	122.987	219.720
	2015	184.433	169.477	8.11	138.061	202.446	123.370	220.125
	2016	188.992	170.016	10.04	138.509	203.066	123.790	220.778
	2017	178.034	167.277	6.04	135.703	200.389	120.980	218.123
	2020	*NA*	173.990	*NA*	141.478	207.271	125.656	225.072
	2030	*NA*	176.330	*NA*	142.645	210.956	127.183	229.420
	2040	*NA*	178.073	*NA*	143.535	214.794	127.751	234.343
	2050	*NA*	179.500	*NA*	143.981	218.735	127.671	239.608
	2060	*NA*	180.782	*NA*	144.039	222.760	127.161	245.112

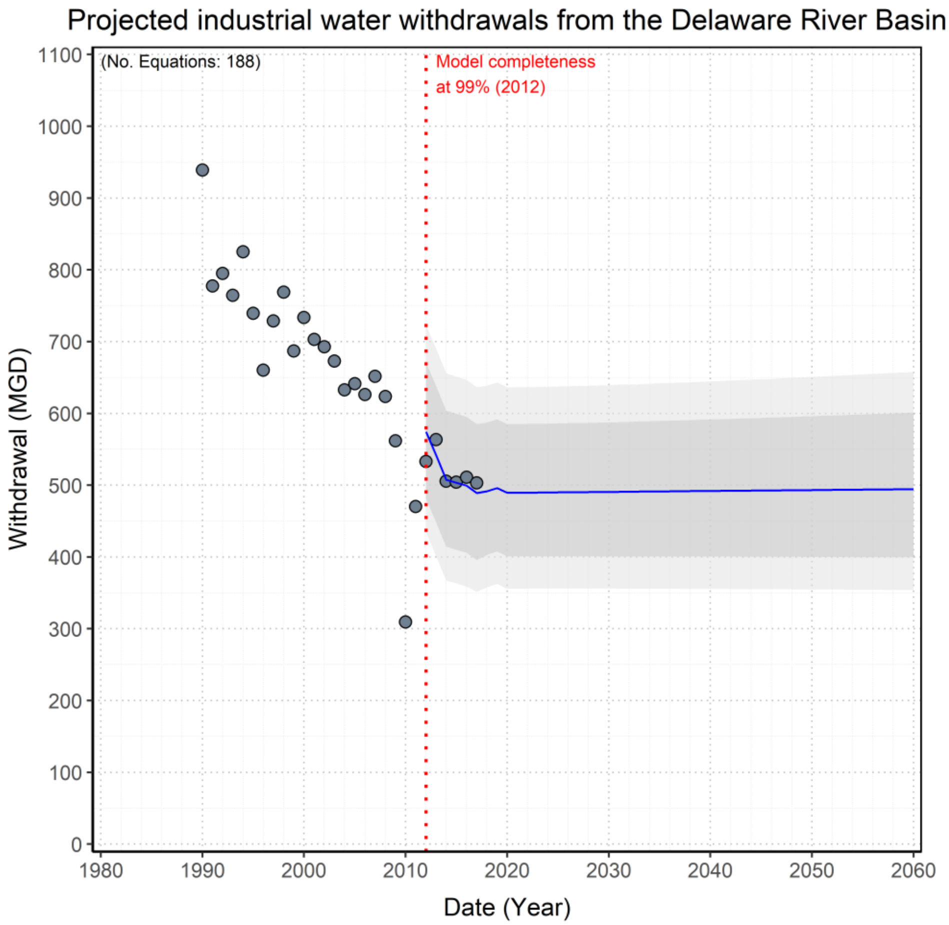

Figure 61: Projected industrial water withdrawals from the Delaware River Basin. *This projection corresponds with the data initially presented as Figure 54. Results of the model for select years are presented in Table 32. Data supporting this figure are provided for reference in Table A-12.*

***Table 32**: Summary of results supporting Figure 61 for the Basin-wide projection of annual average water withdrawal by facilities categorized within the industrial sector of the Delaware River Basin.*

Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
				lwr80	upr80	lwr95	upr95
2013	563.461	541.728	3.86	448.256	637.914	401.162	690.004
2014	505.571	507.708	0.42	414.333	603.682	367.262	655.568
2015	504.223	503.615	0.12	410.247	599.498	363.218	651.252
2016	511.179	499.286	2.33	405.984	595.104	358.946	646.750
2017	503.103	489.176	2.77	395.852	584.941	351.519	636.494
2020	*NA*	489.268	*NA*	400.805	584.956	355.721	636.308
2030	*NA*	490.621	*NA*	400.766	587.633	355.919	639.398
2040	*NA*	491.921	*NA*	400.594	591.595	355.378	644.660
2050	*NA*	493.151	*NA*	400.055	596.153	354.766	650.941
2060	*NA*	494.368	*NA*	399.437	601.055	353.970	657.806

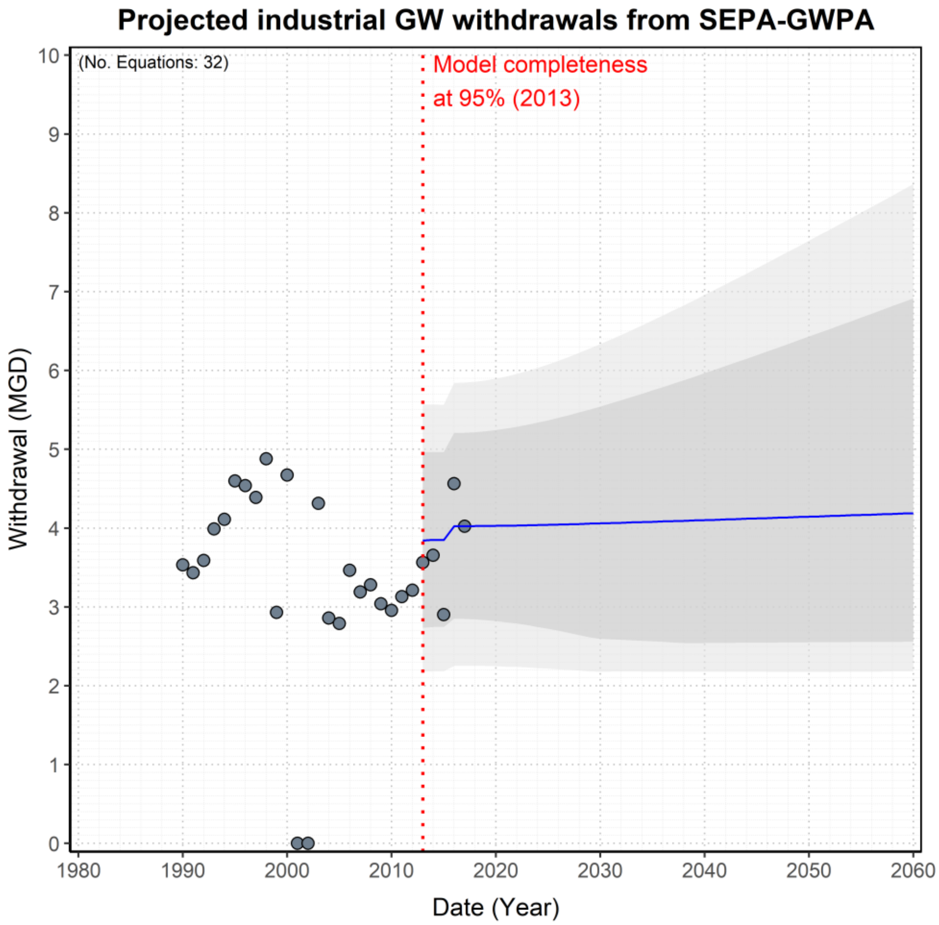

Figure 62: Projected industrial groundwater withdrawals from the Southeastern Pennsylvania Groundwater Protected Area. *This projection corresponds with the data initially presented as Figure 55. Results of the model for select years are presented in Table 34. Data supporting this figure are provided for reference in Table A-13.*

Table 33*: Summary of results supporting Figure 62 for the projection of annual average water withdrawal by industrial facilities within SEPA-GWPA.*

Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
				lwr80	upr80	lwr95	upr95
2013	3.566	3.843	7.77	2.737	4.962	2.179	5.565
2014	3.656	3.851	5.33	2.747	4.968	2.184	5.569
2015	2.901	3.850	32.71	2.747	4.964	2.183	5.564
2016	4.563	4.024	11.81	2.852	5.207	2.253	5.843
2017	4.023	4.024	0.02	2.849	5.210	2.254	5.847
2020	*NA*	4.029	*NA*	2.822	5.245	2.249	5.896
2030	*NA*	4.060	*NA*	2.597	5.543	2.179	6.334
2040	*NA*	4.102	*NA*	2.542	5.966	2.179	6.958
2050	*NA*	4.145	*NA*	2.551	6.431	2.175	7.647
2060	*NA*	4.189	*NA*	2.558	6.915	2.188	8.364

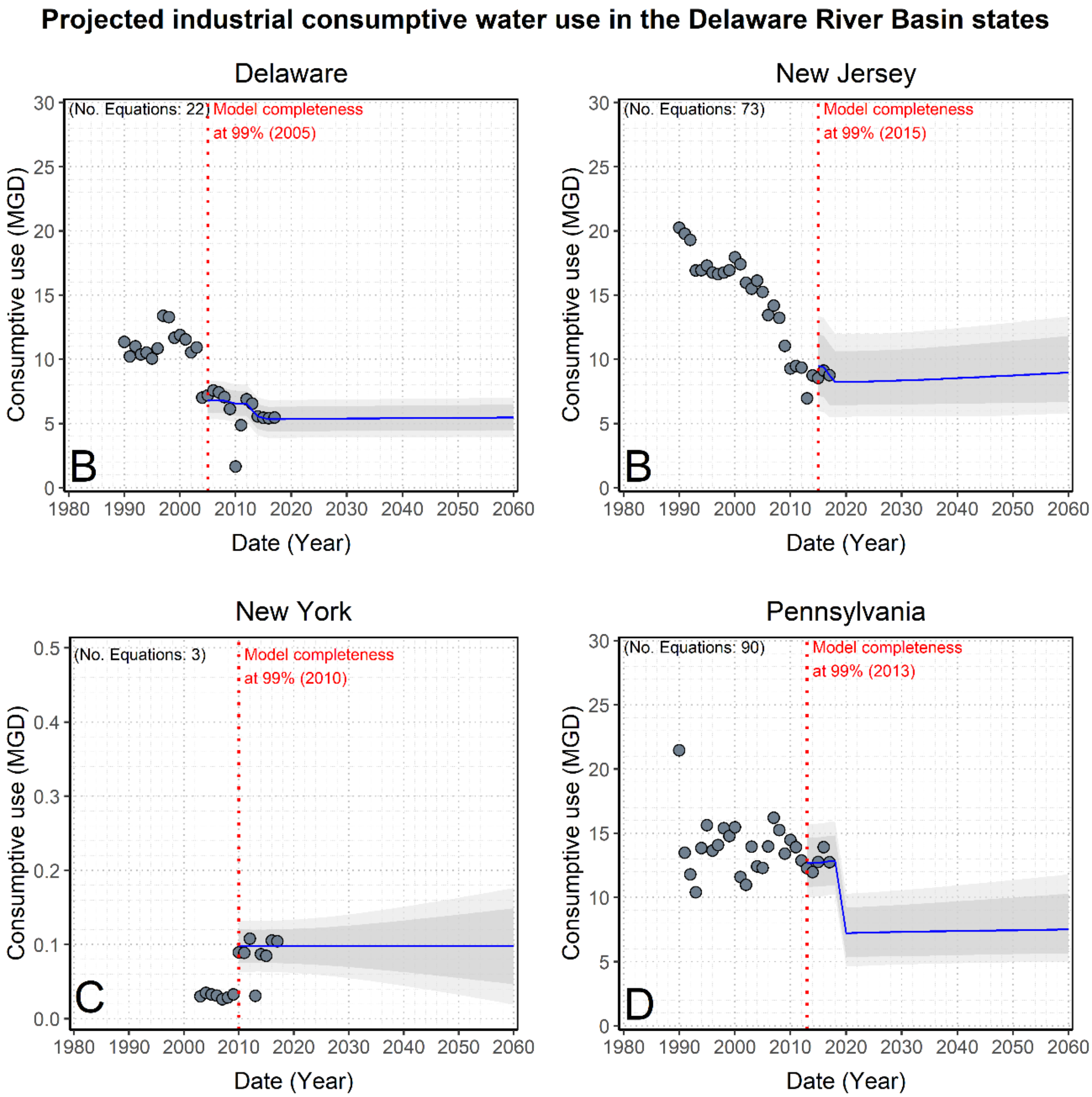

Figure 63: Projected industrial consumptive water use in the Delaware River Basin states. *Aggregated projection results of industrial sector annual average consumptive water use from each state in the Delaware River Basin. These projections correspond with the data initially presented as Figure 56. Results of the model for select years are presented in Table 31. Data supporting these figures are provided for reference in Table A-12.*

***Table 34**: Summary of results supporting Figure 63 for the projections of annual average consumptive use by industrial facilities within the Delaware River Basin states.*

State	Year	Historical Consumptive Use (MGD)	Modelled Consumptive Use (MGD)	Percent Error (%)	Modelled CU prediction intervals			
					lwr80	upr80	lwr95	upr95
Delaware	2013	6.547	6.036	7.810	5.073	7.005	4.572	7.522
	2014	5.559	5.543	0.290	4.580	6.510	4.079	7.027
	2015	5.446	5.436	0.180	4.474	6.403	3.973	6.919
	2016	5.403	5.328	1.390	4.367	6.295	3.866	6.811
	2017	5.459	5.338	2.220	4.376	6.305	3.874	6.821
	2020	*NA*	5.349	*NA*	4.387	6.316	3.885	6.831
	2030	*NA*	5.382	*NA*	4.418	6.354	3.913	6.870
	2040	*NA*	5.412	*NA*	4.440	6.393	3.930	6.914
	2050	*NA*	5.438	*NA*	4.456	6.431	3.941	6.959
	2060	*NA*	5.462	*NA*	4.467	6.469	3.949	7.004
New Jersey	2015	8.539	9.503	11.290	7.160	11.974	5.973	13.377
	2016	9.110	9.391	3.080	7.072	11.839	5.888	13.221
	2017	8.755	8.760	0.060	6.448	11.190	5.504	12.554
	2020	*NA*	8.236	*NA*	6.436	10.635	5.522	11.962
	2030	*NA*	8.354	*NA*	6.484	10.783	5.529	12.093
	2040	*NA*	8.536	*NA*	6.540	11.080	5.526	12.440
	2050	*NA*	8.746	*NA*	6.603	11.436	5.638	12.869
	2060	*NA*	8.970	*NA*	6.688	11.823	5.803	13.341
New York	2013	0.031	0.098	216.130	0.075	0.120	0.063	0.132
	2014	0.087	0.098	12.640	0.075	0.120	0.063	0.132
	2015	0.085	0.098	15.290	0.075	0.120	0.063	0.132
	2016	0.105	0.098	6.670	0.075	0.120	0.063	0.132
	2017	0.104	0.098	5.770	0.075	0.120	0.063	0.132
	2020	*NA*	0.098	*NA*	0.074	0.121	0.062	0.134
	2030	*NA*	0.098	*NA*	0.070	0.126	0.055	0.141
	2040	*NA*	0.098	*NA*	0.063	0.133	0.044	0.151
	2050	*NA*	0.098	*NA*	0.055	0.140	0.032	0.163
	2060	*NA*	0.098	*NA*	0.046	0.149	0.019	0.176
Pennsylvania	2013	12.270	12.682	3.360	10.807	14.656	10.011	15.731
	2014	11.966	12.701	6.140	10.831	14.671	10.048	15.742
	2015	12.756	12.719	0.290	10.851	14.687	10.082	15.756
	2016	13.920	12.751	8.400	10.879	14.726	10.120	15.797
	2017	12.751	12.842	0.710	10.961	14.825	10.214	15.900
	2020	*NA*	7.223	*NA*	5.347	9.214	4.628	10.292
	2030	*NA*	7.319	*NA*	5.421	9.433	4.781	10.571
	2040	*NA*	7.386	*NA*	5.515	9.705	4.880	10.946
	2050	*NA*	7.441	*NA*	5.590	9.997	4.946	11.362
	2060	*NA*	7.525	*NA*	5.642	10.298	5.000	11.797

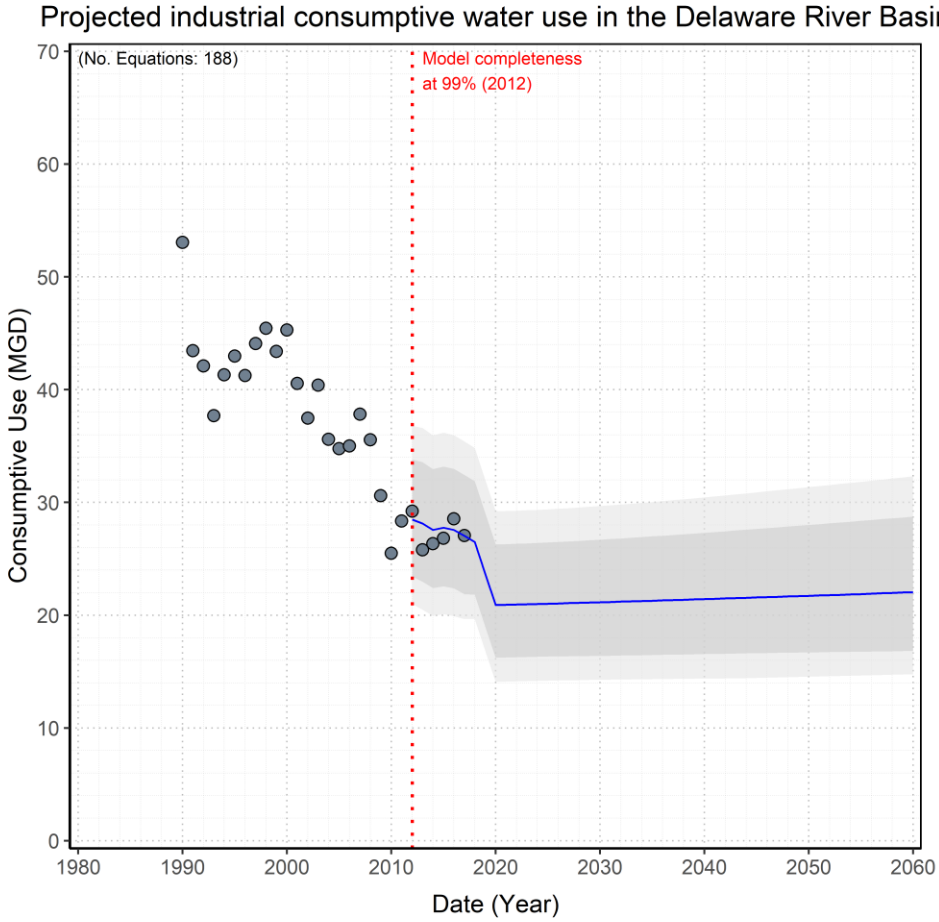

Figure 64: Projected industrial consumptive water use in the Delaware River Basin. *Aggregated projection results of annual average consumptive use by facilities categorized within the industrial sector of the Delaware River Basin. This projection corresponds with the data initially presented as Figure 57. Results of the model for select years are presented in Table 32. Data supporting this figure are provided for reference in Table A-12.*

Table 35*: Summary of results supporting Figure 64 for the projection of annual average water withdrawal by industrial facilities within the Delaware River Basin.*

Year	Historical Consumptive Use (MGD)	Modelled Consumptive Use (MGD)	Percent Error (%)	Modelled CU prediction intervals			
				lwr80	upr80	lwr95	upr95
2013	25.802	28.138	9.050	22.972	33.566	20.494	36.591
2014	26.350	27.563	4.600	22.416	32.956	19.955	35.949
2015	26.826	27.755	3.460	22.560	33.185	20.090	36.185
2016	28.538	27.569	3.400	22.393	32.981	19.937	35.962
2017	27.069	27.037	0.120	21.859	32.440	19.655	35.407
2020	NA	20.905	NA	16.245	26.285	14.097	29.219
2030	NA	21.152	NA	16.392	26.695	14.278	29.675
2040	NA	21.431	NA	16.558	27.310	14.380	30.451
2050	NA	21.722	NA	16.704	28.004	14.557	31.353
2060	NA	22.054	NA	16.844	28.739	14.771	32.319

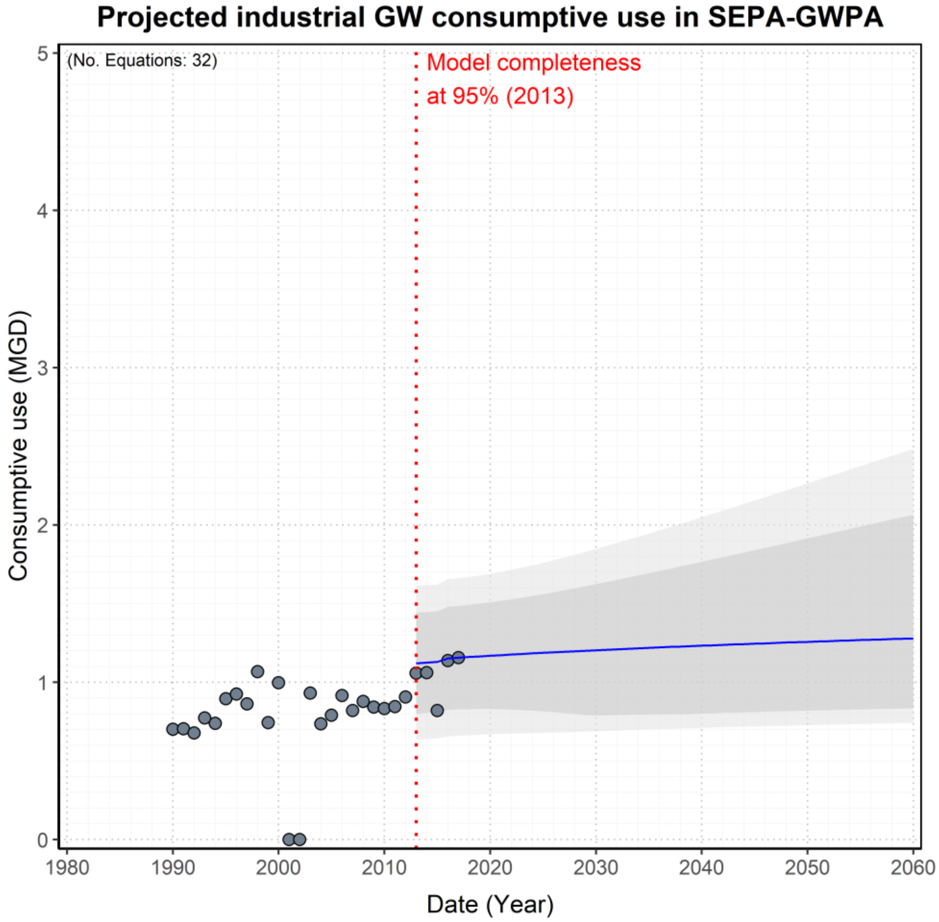

Figure 65: Projected industrial groundwater consumptive use in the Southeastern Pennsylvania Groundwater Protected Area. *This projection corresponds with the data initially presented as Figure 59. Results of the model for select years are presented in Table 36. Data supporting this figure are provided for reference in Table A-13.*

***Table 36**: Summary of results supporting Figure 65 for the projection of annual average groundwater withdrawal by the industrial sector facilities within SEPA-GWPA.*

Year	Historical Consumptive Use (MGD)	Modelled Consumptive Use (MGD)	Percent Error (%)	Modelled CU prediction intervals			
				lwr80	upr80	lwr95	upr95
2013	1.058	1.121	5.950	0.800	1.443	0.635	1.615
2014	1.061	1.126	6.130	0.806	1.447	0.640	1.618
2015	0.820	1.130	37.800	0.811	1.451	0.645	1.622
2016	1.138	1.152	1.230	0.826	1.480	0.656	1.655
2017	1.156	1.157	0.090	0.828	1.486	0.660	1.661
2020	NA	1.169	NA	0.830	1.508	0.670	1.689
2030	NA	1.204	NA	0.789	1.624	0.689	1.847
2040	NA	1.233	NA	0.801	1.766	0.711	2.049
2050	NA	1.257	NA	0.820	1.915	0.727	2.264
2060	NA	1.279	NA	0.835	2.066	0.744	2.484

6.6 Climate change

The effects of climate change on projections of water withdrawals by industrial sector facilities were not addressed quantitatively in this study. However, there are broad concepts related to the industrial sector which largely echo the sentiments outlined in the climate change section for the thermoelectric sector (Section 5.4.4). Namely, given the possibility of increased temperatures and varying conditions of humidity, rates of evaporation may be affected. In turn, this may affect the consumptive use ratio of industrial facilities which primarily use water for cooling, and which use recirculating cooling towers (assuming that technology does not advance to counteract a changing climate's effect on evaporation).

6.7 Summary

Water withdrawals from the Delaware River Basin by facilities in the industrial sector (industrial, refineries, remediation) were presented for 1990-2017 based on self-reported withdrawal data. It was highlighted that historically about 90% of the total withdrawal in this sector was attributed to around 20 facilities which can have major impacts on the trends of the sector (e.g., Figure 54). Significant effort was put towards verifying the relationship between historical data and regulatory approvals, which resulted in over 99% of the reported data being related to approvals. At the Basin scale, withdrawals have decreased by more than 300 MGD when considering the two averaging periods (1990-1994 and 2013-2017) provided in Table 30, and this decrease is primarily attributed to the industrial facilities rather than refineries. Basin-wide consumptive use was shown to have also decreased until recently, to about 27.206 MGD (2010-2017). Despite these recent decreases, facility level trends indicate that future Basin-wide withdrawals may have a minor increase of about 5 MGD over approximately 40 years, representing an increase of only about 1%. Similarly, consumptive use is also projected to have a minor increase of about 1.15 MGD over 40 years, representing an increase of about 5.5%.

An example open pit quarry
near a stream in Pennsylvania.
Credit: © Photovs
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7 MINING

This portion of the study focuses on water withdrawals associated with the processes related to the extraction of minerals from the ground (e.g., mine dewatering, sand and gravel operations). As is shown by Figure 66, there are many mine operations scattered throughout the different geologic areas of the Delaware River Basin. As mine operations vary based on the purpose, the resulting primary use for withdrawn water also varies (e.g., dewatering a quarry, slurry-sand operations, gravel washing, and dust control). There are also many mining operations which may require no water withdrawals, or withdrawals which are below respective regulatory thresholds.

7.1 Review of regional watershed studies

***Table 37**: An expansion of Table 3 in order to more accurately summarize the specific methods utilized by regional watershed studies which projected water use in the mining sector.*

							Mining		
Study	**Study Region**	**Projected data**	**Projected data scale**	**Reported Results Scale**[1]	Total water use	Consumptive water use	Growth rate applied to current water use estimate	Growth rate applied to current water use *(multi-scenario)*	Extrapolation of historical withdrawal estimates
(Hutson et al., 2004)	Tennessee River Watershed	Earnings	County	RCA, WUTA					
(ICPRB, 2012)	Potomic River Basin	EIA projection	County	County	X	X	X		
(USDOI-BR, 2012)	Colorado River Basin	Population	*NA*	State		X		X	
(USDOI-BR, 2016)	Klamath River Basin	*NA*	*NA*	*NA*					
(Balay et al., 2016)	Susquehanna River Basin	Population	County	HUC-10					
(Robinson, 2019)	Cumberland River Watershed	*NA*	*NA*	*NA*					
(Zamani Sabzi et al., 2019)	Red River Basin	USGS NWUE	County	County		X			X

Notes:

HUC	=	Hydrologic Unit Code
RCA	=	Reservoir Catchment Area
WUTA	=	Water-use Tabulation Area
USGS NWUE	=	USGS National Water Use Estimates

An expansion of the studies listed in Table 3 is provided for reference as Table 37 which gives additional details for each study that included projections for this sector. Of the regional watershed studies reviewed in this report, only three directly addressed projections of mining-related water use. It appears that USDOI-BR, 2012 applied growth rates based on multiple scenarios defining the projections, although, it was not clear how growth rates were determined. This could be due to the lack of available projections directly related to the mining sector, which was more directly called out in ICPRB, 2012 by stating that projections for sand and gravel mining industry were not available; therefore, growth rates calculated from USEIA projections of coal and natural gas production were applied to water use data for the mining sector. Another challenge with this sector appears to be the general lack of availability of data for baseline estimates; two of the three studies relied on estimates provided by the USGS National Water Use Estimates.

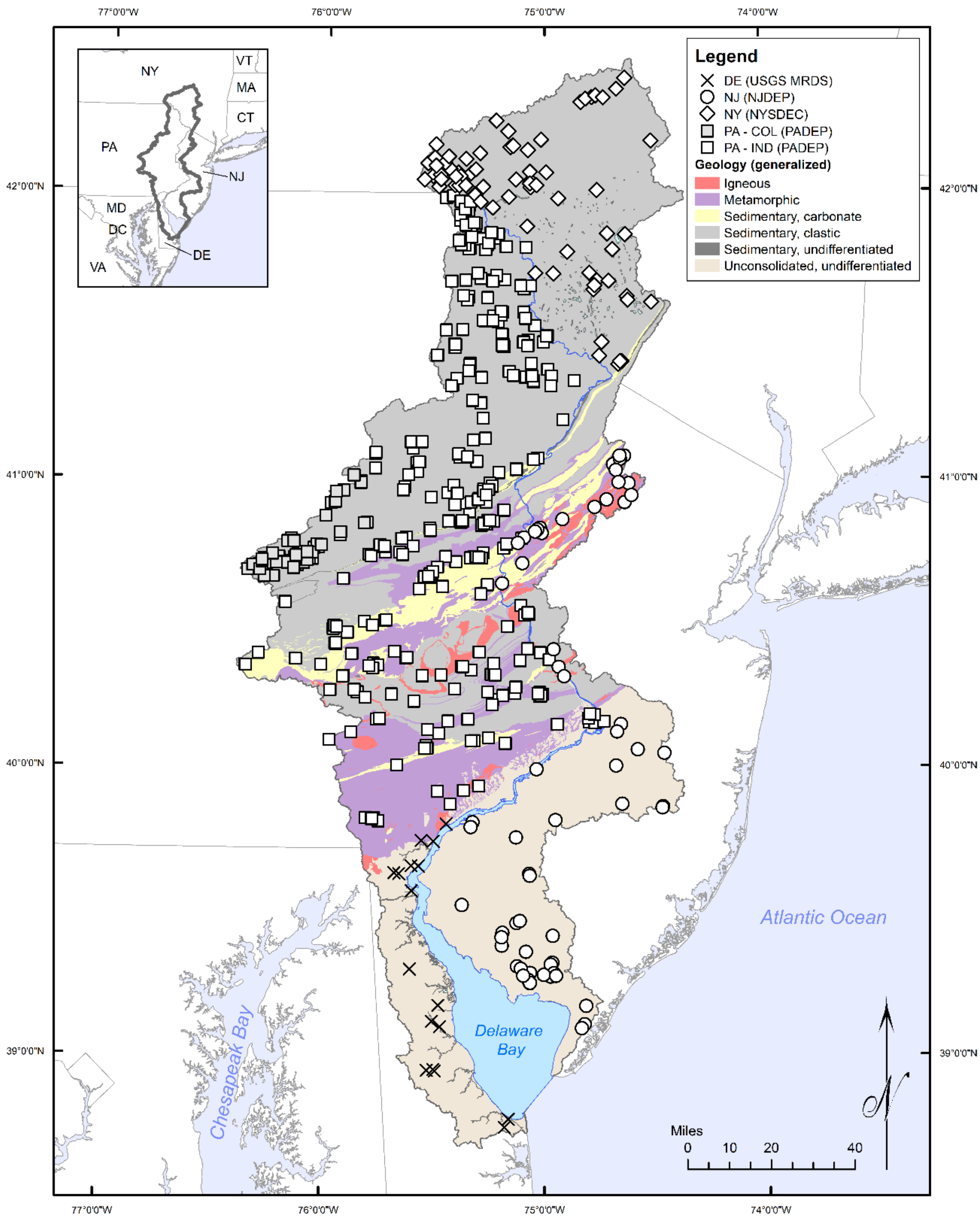

Figure 66: A map of the general geology and active mining-related operations within the Delaware River Basin. *Each respective data source was filtered to only present sites which are considered active. The sources of information on mine locations are datasets which are updated by respective agencies and may change since this publication (McFaul et al., 2000; NJDEP, 2006; NYSDEC, 2006; PADEP, 2016a, 2016b, 2016c). Geology data were obtained from (Horton et al., 2017).*

7.2 Review of studies within the Delaware River Basin

At the time of this publication, there was only one previous study recently published which assessed and projected withdrawals of water by mining facilities in the Delaware River Basin, the *Multi-Jurisdictional Report* (USACE & DRBC, 2008). That study used an estimated year of water withdrawals (2003) and applied projections of mining employment data for Pennsylvania and New Jersey (where available), and otherwise kept all other values constant in the projections. Consumptive use information was site specific for some of the larger mining operations but only used where available.

7.3 Water withdrawal data evaluation

As compared to other sectors in this report, the mining sector has the least consistency in reported data. The type of analysis being performed inherently assumes that regulated entities are reporting water withdrawals, and additional uncertainty is introduced when it is believed that reporting is incomplete. To that end, it is understood that the analysis in this section may be reporting underestimates, and improvements will be made in future assessments as data reporting, collection and dissemination improve.

7.3.1 Associated and unassociated systems

A summary of average total withdrawal volume over the entire dataset time-series is presented in Table 38, indicating which portions of the volume are associated (or not) with DRBC approvals, and whether the withdrawals are surface water or groundwater. From this assessment, it is possible to conclude that only about 66.6% of the water withdrawn for mining-related purposes in the Delaware River Basin is associated with some form of DRBC approval. Furthermore, it may be concluded that historically withdrawals have been split about 65.7% surface water and about 34.3% groundwater. As was referenced before, these statistics are based on reported data, and – because it is assumed that reporting of water withdrawals is inconsistent within the sector - it is expected that these average withdrawals represent underestimates. For reference, a complete list of the associated facilities assessed in this report is included as Appendix C; some facilities may have been reviewed but not projected, as indicated in the appendix (e.g., recently retired facilities).

7.3.2 Data exclusions

The unassociated dataset for surface water withdrawals is presented in figures and summations but is not projected based on the small, comparative size of the dataset.

***Table 38**: A summary of the total water withdrawal data for the mining sector in the Delaware River Basin, categorized by source-type and association with regulatory approvals. These statistics were calculated for the entire basin, corresponding to the data presented in Figure 68.*

Data category	Systems (OAIDs)	Water type	Sources (WSIDs)	Average withdrawal (MGD)	Percent total withdrawal
Associated	29*	SW	54	66.844	63.8%
		GW	81	2.876	2.7%
Unassociated	99	SW	25	1.940	1.9%
		GW	271	33.082	31.6%
Totals:	128	--	431	104.742	100.0%

* *This number represents system/facility identifiers (Organization Address ID; OAID). The same system may have multiple identifiers as ownership changes overtime. The number of unique "associated" systems in this analysis is 29.*

7.3.3 Total water withdrawal

The water withdrawal data for self-supplied mining facilities in the Delaware River Basin are presented for each Basin state in Figure 67, and aggregated to represent the entire Delaware River Basin in Figure 68. The data release supporting the analysis in this section is provided in Appendix A as Table A-14. There are three notes worth highlighting regarding the data:

1. The data presented for Delaware is only from one reporting entity which is associated with a regulatory approval. It appears from review of aerial imagery and review of mine records that this is one of a handful of mines and does not represent the total withdrawal by this sector in the State of Delaware.
2. While there are many mining facilities located within the New York portion of the DRB (Figure 66), many of these are bluestone/shale/slate operations which typically have minimal water withdrawal needs. Additionally, after reviewing aerial imagery of random sand/gravel operations, it appears many are small scale and if they do withdraw water, it may be below regulatory thresholds. Nevertheless, the withdrawal data presented in Figure 67 are only from four facilities.
3. Water withdrawals reported for both Pennsylvania and New Jersey appear to have periods of stronger reporting than others. For facilities with regulatory approvals of withdrawal volumes, reporting was generally observed to be complete.

Another planning scale for this study specific to Pennsylvania is the SEPA-GWPA. Groundwater data which are applicable to the 76 subbasins highlighted in Figure 6 are presented in Figure 69. Note that while the data only extends back to 1990, the regulations defining SEPA-GWPA became effective beginning in January 1981 (18 CFR Part 430, 1980). It is assumed that the dataset's level of completeness is commensurate with that of the overall Basin. Withdrawals of groundwater from the region have been reported as high as an average of 25 MGD, but more recently have been reported around an average of 5 MGD.

Based on the reported data, it is difficult to conclude whether or not peak water withdrawal has been reached due to inconsistencies in reporting across all Basin states. These observations highlight the opportunity for improvement in reporting, leading to a better understanding and facilitation of water resource planning in the future.

7.3.4 Consumptive water use

Site-specific data on consumptive use is also very limited for the mining sector. This analysis relied heavily on a default value for the sector which was defined in this analysis as 12% (Table 5), or information from regulatory approvals (which oftentimes were estimates or reiterations of a default value). Therefore, the trends observed will mirror those presented in Section 7.3.3, and separate figures have not been presented. However, corresponding consumptive use data are included as part of the data release provided in Appendix A as Table A-14.

An example sand mining operation
as typically seen in the Lower Basin.

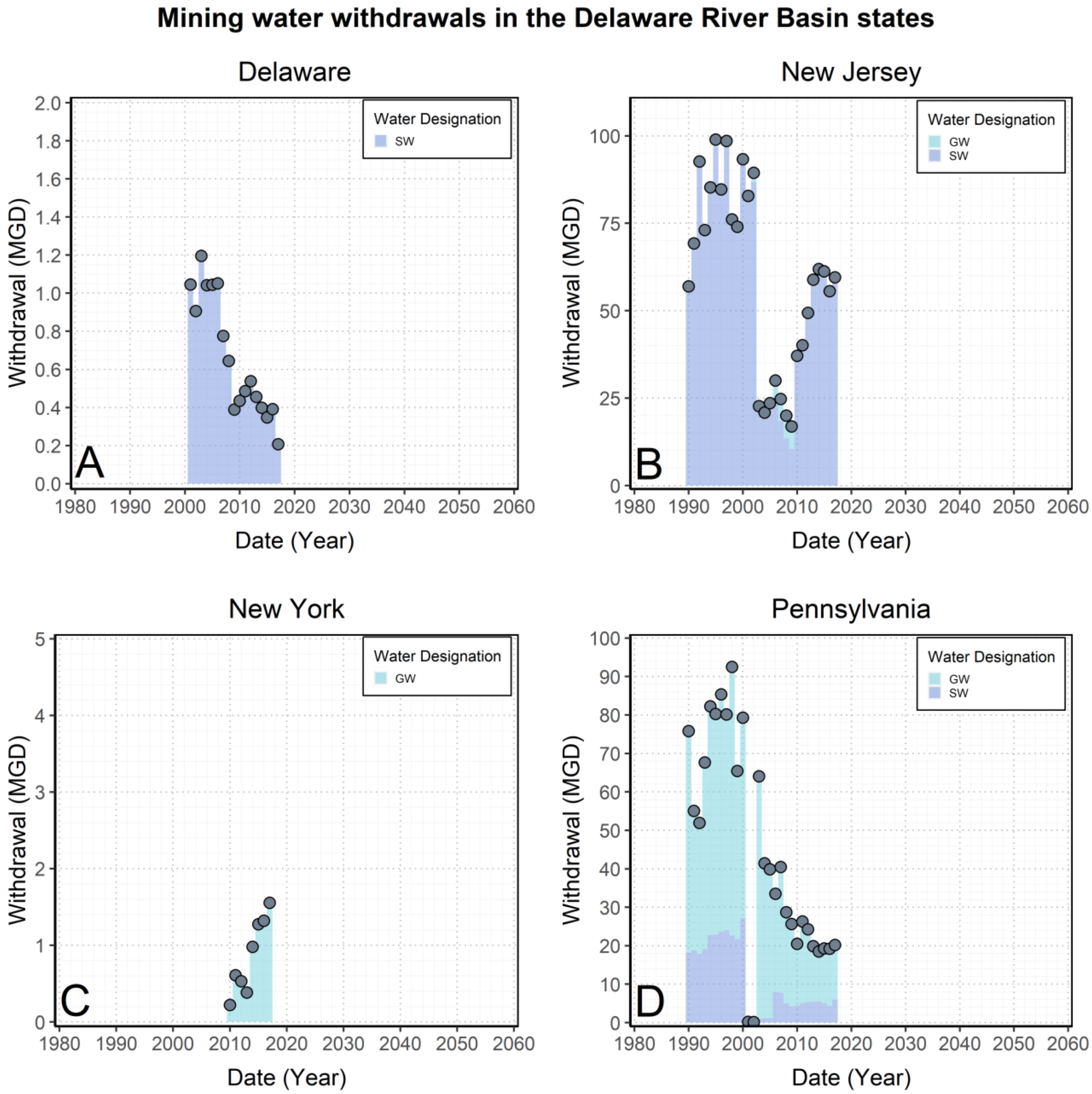

__Figure 67: Mining water withdrawals in the Delaware River Basin states__. Annual average water withdrawals by each state in the Delaware River Basin, grouped by sourcewater designation (GW or SW). This dataset is aggregated to the Basin scale in Figure 68. The projections results for this figure are presented in Figure 70. Data supporting these figures are provided for reference in Table A-14.

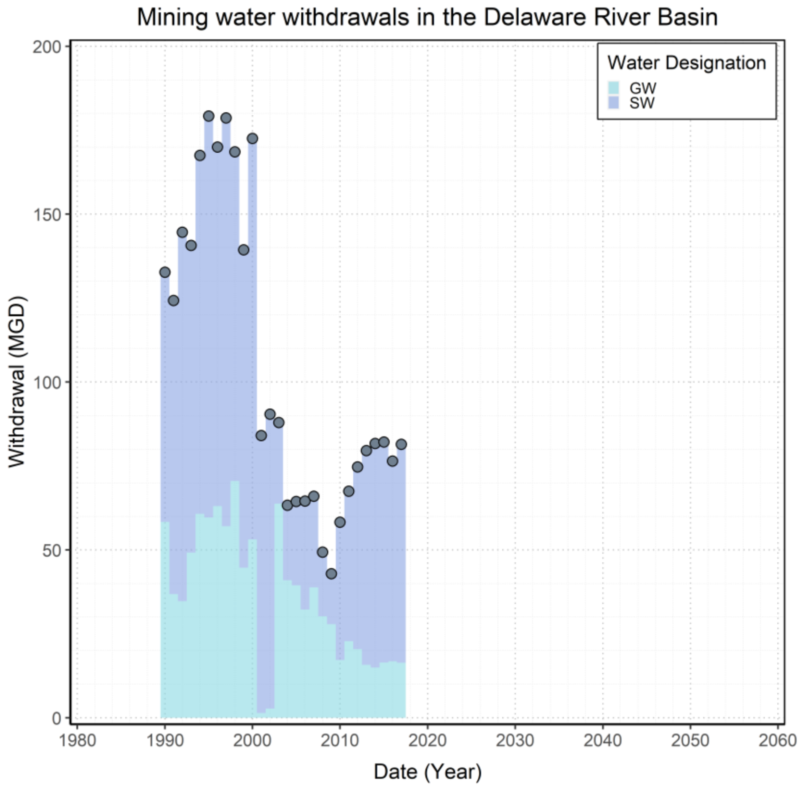

Figure 68: Mining water withdrawals in the Delaware River Basin. *Annual average water withdrawal from the Delaware River Basin, grouped by sourcewater designation (GW or SW). This represents the same data presented in Figure 67, aggregated to the Basin scale. The projections results for this figure are presented in Figure 71. Data supporting this figure are provided for reference in Table A-14.*

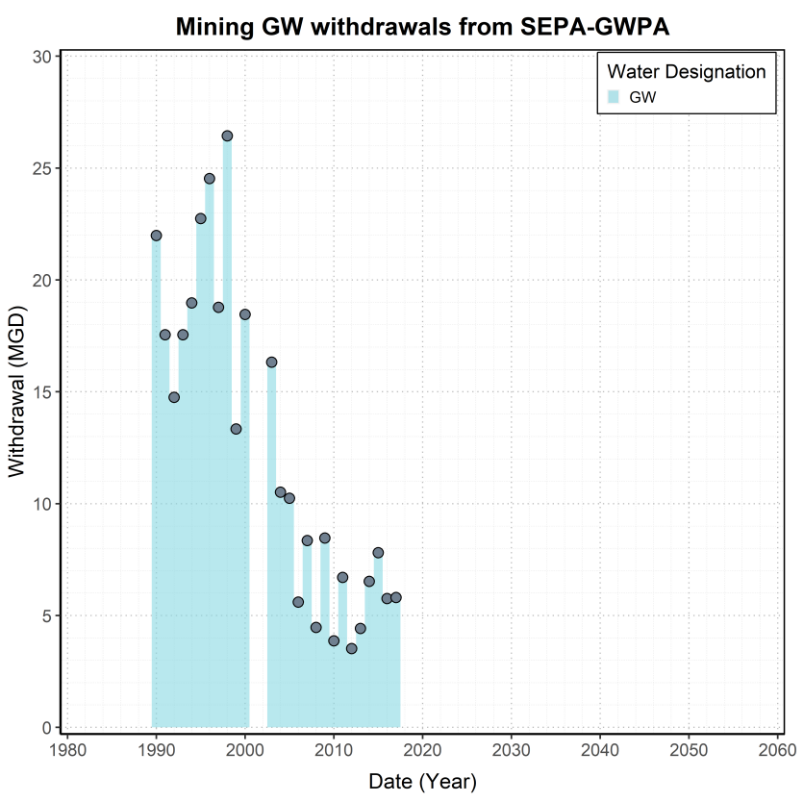

Figure 69: Mining groundwater withdrawals from the Southeastern Pennsylvania Groundwater Protected Area. *These data only represent withdrawal volumes from sources which plotted within the boundary of SEPA-GWPA as shown in Figure 6. The projections results for this figure are presented in Figure 72. Data supporting this figure are provided for reference as part of Table A-14.*

7.4 Methods

The methods used in this analysis for projecting water withdrawals for use in the mining sector are the same as described for the public water supply sector, outlined in Section 3.4. To reiterate, the overall concept of this analysis is to estimate future water demands by extrapolating historical withdrawal data at the water supply system and/or sub-system levels in a manner such that a "bottom-up" approach can be used to re-aggregate the projections. The methods inherently assume that the rate of change in water use over the recent past will continue into the future at the same rate of change, among other assumptions (e.g., Section 3.4.5.4). The results of this analysis are focused on water demand and are intended to be used for water resource planning purposes. It is understood that, specifically for this sector which is known to have gaps in reporting withdrawal data, the methodology can only be as good as the reported data. It is anticipated that as data reporting improves, so will this model.

7.5 Results

7.5.1 Total water withdrawal

The projected withdrawals from the Delaware River Basin by the mining sector in each state are presented in Figure 70, and a summary of the state-level model results are provided in Table 39. The results are then aggregated to provide a Basin-level projection in Figure 71, and a summary of the Basin-level model results are provided in Table 40. The data release supporting this model is provided in Appendix A as Table A-15. Considering both figures, there are three notes worth highlighting:

1. The year at which aggregated projection models are "substantially complete" appear closer to 2017 due to the nature of the datasets being projected. The projection method attempts to capture "current trends" and as was often observed in data from New Jersey, this resulted in a decreased length of dataset.
2. The projection for Delaware only includes one model which extends to zero. It is known that this does not accurately represent the state as a whole (as discussed in Section 7.3.3), and the single facility was consulted prior to selecting the particular projection.
3. The overall magnitude of prediction intervals is quite large for the Basin. The 80% predictive interval ranges from (-35.5%)/(+40.3%) in 2020, to (-44.3%)/(+54.1%) in 2060. The 95% predictive interval ranges from (-50.1%)/(+64.3%) in 2020, to (-59.7%)/(+83.4%) in 2060. While these ranges make it difficult to assess the validity of trends based on reported data, they are determined to be appropriate given the quality of the reported data being projected. These predictive intervals which attempt to quantify uncertainty may also highlight issues with other studies which have similar issues in reported data, but do not report a magnitude of uncertainty.

The projected withdrawal from the SEPA-GWPA by the mining sector is presented in Figure 72, and a summary of the model results are provided in Table 41. The data release supporting this model is provided in Appendix A as Table A-16. This analysis proved difficult as the only reported withdrawals from SEPA-GWPA are considered unassociated, and therefore projections were performed at a subbasin scale considering the entire dataset. If a SEPA-GWPA subbasin had historical data which ended prior to recent years (e.g., around 2000), it was not projected as a withdrawal that ends because it was not verified at the system level that a mining operation stopped withdrawing water. Based on the uncertainty in reported data, such a subbasin was merely not modelled. Therefore, the projection in Figure 72 only includes facilities which are currently reporting through recent years (e.g., 2015-2017). Consistent with the Basin-scale, the predictive interval is very large in comparison to the magnitude of data reported in recent years.

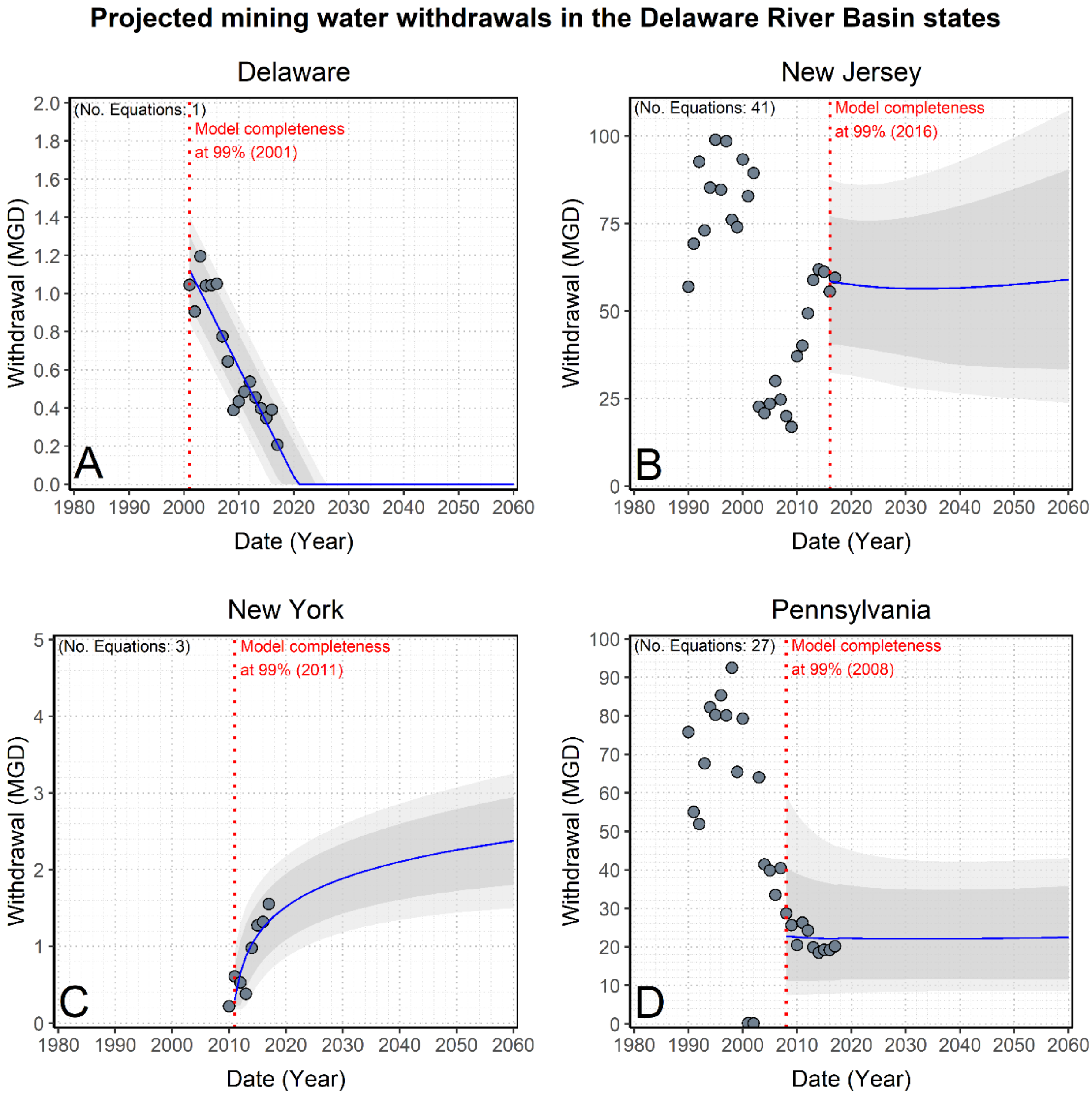

Figure 70: Projected mining water withdrawals in the Delaware River Basin states. *Aggregated projection results of mining sector annual average water withdrawals from each state in the Delaware River Basin. This projection corresponds with the data initially presented as Figure 67. Results of the model for select years are presented in Table 39. Data supporting these figures are provided for reference in Table A-15.*

Table 39: Summary of results supporting Figure 70 for Basin-state projections of total water withdrawals by the mining sector of the Delaware River Basin.

