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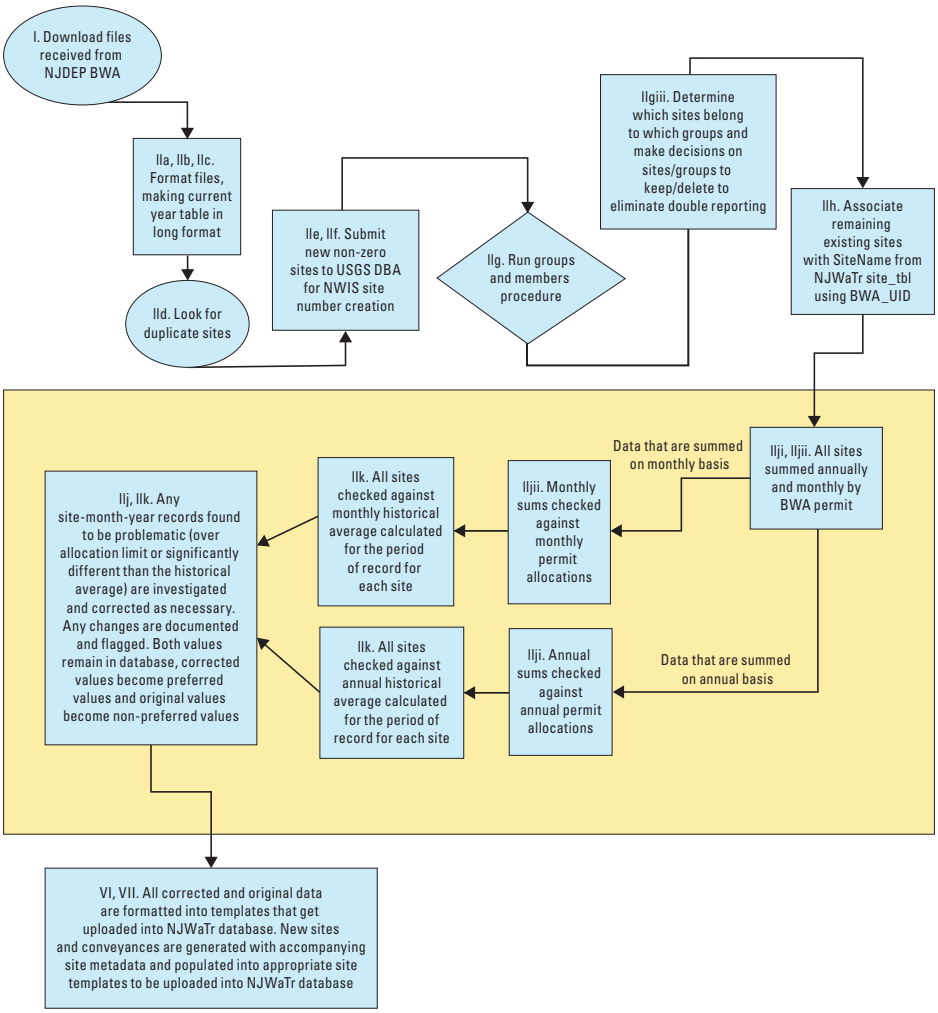
Quality Assurance/Quality Control Procedure for New Jersey's Water-Use Data for the New Jersey Water Transfer Data System (NJWaTr)



Open-File Report 2020–1085

U.S. Department of the Interior
U.S. Geological Survey

Cover: Figure 1 in the report.

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By Jennifer L. Shourds

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U.S. Department of the Interior
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Preface

The U.S. Geological Survey (USGS) has been involved in a cooperative project with the New Jersey Department of Environmental Protection (NJDEP) relating to the New Jersey Water Transfer Data System since 2004. The quality assurance/quality control procedure described in this document is executed on data received from the NJDEP Bureau of Water Allocation, and the data are therefore owned by the State of New Jersey. The USGS assumes no responsibility for the long-term preservation and accessibility of these data under Open Data guidelines that pertain to U.S. Government data products.

Acknowledgments

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
gallon (gal)	3.785	cubic decimeter (dm^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
gallon per day per square mile ([gal/d]/mi^2)	0.001461	cubic meter per day per square kilometer ([m^3/d)]/km^2)
million gallons per day per square mile ([Mgal/d]/mi^2)	1,461	cubic meter per day per square kilometer ([m^3/d]/km^2)
	Volume	
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	264.2	gallon (gal)
cubic decimeter (dm^3)	0.2642	gallon (gal)
cubic meter (m^3)	0.0002642	million gallons (Mgal)
	Flow rate	
liter per second (L/s)	15.85	gallon per minute (gal/min)
cubic meter per day (m^3/d)	264.2	gallon per day (gal/d)
cubic meter per day per square kilometer ([m^3/d]/km^2)	684.28	gallon per day per square mile ([gal/d]/mi^2)
cubic meter per second (m^3/s)	22.83	million gallons per day (Mgal/d)
cubic meter per day per square kilometer ([m^3/d]/km^2)	0.0006844	million gallons per day per square mile ([Mgal/d]/mi^2)

Abbreviations

ASR	aquifer storage and recovery
BWA	Bureau of Water Allocation
DBA	database administrator
GNIS	Geographic Names Information System
HUC	Hydrologic Unit Code
ID(s)	Identifier(s)
MCD	Minor Civil Division
NJDEP	New Jersey Department of Environmental Protection
NJEMS	New Jersey Environmental Management System
NJGWS	New Jersey Geological and Water Survey
NJPDES	New Jersey Pollutant Discharge Elimination System
NJWaTr	New Jersey Water Transfer Data System
NJWSC	New Jersey Water Science Center
NWIS	National Water Information System
PI	Program Interest
QA/QC	quality assurance/quality control
SSA	sewer service area
SW	surface water
UID(s)	Unique Identifier(s)
USGS	U.S. Geological Survey

Quality Assurance/Quality Control Procedure for New Jersey's Water-Use Data for the New Jersey Water Transfer Data System (NJWaTr)

By Jennifer L. Shourds

Abstract

This report is an instructional reference document that describes methods developed and used by the U.S. Geological Survey (USGS) New Jersey Water Science Center (NJWSC) to assure the quality and completeness of water-use data as provided by the New Jersey Department of Environmental Protection (NJDEP) Bureau of Water Allocation. These data are owned wholly by the State of New Jersey. The role of the USGS NJWSC is to assure the quality of these data by compiling, reviewing, and checking the datasets before uploading them into the New Jersey Water Transfer Data System (NJWaTr) database on an annual basis. The complete uploaded version of the NJWaTr database serves as the repository for New Jersey's approved and published water-use data. The State of New Jersey maintains a public-facing version of the NJWaTr database (available online at https://www.nj.gov/dep/njgs/geodata/dgs10-3.htm) that contains monthly water-use data at the municipality and 14-digit Hydrologic Unit Code subwatershed level. The protected version of the NJWaTr database that contains monthly site-specific water-use data is available from the NJDEP upon request.

Introduction

Water-use withdrawals in New Jersey vary as a result of (1) population changes within the State, (2) yearly climate effects (larger withdrawals in dry years than in wet years for most water-use categories), (3) land-use changes over time (for example, residential, commercial, and industrial development), and (4) economic effects. (New Jersey Department of Environmental Protection, 2017). Water-use data are important to the State of New Jersey, but data requests also come from scientists studying and modeling groundwater and surface water, university researchers, non-profit organizations, local governmental agencies, and the public sector.