State	Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
					lwr80	upr80	lwr95	upr95
Delaware	2013	0.455	0.439	3.520	0.262	0.616	0.168	0.711
	2014	0.399	0.382	4.260	0.204	0.560	0.110	0.654
	2015	0.348	0.325	6.610	0.147	0.503	0.052	0.598
	2016	0.391	0.268	31.460	0.089	0.447	0.000	0.542
	2017	0.207	0.211	1.930	0.031	0.391	0.000	0.486
	2020	NA	0.039	NA	0.000	0.223	0.000	0.320
	2030	NA	0.000	NA	0.000	0.000	0.000	0.000
	2040	NA	0.000	NA	0.000	0.000	0.000	0.000
	2050	NA	0.000	NA	0.000	0.000	0.000	0.000
	2060	NA	0.000	NA	0.000	0.000	0.000	0.000
New Jersey	2016	55.560	58.495	5.280	40.641	77.170	32.478	87.428
	2017	59.532	58.250	2.150	40.479	76.820	32.255	87.004
	2020	NA	57.585	NA	39.865	76.101	31.625	86.215
	2030	NA	56.454	NA	37.219	76.717	28.201	87.718
	2040	NA	56.635	NA	34.547	80.115	26.510	92.795
	2050	NA	57.598	NA	33.823	84.917	25.049	99.625
	2060	NA	59.013	NA	33.288	90.493	23.750	107.397
New York	2013	0.382	0.876	129.320	0.453	1.299	0.229	1.524
	2014	0.978	1.030	5.320	0.607	1.452	0.383	1.676
	2015	1.275	1.149	9.880	0.726	1.571	0.501	1.796
	2016	1.320	1.246	5.610	0.822	1.669	0.597	1.894
	2017	1.554	1.328	14.540	0.903	1.753	0.677	1.979
	2020	NA	1.518	NA	1.088	1.949	0.859	2.177
	2030	NA	1.888	NA	1.429	2.346	1.186	2.590
	2040	NA	2.104	NA	1.610	2.598	1.347	2.861
	2050	NA	2.257	NA	1.725	2.790	1.441	3.073
	2060	NA	2.376	NA	1.803	2.950	1.500	3.254
Pennsylvania	2013	19.890	22.311	12.170	11.195	37.497	7.669	49.787
	2014	18.479	22.244	20.370	11.216	37.109	7.710	48.679
	2015	19.274	22.184	15.100	11.235	36.769	7.755	47.732
	2016	19.211	22.130	15.190	11.254	36.469	7.800	46.921
	2017	20.179	22.082	9.430	11.272	36.204	7.842	46.223
	2020	NA	22.240	NA	11.524	35.918	8.123	45.014
	2030	NA	22.092	NA	11.623	34.947	8.382	42.661
	2040	NA	22.141	NA	11.636	34.848	8.507	42.164
	2050	NA	22.286	NA	11.576	35.185	8.550	42.440
	2060	NA	22.475	NA	11.616	35.776	8.549	43.142

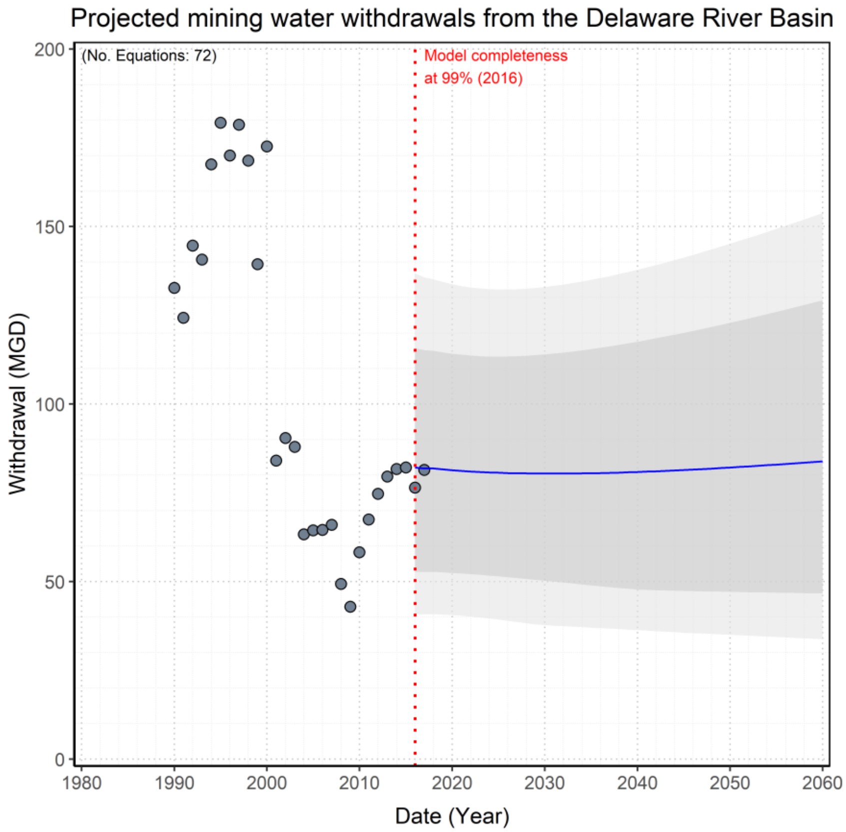

Figure 71: Projected mining water withdrawals from the Delaware River Basin. *Aggregated projection results of annual average water withdrawals by facilities categorized within the mining sector of the Delaware River Basin. This projection corresponds with the data initially presented as Figure 68. Results of the model for select years are presented in Table 40. Data supporting this figure are provided for reference in Table A-15.*

Table 40*: Summary of results supporting Figure 71 for the Basin-wide projection of annual average water withdrawal by facilities categorized within the mining sector of the Delaware River Basin.*

Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
				lwr80	upr80	lwr95	upr95
2016	76.483	82.139	7.400	52.806	115.755	40.874	136.786
2017	81.471	81.871	0.490	52.685	115.168	40.774	135.691
2020	NA	81.383	NA	52.476	114.191	40.607	133.726
2030	NA	80.434	NA	50.271	114.011	37.769	132.969
2040	NA	80.880	NA	47.794	117.561	36.365	137.820
2050	NA	82.141	NA	47.123	122.893	35.041	145.139
2060	NA	83.864	NA	46.707	129.219	33.800	153.793

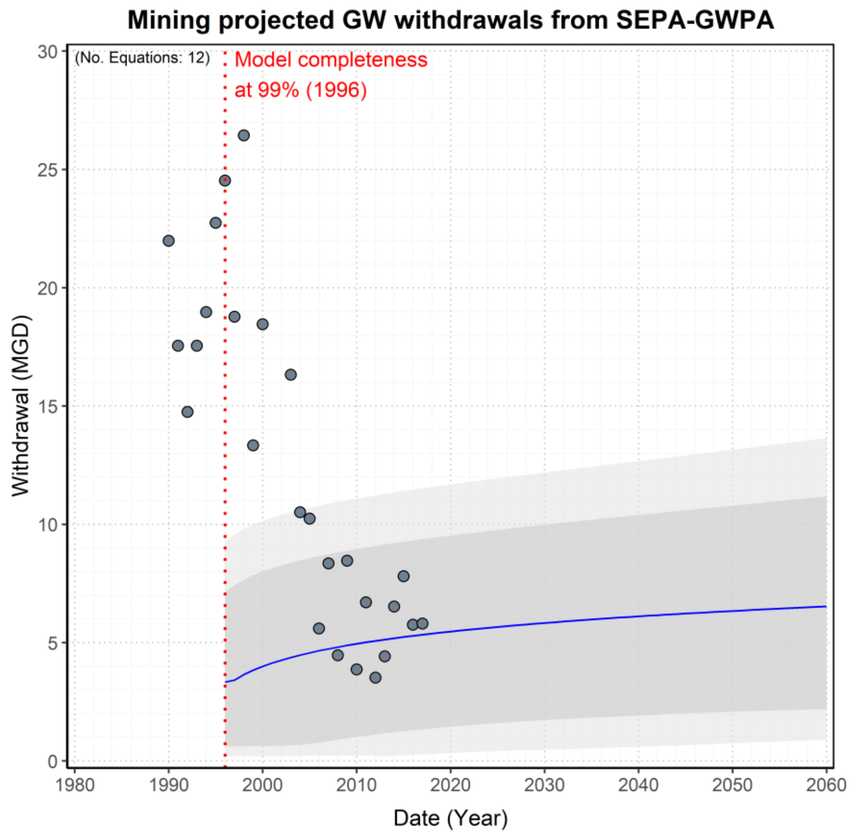

Figure 72: Projected mining groundwater withdrawals from the Southeastern Pennsylvania Groundwater Protected Area. *This projection corresponds with the data initially presented as Figure 69. Results of the model for select years are presented in Table 41. Data supporting this figure are provided for reference in Table A-16.*

Table 41*: Summary of results supporting Figure 72 for the projection of annual average water withdrawal by mining facilities within SEPA-GWPA.*

Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
				lwr80	upr80	lwr95	upr95
2013	4.419	5.134	16.180	1.173	9.152	0.213	11.287
2014	6.524	5.188	20.480	1.218	9.211	0.224	11.347
2015	7.806	5.240	32.870	1.261	9.267	0.246	11.407
2016	5.762	5.290	8.190	1.301	9.322	0.267	11.464
2017	5.805	5.338	8.040	1.339	9.376	0.286	11.521
2020	NA	5.472	NA	1.450	9.529	0.339	11.684
2030	NA	5.834	NA	1.733	9.985	0.484	12.191
2040	NA	6.113	NA	1.926	10.398	0.604	12.675
2050	NA	6.340	NA	2.084	10.793	0.752	13.158
2060	NA	6.532	NA	2.196	11.178	0.902	13.646

7.5.2 Consumptive water use

As was discussed in Section 7.3.4, calculations of historical consumptive use for the mining sector relied heavily on default values listed in Table 5. The same method of calculation is used to generate projections of consumptive use; therefore, the trends observed will mirror those presented in the previous section, and separate figures have not been presented. However, results for the consumptive use model are provided in data releases in Appendix A as a part of Table A-15 and Table A-16.

7.6 Climate change

The effects of climate change on water withdrawal projections in the mining sector were not addressed in this report.

7.7 Summary

Water withdrawals from the Delaware River Basin by facilities in the mining sector were presented for 1990-2017 based on self-reported withdrawal data, although it was noted that this sector is assumed to have the least consistency in reported data when compared to other sectors. Therefore, it is understood that the analysis in this section may be reporting underestimates, and improvements will be made in future assessments as data gathering improves. The historical average withdrawal has fluctuated between different time periods (and is likely attributable to incomplete reporting), but has returned an average value of around 105 MGD, which was split about 66% surface water and 34% groundwater. The Basin-wide projection remains relatively constant, and the prediction intervals are quite large for the Basin. The 80% predictive interval ranges from (-35.5%)/(+40.3%) in 2020, to (-44.3%)/(+54.1%) in 2060. The 95% predictive interval ranges from (-50.1%)/(+64.3%) in 2020, to (-59.7%)/(+83.4%) in 2060. While these ranges make it difficult to assess the validity of trends based on reported data, they are determined to be appropriate given the quality of the reported data being projected.

Cement factory surrounded by quarries in Northampton County, Pennsylvania.
Credit: © Cynthia Farmer
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Agricultural groundwater irrigation near Harrington, Delaware.
Credit: © Daniel Laughman
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8 IRRIGATION

This portion of the study focuses on water withdrawals specifically associated with irrigation (e.g., agriculture, golf courses, nurseries, and landscaping) as defined in Table 1. Agriculture is the largest type of irrigation withdrawal within the Basin; therefore, an analysis has been prepared using the most recent United States Department of Agricultural (USDA) 2017 Census of Agriculture data at the county level (USDA NASS, 2019). Based on this data, Figure 73 presents a summary of total cropland and total irrigated acreage, and it is color coded by the percent of cropland which is irrigated. From this analysis, it becomes clear that most of the agricultural irrigation in the Basin is occurring in Delaware and the southern portion of New Jersey. Referring back to Figure 66, it is likely not a coincidence that these areas coincide with the unconsolidated geology of the Atlantic Coastal Plain. A separate layer added to this map provides point locations of golf courses across the Basin (ESRI & USGS, 2020), which highlights a dense area of golf courses following the Northeast megalopolis, stretching from Washington, D.C., to Boston.

8.1 Review of regional watershed studies

***Table 42**: An expansion of Table 3 in order to more accurately summarize the specific methods utilized by regional watershed studies which projected water use in the irrigation sector.*

									Irrigation / Agriculture			
Study	**Study Region**	**Projected data**	**Projected data scale**	**Reported Results Scale[1]**	All irrigation	Just Agriculture	Total water use	Consumptive water use	Water use factor based on projections of farm earnings	Average per-acre delivery rate applied to irrigated acreage	Variable per-acre delivery rate applied to irrigated acreage	Extrapolation of historical withdrawal estimates
(Hutson et al., 2004)	Tennessee River Watershed	Earnings	County	RCA, WUTA	X		X	X	X			
(ICPRB, 2012)	Potomac River Basin	Irrigated acreage	County	County	X		X	X		X		
(USDOI-BR, 2012)	Colorado River Basin	Irrigated acreage	*NA*	State		X		X			X	
(USDOI-BR, 2016)	Klamath River Basin	*NA*	*NA*	*NA*		X		X			X	
(Balay et al., 2016)	Susquehanna River Basin	Irrigated acreage	County	HUC-10		X		X			X	
(Robinson, 2019)	Cumberland River Watershed	*NA*	*NA*	*NA*								
(Zamani Sabzi et al., 2019)	Red River Basin	USGS NWUE	County	County	X			X				X

An expansion of the studies listed in Table 3 is provided for reference as Table 42 and gives additional details for each study that included projections for this sector. The most common method used by three studies was to apply crop-specific per-acre delivery rates of irrigated water to some form of land-use data, which has been corrected for both crop type and percent irrigated (Balay et al., 2016; USDOI-BR, 2012); it should also be clarified that Table 42 likely is a gross conceptualization of the extensive modelling efforts in USDOI-BR, 2016, which made use of the FAO-56 dual crop coefficient method and work done by the West-Wide Climate Risk Assessment (WWCRA). Another study (ICPRB, 2012) was also based on a similar analysis to this most common method, although only a single per-acre delivery rate was applied to all current and projected irrigated acreage.

8.2 Review of studies within the Delaware River Basin

The most recent assessment of irrigation which covered the entire Delaware River Basin only considered agricultural water withdrawals, which are known to account for the majority of irrigation withdrawals (Barr, 2015). This DRBC study used a similar approach to the most common method outlined in Table 42, in that it assessed per-acre delivery rates for irrigated acreage based on crop type. It used three primary datasets from the USDA to estimate agricultural irrigation withdrawals in each of the 147 subbasins:

1. National Agriculture Statistics Service (NASS) Crop Data Layers (CDL) were used to break down 30x30m raster files resulting in acreage of crop type in each of the 147 planning subbasins for the years 2008 and 2013. Data files are available annually from 2008 to present (USDA NASS, 2020).
1. The U.S. Census of Agriculture provided information on irrigated acreage at the county level for the census years 2007 and 2012 (USDA NASS, 2009, 2014).
2. The U.S. Census of Agriculture – Farm and Ranch Irrigation Survey from 2008 provides data on irrigation rates by crop type and state in million gallons per acre (USDA NASS, 2010).

The study was limited to two years (2008, 2013) based on the necessary data input of irrigated acreage provided by the U.S. Census of Agriculture. While the crop-type raster file could be disaggregated into the 147 subbasins, county level data on irrigated acreage forced assumptions that ratios of irrigated land were split evenly within each county across subbasins, and therefore evenly between cropland inside and outside of the Delaware River Basin.

The withdrawal estimate for 2013 was based on a 100-day growing season and can be transformed into an annual average value in MGD. These results are presented in Table 43 and can be compared against average reported agricultural withdrawals for 2011-2015. Considering the required assumption to apply county level data evenly across planning boundaries, the results are fairly comparable. The finding of most interest in relation to water resource planning is the appearance of under-reported values for Delaware. However, the two counties in Delaware with the most irrigated acreage (Kent and Sussex) have large portions of area outside the Basin (Figure 73). Without finer resolution data on the irrigated acreage to improve the estimates in Barr, 2015, and in consideration of the discussion of reported withdrawal data in Section 8.3, it was determined that the reported data are appropriate for use in this study.

***Table 43**: Estimated agricultural withdrawals as assessed by Barr, 2015 compared to average reported withdrawal data.*

State	Estimated in (Barr, 2015) for 2013		Annual rate from reported data (2011-2015 average MGD)		
	Seasonal rate (MGD)	Annual rate (MGD)	GW	SW	TOTAL
DE	69.5	19.0	7.6	0.8	8.4
NJ	55.0	15.1	18.1	16.6	34.7
NY	0.0	0.0	0.0	0.0	0.0
PA	1.7	0.5	0.2	0.0	0.2
Total	126.2	34.6	25.9	17.4	43.3

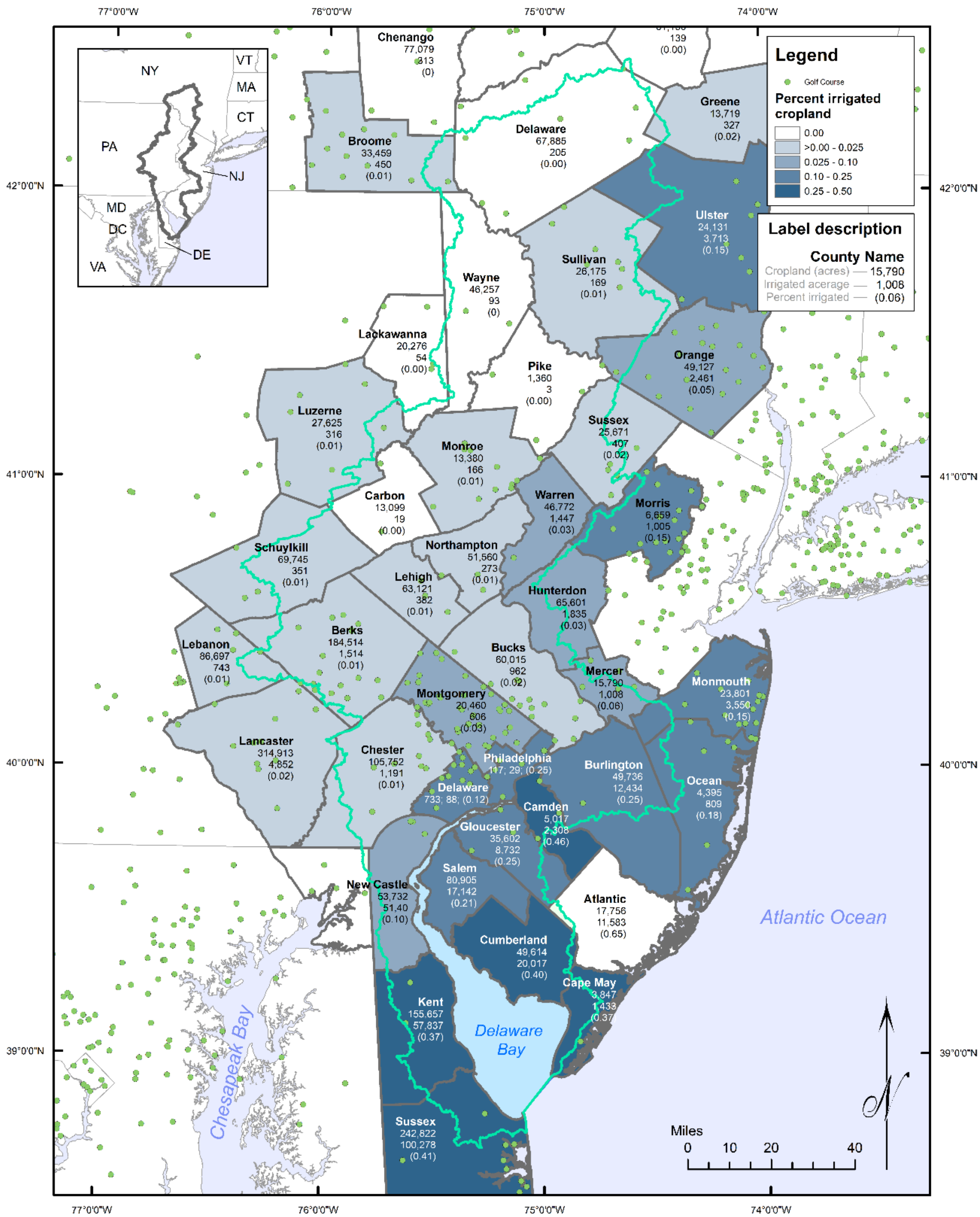

Figure 73: A map of the Delaware River Basin showing USDA Census of Agriculture data on cropland and irrigated cropland, by county. *Data shown on the map highlight that while there is a significant amount of agriculture in many parts of the Delaware River Basin, the majority of irrigation occurs near the Coastal Plain. Agricultural irrigation data were obtained from the USDA 2017 Census of Agriculture data at the county level (USDA NASS, 2019). Golf course locations were obtained from (ESRI & USGS, 2020).*

8.3 Water withdrawal data evaluation

Reported water withdrawal data classified as irrigation were assessed in a different manner than all other sectors in this report. Primarily, consideration to a withdrawal's association with a regulatory approval was not addressed; instead, the entire dataset was used together at the smallest planning levels needed (e.g., 147 subbasin and SEPA-GWPA). This decision was made based on the vast difference in number of current/historical withdrawal sources and approvals as compared to other withdrawal sectors (around 4,700 sources & 480 approvals), resulting in a comparatively much smaller volume withdrawn per source, as well as benefit gained by assessing data on a system level.

8.3.1 Associated and unassociated systems

This assessment is not applicable to the irrigation sector for the purposes of this analysis.

8.3.2 Data exclusions

There is a historical component of reported agricultural withdrawal data associated with cranberry growing/harvesting operations in New Jersey, which largely are related to the flooding of cranberry bogs prior to harvest. The component of reported irrigation withdrawal data associated with cranberry production is largely surface water, has decreased to less than an average of 1 MGD per year (2014-2017) as shown in Figure 74, and is assumed to have zero consumptive use as indicated in Table 5. Therefore, while the historical dataset is still presented, it is not projected into the future.

8.3.3 Total water withdrawal

The reported water withdrawal data for self-supplied irrigation facilities in the Delaware River Basin are presented for each basin state in Figure 74; the data have been broadly classified as agriculture, nurseries, golf courses/country clubs, non-agriculture (e.g., sports fields and parks) and cranberry operations. A second important component needed to better understand the reported withdrawal data is the number of withdrawal sources that reported each year, shown in Figure 75. From these two figures, there are three notes worth highlighting:

1. Irrigation withdrawals are predominantly attributed to agriculture in Delaware and New Jersey. The irrigation withdrawals in Pennsylvania are primarily attributed to golf course irrigation. These conclusions are consistent with the findings from the analysis presented in Figure 73 and previous work by DRBC (Barr, 2015). There are few data reported by facilities located in New York.
2. It appears that there has been an increasing trend in the number of reporting sources over time, with large increases in specific years (Figure 75). It is assumed that the large step-increases observed may be attributed to:
    a. A change in reporting methods; for example, in New Jersey many sources formerly reported data under a "Combined Source" from the 1990s until about 2002. However, it does not appear that the increase observed in Delaware around 2012 was related to changes in reporting methods, as most sources from the early 1990s continue reporting through 2017.
    b. Increased reporting compliance throughout the irrigation/agricultural sector.

    This assessment suggests that the last five years of available reported data provide the best available direct-estimate representation of irrigation withdrawals for the Delaware River Basin.
3. Reported data associated with cranberry operations ("Cranberries") in New Jersey have decreased substantially over time, to the point where annual withdrawals have been below 1 MGD over the four year analysis period (2014-2017). It is not clear if this is a function of operations or data reporting.

These withdrawal data presented at the state-level in Figure 74 are aggregated to represent the entire Delaware River Basin in Figure 76. The annual data supporting these figures have been provided in Appendix A as Table A-17.

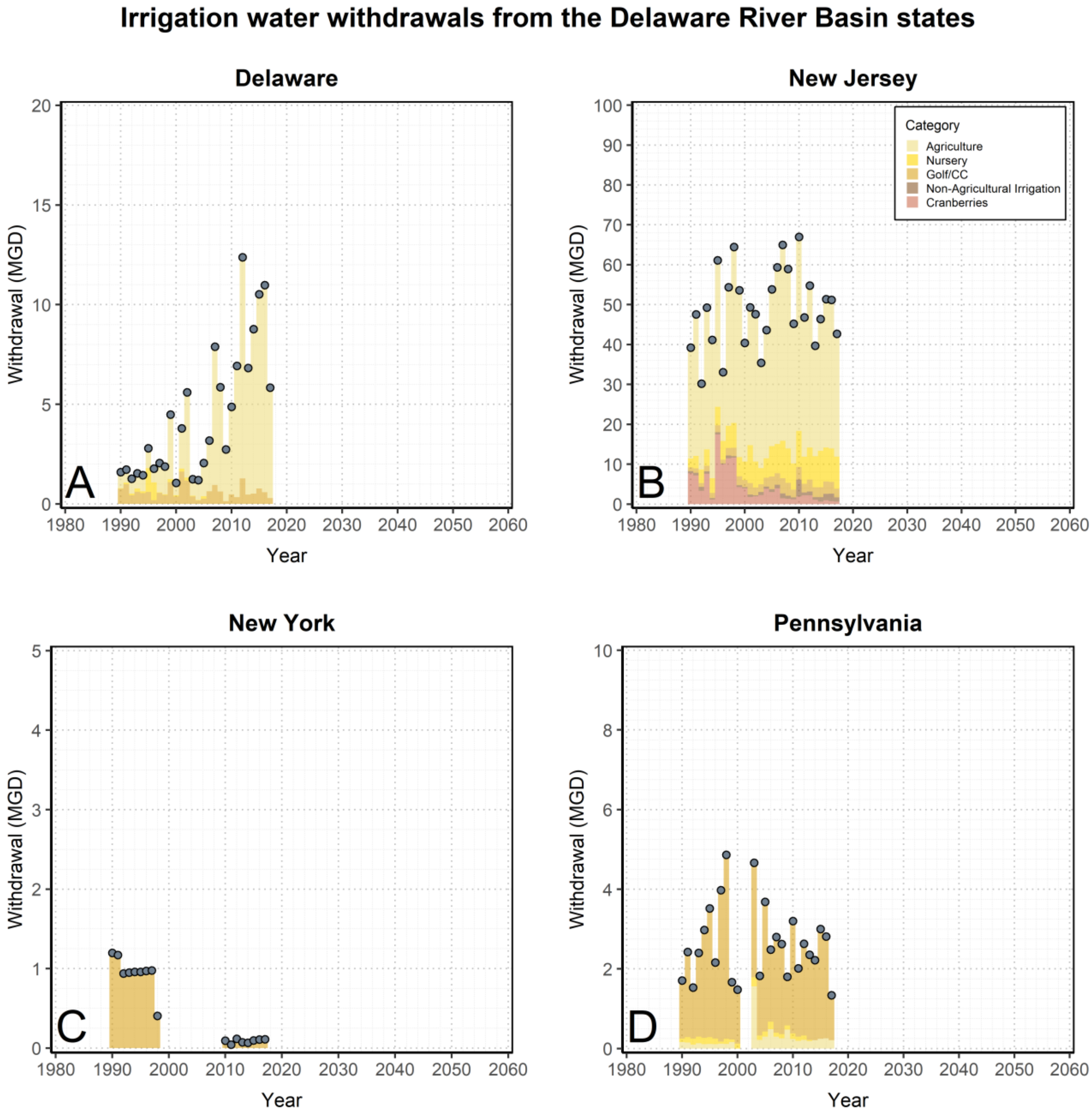

Figure 74: Irrigation water withdrawals from the Delaware River Basin states. *Annual average water withdrawals by each state in the Delaware River Basin, grouped by irrigation sector category (Agriculture, Nursery, Golf/County Clubs, Non-Agricultural Irrigation, and Cranberry Operations). The number of unique reporting sources behind each year of data is presented in Figure 75. These withdrawal data are aggregated to the Basin scale in Figure 76. The projections results for this figure are presented in Figure 81. Data supporting these figures are provided for reference in Table A-17.*

Irrigation withdrawals from the Southeastern Pennsylvania Groundwater Protected Area 76 subbasins are presented in Figure 77. The findings are consistent with data shown in Figure 73, indicating that the majority of irrigation withdrawals from the area are for golf courses. The total SEPA-GWPA irrigation withdrawal has historically been less than 1 MGD.

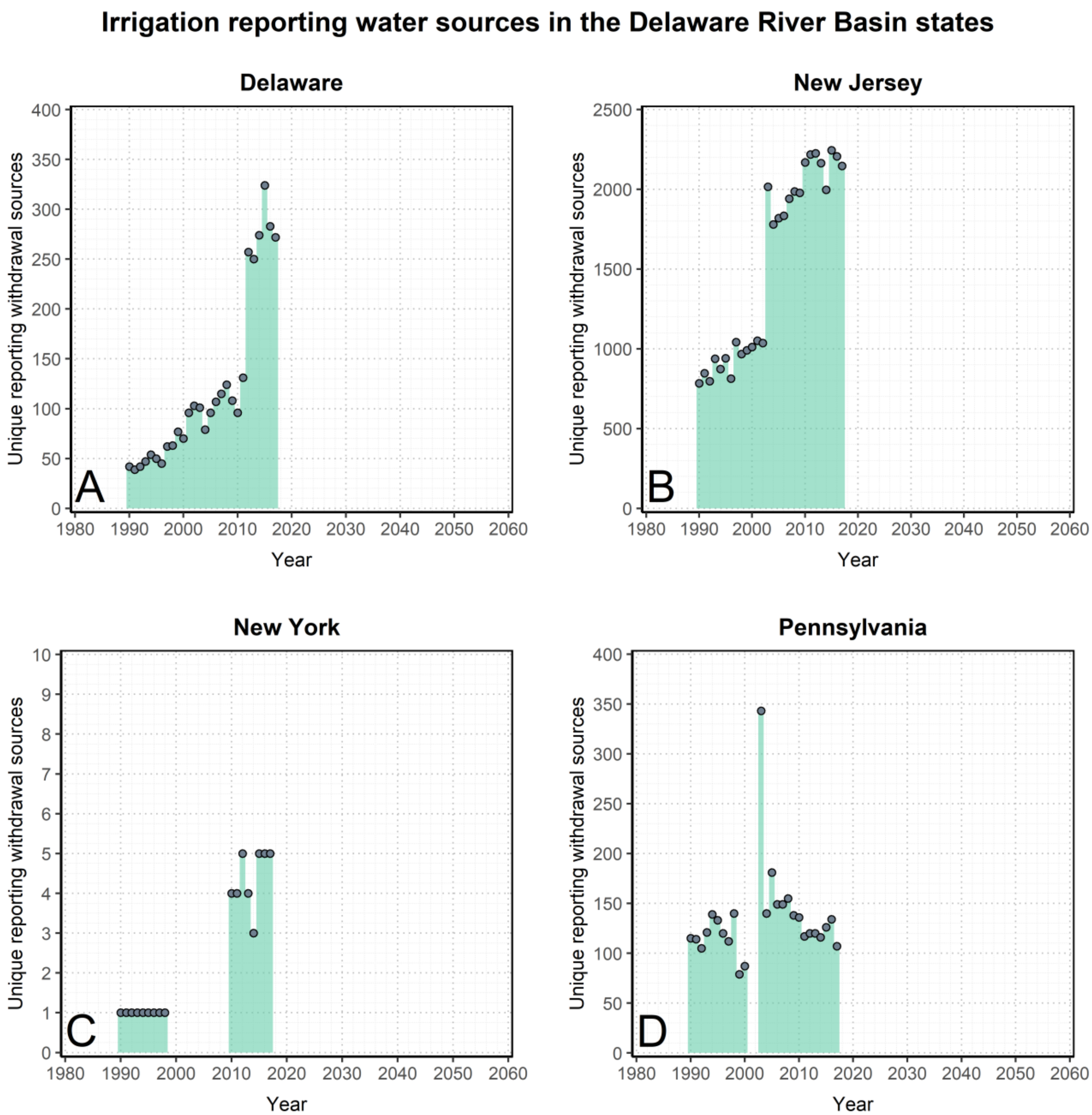

*Figure 75: **Irrigation reporting water sources in the Delaware River Basin states.** Each year presents the number of unique reporting sources which result in the annual average withdrawal volumes presented in Figure 74.*

8.3.4 Consumptive water use

For the irrigation sector, consumptive use is calculated using the default CUR listed in Table 5. Therefore, the trends observed will mirror those presented in Section 8.3.3 (excluding data from cranberry operations), and separate figures have not been presented. However, corresponding annual data have been provided in Appendix A, included as part of Table A-17.

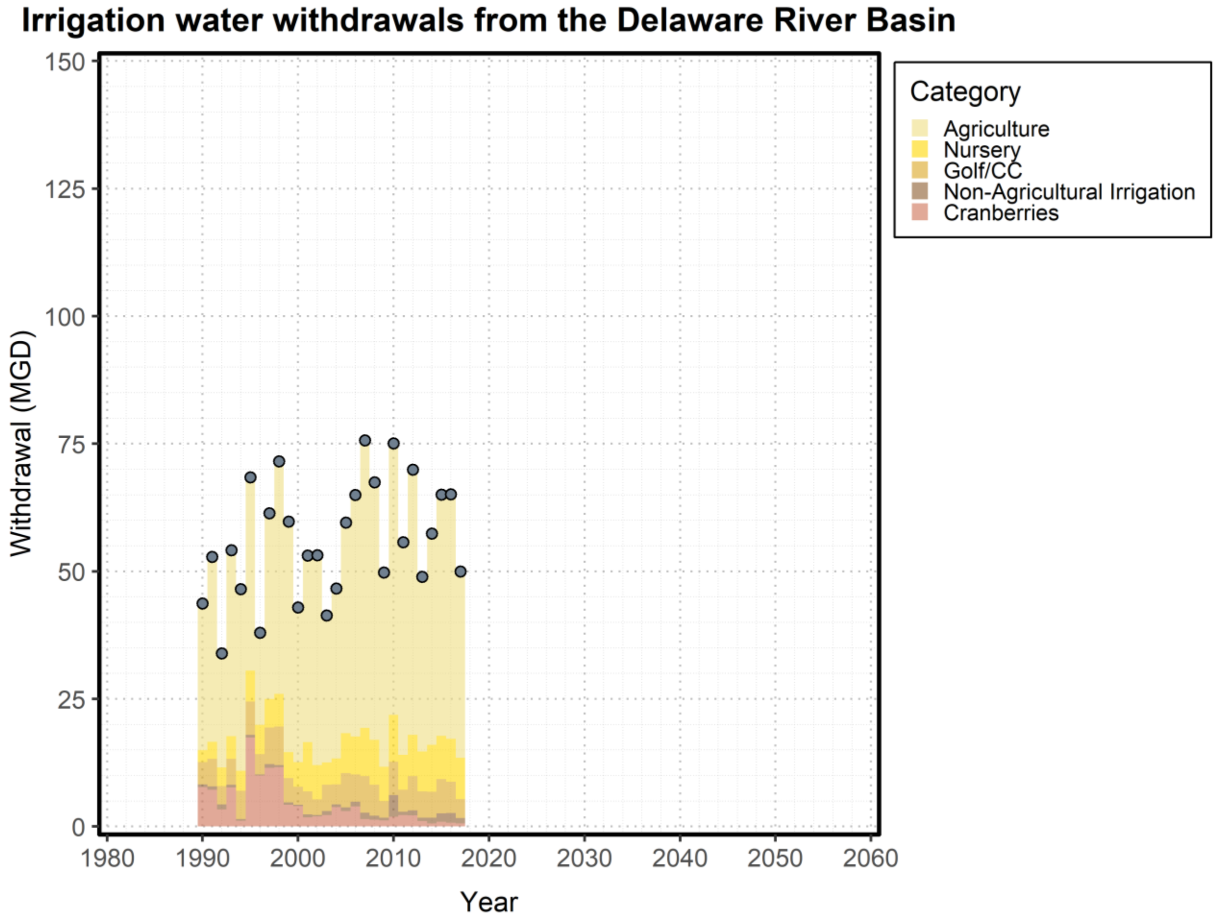

Figure 76: Irrigation water withdrawals from the Delaware River Basin. *Annual average water withdrawals from the Delaware River Basin, grouped by irrigation sector category (Agriculture, Nursery, Golf/County Clubs, Non-Agricultural Irrigation, and Cranberry Operations). This represents the same data presented in Figure 74, aggregated to the Basin scale. The projections results for this figure are presented in Figure 82. Data supporting this figure are provided for reference in Table A-17.*

Cranberry harvesting
in Burlington County, New Jersey.
Credit: © Howard Rann
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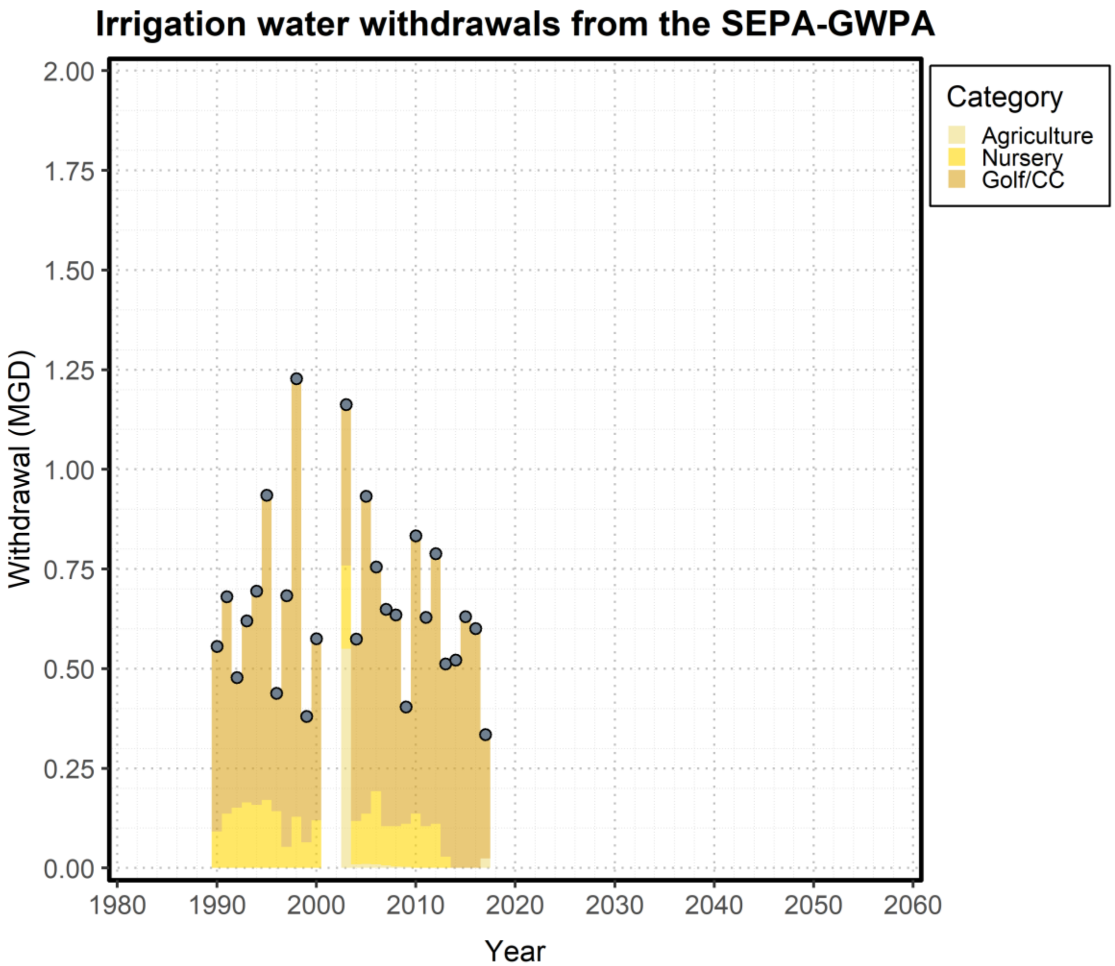


Figure 77: Irrigation water withdrawals from the Southeastern Pennsylvania Groundwater Protected Area. *These data only represent withdrawal volumes from sources which plotted within the boundary of SEPA-GWPA as shown in Figure 6. The projections results for this figure are presented in Figure 83. Data supporting this figure are provided for reference as part of Table A-17.*

An example of non-agricultural
irrigation of sports fields.
Credit: © Eduard Goricev

8.4 Methods

8.4.1 Concept

The methodology used to project water withdrawals for the irrigation sector are different from the trend extrapolation methodology used for most other sectors in this report. The rationale for this decision was made based on two primary factors:

1. The vastly greater number of current/historical irrigation withdrawal sources and approvals (around 4,700 sources & 480 approvals) as compared to other withdrawal sectors.
2. A clear understanding that irrigation withdrawals share a relationship with climate related variables.

Based on a review of the data and planning needs, it was determined that projections only needed to satisfy two levels of aggregation: subbasin (Figure 6) and sourcewater designation (groundwater versus surface water). Therefore, a multivariate linear model was developed for both groundwater and surface water in each subbasin using reported withdrawal data and observed seasonal weather variables (temperature and precipitation). Based on the assessment in Figure 75, it was determined that a third component was pertinent to describing historical water withdrawals: the number of sources that reported results in each withdrawal volume. Once regressions are developed, assumptions are made to simplify the generalized multivariate projection equation to a univariate form which is based solely on seasonal temperature. Projections of irrigation withdrawal are then calculated from two Representative Concentration Pathway (RCP) scenarios from a Regional Climate Model (RCM). Projections of changes in land use were not incorporated into the model as a variable, and therefore land use patterns are assumed to remain constant for the scope of this study.

8.4.2 Weather data (observed and projected)

To assess the validity that a relationship exists between weather and irrigation withdrawals, data were obtained from a separate DRBC study that includes an assessment of climate change data for the Delaware River Basin (DRBC, Pending). In that project, an historical temperature record was developed with 2,141 weather stations using data from the past 70 years. The data were obtained from the Applied Climate Information System (ACIS, 2021). Information from both active and discontinued weather stations was used. Missing data were replaced with the values from the nearest station. Thus, a complete temperature record was developed for each of the 2,141 stations. The data were then transformed into 25 km grid cells by averaging the data at all stations within a 25 km^2 area. Future climate predictions for each grid cell were developed from simulations performed by the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory (NOAA GFDL, 2021) with the Canadian Regional Climate Model version 5 (CRCM5) (Martynov et al., 2013; Šeparović et al., 2013) as part of the Coordinated Regional Downscaling Experiment (Solman et al., 2021). One historical period and two future conditions under climate change, based on two Representative Concentration Pathway (RCP) scenarios (4.5 and 8.5) (Moss et al., 2010) from the Coupled Model Intercomparison Project 5 (CMIP5) (Taylor et al., 2012), were used. Moving forward in this report, this referenced climate model will be abbreviated as "GFDL ESM2M."

Regional climate models may have inherent biases due to the nature of downscaling methods used, which can be "corrected" using quantile delta mapping (Cannon et al., 2015). To do so, a regression is developed to determine the residual ("error") between the distribution of the gridded observation dataset and the historical representation in the GFDL ESM2M model. In DRBC, Pending, the data were grouped into three climate zones, and seasonal regressions were developed for each zone to better represent the different climate regimes in the Basin. The regressions were then applied to bias-correct model results of the two future conditions under climate change and create a more likely distribution of temperature. The weather stations and GFDL ESM2M grid cells used in DRBC, Pending are presented on Figure 78.

Of the total 2,141 weather stations, 957 plot within the Delaware River Basin boundary. These 957 stations are used in developing the multi-variate regressions with withdrawal data because they can easily be aggregated to the subbasin level. Therefore, monthly data from 957 stations were compiled over the timeframe 1990-2017 (for this study) and include the monthly average of “Maximum Daily Temperature in degrees Fahrenheit” and the monthly summation of “Precipitation, in inches.” These data were used to create annual basin-wide averages for comparison against the monthly withdrawal data behind Figure 76. The resulting three boxplots are presented in Figure 79 and visually demonstrate that at least temperature shares a strong correlation with irrigation water withdrawals. Based on a theoretical assumption that increased precipitation will lead to a decreased necessity for irrigation, this parameter was retained for inclusion in the study.

An evaluation of the median monthly withdrawal rates for the Basin shows that more than 75% of irrigation occurs between May and September (Figure 79). For the purposes of this study, an irrigation “season” has therefore been defined as the time between May 1 and September 30. This timeframe was chosen as intuitively the weather patterns during the growing season are likely to have a stronger influence on irrigation withdrawals than the weather patterns during the non-growing season. As this assessment was conducted on a subbasin scale, the following steps were taken to process the weather data:

Observed weather data:

Observed seasonal weather data were obtained from the 957 in-basin weather stations shown in Figure 78 and used to develop a relationship at the subbasin scale with the annual irrigation withdrawal from that subbasin.

1. Given daily weather data from the 957 in-Basin stations, seasonal averages/totals were compiled for each station.
2. Seasonal data for all stations plotting within a subbasin were averaged to create one time series per subbasin.
3. If no weather stations were located within a subbasin, adjacent subbasin weather stations were referenced.

Projected weather data:

The projected weather data was obtained from the 157 GFDL ESM2M grid cells in Figure 78 and used to compile seasonal estimates to project future irrigation water withdrawals.

1. Given projected daily weather data from the 157 GFDL ESM2M grid cells, seasonal averages/totals were compiled for each grid cell.
2. Based on subbasin centroid locations, each subbasin was linked to a seasonal time-series based on the closest GFDL ESM2M grid cell centroid. If a subbasin spanned a state divide, the centroid of the entire subbasin was used, and a single GFDL ESM2M grid cell assigned to both state portions of the subbasin.
3. Two scenarios of data were processed for future conditions under climate change, RCP 4.5 and RCP 8.5.

This methodology resulted in data from only 68 of the 157 GFDL ESM2M grid cells being referenced. The historical seasonal average maximum daily temperature data from the 957 in-Basin weather stations was then compared to the projected seasonal average data from the 68 GFDL ESM2M grid cells in Figure 80. This analysis shows that based on the data from DRBC, Pending, the seasonal average maximum daily temperature (Basin-wide) may increase about +2°F (RCP 4.5) and +3°F (RCP 8.5) by 2060, based on a 5-year moving average. The temperature data from these 68 GFDL ESM2M grid cells are then input into each subbasin regression to develop projections of irrigation withdrawal.

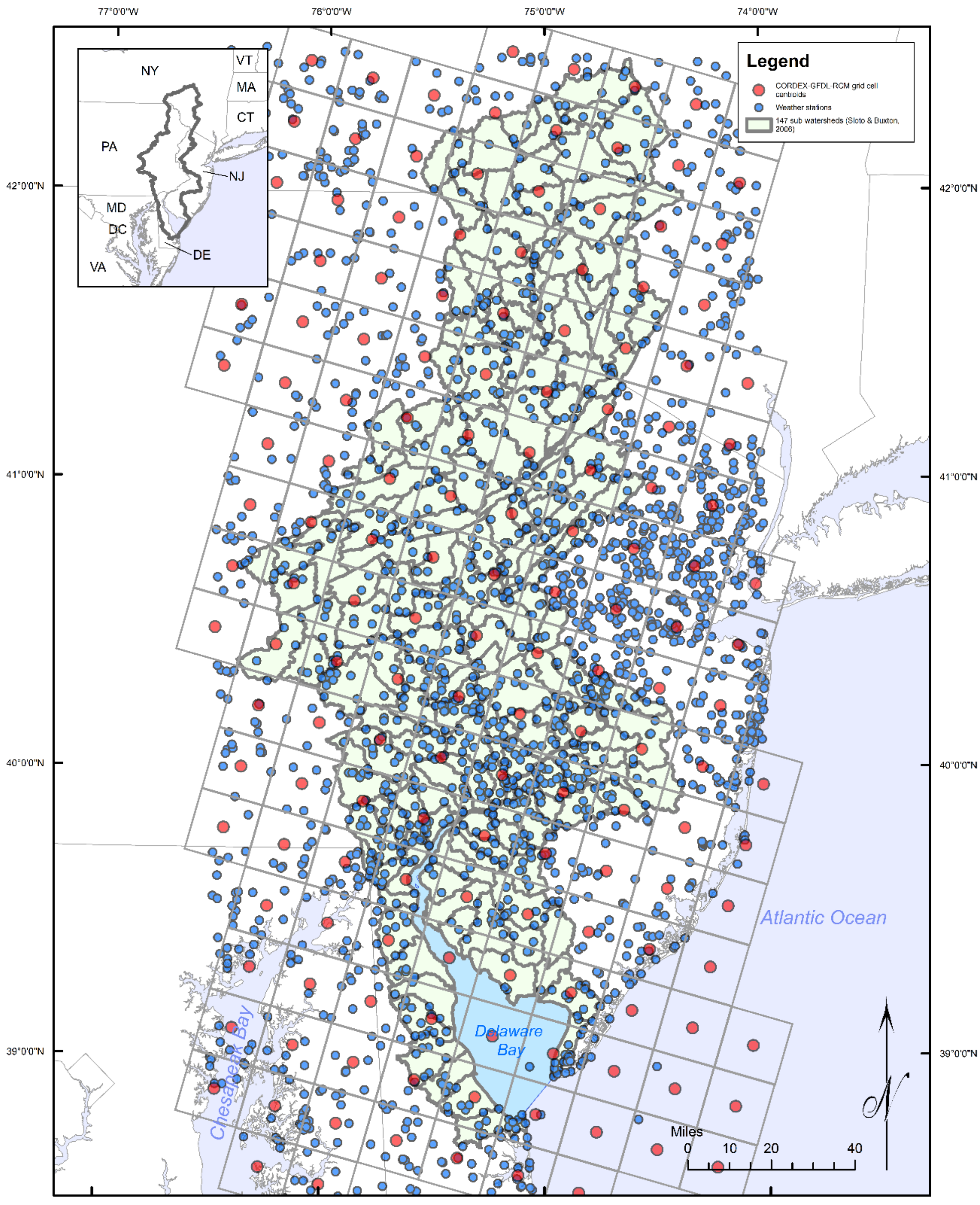
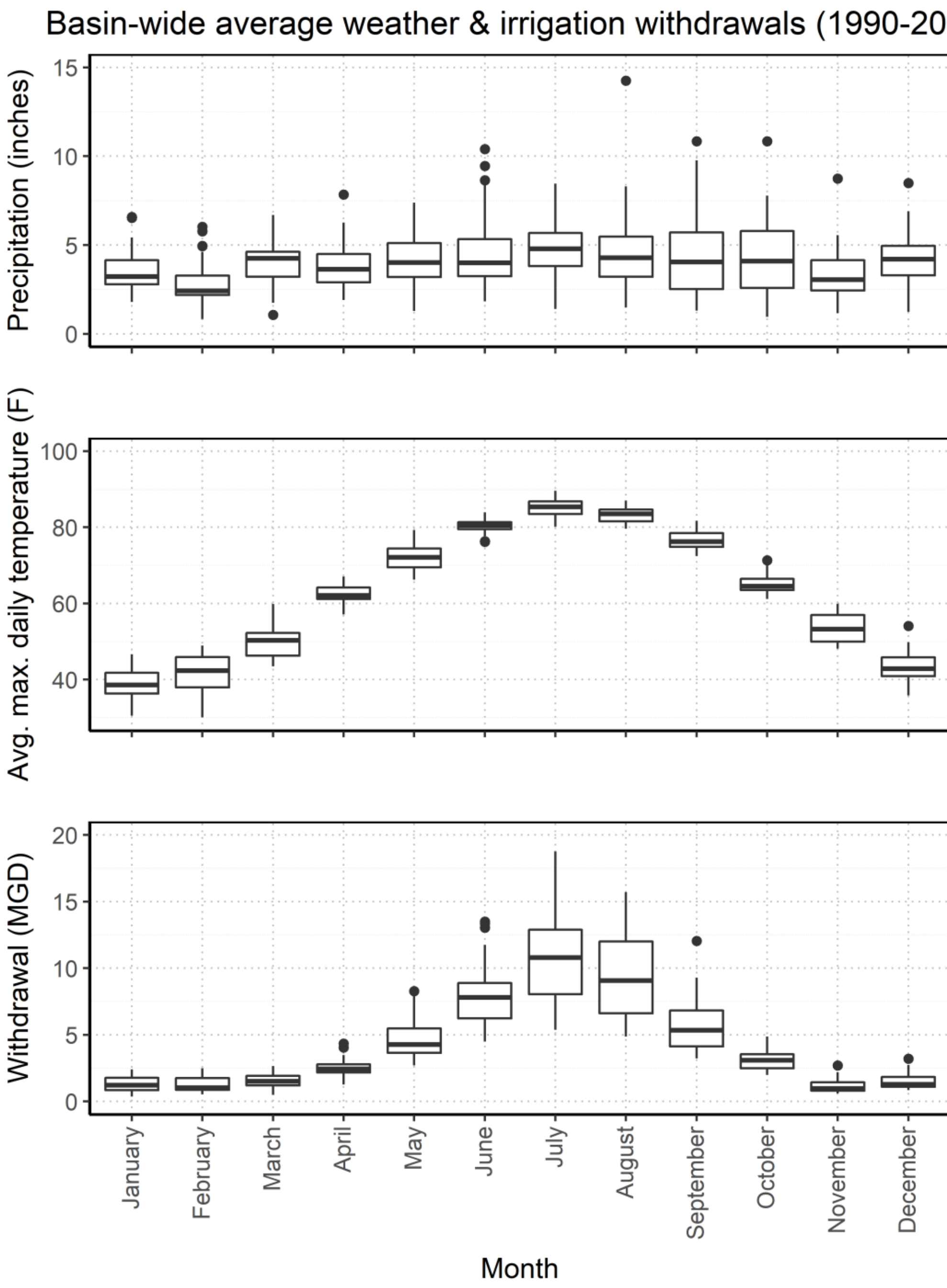


Figure 78: A map showing the location of weather stations used for observed data, and GFDL ESM2M grid cells and centroids. *The GFDL ESM2M results were bias corrected based on observed data from the weather stations as outlined in the DRBC report (DRBC, Pending).*



Month	Median MGD	Percent
January	1.235	2.52%
February	1.044	2.13%
March	1.531	3.13%
April	2.452	5.01%
May	4.285	8.75%
June	7.817	15.96%
July	10.804	22.06%
August	9.078	18.53%
September	5.357	10.94%
October	3.095	6.32%
November	0.978	2.00%
December	1.301	2.66%

56.6% 76.2% 87.6% 92.7%

Figure 79: Basin-wide average weather and irrigation withdrawals (1990-2017). *These monthly values for temperature and precipitation correspond with observed data at weather stations plotting within the Delaware River Basin (Figure 78). The irrigation withdrawal data corresponds with the annual values presented in Figure 76, excluding data associated with cranberry operations.*

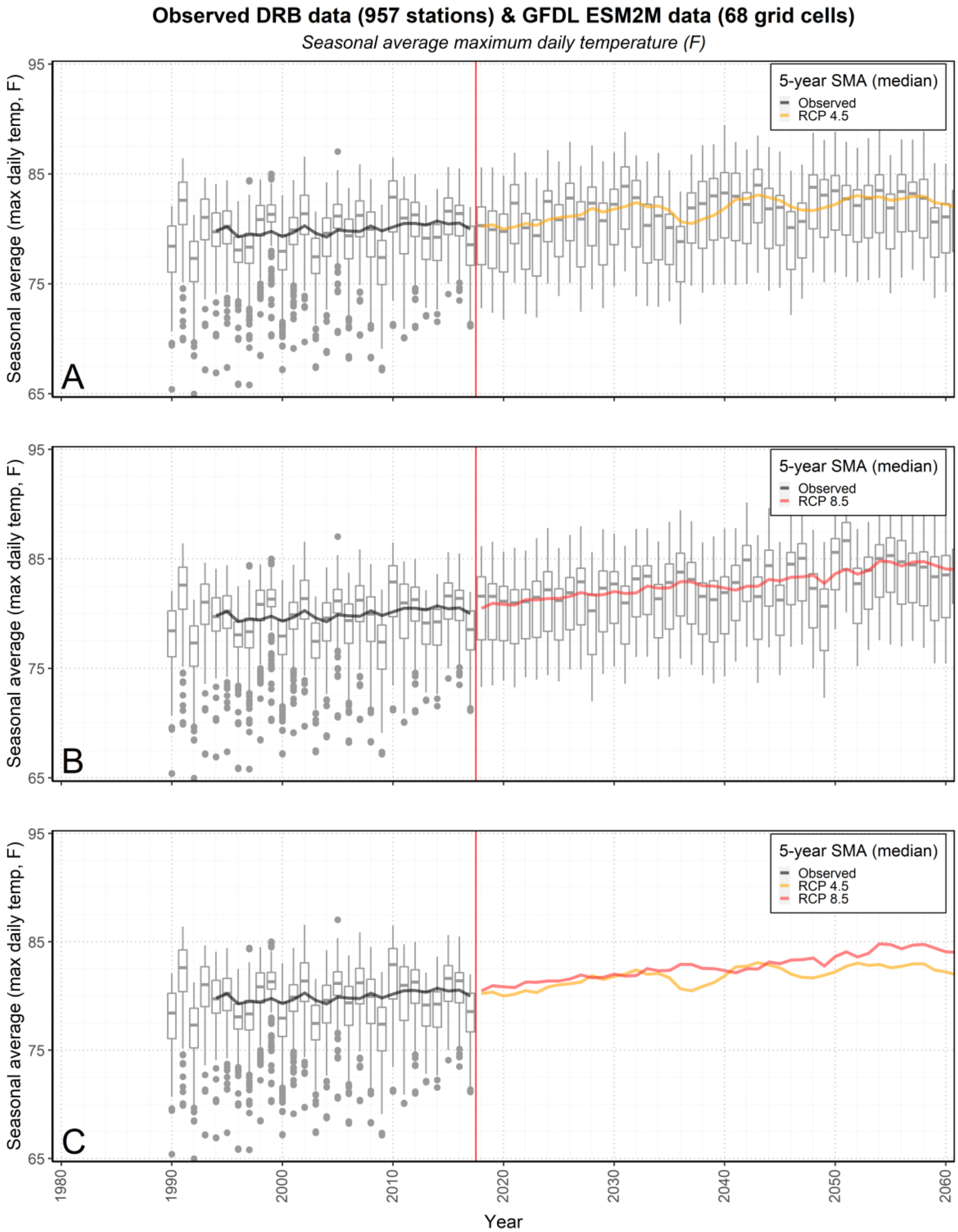


Figure 80: Observed DRB data (957 stations) & GFDL ESM2M data (68 grid cells). *Seasonal average (May-Sept) maximum daily temperatures from the 957 weather stations in the Delaware River Basin boundary, and projected data from the 68 GFDL ESM2M grid cells used in the analysis.*

8.4.3 Multivariate regression

For each subbasin, a multivariate linear regression was developed between the withdrawal volume (surface water and groundwater) and the observed weather data for that subbasin. Each regression is comprised of three components, as indicated in the equation below:

$$W_{i,j,t} = \alpha_j + \beta_j T_{i,t} + \gamma_j P_{i,t} + \delta_j S_{i,j,t}$$

where,

$W_{i,j,t}$ = The annual withdrawal from subbasin *i* at year *t*, where *j* is either GW or SW
$\alpha, \beta, \gamma, \delta$ = Constants from a linear regression, where *j* is either GW or SW
$T_{i,t}$ = Seasonal average daily max temperature (°F) for subbasin *i*, at year *t*
$P_{i,t}$ = Seasonal total precipitation (inches) for subbasin *i*, at year *t*
$S_{i,j,t}$ = The number of sources resulting in the annual withdrawal for $W_{i,j,t}$

This represents the most generalized form of the multivariate linear regression for annual irrigation withdrawals from each subbasin, based on seasonal weather data and the number of sources reporting data. However, the equation can be simplified in the following two ways:

1. It was determined that any subbasin with an adjusted R^2<0.20 would be modelled using a mean value regression instead.
2. If the number of sources was constant over the entire withdrawal timeseries, δ_j becomes zero and does not have an influence on the subbasin model.

8.4.4 Univariate projection

Once regressions were created for each of the subbasins with irrigation withdrawals, two assumptions lead to further simplification of the generalized equation.

1. **Number of sources**: The number of sources reporting in a given subbasin will remain constant at the mean value from the previous five years (2012-2017). This assumption is made with the understanding that there has been an increase in reporting compliance, and that the most recent data are likely the most accurate representation. Including the number of sources in the regression was a means of assessing how well the regression fit actual data, and not intended to be used for projecting withdrawals.
2. **Precipitation**: The bias-corrected precipitation data for the GFDL ESM2M were not yet available at the time of this report, and therefore cannot be included in the projection. However, the strongest predictor of withdrawal based on a component analysis was temperature, alluded to visually in Figure 79. Rather than exclude precipitation from the model entirely, it was included in the regressions and remains constant at the mean value from the previous five years (2012-2017).

These assumptions make the terms in the regression equation for both precipitation and number of reporting sources become part of the intercept, reducing the equation to the form below. Because the projection equation has been reduced to a univariate linear model, the same prediction interval and assumptions were applied as outlined in Section 3.4.5.6.

$$W_{i,j,t} = \alpha_j + \beta_j T_{i,t}$$

Table 44: Summary of modelling methods for irrigation withdrawals in the Delaware River Basin (for the 147 planning subbasins).

Description	GW		SW	
	Number	Avg. MGD	Number	Avg. MGD
Total subbasins with reported data (or state portions):	96	29.055	97	25.323
Modelled via multivariate linear model (MVLM):	47	25.045	52	12.662
Modelled via mean value (MVLM R2<0.2, or *n*<6):	27	3.048	24	12.087
Not modelled (no reports in past 3 years, or only 1 point):	22	0.961	21	0.574

8.5 Results

8.5.1 Total water withdrawal

As it was a planning objective to present results at the state-level, certain subbasins were further divided around state boundaries. Table 44 presents a summary of the number of subbasin areas which have reported irrigation withdrawals, and what portion of those were modelled in what manner, along with the corresponding average withdrawal over the entire period of record. Overall Table 44 shows that there are 74 equations describing groundwater, and 76 equations describing surface water across the subbasins delineated by Sloto & Buxton, 2006. To project the irrigation withdrawals from each subbasin, the corresponding RCP 4.5 or RCP 8.5 temperature data from the GFDL ESM2M were input to the equations. The projected water withdrawals for irrigation in the Delaware River Basin are presented for each Basin state in Figure 81.

From these results it is evident that the regression (blue lines) performed well when considering the adjusted R^2 value for aggregated groundwater and surface water models at the state-level. The general trend for projections based on both RCP scenarios are slight increases in withdrawals, with RCP 8.5 being slightly higher overall. A summary of the state-level results is provided in Table 45. The state-level results have been aggregated to the Basin scale as shown in Figure 82 with the results summarized in Table 46. The data releases supporting the RCP 4.5 and RCP 8.5 irrigation models have been provided in Appendix A as Table A-18 and Table A-19.

A separate model was developed specific to the SEPA-GWPA using the same methods and is presented in Figure 83. A summary of the model results is provided in Table 47. The data releases supporting the RCP 4.5 and RCP 8.5 irrigation models have been provided in Appendix A as Table A-20 and Table A-21. The results suggest that minimal change will occur in regard to irrigation withdrawals; however, the quality of the modelled dataset is likely reflected in the magnitude of the prediction intervals.

8.5.2 Consumptive water use

As was discussed in Section 8.3.4, consumptive use is calculated for the irrigation sector using the default CUR listed in Table 5. The same method of calculation is used to generate projections of consumptive use; therefore, the trends observed will mirror those presented in the previous section, and separate figures have not been presented. However, results for the consumptive use model are provided in data releases in Appendix A as a part of Table A-18 and Table A-19 (RCP 4.5 and 8.5 for the Delaware River Basin, respectively) and Table A-20 and Table A-21 (RCP 4.5 and 8.5 for the SEPA-GWPA, respectively).

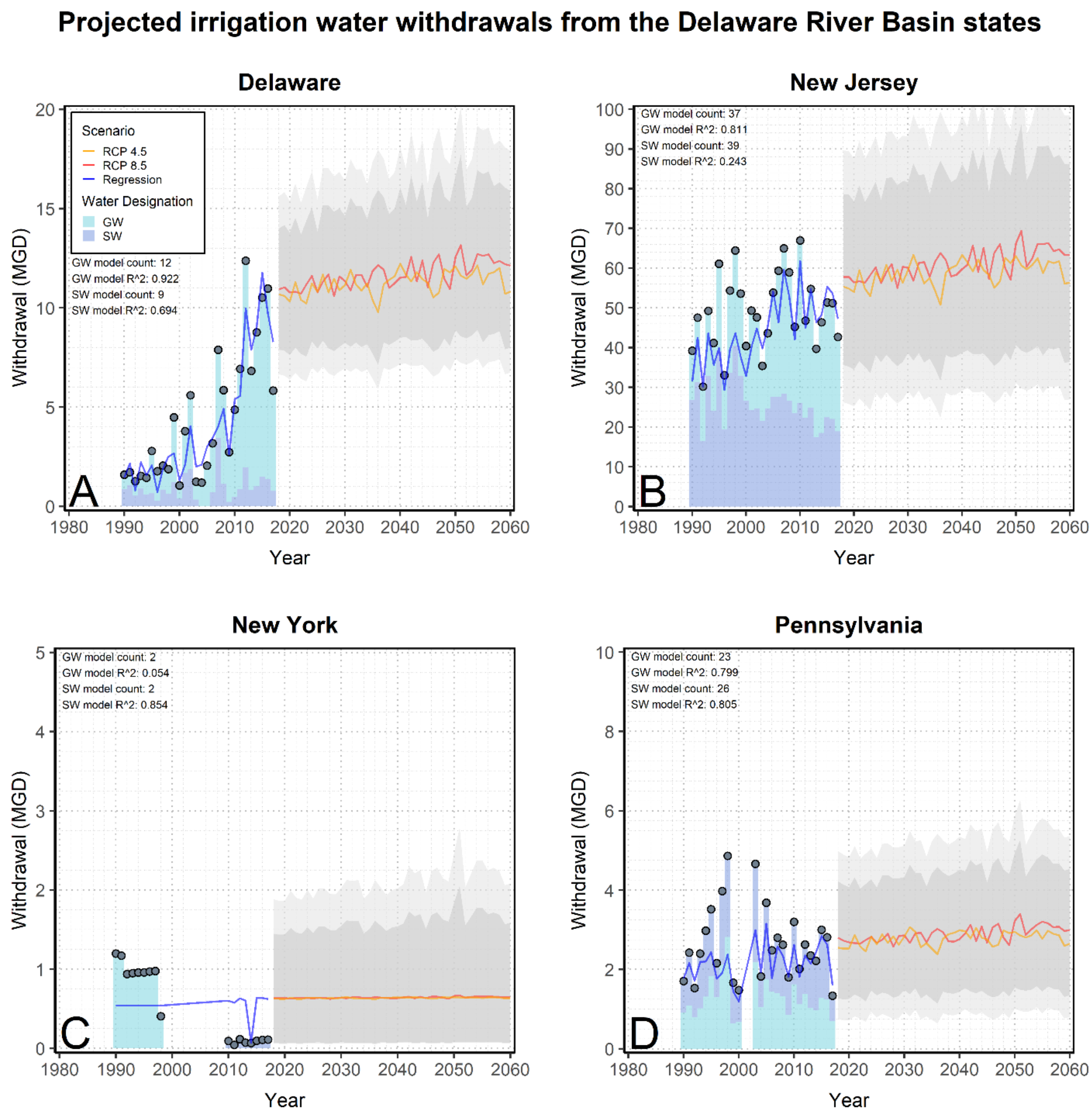


***Figure 81: Projected irrigation water withdrawals from the Delaware River Basin states.** Each state is presented with two projections based on the GFDL ESM2M, the RCP 4.5 and RCP 8.5 scenarios. Note that withdrawal data for cranberry operations are still presented, but that R^2 values were calculated with that data excluded. Prediction intervals presented are the maximum/minimum of the interval for either RCP scenario. These projections correspond with the data initially presented as Figure 74. Results of the model for select years are presented in Table 45. Data supporting these figures are provided for reference in Table A-18 (RCP 4.5) and Table A-19 (RCP 8.5).*

***Table 45**: Summary of results supporting Figure 81 for Basin-state projections of total water withdrawals used in the irrigation sector. Note that historical withdrawal data presented here do not include reported data from cranberry operations.*

State	Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	RCP 4.5	RCP 8.5	Prediction intervals (max/min of 4.5 or 8.5)			
					Modelled Withdrawal (MGD)	Modelled Withdrawal (MGD)	lwr80	upr80	lwr95	upr95
Delaware	2013	6.826	7.886	15.5	NA	NA	NA	NA	NA	NA
	2014	8.776	9.025	2.8	NA	NA	NA	NA	NA	NA
	2015	10.519	11.769	11.9	NA	NA	NA	NA	NA	NA
	2016	10.982	9.724	11.5	NA	NA	NA	NA	NA	NA
	2017	5.840	8.283	41.8	NA	NA	NA	NA	NA	NA
	2020	NA	NA	NA	10.327	10.780	7.634	13.783	6.384	15.378
	2030	NA	NA	NA	11.161	11.346	8.240	14.638	6.961	16.387
	2040	NA	NA	NA	12.218	11.523	8.500	16.052	7.169	18.089
	2050	NA	NA	NA	12.089	12.561	8.875	16.650	7.458	18.822
	2060	NA	NA	NA	10.832	12.127	8.006	15.905	6.752	17.912
New Jersey	2013	38.619	46.445	20.3	NA	NA	NA	NA	NA	NA
	2014	45.738	48.244	5.5	NA	NA	NA	NA	NA	NA
	2015	50.450	55.348	9.7	NA	NA	NA	NA	NA	NA
	2016	50.464	53.656	6.3	NA	NA	NA	NA	NA	NA
	2017	42.067	47.278	12.4	NA	NA	NA	NA	NA	NA
	2020	NA	NA	NA	54.015	56.435	34.537	76.752	25.204	87.545
	2030	NA	NA	NA	59.589	60.134	38.677	81.675	29.139	93.119
	2040	NA	NA	NA	63.362	59.757	38.772	86.256	29.215	98.418
	2050	NA	NA	NA	63.072	66.215	40.637	90.922	31.067	104.047
	2060	NA	NA	NA	56.361	63.283	36.401	86.211	26.978	98.391
New York	2013	0.074	0.604	719.4	NA	NA	NA	NA	NA	NA
	2014	0.069	0.071	3.9	NA	NA	NA	NA	NA	NA
	2015	0.098	0.638	551.1	NA	NA	NA	NA	NA	NA
	2016	0.110	0.637	481.4	NA	NA	NA	NA	NA	NA
	2017	0.112	0.623	458.8	NA	NA	NA	NA	NA	NA
	2020	NA	NA	NA	0.624	0.634	0.065	1.440	0.056	1.867
	2030	NA	NA	NA	0.640	0.643	0.079	1.547	0.069	2.028
	2040	NA	NA	NA	0.641	0.637	0.077	1.544	0.067	2.023
	2050	NA	NA	NA	0.647	0.662	0.083	1.839	0.071	2.464
	2060	NA	NA	NA	0.637	0.644	0.077	1.585	0.067	2.084
Pennsylvania	2013	2.352	2.151	8.5	NA	NA	NA	NA	NA	NA
	2014	2.222	2.431	9.4	NA	NA	NA	NA	NA	NA
	2015	3.002	2.842	5.3	NA	NA	NA	NA	NA	NA
	2016	2.810	2.623	6.7	NA	NA	NA	NA	NA	NA
	2017	1.337	1.601	19.7	NA	NA	NA	NA	NA	NA
	2020	NA	NA	NA	2.529	2.683	1.259	4.074	0.723	4.821
	2030	NA	NA	NA	2.832	2.861	1.486	4.327	0.946	5.118
	2040	NA	NA	NA	2.989	2.769	1.438	4.519	0.896	5.348
	2050	NA	NA	NA	2.947	3.228	1.545	4.942	1.017	5.874
	2060	NA	NA	NA	2.652	2.995	1.355	4.532	0.803	5.363

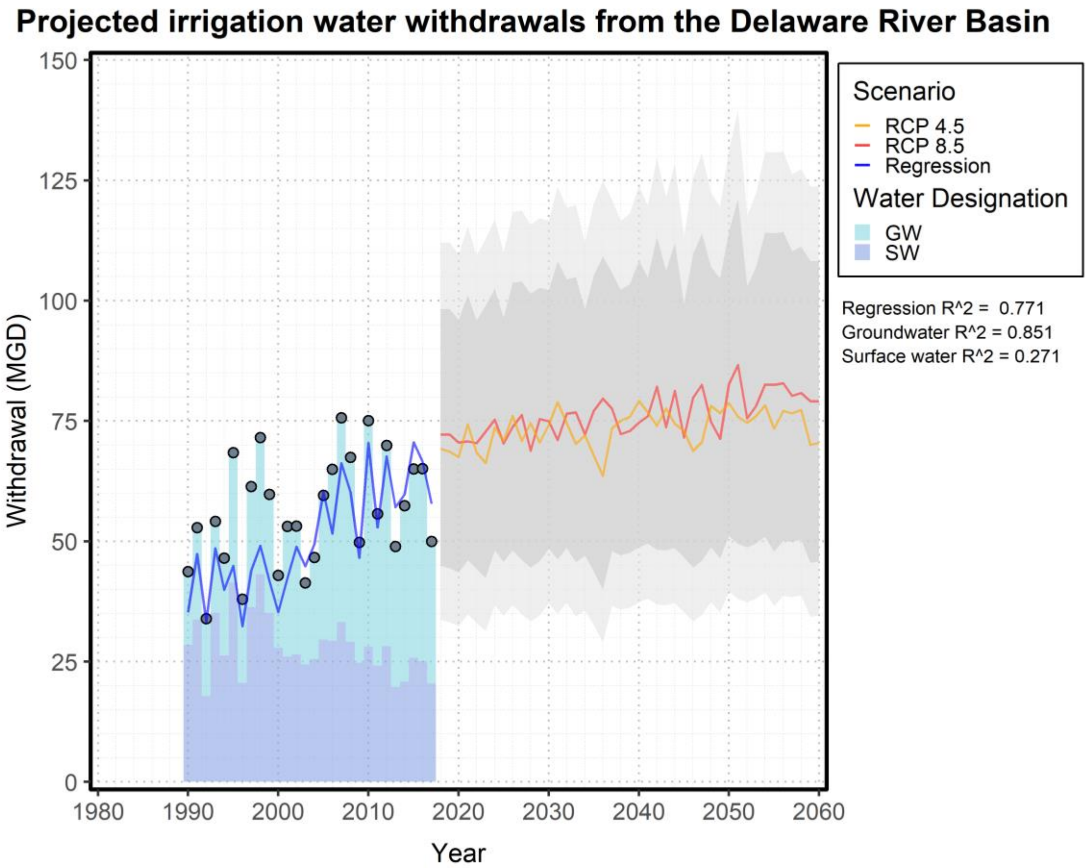


***Figure 82**: **Projected irrigation water withdrawals from the Delaware River Basin.** Two projections are presented based on the GFDL ESM2M, the RCP 4.5 and RCP 8.5 scenarios. Note that withdrawal data for cranberry operations are still presented, but R^2 values were calculated with that data excluded. Prediction intervals presented are the maximum/minimum of the interval for either RCP scenario. This projection corresponds with the data initially presented as Figure 76. Results of the model for select years are presented in Table 46. Data supporting these figures are provided for reference in Table A-18 (RCP 4.5) and Table A-19 (RCP 8.5).*

***Table 46**: Summary of results supporting Figure 82 for the Basin-wide projection of annual average water withdrawal by the irrigation sector of the Delaware River Basin. Note that historical withdrawal data presented here do not include reported data from cranberry operations.*

Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	RCP 4.5	RCP 8.5	Prediction intervals (max/min of 4.5 or 8.5)			
				Modelled Withdrawal (MGD)	Modelled Withdrawal (MGD)	lwr80	upr80	lwr95	upr95
2013	47.870	57.087	19.3	NA	NA	NA	NA	NA	NA
2014	56.805	59.771	5.2	NA	NA	NA	NA	NA	NA
2015	64.069	70.597	10.2	NA	NA	NA	NA	NA	NA
2016	64.366	66.640	3.5	NA	NA	NA	NA	NA	NA
2017	49.356	57.786	17.1	NA	NA	NA	NA	NA	NA
2020	NA	NA	NA	67.494	70.533	43.495	96.048	32.367	109.612
2030	NA	NA	NA	74.223	74.984	48.482	102.188	37.115	116.652
2040	NA	NA	NA	79.210	74.686	48.786	108.371	37.348	123.878
2050	NA	NA	NA	78.755	82.665	51.139	114.352	39.612	131.207
2060	NA	NA	NA	70.482	79.049	45.839	108.233	34.600	123.751

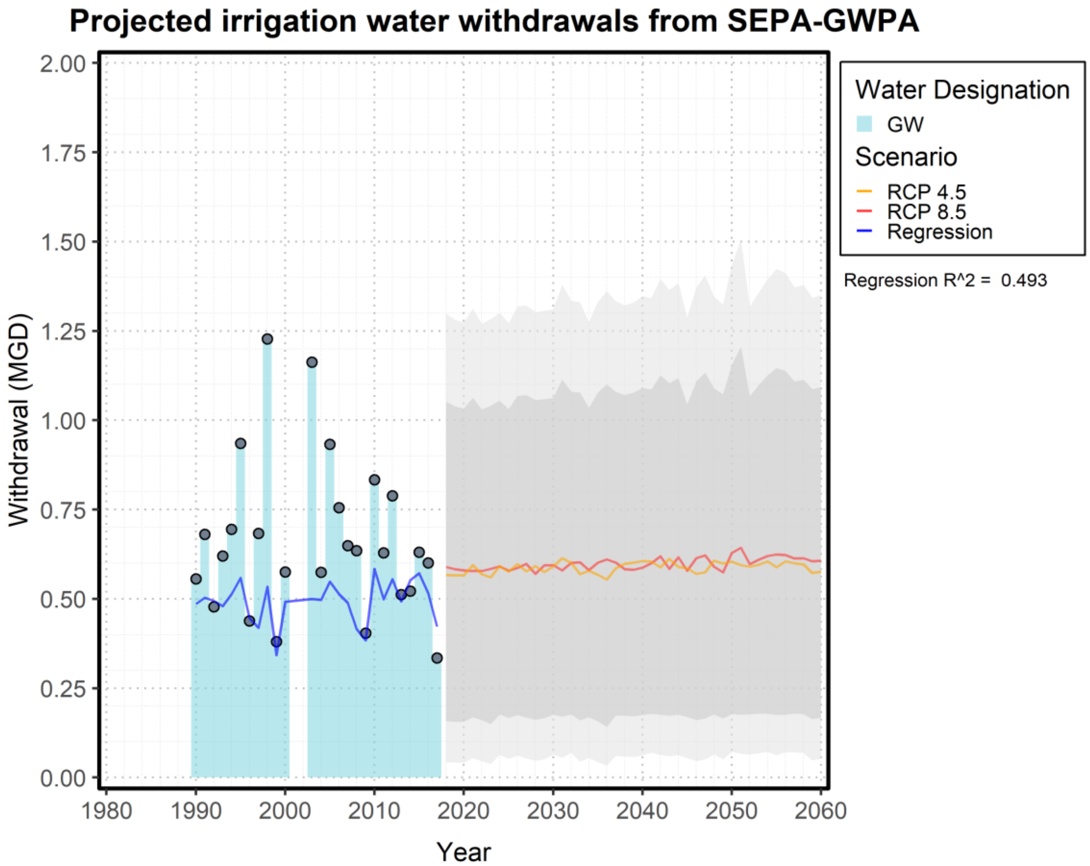


***Figure 83**: **Projected irrigation water withdrawals from the Southeastern Pennsylvania Groundwater Protected Area.** Two projections are presented based on the GFDL ESM2M, the RCP 4.5 and RCP 8.5 scenarios. Prediction intervals presented are the maximum/minimum of the interval for either RCP scenario. This projection corresponds with the data initially presented as Figure 77. Results of the model for select years are presented in Table 47. Data supporting this figure are provided for reference in Table A-20 (RCP 4.5) and Table A-21 (RCP 8.5).*

***Table 47**: Summary of results supporting Figure 83 for the projection of annual average water withdrawal by the irrigation sector in SEPA-GWPA.*

Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	RCP 4.5	RCP 8.5	Prediction intervals (max/min of 4.5 or 8.5)			
				Modelled Withdrawal (MGD)	Modelled Withdrawal (MGD)	lwr80	upr80	lwr95	upr95
2013	0.512	0.493	3.6	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
2014	0.521	0.553	6.0	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
2015	0.631	0.572	9.3	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
2016	0.600	0.515	14.2	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
2017	0.335	0.422	26.1	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
2020	*NA*	*NA*	*NA*	0.565	0.579	0.157	1.033	0.042	1.273
2030	*NA*	*NA*	*NA*	0.591	0.595	0.176	1.062	0.064	1.310
2040	*NA*	*NA*	*NA*	0.606	0.588	0.175	1.090	0.062	1.347
2050	*NA*	*NA*	*NA*	0.604	0.629	0.177	1.155	0.073	1.435
2060	*NA*	*NA*	*NA*	0.577	0.607	0.168	1.093	0.053	1.351

8.6 Climate change

The effects of climate change on irrigation withdrawal projections were directly addressed through the incorporation of projected temperature data as the driver of a multivariate model. The irrigation model was developed using input data from GFDL ESM2M for both the RCP 4.5 and RCP 8.5 scenarios. Results were presented for each scenario, and a broad overview of the temperature data specific to this irrigation model was provided. It was generally observed that increased temperatures are expected to drive increases in irrigation withdrawals.

8.7 Summary

Spatial analysis of agricultural irrigation data showed that the while cropland is distributed throughout the Delaware River Basin, the majority of the irrigation takes place in the Lower Basin around the Coastal Plain (Figure 73). Water withdrawals from the Delaware River Basin by self-supplied irrigation facilities were presented for 1990-2017 based on self-reported withdrawal data. It was demonstrated that this dataset is sufficiently complete for use in a multivariate regression based on a comparison to estimates generated

from irrigated acreage, crop type and irrigation rates (Barr, 2015). The withdrawal data show large fluctuations between years, as well as an apparent increasing number of reporting sources assumed to be attributed to changes in reporting methods and increased reporting compliance.

Climate data were obtained from a separate DRBC study in order to incorporate historical observed temperature and precipitation data, as well as bias-corrected temperature data from a regional climate model (GFDL ESM2M) (DRBC, Pending). The observed climate data were used to create a multivariate regression against irrigation withdrawal volume at the subbasin level, and the projected climate data were input to the regressions to develop projections of withdrawal. The GFDL ESM2M climate projections from the 68 grid cells used in the analysis suggest the seasonal average maximum daily temperature (Basin-wide) may increase about +2°F (RCP 4.5) and +3°F (RCP 8.5) by 2060, based on a 5-year moving average. This resulted in a Basin-wide projected increase in irrigation withdrawal from the 5-year historical average of 62.376 MGD (2013-2017), up to a possible 78.755 MGD (peak in 2050, RCP 4.5) and 86.614 MGD (peak in 2051, RCP 8.5). This represents an increase of up to about 20 MGD, or approximately 32% in the 5-year modelled average withdrawal. As these are Basin-wide values, it is important to consider that there is also uneven distribution between subbasins. Consumptive use was estimated based on withdrawal projections and default consumptive use values for the sector.

Irrigation at Yardley County Club
In Bucks County, Pennsylvania.
Credit: Michael Thompson, DRBC

Snowmaking at Camelback Mountain Resort
in Monroe County, Pennsylvania.
Credit: © Kris Arnold
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9 OTHER SECTOR

This portion of the study focuses on water withdrawals which did not fall into any previous withdrawal sector, is broadly termed the “other sector” as defined in Table 1 and includes withdrawal categories summarized in Table 5. This section of the report is slightly different from previous sections because it covers such a broad range of applications and water uses. A review of regional studies and previous DRBC studies is not included. This sector historically has had the smallest withdrawal volume and consumptive use of any sector, nonetheless, it is important to provide a complete and accurate account of water withdrawals within the Delaware River Basin.

9.1 Water withdrawal data evaluation

9.1.1 Associated and unassociated systems

A summary of the entire data history is provided in Table 48, highlighting that this sector is slightly different from others in that there is a higher percentage of unassociated data. Assessing the unassociated data presented later in this report section, it becomes clear that the large volume of unassociated surface water data is related to more recent data reports (post-2003). An analysis which further breaks down the unassociated data into categories is provided in Table 49, showing that the unassociated surface water withdrawals are largely attributed to aquaculture in Pennsylvania. For reference, a complete list of the associated facilities assessed in this report is included as Appendix C; some facilities may have been reviewed but not projected, as indicated in the appendix.

9.1.2 Data exclusions

The unassociated dataset for surface water withdrawals is presented in figures and included in data releases but is not projected and is not included in summations within tables comparing projection results against historical data.

***Table 48**: A summary of the total water withdrawal data for the other sector in the Delaware River Basin, categorized by source-type and association with regulatory approvals. These statistics were calculated for the entire Basin, corresponding to the data presented in Figure 85. A breakdown of the unassociated data by source category is presented in Table 49.*

Data category	Systems (OAIDs)	Water type	Sources (WSIDs)	Average withdrawal (MGD)	Percent total withdrawal
Associated	59*	SW	14	2.754	9.6%
		GW	235	15.760	55.0%
Unassociated	205	SW	51	7.260	25.3%
		GW	362	2.880	10.1%
Totals:	264	--	662	28.654	100.0%

Notes:
*Accounts for 55 associated facilities. Some systems encompass data assigned under multiple facility IDs in cases where the current system extents have evolved over time, or an approval covers multiple smaller systems operated by a single entity.

9.1.3 Total water withdrawal

The water withdrawal data for self-supplied facilities within the other sector of the Delaware River Basin are presented for each Basin state in Figure 84. The data are color coded by category for associated facilities and grouped by sourcewater for unassociated facilities. The data are then aggregated to represent the entire Delaware River Basin in Figure 85. A final data aggregation of groundwater data specific to the SEPA-GWPA (76 subbasins highlighted in Figure 6) is presented in Figure 86. The data release supporting the analysis in this section is provided in Appendix A as Table A-22.

From the data presented in Figure 85, a difference is clear between unassociated before and after 2003. A further assessment of the source-level withdrawal category of unassociated data is presented in Table 49, and shows that the post-2002 increase is due largely to data reporting from unassociated aquaculture facilities (i.e., fish hatcheries), primarily in Pennsylvania. As was previously mentioned in Section 9.1.2, unassociated surface water data are not projected.

The trends observed in the data are relatively simple but vary from state to state (particularly regarding what category of withdrawal is present). In Delaware, there are minimal data reported in recent years which are unassociated, and the declines appear to be largely associated with military facilities. In New Jersey, declines in military withdrawals appear to have been offset by increased withdrawals in the other categories within this sector, creating an overall constant trend. In New York there is little data which fall within this sector, and the unassociated surface water data are comprised of one fish hatchery and one skiing facility. As noted before, Pennsylvania data show increases in unassociated data, assumed to be attributed to increased reporting after 2003. Basin-wide since 2003, the other sector data being projected have remained relatively constant around 24 MGD on average, annually (excluding the variable unassociated surface water data).

9.1.4 Consumptive water use

Consumptive use ratios were applied to the historical water withdrawal data in order to calculate a historical consumptive water use dataset for each Basin state, as presented in Figure 87. The consumptive use data are then aggregated to represent the entire Delaware River Basin in Figure 88. A final analysis of the consumptive use of groundwater withdrawals from SEPA-GWPA is presented in Figure 89. The data release supporting the analysis in this section is provided in Appendix A as a part of Table A-22.

Overall, the Basin-wide consumptive use by facilities within the other sector is small and increased from only about 2.5 MGD to 4 MGD in recent years (excluding unassociated surface water data). Perhaps the most drastic observation Basin-wide that can be made regarding consumptive use is the increase in withdrawals by bottled water facilities, which are typically considered 100% consumptive (as stated in approvals). Therefore, while the total withdrawals were comparatively small in Figure 85, they are much more pronounced in Figure 88 given the high consumptive use ratio.

Pequest Trout Hatchery and
Natural Resource Education Center
in Warren County, New Jersey.
Credit: © Campbell Scientific
Used with permission

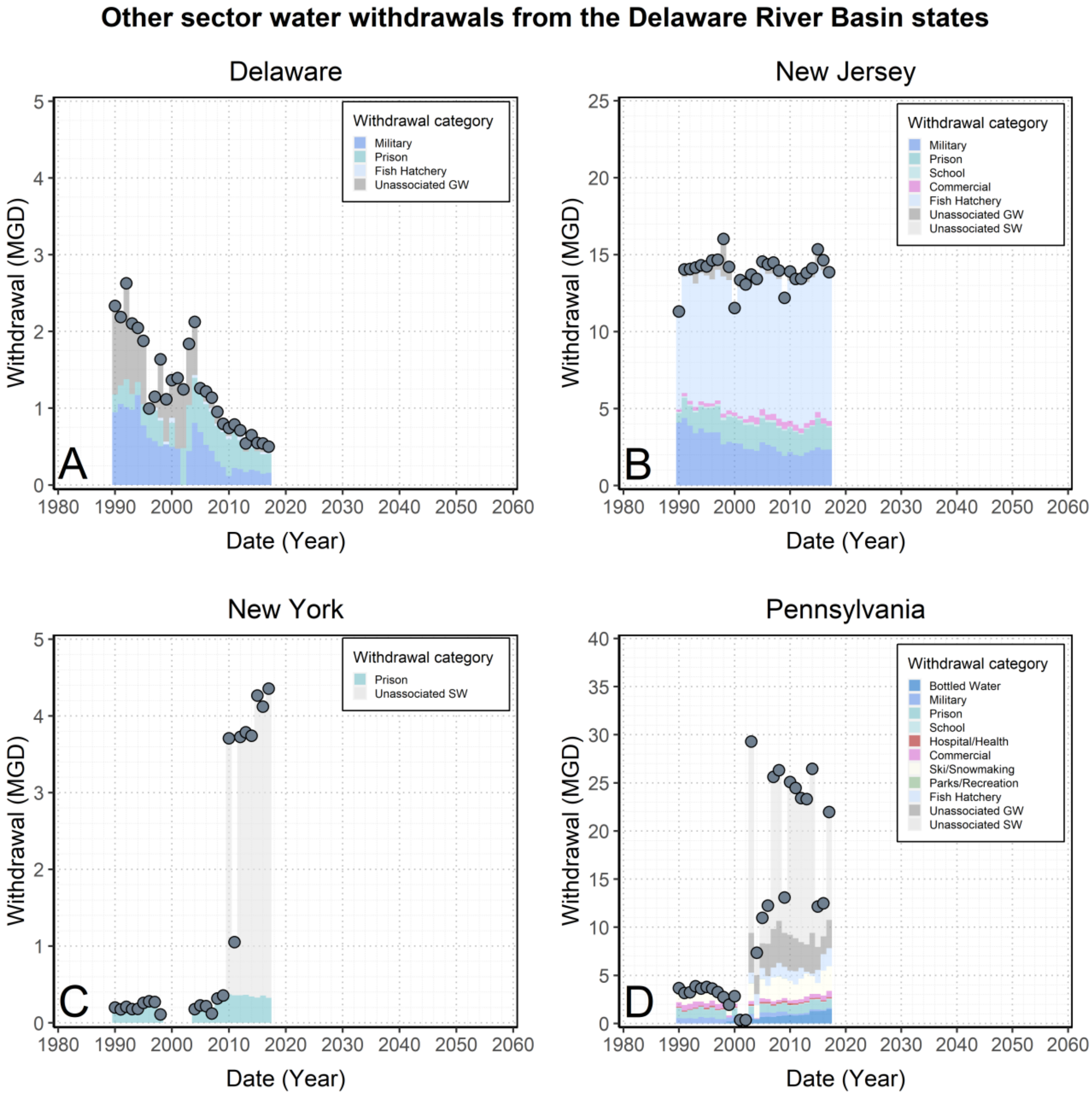

Figure 84: Other sector water withdrawals from the Delaware River Basin states. *Annual average water withdrawals by each state in the Delaware River Basin, grouped by other sector category. This dataset is aggregated to the Basin scale in Figure 85. The projections results for this figure are presented in Figure 90. Data supporting these figures are provided for reference in Table A-22.*

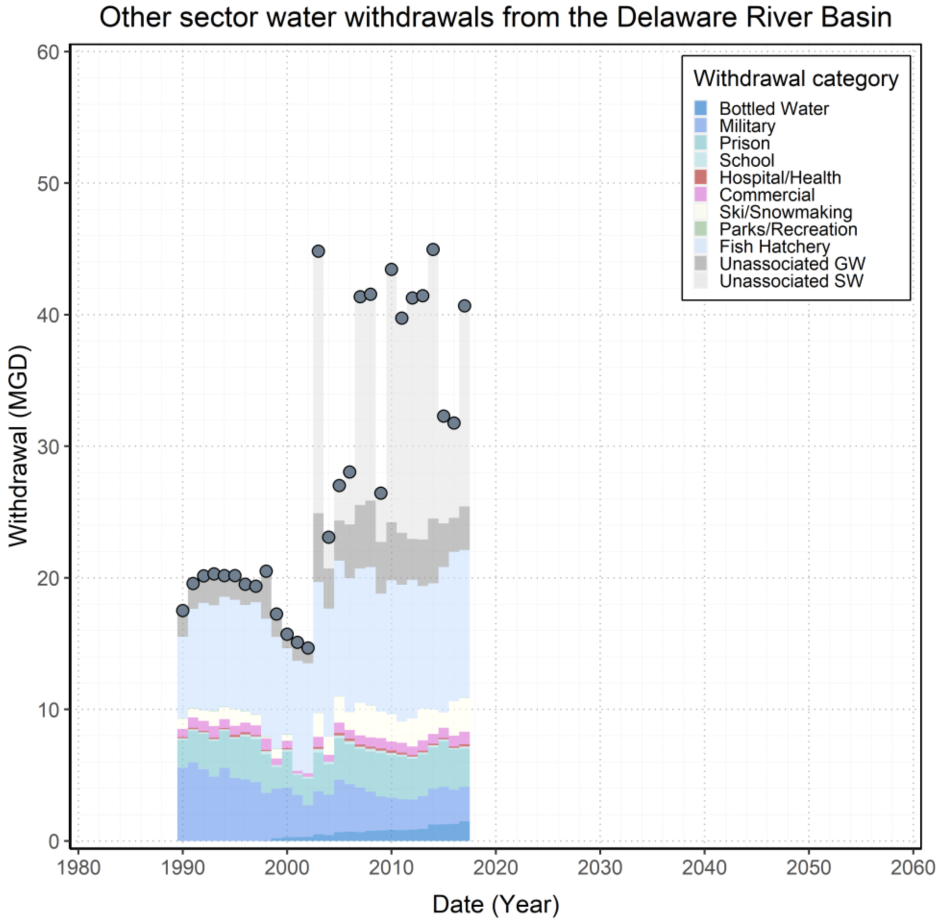

Figure 85: Other sector water withdrawals from the Delaware River Basin. *Annual average water withdrawals from the Delaware River Basin, grouped by the facility level withdrawal category. Data from associated facilities are grouped into labelled facility-level withdrawal categories, while data from all unassociated facilities are grouped by sourcewater designation. This represents the same data presented in Figure 84, aggregated to the Basin scale. Data supporting this figure are provided for reference in Table A-22.*

Table 49: *A summary of the unassociated data presented in Figure 85, based on source-level category.*

Source-level category	Pre-2003				Post-2002			
	Groundwater		Surface water		Groundwater		Surface water	
	Average MGD	Percent	Average MGD	Percent	Average MGD	Percent	Average MGD	Percent
Bottled Water	NA	NA	NA	NA	0.042	1.1%	NA	NA
Commercial	0.132	7.7%	0.068	70.9%	0.271	7.0%	0.039	0.3%
Fire	0.023	1.3%	NA	NA	0.022	0.6%	0.000	0.0%
Fish Hatchery	NA	NA	NA	NA	2.456	63.1%	12.261	98.1%
Hospital/Health	0.968	56.5%	0.015	15.4%	0.461	11.8%	0.038	0.3%
Other	0.369	21.5%	NA	NA	0.217	5.6%	0.000	0.0%
Parks/Recreation	0.011	0.6%	NA	NA	0.034	0.9%	NA	NA
Prison	NA	NA	NA	NA	0.097	2.5%	NA	NA
School	0.211	12.3%	NA	NA	0.291	7.5%	0.000	0.0%
Ski/Snowmaking	NA	NA	0.013	13.7%	NA	NA	0.163	1.3%
Totals:	1.713	100.0%	0.095	100.0%	3.892	100.0%	12.501	100.0%

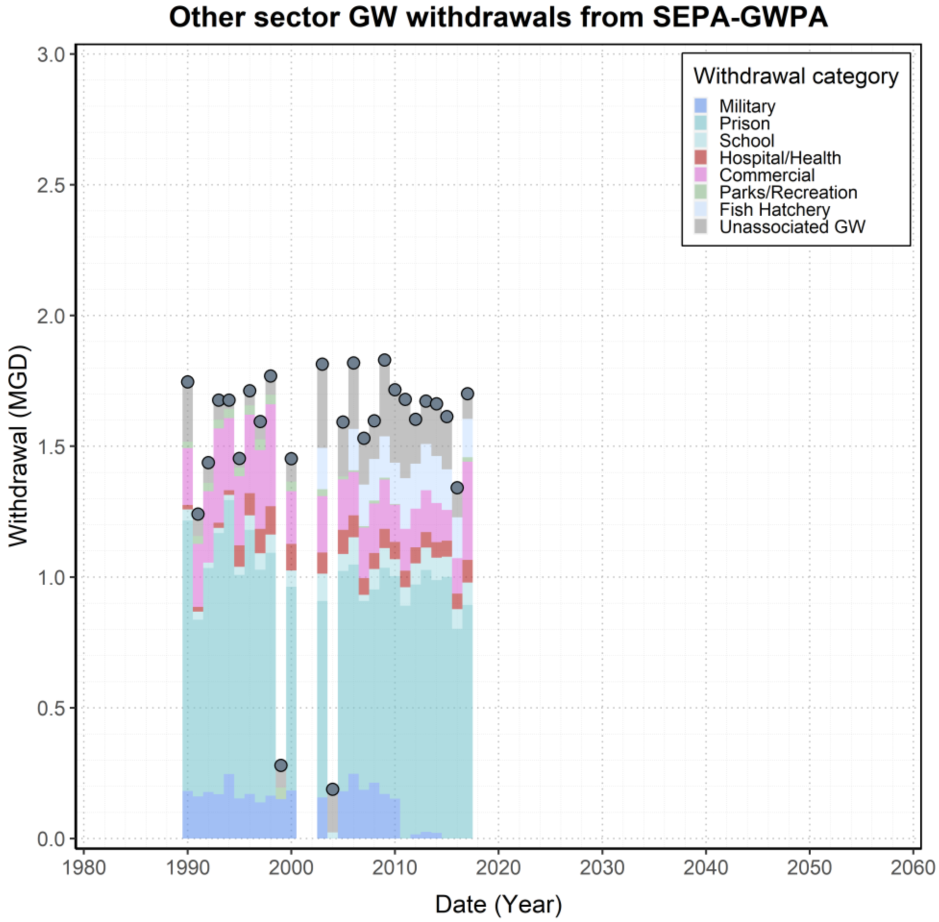

Figure 86: Other sector groundwater withdrawals from the Southeastern Pennsylvania Groundwater Protected Area. *These data only represent withdrawal volumes from sources which plotted within the boundary of SEPA-GWPA as shown in Figure 6. The projections results for this figure are presented in Figure 92. Data supporting this figure are provided for reference as part of Table A-22.*

9.2 Methods

The methods used in this analysis for projecting water withdrawals in the other sector category are almost entirely the same as described for the public water supply sector, outlined in Section 3.4. To reiterate, the overall concept of this analysis is to estimate future water demands by extrapolating historical withdrawal data at the water supply system and/or sub-system levels in a manner such that a “bottom-up” approach can be used to re-aggregate the projections. The methods inherently assume that the rate of change in water use over the recent past will continue into the future at the same rate of change, among other assumptions (e.g., Section 3.4.5.4). The results of this analysis are focused on water demand and intended to be used for water resource planning purposes.

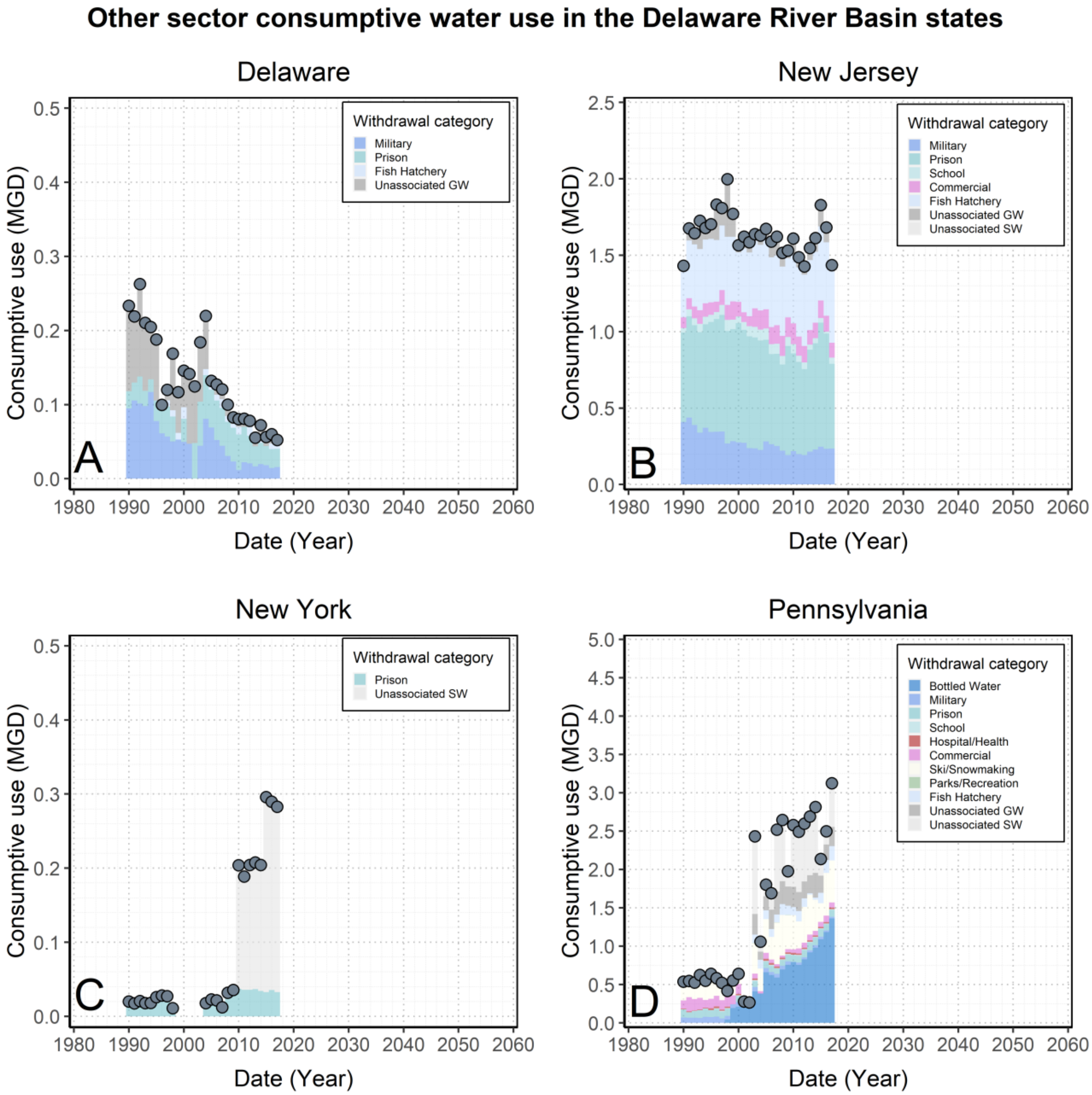

Figure 87: Other sector consumptive water use in the Delaware River Basin states. *Annual average consumptive water use for each state in the Delaware River Basin, grouped by other sector category. These data were calculated using the withdrawal data presented in Figure 84, multiplied by specific consumptive use ratios (calculated, referenced or default). Note the different y-axis scales. This dataset is aggregated to the Basin scale in Figure 88. The projections results for this figure are presented in Figure 93. Data supporting this figure are provided for reference as part of Table A-22.*

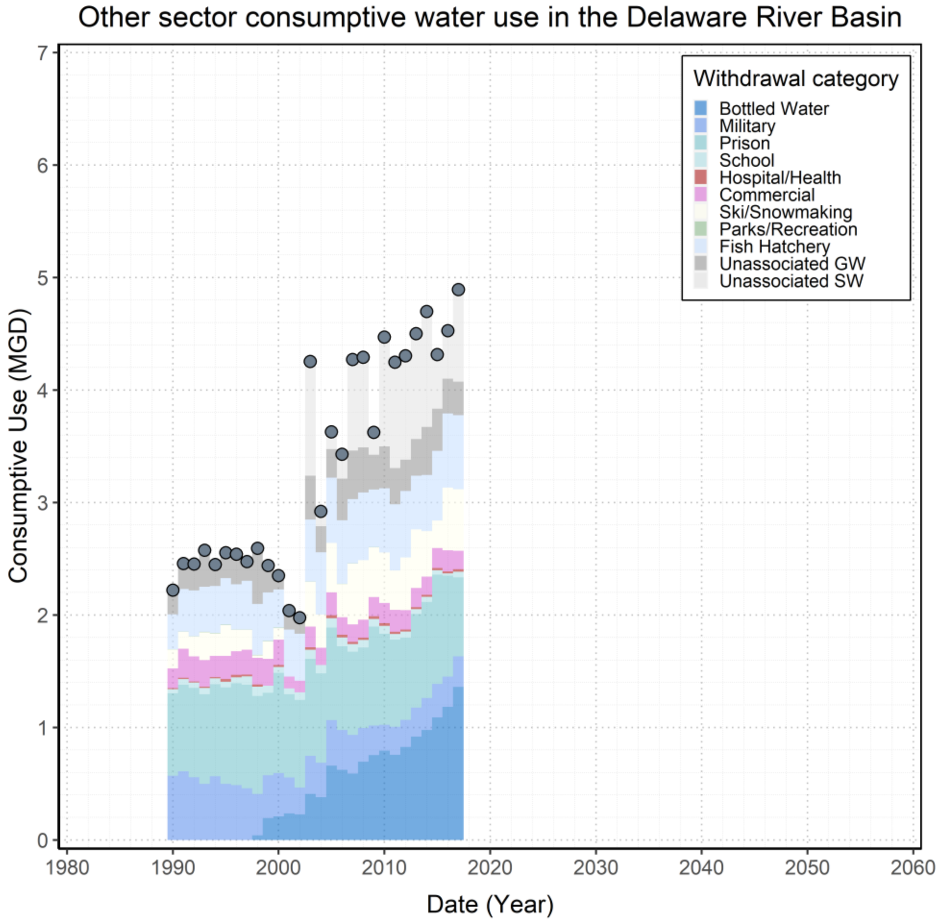

***Figure 88**: **Other sector consumptive water use in the Delaware River Basin, by withdrawal category.** Annual average consumptive water use for the Delaware River Basin, grouped by other sector category. This represents the same data presented in Figure 87, aggregated to the Basin scale. The corresponding figure showing total water withdrawals is Figure 85. The projections results for this figure are presented in Figure 94. Data supporting this figure are provided for reference as part of Table A-22.*

All consumptive use projections for associated systems were performed in a manner consistent with Section 3.4. The only difference in methodology for this sector is how CURs were applied to projection equations of unassociated groundwater. This is the only sector where individual, unassociated sources have many different withdrawal categories, and therefore data aggregated to various planning areas may be comprised of various source-level CURs. Rather than create two separate equations for a single scale (withdrawal & consumptive use) versus one equation with a CUR multiplier, the following methods were implemented:

1. A new CUR was developed based on a weighted average (by volume) of unassociated groundwater post-2003 as outlined in Table 49. The calculated CUR was equal to about 9% and was applied to all unassociated groundwater projection equations to create projections of consumptive use (for unassociated groundwater).
2. In one very specific circumstance, an unassociated bottled water facility required one SEPA-GWPA equation to have a manually specified CUR equal to 100%.