The regulation and data collection for New Jersey's water resources are overseen by multiple New Jersey Department of Environmental Protection (NJDEP) agencies, including programs for land use, water quality, water supply, and wildlife. Two issues common to these programs are the limited amount of water available to meet competing demands and the lack of available water-use data. Independent collection and storage of water-use data by these agencies make data retrieval and use problematic. Water-resource managers and scientists require a single source of consistent, accurate, relevant, and easily accessible water-use data to plan for current demands and future needs.

In the early 1990s, the USGS established an internal water-use database (specific to the New Jersey Water Science Center [NJWSC]) that contains monthly site-specific withdrawal data from 1918 to the present and has been compiling, checking, and preparing quality-assured water-use data for its own projects since the early 1990s. To help the State of New Jersey meet its water-supply-planning goals and to provide a centralized database to house water-use data, a cooperative project between the NJDEP New Jersey Geological and Water Survey (NJGWS) and the USGS led to the creation of the New Jersey Water Transfer Data System (Tessler, 2003), commonly referred to as NJWaTr or the NJWaTr database. The NJWaTr database was initially populated with 10 years of New Jersey water-use, water-transfer, and related data from 1990 through 1999.

One of the cooperative project's main goals is to annually populate the NJWaTr database with quality-assured, site-specific monthly data. As such, the USGS developed a procedure to assure the quality of the data received from the NJDEP Bureau of Water Allocation (BWA) and has adapted the procedure to meet the needs of the cooperative project throughout the years. This quality assurance/quality control (QA/QC) procedure has evolved over time, and the steps have been automated whenever possible.

Table 1 shows that for 2004 to 2010, the QA/QC procedure was very important in ensuring the quality and accuracy of the data in NJWaTr. The large percentage decreases in total annual withdrawals, original (raw) data compared to quality-assured data, ranging from 91.2 to 99.7 percent, justify the need to correct the raw data received from the State and track changes made to the original data. Large errors generally result from order of magnitude errors as a result of incorrect

Table 1. Examples of changes to the annual withdrawal totals resulting from the Quality Assurance/Quality Control effort.

[QA/QC, quality assurance and quality control; Mgal/yr, million gallons per year; NJDEP New Jersey Department of Environmental Protection; BWA, Bureau of Water Allocation; NJWaTr, New Jersey Water Transfer Data System]

Year	Sum of annual withdrawals, in Mgal/yr		Decrease in sum of annual withdrawal from original, in percent
	Pre QA/QC, original (raw) data from NJDEP BWA	Post QA/QC data, as stored in NJWaTr	
2004	376,567,740	1,031,222	99.7
2005	70,416,700	1,062,918	98.5
2006	136,318,122	1,024,497	99.2
2007	131,747,707	946,181	99.3
2008	160,190,301	917,739	99.4
2009	129,787,103	1,172,169	99.1
2010	8,162,042	716,109	91.2

units reported by the purveyor. These types of units errors, as well as other types of errors, are fixed as a result of the QA/QC procedure.

The initial cooperative work was followed by further refinements to the data model and the development of tools to assist with updating, exporting, checking, and transforming the data into additional outputs serving specific uses. Recent cooperative work has been focused on updating the original database design and supporting applications to accommodate new requirements and meet user needs, and compiling, checking, and preparing new data that are added annually to the NJWaTr database.

Annual updates to the NJWaTr database ensure that current, high-quality, water-use data are readily available to the NJDEP and other water-use data users from a consistent, centralized source. The site-specific, water-use data are accompanied by relevant information pertaining to each site and its resource. The State of New Jersey maintains a public-facing version of the NJWaTr database (available online at https://www.nj.gov/dep/njgs/geodata/dgs10-3.htm) that contains monthly water-use data at the municipality and 14-digit Hydrologic Unit Code subwatershed level. The protected version of the NJWaTr database that contains monthly site-specific water-use data is available from the NJDEP upon request. Appendix 1 lists selected publications that include the quality-assured, water-use data retrieved from the protected version of NJWaTr.

The purpose of this report is to document the QA/QC procedure that the NJWSC uses to compile, check, and prepare water-use data received from the NJDEP BWA for inclusion in NJWaTr. This report is intended for use as a reference document and is intended to be read by those using data from NJWaTr. Although this report describes the QA/QC procedures performed on many different types of data (withdrawal, aquifer storage and recovery (ASR), surface-water returns, and wastewater), the focus is on the withdrawal data because they account for the largest number of data values and have the most accompanying, ancillary information, which allows inconsistencies and errors to be easily identified and corrected.

Quality Assurance/Quality Control Procedure For New Jersey's Water-Use Data

The QA/QC procedure has been refined over the years and is presented in this report as a series of steps. The steps are described in the following sections by data type: withdrawal data, aquifer-storage and recovery data, surface-water return data, and wastewater discharge data.

NJDEP BWA provides data tables to the USGS as text files that need to be formatted and verified. The raw datasets arrive in a wide format with one row containing one site and 12 withdrawal volume values for the 12 months of the calendar year. These data are generated by the State's New Jersey Environmental Management System (NJEMS) and are sent to an electronic mailing address list twice a year. Withdrawal data also can be found in raw, original, pre-QA/QC form on the State's data miner website at https://www13.state.nj.us/DataMiner.

Withdrawal Data

This section describes the procedure used to compile and assure the quality of the withdrawal water-use data as obtained from the NJDEP BWA. The data include surface-water diversions and groundwater withdrawals. Accompanying site information included in the electronic dataset show which sites are designated as groundwater and which sites are designated as surface water.

The diagram in figure 1 and the outline in table 2 show the steps that make up the QA/QC procedure for the withdrawal data in an enumerated format to help the reader follow the steps described in the sections below.

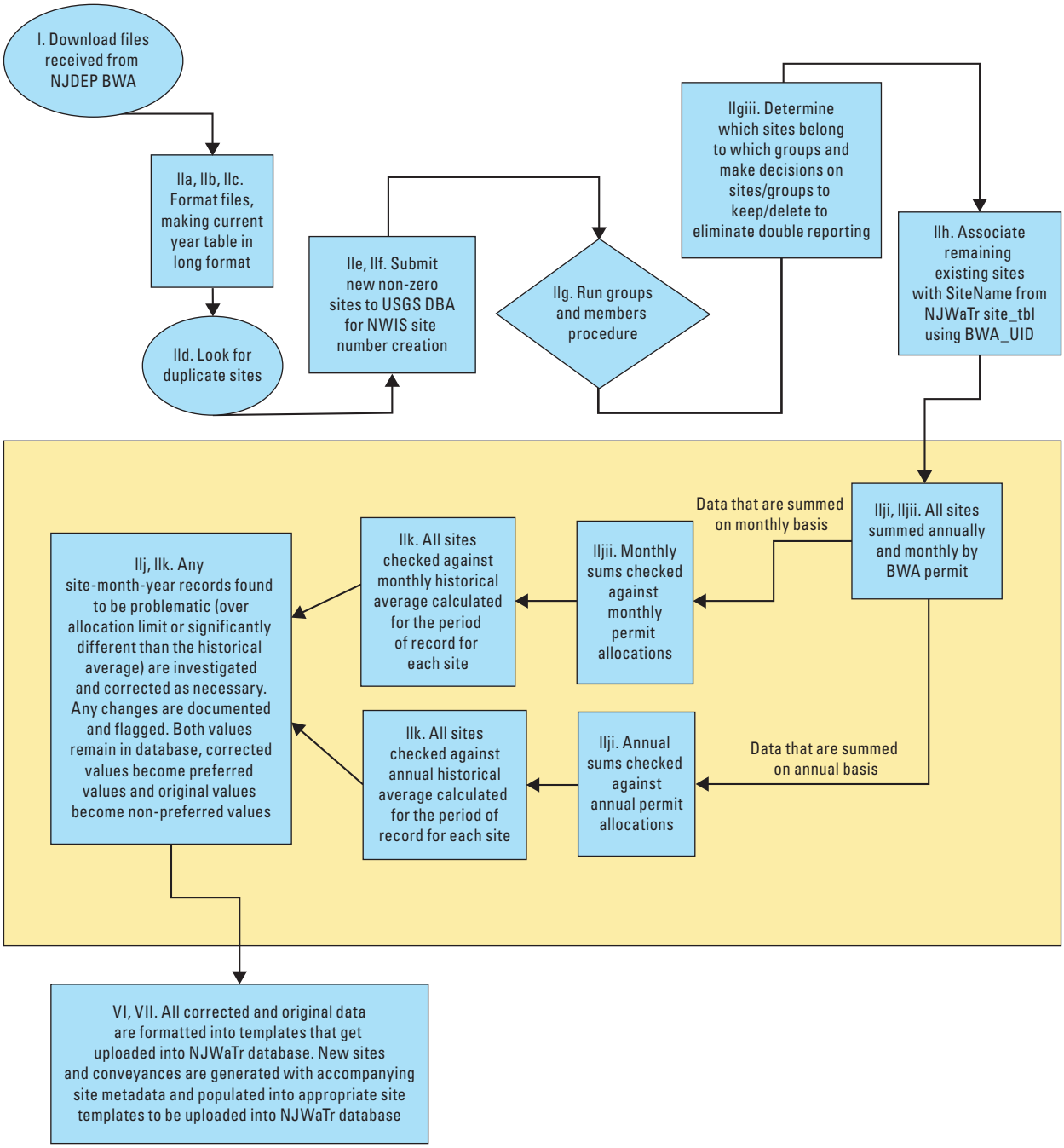

Figure 1. Schematic diagram showing a flow chart summarizing the quality assurance/quality control procedure for withdrawal data received from the New Jersey Department of Environmental Protection Bureau of Water Allocation. Alphanumeric codes in the polygons correspond to process steps in table 2; pale yellow box in center signifies the part of the Quality Assurance/Quality Control procedure where withdrawal volume data checks are executed; step IIi, from table 2, which references handling null withdrawal volume data, is omitted from this diagram for clarity. (NJDEP, New Jersey Department of Environmental Protection; BWA, Bureau of Water Allocation; USGS, U.S. Geological Survey; DBA, Database Administrator; NWIS, National Water Information System; NJWaTr, New Jersey Water Transfer Data System; BWA_UID, Bureau of Water Allocation_Unique Identifier)

Table 2. Enumerated Quality Assurance/Quality Control Procedure Steps for all water-use data.

[Steps are illustrated in figure 1. QA/QC, quality assurance/quality control; NJDEP, New Jersey Department of Environmental Protection; BWA, Bureau of Water Allocation; USGS, U.S. Geological Survey; NWIS, National Water Information System; NJWaTr, New Jersey Water Transfer Data System; BWA_UID, Bureau of Water Allocation_ Unique Identifier; DBA, Database Administrator]

Step	Description of process
I.	Obtain source data
II.	Process and QA/QC withdrawal data
	a. Obtain list of electronic files from NJDEP BWA
	b. Create new folder for the year
	c. Create long table for the year of interest
	d. Search for duplicate sites
	e. Mark new sites
	f. Mark new sites without NWIS site numbers and submit new, non-zero sites to USGS DBA for NWIS Site Creation
	g. Run groups and members procedure
	i. Link BWA Files to Database
	ii. Run Allocation Tool—to create SiteGroupPercent table which shows which sites are associated with which groups and which permits; allows for annual totals for both sites and groups to be associated to their respective permits and for annual totals to be compared against each other
	iii. Analyze and decide whether to keep sites or keep groups to eliminate double reporting
	h. Associate current year sites to pre-existing sites in NJWaTr using BWA_UID.
	i. Process null withdrawal volume data
	i. Pre-2017 data—Estimate null withdrawal values when possible
	ii. 2017 and Post-2017 data—Create table of Null Records
	j. Analyze data at BWA permit level
	i. Annual withdrawals
	1. Calculate sum of annual withdrawal values for all related sites belonging to a BWA permit
	2. Compare sum of annual withdrawal to the annual allocation for a BWA permit
	3. Calculate the percent difference between the sum of annual withdrawal and the sum of the allocation limits by BWA Permit
	4. Investigate monthly records for individual sites that make up the BWA Permits showing a percent difference between the annual withdrawal and the annual allocation limit that is greater than 25 percent
	5. Fix, flag, and document correctable errors
	ii. Monthly withdrawals
	1. Calculate monthly sums by BWA permit
	2. Compare sums of monthly withdrawal values to sums of monthly allocation limits for each BWA Permit
	3. Calculate the percent difference between the sum of the monthly withdrawal values and the sum of the monthly allocation limits by BWA Permit
	4. Investigate monthly records for individual sites that make up the BWA Permits showing a percent difference between the summed monthly withdrawal values and the summed monthly allocation limits that is greater than 25 percent
	5. Fix, flag, and document correctable errors
	k. Analyze Data as Compared to Historical Data
	i. Generate and export historical data from NJWaTr matching sites to year-of-interest data
	ii. Compare year-of-interest data against historical data—both annual totals and monthly withdrawal values
	iii. Correctable errors are fixed, flagged, and documented
III.	Process aquifer storage and recovery data
IV.	Process surface-water returns data
V.	Process wastewater discharge data
VI.	Final processing and template creation
VII.	Load all data into NJWaTr via templates

Obtain and Process Source Data

The data are obtained from the NJDEP BWA twice a year, usually in May and November. The QA/QC procedure is usually based on the November deliverable because the November annual dataset typically contains more datapoints than the May dataset and can be considered a revised, more complete version of the May dataset with fewer null records. The zipped, compressed folder of datafiles includes 17 files, as shown in figure 2.

To begin the QA/QC process, a new work area folder is set up in the water-use directory with the same configuration as folders from previous years. The work area folder includes the various databases used to format and process the data each year. Each of the 12 databases represents a step in the procedure. Nine of the 12 databases process the withdrawal data (current and historical), one database contains the process for ASR and surface-water returns data, one database contains the process for the wastewater data, and the final database compiles all the data to be stored in one location to generate the NJWaTr final loading templates.

A new data table is created for the new year of data from the electronic file dataset described in figure 2 that represents the year of interest. A link to the most recently received diverted water-data file (in this example, the first file in figure 2 titled "DIVERTED WATER DATA 01012003 to 05202015.csv") is created in the first of the 12 Microsoft Access databases that is used to process and format the data for the year of interest. This DIVERTED WATER DATA file is a comma-separated text file that contains all the monthly withdrawal data from January 2003 to the date of retrieval by the NJDEP BWA. The dataset contained in the DIVERTED WATER DATA file is delivered in a wide format and contains all available data downloaded from the NJDEP BWA database, commonly referred to as NJEMS (fig. 3).