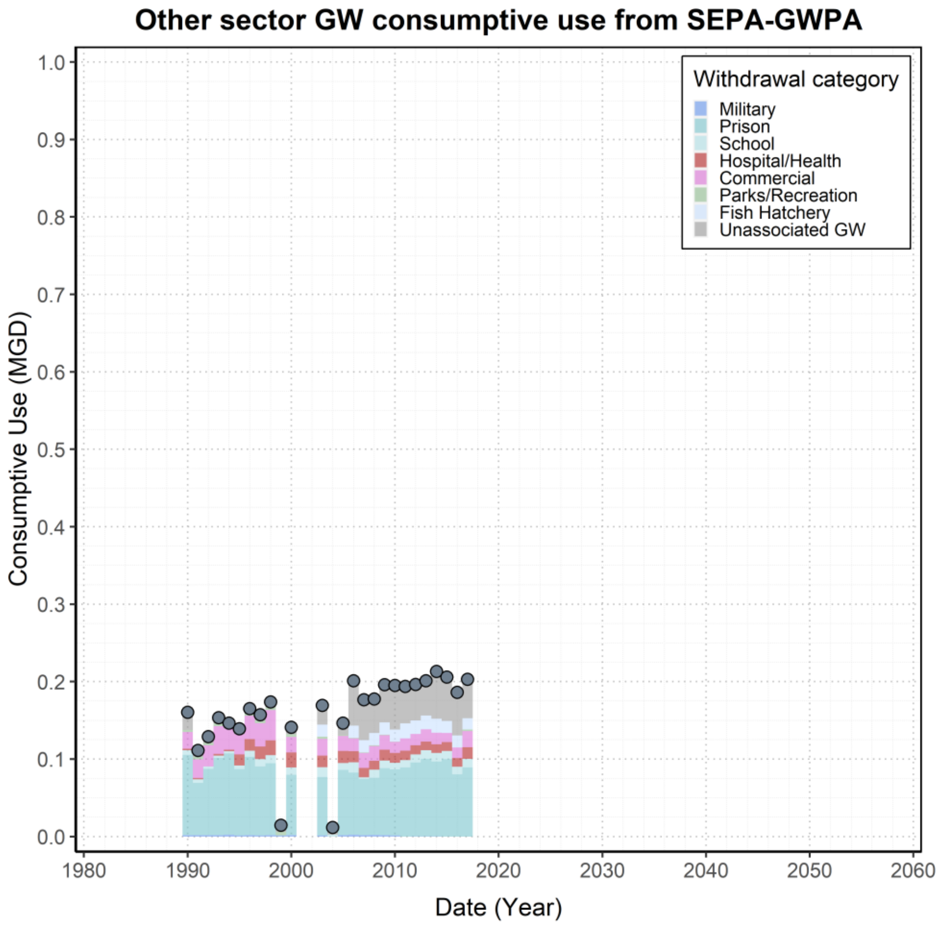

Figure 89: Other sector groundwater withdrawals from the Southeastern Pennsylvania Groundwater Protected Area. *These data only represent consumptive use volumes from sources which plotted within the boundary of SEPA-GWPA as shown in Figure 6. The projections results for this figure are presented in Figure 95. Data supporting this figure are provided for reference as part of Table A-22.*

9.3 Results

9.3.1 Total water withdrawal

The projected withdrawals from the Delaware River Basin by the other sector in each state (excluding data from unassociated surface water withdrawals) are presented in Figure 90, and a summary of the state-level model results are provided in Table 50. The results are then aggregated to provide a Basin-level projection in Figure 91, and a summary of the Basin-level model results are provided in Table 51. The data release supporting this model is provided in Appendix A as Table A-23. Considering both figures, there are few conclusions to be drawn aside from the fact that the models appear coherent and suggest an equilibrium based on facility level trends. It is worth highlighting that the “percent completeness” threshold was reduced from the standard 99% or 95% typically used in this report in order to help show more overlap of the model with actual data.

The projected withdrawals from the SEPA-GWPA by the other sector are presented in Figure 92, and a summary of the model results are provided in Table 52. The data release supporting this model is provided in Appendix A as Table A-24. The apparent underestimate in recent years (2012-2014) is a result of fluctuating data at facility levels above facility projections (and not an omission of data as it may appear). The steep increase at the end of the projection is due to a new facility which began reporting in 2017 with a comparatively large withdrawal for other sector facilities in SEPA-GWPA.

9.3.2 Consumptive water use

The projected consumptive use from the Delaware River Basin by the other sector in each state are presented in Figure 93, and a summary of the state-level model results are provided in Table 53. The results are then aggregated to provide a Basin-level projection in Figure 94, and a summary of the Basin-level model results are provided in Table 54. The data release supporting this model is provided in Appendix A as Table A-23.

The presentation of projected data in Figure 94 is slightly different than all others because the color-coded columns for projected volumes were also plotted, separated from historical data by a blue dashed line. This was done due to the high number of withdrawal categories in this sector; however, as the graphics became increasingly complicated, it was not done for all other plots. Basin-wide, a low rate of growth in consumptive use of about 10% over 40 years is projected for other sector withdrawals (0.366 MGD annually, overall). This is largely drive by small increases in New Jersey and Pennsylvania, offset by a small decrease in Delaware.

The projected consumptive use in the SEPA-GWPA by the other sector is presented in Figure 95, and a summary of the model results is provided in Table 55. The data release supporting this model is provided in Appendix A as Table A-24. The volumes are very small, and the projection essentially represents an equilibrium scenario.

9.4 Climate change

The effects of climate change on projections of water withdrawals by other sector facilities were not addressed in this report.

9.5 Summary

The Other-sector is unique in that it encompasses the most categories of withdrawal, the categories vary widely and they potentially have very different consumptive use characteristics (Table 5). Water withdrawals from the Delaware River Basin by facilities in the other sector were presented for 1990-2017 based on self-reported withdrawal data (Figure 85). It was determined that the majority of the surface water data unassociated with regulatory approvals were attributed to aquaculture in Pennsylvania and were not projected. There is a clear difference between data pre- and post-2003, which is assumed to be largely related to data availability in Pennsylvania (Figure 84D). Overall many facilities did have complete datasets for projection; the Basin-wide projection of all categories is relatively coherent with the data and indicates nominal increases over the next 40 years. Potentially the most pronounced trend observed in this sector is the historical growth in withdrawals (and consumptive use) of bottled water facilities (Figure 88). Despite this historical growth, growth in the number of bottled water facilities was projected to not continue increasing at the same rate as shown by the historical data as many system level projections also considered external metadata such as current regulatory limits.

The other notable trend is observed to be from snowmaking facilities, which showed a change in historical data between 1990-2017 of +1.789 MGD (+231%). While this is assumed to be attributed in part to data reporting (many data are incomplete before 2000), the withdrawals by snowmaking facilities are projected to continue increasing +1.066 MGD over the next 40 years (+49%). This is the largest magnitude increase of any projected category and results in the largest magnitude increase of consumptive use +0.231 MGD (based on a CUR of 22%). This is larger than the magnitude of the projected increase in consumptive use for bottled water facilities of +0.197 MGD (based on a default CUR of 80%, but often times with a regulatory CUR of 100%).

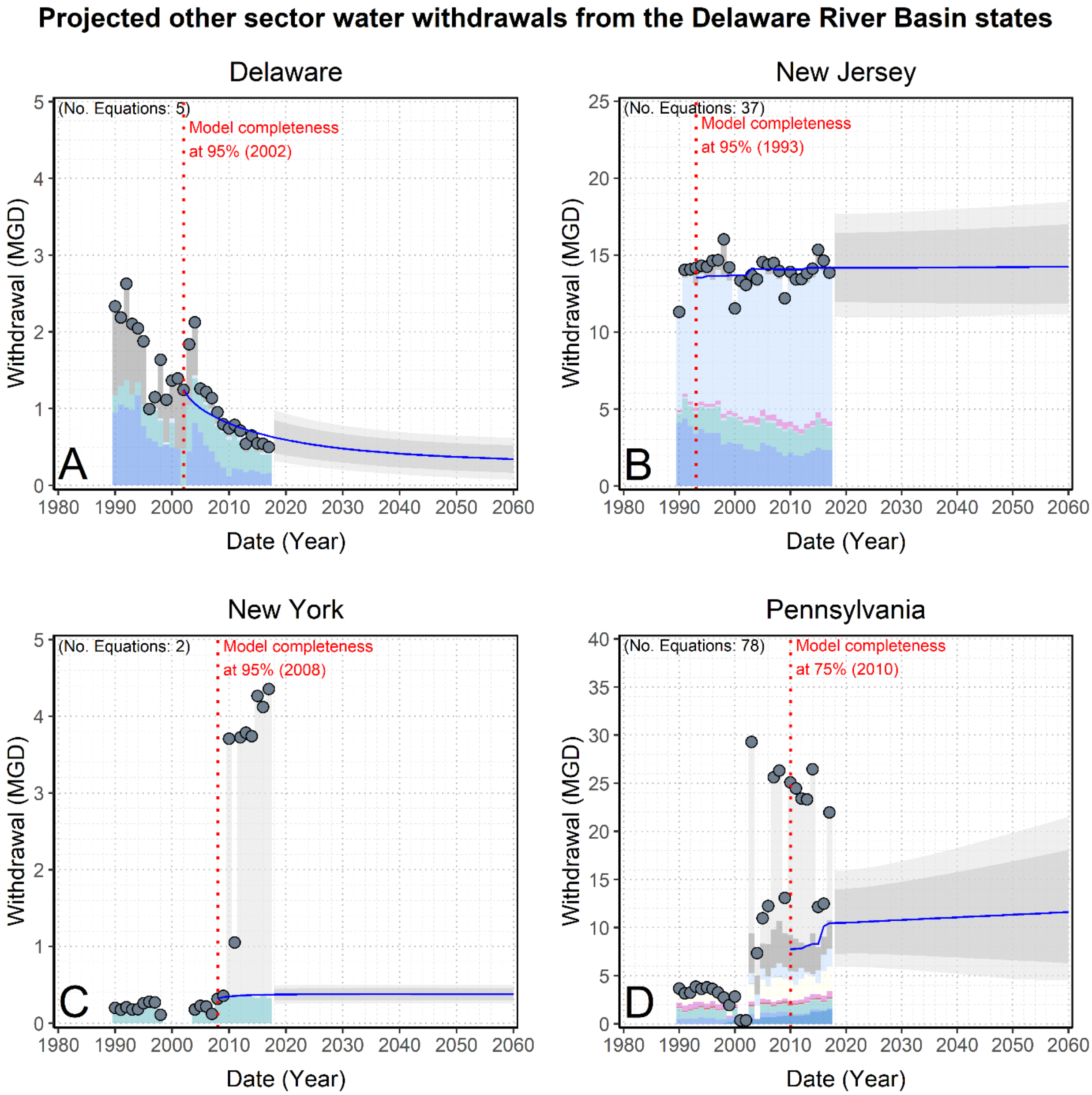

Figure 90: Projected other-sector water withdrawals in the Delaware River Basin states. *Aggregated projection results of the other sector annual average water withdrawals from each state in the Delaware River Basin. These projections correspond with the data initially presented in Figure 84. Results of the model for select years are presented in Table 50. Data supporting these figures are provided for reference in Table A-23.*

__Table 50__: Summary of results supporting Figure 90 for Basin-state projections of total water withdrawals by the other sector of the Delaware River Basin. The historical withdrawal volumes presented in this table do not include any data from the unassociated surface water category.

State	Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
					lwr80	upr80	lwr95	upr95
Delaware	2013	0.540	0.727	34.63	0.505	0.975	0.395	1.119
	2014	0.649	0.704	8.47	0.486	0.946	0.377	1.087
	2015	0.546	0.683	25.09	0.468	0.920	0.361	1.057
	2016	0.542	0.663	22.32	0.452	0.895	0.346	1.029
	2017	0.498	0.644	29.32	0.436	0.872	0.331	1.003
	2020	*NA*	0.595	*NA*	0.394	0.811	0.293	0.934
	2030	*NA*	0.481	*NA*	0.297	0.674	0.202	0.781
	2040	*NA*	0.414	*NA*	0.237	0.597	0.144	0.697
	2050	*NA*	0.372	*NA*	0.195	0.552	0.103	0.649
	2060	*NA*	0.343	*NA*	0.163	0.524	0.075	0.621
New Jersey	2013	13.799	14.173	2.71	11.953	16.445	10.978	17.667
	2014	14.104	14.171	0.48	11.952	16.442	10.977	17.662
	2015	15.329	14.170	7.56	11.951	16.440	10.976	17.659
	2016	14.627	14.169	3.13	11.949	16.440	10.975	17.659
	2017	13.852	14.168	2.28	11.946	16.441	10.973	17.660
	2020	*NA*	14.167	*NA*	11.936	16.451	10.966	17.673
	2030	*NA*	14.176	*NA*	11.882	16.535	10.950	17.795
	2040	*NA*	14.194	*NA*	11.857	16.668	11.008	17.986
	2050	*NA*	14.218	*NA*	11.828	16.829	11.097	18.218
	2060	*NA*	14.244	*NA*	11.852	17.007	11.165	18.476
New York	2013	0.366	0.364	0.55	0.286	0.441	0.244	0.483
	2014	0.343	0.366	6.71	0.288	0.444	0.247	0.485
	2015	0.328	0.368	12.20	0.290	0.446	0.249	0.488
	2016	0.354	0.370	4.52	0.292	0.448	0.251	0.489
	2017	0.326	0.371	13.80	0.293	0.449	0.252	0.491
	2020	*NA*	0.374	*NA*	0.296	0.452	0.255	0.494
	2030	*NA*	0.378	*NA*	0.300	0.456	0.258	0.498
	2040	*NA*	0.378	*NA*	0.300	0.457	0.258	0.498
	2050	*NA*	0.378	*NA*	0.299	0.456	0.257	0.498
	2060	*NA*	0.376	*NA*	0.298	0.455	0.256	0.497
Pennsylvania	2013	8.203	8.120	1.01	5.446	11.161	4.412	12.942
	2014	9.406	8.299	11.77	5.544	11.396	4.449	13.179
	2015	7.933	8.309	4.74	5.562	11.377	4.466	13.122
	2016	9.046	10.164	12.36	7.131	13.505	5.881	15.377
	2017	10.754	10.471	2.63	7.267	13.974	5.925	15.916
	2020	*NA*	10.516	*NA*	7.288	14.030	5.931	15.950
	2030	*NA*	10.798	*NA*	7.185	14.765	5.670	16.893
	2040	*NA*	11.075	*NA*	6.905	15.776	5.205	18.284
	2050	*NA*	11.347	*NA*	6.616	16.897	4.661	19.853
	2060	*NA*	11.615	*NA*	6.312	18.077	4.499	21.517

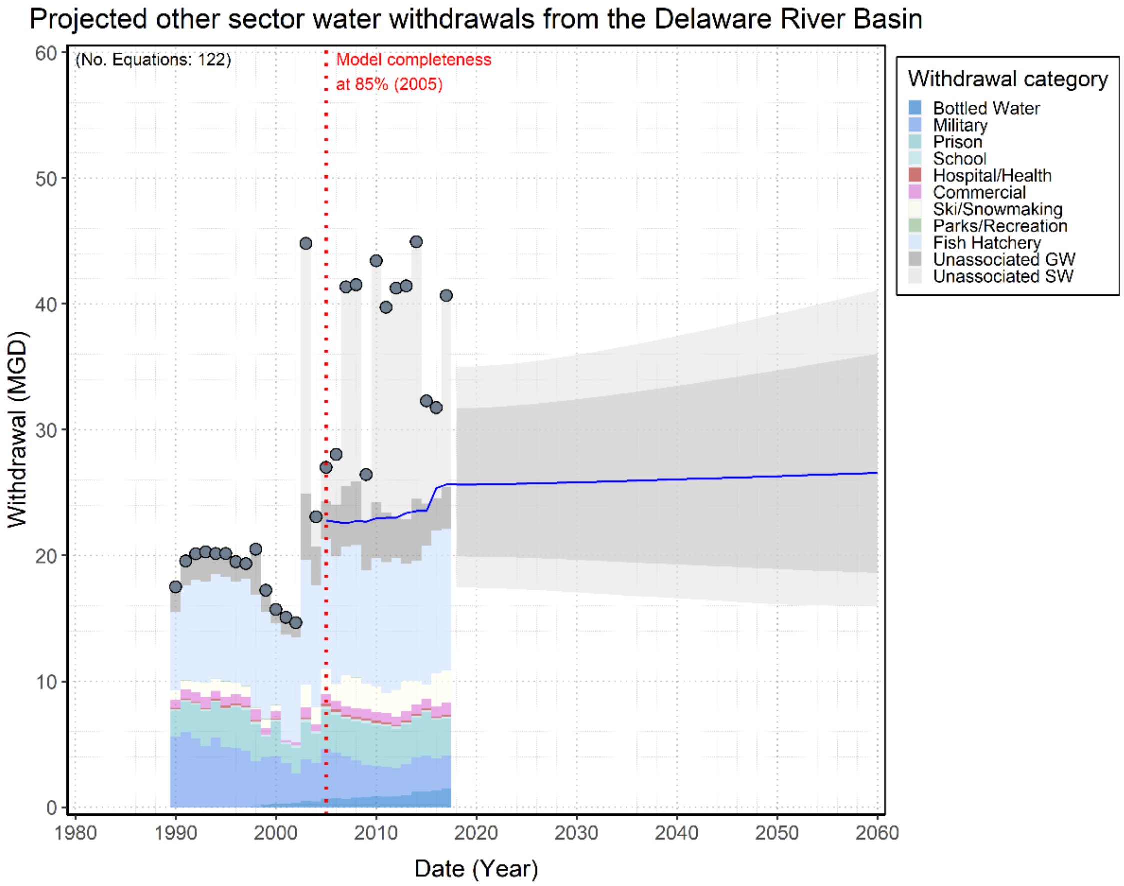

Figure 91: Projected other-sector water withdrawals from the Delaware River Basin. *Aggregated projection results of annual average water withdrawal by facilities categorized within the other sector of the Delaware River Basin. This projection corresponds with the data initially presented as Figure 85. Results of the model for select years are presented in Table 51. Data supporting this figure are provided for reference in Table A-23.*

Table 51*: Summary of results supporting Figure 91 for the Basin-wide projection of annual average water withdrawal by facilities categorized within the other sector of the Delaware River Basin. The historical withdrawal volumes presented in this table do not include any data from the unassociated surface water category.*

Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
				lwr80	upr80	lwr95	upr95
2013	22.908	23.384	2.080	18.190	29.022	16.029	32.211
2014	24.502	23.541	3.920	18.270	29.228	16.051	32.414
2015	24.136	23.530	2.510	18.271	29.183	16.052	32.327
2016	24.569	25.366	3.240	19.823	31.288	17.452	34.554
2017	25.430	25.655	0.880	19.943	31.735	17.480	35.070
2020	*NA*	25.651	*NA*	19.915	31.743	17.445	35.051
2030	*NA*	25.833	*NA*	19.663	32.430	17.080	35.966
2040	*NA*	26.062	*NA*	19.299	33.498	16.615	37.465
2050	*NA*	26.314	*NA*	18.938	34.733	16.119	39.217
2060	*NA*	26.578	*NA*	18.626	36.063	15.995	41.110

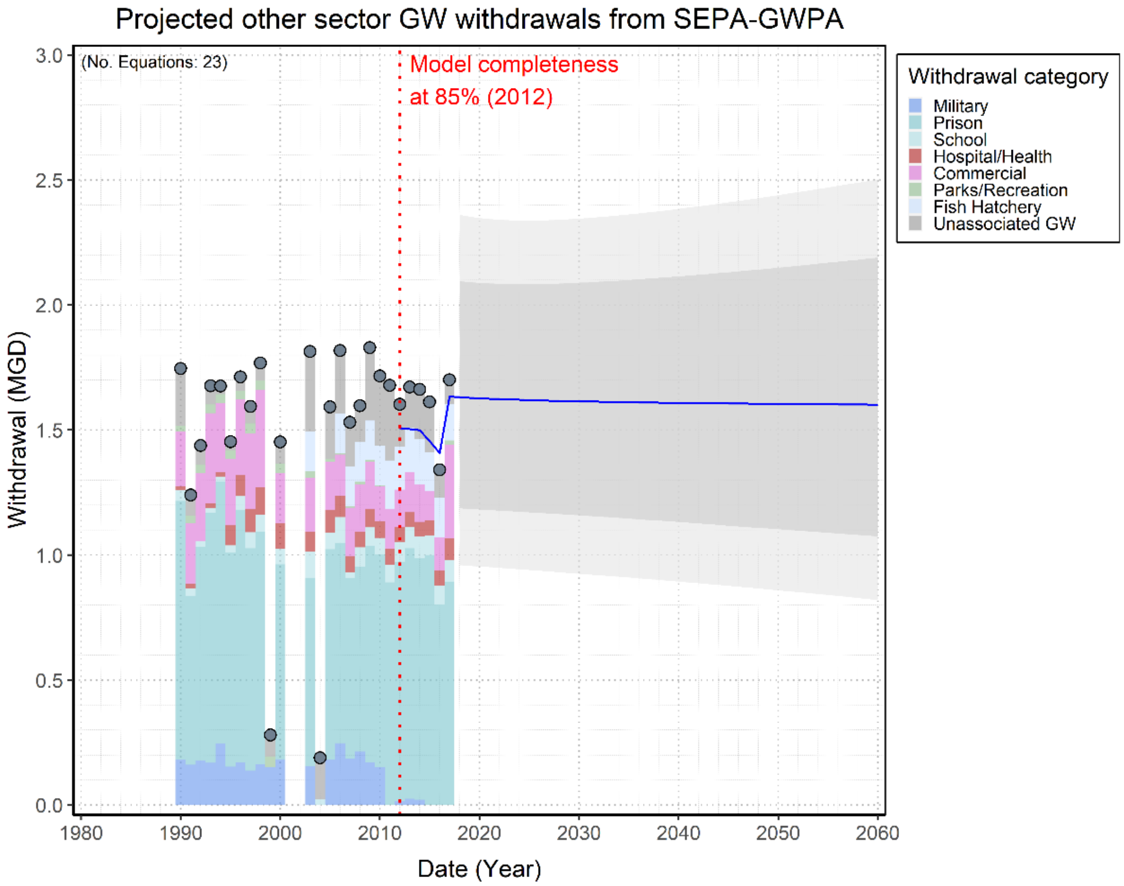

Figure 92: Projected other sector groundwater withdrawals from the Southeastern Pennsylvania Groundwater Protected Area. *This projection corresponds with the data initially presented as Figure 86. Results of the model for select years are presented in Table 52. Data supporting this figure are provided for reference in Table A-24.*

Table 52*: Summary of results supporting Figure 92 for the projection of annual average water withdrawals by other sector facilities within SEPA-GWPA.*

Year	Historical Withdrawal (MGD)	Modelled Withdrawal (MGD)	Percent Error (%)	Modelled withdrawal prediction intervals			
				lwr80	upr80	lwr95	upr95
2013	1.673	1.504	10.100	1.211	1.830	1.062	2.038
2014	1.662	1.500	9.750	1.208	1.820	1.060	2.020
2015	1.613	1.457	9.670	1.160	1.781	1.012	1.979
2016	1.341	1.408	5.000	1.112	1.728	0.964	1.921
2017	1.701	1.634	3.940	1.189	2.101	0.962	2.369
2020	*NA*	1.627	*NA*	1.183	2.089	0.954	2.348
2030	*NA*	1.615	*NA*	1.159	2.089	0.926	2.346
2040	*NA*	1.609	*NA*	1.132	2.115	0.894	2.385
2050	*NA*	1.605	*NA*	1.104	2.150	0.859	2.440
2060	*NA*	1.602	*NA*	1.075	2.190	0.821	2.502

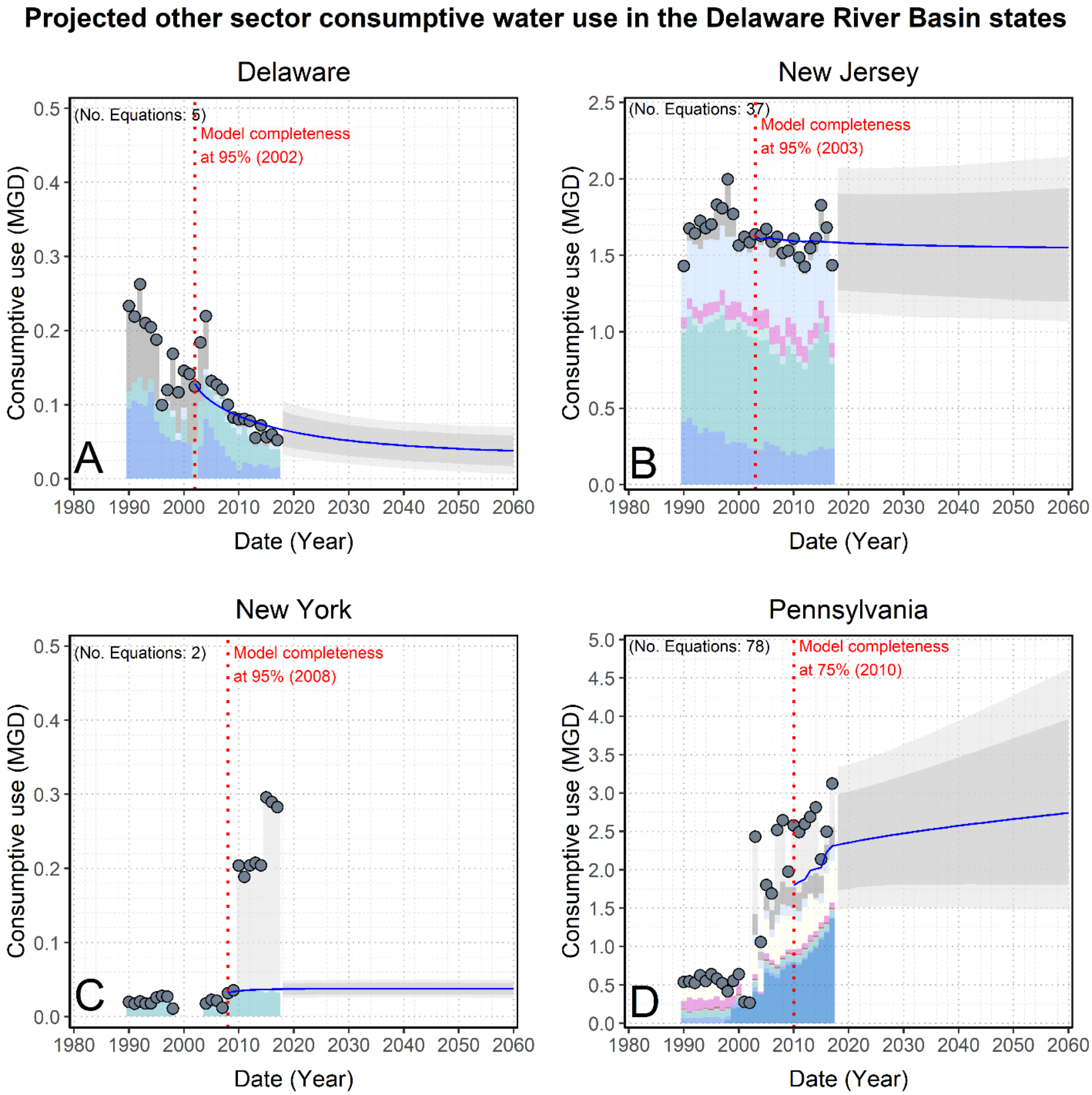

Figure 93: Projected other sector consumptive water use in the Delaware River Basin states. *Aggregated projection results of the other sector annual average consumptive water use from each state in the Delaware River Basin. These projections correspond with the data initially presented as Figure 87. Results of the model for select years are presented in Table 53. Data supporting these figures are provided for reference in Table A-23.*

__Table 53__: Summary of results supporting Figure 93 for the projection of annual average consumptive use by other sector facilities within the Delaware River Basin states. The historical consumptive use volumes presented in this table do not include any data from the unassociated surface water category.

State	Year	Historical Consumptive Use (MGD)	Modelled Consumptive Use (MGD)	Percent Error (%)	Modelled CU prediction intervals			
					lwr80	upr80	lwr95	upr95
Delaware	2013	0.055	0.076	38.180	0.052	0.103	0.040	0.119
	2014	0.072	0.074	2.780	0.050	0.100	0.038	0.116
	2015	0.056	0.072	28.570	0.049	0.098	0.037	0.113
	2016	0.060	0.070	16.670	0.047	0.095	0.035	0.110
	2017	0.052	0.068	30.770	0.045	0.093	0.034	0.107
	2020	NA	0.063	NA	0.041	0.087	0.030	0.100
	2030	NA	0.052	NA	0.031	0.073	0.021	0.085
	2040	NA	0.045	NA	0.025	0.066	0.014	0.077
	2050	NA	0.041	NA	0.021	0.061	0.010	0.072
	2060	NA	0.038	NA	0.017	0.059	0.007	0.070
New Jersey	2013	1.547	1.596	3.170	1.283	1.917	1.139	2.091
	2014	1.610	1.593	1.060	1.280	1.913	1.137	2.087
	2015	1.827	1.590	12.970	1.278	1.910	1.134	2.083
	2016	1.681	1.588	5.530	1.276	1.908	1.132	2.080
	2017	1.435	1.586	10.520	1.274	1.906	1.130	2.078
	2020	NA	1.580	NA	1.267	1.901	1.123	2.073
	2030	NA	1.568	NA	1.245	1.898	1.103	2.075
	2040	NA	1.560	NA	1.227	1.906	1.090	2.091
	2050	NA	1.555	NA	1.209	1.921	1.081	2.116
	2060	NA	1.551	NA	1.197	1.940	1.069	2.147
New York	2013	0.037	0.036	2.700	0.029	0.044	0.024	0.048
	2014	0.034	0.037	8.820	0.029	0.044	0.025	0.049
	2015	0.033	0.037	12.120	0.029	0.045	0.025	0.049
	2016	0.035	0.037	5.710	0.029	0.045	0.025	0.049
	2017	0.033	0.037	12.120	0.029	0.045	0.025	0.049
	2020	NA	0.037	NA	0.030	0.045	0.025	0.049
	2030	NA	0.038	NA	0.030	0.046	0.026	0.050
	2040	NA	0.038	NA	0.030	0.046	0.026	0.050
	2050	NA	0.038	NA	0.030	0.046	0.026	0.050
	2060	NA	0.038	NA	0.030	0.046	0.026	0.050
Pennsylvania	2013	1.924	1.989	3.380	1.451	2.596	1.243	2.933
	2014	1.954	2.010	2.870	1.474	2.613	1.253	2.947
	2015	1.918	2.029	5.790	1.493	2.630	1.269	2.960
	2016	2.325	2.233	3.960	1.668	2.863	1.428	3.207
	2017	2.553	2.310	9.520	1.717	2.967	1.463	3.324
	2020	NA	2.353	NA	1.754	3.017	1.497	3.374
	2030	NA	2.475	NA	1.806	3.229	1.517	3.632
	2040	NA	2.574	NA	1.808	3.467	1.502	3.942
	2050	NA	2.661	NA	1.804	3.713	1.479	4.273
	2060	NA	2.741	NA	1.806	3.965	1.486	4.615

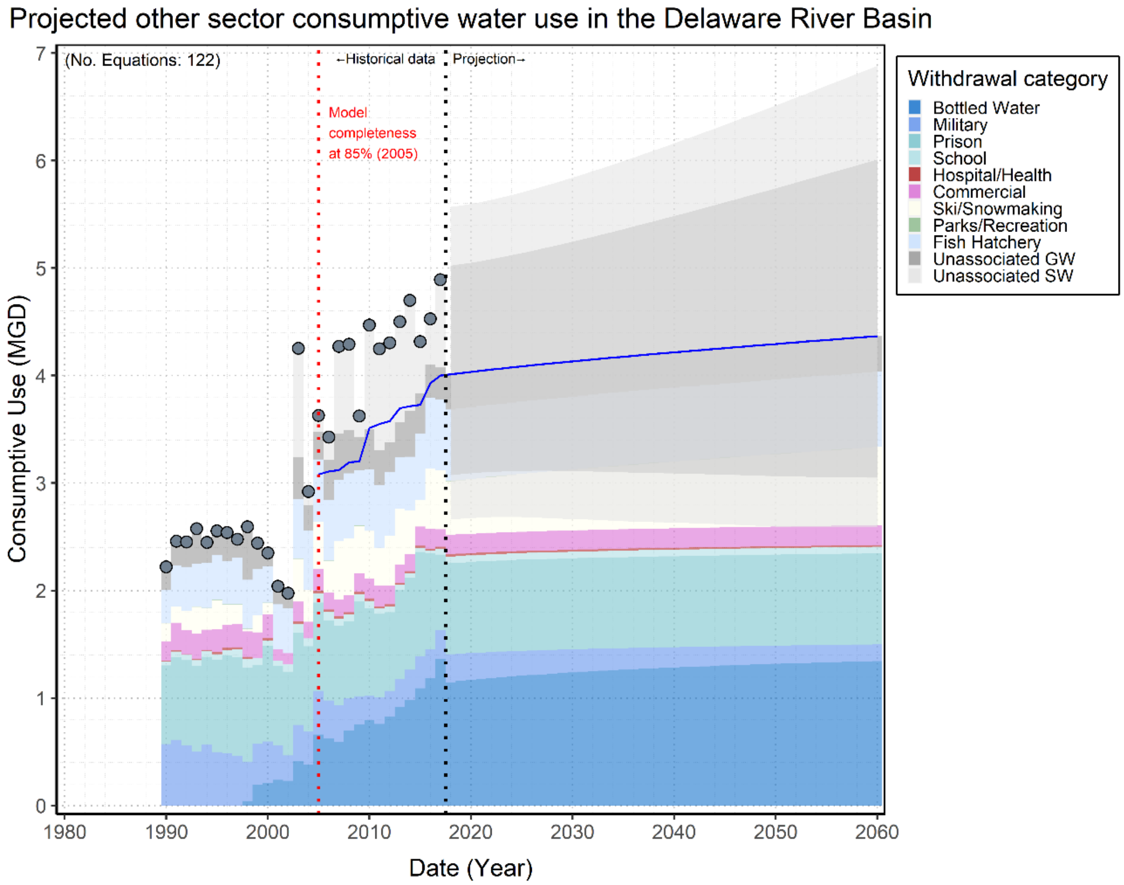

Figure 94: Projected other sector consumptive water use in the Delaware River Basin. *Aggregated projection results of annual average consumptive use by facilities categorized within the other sector of the Delaware River Basin. This projection corresponds with the data initially presented as Figure 88. Results of the model for select years are presented in Table 54. Data supporting this figure are provided for reference in Table A-23.*

Table 54*: Summary of results supporting Figure 94 for the projection of annual average water withdrawals by other sector facilities within the Delaware River Basin.*

Year	Historical Consumptive Use (MGD)	Modelled Consumptive Use (MGD)	Percent Error (%)	Modelled CU prediction intervals			
				lwr80	upr80	lwr95	upr95
2013	3.563	3.698	3.790	2.815	4.660	2.447	5.191
2014	3.671	3.714	1.170	2.833	4.671	2.453	5.197
2015	3.834	3.728	2.760	2.849	4.683	2.465	5.205
2016	4.101	3.928	4.220	3.019	4.911	2.620	5.445
2017	4.073	4.002	1.740	3.065	5.011	2.651	5.558
2020	NA	4.034	NA	3.092	5.050	2.675	5.597
2030	NA	4.133	NA	3.112	5.246	2.666	5.841
2040	NA	4.217	NA	3.090	5.484	2.632	6.160
2050	NA	4.294	NA	3.064	5.742	2.595	6.512
2060	NA	4.368	NA	3.050	6.009	2.587	6.883

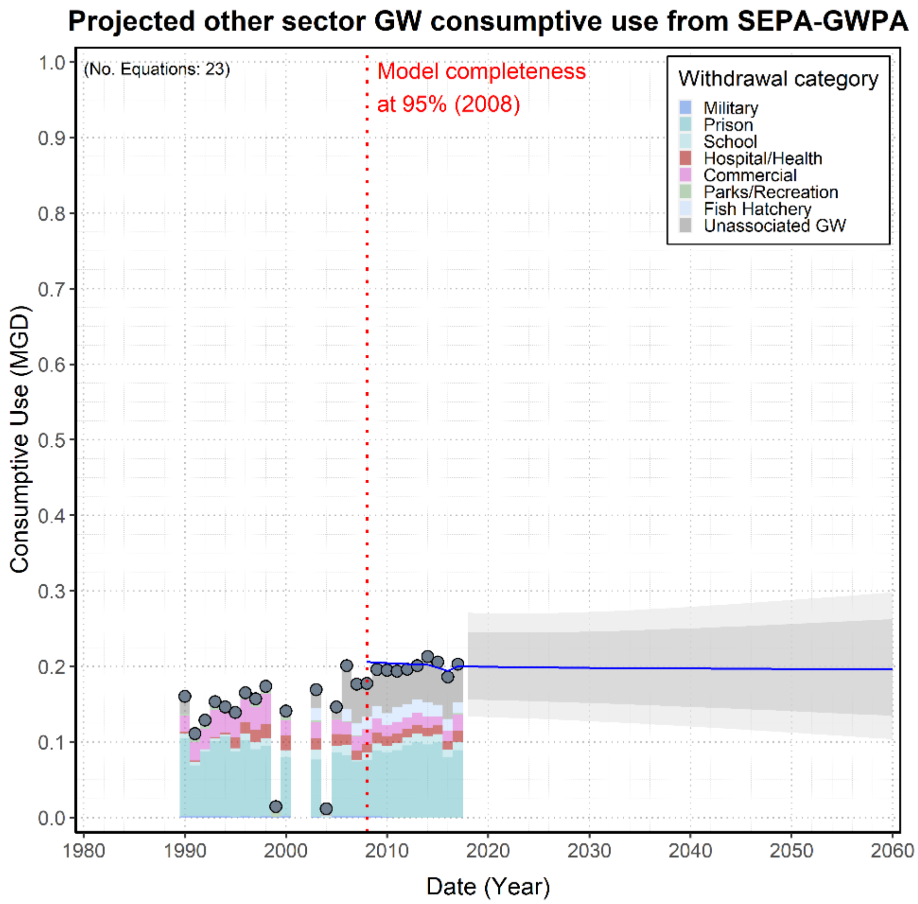

Figure 95: Projected other sector groundwater consumptive use in the Southeastern Pennsylvania Groundwater Protected Area. *This projection corresponds with the data initially presented as Figure 89. Results of the model for select years are presented in Table 55. Data supporting this figure are provided for reference in Table A-24.*

Table 55*: Summary of results supporting Figure 95 for the projection of annual average groundwater withdrawals by other sector facilities within the SEPA-GWPA.*

Year	Historical Consumptive Use (MGD)	Modelled Consumptive Use (MGD)	Percent Error (%)	Modelled CU prediction intervals			
				lwr80	upr80	lwr95	upr95
2013	0.201	0.203	1.000	0.164	0.245	0.144	0.270
2014	0.213	0.202	5.160	0.164	0.244	0.144	0.269
2015	0.206	0.199	3.400	0.159	0.240	0.139	0.265
2016	0.186	0.194	4.300	0.155	0.236	0.135	0.260
2017	0.203	0.200	1.480	0.157	0.246	0.134	0.272
2020	*NA*	0.200	*NA*	0.156	0.245	0.133	0.270
2030	*NA*	0.198	*NA*	0.152	0.246	0.128	0.272
2040	*NA*	0.197	*NA*	0.147	0.251	0.121	0.279
2050	*NA*	0.197	*NA*	0.141	0.256	0.113	0.288
2060	*NA*	0.196	*NA*	0.135	0.263	0.104	0.298

Delaware River near
Point Mountain in Hancock, NY.
Credit: © David B. Soete
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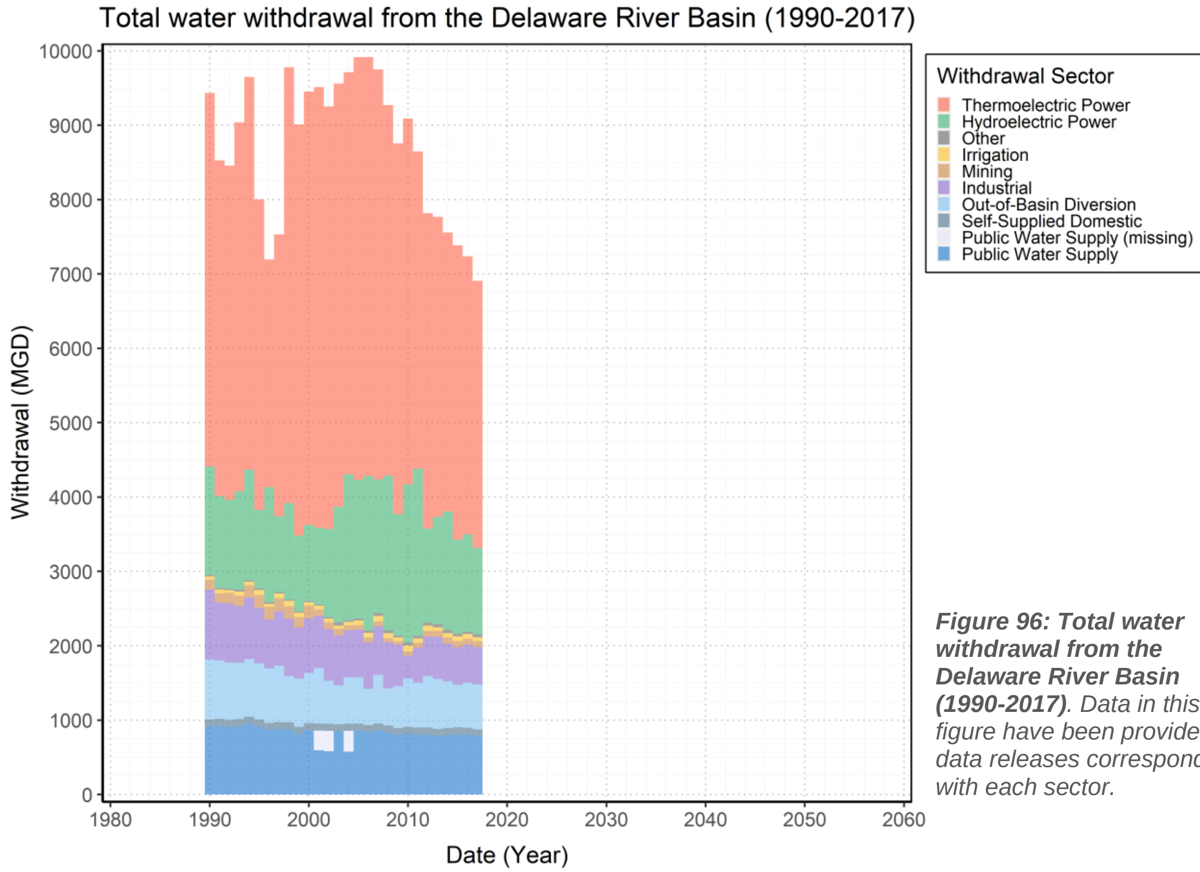

Figure 96: Total water withdrawal from the Delaware River Basin (1990-2017)*. Data in this figure have been provided in data releases corresponding with each sector.*

10 CONCLUSIONS

10.1 Delaware River Basin

Historical water withdrawals have been reported and estimated for the Delaware River Basin between 1990 and 2017, as presented in Figure 96. This figure combines the data presented in each section of this report into one comprehensive assessment of all water withdrawal sectors; as there were known significant data gaps in public water supply data, these have been "backfilled" with a linear interpolation for presentation purposes. The estimated self-supplied domestic withdrawal value for 2010 was extended backwards to 1990 to normalize the data set.

A compiled projection of all sectors from 2018 through 2060 is provided in Figure 97, and results for select years are presented in Table 56. This projection is the result of developing and reviewing over 550 reports for individual withdrawal facilities, resulting in over 1,100 regression equations at various spatial scales. Additionally, this includes a multi-variate projection for irrigation withdrawals under the regional climate model (GFDL ESM2M) scenario RCP 8.5, and a projection of self-supplied domestic withdrawal based on a population projection under Shared Socioeconomic Pathway scenario SSP2. The same compiled withdrawal projection is presented in Figure 98 with the aggregated predictive interval. Predictive interval results are presented for select years in Table 57; note that predictive intervals are not calculated for the projection of self-supplied domestic or the out-of-Basin diversions.

Consumptive use was calculated for the Delaware River Basin between 1990 and 2017 and projected to 2060. The data and projection are presented in Figure 99 and Figure 100; model and prediction interval results for select years are presented in Table 58 and Table 59.

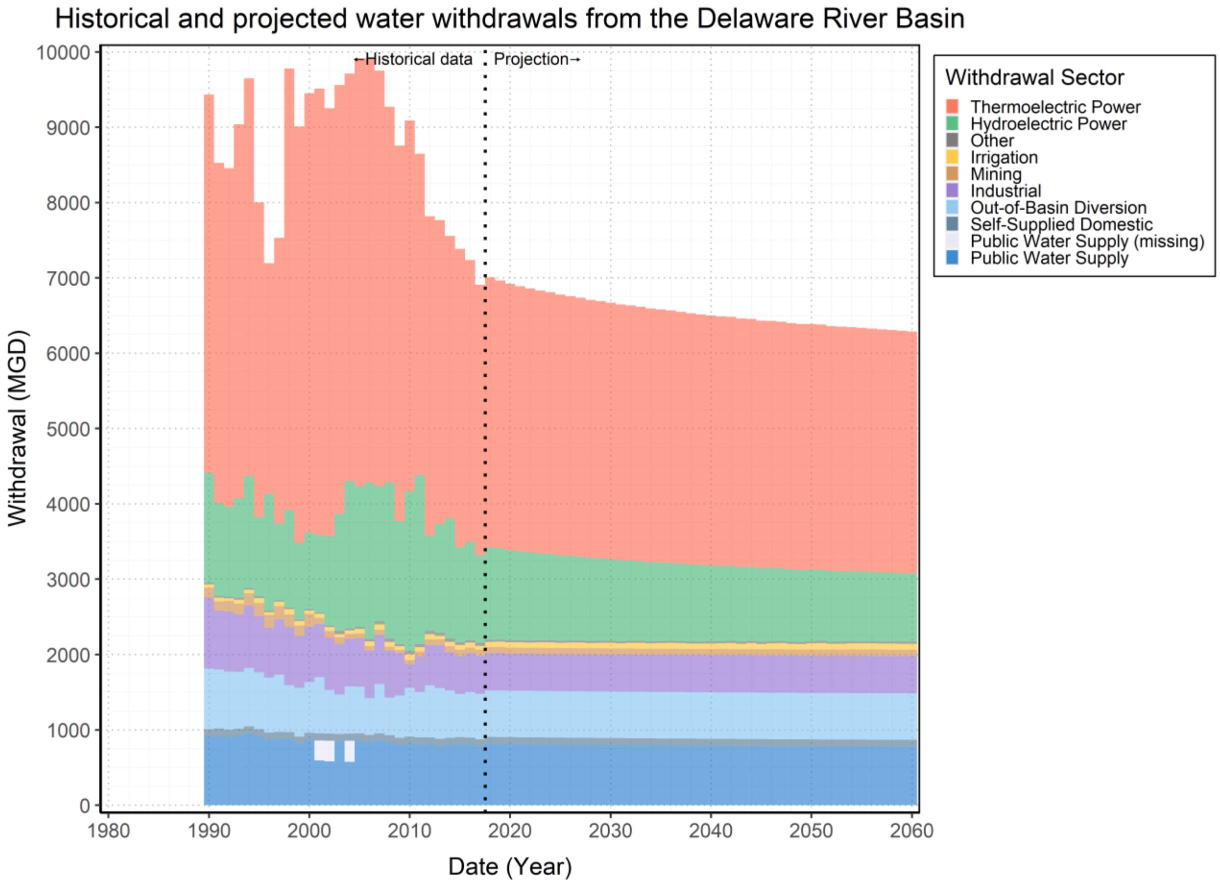

***Figure 97: Historical and projected water withdrawals from the Delaware River Basin**. Data in this figure have been provided in data releases corresponding with each sector. The irrigation model presented is for RCP 8.5. The projection has been color coded by sector to demonstrate the relative magnitude and trends of the expected values.*

***Table 56**: Summary of results supporting Figure 97 for the projection of water withdrawals from the Delaware River Basin in all sectors. Unassociated surface water was excluded from the 2013-2017 average of the other sector.*

Sector	2013-2017 Average	2020	2030	2040	2050	2060
Thermoelectric Power	3,815.514	3,535.692	3,404.024	3,319.242	3,258.866	3,213.843
Hydroelectric Power	1,354.203	1,197.911	1,085.874	1,009.569	951.633	904.916
Other	24.309	25.651	25.833	26.062	26.314	26.578
Irrigation (RCP 8.5)	57.300	70.533	74.984	74.686	82.665	79.049
Mining	80.276	81.383	80.434	80.880	82.141	83.864
Industrial	517.507	489.268	490.621	491.921	493.151	494.368
Out-of-Basin Diversions	618.804	618.804	618.804	618.804	618.804	618.804
Self-Supplied Domestic	95.692	96.159	95.865	94.387	92.242	91.238
Public Water Supply	793.921	806.509	794.777	786.754	780.910	776.505
Totals:	7,357.526	6,921.911	6,671.214	6,502.304	6,386.726	6,289.164

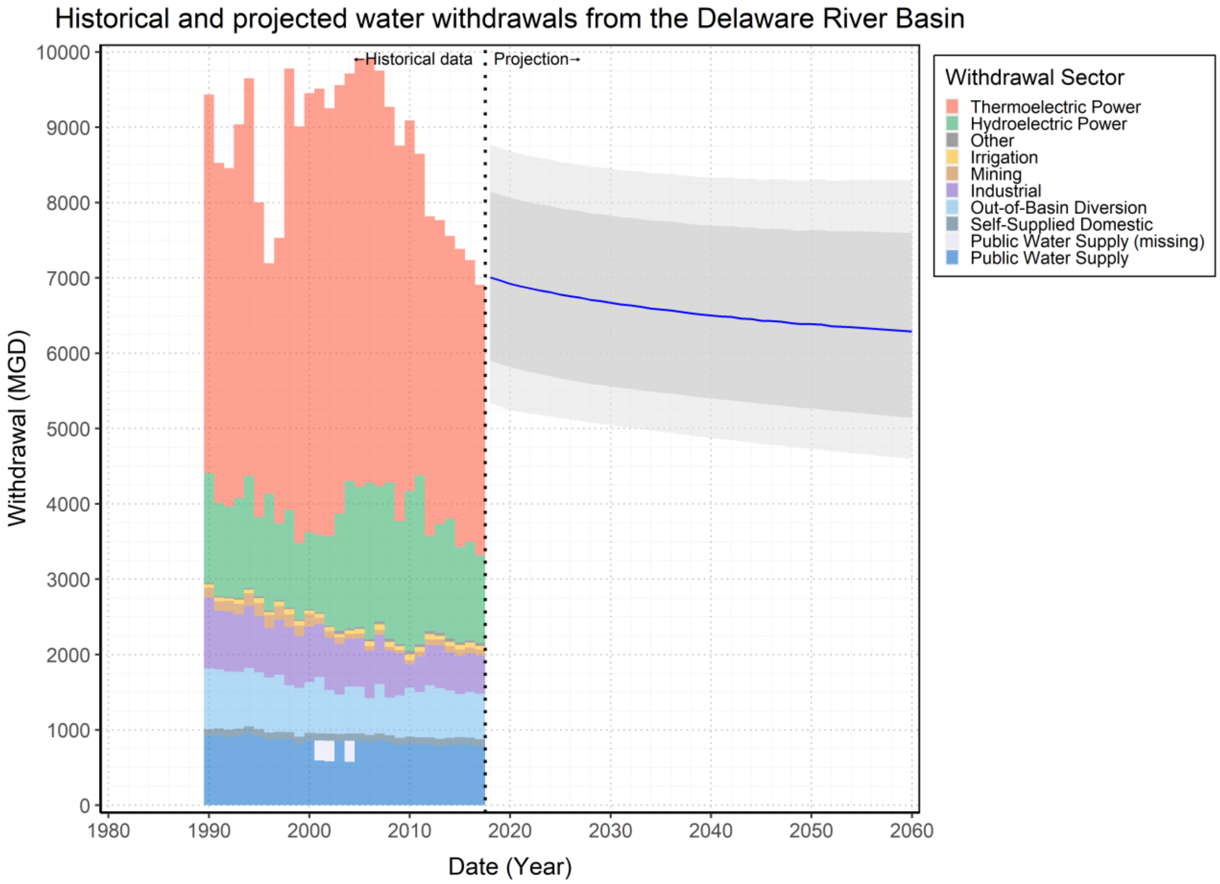

Figure 98: Historical and projected water withdrawals from the Delaware River Basin with predictive interval*. Data in this figure have been provided in data releases corresponding with each sector. The irrigation model presented is for RCP 8.5. The predictive interval shown represents the aggregated predictive intervals for all sectors. Note that no predictive intervals were calculated for self-supplied domestic or out-of-Basin diversions.*

Table 57*: Prediction interval summary supporting Figure 98 for the projection of water withdrawals from the Delaware River Basin in all sectors.*

Sector	PI	2020		2030		2040		2050		2060	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
THM	80	-348.288	368.672	-334.055	364.941	-298.702	371.875	-281.903	386.143	-275.999	405.667
	95	-527.782	572.218	-454.337	564.569	-422.526	573.924	-412.362	594.885	-416.303	624.127
HYD	80	-509.495	509.495	-522.602	522.602	-540.834	540.834	-563.446	563.446	-589.721	589.721
	95	-777.202	780.164	-794.385	800.235	-818.163	828.152	-843.061	862.777	-866.886	903.010
OTH	80	-5.736	6.092	-6.169	6.598	-6.763	7.436	-7.376	8.419	-7.953	9.485
	95	-8.206	9.400	-8.753	10.133	-9.447	11.404	-10.195	12.903	-10.583	14.532
IRR (RCP 8.5)	80	-24.678	25.516	-26.115	27.204	-25.900	26.968	-29.658	31.687	-27.761	29.184
	95	-35.887	39.079	-37.440	41.668	-37.338	41.304	-41.344	48.542	-39.284	44.702
MIN	80	-28.907	32.808	-30.162	33.577	-33.086	36.681	-35.017	40.752	-37.157	45.355
	95	-40.776	52.343	-42.665	52.536	-44.515	56.940	-47.100	62.998	-50.064	69.930
IND	80	-88.463	95.688	-89.855	97.013	-91.327	99.674	-93.096	103.003	-94.931	106.687
	95	-133.547	147.040	-134.701	148.777	-136.543	152.739	-138.385	157.790	-140.398	163.438
DIV	--	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SSD	--	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PWS	80	-99.157	101.792	-101.437	104.904	-104.455	110.159	-108.372	116.594	-112.886	123.835
	95	-149.218	156.479	-151.309	161.130	-155.774	169.023	-161.543	178.839	-167.940	189.870