The DIVERTED WATER DATA file, referenced in figures 2 and 3, contains 108,406 rows (sites with multiple years of data from 2003 to 2015 and 2,835 BWA Permits ("PREF_ID_NUM"), which represent 12,391 sites. Because of the current size restrictions that the NJDEP BWA has for NJEMS, this DIVERTED WATER DATA file currently (2020) must be split into three files. From the DIVERTED WATER DATA file, the year of interest table is created, and all the QA/QC steps are performed upon that dataset. The year of interest

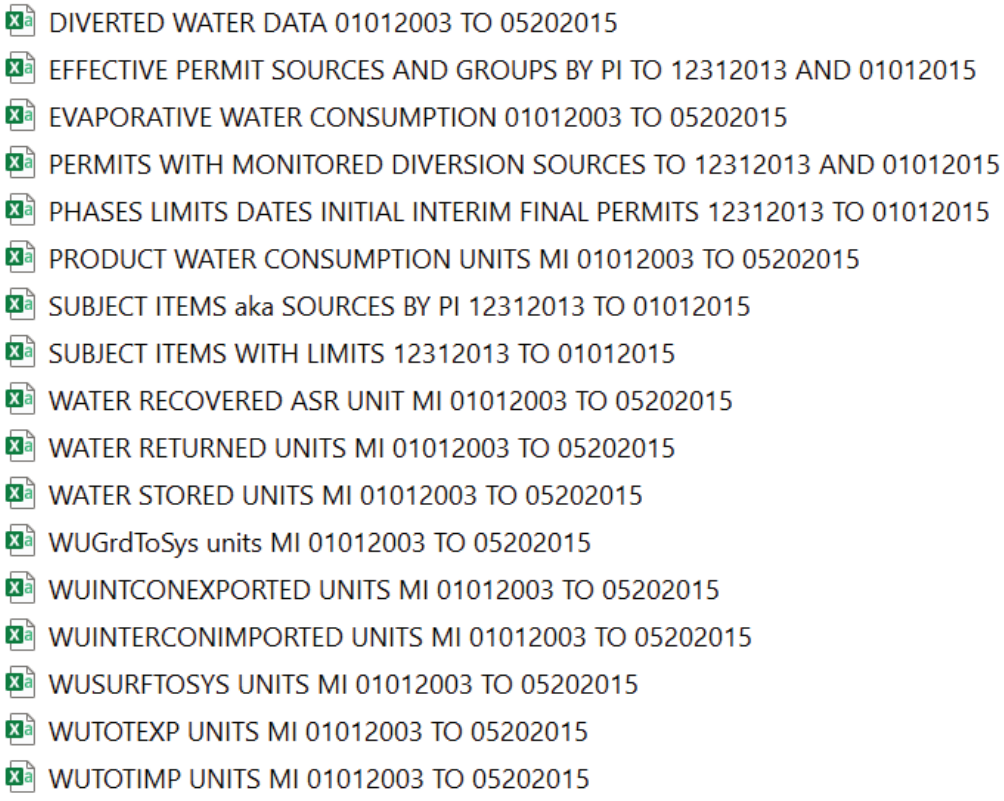

Figure 2. Screen shot showing example list of files received from New Jersey Department of Environmental Protection Bureau of Water Allocation.

is selected, and a table is created with a long-table format from the wide-table format with identifiers (IDs) ("PREF_ID_NUM", "SUBJECT_ITEM_ID", and "SUBJECT_ITEM_DESIGNATION", which are the second, third, and last columns in the DIVERTED WATER DATA file, respectively, as shown in figure 3). Each month is represented by a column heading, and the volume (in million gallons) is listed below the heading. Each month (January through December) is appended to the table, and total record counts are checked to ensure the long table was generated properly.

New Site Identification Creation and Vetting for Duplicates

The year of interest table, generated in the first Microsoft Access database, is linked into the subsequent Microsoft Access databases and used to check for duplicate sites and duplicate ID numbers, both of which are rectified, where appropriate. In general, duplicate data are relatively straightforward to rectify. They typically consist of duplicate withdrawal volume values with the same BWA_Unique Identifier (BWA_UID) (shown in fig. 3 as SUBJECT_ITEM_ID) but different BWA Permits (shown in fig. 3 as PREF_ID_NUM). Some duplicate BWA_UIDs exist under different BWA Permits with some missing monthly data, whereas the same site (same BWA_UID under a different BWA Permit) has actual values for those same months. Other cases of duplicate IDs require more investigation. If two withdrawal volume values are different for a specific site-month-year combination, both withdrawal volume values are included as separate records but with two different NJWaTr SiteName IDs (which reflects the different BWA permit within the SiteName). The NJWaTr SiteName is made up of the BWA permit and the SUBJECT_ITEM_DESIGNATION; for example, in figure 3, the NJWaTr SiteName for the site on the first row would become BWA:10000W:4500061135. The various IDs—BWA Permit (listed in fig. 3 as PREF_ID_NUM), BWA_UID (listed in fig. 3 as SUBJECT_ITEM_ID), and NJPermit (listed in fig. 3 as SUBJECT_ITEM_DESIGNATION)—are used to compare to existing sites in the USGS National Water Information System (NWIS). Sites that do not have corresponding NWIS site numbers are considered new sites. New sites are listed in a separate table, in addition to any pre-existing sites that do not yet have NWIS numbers (hereafter referred to as "undocumented").

The NWIS site number is a unique identification number for a groundwater or surface-water site that has been created by the NJWSC database administrator (DBA). The link between the State's water-use sites (NJWaTr SiteNames) and the USGS sites (NWIS site number) is important because additional information is contained within the NWIS sitefile that describes the site, making the water-use data contained in NJWaTr more informative and useable for certain situations, such as groundwater flow models. For example, for a groundwater water-use site, NWIS contains information regarding the location and depth of the well and the aquifer in which the well is screened and from which the well is drawing water.

Annual totals of monthly withdrawal values are summed, per site, in order to avoid generating an NWIS site number for sites that have a zero-volume total withdrawal for the year. Oftentimes, new sites with a zero-volume total withdrawal for the year are sites proposed for construction and when constructed will have non-zero annual totals in subsequent years. When this occurs, sites are subsequently created and entered in the year in which there is a non-zero-volume annual withdrawal total. New sites, and any undocumented sites, are submitted to the NJWSC DBA to be entered into the NWIS database, given a new, unique NWIS site number, and tracked as new water-use sites. Typically, 80 to 100 new sites with non-zero-volume annual withdrawal totals are added to the NWIS database in any given year.

MON_YEAR	PREF_ID_NUM	SUBJECT_ITEM_ID	JAN_RESULT	FEB_RESULT	MAR_RESULT	APR_RESULT	MAY_RESULT	JUN_RESULT	JUL_RESULT	AUG_RESULT	SEP_RESULT	OCT_RESULT	NOV_RESULT	DEC_RESULT	SUBJECT_ITEM_DESIGNATION
2003	10000W	WSWL70066	0.03	0.028	0.032	0.027	0.029	0.031	0.021	0.024	0.027	0.025	0.028	0.025	4500061135
2004	10000W	WSWL70066	0.037	0.031	0.034	0.029	0.031	0.035	0.021	0.026	0.03	0.029	0.034	0.028	4500061135
2005	10000W	WSWL70066	0.037	0.037	0.037	0.034	0.035	0.03	0.027	0.023	0.037	0.033	0.03	0.024	4500061135
2006	10000W	WSWL70066	0.037	0.028	0.026	0.03	0.043	0.032	0.029	0.043	0.034	0.03	0.025	0.025	4500061135
2007	10000W	WSWL70066	0.039	0.03	0.027	0.035	0.044	0.035	0.02	0.035	0.032	0.028	0.022	0.02	4500061135
2008	10000W	WSWL70066	0.041	0.039	0.04	0.038	0.048	0.03	0.015	0.02	0.022	0.025	0.021	0.024	4500061135
2009	10000W	WSWL70066	0.022	0.015	0.015	0.024	0.025	0.032	0.027	0.032	0.02	0.021	0.022	0.02	4500061135
2010	10000W	WSWL70066	0	0	0	0	0	0	0	0	0	0	0	0	4500061135
2011	10000W	WSWL70066	0.012	0.013	0.016	0.019	0.023	0.028	0.026	0.026	0.029	0.022	0.019	0.029	4500061135
2012	10000W	WSWL70066	0.019	0.023	0.022	0.017	0.024	0.029	0.028	0.011	0.019	0.016	0.015	0.028	4500061135
2013	10000W	WSWL70066	0.027	0.013	0.02	0.018	0.029	0.028	0.024	0.028	0.029	0.017	0.012	0.018	4500061135
2014	10000W	WSWL70066	0.026	0.023	0.023	0.017	0.017	0.018	0.023	0.024	0.02	0.023	0.016	0.015	4500061135
2015	10000W	WSWL70066													4500061135
2003	10001W	WSWL70210	0.9	0.8	0.8	0.7	0.6	0.7	1	0.9	0.8	0.8	0.7	0.7	4600040764
2004	10001W	WSWL70210	0.85	0.91	0.73	0.69	0.79	0.68	0.67	0.7	0.77	0.91	0.68	0.71	4600040764
2005	10001W	WSWL70210	0	0	0	0	0	0	0	0	0	0	0	0	4600040764
2006	10001W	WSWL70210	1.15	1.92	1.3	1.3	1.43	1.38	1.45	1.39	1.92	1.82	1.93	1.92	4600040764
2007	10001W	WSWL70210	0.4	1.3	0.6	1.1	1.1	1.6	0.6	0.8	1	1.2	1.1	1.2	4600040764
2008	10001W	WSWL70210	1.986	1.094	2.019	1.038	0.941	1.613	1.155	1.529	1.019	1.515	2.378	1.987	4600040764
2009	10001W	WSWL70210	0.8	0.8	0.8	0.8	0.9	0.8	0.8	0.9	0.8	0.9	0.9	0.9	4600040764
2010	10001W	WSWL70210	0.6	0.5	0.7	0.8	0.5	0.7	0.7	0.8	0.8	0.8	0.7	0.8	4600040764
2011	10001W	WSWL70210	0.9	1.4	1.3	1.2	1.2	1.7	1.1	0.9	1.1	0.9	0.8	0.9	4600040764
2012	10001W	WSWL70210	1	0.7	1.1	1	1.1	1.7	1.5	1.9	1.8	1.4	0.1	0.2	4600040764
2013	10001W	WSWL70210	0.5	0.7	1	1.6	0.6	1.3	1.1	0.5	0	0.4	1	0	4600040764
2014	10001W	WSWL70210	0.017	0.04	0.008	0.11	0.3	0.2	0.6	0.5	0.5	0.5	0.3	0.3	4600040764
2015	10001W	WSWL70210													4600040764

Figure 3. Example table showing format and appearance of the raw NJEMS (New Jersey Environmental Management System) data file. (MON, Monitoring; PREF, Preferred; ID, Identification; NUM, Number)

Groups and Members Procedure

The groups and members procedure determines which group(s) each site belongs to. This procedure was set up originally to elucidate the allocation limit (full allocation) per site from an interwoven group of allocation limits where sites are part of multiple groups, sometimes as members of more than one group with differing allocation limits. Two text files from the NJDEP BWA electronic file dataset (EFFECTIVE PERMIT SOURCES AND GROUPS BY PI TO MMDDYYYY and MMDDYYYY.csv and SUBJECT ITEMS WITH LIMITS MMDDYYYY and MMDDYYYY.csv, see fig. 2) are linked into the procedural database titled the AllocPreProcessor (see fig. 4). The AllocPreProcessor database runs the sites and groups procedure that generates a table, SiteGroupPercent, that shows which sites, according to BWA permit, belong to which groups. A BWA permit consists of a group of sites and (sometimes) groups that share the same owner. Owners can possess more than one BWA permit and often require multiple permits over time, as new resources are obtained and utilized.

As shown in figures 5–8, a site can be a member of more than one group, but both the groups and members (sites) that make up the group have the same BWA permit number. Figures 5–8 illustrate the complexity of the allocation permitting process and depict example results from the sites and groups procedure needed to parse out which sites belong to which group(s). A tool in Microsoft Access, which includes the AllocPreProcessor, was developed to elucidate the smallest allocation per site (Mary Chepiga, USGS, written and oral commun., 2016).

Part of the allocation limit per site process generates the SiteGroupPercent table (fig. 9) that lists groups and associated member sites. The SiteGroupPercent table is instrumental in the process of determining which groups or which sites to retain to avoid the double counting; double counting results from double reporting that occurs in the raw data from the electronic dataset. For example, site WSWL960664 in figure 9 is a member of two groups—in this case, group WARG1019538 and group WSWA73890. When this situation is encountered, the steps described below are taken to determine whether to retain the sites' or the group's withdrawal data.

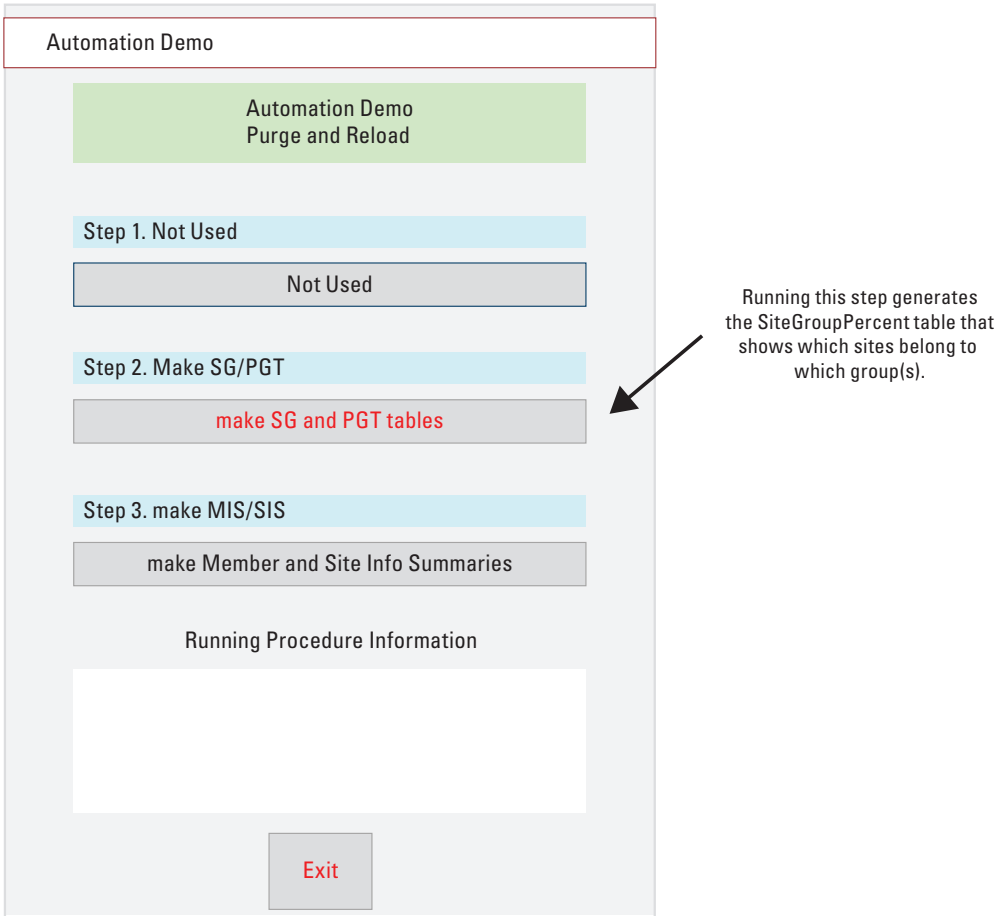

Figure 4. The form used to run the AllocPreProcessor procedure that generates the SiteGroupPercent table.