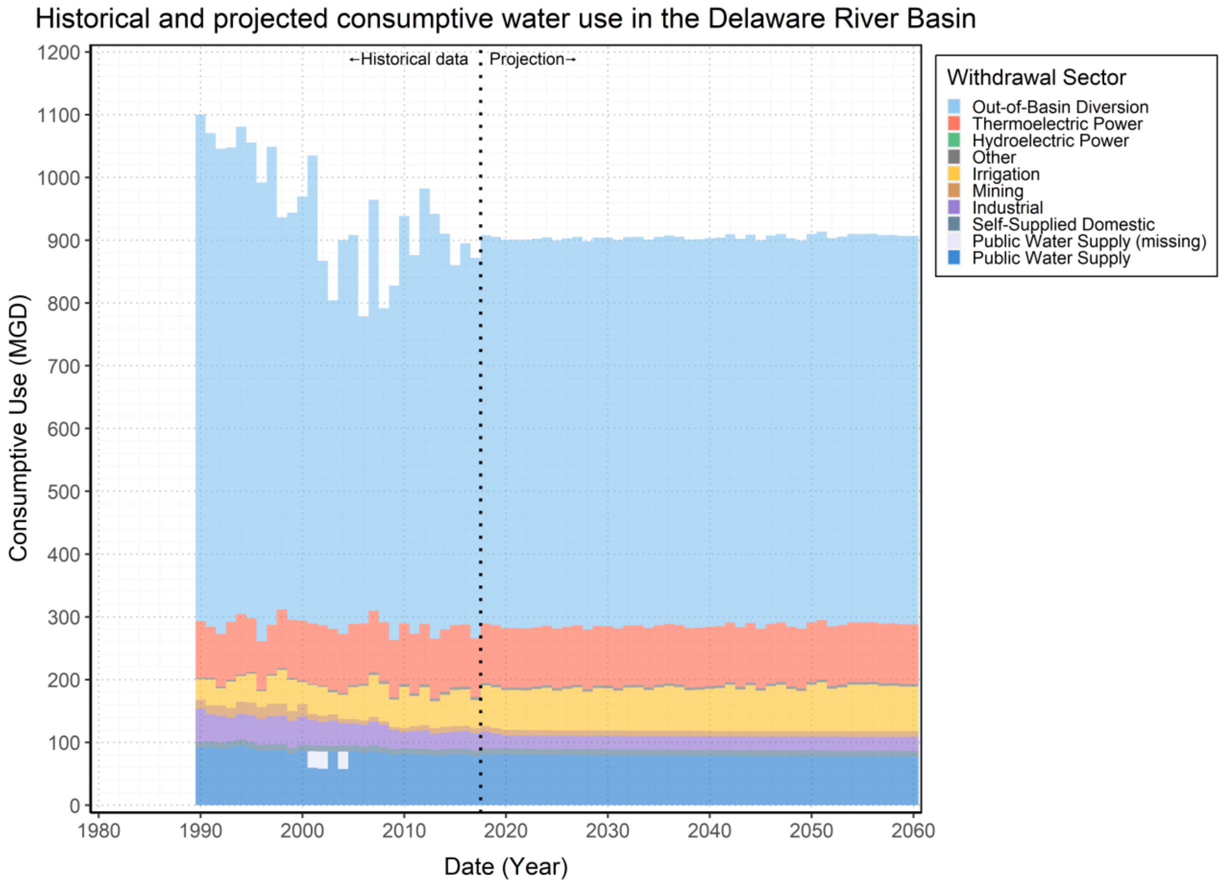

***Figure 99: Historical and projected consumptive water use in the Delaware River Basin**. Data in this figure have been provided in data releases corresponding with each sector. The irrigation model presented is for RCP 8.5. The projection has been color coded by sector to demonstrate the relative magnitude and trends of the expected values.*

***Table 58**: Summary of results supporting Figure 99 for the compiled projection of consumptive water use in the Delaware River Basin in all sectors. Unassociated surface water was excluded from the 2013-2017 average of the other sector.*

Sector	2013-2017 Average	2020	2030	2040	2050	2060
Thermoelectric Power	97.058	94.539	94.681	94.763	94.853	94.956
Hydroelectric Power	0.000	0.000	0.000	0.000	0.000	0.000
Other	3.849	4.034	4.133	4.217	4.294	4.368
Irrigation (RCP 8.5)	50.844	63.480	67.485	67.217	74.399	71.144
Mining	8.666	8.721	8.539	8.539	8.644	8.806
Industrial	26.917	20.905	21.152	21.431	21.722	22.054
Out-of-Basin Diversions	618.804	618.804	618.804	618.804	618.804	618.804
Self-Supplied Domestic	9.569	9.616	9.586	9.439	9.224	9.124
Public Water Supply	79.392	80.651	79.478	78.675	78.091	77.650
Totals:	895.098	900.750	903.858	903.085	910.030	906.905

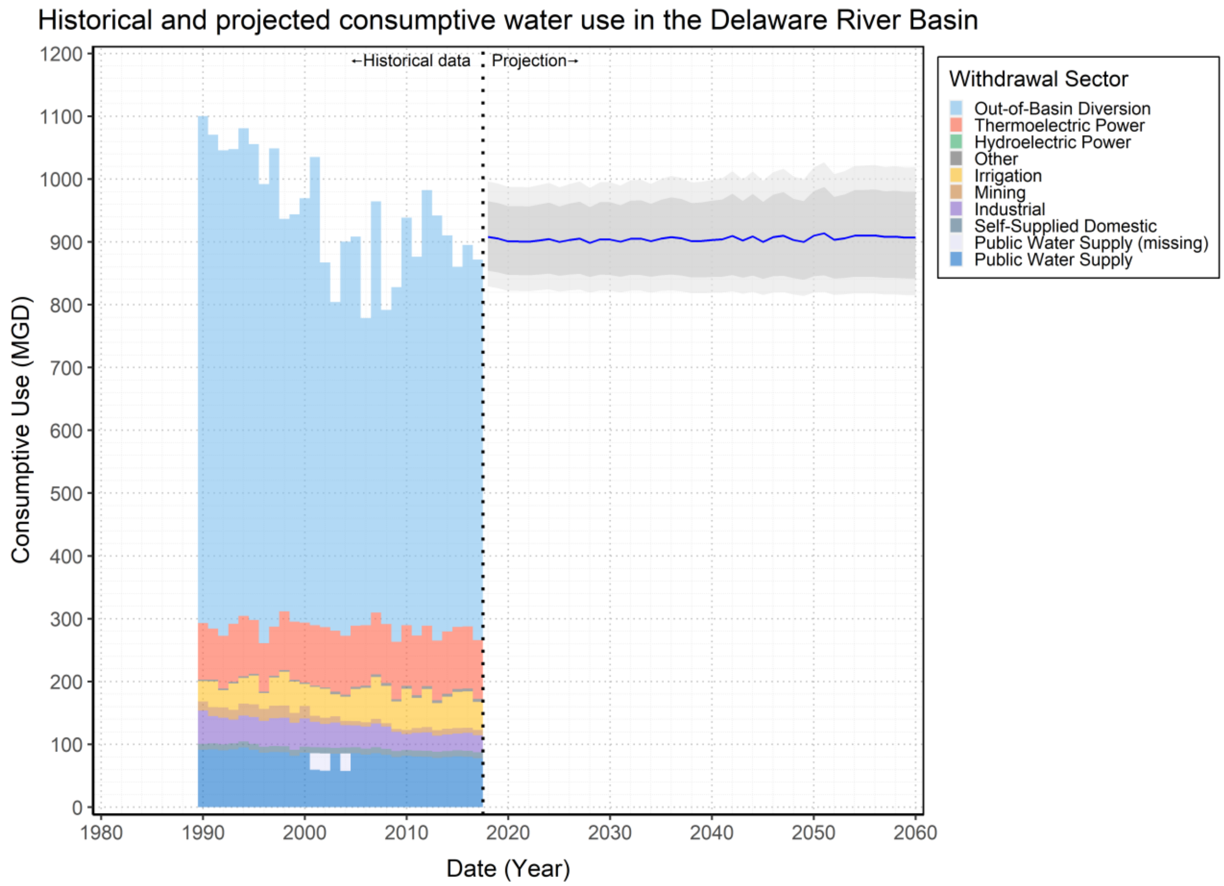

Figure 100: Historical and projected consumptive water use in the Delaware River Basin*. Data in this figure have been provided in data releases corresponding with each sector. The irrigation model presented is for RCP 8.5. The predictive interval shown represents the aggregated predictive intervals for all sectors. Note that no predictive intervals were calculated for self-supplied domestic or out-of-Basin diversions.*

Table 59*: Prediction interval summary supporting Figure 100 for the projection of consumptive water use in the Delaware River Basin in all sectors.*

Sector	PI	2020		2030		2040		2050		2060	
		Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
THM	80	-12.532	13.034	-13.712	14.047	-15.365	16.026	-16.862	18.436	-18.341	21.082
	95	-18.698	20.249	-19.593	21.636	-21.371	24.633	-23.204	28.303	-25.150	32.340
HYD	80	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	95	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
OTH	80	-0.942	1.016	-1.021	1.113	-1.126	1.268	-1.230	1.448	-1.318	1.642
	95	-1.359	1.563	-1.466	1.708	-1.584	1.943	-1.699	2.218	-1.781	2.515
IRR (RCP 8.5)	80	-22.211	22.964	-23.503	24.484	-23.310	24.271	-26.692	28.518	-24.985	26.265
	95	-32.298	35.171	-33.696	37.502	-33.604	37.174	-37.210	43.687	-35.355	40.232
MIN	80	-3.109	3.543	-3.263	3.642	-3.606	4.000	-3.825	4.469	-4.064	4.999
	95	-4.371	5.670	-4.595	5.705	-4.802	6.211	-5.092	6.909	-5.426	7.707
IND	80	-4.661	5.380	-4.760	5.543	-4.873	5.879	-5.018	6.282	-5.210	6.686
	95	-6.808	8.314	-6.874	8.523	-7.051	9.020	-7.165	9.631	-7.283	10.265
DIV	--	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
SSD	--	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PWS	80	-9.916	10.179	-10.144	10.490	-10.445	11.016	-10.837	11.659	-11.289	12.384
	95	-14.922	15.648	-15.131	16.113	-15.577	16.902	-16.154	17.884	-16.794	18.987

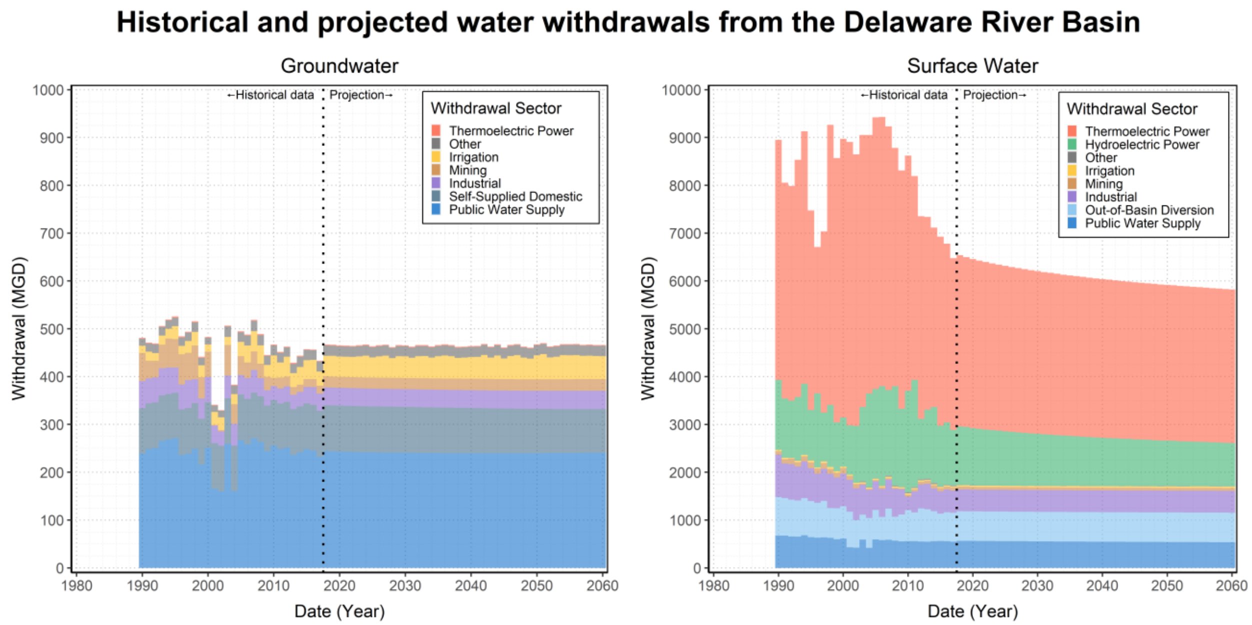

Figure 101: Historical and projected water withdrawals from the Delaware River Basin, by sourcewater designation and withdrawal sector. *Note that not all sectors are present in each figure, and the scale of the y-axis is different for each figure.*

Considering the data that have been presented throughout this report and summarized in Figure 97 through Figure 100, there are multiple conclusions which can be drawn regarding water withdrawals and consumptive use in the Delaware River Basin:

1. Peak water withdrawal from the Delaware River Basin has likely already occurred. The maximum total withdrawal shown in Figure 96 was estimated to occur in 2005/2006 at an annual average rate of approximately 9.917 billion gallons per day. The projections summarized in Figure 97 indicate a continued decrease in overall withdrawal under the assumptions and limitations of this study, supporting a conclusion on peak withdrawal. Historically, average withdrawals have been about 5.4% groundwater and 94.6% surface water, although in 2017 they were 6.3% and 93.7%, respectively. As most of the projected Basin-wide decrease in withdrawal is attributed to surface water, the split is projected to be about 8.3% groundwater to 91.7% surface water in 2060 (Figure 101).

2. Excluding the out-of-Basin diversions, consumptive use in the Delaware River Basin has remained relatively constant at an historical annual average of about 286 MGD with a coefficient of variation of about 4.5% (Figure 99). The data used to calculate historical consumptive use likely present an advancement over previous studies due to the preferential order of CURs applied (most industrial and thermoelectric data are based on facility reported CUR data). It is understood based on the analysis of irrigation data that early years in the 1990s may be under-reported; however, the projection accounted for this finding. The projection showed no change or slight decreases across all sectors aside from irrigation, which was the only sector with a substantial projected increase.

   The out-of-Basin diversions have fluctuated in the recent past, and the data suggest that the overall consumptive use for the Delaware River Basin has fluctuated between about 1,100 MGD and 800 MGD, more recently averaging about 900 MGD.

   Basin-wide consumptive use has historically been the most consistently projected form of data. Therefore, Figure 3 was prepared to summarize the results of the previously referenced studies;

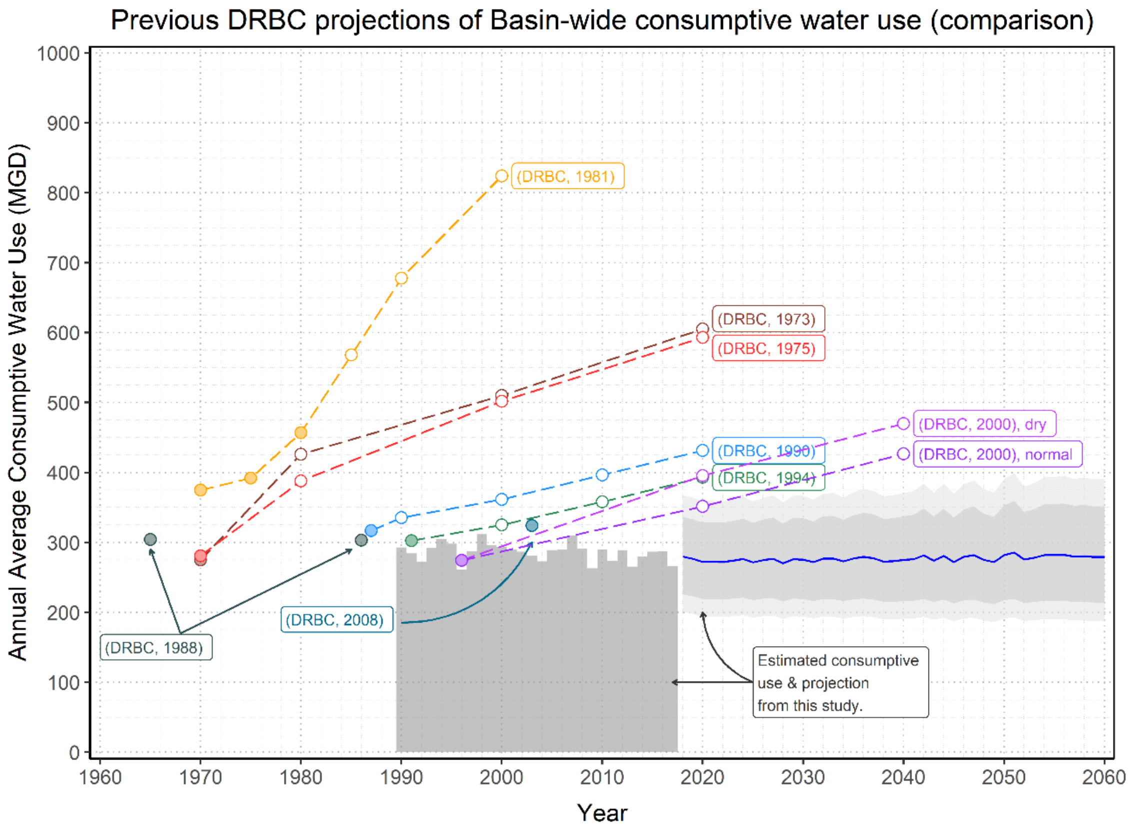

Figure 102: Previous DRBC projections of Basin wide consumptive water use as compared to the current study. *Note that this figure is an updated version of the analysis presented as Figure 3. The projection data from previous studies correspond with the reports outlined in Table 2 (filled circles represent historical estimates, hollow circles represent projections). The historical estimated consumptive use (1990-2017, grey shading) and projection (solid blue line) from the current study correspond to that presented in Figure 100; however, the out-of-Basin diversions are not included to be consistent with previous studies.*

filled circles represent historical estimates of consumptive use, and hollow circles represent projections. This figure was amended to include the data and projections from Figure 100, and the updated version is presented as Figure 102. Overall, the Basin-wide consumptive water use estimated in this study compares to previous estimates fairly well. Out-of-Basin diversions were excluded for consistency with previous studies.

It is worth noting that many previous projections were typically based upon one year of estimated consumptive water use and projecting via indirect methods. Additionally, many included significant increases in consumptive use by the power generation sector based on trends in power generation and withdrawals, prior to significant trend changes observed starting around 2007 (Section 5.3). While the projection provided in the current analysis is the only one that does not result in substantial increases, the estimated historical data (1990-2017) supports this conclusion.

3. The population residing within the Delaware River Basin in 2010 was estimated to be approximately 8.252 million people, of which approximately 86% reside within public water supply service areas (7.106MM) and approximately 14% reside outside of public water supply service areas (1.146MM). Furthermore, it was shown that the population has not only increased historically but is projected to continue increasing under Shared Socioeconomic Pathway scenario SSP2 (Figure 28). Public water supply withdrawals largely end up serving residential populations; however, the projected trend in

withdrawals is counter that of population growth in the Delaware River Basin (Figure 9). The projection for public water supply withdrawals indicates continued slight decreases, at a rate slightly smaller than declines in recent history. This projection will likely be representative until water conservation measures are largely exhausted, at which point the projection may begin to more strongly reflect changes in population. Despite a growing Basin-wide population, the projected growth is weighted in areas with municipal water supply, and consequently the self-supplied population (and withdrawal) is also projected to decrease slightly. As consumptive use is calculated for these two sectors using a default rate, the conclusions for consumptive use are largely the same.

4. 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; these findings are consistent with other studies at the national level which highlighted the closure of many such facilities (Section 5.3). The rapid declines in withdrawal by thermoelectric power facilities are projected to slow, with continued decreases almost entirely restricted to facilities using once-through freshwater (OTFW) cooling systems. The withdrawal by OTFW facilities in 2006 was approximately 2,000 MGD whereas the historical decreases resulted in a 2017 withdrawal of 359 MGD and a projected 2060 withdrawal of 100 MGD, with a lower 95% predictive interval of only 66 MGD. As with all sectors, this projection assumes a continuation of recent trends into the future and does not account for the sudden closure of random facilities.

   Despite significant decreases in water withdrawals, consumptive use by thermoelectric facilities has historically remained constant (or even shown a slight increase). This was determined to be attributed to new facilities with recirculating systems that withdrawal less water but use it at a higher consumptive rate, to the point where consumptive water use by non-nuclear facilities has become almost entirely attributed to facilities with recircuiting cooling (Figure 41).

   It is difficult to predict what changes may occur Basin-wide in this sector with changing national priorities and regional strategies addressing generation technologies (e.g., wind and solar). As was shown in Section 5.3, the total net generation currently provided by solar, wind and hydropower was only 1% of that generated in the Delaware River Basin for 2019. There are also many regional considerations, as neighboring watersheds (e.g., Susquehanna and Hudson) help supply the same energy grid which spans to areas past the Great Lakes (Figure 31).

5. Self-supplied water withdrawals by the industrial sector have historically been driven by a handful of major facilities that include industries such as steel manufacturing and fabrication, chemical manufacturing, paper production and refineries. These facilities can have significant impacts on withdrawal trends (e.g., Bethlehem Steel closure, Figure 54) and consumptive use trends (e.g., closure of Philadelphia Energy Solutions). It is not in the scope of this study to attempt to predict such facility closures, nor is the study meant to correlate self-supplied industrial withdrawals with economic indicators for the Basin. That said, despite historical decreases the projection of facility level trends indicates a plateau and even slight reversal of this trend.

6. An assessment of mining records in the Delaware River Basin suggests that there are many scales and categories of mineral related operations (Figure 66); however, it is understood that not all operations require the withdrawal of water. More importantly, it was determined that this sector likely has room for improvement in terms of reporting actual water withdrawals to state agencies; furthermore, electronic data sharing may also be an area for improvement. The projection of withdrawals is relatively constant and has wide prediction intervals commensurate with the quality of extrapolated data. The consumptive use is calculated primarily with a default ratio, and therefore the results mirror those of the withdrawals.

7. Most agricultural irrigation in the Delaware River Basin was shown to occur in the Atlantic Coastal Plain areas of Delaware and southern New Jersey (Figure 73). Reporting of withdrawals in the irrigation sector have improved over time; therefore, the most recent records were leveraged to drive

the projection. It was demonstrated that a relationship exists between weather and irrigation demand, which led to a multi-variate projection using a downscaled regional climate model output for temperature. Two different climate change scenarios were evaluated (RCP 4.5 and 8.5), both of which indicated increasing irrigation withdrawals. All consumptive use was calculated using a default value, and therefore the results mirror those of the withdrawals. The results for RCP 8.5 were presented in this section.

It is important to highlight that this study is focusing on annual average demands, not maximum monthly or peak daily demands (which will be different and vary based on the sector). The results of this assessment extend beyond that of just the Basin-scale and are able to be downscaled to various spatial planning scales. The following report subsections highlight how the results can be aggregated for different applications. Finally, extensive effort was put forth to compile the results into a usable dataset (Appendix A) such that others in the Basin may make use of this data for their purposes. DRBC plans to take the results of this projection work and incorporate them into both groundwater and surface water availability assessments.

10.2 Basin states

The water withdrawal and consumptive use estimates and projections can be aggregated by each Basin-state, as presented in Figure 103 and Figure 104. It is evident from these figures that there are broad categorical differences between states based on which sector accounts for the majority of water being withdrawn and consumptively used.

- **Delaware.** Considering data in the last five years (2013-2017, which averaged 644.124 MGD), the withdrawals in Delaware are heavily attributed to three sectors. The withdrawals were split between industrial (46.5%), thermoelectric power (41.2%) and public water supply (9.3%). The projected withdrawals in 2060 indicate little growth in self-supplied domestic (+2.686 MGD), public water supply (+0.996 MGD), irrigation (+1.196 MGD) and industrial withdrawals (+0.385). However, the overall projection is driven by declines in withdrawals for thermoelectric power (-165.014 MGD). Interestingly, consumptive use is projected to increase across all sectors, except mining and the other sector, totaling an increase of about +1.566 MGD in consumptive used by 2060.
- **New Jersey.** Withdrawals in New Jersey over the last five years have averaged about 4,344.776 MGD and are predominantly split between thermoelectric power (71.3%) and hydroelectric power (18.6%). However, this includes the largest withdrawal in the Basin (a nuclear power generation facility, which draws water from the Delaware Estuary) and may slightly mischaracterize withdrawals from the New Jersey portion of the Delaware River Basin. Excluding hydroelectric power facilities and thermoelectric power facilities using once-through saline cooling, the total average withdrawal is reduced to 613.529 MGD for the same time period. This value is proportionally split between thermoelectric power (28.5%), public water supply (27.4%), out-of-Basin diversions (13.7%), mining (9.7%), irrigation (7.5%), industrial (6.0%), self-supplied domestic (4.9%) and other sector (2.3%). The projection for all data (2018-2060) indicates decreases in thermoelectric power (-14.270 MGD), public water supply (-6.052 MGD), self-supplied domestic (-4.769 MGD) and industrial withdrawals (-2.395 MGD); increases are projected for irrigation (+5.490 MGD), mining (0.999 MGD) and the other sector (0.077 MGD).

  Consumptive use over the last five years (2013-2017, which averaged 97.096 MGD) has been predominantly split between irrigation (42.1%), thermoelectric power (20.6%) and public water supply (17.3%). Most sectors have a negligible change in projected values from 2018-2060 (<1 MGD either way), whereas irrigation was projected to increase +4.941 MGD. These values exclude the out-of-Basin diversions, which averaged 84.230 MGD over the same time period.

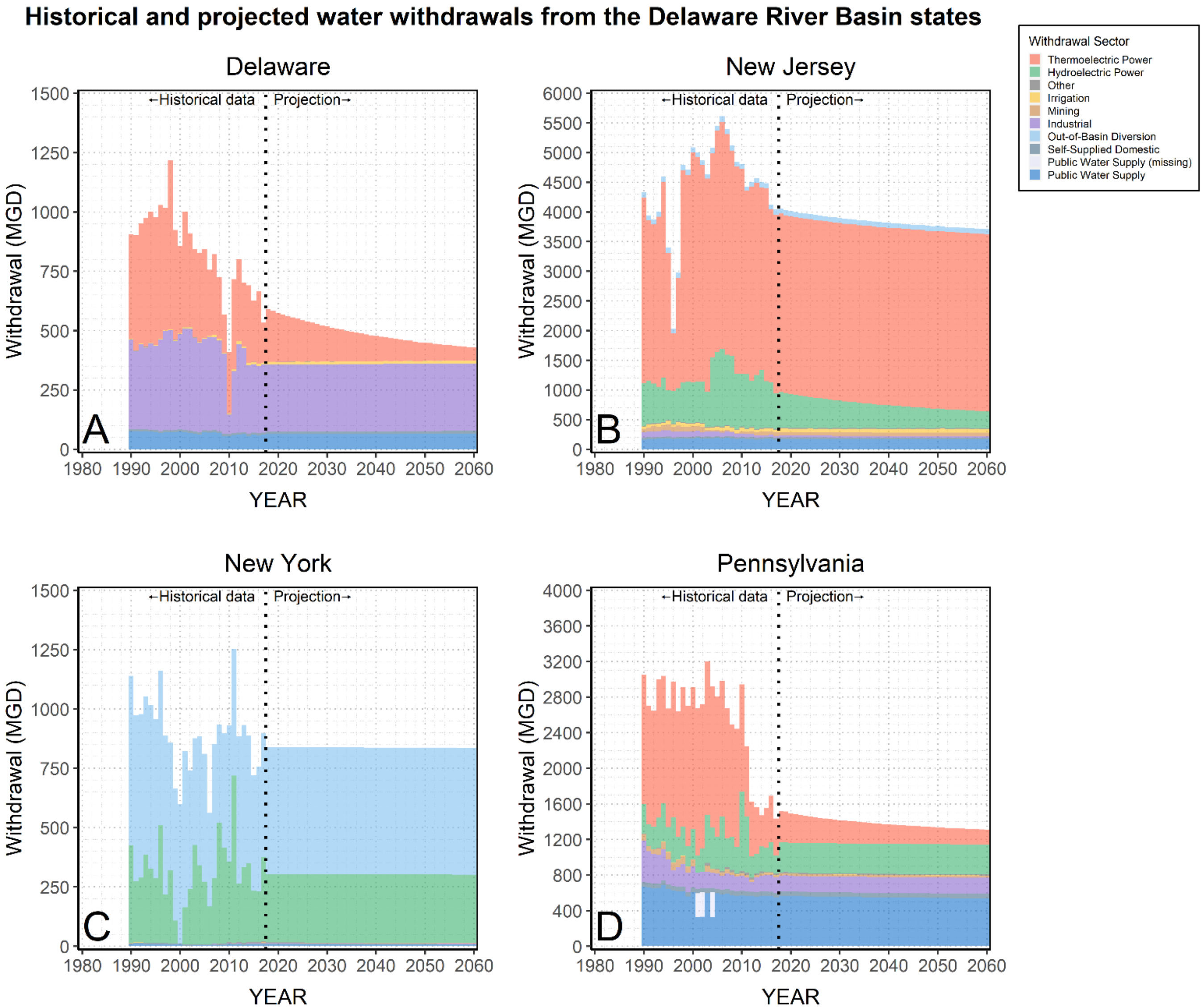

Figure 103: Historical and projected water withdrawals from the Delaware River Basin, separated by state and classified by withdrawal sector.

- **New York.** The overwhelming majority of water being withdrawn in New York is for out-of-Basin diversions (63.7%) and hydroelectric power generation (34.1%), based on average values from the last five years (2013-2017). This means that all other sectors only account for about 18.831 MGD (or about 2.2% of the total withdrawals in the New York portion of the DRB). While hydroelectric withdrawals are considered to have zero consumptive use (in this study), consumptive use is eclipsed by the out-of-Basin diversions that are considered entirely consumptive.

  Thus, it may be more appropriate to indicate proportions of the remaining withdrawals (not out-of-Basin diversions or hydroelectric) based on the projected values for 2018-2022. The remaining withdrawals average 16.164 MGD, which are attributed to public water supply (46.0%), self-supplied domestic (28.0%), industrial (10.4%), mining (9.4%), irrigation (3.9%) and the other sector (2.3%). The resulting breakdown of consumptive use for these sectors for the same projection period (2018-2022) suggests the majority is attributed to public water supply (35.7%), self-supplied domestic (21.8%) and irrigation (27.4%).

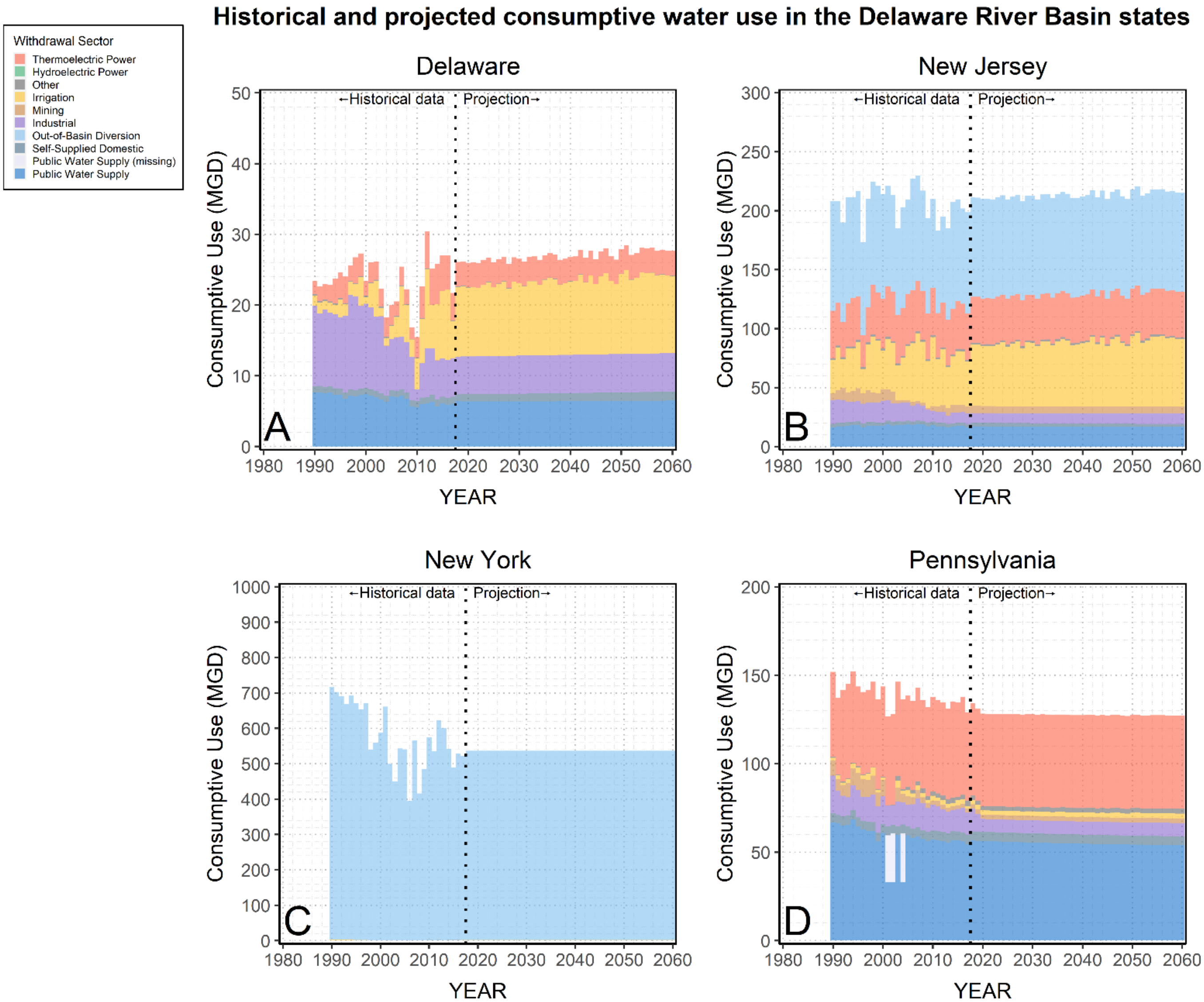

Figure 104: Historical and projected consumptive water use in the Delaware River Basin, separated by state and classified by withdrawal sector.

- **Pennsylvania.** Withdrawals in Pennsylvania were clearly impacted by the changes in trends within the thermoelectric power sector. Considering data in the last five years (2013-2017, which averaged 644.124 MGD), the proportional distribution of withdrawals has changed since the 1990's and 2000's. The four primary sectors have been public water supply (36.2%), thermoelectric power (29.3%), hydroelectric power (16.9%) and industrial (11.7%). Only three of these sectors showed significant changes in the projection for 2018-2060, including thermoelectric power (-189.589 MGD), public water supply (-26.846 MGD) and industrial (+4.931 MGD). The consumptive use for the last five years (2013-2017, which averaged 133.619 MGD), was predominantly split between public water supply (41.8%), thermoelectric power (39.6%) and industrial (9.5%). Only two of these sectors showed significant changes in the projection for 2018-2060, including industrial (-5.302 MGD) and public water supply (-2.685 MGD).

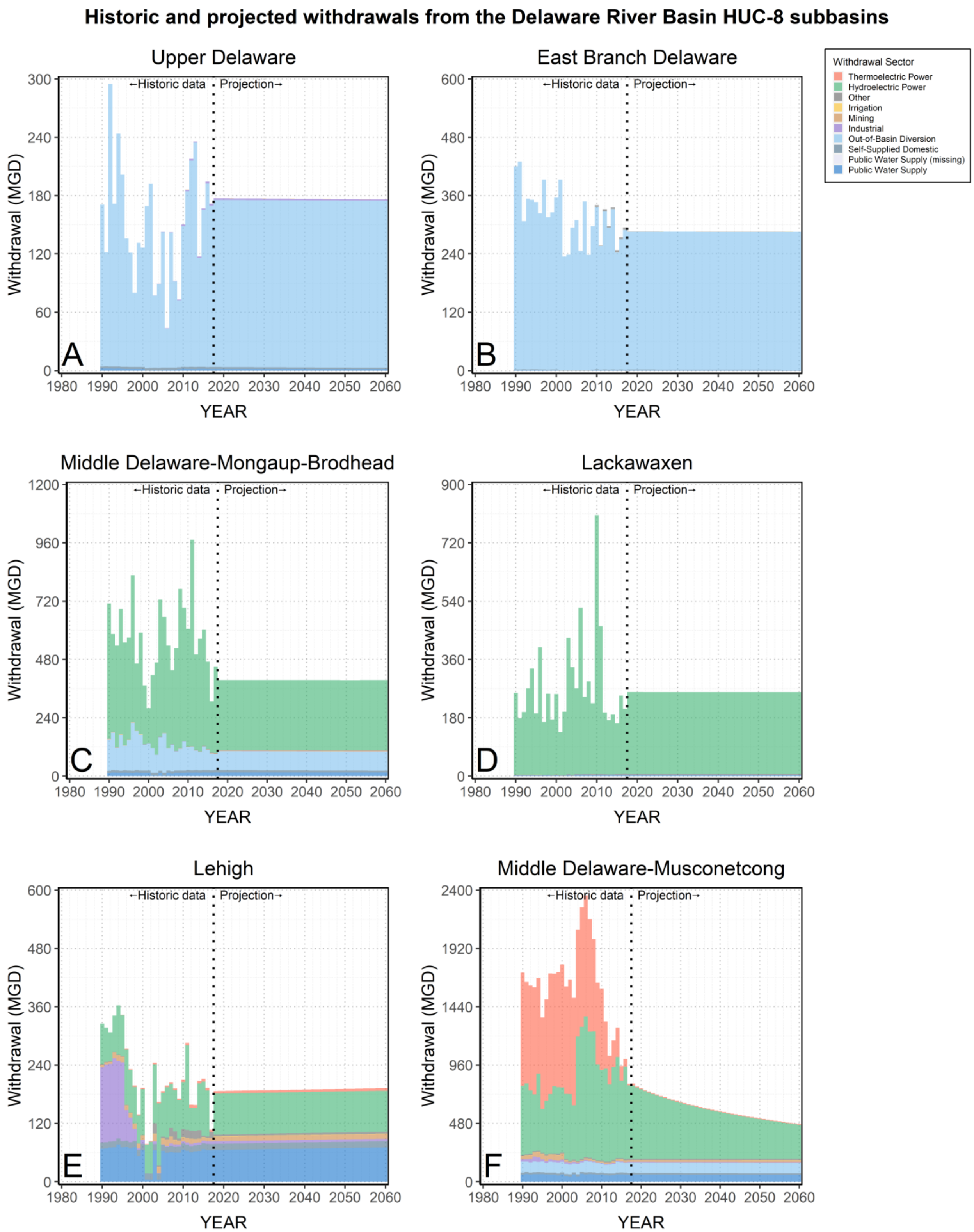

Figure 105: Historical and projected water withdrawals from the Delaware River Basin, separated by HUC-8 subbasin and classified by withdrawal sector.

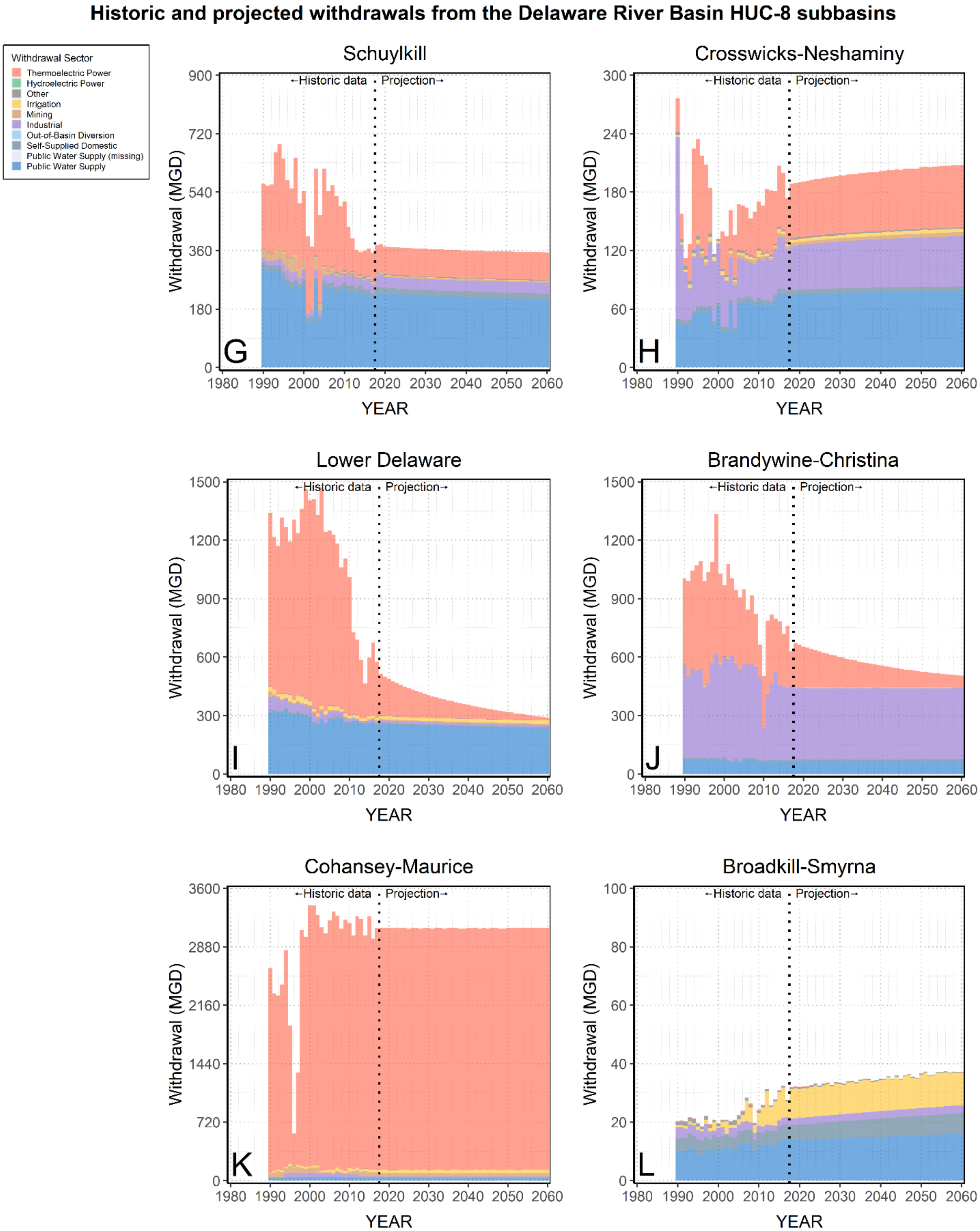

Figure 105: Historical and projected water withdrawals from the Delaware River Basin, separated by HUC-8 subbasin and classified by withdrawal sector.

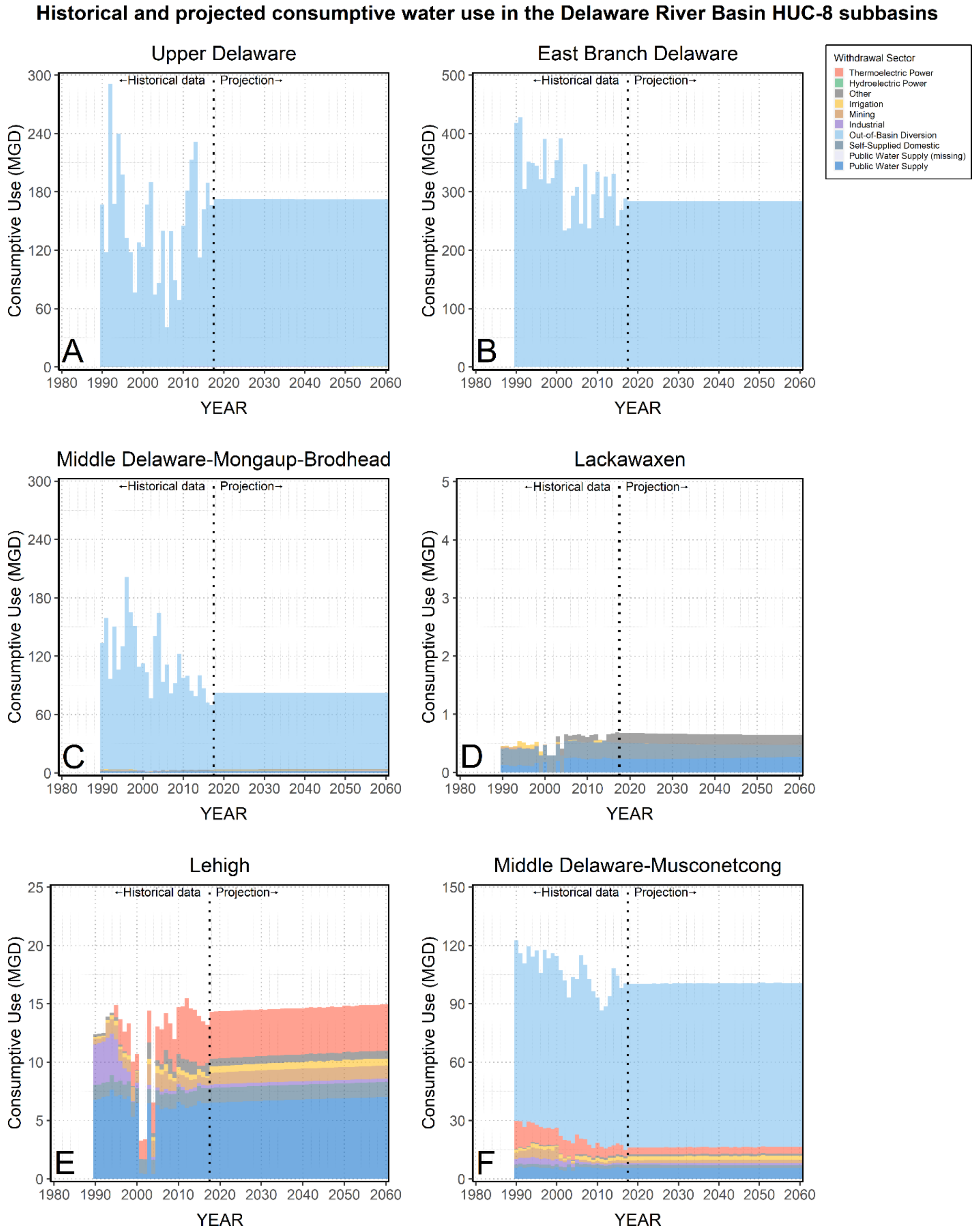

Figure 106: Historical and projected consumptive water use in the Delaware River Basin, separated by HUC-8 subbasin and classified by withdrawal sector.

Historical and projected consumptive water use in the Delaware River Basin HUC-8 subbasins

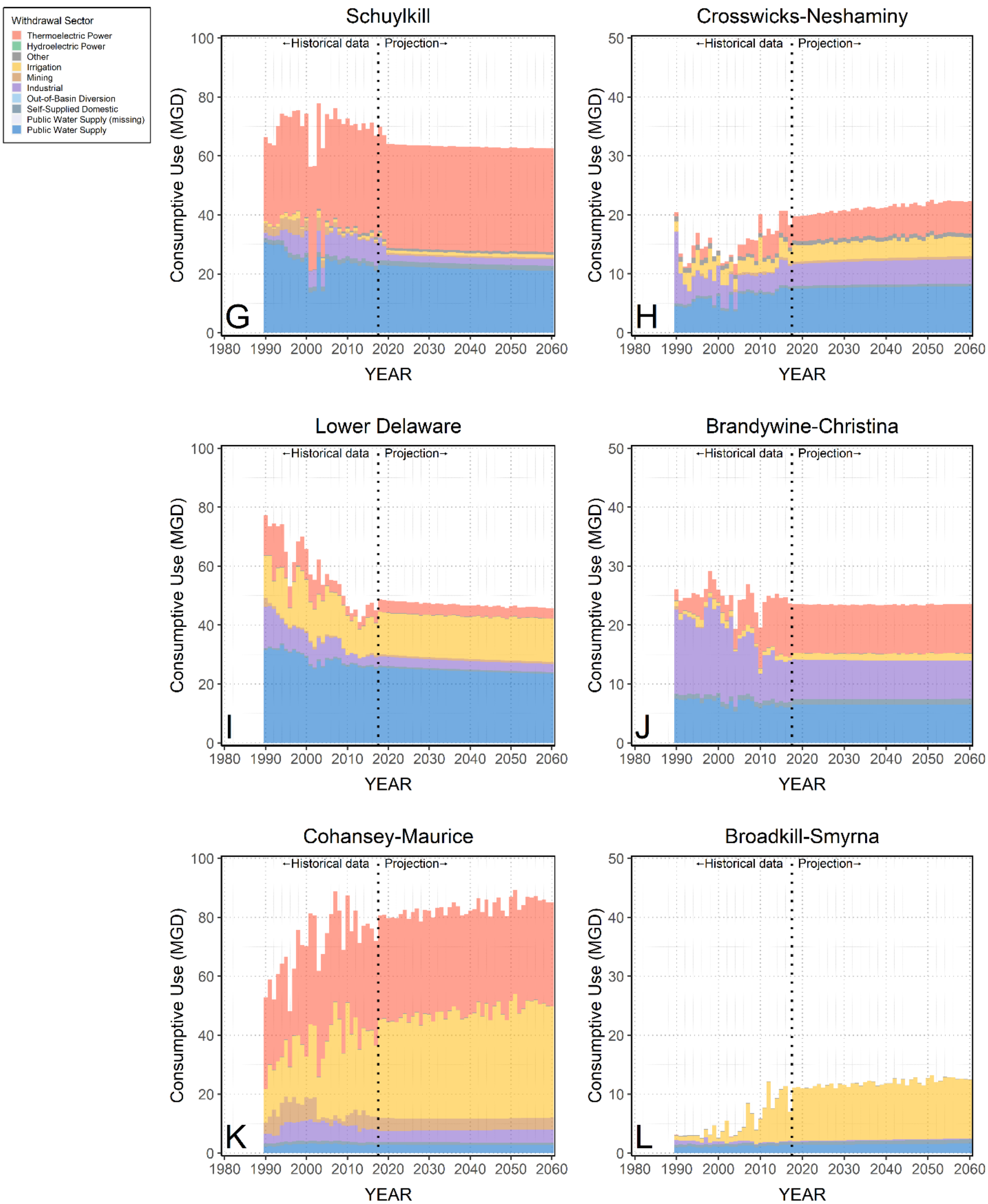

Figure 106: Historical and projected consumptive water use in the Delaware River Basin, separated by HUC-8 subbasin and classified by withdrawal sector.

Table 60: Summary of projected withdrawal change from 2018 to 2060 for each HUC-8 subbasin and sector.

HUC-8 \ Sector	Thermoelectric Power	Hydroelectric Power	Other	Irrigation	Mining	Industrial	Out-of-Basin Diversions	Self-Supplied Domestic	Public Water Supply	**Subbasin Totals:**
Brandywine-Christina (PA/DE)	-164.892	NA	-0.002	0.129	-0.154	-0.628	NA	1.191	-0.611	-164.965
Broadkill-Smyrna (PA)	-0.122	NA	-0.284	1.080	NA	0.399	NA	1.887	2.337	5.296
Cohansey-Maurice (NJ)	-0.145	NA	0.124	4.786	-1.606	-1.422	NA	-1.895	-0.679	-0.838
Crosswicks-Neshaminy (PA)	8.364	NA	-0.599	0.290	0.875	6.391	NA	-0.440	4.317	19.199
East Branch Delaware (NY)	NA	NA	NA	0.000	0.000	NA	0.000	-0.319	-0.153	-0.472
Lackawaxen (PA)	NA	0.000	0.000	NA	0.000	NA	NA	-0.736	0.395	-0.342
Lehigh (PA)	0.215	0.000	0.013	0.027	0.743	-0.078	NA	0.225	4.976	6.121
Lower Delaware (DE)	-201.399	NA	-0.173	0.355	0.339	-1.691	NA	-0.377	-21.921	-224.866
Middle Delaware-Mongaup-Brodhead (PA/NY)	NA	0.000	0.950	0.009	0.975	0.000	0.000	-2.354	0.338	-0.082
Middle Delaware-Musconetcong (PA/NJ)	-10.836	-323.306	0.757	0.106	2.301	1.482	0.000	-2.283	-1.886	-333.665
Schuylkill (PA)	-0.059	NA	0.144	0.105	-1.487	-1.532	NA	1.078	-20.061	-21.813
Upper Delaware (PA)	NA	NA	0.000	0.007	NA	0.000	0.000	-0.743	-0.133	-0.870
Sector Totals	-368.873	-323.306	0.929	6.893	1.987	2.921	0.000	-4.767	-33.081	

Notes:

Cells highlighted RED have values ∆ < -1 MGD
Cells highlighted BLUE have values ∆ > 1 MGD

10.3 HUC-8 Subbasins

Stepping down spatially, the next smallest scale at which to aggregate data moves away from state boundaries and focuses on a regional water resource planning scale (the USGS HUC-8 subbasin, shown in Figure 5). The total water withdrawals from each HUC-8 subbasin are presented in Figure 105, and the consumptive use for each HUC-8 subbasin is presented in Figure 106. Conclusions regarding the spatial distribution of withdrawals based on sector were largely discussed in the state-level analysis, and data here present similar findings. A summary of the 2018-2060 projected differences in withdrawals (in MGD) is provided in Table 60, and the consumptive use summary (in MGD) is provided in Table 61. From these analyses, there are several broad conclusions which can be stated:

1. **Withdrawals are projected to increase in three subbasins**:
   - Crosswicks-Neshaminy, PA (thermoelectric power, industrial and public water supply),
   - Lehigh, PA (primarily public water supply), and
   - Broadkill-Smyrna, PA (public water supply, self-supplied domestic and irrigation).
2. **Withdrawals are projected to decrease in four subbasins:** the Brandywine-Christina (PA/DE), Lower Delaware (DE), Middle Delaware-Musconetcong (NJ) and Schuylkill (PA). Most major decreases are attributed to either thermoelectric power generating or public water supply.
3. **Consumptive use** trends from 2018-2060 show less dramatic magnitude changes than the changes in overall withdrawals. There are two primary sectors driving decreases: self-supplied industrial and public water supply. Whereas irrigation is the primary diver across the Basin for consumptive use increases, smaller regions may have single sectors (e.g., Crosswicks-Neshaminy; thermoelectric) or have increases as the result of many sectors (e.g., Broadkill-Smyrna).