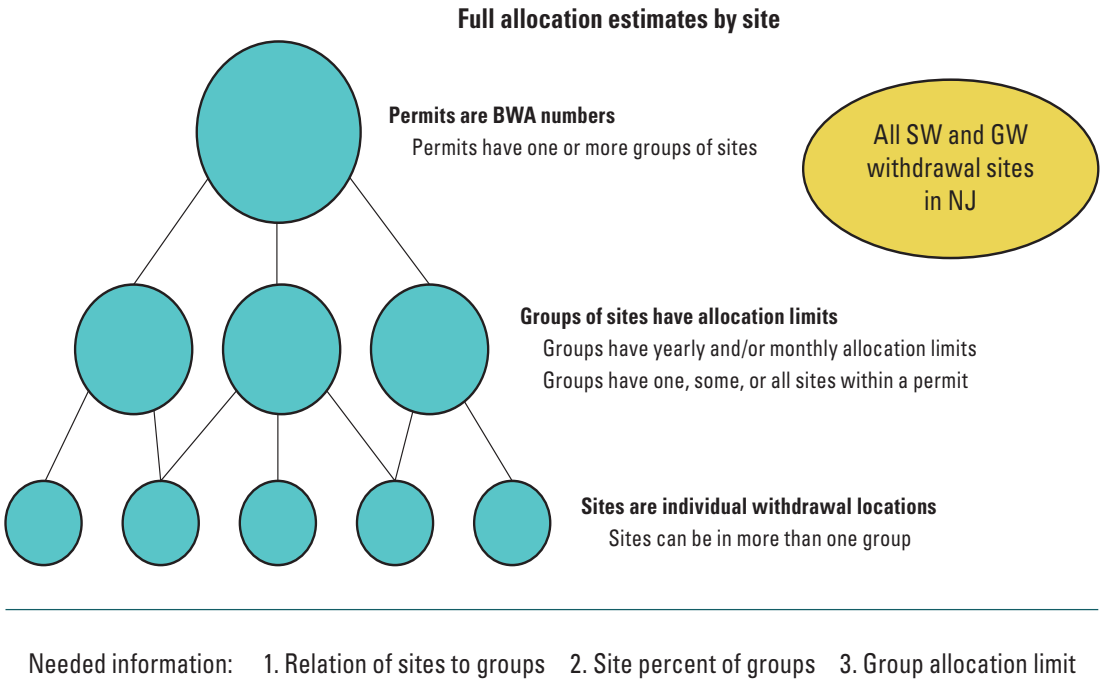

Figure 5. Schematic diagram showing the basics of allocation permitting and depicting how groups are made up of sites. (BWA, Bureau of Water Allocation; SW, Surface Water; GW, Groundwater; NJ, New Jersey)

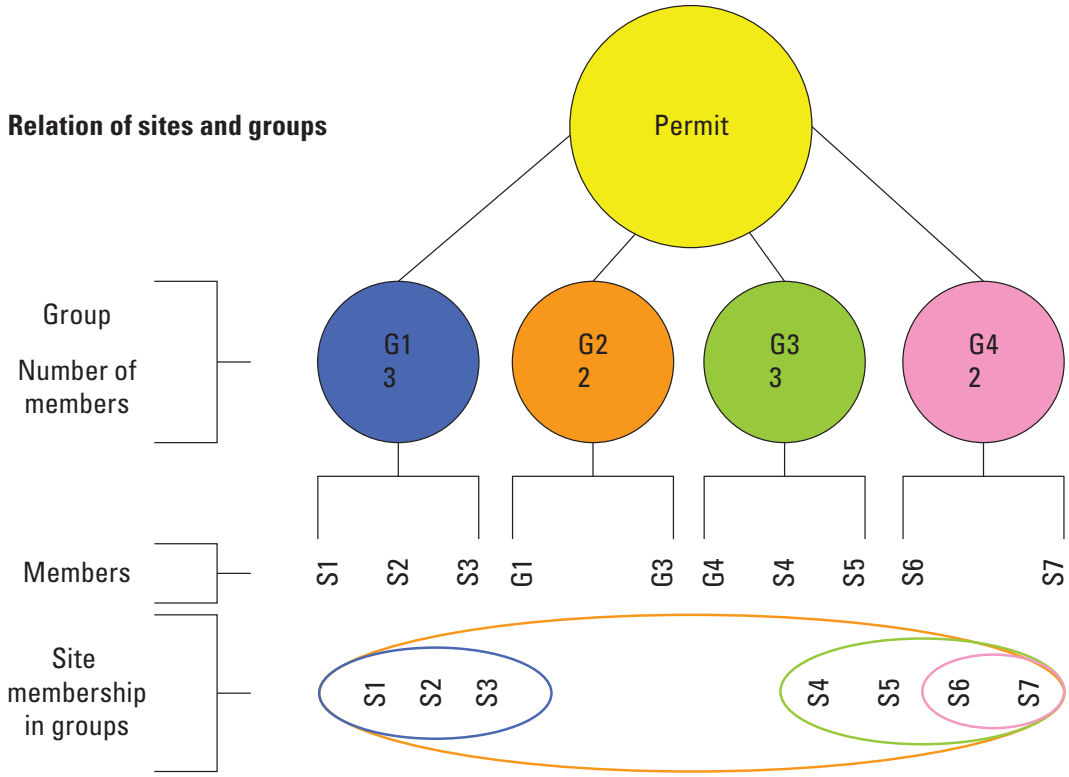

Figure 6. Schematic diagram showing an example of the contents of a permit and how its members, made up of sites and groups, relate to the original permit. (G, Group; S, Site)

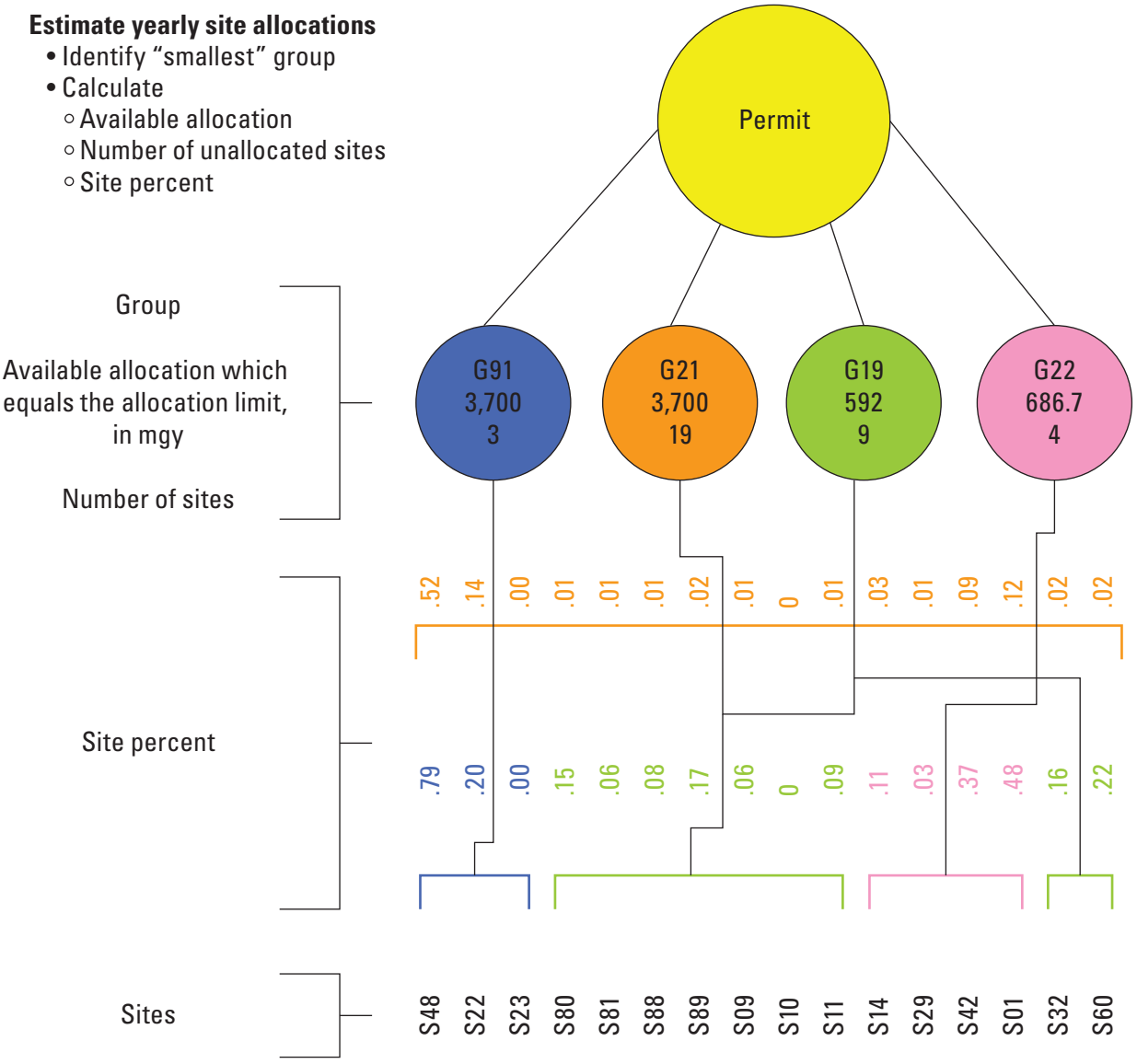

Figure 7. Schematic diagram showing an example of the contents of a permit and its members (made up of sites and groups) and how the allocation processor works to calculate the percent that each site contributes to the group's overall allocation limit(s) or its site percent. (G, Group; S, Site)

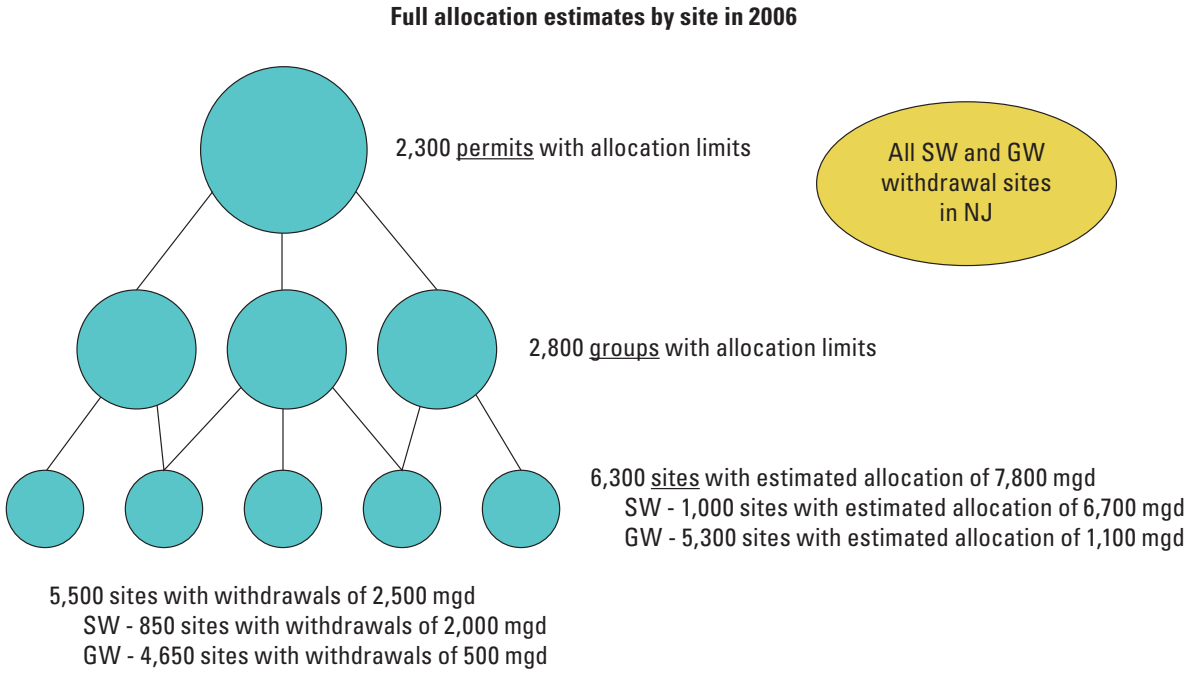

Figure 8. Schematic diagram showing example results from the full allocation process, as run on 2006 data. (SW, Surface Water; GW, Groundwater; NJ, New Jersey; mgd, million gallons per day)

Once the SiteGroupPercent table has been generated, the annual withdrawal value totals are calculated for the groups and the individual sites. The annual withdrawal totals for the individual sites that make up a group are then summed for comparison to the annual group withdrawal total (fig. 10). The summed site total and group total may differ as a result of the way in which the water-use data are reported by the permittee. The permittee may report a group value only, individual withdrawal values for some or all of the sites, or both, depending on reporting requirements. In some situations, the group and site totals do not match, and as a result, a decision must be made as to whether there is more confidence in the group total or the summed site total. If the sum of the individual sites within a group has a non-zero withdrawal value and the group total is null, the individual sites are retained. If the annual total for the group has a non-zero withdrawal value and the sum of the individual sites within that group is null, the group value is retained. In some situations where both the group and the sites making up that group have a non-zero sum total, it is necessary to compare the totals to determine which group, or group of sites, to retain in order to avoid double counting (fig. 10). In order to determine which group, or group of individual sites, is more complete and more accurately represents the actual volumes of withdrawals, the totals are compared. If there are null values within either the group or the site values (for example, a site within the group may have no data for a whole year or may have months within the year with no data [partial year data]), precedence is given to keeping the group. Another evaluation compares the historical decision made for the group and its site members and uses that decision as guidance for the year of interest's data. This method establishes consistency over time. In general, the preference is to keep the individual site data and discard the group data to retain as much site-specific data as possible. In the example shown in figure 10, the total withdrawal for all sites equals 2,048.383 million gallons per year, and the total withdrawal for the corresponding group equals 18,435.564 million gallons per year. In this situation, the sites and their monthly records were retained, and the group and its monthly records were deleted because the site data were complete and contained no null monthly records nor any sites with all null withdrawal values. Though the total withdrawal for the group was larger, that total was deemed not as trustworthy as the withdrawal data for individual sites. In addition, historically, this group and its monthly data have been deleted, and the sites and their monthly records have been retained, during the previous years' QA/QC processing.