Table 61: Summary of projected consumptive use change from 2018 to 2060 for each HUC-8 subbasin and sector.

HUC-8 \ Sector	Thermoelectric Power	Hydroelectric Power	Other	Irrigation	Mining	Industrial	Out-of-Basin Diversions	Self-Supplied Domestic	Public Water Supply	**Subbasin Totals:**
Brandywine-Christina (PA/DE)	0.038	NA	0.000	0.116	-0.005	-0.250	NA	0.119	-0.061	-0.044
Broadkill-Smyrna (PA)	-0.002	NA	-0.029	0.972	NA	0.014	NA	0.189	0.234	1.377
Cohansey-Maurice (NJ)	-0.047	NA	0.012	4.307	-0.423	0.779	NA	-0.190	-0.068	4.371
Crosswicks-Neshaminy (PA)	1.337	NA	-0.045	0.261	0.105	0.475	NA	-0.044	0.432	2.521
East Branch Delaware (NY)	NA	NA	NA	0.000	0.000	NA	0.000	-0.032	-0.015	-0.047
Lackawaxen (PA)	NA	0.000	0.000	NA	0.000	NA	NA	-0.074	0.039	-0.034
Lehigh (PA)	-0.062	0.000	0.018	0.024	0.130	-0.008	NA	0.023	0.498	0.623
Lower Delaware (DE)	-0.690	NA	-0.040	0.320	0.042	-0.409	NA	-0.038	-2.192	-3.008
Middle Delaware-Mongaup-Brodhead (PA/NY)	NA	0.000	0.205	0.008	0.117	0.000	0.000	-0.235	0.034	0.128
Middle Delaware-Musconetcong (PA/NJ)	-0.093	0.000	0.118	0.095	0.229	0.370	0.000	-0.228	-0.189	0.302
Schuylkill (PA)	-0.058	NA	0.115	0.094	-0.178	-5.409	NA	0.108	-2.006	-7.334
Upper Delaware (PA)	NA	NA	0.000	0.006	NA	0.000	0.000	-0.074	-0.013	-0.082
Sector Totals	0.422	0.000	0.355	6.204	0.016	-4.439	0.000	-0.477	-3.308	

Notes:

Cells highlighted DARK RED Δ < -1.0 MGD
Cells highlighted RED -1.0 MGD < Δ < -0.1 MGD
Cells highlighted BLUE +0.1 MGD < Δ < +1.0 MGD
Cells highlighted DARK BLUE +1.0 MGD < Δ

The Delaware Bay pictured near Lewes, Delaware.
Credit: Chad Pindar, DRBC

10.4 Groundwater (147 subbasins)

The 147 subbasins as defined in Sloto & Buxton, 2006 are nested within the HUC-8 boundaries, and groundwater data can be assessed at this scale. The differences in groundwater withdrawals between the 2018 and 2060 projected values for each subbasin are presented in Figure 107. Multiple conclusions can be drawn from this analysis:

1. It was shown in Figure 101 that the Basin-wide groundwater average withdrawal from 2013-2017 was about 443.915 MGD. The projection model estimates a groundwater withdrawal of 466.739 MGD in 2018 and 465.718 MGD in 2060, suggesting a constant or equilibrium type projection. However, it is evident from Figure 107 that there are actually many subbasins which are projected to have increased groundwater withdrawals. Dividing the subbasins into three groups, it is possible to summarize the total absolute change for each group:
    - Decreasing (Δ < -0.10 MGD) ....51 subbasins (-26.500 MGD)
    - Neutral (-0.10 < Δ < 0.10 MGD)........56 subbasins (-1.451 MGD)
    - Increasing (Δ > 0.10 MGD) ....40 subbasins (+26.930 MGD)
2. Most subbasins with the largest projected decreases are not surprisingly within groundwater management areas, such as Critical Area 2 (New Jersey) and the Southeastern Pennsylvania Groundwater Protected Area.
3. The increases projected for individual subbasins are not related to a single pattern from a single sector but are attributed to local factors affecting water withdrawals. For example, DB-133 is projected to have the highest increase in withdrawals by 2060 (+2.474 MGD), which is largely attributed to the industrial and irrigation sectors. Whereas the subbasin projected to have the second highest increase, DB-130 (+2.305 MGD), is entirely attributed to public water supply and a small portion of self-supplied domestic.

10.5 Groundwater (SEPA-GWPA)

The Southeastern Pennsylvania Groundwater Protected Area (SEPA-GWPA) was established in response to numerous factors such as increasing population and demand for groundwater resources, increased frequency of interference among water users, lowering stream levels, and decreased recharge rates of bedrock geology. The regulations defining the Southeastern Pennsylvania Groundwater Protected Area became effective beginning in January 1981 (18 CFR Part 430, 1980), initially presented in Figure 6. Within the SEPA-GWPA, there are 76 subbasins that are used as assessment units. Assessments are based on numerical groundwater withdrawal limits on a subbasin level that were established based on multiple studies (Schreffler, 1996; USGS, 1998). Therefore, a figure presenting the historical and projected groundwater withdrawals from SEPA-GWPA is presented as Figure 108.

Overall, the data in Figure 108 suggest that groundwater withdrawals have decreased in the SEPA-GWPA from 79.811 MGD (1990-1994 average) to 63.461 MGD (2013-2017 average). Since 2005, the withdrawal rate has not risen above the 1990-1994 average, representing a reduced overall withdrawal of approximately 66.5 billion gallons of groundwater. It is also important to recall that these calculations are only as good as the data input to the projections; advances in the assessment of mining related groundwater data may help to refine these findings in the future.

The projection model in Figure 108 predicted a groundwater withdrawal of 61.921 MGD in 2018 and 61.602 MGD in 2060, suggesting an essentially constant or equilibrium type projection. However, similar to the 147 subbasin analysis, it is important to look at the projected change between 2018-2060 at the 76 subbasin level as shown in Figure 109. Dividing the subbasins into three groups, it is possible to summarize the total changes for each group:

- Decreasing (Δ < -0.10 MGD) ....7 subbasins (-5.273 MGD)
- Neutral (-0.10 < Δ < 0.10 MGD)......51 subbasins (+0.325 MGD)
- Increasing (Δ > 0.10 MGD) ....16 subbasins (+4.629 MGD)

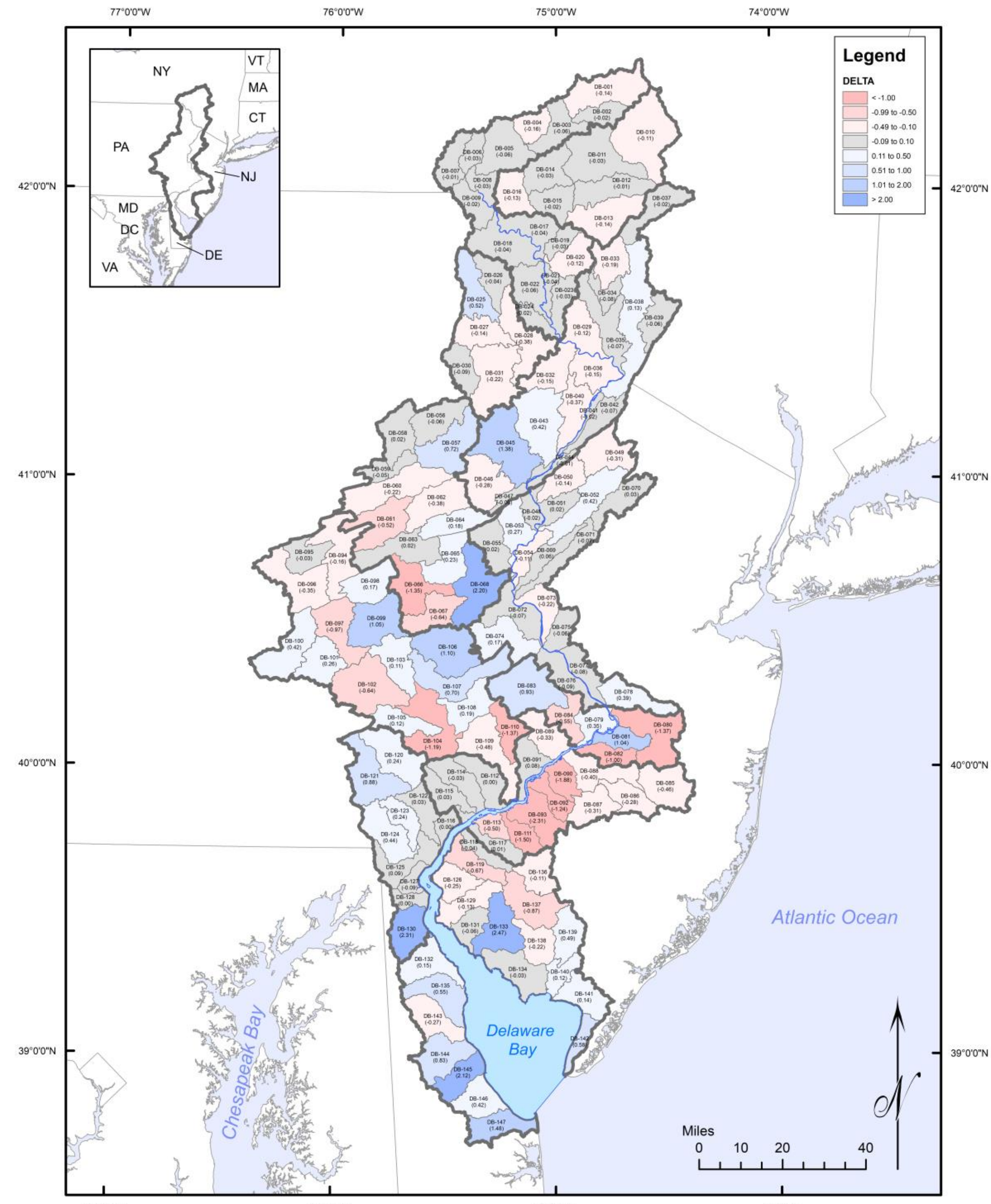

Figure 107: A map of the projected change in groundwater withdrawal by the 147 subbasins, 2018 to 2060. *The subbasins presented were defined in Sloto & Buxton, 2006, initially presented as Figure 5. The subbasins are color coded by the change in groundwater withdrawal based on the projected values for 2018 and 2060.*

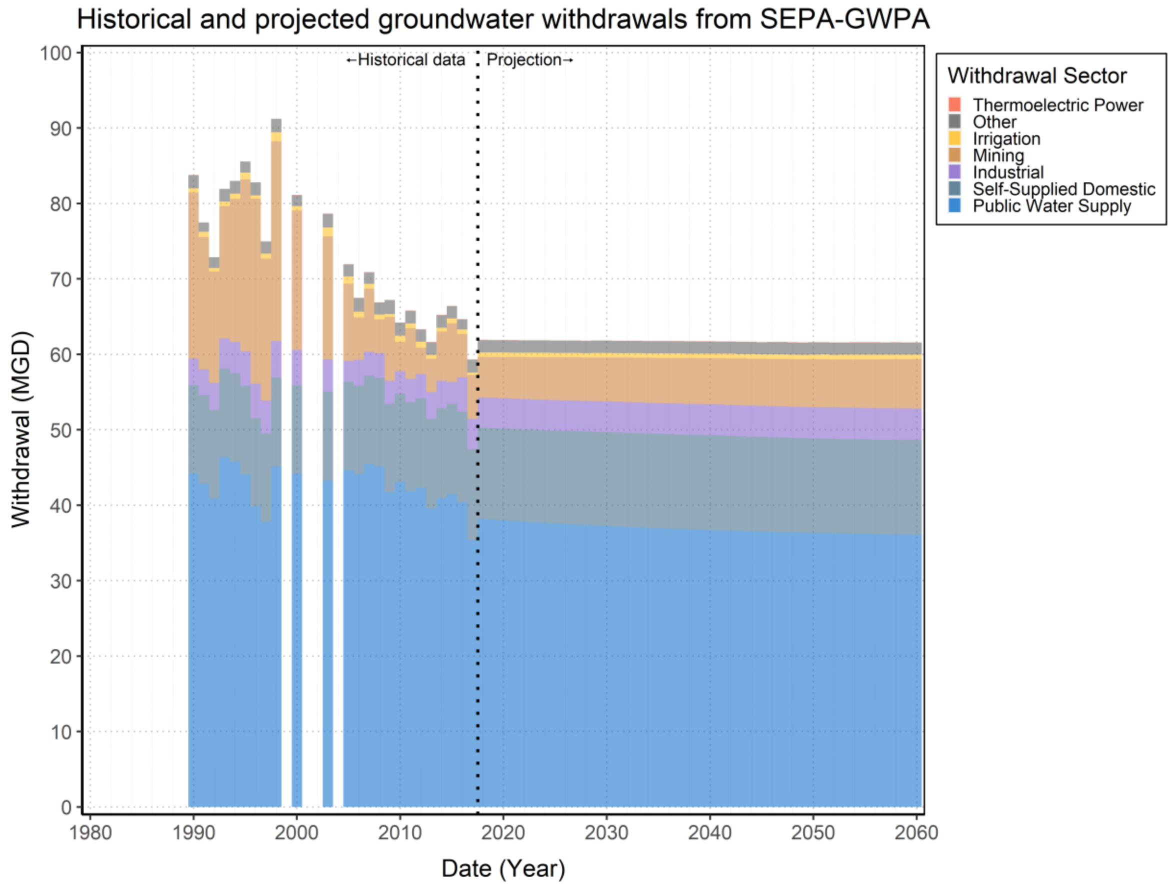

Figure 108: Historical and projected groundwater withdrawals from the Southeastern Pennsylvania Groundwater Protected Area. *The data in this figure represent data from all 76 subbasins, across all withdrawal sectors.*

Table 62*: Summary of results supporting Figure 108 for the projection of water withdrawals from the Southeastern Pennsylvania Groundwater Protected Area, in all sectors. Unassociated surface water was excluded from the 2013-2017 average of the other sector*

Sector	2013-2017 Average	2020	2030	2040	2050	2060
Thermoelectric Power	0.037	0.037	0.037	0.037	0.037	0.037
Hydroelectric Power	0.000	0.000	0.000	0.000	0.000	0.000
Other	1.598	1.627	1.615	1.609	1.605	1.602
Irrigation	0.520	0.579	0.595	0.588	0.629	0.607
Mining	6.063	5.472	5.834	6.113	6.340	6.532
Industrial	3.742	4.029	4.060	4.102	4.145	4.189
Out-of-Basin Diversions	0.000	0.000	0.000	0.000	0.000	0.000
Self-Supplied Domestic	11.939	12.163	12.452	12.565	12.520	12.550
Public Water Supply	39.562	37.998	37.250	36.717	36.342	36.084
Totals:	63.461	61.905	61.845	61.731	61.618	61.602

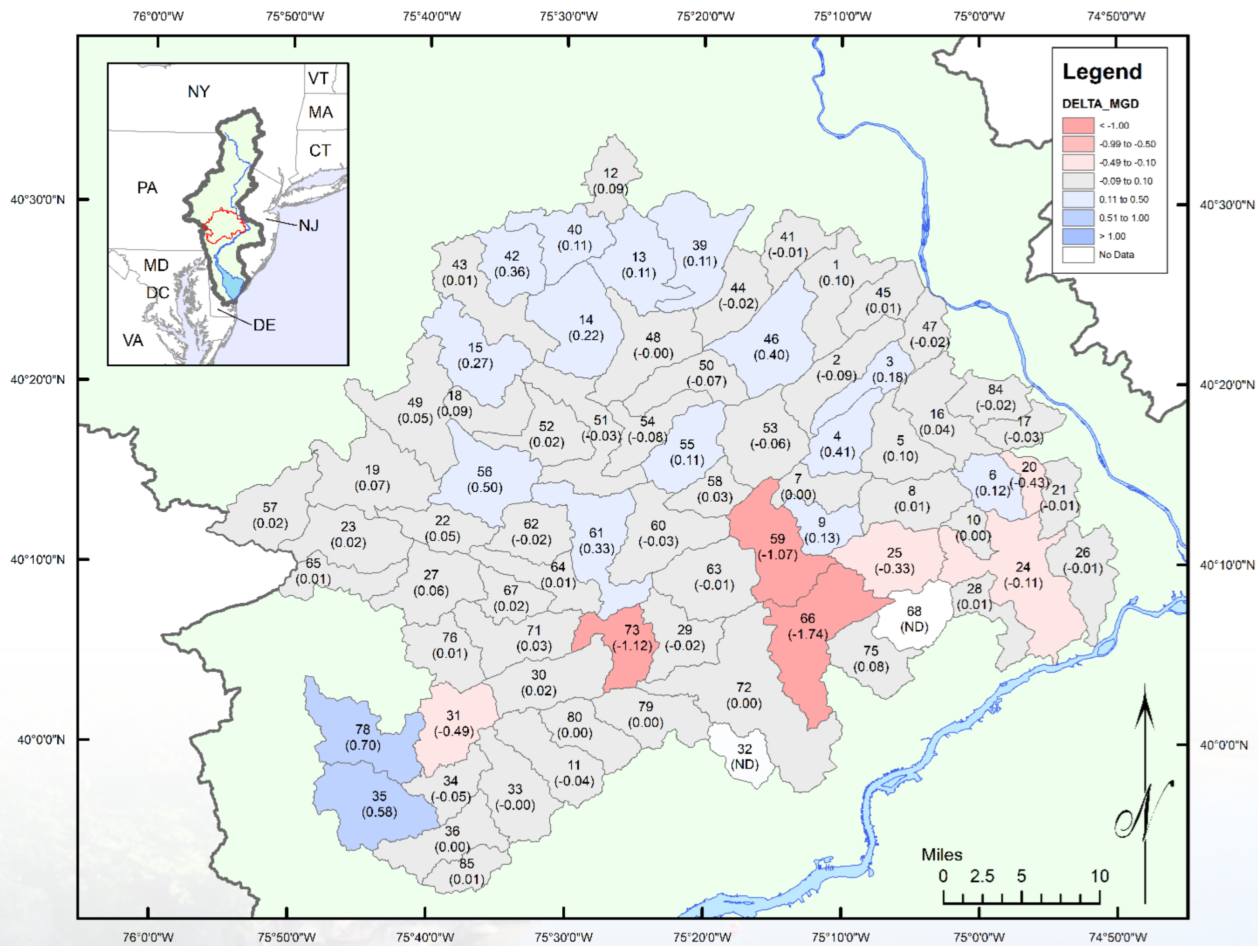

Figure 109: A map of the projected change in groundwater withdrawal by subbasin in the Southeastern Pennsylvania Groundwater Protected Area, 2018 to 2060. *The subbasins were initially presented in Figure 6. The subbasins are color coded by the change in groundwater withdrawal on the projected values for 2018 and 2060.*

The 2019 Delaware River Sojourn
Credit: Chuck Haupt

10.6 Recommendations

More often than not, when conducting studies, researchers must consider external constraints such as time, funding and the intended application of the results. Consequently, there is often room for improvement in most studies. This research is no different, and it was intended that the methods developed in this report look to the future in terms of promoting continued development and improvement. There are some specific recommendations that may help guide future work on projecting water withdrawals in the Delaware River Basin:

- This study has focused on annual average values for the specific needs of DRBC in performing subsequent water availability assessments. However, other planning scales such as maximum monthly withdrawal or daily maximum withdrawal are also important and should be considered.
- Further investigation into default consumptive use rates may be warranted based on the extensive review of both reported data and regulatory approvals. A specific example may include analysis of public water supplier end use percentages (as data become available).
- As system interconnection data could not be located for facilities in Delaware and New York, this information may be helpful in future studies as it is incorporated into reports for review (and is likely more important in northern Delaware than other areas).

- The self-supplied domestic water withdrawal values have additional potential for refinement, specifically using a technique adopted from or similar to that proposed in Van Abs et al., 2018. Application of variable, per-capita rates based on variables such as housing density and physiographic province are understood to be more accurate than a single number; however, such an application was beyond the scope of this work. It did not seem appropriate in this study to apply such a methodology to a single Basin-state, but perhaps a future study on self-supplied domestic withdrawals may assess the entire Basin.
- Continued coordination with stakeholders in the mining and aquaculture sectors to obtain and share data will provide a more complete picture on water withdrawals and would increase model accuracy. While records may exist (e.g., paper files in an office), the emphasis on data accessibility is critical to making such data useful for planning purposes.
- Continued efforts to improve both the reporting compliance and means of estimating/measuring withdrawals in the agricultural sector will improve model predictions.
- Continued development and tracking of the methods outlined in this report will facilitate future model updates. As more data becomes available, it will be beneficial to establish and use a method such that projections can be easily updated.

The Delaware River flowing under the Benjamin Franklin
Bridge with the Philadelphia skyline behind.
Credit: © Chris Boswell
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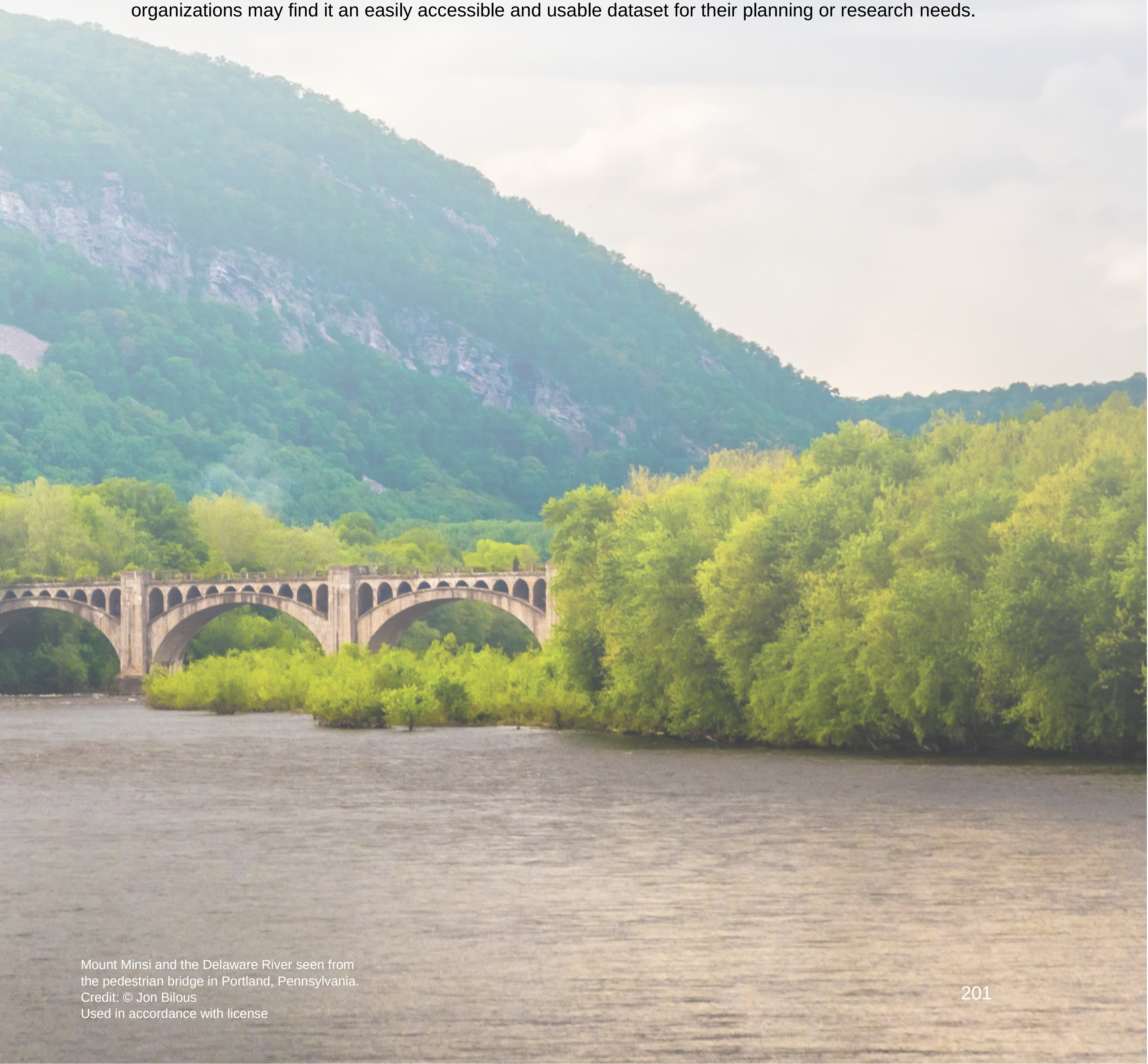
10.7 Closing remarks

A significant amount of data which has been collected over decades has been compiled and assessed as part of this study. It provides the most comprehensive and current opportunity to draw conclusions about the history of water withdrawals from the Delaware River Basin, the consumptive use of that water, and how future water withdrawals may unfold given a continuation of the current trends. The narrative of water use in the Delaware River Basin is continually evolving, and newer and expanded data are constantly available. As is mentioned in the report, some data were incorporated in projections extending past 2017 as it was available or necessary; however, historical data were only ever presented through 2017 as it marks the last year of data providing a complete picture. DRBC has compiled the historical data (1990-2017) and the model projections (2018-2060) in a series of data releases supporting this report in the hopes that other organizations may find it an easily accessible and usable dataset for their planning or research needs.



Mount Minsi and the Delaware River seen from the pedestrian bridge in Portland, Pennsylvania.
Credit: © Jon Bilous
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12 GLOSSARY

Disclaimer:
This report is not a rule, regulation or guidance and has no legal significance. Although certain definitions in this Glossary are derived from the Delaware River Basin Compact and implementing regulations, all definitions, regardless of their sources, are provided solely to assist readers in understanding the data and other information presented herein.

AER Fuel Type: This represents a partial aggregation of the reported fuel type codes into larger categories used by EIA in, for example, the Annual Energy Review (AER). This was selected over 'Reported Fuel Type' data as it provides a more manageable view of the data. For example, the AER fuel type "COL" includes reported fuel types for anthracite coal (ANT), bituminous coal (BIT), lignite coal (LIG), and subbituminous coal (SUB)).

Allocation: *See Water Allocation*

Associated (data or facility): A facility or data which was determined to be associated with some form of regulatory approval related to DRBC. *The opposite of Unassociated.*

Aquaculture: Water use associated with raising organisms that live in water—such as finfish and shellfish—for food, restoration, conservation, or sport.

Aquifer: A waterbearing formation that contains sufficient ground water to be important as a source of supply (18 CFR §430.5).

Basin: The area of drainage into the Delaware River and its tributaries, including Delaware Bay (Pub. L. No. 87-328, 75 Stat. 688, §1.2(a)). *Synonymous with Delaware River Basin, unless specified otherwise*

Cogeneration (or Cogen): A process by which both steam and electricity are produced, both of which may be used or transferred as a commodity.

Commission: The Delaware River Basin Commission created and constituted by the Compact (PL 87-328, 75 Stat. 688, §1.2(b)). *Synonymous with Delaware River Basin Commission (DRBC)*

Compact: Defined as Part I of Public Law 87-328 (Pub. L. No. 87-328, 75 Stat. 688, §1.2(c)). *Synonymous with Delaware River Basin Compact*

Comprehensive Plan: The plans, policies and programs adopted as part of the Comprehensive Plan of the Delaware Basin in accordance with section 3.2 and Article 13 of the Delaware River Basin Compact (18 CFR §430.5).

Consumptive use: 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 (18 CFR §420.1).

Consumptive use ratio (CUR): Is the ratio between the total withdrawal amount, and the portion of the withdrawal which is consumptively used. For specific facilities, a consumptive use ratio may be the result of direct measurement, calculation, estimation, or a "default" value based on the withdrawal category and literature review.

Cooling (once-through): A system which withdrawals a large amount of water, passes the water through a heat exchanger to condense steam, and discharges the water with a heat load. This form of cooling uses more water than a recirculating tower system.

Cooling (recirculating tower): Water is withdrawn into a system where water is sent through a heat exchanged to condense steam, then passed through a cooling tower (or pond) before looping back to the condenser. "Make-up" water is taken into the system to replace water lost to evaporation from the cooling towers (or ponds).

Depletive use: *See also Consumptive use.*

Drought of Record: The drought of record, which occurred in the period 1961-1967, shall be the basis for determination and planning of dependable Basin water supply (DRB Water Code §2.400.1)[1].

Electric nonutility: A corporation, person, agency, authority, or other legal entity or instrumentality that owns or operates facilities for electric generation and is not an electric utility.

Electric utility: A corporation, person, agency, authority, or other legal entity or instrumentality aligned with distribution facilities for delivery of electric energy for use primarily by the public.

End-use (water): The point and or classification at which water is consumed or used, which may or may not be different from the point of withdrawal. *See also Water use*

Export: An exportation of water is water taken from within the Delaware River Basin and transferred or conveyed to an area outside the drainage area of the Delaware River and its tributaries, including the Delaware Bay, and not returned to the Delaware River Basin (DRB Water Code §2.30.1).

Facility: Any entity meeting the definition of the term "facility" as outlined in the Compact (Pub. L. No. 87-328, 75 Stat. 688, §1.2(e)). In the context of this report, it is generally meant as a synonym of Water User, but more specifically, inclusive of the withdrawal sources. *See also Water User*

Fish hatchery: *See also Aquaculture*

GFDL ESM2M: The climate model referenced in this report used in the model for the Irrigation sector.

Groundwater: All water beneath the surface of the ground (18 CFR §430.5).

Groundwater basin: A subsurface structure having the character of a basin with respect to the collection, retention and outflow of water (18 CFR §430.5).

Groundwater protected area: The areas declared and delineated by the Commission to be a ground water protected area pursuant to Article 10 of the Delaware River Basin Compact and these regulations (18 CFR §430.5).

Hydroelectric (conventional): Hydroelectric power generated by the flow of a river and the head developed by damming the river.

Hydroelectric (pumped storage): A hydroelectric system in which electricity is generated during periods of greatest consumption by the use of water that has been pumped into a reservoir at a higher altitude during periods of low consumption.

Import: An importation of water is water conveyed or transferred into the Delaware River Basin from a source outside the drainage area of the Delaware River and its tributaries, including the Delaware Bay. The water is then used, depleted, or discharged within the Delaware River Basin (DRB Water Code, §2.30.1).

Inter-basin transfer: The transfer of water into or out of the river Basin. *See also Export, and Import*

Interconnection: The transfer of water between two separately operated facilities.

Intra-basin transfer: The transfer of water from one location to another, within the same river basin or subbasin.

Legal entitlement: The quantity or volume of water expressed in million gallons per month determined by the lesser of the following condition: (i) A valid and subsisting permit, issued under the authority of one of the signatory parties, if such permit was required as of October 27, 1961, or thereafter; (ii) Physical capability as required for such taking; or (iii) The total allocable flow without augmentation by the Commission, using a seven-day, ten-year, low-flow criterion measured at the point of withdrawal or diversion (18 CFR §420.23(b)(1)).

Make-up water: *See Cooling (recirculating tower)*

Net generation: The amount of gross generation less the electrical energy consumed at the generating station(s) for station service or auxiliaries.

Non-revenue water: Defined by AWWA, it is the sum of unbilled authorized consumption, apparent losses and real losses. "Non-revenue water percent" is defined as non-revenue water divided by the amount of water entering the distribution system times 100 percent (DRB Water Code, §2.1.6(A)).

[1] The Delaware River Basin Water Code is incorporated by reference at 18 CFR Part 410.

Primary Mover Type: The engine, turbine, water wheel, or similar machine that drives an electric generator; or, for reporting purposes, a device that converts energy to electricity directly (e.g. steam turbine [ST]).

Self-supplied: Water users responsible for their own sources of supply, e.g. a residential dwelling with its own well, or an industry with its own water intake.

Signatory party: A state or commonwealth party to the Compact, and the federal government (Pub. L. No. 87-328, 75 Stat. 688, §1.2(h)).

Sourcewater: An aquifer or surface water body from which water is taken either periodically or continuously for off-stream uses.

Southeastern Pennsylvania Ground Water Protected Area (SEPA-GWPA): The "Southeastern Pennsylvania Ground Water Protected Area" shall consist of those portions of the listed counties and political subdivision located within the Delaware Basin, as outlined in 18 CFR §430.7(a).

Subbasin: A drainage area subdivision that forms a convenient natural unit for purposes of resource management. *See also Groundwater basin, see also Watershed*

Surface water: An open body of water such as a lake, river, or stream.

Thermoelectric: The process of using or generating heat to in turn generate electricity (such as steam turbines or combustion turbines). Water is typically used within steam systems and for cooling.

Unassociated (data or facility): A facility or data which was determined not to be associated with some form of regulatory approval related to DRBC. *The opposite of Associated.*

Water Allocation: Generally, a regulated withdrawal of water from a ground or surface source on the basis of total volume and/or rate of withdrawal. This term is also applied to designated amounts of storage in a reservoirs and conservation releases. This is not to be confused with the terms load allocation or waste load allocation which are permitted discharges regulated as part of a TMDL.

Water resources: Includes water and related natural resources in, on, under, or above the ground, including related uses of land, which are subject to beneficial use, ownership or control (Pub. L. No. 87-328, 75 Stat. 688, §1.2(i)).

Water supply: This term is typically used to describe the sum of all water sources available for use. It can be understood in the context of balancing available water supply (what we have) with water demand (what we want). It is distinct from the term Public Water Supply that refers to a specific category of water use.

Water use: Refers broadly to withdrawals (water which is either withdrawn or diverted for any purpose) and/or the end-use of water (the point at which water is consumed or used). *See also Withdrawal, See also End-use*

Water use category: A category assigned to the end-use of water after it is withdrawn.

Water user: Any person, corporation, partnership, association, trust, or other entity, public or private who uses, takes, withdraws or diverts surface waters within the Delaware River Basin (18 CFR §420.1).

Watershed: The total area above a given point on a watercourse that contributes water to its flow; the entire region drained by a waterway or watercourse that drains into a lake, reservoir or bay.

Withdrawal (water): Water withdrawn from its source for any purpose. *See also Water use*

Withdrawal category: A category assigned to withdrawal sources which describe the source/facility performing the withdrawal (and not necessarily the end use of water).

Withdrawal sector: A group of common withdrawal categories for the purposes of planning and data management.

Withdrawal sector (Industrial): Water withdrawals by facilities associated with fabrication, processing, washing, and cooling. This includes industries such as chemical and allied products, food, paper and allied products, petroleum refining (i.e., refineries), and steel. Due to the generally close relationship, water withdrawn for groundwater remediation purposes are also included in this sector. However, this sector does not include withdrawals associated with commercial, mining, or power generation facilities (including cogeneration facilities).

Withdrawal sector (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. Irrigation includes water that is applied for pre-irrigation, frost protection, chemical application, weed control, field preparation, crop cooling, harvesting, dust suppression, leaching of salts from the root zone, and conveyance losses. This does not include withdrawals/diversions associated with aquaculture.

Withdrawal sector (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.

Withdrawal sector (Other): This includes all other categories of withdrawals not captured by the industrial, irrigation, mining, public water supply or power generation sectors. This includes facilities which may be classified as aquaculture, bottled water, commercial (e.g. hotels, restaurants, office buildings, retail stores), fire suppression, hospital/health, military, parks/recreation, prisons, schools, and ski/snowmaking.

Withdrawal sector (Power Generation): Water withdrawn/diverted by facilities associated with the process of generating electricity. Within the Delaware River Basin, this refers water withdrawn/diverted by both thermoelectric (including cogeneration) and hydroelectric facilities. Thermoelectric withdrawals may include both water and reclaimed wastewater, and are typically used for cooling purposes. Hydroelectric facility water diversions are typically used as the primary mover for power generation.

Withdrawal sector (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.

APPENDICES

Rafting on the Delaware River.
Credit Sjohnwilkin
Used in accordance with license

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Appendix A

DATA RELEASE – LIST OF TABLES

PUBLIC WATER SUPPLY SECTOR DATA RELEASE (Section 3)

SELF-SUPPLIED DOMESTIC SECTOR DATA RELEASE (Section 4)

POWER GENERATION SECTOR DATA RELEASE (Section 5)

INDUSTRIAL SECTOR DATA RELEASE (Section 6)

MINING SECTOR DATA RELEASE (Section 7)

IRRIGATION SECTOR DATA RELEASE (Section 8)

OTHER SECTOR DATA RELEASE (Section 8.6)

Appendix B

Example System Report

Individual system reports are not published with this study and are retained by the Delaware River Basin Commission. Should a facility want a copy of their individual projection report, please contact the Delaware River Basin Commission directly.

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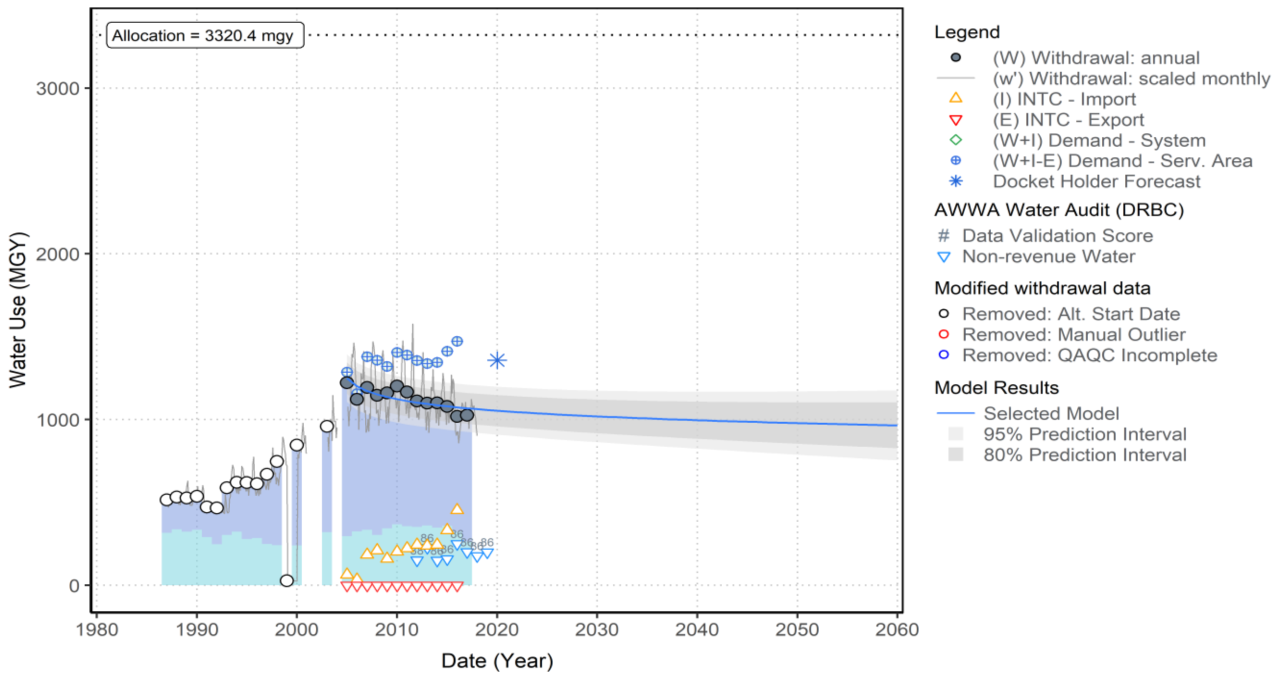
Org Name: Example organization name
System Name: Example system name
WaterUse OAID: 12345
State: DE, NJ, NY or PA
Docket No.: D-1234-567 CP-8
Analysis: 0: Report Cover Sheet



Report Review Information:

Review field	Information
Report Status:	Final
Approved Date:	1/1/1900
Initial Review:	1/1/1900
Reviewer(s):	Staff

All system names for sources included in analysis:

OAID	System Name
12345	Example system name

General conspumtive use information:

Category	Consumptive Use Data
Water use sector:	Public Water Supply
Default sector CUR:	0.1
Manual specify CUR:	NA
Datasource:	NA

Source-specific conspumtive use information:

WSID	Source Name	CUR	CUR.sd	Num pts	Yr.min	Yr.max
1234	Surface water intake #1	0.100	0.000	16	2002	2018

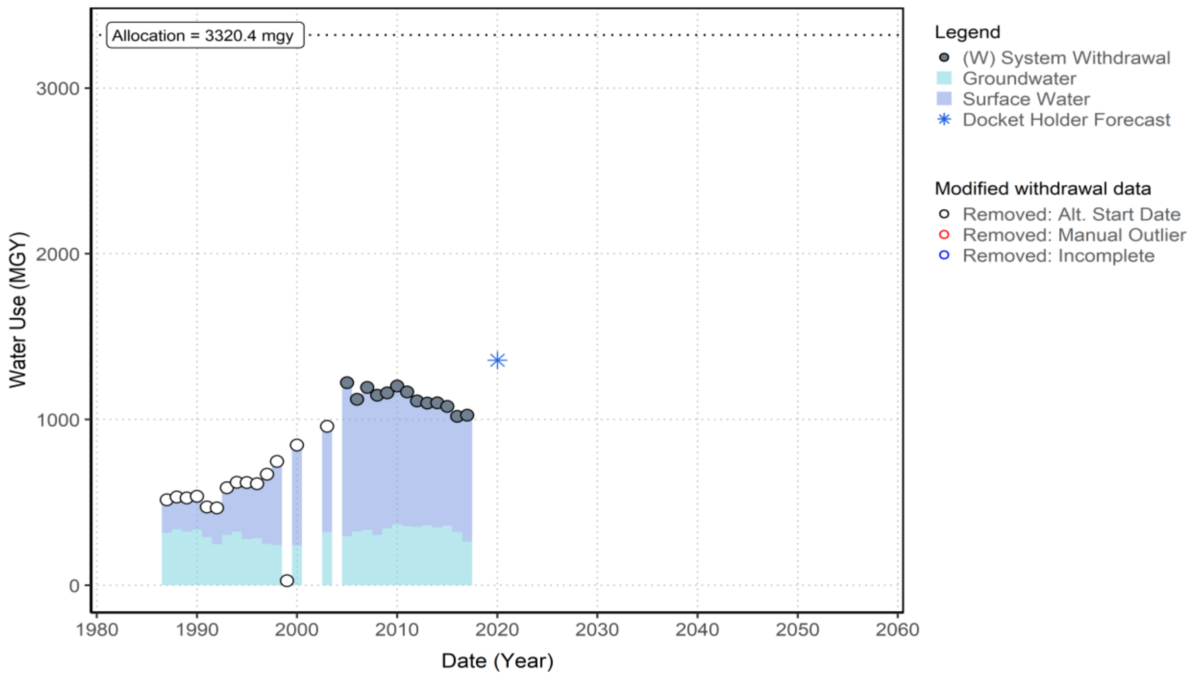
Selected models for water use data:

Level	Des.	WSID	HUC	GWPA	Method	Year (X=1)	Equation (Y= ...)	1.96*RSE	CUR_Cat	CUR
Source	SW	1234	DB-104	NA	LOG	2005	(915.888) + (-70.599)*log(X)	68.245	Calc.	0.100
HUC	GW	3	DB-104	62	AVG	2005	(295.031) + (0)*X	55.121	Default	0.100
HUC	GW	1	DB-105	67	AVG	2005	(38.436) + (0)*X	16.366	Default	0.100

Comments:

Example text can be placed here during staff review to document why decisions were made regarding the final projections. This report includes actual data for a public water supply system, although some data has been removed for confidentiality. The system has both groundwater and surface water sources. There is an interconnection and therefore a service area demand is calculated. Data from the AWWA water audits is included graphically, as well as a projection provided by the docket holder. The selected projection provides an example of an adjusted starting year based on the trends in historic data. All groundwater sources plot within SEPA-GWPA, and therefore the 147-subbasin and 76-subbasin equations are the same (which is not always the case).

Org Name:	Example organization name
System Name:	Example system name
WaterUse OAID:	12345
State:	DE, NJ, NY or PA
Docket No.:	D-1234-567 CP-8
Analysis:	1: System Level Analysis



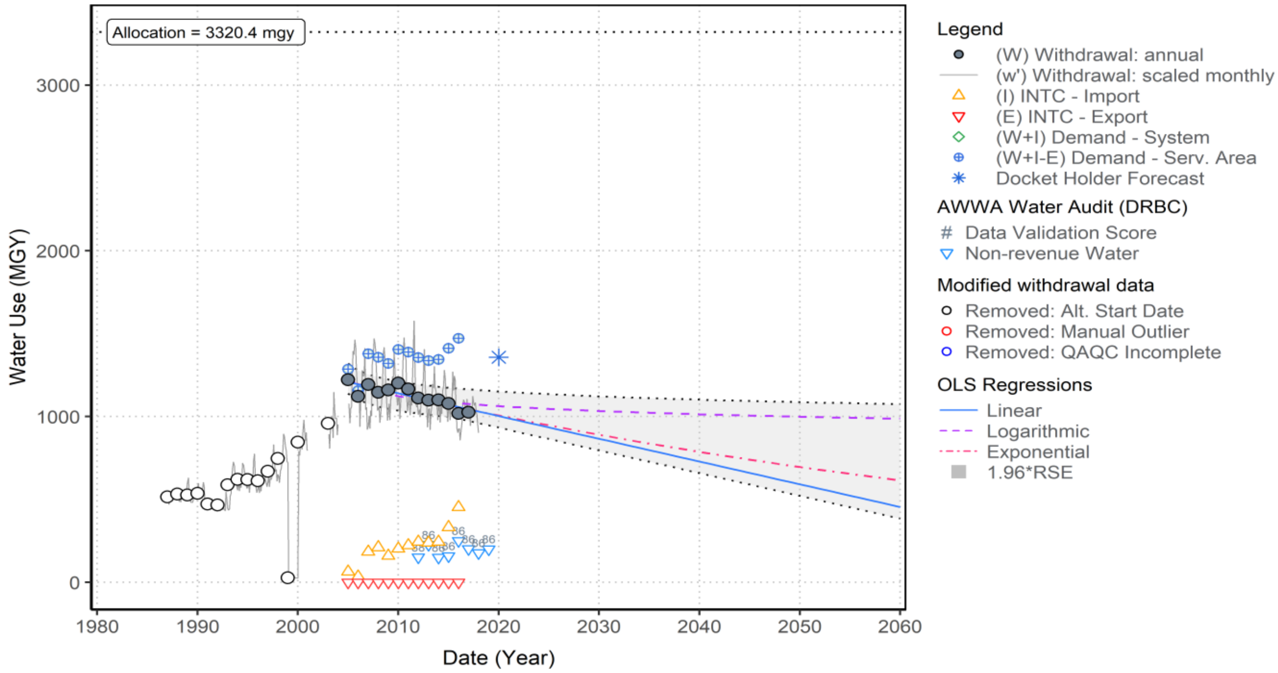
Docket holder forecast (if available):

Description	Value	Units
Year of analysis:	1990	--
Predicted Year:	2020	--
Predicted Avg. Use:	3.72	MGD
Predicted Avg. Use:	1357.8	MGY

Annual data summary in analysis:

Year	UseAmount	With_GW	With_SW	INTC_IMP	INTC_EXP	Qualifier
1987	514.963	316.463	198.500	NA	NA	Removed - bimodal
1988	532.976	338.476	194.500	NA	NA	Removed - bimodal
1989	526.224	323.524	202.700	NA	NA	Removed - bimodal
1990	537.329	335.529	201.800	NA	NA	Removed - bimodal
1991	473.006	290.306	182.700	NA	NA	Removed - bimodal
1992	467.060	247.460	219.600	NA	NA	Removed - bimodal
1993	588.559	303.259	285.300	NA	NA	Removed - bimodal
1994	621.170	323.070	298.100	NA	NA	Removed - bimodal
1995	619.730	278.830	340.900	NA	NA	Removed - bimodal
1996	613.360	285.060	328.300	NA	NA	Removed - bimodal
1997	669.220	248.820	420.400	NA	NA	Removed - bimodal
1998	747.334	242.229	505.104	NA	NA	Removed - bimodal
1999	27.199	27.199	NA	NA	NA	Removed - bimodal
2000	846.559	240.443	606.116	NA	NA	Removed - bimodal
2003	959.120	321.011	638.109	NA	NA	Removed - bimodal
2005	1,221.609	295.891	925.718	64.497	0.000	
2006	1,121.777	325.215	796.562	34.054	0.000	
2007	1,193.795	334.628	859.167	185.401	0.000	
2008	1,146.996	304.263	842.733	211.304	0.000	
2009	1,160.421	343.702	816.719	159.956	0.000	
2010	1,202.586	368.170	834.416	202.911	0.230	
2011	1,166.505	356.465	810.041	223.174	0.000	
2012	1,111.732	352.331	759.401	245.038	0.108	
2013	1,099.392	360.913	738.479	238.769	0.000	
2014	1,100.153	348.219	751.934	245.076	0.000	
2015	1,079.437	360.026	719.411	332.863	0.005	
2016	1,018.740	321.768	696.972	453.387	0.000	
2017	1,026.328	263.485	762.843	NA	NA	

Org Name: Example organization name
System Name: Example system name
WaterUse OAID: 12345
State: DE, NJ, NY or PA
Docket No.: D-1234-567 CP-8
Analysis: 1: System Level Analysis



Modeled data summary:

Param.	Value	Units
Mean:	1126.882	mgy
Mean(5yr)	1064.810	mgy
Median:	1121.777	mgy
Sigma:	63.287	mgy
CV:	0.056	---
x-start:	2005	(i.e. x=1)
NumPts:	13	---

System model thresholds:

Description	Threshold
Adj. R2 min:	0.2
p-value max:	0.05
2060_bottom:	0
2060_runaway:	10
2060_horiz:	0.75-1.25

Withdrawal QAQC thresholds:

QAQC Param.	Threshold
No. months (>=):	3
Low-limit (mgm,<=):	0.01
Bimodal Year:	2005
Outlier Year(s):	1999

System model results summary:

Model	Adj. R2	p-value	2060(mgy)	b-coef	c-coef	1.96_SE	P/F
LIN	0.687	0.000	454.414	1222.949	-13.724	69.384	Pass
LOG	0.504	0.004	987.026	1232.804	-61.058	87.359	Pass
EXP	0.690	0.000	615.421	1226.526	-0.012	70.586	Pass

Equation: y = c*X + b
Equation: y = (c*Ln[X]) + b
Equation: y = b * e^(c*X)

WSID's included in the analysis:

WSID	No. OAID(s)	Desig.	WU-CatID	HUC-147	NoRecords <>(NA,0)	Start	End	Source Name
	1	GW	21	DB-104	314	1987	2017	Groundwater source #1
	1	GW	21	DB-105	332	1987	2017	Groundwater source #2
	1	SW	21	DB-104	324	1987	2017	Surface water intake #1
	1	GW	21	DB-104	320	1987	2017	Groundwater source #4
	1	GW	21	DB-104	319	1987	2017	Groundwater source #3

WSIDs not included in this analysis:

WSID	No. OAID(s)	Desig.	WU-CatID	In DRB?	Reason Excluded	Source Name

There are no other non-INTC sources for this OAID.

INTC's included in the analysis:

PWSID	Primary_WUDS	OAID	Imp_Exp	ToFrom_PWSID	ToFrom_WUDS	ToFrom_OAID	UseAmount	ToFrom_Name
			Import				2306.5	Name #1
			Import				258.1	Name #2
			Import				31.9	Name #3
			Export				0.3	Name #1
			Export				0.0	Name #2
			Export				0.0	Name #3

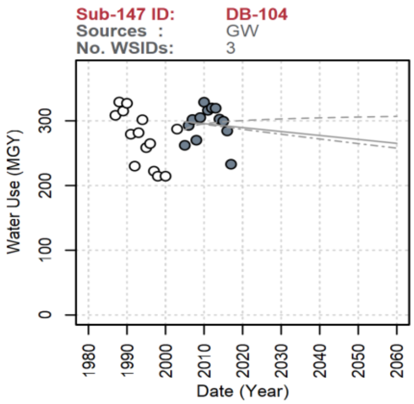
Org Name: Example organization name
System Name: Example system name
WaterUse OAID: 12345
State: DE, NJ, NY or PA
Docket No.: D-1234-567 CP-8
Analysis: 2a: Sub-watershed Analysis (147)

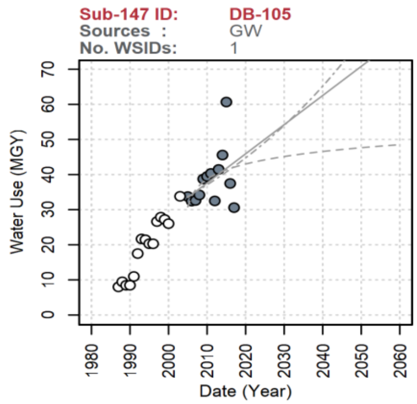
Withdrawal QAQC thresholds:

QAQC Param.	Threshold
No. months (>=):	6
Low-limit (mgm,<=):	0.001
Bimodal Year:	2005
Outlier Year(s):	1999

Legend

- Source Withdrawal
- Removed: Alt. Start Date
- Removed: Manual Outlier
- Removed: Incomplete
- 95% Conf. Interv.
- Linear
- Logarithmic
- Exponential





HUC147	mean	sigma	start	end	pts	Model	Adj.R2	p-val	2060(mgy)	b-coef	c-coef	1.96_SE	P/F
DB-104	295.031	26.926	2005	2017	13	LIN	-0.082	0.775	265.213	299.291	-0.609	54.908	Fail
DB-104	295.031	26.926	2005	2017	13	LOG	-0.068	0.634	306.813	286.108	5.144	54.529	Fail
DB-104	295.031	26.926	2005	2017	13	EXP	-0.078	0.725	257.839	299.356	-0.003	55.008	Fail
DB-105	38.436	7.994	2005	2017	13	LIN	0.088	0.170	79.125	32.623	0.830	14.967	Fail
DB-105	38.436	7.994	2005	2017	13	LOG	0.102	0.152	48.508	30.807	4.397	14.845	Fail
DB-105	38.436	7.994	2005	2017	13	EXP	0.080	0.181	94.913	33.130	0.019	15.098	Fail

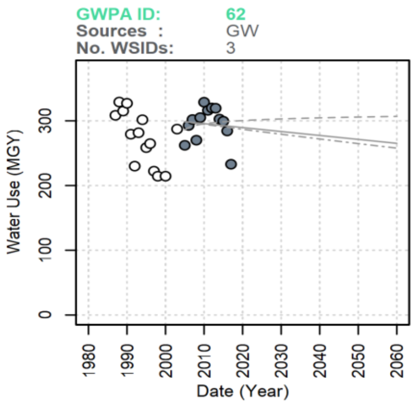
Org Name: Example organization name
System Name: Example system name
WaterUse OAID: 12345
State: DE, NJ, NY or PA
Docket No.: D-1234-567 CP-8
Analysis: 2b: SEPA-GWPA Analysis

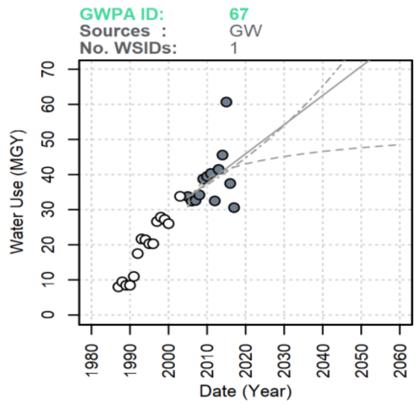
Withdrawal QAQC thresholds:

QAQC Param.	Threshold
No. months (>=):	6
Low-limit (mgm,<=):	0.001
Bimodal Year:	2005
Outlier Year(s):	1999

Legend

- Source Withdrawal
- Removed: Alt. Start Date
- Removed: Manual Outlier
- Removed: Incomplete
- 95% Conf. Interv.
- Linear
- Logarithmic
- Exponential





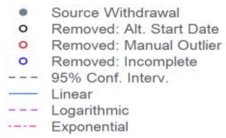
GWPA.ID	mean	sigma	start	end	pts	Model	Adj.R2	p-val	2060(mgy)	b-coef	c-coef	1.96_SE	P/F
62	295.031	26.926	2005	2017	13	LIN	-0.082	0.775	265.213	299.291	-0.609	54.908	Fail
62	295.031	26.926	2005	2017	13	LOG	-0.068	0.634	306.813	286.108	5.144	54.529	Fail
62	295.031	26.926	2005	2017	13	EXP	-0.078	0.725	257.839	299.356	-0.003	55.008	Fail
67	38.436	7.994	2005	2017	13	LIN	0.088	0.170	79.125	32.623	0.830	14.967	Fail
67	38.436	7.994	2005	2017	13	LOG	0.102	0.152	48.508	30.807	4.397	14.845	Fail
67	38.436	7.994	2005	2017	13	EXP	0.080	0.181	94.913	33.130	0.019	15.098	Fail

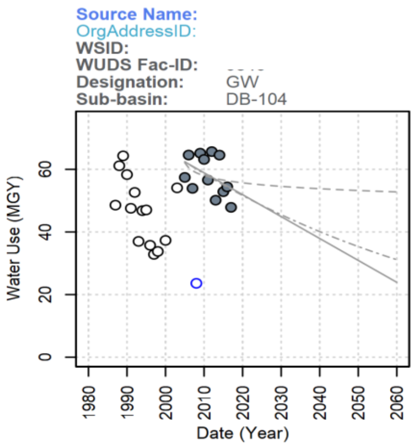
Org Name: Example organization name
System Name: Example system name
WaterUse OAID: 12345
State: DE, NJ, NY or PA
Docket No.: D-1234-567 CP-8
Analysis: 3: Source Level Analysis

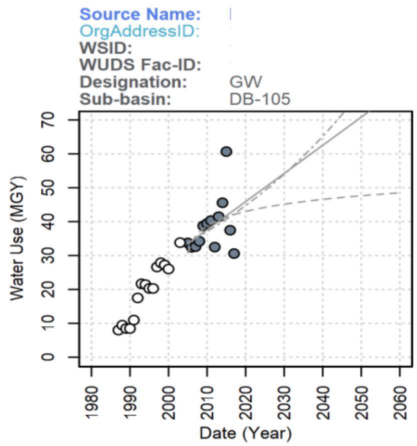
Withdrawal QAQC thresholds:

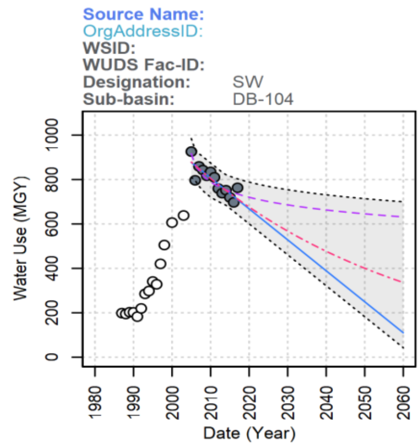
QAQC Param.	Threshold
No. months (>=):	6
Low-limit (mgm,<=):	0.001
Bimodal Year:	2005
Outlier Year(s):	1999

Legend

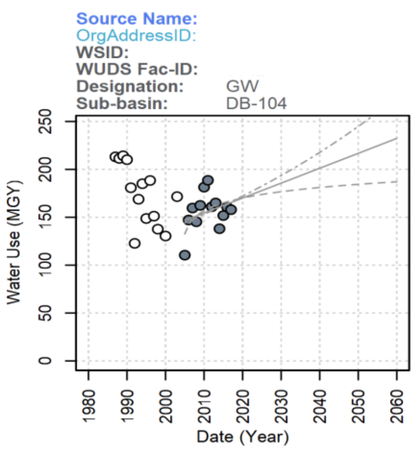


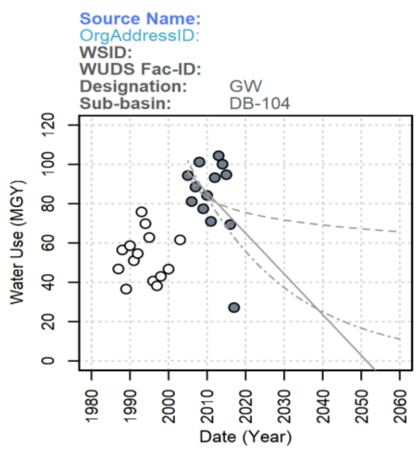






WSID	mean	sigma	start	end	pts	Model	Adj.R2	p-val	2060(mgy)	b-coef	c-coef	1.96_SE	P/F
Source #1	58.026	6.366	2005	2017	12	LIN	0.108	0.158	23.924	63.098	-0.700	11.784	Fail
Source #1	58.026	6.366	2005	2017	12	LOG	-0.009	0.364	52.791	62.110	-2.315	12.532	Fail
Source #1	58.026	6.366	2005	2017	12	EXP	0.123	0.142	31.143	63.244	-0.013	11.862	Fail
Source #2	38.436	7.994	2005	2017	13	LIN	0.088	0.170	79.125	32.623	0.830	14.967	Fail
Source #2	38.436	7.994	2005	2017	13	LOG	0.102	0.152	48.508	30.807	4.397	14.845	Fail
Source #2	38.436	7.994	2005	2017	13	EXP	0.080	0.181	94.913	33.130	0.019	15.098	Fail
Source #3	793.415	63.494	2005	2017	13	LIN	0.707	0.000	110.076	891.035	-13.946	67.335	Pass
Source #3	793.415	63.494	2005	2017	13	LOG	0.699	0.000	631.704	915.888	-70.599	68.244	Pass
Source #3	793.415	63.494	2005	2017	13	EXP	0.712	0.000	336.360	893.914	-0.017	66.722	Pass





WSID	mean	sigma	start	end	pts	Model	Adj.R2	p-val	2060(mgy)	b-coef	c-coef	1.96_SE	P/F
Source #4	156.071	19.362	2005	2017	13	LIN	0.016	0.298	232.310	145.180	1.556	37.646	Fail
Source #4	156.071	19.362	2005	2017	13	LOG	0.221	0.060	187.033	132.622	13.517	33.504	Fail
Source #4	156.071	19.362	2005	2017	13	EXP	0.040	0.246	275.308	142.658	0.012	37.954	Fail
Source #5	83.582	20.333	2005	2017	13	LIN	0.081	0.180	-17.841	98.071	-2.070	38.213	Fail
Source #5	83.582	20.333	2005	2017	13	LOG	0.003	0.330	65.697	97.128	-7.808	39.785	Fail
Source #5	83.582	20.333	2005	2017	13	EXP	0.127	0.126	11.179	105.979	-0.040	40.535	Fail

Appendix C

List of associated facilities

Individual system reports are not published with this study and are retained by the Delaware River Basin Commission. Should a facility want a copy of their individual projection report, please contact the Delaware River Basin Commission directly.

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	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
1	PA	IND	Remediation	D-1986-069 -2	ABB Inc.	ABB Inc.	Modelled
2	PA	IND	Remediation	P-1991-061 -3	ABB Installation Products, Inc.	ABB Installation Products, Inc.	Modelled
3	PA	IND	Industrial	D-1986-079 RENEWAL 2	AGERE SYSTEMS, INC.		Modelled
4	NJ	OTH	Prison	OP-1990-002 CP	ALBERT C WAGNER YOUTH CORRECTIONAL FACILITY	ALBERT C WAGNER YOUTH CORRECTIONAL FACILITY	Modelled
5	PA	PWS	Public Water Supply	D-1991-042 CP-4	ALBURTIS BOROUGH	ALBURTIS BOROUGH	Modelled
6	PA	IND	Industrial	D-1991-042 CP-4	ALBURTIS BOROUGH	Alburtis Borough - Swabia Creek	Not Modeled - OR
7	NJ	PWS	Public Water Supply	AA-1977-060 CP	Allamuchy Township	Allamuchy Township Water Department	Modelled
8	DE	IND	Industrial	AA-1989-043	ALLEN FAMILY FOODS, INC.	Allen Family Foods, Inc. - Harbeson Township	Modelled
9	NJ	PWS	Public Water Supply	D-1989-032 CP REN	Allentown Borough	Allentown Borough	Modelled
10	PA	PWS	Public Water Supply	D-1984-016 CP	Allentown City	Allentown City	Modelled
11	DE	IND	Industrial	ENT-146	ALLIED CHEMICAL CORP. (GENERAL CHEMICAL)	ALLIED CHEMICAL CORP. (GENERAL CHEMICAL)	Modelled
12	NJ	PWS	Public Water Supply	OP-1987-062 CP REN-2	ALPHA BOROUGH	ALPHA BOROUGH	Modelled
13	NJ	MIN	Mining	D-1973-139	ALPHA-FILL INC		Not Modeled - OR
14	PA	OTH	Ski/Snowmaking	D-1990-008-2	Alpine Mountain Ski Area	Alpine Mountain Ski Area	Not Modelled - HD
15	PA	PWS	Public Water Supply	D-1985-026 CP-6	Ambler Borough	Ambler Borough - Whitemarsh	Modelled
16	PA	IND	Remediation	D-2012-005 -1	American Household, Inc.- C/O Newell Co.	American Household, Inc.- C/O Newell Co.	Modelled
17	PA	IND	Remediation	D-1993-025 -3	Ametek US Gauge Division	Ametek US Gauge Division	Modelled
18	NJ	PWS	Public Water Supply	AA-1967-071	ANDOVER BORO WATER DEPT	ANDOVER BORO WATER DEPT	Modelled
19	NJ	PWS	Public Water Supply	AA-1977-061 CP	Aqua New Jersey, Inc.	Aqua NJ - Phillipsburg	Modelled
20	NJ	PWS	Public Water Supply	AA-2000-037 CP	Aqua New Jersey, Inc.	Aqua NJ - Woolwich	Modelled
21	NJ	PWS	Public Water Supply	AA-1977-049 CP-2	Aqua New Jersey, Inc.	Aqua NJ - Riegel Ridge	Modelled
22	NJ	PWS	Public Water Supply	OP-1983-026 CP REN-2	Aqua New Jersey, Inc.	Aqua NJ - Lawrenceville	Modelled
23	NJ	PWS	Public Water Supply	AA-2000-036	Aqua New Jersey, Inc.	Aqua NJ - Hamilton	Modelled
24	NJ	PWS	Public Water Supply	D-1993-013 CP-4	Aqua New Jersey, Inc.	Aqua NJ - Blackwood	Modelled
25	PA	PWS	Public Water Supply	Multiple (See Comments)	Aqua Pennsylvania, Inc.	Aqua PA - Main - Hatboro	Modelled
26	PA	PWS	Public Water Supply	D-1977-094 CP-2	Aqua Pennsylvania, Inc.	Aqua PA - Flying Hills	Modelled
27	PA	PWS	Public Water Supply	D-1975-078 CP-5	Aqua Pennsylvania, Inc.	Aqua PA - Waymart	Modelled
28	PA	PWS	Public Water Supply	D-1989-040 CP REN	Aqua Pennsylvania, Inc.	Aqua PA - UGS South (Spring Run)	Modelled
29	PA	PWS	Public Water Supply	D-2003-033 CP-2	Aqua Pennsylvania, Inc.	Aqua PA - UGS North (Friendship)	Modelled
30	PA	PWS	Public Water Supply	D-2010-042 CP-1	Aqua Pennsylvania, Inc.	Aqua PA - Tanglewood Lakes	Modelled
31	PA	PWS	Public Water Supply	D-2001-015 CP-6	Aqua Pennsylvania, Inc.	Aqua PA - Superior Water Company	Modelled
32	PA	PWS	Public Water Supply	D-1976-104 CP	Aqua Pennsylvania, Inc.	Aqua PA - Perkiomen Woods	Modelled
33	PA	PWS	Public Water Supply	D-2001-050 CP-3	Aqua Pennsylvania, Inc.	Aqua PA - Perkiomen Creek	Modelled
34	PA	PWS	Public Water Supply	Multiple (See Comments)	Aqua Pennsylvania, Inc.	Aqua PA - Main - West Chester	Modelled
35	PA	PWS	Public Water Supply	D-1990-050 CP-3	Aqua Pennsylvania, Inc.	Aqua PA - Main - Uwchlan	Modelled
36	PA	PWS	Public Water Supply	Multiple (See Comments)	Aqua Pennsylvania, Inc.	Aqua PA - Main - Main	Modelled
37	PA	PWS	Public Water Supply	D-1989-097 CP	Aqua Pennsylvania, Inc.	Aqua PA - Main - Bristol	Modelled
38	PA	PWS	Public Water Supply	D-1981-061 CP-4	Aqua Pennsylvania, Inc.	Aqua PA - Lackawaxen	Modelled
39	PA	PWS	Public Water Supply	D-1995-057 CP-2	Aqua Pennsylvania, Inc.	Aqua PA - Honesdale	Modelled
40	PA	PWS	Public Water Supply	D-2014-007 CP-1	Aqua Pennsylvania, Inc.	Aqua PA - Hawley	Modelled
41	PA	PWS	Public Water Supply	D-1985-055 CP-4	Aqua Pennsylvania, Inc.	Aqua PA - Hamilton/Saylors Lake	Modelled
42	PA	PWS	Public Water Supply	D-1993-083 CP-2	Aqua Pennsylvania, Inc.	Aqua PA - Chalfont	Modelled
43	PA	IND	Industrial	D-2008-036 -1	Arcelor Mittal Plate	Arcelor Mittal Plate, Coatesville	Modelled

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
44	PA	IND	Industrial	D-2009-039 -1	Arcelor Mittal Plate	Arcelor Mittal, Conshohocken	Modelled
45	PA	IND	Industrial	D-2010-041 -1	Arkema Inc.	Arkema Inc. - Bristol Plant	Modelled
46	DE	PWS	Public Water Supply	D-2001-025 CP	Artesian Water Company	Artesian Water Company - Windsong	Modelled
47	DE	PWS	Public Water Supply	D-2007-042 CP-1	Artesian Water Company	Artesian Water Company - Weatherstone Crossing	Modelled
48	DE	PWS	Public Water Supply	D-2003-022 CP-4	Artesian Water Company	Artesian Water Company - Southern System	Modelled
49	DE	PWS	Public Water Supply	D-2002-034 CP-4	Artesian Water Company	Artesian Water Company - New Castle County (Main)	Modelled
50	DE	PWS	Public Water Supply	D-2001-034 CP	Artesian Water Company	Artesian Water Company - Church Creek	Modelled
51	DE	PWS	Public Water Supply	D-2004-001 CP-1	Artesian Water Company	Artesian Water Company - Burtonwood (aka Big Oak)	Modelled
52	DE	PWS	Public Water Supply	AA-2010-512	Artesian Water Company	Artesian Water Company - Beaver Creek	Modelled
53	DE	OTH	Prison	D-2000-046 CP	Artesian Water Company	Artesian Water Company - Delaware Correctional Facil	Modelled
54	NJ	IND	Industrial	ENT-390 (D-2007-026-1)	Asbury Graphite Mills Inc.	Musconetcong River	Not Modelled - HD
55	PA	PWS	Public Water Supply	D-1990-052 CP / ENT-103	Auburn Municipal Authority	Auburn Municipal Authority	Modelled
56	PA	PWS	Public Water Supply	D-2004-004 CP-3	AUDUBON WATER COMPANY	AUDUBON WATER COMPANY	Modelled
57	NJ	IND	Industrial	AA-1999-035	Avantor Performance Materials	AVANTOR PERFORMANCE MATERIALS	Modelled
58	PA	IND	Industrial	D-1991-031	AVENTIS PASTEUR INC.	AVENTIS PASTEUR, INC.	Not Modelled - HD
59	NJ	IND	Industrial	OP-1995-033	B & B POULTRY CO INC	B & B POULTRY CO INC	Modelled
60	NJ	MIN	Mining	OP-1990-018 -3	BAER AGGREGATES INC	Baer Aggregates Inc	Modelled
61	NJ	IND	Industrial	OP-1977-042	BASF Corporation		Modelled
62	PA	PWS	Public Water Supply	D-2007-016 CP-2	Bath Borough Authority	BATH BORO MUNI AUTH	Modelled
63	PA	OTH	Ski/Snowmaking	D-2004-035 -2	Bear Creek Management Company	Bear Creek Management Company	Modelled
64	DE	MIN	Mining	D-1999-008	Bear Materials LLC (Parkway Gravel, Inc.)		Modelled
65	PA	PWS	Public Water Supply	D-2004-002 CP-2	Bedminster Municipal Authority	Bedminster Municipal Authority	Modelled
66	PA	PWS	Public Water Supply	P-2004-032 CP-2	Bedminster Municipal Authority	Bedminster Municipal Authority	Modelled
67	NJ	PWS	Public Water Supply	D-1990-082 CP REN	BELLMAWR BOROUGH	BELLMAWR BOROUGH	Modelled
68	NJ	PWS	Public Water Supply	D-1995-024 CP	BERLIN BOROUGH		Not Modelled - HD
69	NJ	PWS	Public Water Supply	OP-2019-507	BERRYMANS BRANCH MOBILE HOME PARK	BERRYMANS BRANCH MOBILE HOME PARK	Modelled
70	PA	OTH	Bottled Water	D-2010-043 -1	BETHANY CHILDRENS HOME	BETHANY CHILDRENS HOME	Modelled
71	PA	PWS	Public Water Supply	D-1995-019 CP-2	Bethlehem City	Bethlehem City	Modelled
72	PA	IND	Industrial	ENT-157	BETHLEHEM STEEL CORP	BETHLEHEM STEEL CORP (INTERNATIONAL STEEL GRO	Modelled
73	PA	PWS	Public Water Supply	D-0000-001 ENT 277	Birdsboro Municipal Authority	Birdsboro Municipal Authority	Modelled
74	PA	PWR	Thermoelectric	D-2016-004 -1	Birdsboro Power LLC	Birdsboro Power LLC	Not Modeled - OR
75	PA	OTH	Commercial	D-1993-027 -3	BLUE MOUNTAIN WATER COOPERATIVE	Blue Mountain Water Cooperative	Modelled
76	PA	PWS	Public Water Supply	D-1991-051 CP	Blythe Township Municipal Authority	Blythe Township Municipal Authority	Modelled
77	NJ	PWS	Public Water Supply	OP-2004-011 CP-2	BORDENTOWN CITY	BORDENTOWN CITY	Modelled
78	NJ	IND	Industrial	D-2000-039	Borealis Compounds, Inc.	Borealis Compounds, Inc. - Chemical Facility	Modelled
79	PA	PWS	Public Water Supply	D-1978-019 CP-3	Borough of Bally	Borough of Bally	Modelled
80	PA	PWS	Public Water Supply	D-1967-123 CP-3	Borough of Phoenixville	Borough of Phoenixville	Modelled
81	PA	PWS	Public Water Supply	D-1980-074 CP	Boyertown Boro	Boyertown Boro	Modelled
82	PA	IND	Industrial	D-1985-080 -4	BOYERTOWN FOUNDRY CO	Boyertown Foundry Co	Modelled
83	NJ	IND	Remediation	OP-1991-032 (G)	BP - Paulsboro	BP - Paulsboro	Modelled
84	NJ	MIN	Mining	AA-2011-504	Braen Royalty Llc	Braen Royalty Llc	Modelled
85	NJ	PWS	Public Water Supply	D-2000-027 CP	Branchville Borough	Branchville Borough	Modelled
86	PA	IND	Industrial	ENT-BRP	BRANDYWINE PAPERBOARD CORP	BRANDYWINE CR	Not Modelled - HD

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
87	NJ	IND	Industrial	D-1972-049 -2	Bridgeport Disposal LLC	Bridgeport Disposal (Safety-Kleen)	Modelled
88	NJ	PWS	Public Water Supply	AA-1998-050 CP	BRIDGETON CITY	City of Bridgeton	Modelled
89	DE	PWS	Public Water Supply	D-1971-195 CP	BROADKILL BEACH WATER CO	BROADKILL BEACH WATER CO	Modelled
90	PA	PWS	Public Water Supply	D-1991-001 CP-4	Brodhead Creek Regional Authority	Brodhead Creek Regional Authority	Modelled
91	NJ	PWS	Public Water Supply	OP-1985-018 CP REN-2	BROOKLAWN BOROUGH	BROOKLAWN BOROUGH	Modelled
92	PA	PWS	Public Water Supply	D-2009-002 CP-1	Buck Hill Falls Co.	Buck Hill Falls Co.	Modelled
93	PA	PWS	Public Water Supply	D-2003-013 CP-7	Buckingham Township	Township Office	Modelled
94	PA	OTH	Commercial	P-2005-017 -2	Buckingham Valley Rehabilitation & Nursing	Buckingham Valley Rehabilitation & Nursing	Modelled
95	PA	IND	Industrial	P-2011-006 -1	Buckman's, Inc.	Buckman's, Inc.	Modelled
96	PA	OTH	Commercial	D-1991-036 CP-3	BUCKS COUNTY	Bucks County	Modelled
97	PA	OTH	School	P-2009-032 -2	Bucks County Community College	Bucks County Community College	Modelled
98	PA	PWS	Public Water Supply	D-1999-066 CP-2	Bucks County Water and Sewer Authority	Bucks County Water and Sewer Authority - Solebury	Modelled
99	PA	PWS	Public Water Supply	D-2004-039 CP-2	Bucks County Water and Sewer Authority	Bucks County Water and Sewer Authority - New Hope	Modelled
100	PA	PWS	Public Water Supply	D-2012-021 CP-1	Bucks County Water and Sewer Authority	Bucks County Water and Sewer Authority	Not Modeled - OR
101	NJ	PWS	Public Water Supply	AA-2002-037	BUENA BOROUGH MUNICIPAL UTILITIES AUTHORITY	BUENA BOROUGH MUNICIPAL UTILITIES AUTHORITY	Modelled
102	NJ	PWS	Public Water Supply	OP-1973-046 CP-2	Burlington City	Burlington City	Modelled
103	NJ	PWS	Public Water Supply	D-1970-127	BURLINGTON COUNTY INSTITUTIONS	Buildings & Grounds	Modelled
104	NJ	PWS	Public Water Supply	OP-1999-050 CP-2	Burlington Township Water Department	Burlington Township Water Department	Modelled
105	PA	MIN	Mining	ENT-150	Buzzi Unicem (HERCULES CEMENT, RC CEMENT CO IN(	BUSHKILL CR	Modelled
106	PA	IND	Industrial	ENT-384	Cabot Supermetals	Cabot Supermetals	Modelled
107	NY	PWS	Public Water Supply	D-2011-012 CP-1	Callicoon Water Company, Inc.	Callicoon Water Company, Inc.	Modelled
108	PA	PWR	Thermoelectric	D-2001-031	Calpine Corporation	Calpine Corporation - Bethlehem	Modelled
109	DE	PWR	Thermoelectric	D-2000-012 CP-2	Calpine Corporation	Calpine Corporation - Edge Moor & Hay Road Energy C	Modelled
110	NJ	PWR	Thermoelectric	D-1992-057 REN	Calpine Corporation	Calpine Corporation - Deepwater Generating Station	Modelled
111	PA	IND	Industrial	D-2012-025 -1	Cambridge-Lee Industries, LLC	CAMBRIDGE-LEE INDUSTRIES, LLC	Modelled
112	NJ	PWS	Public Water Supply	OP-1979-083 CP-1	CAMDEN CITY	CAMDEN CITY	Modelled
113	DE	PWS	Public Water Supply	AA-1997-030 CP	CAMDEN-WYOMING SEWER & WATER AUTHORITY	CAMDEN-WYOMING SEWER & WATER AUTHORITY	Modelled
114	NJ	IND	Industrial	D-1972-082	Campbell Soup Company	Campbell Soup Company	Not Modeled - OR
115	PA	PWS	Public Water Supply	D-1987-060 CP-4	Catasauqua Borough	Catasauqua Borough	Modelled
116	NJ	PWS	Public Water Supply	D-2009-046 CP-1	CEDAR GLEN LAKES WATER CO	CEDAR GLEN LAKES WATER CO	Modelled
117	PA	OTH	School	P-1995-020 -3	Central Bucks School District	Central Bucks School District	Modelled
118	NJ	PWR	Thermoelectric	D-1991-019 -2	Chambers Cogeneration, LP	Carney's Pt. Generating Plant	Modelled
119	DE	IND	Industrial	D-2015-003 -1	Chemours Company, The	Chemours- Edge Moor	Modelled
120	NJ	IND	Industrial	OP-1985-032 -3	Chemours Company, The	Chemours-Repauno	Modelled
121	NJ	IND	Industrial	D-1993-019 -2	Chemours Company, The	Chemours-Chambers Works	Modelled
122	NJ	IND	Industrial	D-1969-059 -2	Chemours Company, The	Chemours-Chambers Works	Not Modeled - OR
123	PA	PWS	Public Water Supply	D-1984-055 CP	Chester Water Authority	Chester Water Authority	Not Modeled - OR
124	DE	IND	Industrial	D-1984-012	CIBA-GEIGY CORP	Ciba-Geigy Corp	Not Modeled - OR
125	PA	IND	Remediation	D-1990-030	CIBA-GEIGY CORP	Ciba-Geigy Corp	Not Modeled - OR
126	DE	PWS	Public Water Supply	D-1978-071 CP-3	City of New Castle	City of New Castle	Modelled
127	NJ	PWS	Public Water Supply	D-2008-042 CP-1	City of Wildwood Water Utility	City of Wildwood Water Utility	Modelled
128	NJ	PWS	Public Water Supply	AA-1995-045 CP	CLAYTON BOROUGH	CLAYTON BOROUGH	Modelled
129	NJ	MIN	Mining	OP-2008-037 -1	Clayton Sand Company	Clayton Sand Company	Modelled

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
130	DE	PWS	Public Water Supply	D-1984-034 CP RENEWAL 3	CLAYTON TOWN	CLAYTON TOWN	Modelled
131	PA	IND	Industrial	D-1999-072 -3	Clemens Food Group, LLC		Modelled
132	NJ	PWS	Public Water Supply	OP-1987-092 CP REN	CLEMENTON BOROUGH	CLEMENTON BOROUGH	Modelled
133	PA	OTH	Ski/Snowmaking	D-2001-040 -2	CMBK Resort Holdings, LLC	CMBK Resort Holdings, LLC	Modelled
134	PA	OTH	Ski/Snowmaking	D-2008-026 -2	CMBK Resort Holdings, LLC	CMBK Resort Holdings, LLC	Modelled
135	NJ	IND	Industrial	OP-1977-086	COIM USA INC. (Formerly Air Products)	Coim USA Inc. (Formerly Air Products)	Not Modelled - HD
136	PA	PWS	Public Water Supply	D-2000-057 CP-2	COLLEGEVILLE-TRAPPE JOINT PUBLIC WORKS DEPARTI	COLLEGEVILLE-TRAPPE JOINT PUBLIC WORKS DEPARTI	Modelled
137	NJ	PWS	Public Water Supply	D-1989-003 CP REN	COLLINGSWOOD BOROUGH	COLLINGSWOOD BOROUGH	Modelled
138	NJ	IND	Industrial	AA-1984-046	COLORITE SPECIALTY RESINS	COLORITE SPECIALTY RESINS	Modelled
139	PA	PWS	Public Water Supply	D-2003-036 CP-3	Community Utilities of Pennsylvania, Inc.	Penn Estates	Modelled
140	PA	IND	Industrial	ENT-166	CONNELLY CONTAINERS, INC	SCHUYLKILL RIVER	Not Modelled - HD
141	PA	IND	Remediation	D-1991-083	COOPER INDUSTRIES, INC	COOPER INDUSTRIES, INC	Not Modelled - HD
142	PA	PWS	Public Water Supply	D-1967-125 CP	COOPERSBURG BOROUGH	COOPERSBURG BOROUGH	Modelled
143	PA	IND	Industrial	ENT-296	Corco Chemical Corporation	Corco Chemical Corporation	Modelled
144	NJ	IND	Industrial	D-1999-023	Corning Pharmaceutical Glass, LLC	Vineland	Modelled
145	PA	PWR	Thermoelectric	D-2011-003 CP-1	Covanta Delaware Valley, LP	Covanta Delaware Valley, LP	Modelled
146	PA	PWR	Thermoelectric	D-2012-016 CP-1	Covanta Plymouth Renewable Energy LP	Covanta Plymouth Renewable Energy LP	Not Modeled - OR
147	NJ	PWR	Thermoelectric	AA-1985-090	COVANTA WARREN ENERGY RESOURCE	COVANTA WARREN ENERGY RESOURCE	Modelled
148	PA	PWS	Public Water Supply	P-1997-002 CP-2	COVENTRY TERRACE MOBILE HOME PARK LLC	COVENTRY TERRACE MOBILE HOME PARK LLC	Modelled
149	NJ	IND	Industrial	D-2001-027 -4	CPI Operations LLC	CPI Operations LLC	Modelled
150	PA	PWS	Public Water Supply	P-1996-062 -2	CRADLE OF LIBERTY COUNCIL/BOY SCOUTS OF AMERI(	CRADLE OF LIBERTY COUNCIL/BOY SCOUTS OF AMERI(	Modelled
151	PA	IND	Industrial	D-2000-033 -2	Crayola, LLC.	Crayola, LLC.	Modelled
152	PA	IND	Remediation	P-2011-021 -1	CRC Industries, Inc.	CRC Industries, Inc.	Modelled
153	DE	IND	Industrial	D-1988-074 -3	Croda Inc.	Croda Uniqema	Modelled
154	NY	OTH	Commercial	D-2016-003 CP-1	Crossroads Ventures, LLC	Crossroads Ventures, LLC	Not Modeled - OR
155	DE	IND	Remediation	D-1978-069	CROWN ZELLERBACH CORP	Crown Zellerbach Corp	Not Modeled - OR
156	NY	PWS	Public Water Supply	D-1986-022 CP-4	Crystal Water Supply Co. Inc.	Crystal Water Supply Co. Inc.	Modelled
157	DE	IND	Industrial	ENT-168	CURTIS PAPER CO (NEWARK MILL)	WHITE CLAY CR	Not Modelled - HD
158	DE	IND	Industrial	D-1967-061	DADE BEHRING, INC	Dade Behring, Inc	Not Modeled - OR
159	PA	MIN	Mining	ENT-278	Dally Slate Company	DALLY QUARRY	Modelled
160	PA	MIN	Mining	ENT-173	Dally Slate Company	DIAMOND SLATE CO (DALLY SLATE CO)	Not Modelled - HD
161	DE	IND	Refinery	D-1993-004 -7	Delaware City Refining Company, LLC	Delaware City Refining Company, LLC	Modelled
162	DE	PWS	Public Water Supply	D-1998-046 CP	DELAWARE CITY, DE	DELAWARE CITY, DE	Modelled
163	DE	OTH	Fish Hatchery	D-1999-076	DELAWARE STATE UNIVERSITY	DELAWARE STATE UNIVERSITY	Modelled
164	PA	OTH	Fish Hatchery	D-2004-008 -2	DELAWARE VALLEY FISH COMPANY		Not Modelled - ND
165	PA	OTH	School	D-1994-050 CP-3	DELAWARE VALLEY UNIVERSITY	Delaware Valley University	Modelled
166	PA	PWS	Public Water Supply	D-1997-032 CP-2	Delaware Water Gap Borough	Delaware Water Gap Borough	Modelled
167	NY	PWS	Public Water Supply	D-1999-064 CP-2	Deposit Village	Village of Deposit	Modelled
168	NJ	PWS	Public Water Supply	OP-1994-068 CP-2	Deptford Township Municipal Utilities Authority	Deptford Township Municipal Utilities Authority	Modelled
169	NJ	MIN	Mining	D-2007-027 -2	DIAMOND SAND AND GRAVEL, INC.	DIAMOND SAND AND GRAVEL, INC.	Modelled
170	PA	OTH	Commercial	D-2012-009 -2	Dorney Park and Wildwater Kingdom	Dorney Park and Wildwater Kingdom	Modelled
171	DE	PWS	Public Water Supply	D-2001-043 CP	DOVER CITY	DOVER CITY	Modelled
172	DE	MIN	Mining	D-1967-104	DOVER EQUIP & MACHINE CO	Dover Equip & Machine Co	Not Modelled - ND

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
173	DE	PWR	Thermoelectric	D-2009-014 CP-1	Dover, City of	McKee Run Generating Station	Not Modeled - OR
174	DE	IND	Industrial	D-1999-032 -2	Dow Reichhold Specialty Latex LLC		Modelled
175	PA	PWS	Public Water Supply	D-1989-063 CP-3	Downingtown Municipal Water Authority	Downingtown Municipal Water Authority	Modelled
176	PA	PWS	Public Water Supply	D-1979-018 CP-6	DOYLESTOWN BOROUGH	Doylestown Borough	Modelled
177	PA	PWS	Public Water Supply	D-1995-009 CP-3	DOYLESTOWN TOWNSHIP MUNICIPAL AUTHORITY	DOYLESTOWN TOWNSHIP MUNICIPAL AUTHORITY	Modelled
178	NJ	IND	Industrial	D-1985-014 -4	DSM Nutritional Products, Inc.	DSM NUTRITIONAL PRODUCTS	Modelled
179	PA	PWS	Public Water Supply	D-2000-011 CP-2	Dublin Borough	Dublin Borough	Modelled
180	NJ	MIN	Mining	AA-2012-501	Dun Rite Sand & Gravel Inc	Dun Rite Sand & Gravel Inc	Modelled
181	NY	PWR	Hydroelectric	D-2001-038 CP-3	Eagle Creek Hydro Power, LLC	Swinging Bridge 2	Modelled
182	NY	PWR	Hydroelectric	D-2011-020 CP-1	Eagle Creek Hydro Power, LLC	Mongaup Falls	Modelled
183	NY	PWR	Hydroelectric	D-2011-020 CP-1	Eagle Creek Hydro Power, LLC	Rio	Modelled
184	NY	PWR	Hydroelectric	D-2001-038 CP-3	Eagle Creek Hydro Power, LLC	Swinging Bridge 1	Modelled
185	NJ	IND	Industrial	ENT-174	EAGLE DYEING & FINISHING CO	Ranccas Creek	Not Modelled - HD
186	NJ	PWR	Thermoelectric	D-2012-010 CP-1	Eagle Point Power Generation LLC	Eagle Point Power Generation LLC	Modelled
187	PA	PWS	Public Water Supply	D-2004-003 CP-2	East Greenville Borough	East Greenville Borough	Modelled
188	NJ	PWS	Public Water Supply	AA-1974-132 CP	EAST GREENWICH TOWNSHIP	EAST GREENWICH TOWNSHIP	Modelled
189	PA	IND	Industrial	D-2003-023 -3	EAST PENN MANUFACTURING COMPANY	East Penn Manufacturing Company	Modelled
190	PA	PWS	Public Water Supply	D-1992-072 CP-2	East Stroudsburg Borough	East Stroudsburg Borough	Modelled
191	NJ	MIN	Mining	OP-2018-500 -1	Eastern Concrete Materials, Inc.	Eastern Concrete Materials, Inc.	Modelled
192	PA	MIN	Mining	D-1987-073	EASTERN INDUSTRIES, INC	Eastern Industries, Inc - Buckwha Creek	Not Modelled - HD
193	PA	PWS	Public Water Supply	D-1999-062 CP-2	Easton Suburban Water Authority	Easton Suburban Water Authority	Modelled
194	NJ	PWS	Public Water Supply	D-1985-024 CP-4	ELMER BOROUGH	ELMER BOROUGH	Modelled
195	PA	PWS	Public Water Supply	P-1996-048 CP-2	ELVERSON WATER CO INC	ELVERSON WATER CO INC	Modelled
196	NY	PWS	Public Water Supply	D-1971-175 CP	Emerald Green Lake Louise Marie Water Company	Emerald Green Lake Louise Marie Water Company	Modelled
197	PA	PWS	Public Water Supply	D-1976-058 CP	EMMAUS BOROUGH	EMMAUS BOROUGH	Modelled
198	NJ	IND	Industrial	D-1984-045	ESSEX INDUSTRIAL CHEMICALS	ESSEX INDUSTRIAL CHEMICALS	Not Modelled - HD
199	NJ	PWS	Public Water Supply	AA-1994-056 CP	ESTAUGH CORPORATION T/A MEDFORD LEAS	ESTAUGH CORPORATION T/A MEDFORD LEAS	Modelled
200	PA	PWR	Thermoelectric	D-2008-011 -2	Evergreen Community Power, LLC	Evergreen Community Power, LLC	Not Modelled - HD
201	NJ	PWS	Public Water Supply	OP-1998-015 CP-1	Evesham Municipal Utilities Authority	Evesham Municipal Utilities Authority	Modelled
202	PA	IND	Industrial	D-1992-038	Excalibur Realty Company	Excalibur Realty Company	Modelled
203	NJ	MIN	Mining	AA-2011-505	Excavation Materials & Equipment Inc.	Excavation Materials & Equipment Inc. - Sand/Gravel M	Modelled
204	PA	PWR	Thermoelectric	D-2006-044-1	Exelon	Exelon - Cromby (DO NOT USE - CLOSED)	Modelled
205	PA	PWR	Thermoelectric	ENT-228	Exelon	Exelon - Delaware Generating Station	Modelled
206	PA	PWR	Thermoelectric	D-1996-063 CP-2	Exelon	Exelon - Fairless Hills Generating Station	Modelled
207	PA	PWR	Thermoelectric	D-1969-210 CP-15	Exelon	Exelon - Limerick Generating Station	Modelled
208	PA	PWR	Thermoelectric	D-2008-038 CP-2	Exelon	Exelon - Eddystone Generating Station	Modelled
209	NJ	IND	Industrial	AA-2008-017	F & S PRODUCE CO	F & S PRODUCE CO	Modelled
210	PA	PWR	Thermoelectric	D-2001-028 CP-2	Fairless Energy, LLC	Fairless Energy, LLC	Modelled
211	NJ	OTH	Prison	OP-1998-005 CP	FAIRTON FEDERAL CORRECTIONAL INSTITUTION	Fairton Federal Correctional Institution	Modelled
212	NY	PWS	Public Water Supply	D-1990-105 CP-4	FALLSBURG CONSOLIDATED WATER DISTRICT	FALLSBURG CONSOLIDATED WATER DISTRICT	Modelled
213	PA	IND	Industrial	ENT-182	Federal Paperboard (Reading Paperboard)	Cacoosing Creek	Not Modelled - HD
214	PA	IND	Industrial	D-1982-031 -5	FIBER MARK INC	FiberMark Inc.	Modelled
215	PA	PWS	Public Water Supply	D-1995-058 CP-3	Fleetwood, Borough of	Fleetwood, Borough of	Modelled

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
216	NY	PWS	Public Water Supply	D-2009-008 CP-2	Fleischmanns Village	FLEISCHMANNS VILLAGE	Modelled
217	NJ	PWS	Public Water Supply	AA-1994-082 CP	Florence Township	Florence Township	Modelled
218	NJ	PWS	Public Water Supply	AA-1974-094 CP	Forest Lakes Water Company	Forest Lakes Water Company	Modelled
219	DE	PWS	Public Water Supply	D-1989-073 CP RENEWAL	FREDERICA TOWN	FREDERICA TOWN	Modelled
220	PA	PWS	Public Water Supply	P-1999-060 CP-2	FREDERICK MENNONITE COMMUNITY	FREDERICK MENNONITE COMMUNITY	Modelled
221	PA	PWS	Public Water Supply	D-1994-063 CP-3	Freeland Borough Municipal Authority	Freeland Borough Municipal Authority - PWS	Modelled
222	PA	OTH	Parks/Recreation	D-1967-104	FRENCH CREEK STATE PARK	FRENCH CREEK STATE PARK	Modelled
223	NY	IND	Industrial	D-2010-010 -2	Friesland Campina Ingredients North America	Vitamin Manufacturing Facility - IWTP	Modelled
224	PA	IND	Industrial	P-1996-049 -4	G&W Laboratories	G&W Laboratories	Modelled
225	NJ	PWR	Thermoelectric	D-1993-071	GenOn REMA, LLC.	Gilbert Generating Station	Modelled
226	PA	PWR	Thermoelectric	ENT-204	GenOn REMA, LLC.	GenOn REMA, LLC - Titus Generating Station	Modelled
227	PA	IND	Industrial	D-1965-122 -2	GEO Specialty Chemicals, Inc.	GEO Specialty Chemicals, Inc.	Modelled
228	DE	PWS	Public Water Supply	D-1994-037 CP-3	GEORGETOWN TOWN	GEORGETOWN TOWN	Modelled
229	PA	IND	Industrial	P-2009-042 -1	GESSNER PRODUCTS CO INC	GESSNER PRODUCTS CO INC	Modelled
230	PA	MIN	Mining	D-1967-129	GINTHER COAL CO INC		Not Modeled - OR
231	PA	IND	Industrial	D-2014-016 -1	Giorgio Foods, Inc.	Giorgio Foods, Inc.	Modelled
232	NJ	PWS	Public Water Supply	D-1996-054 CP-2	GLASSBORO BOROUGH WATER DEPT	GLASSBORO BOROUGH WATER DEPT	Modelled
233	PA	IND	Remediation	D-1976-017 -4	Glenn Springs Holdings, Inc.	Glenn Springs Holdings, Inc. - GWTP	Modelled
234	NJ	PWS	Public Water Supply	D-1968-114 CP	GLOUCESTER CITY	GLOUCESTER CITY	Modelled
235	PA	OTH	Hospital/Health	D-1992-063 CP-3	GRAND VIEW HOSPITAL	Grand View Hospital	Modelled
236	NJ	IND	Industrial	AA-2012-508	GRASSO FOODS INC	GRASSO FOODS INC	Modelled
237	PA	OTH	Prison	D-1965-112 CP-2	GRATERFORD STATE CORR INST	GRATERFORD STATE CORR INST	Modelled
238	NJ	PWR	Hydroelectric	D-1986-046	GREAT BEAR HYDROPOWER INC	Great Bear Hydropower Inc - Columbia Dam Powerhou	Modelled
239	PA	PWS	Public Water Supply	P-2010-030 CP-1	Green Hill Mobile Home Park	Green Hill MHP	Modelled
240	PA	PWS	Public Water Supply	P-2009-030 CP-1	Green Top Management, LLC	Green Top Management, LLC - Mobile Home Park	Modelled
241	PA	OTH	Fish Hatchery	D-2006-008 -2	GREEN WALK TROUT HATCHERY, INC.	Green Walk Trout Hatchery	Not Modelled - ND
242	PA	OTH	Fish Hatchery	D-2008-008 -2	GREEN WALK TROUT HATCHERY, INC.	Johnsonville Facility?	Not Modelled - ND
243	NJ	PWS	Public Water Supply	OP-1994-051 CP-2	Greenwich Township	GREENWICH TOWNSHIP	Modelled
244	NJ	PWS	Public Water Supply	AA-2004-023 CP	Hackettstown Municipal Utilities Authority	Hackettstown Municipal Utilities Authority	Modelled
245	NJ	PWS	Public Water Supply	D-1966-065 CP-2	HADDON TOWNSHIP	HADDON TOWNSHIP	Modelled
246	PA	PWS	Public Water Supply	D-2012-022 CP-1	Hamburg Municipal Authority	Hamburg Municipal Authority	Modelled
247	NJ	PWS	Public Water Supply	D-1974-008 CP REN	HAMPTON BOROUGH	HAMPTON BOROUGH	Modelled
248	NY	PWS	Public Water Supply	D-1969-058 CP	Hancock Village	Hancock Village	Modelled
249	DE	IND	Industrial	D-1985-070 REN	Hanover Foods Corporation	Hanover Foods Corporation - Clayton	Modelled
250	PA	MIN	Mining	ENT-185	Hanson Aggregates, Inc.	CHESTER CREEK	Modelled
251	NJ	MIN	Mining	AA-1973-080	Hanson Aggregates, Inc.	HANSON AGGREGATES PA INC STROUDSBURG QUARR	Not Modeled - OR
252	NJ	PWS	Public Water Supply	OP-1975-097 -1	Harding Woods MHC, LLC	Harding Woods MHC, LLC	Modelled
253	NJ	MIN	Mining	AA-2006-004	HARMONY SAND AND GRAVEL	Harmony Sand and Gravel	Modelled
254	DE	PWS	Public Water Supply	AA-1988-027 CP	Harrington City	Harrington City	Modelled
255	DE	IND	Industrial	ENT-189	HAVEG INDUSTRIES-MARSHALLTON PL	RED CLAY CR	Not Modeled - OR
256	PA	PWS	Public Water Supply	D-1991-065 CP-3	Hazleton City Authority	Hazleton City Authority	Modelled
257	PA	PWR	Thermoelectric	D-1997-045 -3	Helix Ironwood, LLC	Helix Ironwood, LLC	Modelled
258	PA	PWS	Public Water Supply	D-2000-053 CP-2	HELLERTOWN BOROUGH AUTHORITY	HELLERTOWN BOROUGH AUTHORITY	Modelled

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
259	PA	PWS	Public Water Supply	D-2000-060 CP-2	HEMLOCK FARMS COMMUNITY ASSOCIATION	HEMLOCK FARMS COMMUNITY ASSOCIATION	Modelled
260	DE	IND	Industrial	ENT-324	Hercules, Inc-Research Center (Ashland Hercules Resea	Red Clay Creek	Not Modelled - HD
261	NJ	IND	Remediation	OP-1987-043 -3	Hercules, LLC	Hercules, LLC	Modelled
262	PA	MIN	Mining	D-1987-002 PA REN	HIGHWAY MATERIALS INC	HIGHWAY MATERIALS INC	Not Modeled - OR
263	PA	PWS	Public Water Supply	D-1992-020 CP-4	Hilltown Township Water & Sewer Authority	Hilltown Township Water & Sewer Authority	Modelled
264	NY	PWS	Public Water Supply	D-1976-094 CP	Hobart Village	Hobart Village	Modelled
265	PA	MIN	Mining	D-1974-189 -2	Holcim (US) Inc.	Holcim (US) Inc.	Modelled
266	NJ	IND	Remediation	D-2004-025-1	Holman Parts Distribution	Holman Parts Distribution - RMP Facility	Modelled
267	PA	PWS	Public Water Supply	D-1991-099 CP-3	HONEY BROOK BOROUGH AUTHORITY	Honey Brook Borough Authority	Modelled
268	PA	IND	Remediation	P-1997-010 -2	Honeywell International, Inc.	Honeywell International, Inc.	Not Modelled - HD
269	NJ	PWS	Public Water Supply	D-1992-085 CP-3	HOPATCONG BOROUGH	HOPATCONG BOROUGH	Modelled
270	PA	OTH	Military	D-2010-020 CP-1	Horsham Air Guard Station	Horsham Air Guard Station	Modelled
271	PA	OTH	Hospital/Health	P-2007-007 -3	HORSHAM CLINIC INC	HORSHAM CLINIC INC	Modelled
272	PA	PWS	Public Water Supply	D-1997-016 CP-4	Horsham Water and Sewer Authority	Horsham Water and Sewer Authority	Modelled
273	NJ	OTH	Commercial	D-1965-071	HOUSE OF GOOD SHEPHERD	HOUSE OF GOOD SHEPHERD	Not Modelled - HD
274	NJ	IND	Industrial	ENT-381	IMO INDUSTRIES,DELAVAL TURBINE (DEMAG DELAVAI	IMO INDUSTRIES,DELAVAL TURBINE (DEMAG DELAVAI	Modelled
275	NJ	IND	Remediation	D-1989-060	Ingersoll Rand	Ingersoll Rand - Phillipsburg Plantsite	Modelled
276	NJ	MIN	Mining	D-2007-015 -1	INVERSAND COMPANY	Inversand Company - Sand Mining	Modelled
277	DE	IND	Industrial	D-1989-048 CP-4	J.G. Townsend, Jr & Company	J.G. Townsend, Jr & Company	Not Modeled - OR
278	NJ	PWS	Public Water Supply	D-1994-018 CP-3	Jackson Township Municipal Utilities Authority	Jackson Township Municipal Utilities Authority	Modelled
279	NJ	MIN	Mining	OP-2016-500 -1	JDM Materials Company-Tri-Boro Sand and Stone, Inc.	JDM Materials Company: Tri Boro sand and Stone, Inc.	Modelled
280	NJ	PWR	Hydroelectric	D-1962-002	JERSEY CENTRAL POWER & LIGHT COMPANY	Jersey Central Power & Light Company	Modelled
281	PA	OTH	Ski/Snowmaking	D-1993-053 -3	JFBB Ski Areas, Inc.	JFBB Ski Areas, Inc. - Big Boulder Ski Area	Modelled
282	PA	OTH	Ski/Snowmaking	D-1993-057 -3	JFBB Ski Areas, Inc.	JFBB Ski Areas, Inc. - Jack Frost Ski Area	Modelled
283	PA	PWS	Public Water Supply	D-1981-071 CP-5	Jim Thorpe Borough	Jim Thorpe Borough	Modelled
284	PA	IND	Industrial	D-2017-003 -2	Joe Jurgielewicz & Son, Ltd.	Joe Jurgielewicz & Son, Ltd.	Modelled
285	NJ	OTH	Military	OP-2006-040 CP-1	Joint Base McGuire-Dix-Lakehurst	Joint Base McGuire-Dix-Lakehurst	Modelled
286	PA	PWS	Public Water Supply	D-2012-003 CP-1	Kennett Square Borough	Kennett Square Borough	Modelled
287	PA	MIN	Mining	D-2018-003 -1	Keystone Anthracite Co., Inc.	Keystone Anthracite Co., Inc.	Modelled
288	NY	PWS	Public Water Supply	D-1990-068 CP-4	KIAMESHA ARTESIAN SPRING WATER CO	KIAMESHA ARTESIAN SPRING WATER COMPANY, INC.	Modelled
289	PA	PWR	Thermoelectric	D-2012-012 CP-1	Kimberly-Clark Corporation	KIMBERLY CLARK CORP	Modelled
290	DE	IND	Industrial	D-1992-053 REVISED	Kraft Foods Dover	Kraft Foods Dover	Modelled
291	PA	PWS	Public Water Supply	D-1983-023 CP-4	Kutztown Borough	Kutztown Borough - PWS	Modelled
292	PA	PWS	Public Water Supply	D-2011-002 CP-1	Lake Adventure Comm. Assoc.	Lake Adventure Comm. Assoc.	Modelled
293	NJ	PWS	Public Water Supply	D-1968-137 CP	LAKE LENAPE WATER CO	Lake Lenape Water Co	Modelled
294	NJ	IND	Industrial	OP-1974-129	LaMonica Fine Foods	LaMonica Fine Foods	Modelled
295	PA	PWS	Public Water Supply	D-1995-013 CP-2	LANSFORD-COALDALE JOINT WATER AUTH	LANSFORD-COALDALE JOINT WATER AUTH	Modelled
296	NJ	IND	Industrial	OP-1995-037 -2	Lassonde Pappas and Company, Inc.	Lassonde Pappas - Seabrook	Modelled
297	NJ	OTH	School	D-2005-013-1	LAWRENCE SCHOOL, THE	Lawrence School	Modelled
298	PA	PWS	Public Water Supply	D-2001-012 CP-2	LEESPORT BOROUGH	LEESPORT BOROUGH	Modelled
299	PA	PWS	Public Water Supply	D-2001-020 CP-5	Lehigh County Authority	Lehigh County Authority	Modelled
300	PA	PWS	Public Water Supply	D-1992-040 CP	Lehigh County Authority	Lehigh County Authority	Not Modeled - OR
301	PA	PWS	Public Water Supply	D-1989-093 CP	Lehighton Water Authority	Lehighton Water Authority	Modelled

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
302	PA	IND	Industrial	D-1993-021 -3	LEIDYS INC	Leidys Pork Processing Plant	Modelled
303	NJ	OTH	School	D-2006-042 CP-1	LENAPE REGIONAL HIGH SCHOOL DISTRICT	Lenape Regional High School District	Not Modelled - HD
304	DE	PWS	Public Water Supply	D-1985-054 CP RENEWAL	LEWES BOARD OF PUBLIC WORKS	Lewes Board of Public Works	Modelled
305	PA	PWR	Thermoelectric	D-1999-061	Liberty Electric Power	Liberty Electric Power	Not Modeled - OR
306	PA	PWR	Thermoelectric	D-1999-054	LMBE Project Company, LLC	LMBE Project Company, LLC - Power Plant	Modelled
307	NJ	PWR	Thermoelectric	OP-1990-048 -1	Logan Generating Company	Logan Generating Company	Modelled
308	DE	PWR	Thermoelectric	OP-1990-048 -1	Logan Generating Company	Logan Generating Company	Not Modeled - OR
309	NY	PWS	Public Water Supply	D-2011-007 CP-1	Lost Lake Resorts, Inc. / Double Diamond Companies	Lost Lake Resorts, Inc. / Double Diamond Companies	Not Modeled - OR
310	PA	PWS	Public Water Supply	D-1969-190 CP	Lower Bucks County Joint Municipal Authority	Lower Bucks County Joint Municipal Authority	Modelled
311	PA	PWS	Public Water Supply	D-1111-001	Lower Saucon Authority	Lower Saucon Authority	Not Modeled - OR
312	NJ	PWS	Public Water Supply	D-1994-021 CP-3	Lower Township Municipal Utilities Authority	Lower Township MUA	Modelled
313	PA	PWS	Public Water Supply	D-1965-008 CP	Lyons Borough Municipal Authority	Lyons Borough Municipal Authority	Modelled
314	PA	IND	Industrial	D-1975-063	Mack Trucks Inc.	Mack Trucks (Lehigh Valley Operations)	Not Modeled - OR
315	PA	PWS	Public Water Supply	D-1968-057 CP	MACUNGIE BOROUGH	MACUNGIE BOROUGH	Modelled
316	NJ	IND	Industrial	OP-2004-038 -2	MAFCO Worldwide Corporation	MAFCO Worldwide Corporation	Modelled
317	PA	PWS	Public Water Supply	D-1991-058 CP-4	Maidencreek Township Authority	Maidencreek Township Authority - PWS	Modelled
318	NJ	PWS	Public Water Supply	AA-2000-004	MANTUA TOWNSHIP MUNICIPAL UTILITIES AUTHORIT	MANTUA TOWNSHIP MUNICIPAL UTILITIES AUTHORIT	Modelled
319	PA	PWS	Public Water Supply	D-1989-050 CP-5	MANWALAMINK WATER CO	MANWALAMINK WATER CO	Modelled
320	NJ	PWS	Public Water Supply	D-1978-018 CP-2	Maple Shade Township	Maple Shade Township	Modelled
321	PA	PWR	Thermoelectric	D-1998-053	Marcus Hook 50, L.P.	Marcus Hook 50, L.P. - Cogen Facility	Modelled
322	PA	PWR	Thermoelectric	D-2000-044 -2	Marcus Hook Energy, L.P.	PurEnergy, LLC	Modelled
323	NY	PWS	Public Water Supply	D-1974-157 CP-3	MARGARETVILLE VILLAGE	MARGARETVILLE VILLAGE	Modelled
324	PA	IND	Industrial	P-2009-029 -2	Markel Corp.	Markel Corp.	Modelled
325	PA	PWS	Public Water Supply	D-1981-078 CP-9	Matamoras Municipal Authority	Matamoras Municipal Authority	Modelled
326	NJ	MIN	Mining	OP-2007-032 -1	Mays Landing Sand and Gravel Corporation	Mays Landing Sand and Gravel Corporation	Modelled
327	PA	PWR	Thermoelectric	D-1970-025 CP-2	MC Project Company, LLC	MC Project Company, LLC - Martins Creek Electric Gen	Modelled
328	PA	OTH	Bottled Water	D-2000-065 -2	MC RESOURCE DEVELOPMENT COMPANY	MC Resource Development Company - Bulk Water	Modelled
329	PA	IND	Industrial	D-1980-083	MCCONWAY & TORLEY CORPORATION	McConway & Torley Corporation - Kutztown Foundry	Modelled
330	NJ	PWS	Public Water Supply	AA-1995-055 CP	MEDFORD TOWNSHIP	MEDFORD TOWNSHIP	Modelled
331	NJ	IND	Industrial	OP-1994-073 -2	MEL Chemicals, Inc.	Magnesium Elektron	Modelled
332	NJ	OTH	Prison	OP-2002-050 CP-1	MERCER COUNTY CORRECTIONAL FACILITY	MERCER COUNTY CORRECTIONAL FACILITY	Modelled
333	NJ	PWS	Public Water Supply	OP-1997-005 CP-2	MERCHANTVILLE-PENNSAUKEN WATER COMMISSION	MERCHANTVILLE-PENNSAUKEN WATER COMMISSION	Modelled
334	PA	IND	Industrial	D-1998-014 -3	Merck Sharp & Dohme Corporation	Merck West Point System	Modelled
335	NJ	PWR	Thermoelectric	D-1977-110 CP-19	Merrill Creek Owners Group	MCOG	Not Modeled - OR
336	DE	IND	Remediation	D-1984-051	METACHEM PRODUCTS LLC	METACHEM PRODUCTS, LLC	Not Modelled - HD
337	PA	PWS	Public Water Supply	D-1994-049 CP-3	METER SERVICES COMPANY	METER SERVICES COMPANY	Modelled
338	NJ	IND	Industrial	OP-1989-074 -2	Mexichem Specialty Resins, Inc.	Mexichem - Pedricktown	Modelled
339	DE	PWS	Public Water Supply	D-1978-064 CP-2	MIDDLETOWN TOWN	MIDDLETOWN TOWN	Modelled
340	NJ	PWS	Public Water Supply	OP-1968-095 CP-1	MILFORD BORO WATER DEPT	MILFORD BORO WATER DEPT	Modelled
341	DE	PWS	Public Water Supply	D-1995-044 CP	Milford City	Milford City	Modelled
342	PA	PWS	Public Water Supply	D-2003-037 CP-2	MILFORD TOWNSHIP WATER AUTHORITY	MILFORD TOWNSHIP WATER AUTHORITY	Modelled
343	NJ	PWS	Public Water Supply	AA-1996-005 CP	MILLVILLE CITY WATER DEPT	MILLVILLE CITY WATER DEPT	Modelled
344	PA	PWS	Public Water Supply	D-2014-001 CP-1	Minersville Borough Municipal Authority	Minersville Borough Municipal Authority	Modelled

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
345	PA	PWS	Public Water Supply	P-2010-039 CP-1	MISA CORP	MISA Corporation - Appleville Mobile Home Park	Modelled
346	PA	IND	Industrial	ENT-209	MODERN CONCRETE SEPTIC TANK CO	OTTSVILLE CR	Not Modeled - OR
347	PA	IND	Refinery	D-1996-052 -2	Monroe Energy, LLC	Monroe Energy, LLC - Trainer Refinery	Modelled
348	NJ	PWS	Public Water Supply	OP-1993-009 CP-2	MONROE TOWNSHIP MUNICIPAL UTILITIES AUTHORIT	MONROE TOWNSHIP MUNICIPAL UTILITIES AUTHORIT	Modelled
349	NJ	PWS	Public Water Supply	AA-1991-075 CP REN	MONTAGUE WATER CO	MONTAGUE WATER CO	Modelled
350	NJ	PWS	Public Water Supply	AA-1995-059 CP	Moorestown Township	Moorestown Township	Modelled
351	PA	PWS	Public Water Supply	D-1974-072 CP	Morrisville Municipal Authority	Morrisville Municipal Authority	Modelled
352	PA	OTH	Commercial	D-1989-037-3	Mount Airy #1, LCC	Mount Airy Lodge	Modelled
353	NJ	PWS	Public Water Supply	AA-1985-009 CP	Mount Laurel Municipal Utilities Authority	Mount Laurel Municipal Utilities Authority - PWS	Modelled
354	NJ	PWS	Public Water Supply	D-2006-027 CP-1	Mount Laurel Municipal Utilities Authority	Mount Laurel Municipal Utilities Authority - PWS	Not Modeled - OR
355	NJ	PWS	Public Water Supply	D-1971-059 CP	MOUNT OLIVE TOWNSHIP	MOUNT OLIVE TOWNSHIP	Modelled
356	PA	IND	Industrial	D-2002-026	MOYER PACKING CO		Not Modelled - HD
357	PA	PWS	Public Water Supply	D-1969-161 CP	Mt. Penn Borough Municipal Authority	Mt. Penn Borough Municipal Authority	Modelled
358	PA	PWS	Public Water Supply	D-2001-030 CP-3	MUHLENBERG TOWNSHIP AUTHORITY	Muhlenberg Township Authority Water Distribution Sy	Modelled
359	PA	IND	Industrial	D-1987-088 PA	MYERS FOODS	MYERS FOODS	Not Modelled - HD
360	PA	PWS	Public Water Supply	D-1981-067 CP-4	MYERSTOWN WATER AUTHORITY	MYERSTOWN WATER AUTHORITY	Modelled
361	NY	PWS	Public Water Supply	D-1992-081 CP-3	Narrowsburg Water District	Narrowsburg Water District	Modelled
362	PA	IND	Industrial	ENT-210	NATIONAL MILLING & CHEMICAL CO	MANAYUNK CANAL	Not Modelled - HD
363	NJ	PWS	Public Water Supply	D-1977-018 CP-2	NATIONAL PARK BOROUGH	NATIONAL PARK BOROUGH	Modelled
364	NJ	OTH	Military	ENT-377	NAVAL AIR PROPULSION CENTER	DELAWARE RIVER	Not Modelled - HD
365	PA	IND	Industrial	D-2009-003 CP-2	Naval Surface Warfare Center Philadelphia Division	Naval Surface Warfare Center Philadelphia Division	Modelled
366	PA	PWS	Public Water Supply	D-1994-047 CP-2	Nesquehoning Borough Authority (Panther Creek Coge	Nesquehoning Borough Authority (Panther Creek Coge	Modelled
367	PA	IND	Industrial	D-1984-002 -6	Nestle Purina Petcare Co.	Nestle Purina Petcare	Modelled
368	PA	OTH	Bottled Water	D-1998-027 -4	Nestle Waters North America, Inc.	Hoffman Springs	Modelled
369	PA	OTH	Bottled Water	D-1997-046 -4	Nestle Waters North America, Inc.	Arrowhead Springs	Modelled
370	PA	OTH	Bottled Water	D-1998-055 -5	Nestle Waters North America, Inc.	Greenwaltz Facility	Modelled
371	PA	OTH	Bottled Water	D-2002-045 -2	Nestle Waters North America, Inc.	Breinigsville Plant	Modelled
372	PA	OTH	Bottled Water	D-2013-020 -2	Nestle Waters North America, Inc.	Greenwaltz Interceptor Trench	Modelled
373	NJ	PWS	Public Water Supply	AA-2000-041 CP	NETCONG BOROUGH	NETCONG BOROUGH	Modelled
374	NJ	PWS	Public Water Supply	OP-1985-002 CP-3	New Jersey American Water Company	New Jersey American Water Company - Washington	Modelled
375	NJ	PWS	Public Water Supply	AA-2001-003 CP	New Jersey American Water Company	New Jersey American Water Company - Sunbury Syste	Modelled
376	NJ	PWS	Public Water Supply	D-1981-017 CP-4	New Jersey American Water Company	New Jersey American Water Company - Raritan	Modelled
377	NJ	PWS	Public Water Supply	OP-1993-077 CP-3	New Jersey American Water Company	New Jersey American Water Company - Pennsgrove	Modelled
378	NJ	PWS	Public Water Supply	OP-2009-050 CP-1	New Jersey American Water Company	New Jersey American Water Company - New Egypt Sys	Modelled
379	NJ	PWS	Public Water Supply	D-1995-046 CP-2	New Jersey American Water Company	New Jersey American Water Company - Mount Holly	Modelled
380	NJ	PWS	Public Water Supply	AA-1999-073 CP	New Jersey American Water Company	New Jersey American Water Company - LOGAN SYSTE	Modelled
381	NJ	PWS	Public Water Supply	OP-1981-073 CP-4	New Jersey American Water Company	New Jersey American Water Company - Homestead W	Modelled
382	NJ	PWS	Public Water Supply	OP-1999-057 CP-1	New Jersey American Water Company	New Jersey American Water Company - HARRISON	Modelled
383	NJ	PWS	Public Water Supply	D-1968-115 CP	New Jersey American Water Company	New Jersey American Water Company - FRENCHTOWN	Modelled
384	NJ	PWS	Public Water Supply	D-1975-084 CP-2	New Jersey American Water Company	New Jersey American Water Company - Delaware	Modelled
385	NJ	PWS	Public Water Supply	D-1990-108 CP-3	New Jersey American Water Company	New Jersey American Water Company - Delaware	Modelled
386	NJ	PWS	Public Water Supply	OP-1993-028 CP-3	New Jersey American Water Company	New Jersey American Water Company - Bridgeport	Modelled
387	NJ	PWS	Public Water Supply	AA-1990-089 CP	New Jersey American Water Company	New Jersey American Water Company - BELVIDERE SY	Modelled

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
388	NJ	PWS	Public Water Supply	D-1992-077 CP	New Jersey American Water Company	New Jersey American Water Company - Delaware	Not Modeled - OR
389	NJ	PWS	Public Water Supply	OP-1988-011 CP-1	New Jersey American Water Company	New Jersey American Water - Oxford System	Not Modeled - OR
390	NJ	OTH	Commercial	D-1994-083	New Jersey American Water Company	New Jersey American Water Company - ITC	Modelled
391	NJ	OTH	Fish Hatchery	D-2013-014 CP-1	New Jersey Department of Environmental Protection	New Jersey Department of Environmental Protection,	Not Modeled - OR
392	NJ	OTH	Prison	D-2000-010 CP	New Jersey State Corrections	New Jersey State Corrections - Bayside	Modelled
393	NJ	OTH	Commercial	D-1996-055 CP	New Jersey Turnpike Authority	New Jersey Turnpike Authority	Modelled
394	NJ	OTH	Commercial	AA-2003-008 CP	NEW LISBON DEVELOPMENT CENTER	New Lisbon Development Center	Modelled
395	NY	OTH	Prison	D-2007-028 CP-2	New York State Department of Corrections and Comm	Woodburne Correctional Facility	Modelled
396	DE	PWS	Public Water Supply	D-2002-002 CP	Newark, City of	Newark, City of	Modelled
397	NJ	PWS	Public Water Supply	D-1977-028 CP	NEWFIELD BOROUGH	NEWFIELD BOROUGH	Modelled
398	PA	PWS	Public Water Supply	D-1997-040 CP-2	NEWMANSTOWN WATER AUTHORITY	NEWMANSTOWN WATER AUTHORITY	Modelled
399	NJ	MIN	Mining	OP-1973-080	Newport Sand and Gravel	Newport Sand and Gravel	Modelled
400	NJ	PWS	Public Water Supply	D-1990-111 CP RENEWAL	Newton Town	Newton Town - PWS	Modelled
401	PA	PWS	Public Water Supply	D-1978-029 CP-4	NEWTOWN ARTESIAN WATER COMPANY	NEWTOWN ARTESIAN WATER COMPANY	Modelled
402	NJ	IND	Industrial	D-2005-004-1	NGC INDUSTRIES	NGC Industries - National Gypsum Company	Modelled
403	NJ	IND	Industrial	OP-2009-009 -1	NGC INDUSTRIES	NGC Industries - National Gypsum Company	Modelled
404	PA	IND	Remediation	D-1989-053 -4	NGK Metals Corp.	NGK Metals Corp. - Groundwater Treatment Plant	Modelled
405	PA	IND	Industrial	D-1986-083 -3	Niagara Drinking Waters Inc.	Niagara - Water Filtration Plant	Not Modelled - HD
406	NJ	IND	Industrial	OP-1992-014 -2	Nipro Glass Americas Corporation	NiPro Plant No. 3 Wheaton Avenue	Modelled
407	PA	PWS	Public Water Supply	D-2002-047 CP-2	North Coventry Water Authority	North Coventry Water Authority	Not Modeled - OR
408	PA	PWS	Public Water Supply	D-1965-076 CP (8)	North Penn & North Wales Water Authority	North Penn & North Wales Water Authority	Modelled
409	PA	PWS	Public Water Supply	D-1992-044 CP-4	NORTH PENN WATER AUTHORITY	NORTH PENN WATER AUTHORITY	Modelled
410	PA	PWS	Public Water Supply	P-2009-033 -2	North Wales Water Authority	North Wales Water Authority - Forest Park Water Trea	Modelled
411	PA	PWS	Public Water Supply	P-1973-020 CP-5	North Wales Water Authority	North Wales Water Authority	Modelled
412	PA	PWS	Public Water Supply	D-1990-006 CP-3	North Wales Water Authority	North Wales Water Authority	Modelled
413	PA	PWS	Public Water Supply	D-2004-006 CP-2	Northampton Boro MA	Northampton Borough Municipal Authority	Modelled
414	PA	PWS	Public Water Supply	D-2001-013 CP-3	NORTHAMPTON BUCKS COUNTY MUNICIPAL AUTHOR	NORTHAMPTON BUCKS COUNTY MUNICIPAL AUTHOR	Modelled
415	PA	PWR	Thermoelectric	D-1998-040	Northampton Generating Company	NORTHAMPTON GENERATING PLT	Modelled
416	PA	PWS	Public Water Supply	D-1989-010 CP-4	Northeast Land Company	Northeast Land Company	Modelled
417	PA	PWR	Thermoelectric	D-1998-039 -2	Northeastern Power Company	Northeastern Power Company	Modelled
418	DE	PWR	Thermoelectric	D-1996-010	NRG ENERGY CENTER DOVER LLC	NRG Energy Center Dover LLC - Cogen Plant	Modelled
419	DE	IND	Industrial	ENT-219	NVF Company/Yorklyn Plant	NVF Company/Yorklyn Plant	Modelled
420	NJ	IND	Industrial	D-1973-124	OCEAN SPRAY CRANBERRIES INC	Ocean Spray Cranberries Inc	Modelled
421	PA	PWS	Public Water Supply	D-2001-036 CP-2	Oley Township Municipal Authority	Oley Township Municipal Authority	Modelled
422	PA	PWR	Thermoelectric	D-2000-014	Ontelaunee Power Operating Company, LLC (Dynegy)	Ontelaunee Energy Facility	Not Modeled - OR
423	PA	PWS	Public Water Supply	D-1992-005 CP-3	ORWIGSBURG BOROUGH	ORWIGSBURG BOROUGH	Modelled
424	PA	OTH	School	P-2011-001 CP-1	OWEN J ROBERTS SCH DIST MAIN CAMPUS	OWEN J ROBERTS SCH DIST MAIN CAMPUS	Modelled
425	NJ	IND	Industrial	ENT-379	Oxford Textile Inc.	Oxford Textile Inc.	Modelled
426	NJ	MIN	Mining	AA-2013-500	P. Michelotti & Sons Concrete Division		Not Modelled - HD
427	PA	OTH	Fish Hatchery	D-1980-032 CP-4	PA Fish and Boat Commission	Pleasant Mt Fish Hatchery	Modelled
428	PA	PWS	Public Water Supply	D-1981-024 CP-8	Palmerton Borough	Office of the Mayor	Modelled
429	PA	IND	Industrial	D-1981-024 CP-8	Palmerton Borough	Palmerton Borough	Not Modeled - OR
430	PA	PWR	Thermoelectric	D-1987-066 -6	Panther Creek Power Operating, LLC	Panther Creek Cogen Plant	Modelled

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
431	PA	IND	Industrial	D-2007-020 -2	PaperWorks Industries, Inc.	PaperWorks Industries, Inc.	Modelled
432	PA	OTH	Commercial	D-2000-040 CP-2	Parkhouse Providence Pointe	Parkhouse Providence Pointe	Modelled
433	NJ	PWS	Public Water Supply	AA-1972-067 CP	PAULSBORO BOROUGH	PAULSBORO BOROUGH	Modelled
434	NJ	IND	Refinery	OP-2006-028 -1	Paulsboro Refining Company, LLC	Paulsboro Refining Company, LLC	Modelled
435	NJ	IND	Industrial	D-1997-050 (REN)	Pechiney Plastic Packaging, Inc.	Pechiney Plastic Packaging, Inc.	Not Modeled - OR
436	NJ	PWS	Public Water Supply	AA-1996-007 CP	PEMBERTON BOROUGH WATER DEPT	PEMBERTON BOROUGH WATER DEPT	Modelled
437	NJ	PWS	Public Water Supply	AA-1992-056 CP	Pemberton, Township of	Pemberton Township Water Division	Modelled
438	PA	IND	Industrial	P-1986-031 -4	PENN ENGINEERING AND MANUFACTURING CORPORA	Penn Engineering & Manufacturing Corporation	Modelled
439	NJ	PWS	Public Water Supply	D-1984-033 CP-4	PENNINGTON BOROUGH	PENNINGTON BOROUGH	Modelled
440	NJ	PWS	Public Water Supply	OP-2002-016 CP	PENNSVILLE TOWNSHIP WATER DEPARTMENT	PENNSVILLE TOWNSHIP WATER DEPARTMENT	Modelled
441	PA	PWS	Public Water Supply	D-2003-006 CP-2	Pennsylvania American Water Company	Pennsylvania American Water Company - Lehman - Mi	Modelled
442	PA	PWS	Public Water Supply	D-1996-009 CP-2	Pennsylvania American Water Company	Pennsylvania American Water Company - Lehman - Fe	Modelled
443	PA	PWS	Public Water Supply	D-1995-053 CP	Pennsylvania American Water Company	Pennsylvania American Water Company - Yardley	Modelled
444	PA	PWS	Public Water Supply	D-1998-043 CP-3	Pennsylvania American Water Company	Pennsylvania American Water Company - Wyomissing,	Modelled
445	PA	PWS	Public Water Supply	D-1998-016 CP-3	Pennsylvania American Water Company	Pennsylvania American Water Company - Pocono Distr	Modelled
446	PA	PWS	Public Water Supply	D-1966-100 CP-2	Pennsylvania American Water Company	Pennsylvania American Water Company - Norristown	Modelled
447	PA	PWS	Public Water Supply	D-1997-034 CP-3	Pennsylvania American Water Company	Pennsylvania American Water Company - Lehman - Sa	Modelled
448	PA	PWS	Public Water Supply	D-2003-019 CP-2	Pennsylvania American Water Company	Pennsylvania American Water Company - Lehman - Pir	Modelled
449	PA	PWS	Public Water Supply	D-2006-025 CP-2	Pennsylvania American Water Company	Pennsylvania American Water Company - Lehman - Mi	Modelled
450	PA	PWS	Public Water Supply	D-1987-031 CP-4	Pennsylvania American Water Company	Pennsylvania American Water Company - Lehman - Hi	Modelled
451	PA	PWS	Public Water Supply	D-2006-033 CP-3	Pennsylvania American Water Company	Pennsylvania American Water Company - Lehman - Bl	Modelled
452	PA	PWS	Public Water Supply	D-1990-027 CP	Pennsylvania American Water Company	Pennsylvania American Water Company - Home/Roye	Modelled
453	PA	PWS	Public Water Supply	D-1999-030 CP-5	Pennsylvania American Water Company	Pennsylvania American Water Company - Glen Alsace	Modelled
454	PA	PWS	Public Water Supply	D-1996-016 CP-3	Pennsylvania American Water Company	Pennsylvania American Water Company - Coatesville	Modelled
455	PA	PWS	Public Water Supply	D-1977-047 CP	Pennsylvania American Water Company	Pennsylvania American Water Company - Blue Mounta	Modelled
456	PA	PWS	Public Water Supply	D-1962-004 REV	Pennsylvania American Water Company	Pennsylvania American Water Company - Springbrook	Not Modeled - OR
457	PA	OTH	Parks/Recreation	D-2015-017 CP-2	Pennsylvania Department of Conservation and Natural	Pennsylvania Department of Conservation and Natural	Not Modelled - ND
458	PA	MIN	Mining	D-2015-021 CP-2	Pennsylvania Department of Environmental Protection	Northeast Regional Office	Not Modeled - OR
459	PA	OTH	Parks/Recreation	D-1973-023 CP	Pennsylvania State DEP	Pennsylvania State DEP - Nockamixon State Park	Not Modelled - ND
460	PA	OTH	Hospital/Health	D-1971-200 CP	PENNSYLVANIA STATE PUBLIC WELFARE	Pennsylvania State Public Welfare - White Haven State	Modelled
461	PA	PWS	Public Water Supply	D-1989-033 CP-4	Pennsylvania Utility Company	Pennsylvania Utility Company - Lehman Township	Modelled
462	NJ	OTH	Fish Hatchery	AA-1973-195 CP	PEQUEST FISH HATCHERY	PEQUEST FISH HATCHERY	Modelled
463	DE	IND	Industrial	AA-2000-003	Perdue Farms, Inc.	Perdue Farms, Inc.	Modelled
464	DE	IND	Industrial	D-1984-015 -3	Perdue Foods LLC	Perdue - Poultry Processing - Milford DE	Modelled
465	PA	PWS	Public Water Supply	D-1997-012 CP-4	Perkasie Regional Authority	Perkasie Regional Authority	Modelled
466	PA	IND	Industrial	ENT-325	PFD/PENN COLOR INC	PINE RUN CR, 3 WELLS	Not Modelled - HD
467	PA	PWS	Public Water Supply	D-0000-002 ENT PHL	Philadelphia (City of)	Philadelphia Water Department	Modelled
468	PA	IND	Remediation	D-1996-036 CP-3	PHILADELPHIA CITY - AVIATION DIVISION	Philadelphia City - Aviation Division	Not Modeled - OR
469	PA	IND	Refinery	D-2012-026 -1	Philadelphia Energy Solutions Refining and Marketing (	Philadelphia Energy Solutions R&M - Girard Point	Modelled
470	PA	IND	Industrial	D-2012-017 CP-1	Philadelphia Gas Works	Philadelphia Gas Works - Richmond	Modelled
471	PA	IND	Industrial	ENT-235	PHILADELPHIA GAS WORKS-PASSYUNK	Schuylkill River	Not Modelled - HD
472	PA	IND	Remediation	D-1995-041 -2	Philadelphia Refinery Operations, a series of Evergreen	Philadelphia Refinery Operations, a series of Evergreen	Modelled
473	DE	IND	Industrial	ENT-237	PHOENIX STEEL (CITISTEEL USA)	PHOENIX STEEL (CITISTEEL USA)	Modelled

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
474	PA	IND	Industrial	ENT-238	PHOENIX STEEL-PHOENIXVILLE (PHOENIX PIPE & TUBE	SCHUYLKILL, FRENCH CR	Not Modelled - HD
475	NJ	PWS	Public Water Supply	OP-2018-501 -1	PINE HILL BOROUGH MUA	PINE HILL BOROUGH MUA	Modelled
476	NJ	PWS	Public Water Supply	OP-2017-502 -1	PINE VIEW TERRACE INC	PINE VIEW TERRACE INC	Modelled
477	NJ	PWS	Public Water Supply	AA-1992-042 CP	Pinelands Water Company	PINELANDS WATER CO	Modelled
478	NJ	PWS	Public Water Supply	AA-1971-155 CP	PITMAN BOROUGH	PITMAN BOROUGH	Modelled
479	DE	IND	Industrial	D-1990-106 REN	PLAYTEX FAMILY PRODUCTS CORPORATION		Modelled
480	PA	PWS	Public Water Supply	D-1991-020 CP-4	Plum Creek Municipal Authority	Plum Creek Municipal Authority	Modelled
481	PA	PWS	Public Water Supply	D-1997-033 CP-3	PLUMSTEAD TOWNSHIP	Plumstead Township - North Branch Durham Ridge	Modelled
482	NJ	IND	Industrial	D-1971-161	PMC CANNING COMPANY	PMC CANNING COMPANY	Not Modelled - HD
483	PA	PWR	Hydroelectric	D-1985-040	POCONO LAKE PRESERVE	Pocono Lake Dam	Modelled
484	NJ	IND	Industrial	D-1969-036 (REV)	Polymer Additives Inc., DBA Valtris Specialty Chemicals	Polymer Additives Inc - Ferro IWTP	Modelled
485	NY	PWS	Public Water Supply	D-2013-019 CP-1	PORT JERVIS CITY	Department of Public Works	Modelled
486	PA	PWS	Public Water Supply	D-1997-029 CP-4	PORTLAND BOROUGH AUTHORITY	PORTLAND BOROUGH AUTHORITY	Modelled
487	PA	PWR	Thermoelectric	D-1993-060 -2	Portland Power LLC	Portland Generating Station	Modelled
488	PA	PWR	Thermoelectric	D-1978-016	Portland Power LLC	Portland Generating Station	Not Modeled - OR
489	PA	PWS	Public Water Supply	D-1964-036 CP-2	Pottstown Borough Water Authority	Pottstown Borough	Modelled
490	PA	IND	Industrial	D-1986-068 REN 2	POTTSTOWN PLATING WORKS INC	POTTSTOWN PLATING WORKS INC	Not Modelled - HD
491	PA	PWR	Hydroelectric	Pre-compact	PPL Utilities Corp.	PPL - WALLENPAUPACK	Modelled
492	PA	IND	Industrial	P-2007-029 -2	Precision Tube Company	Precision Tube Company	Modelled
493	PA	MIN	Mining	D-1968-038	PREMIUM FINE COAL INC		Not Modeled - OR
494	NJ	PWR	Thermoelectric	ENT-239	PSEG Fossil, LLC	Mercer Generating Station	Modelled
495	NJ	PWR	Thermoelectric	ENT-285	PSEG Fossil, LLC	Burlington Generating Station	Modelled
496	NJ	PWR	Thermoelectric	AA-1990-071 CP	PSEG Nuclear, LLC	Salem Generating Station	Modelled
497	NJ	PWR	Thermoelectric	D-1973-193 CP-3	PSEG Nuclear, LLC	Hope Creek Generating Station	Modelled
498	NJ	PWR	Thermoelectric	D-1968-020 CP (REVISION 2)	PSEG Nuclear, LLC	Salem Generating Station	Modelled
499	NJ	IND	Remediation	OP-1993-034 (G)-2	PUREX INDUSTRIES, INC.	Purex Industries, Inc. - Airwork Site	Modelled
500	PA	PWS	Public Water Supply	D-2000-064 CP-4	Quakertown Borough	Quakertown Borough	Modelled
501	PA	OTH	Commercial	D-2017-010 -1	Radisson Valley Forge Hotel	Valley Forge Casino Resort	Modelled
502	NJ	MIN	Mining	OP-2017-504 -1	RE Pierson Materials Corp	RE Pierson Materials Corp	Modelled
503	PA	IND	Industrial	D-2011-023 -1	Reading Alloys, Inc. (Ametek)	Reading Alloys, Inc.	Modelled
504	PA	PWS	Public Water Supply	D-2000-059 CP-2	READING AREA WATER AUTHORITY	READING AREA WATER AUTHORITY	Modelled
505	PA	PWR	Thermoelectric	D-2000-059 CP-2	READING AREA WATER AUTHORITY	Reading Area Water Authority	Not Modeled - OR
506	NJ	MIN	Mining	OP-2005-010 -1	Ricci Bros. Sand Co., Inc.	Ricci Bros. Sand Co., Inc.	Modelled
507	PA	PWS	Public Water Supply	P-1997-042 CP-2	Richland Meadows Mobile Home Park	Richland Meadows Mobile Home Park	Modelled
508	PA	PWS	Public Water Supply	D-1996-044 CP-4	RICHLAND TOWNSHIP WATER AUTHORITY	RICHLAND TOWNSHIP WATER AUTHORITY	Modelled
509	PA	PWS	Public Water Supply	D-1992-001 CP-3	Richland, Borough of	Borough of Richland	Modelled
510	PA	PWS	Public Water Supply	D-1969-148 CP	RICHLANDTOWN BOROUGH	RICHLANDTOWN BOROUGH	Modelled
511	NJ	IND	Industrial	ENT-244	RIEGEL PAPER, MILFORD (*CROWN VANTAGE, JAMES	RIEGEL PAPER, MILFORD (*CROWN VANTAGE, JAMES	Modelled
512	NJ	IND	Industrial	ENT-243 and ENT-246	RIEGEL PAPER, WARREN GLEN (*FIBERMARK, INC,CPG	RIEGEL PAPER, WARREN GLEN (*FIBERMARK, INC,CPG	Modelled
513	PA	PWS	Public Water Supply	D-1967-085 CP	RIEGELSVILLE BOROUGH	RIEGELSVILLE BOROUGH	Modelled
514	NJ	IND	Industrial	AA-2012-511	Rimtec Corporation	Rimtech Corporation	Modelled
515	NJ	PWR	Thermoelectric	AA-1992-037	Riverstone Holdings	Pedricktown Cogeneration Company LP	Modelled
516	PA	PWS	Public Water Supply	D-1988-045 CP-4	Roamingwood Sewer and Water Association	Roamingwood Sewer and Water Association - PWS	Modelled

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
517	NJ	IND	Industrial	D-1977-026	ROCHE VITAMINS INC	Roche Vitamins	Not Modeled - OR
518	PA	IND	Remediation	D-1989-008 PA REN	Rohm & Haas Delaware Valley, Inc.	Rohm & Haas Delaware Valley, Inc. - Spring House Res	Not Modelled - HD
519	PA	IND	Industrial	ENT-249	Rohm & Haas Delaware Valley, Inc. - Bristol	Rohm & Haas Delaware Valley, Inc. - Bristol	Modelled
520	PA	IND	Industrial	ENT-250	Rohm & Haas Delaware Valley, Inc. - Philadelphia	Rohm & Haas Delaware Valley, Inc. - Philadelphia	Modelled
521	NJ	PWS	Public Water Supply	D-1985-008 CP REN 2	Roosevelt Borough	Roosevelt Borough	Modelled
522	PA	IND	Industrial	D-1995-001 -2	ROSENBERGERS DAIRIES, INC.		Not Modelled - HD
523	NY	PWS	Public Water Supply	D-2002-014 CP-2	ROXBURY TOWN	ROXBURY TOWN	Modelled
524	NJ	PWS	Public Water Supply	OP-1996-017 CP-2	ROXBURY TOWNSHIP	ROXBURY TOWNSHIP	Modelled
525	NJ	PWS	Public Water Supply	D-2002-046 CP	Salem City	Salem City	Modelled
526	NY	IND	Industrial	D-1972-146 -2	Saputo Dairy Foods USA, LLC	Saputo Dairy Foods - Processing Facility	Modelled
527	NJ	MIN	Mining	OP-2011-503	Saxon Falls Sand & Gravel Co	Saxon Falls Sand & Gravel Co	Modelled
528	PA	PWS	Public Water Supply	D-1990-049 CP-4	Schuylkill County Municipal Authority	Schuylkill County Municipal Authority	Modelled
529	PA	IND	Industrial	D-1971-087	Schuylkill County Municipal Authority	Schuylkill County Municipal Authority	Not Modeled - OR
530	PA	IND	Industrial	D-1981-030 REN 2	SCHUYLKILL HAVEN BLEACH & DYE WORKS	SCHUYLKILL HAVEN BLEACH & DYE WORKS	Not Modelled - HD
531	PA	PWS	Public Water Supply	D-1989-096 CP REV	SCHUYLKILL HAVEN BORO	Schuylkill Haven Borough Water Department	Modelled
532	PA	PWS	Public Water Supply	D-2003-029 CP-2	Schwenksville Borough Authority	Schwenksville Borough Authority	Modelled
533	NJ	IND	Industrial	OP-1998-044 -1	Seabrook Farms, Inc.	Seabrook Farms	Modelled
534	PA	IND	Industrial	D-1994-081 -3	SEALED AIR CORPORATION	Recycled Paper Mill	Modelled
535	PA	PWS	Public Water Supply	ENT-318	Sellersville Borough	SMOKETOWN CRK	Not Modelled - HD
536	PA	OTH	Ski/Snowmaking	D-1988-050	Shawnee Mountain Ski Area	Shawnee Mountain Ski Area	Modelled
537	NJ	IND	Remediation	D-1988-053 REN	SHIELDALLOY		Not Modelled - HD
538	PA	PWS	Public Water Supply	D-1990-007 CP-4	SHOEMAKERSVILLE BOROUGH	Shoemakersville Borough	Modelled
539	PA	IND	Industrial	ENT-254	SHRYOCK BROS INC	E BR BRANDYWINE CR	Not Modelled - HD
540	NJ	IND	Industrial	D-1971-057	Siegfried USA, LLC	Siegfried USA, LLC - Pennsville	Modelled
541	DE	IND	Industrial	D-1970-086 -2	Siemens Healthcare Diagnostics, Inc.	Siemens Healthcare Diagnostics, Inc.	Modelled
542	NJ	OTH	Commercial	D-1996-006 CP-2	SIX FLAGS GREAT ADVENTURE	Six Flags Great Adventure	Modelled
543	PA	PWS	Public Water Supply	D-1990-097 CP	Slatington Borough	Slatington Borough	Modelled
544	NJ	IND	Industrial	D-1969-084 -3	Solvay Specialty Polymers USA, LLC	Solvay Specialty Polymers USA, LLC	Modelled
545	PA	IND	Industrial	ENT-255	SONOCO PRODUCTS-DOWNINGTON PAPER	SONOCO PRODUCTS-DOWNINGTON PAPER	Modelled
546	PA	PWS	Public Water Supply	D-2000-026 CP-2	South Coventry Township	South Coventry Township	Modelled
547	PA	MIN	Mining	ENT-256	South Tamaqua Coal Pockets, Inc.	South Tamaqua Coal Pockets, Inc.	Not Modeled - OR
548	PA	PWS	Public Water Supply	D-1991-082 CP-3	South Whitehall Township	South Whitehall Township	Modelled
549	NJ	PWS	Public Water Supply	D-1998-001 CP	SPARTA TOWNSHIP	SPARTA TOWNSHIP	Modelled
550	DE	IND	Industrial	D-1978-085 2	SPI Pharma	SPI Pharma - Lewes	Modelled
551	PA	IND	Industrial	D-1979-088 -5	SPS TECHNOLOGIES	SPS Technologies	Modelled
552	NJ	PWS	Public Water Supply	AA-1980-084 CP	Stanhope Borough Water Department	Stanhope Borough Water Department	Modelled
553	PA	IND	Remediation	D-1987-032 -4	Stanley Black and Decker	Stanley Black and Decker	Modelled
554	NJ	IND	Industrial	ENT-257	Stepan Company/Industrial Chemicals Division	Stepan Company/Industrial Chemicals Division	Modelled
555	NJ	PWS	Public Water Supply	D-1979-056 CP	STILLWATER WATER DIST NO. 1	STILLWATER WATER DIST NO. 1	Modelled
556	NJ	PWS	Public Water Supply	OP-1995-051 CP-1	STOCKTON BOROUGH	STOCKTON BOROUGH	Modelled
557	PA	OTH	Fish Hatchery	D-2004-012 -2	STONY CREEK ANGLERS, INC	Stony Creek Anglers, Inc - Trout Nursery	Modelled
558	NJ	PWS	Public Water Supply	D-0000-003 ENT 305	Suez Lambertville	Suez Lambertville	Modelled
559	DE	PWS	Public Water Supply	D-1996-050 CP-3	Suez Water Delaware	Suez Water Delaware	Modelled

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
560	PA	PWS	Public Water Supply	D-1984-003 CP-4	SUMMIT HILL WATER AUTHORITY	SUMMIT HILL WATER AUTHORITY	Modelled
561	PA	PWS	Public Water Supply	D-2001-056 CP-2	SUMMIT MANAGEMENT & UTILITIES, INC	SUMMIT MANAGEMENT & UTILITIES, INC	Modelled
562	NJ	IND	Refinery	D-1986-015 -4	Sunoco Logistics Partners, L.P.	Sunoco Logistics	Modelled
563	DE	IND	Industrial	D-1967-240 -2	Sunoco Partners Marketing & Terminals LP	Marcus Hook Industrial Complex	Not Modeled - OR
564	PA	IND	Refinery	D-1967-240 -2	Sunoco Partners Marketing & Terminals LP	Marcus Hook Industrial Complex	Modelled
565	PA	IND	Industrial	D-1996-013 -2	Superior Tube Company, Inc.	Superior Tube Company, Inc.	Modelled
566	NJ	IND	Industrial	AA-2010-510	Surfside Products, LLC.	Surfside Products, LLC.	Modelled
567	NJ	PWS	Public Water Supply	OP-1970-112 CP-1	SWEDESBORO WATER DEPARTMENT	SWEDESBORO WATER DEPARTMENT	Modelled
568	NJ	IND	Industrial	D-1985-005 -3	SYBRON CHEMICALS INC		Modelled
569	PA	PWS	Public Water Supply	D-2010-028 CP-1	Tamaqua Area Water Authority	Tamaqua Area Water Authority Still Creek Reservoir	Modelled
570	PA	PWS	Public Water Supply	D-2004-010 CP-2	TELFORD BOROUGH AUTHORITY	TELFORD BOROUGH AUTHORITY	Modelled
571	PA	IND	Industrial	P-2010-023 -1	THERMCO PRODUCTS CORP	THERMCO PRODUCTS CORP	Not Modelled - HD
572	NJ	IND	Industrial	AA-1995-054	Thomas & Betts Corporation	Thomas & Betts Corporation - Elastimold	Modelled
573	DE	PWS	Public Water Supply	D-2002-004 CP-3	Tidewater Utilities, Inc.	Tidewater Utilities, Inc. - Rehoboth - Lewes	Modelled
574	DE	PWS	Public Water Supply	D-2004-024 CP-3	Tidewater Utilities, Inc.	Tidewater Utilities, Inc. - Camden	Modelled
575	DE	PWS	Public Water Supply	D-2005-027 CP-2	Tidewater Utilities, Inc.	Tidewater Utilities, Inc. - Wild Quail	Modelled
576	DE	PWS	Public Water Supply	D-2005-026 CP-2	Tidewater Utilities, Inc.	Tidewater Utilities, Inc. - Garrison Lake - North Dover D	Modelled
577	DE	PWS	Public Water Supply	AA-2006-012	Tidewater Utilities, Inc.	Tidewater Utilities, Inc. - East District	Modelled
578	DE	PWS	Public Water Supply	D-2008-003 CP-1	Tidewater Utilities, Inc.	Tidewater Utilities, Inc. - Felton District	Not Modeled - OR
579	PA	OTH	Military	D-1987-057 CP-4	Tobyhanna Army Depot	Tobyhanna Army Depot	Modelled
580	PA	PWS	Public Water Supply	P-2015-012 CP-1	TOLL BROTHERS INC	TOLL BROTHERS INC	Modelled
581	PA	PWS	Public Water Supply	P-2015-016 CP-1	TOLL BROTHERS INC	Toll Brothers Inc - Estates at Mill Creek Subdivision	Not Modeled - OR
582	PA	PWS	Public Water Supply	D-1973-121 CP	Topton Borough	Topton Borough	Modelled
583	DE	PWS	Public Water Supply	D-1999-026 CP-2	Town of Felton	Town of Felton	Modelled
584	NY	PWS	Public Water Supply	D-1967-121 CP-2	Town of Liberty (NY)	Town of Liberty (NY)	Modelled
585	DE	PWS	Public Water Supply	D-1983-022 CP REN 2	Town of Milton	Town of Milton	Modelled
586	NY	PWS	Public Water Supply	D-1963-004 CP-2	Town of Rockland	Town of Rockland	Modelled
587	DE	PWS	Public Water Supply	AA-1993-072 CP	Town of Smyrna	Town of Smyrna	Modelled
588	NJ	PWS	Public Water Supply	OP-1998-009 CP-2	Trenton Water Works, City of Trenton	Trenton Water Works, City of Trenton	Modelled
589	PA	PWS	Public Water Supply	D-1977-005 CP	TRUMBAUERSVILLE BOROUGH	TRUMBAUERSVILLE BOROUGH	Modelled
590	PA	IND	Industrial	D-2009-043 -1	Tuscan Lehigh Dairies - Montgomery Co	Tuscan Lehigh Dairies - Montgomery Co	Modelled
591	PA	OTH	Ski/Snowmaking	D-2010-026 -1	Tuthill Corporation & Aquashicola-Little Gap, Inc.	Blue Mountain Ski Area	Modelled
592	NJ	IND	Industrial	AA-1984-058	TWIST BEAUTY PACKAGING US INC.	TWIST BEAUTY PACKAGING US INC	Modelled
593	NJ	MIN	Mining	D-2004-030-1	U.S. SILICA COMPANY	U.S. SILICA COMPANY	Modelled
594	NJ	MIN	Mining	OP-2007-037 -1	U.S. Silica Company	Port Elizabeth Mine	Modelled
595	NJ	PWS	Public Water Supply	D-2007-022 CP-2	UMH Properties, Inc.	UMH - Fairview Manor Mobile Home Park (NJ)	Modelled
596	PA	PWS	Public Water Supply	P-1998-004 -2	UMH Properties, Inc.	UMH - Arbor Estates Mobile Home Park (PA)	Modelled
597	NJ	MIN	Mining	AA-2007-013	Unimin Corporation	Unimin Corporation - Silica Processing Facility	Modelled
598	PA	PWS	Public Water Supply	P-2003-031 CP-2	Union Township Municipal Authority	Union Greene Water System	Modelled
599	PA	IND	Industrial	D-1993-040 -3	UNITED CORRSTACK INC	United Corrstack Inc - Reading	Not Modelled - ND
600	DE	OTH	Military	D-2000-005 CP-2	UNITED STATES AIR FORCE - DOVER AIR FORCE BASE	Dover Air Force Base	Modelled
601	NY	OTH	Prison	D-1983-007 CP-4	United States Department of Justice	Otisville Federal Correctional Institution	Modelled
602	NJ	IND	Remediation	D-2015-022 CP-1	United States EPA	Region 2	Not Modelled - ND

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
603	NJ	IND	Remediation	OP-2017-501 -1	United States EPA (Region 2)	Cosden Chemical Coatings Corp	Modelled
604	NJ	PWS	Public Water Supply	OP-1993-016 CP-3	UPPER DEERFIELD TOWNSHIP	UPPER DEERFIELD TOWNSHIP	Modelled
605	PA	PWS	Public Water Supply	P-1994-057 CP-3	UPPER FREDERICK TOWNSHIP	UPPER FREDERICK TOWNSHIP	Modelled
606	PA	PWS	Public Water Supply	D-2002-010 CP-4	Upper Hanover Authority	Upper Hanover Authority - PWS	Modelled
607	PA	PWS	Public Water Supply	D-2007-024 CP-2	Upper Makefield Township	Upper Makefield Township	Modelled
608	PA	PWS	Public Water Supply	D-2000-051 CP-3	UPPER SAUCON TOWNSHIP	UPPER SAUCON TOWNSHIP	Modelled
609	PA	PWS	Public Water Supply	D-1965-023 CP-2	UPPER SOUTHAMPTON AUTH	Upper Southampton Municipal Authority	Modelled
610	PA	IND	Industrial	D-2009-006 -1	US Steel Real Estate	US Steel Real Estate	Modelled
611	PA	PWS	Public Water Supply	D-1968-111 CP	Utilities Inc. - Westgate	Utilities Inc. - Westgate	Modelled
612	PA	IND	Industrial	P-2010-027 CP-1	Valley Forge Sewer Authority	Valley Forge Sewer Authority	Modelled
613	PA	IND	Industrial	ENT-267	VALLEY PAPER MILL (EXTON PAPER)	DENNIS RUN	Not Modelled - HD
614	PA	PWS	Public Water Supply	D-1988-031 CP-4	Valley Township	Valley Township	Modelled
615	PA	PWR	Thermoelectric	D-1995-010 CP-2	Veolia Energy	Veolia Energy - Tri-Gen Energy Generating Facility	Modelled
616	PA	PWR	Thermoelectric	D-1964-074 CP-2	Veolia Energy	Veolia Energy-Schuykill	Modelled
617	PA	PWR	Thermoelectric	D-1995-032 CP-2	Veolia Energy	Veolia Energy - Grays Ferry Cogeneration Facility	Modelled
618	PA	IND	Remediation	D-1993-061 -3	Viant Collegeville, LLC	Viant Collegeville, LLC	Modelled
619	PA	PWS	Public Water Supply	D-1970-006 CP	VILLAGE II AT NEW HOPE, INC	VILLAGE II AT NEW HOPE, INC	Modelled
620	NY	PWS	Public Water Supply	D-1975-070 CP-2	Village of Delhi	Village of Delhi	Modelled
621	NY	PWS	Public Water Supply	D-2013-002 CP-1	Village of Liberty	Village of Liberty	Modelled
622	NY	PWS	Public Water Supply	D-2001-005 CP-2	Village of Monticello	Village of Monticello	Modelled
623	NY	PWS	Public Water Supply	D-1994-025 CP-2	Village of Wurtsboro	Village of Wurtsboro	Modelled
624	NJ	PWS	Public Water Supply	AA-1995-047 CP	VINELAND CITY	VINELAND CITY	Modelled
625	NJ	OTH	Hospital/Health	AA-2012-507	Virtua Voorhees Hospital	Virtua Voorhees Hospital	Not Modeled - OR
626	PA	OTH	Bottled Water	D-2007-010 -2	VOGEL FARM AND BROAD MOUNTAIN SPRING WATEF	Vogel Farm and Broad Mountain Spring Water	Not Modelled - ND
627	PA	PWS	Public Water Supply	D-1971-150 CP-2	Wallenpaupack Lake Estates POA	Wallenpaupack Lake Estates	Modelled
628	PA	PWS	Public Water Supply	D-1990-087 CP-3	WALNUTPORT AUTHORITY	WALNUTPORT AUTHORITY	Modelled
629	NY	PWS	Public Water Supply	D-1972-061 CP	Walton Village	Walton Village	Modelled
630	NJ	MIN	Mining	OP-2019-509	WARD SAND & MATERIALS CO	WARD SAND & MATERIALS CO	Modelled
631	PA	PWS	Public Water Supply	D-2000-019 CP-2	Warminster Municipal Authority	Warminster Municipal Authority	Modelled
632	PA	PWS	Public Water Supply	D-1990-019 CP-3	Warrington Township	Warrington Township	Modelled
633	PA	PWS	Public Water Supply	D-1998-019 CP-2	Warwick Township Water & Sewer Authority	Warwick Township Water & Sewer Authority	Modelled
634	NJ	OTH	School	D-1971-162 CP	WASHINGTON TOWNSHIP BOARD OF EDUCATION	Washington Township Board of Education - High Schoo	Modelled
635	NJ	PWS	Public Water Supply	AA-1999-043 CP	WASHINGTON TOWNSHIP MUNICIPAL UTILITIES AUTH	WASHINGTON TOWNSHIP MUNICIPAL UTILITIES AUTH	Modelled
636	PA	IND	Industrial	D-1991-090 -3	Waste Management Disposal Services of Pennsylvania	Waste Management - Grows, Grows North, Tulleytowı	Modelled
637	PA	IND	Remediation	P-1991-047 -4	Waste Management Disposal Services of Pennsylvania	Waste Management Disposal Services of Pennsylvania	Modelled
638	PA	PWS	Public Water Supply	D-1980-080 CP-4	Weatherly Borough	Weatherly Borough	Modelled
639	NJ	PWS	Public Water Supply	OP-2013-003 CP-1	Wenonah Borough	Wenonah Borough	Modelled
640	PA	PWS	Public Water Supply	D-2001-017 CP-2	WERNERSVILLE MUNICIPAL AUTHORITY	WERNERSVILLE MUNICIPAL AUTHORITY	Modelled
641	PA	MIN	Mining	D-1966-123	WESNER COAL CO		Not Modeled - OR
642	NJ	IND	Industrial	D-1974-180	WEST COMPANY		Not Modelled - HD
643	NJ	PWR	Thermoelectric	D-2008-027 CP-3	West Deptford Energy	West Deptford Energy Station	Modelled
644	NJ	PWS	Public Water Supply	OP-1979-082 CP-4	West Deptford Township	West Deptford Township	Modelled
645	PA	PWS	Public Water Supply	D-1996-026 CP-2	WEST GROVE BOROUGH	WEST GROVE BOROUGH	Modelled
646	PA	PWS	Public Water Supply	D-1969-055 CP-4	WESTERN BERKS WATER AUTHORITY	Western Berks WA Facility	Modelled

	State	Sector	Category	Primary Docket Number	Organization Name	System Name	Model Status
647	PA	IND	Industrial	ENT-271	Westlake Plastics Company	Westlake Plastics Company	Modelled
648	PA	IND	Industrial	D-1980-025 -2	WestRock Converting Company, LLC	WestRock Stroudsburg Mill	Modelled
649	NJ	PWS	Public Water Supply	OP-1979-086 CP RENEWAL	WESTVILLE BOROUGH	WESTVILLE BOROUGH	Modelled
650	PA	IND	Industrial	ENT-272	WEYERHAUSER CO (SIMPSON PAPER)	MANOR CR RUN	Not Modelled - HD
651	PA	PWR	Thermoelectric	D-1986-048	Wheelabrator Frackville Energy Co.	Wheelabrator Frackville Energy Co.	Modelled
652	NJ	PWR	Thermoelectric	D-1987-038	Wheelabrator Gloucester Co., LP	Wheelabrator Gloucester Co., LP	Modelled
653	NJ	MIN	Mining	AA-2011-507	WHIBCO INC	WHIBCO INC	Modelled
654	PA	OTH	Bottled Water	D-2008-012 CP-2	White Haven Borough	White Haven Borough - Fogelsvilles/Pittston Bottling S	Modelled
655	PA	PWS	Public Water Supply	D-2000-009 CP-2	Whitehall Township Authority	Whitehall Township Authority	Modelled
656	NJ	PWS	Public Water Supply	OP-1987-042 CP-3	Willingboro Municipal Utilities Authority	Willingboro Municipal Utilities Authority	Modelled
657	DE	PWS	Public Water Supply	D-0000-004 ENT 140	Wilmington City	Wilmington Department of Public Works/Water Divisi	Modelled
658	PA	PWS	Public Water Supply	D-1998-023 CP-3	Womelsdorf - Robesonia Joint Authority	Womelsdorf - Robesonia Joint Authority	Modelled
659	NJ	PWS	Public Water Supply	OP-1980-062 CP	WOODBURY CITY	WOODBURY CITY	Modelled
660	NJ	PWS	Public Water Supply	OP-1973-120 CP-1	WOODBURY HEIGHTS BOROUGH	WOODBURY HEIGHTS BOROUGH	Modelled
661	NJ	PWS	Public Water Supply	D-1999-004 CP-2	WOODSTOWN BOROUGH	WOODSTOWN BOROUGH	Modelled
662	NJ	PWS	Public Water Supply	AA-1974-113 CP	WRIGHTSTOWN BOROUGH MUA	WRIGHTSTOWN BOROUGH MUA	Modelled
663	PA	PWS	Public Water Supply	P-2011-016 CP-1	YERKES WATER ASSN	YERKES WATER ASSN	Modelled
664	NY	IND	Industrial	D-2003-026 -2	Yukiguni Maitake Manufacturing Corporation of Ameri	Yukiguni Maitake Manufacturing Corporation of Ameri	Not Modeled - OR

Notes:

Not Modelled - HD = Not modelled, but historic data was linked to an inactive approval.

Not Modeled - ND = Not modelled because there is no available data.

Not Modeled - OR = Not modelled for "other reason" (e.g. this docket record was included in the final review list, but the withdrawal is inherently captured under another docket).

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Delaware River Basin Commission
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