Typically, keeping sites has precedence over keeping groups, and historically, the site data have been retained and the group data have been removed roughly 90 percent of the time. This check produces a table (fig. 11), which provides justification and documentation for the decision made for each case. Once decisions have been made, the original dataset is marked with "keep sites" or "keep group," and associated monthly records are deleted, as appropriate.

Permit	Group	Site
10054W	WARG1019538	WSWL960664
10054W	WSWA73890	WSWL960664
10054W	WARG1019538	WSWL69266
10054W	WSWA73890	WSWL69266
10054W	WARG1019538	WSWL68952
10054W	WSWA73890	WSWL68952
10055W	WARG985573	WSWL68687
10055W	WSWA73886	WSWL68687
10055W	WARG985573	WSWL202583
10055W	WSWA73886	WSWL202583
10057W	WSWA74445	WSWL70050
10057W	WSWA74445	WSWL65162
10057W	WSWA74445	WSWL64953
10057W	WSWA74445	WSWL64932

Figure 9. Screen shot showing an example of the SiteGroupPercent table. A site can be a member of more than one group; for example, site WSWL960664 (highlighted in yellow) is a member of group WARG1019538 (circled in red) and group WSWA73890 (circled in blue).

sites and groups with totals_2016

Site	Group	GroupTotal	SiteTotal	DeleteGroup	DeleteSites
WSWL70009	WARG748121	18435.564	53.359	✓	
WSWL69948	WARG748121	18435.564	91.652	✓	
WSWL65167	WARG748121	18435.564	102.399	✓	
WSWL65006	WARG748121	18435.564	366.904	✓	
WSWL65005	WARG748121	18435.564	310.429	✓	
WSWL64823	WARG748121	18435.564	291.679	✓	
WSWL64790	WARG748121	18435.564	831.961	✓	
	Grand Total	18435.564	2048.383		

Figure 10. Screen shot showing an example of a group total that differs from the site total. (All withdrawal values are in units of million gallons per year)

Group	BWA	GroupTotal	SumOfSiteTotal	What to do	Comment	Historical
WSWA81635	5000X	115300.12	4434.624	keep sites	checked nulls, some sites have recent data (2012 and 2015) but historically keep sites	Keep sites
WARG81637	5000X	25975.572	1855.399	keep sites	no nulls in sites	
WSWA81600	5014X	142130.45	2655.246	keep sites	checked nulls, haven't seen non-zero withdrawals in many (10+) years if ever	Delete group
WSWA83808	5020X	5688826.8	48884.7589	keep sites	checked nulls (lots) but despite recent data (up to 2015, looks estimated) and keeping with historical	Delete group
WSWA75771	5062X	108.3	36.1	keep sites	checked nulls, haven't seen withdrawals in many (10+) years	Delete group
WSWA75770	5062X	572.784	0	keep group	nulls and zero summed sites	
WSWA81571	5188X	2844.355	167.315	keep sites	checked nulls, haven't seen non-zero withdrawals in many (10+) years if ever	Keep sites
WSWA75826	5206X	1721.384	430.346	keep sites	checked nulls, one has recentish data 2013 but other is older than 10+ years	Keep sites
WSWA75827	5206X	17670.862	1606.442	keep sites	no nulls in sites	
WSWA75828	5206X	276.555	92.185	keep sites	no nulls in sites	
WSWA75829	5206X	8028.639	908.667	keep sites	nulls in sites are actually groups and don't exist in NJWaTr at all	
WSWA75825	5206X	884.342	441.913	keep sites	no nulls in sites	Keep sites
WSWA670353	5220X	8212.1	631.65	keep sites	checked nulls, some have recent-ish data going back to 2013 but could be estimations and going with historically	Keep sites
WARG748121	5264X	18435.564	2048.383	keep sites	checked nulls, haven't seen withdrawals in many (10+) years	Delete group
WSWA138268	5264X	35498.021	2730.607	keep sites	checked nulls, haven't seen withdrawals in many (10+) years	Keep sites
WSWA533773	5347X	2575.304	321.913	keep sites	checked nulls, haven't seen withdrawals in many (10+) years	Keep sites

Figure 11. Example table with group and site totals that are not equal, decisions made about keeping the sites' monthly records or the group's monthly records, and current and historical rationales for decisions. (BWA, Bureau of Water Allocation)

Linking Current Year's Sites to Pre-Existing Sites in NJWaTr

Once the duplicate sites and (or) groups have been removed, the remaining site-month-withdrawal volume combinations are linked to the corresponding SiteName in NJWaTr using a few techniques. The sites can be linked to their corresponding SiteNames in the site table in NJWaTr by NJEMS ID, which can be found in the original electronic dataset file DIVERTED WATER DATA 01012003 to MMDDYYYY.csv, listed in the third column as SUBJECT_ITEM_ID (fig. 3). The NJEMS ID, commonly referred to as BWA_UID, is a concatenation of two columns (SUBJECT_ITEM_CATEGORY_CODE and SUBJECT_ITEM_ID) that can be found in the file SUBJECT ITEMS also known as SOURCES BY PI MMDDYYYY TO MMDDYYYY.csv in the original electronic dataset (fig. 2). Sites can also be linked to their correct, corresponding NJWaTr SiteName by using the previous years' datasets and (or) the lookup table available in the USGS NJWSC historical usage database and linking by PI ID, or Program Interest identifier (BWA Permit), and Subject Item Designation (NJPermit), which are in the files SUBJECT ITEMS also known as SOURCES BY PI MMDDYYYY TO MMDDYYYY.csv and DIVERTED WATER DATA 01012003 TO MMDDYYYY.csv (fig. 3).

For new sites, two new site IDs are generated—an NJWaTr SiteName and an NWIS Site Number. The new NJWaTr SiteName is created using the format BWA: PI ID: Subject Item Designation. The Program Interest Identification (PI ID; BWA Permit), also written as PREF_ID_NUM, and the Subject Item Designation (NJPermit) are items found in the file DIVERTED WATER DATA 01012003 TO MMDDYYYY.csv (fig. 3). An example of a the NJWaTr SiteName using the example data found in the first row in the DIVERTED WATER DATA file in figure 3 is BWA:10000W:4500061135. The NWIS Site Number is a unique identifier generated by the USGS NJWSC DBA that incorporates the longitude and latitude for a groundwater site and the downstream order number for a surface-water site and is used for tracking the site in NWIS. These new sites are entered into the NJWaTr database with their accompanying information—NJWaTr SiteName, NWIS Site Number, NJEMS ID, geographical information that describes the site location and resource, and other identifying information.

Handling Null Volume Withdrawal Data

For withdrawal data before 2017, any site having null withdrawal values for all 12 months in the year of interest was removed from the dataset because it was decided that the null data points served as holders as they were most likely new sites without any withdrawal values to date. The database does not allow for null values to be entered, and a null value is considered to be different from a known value of zero. A new or proposed site that has 11 months with null withdrawal values and 1 month with a zero value is also removed. A site having all zero or some non-zero withdrawal values for any of the 12 months is retained. In the past, a site having null withdrawal values for all months but displaying non-zero or zero withdrawal values in subsequent datasets, as updated electronic datasets are received from the BWA, was added to the dataset, and for any months with null withdrawal values, values were estimated, if appropriate. Starting with the review of the 2017 data, withdrawal values are no longer estimated for sites with null withdrawal values. Owing to the increasing quality and completeness of the raw data received from the BWA in recent years, estimates were deemed redundant and unnecessary and, as a result, will no longer be calculated. Sites with null withdrawal values will be maintained in a site inventory table to discern sites that have been active in the past but currently have no withdrawals.

Analysis of Data by Permit

The next two sections of this report, Comparing Current Year's Data to Permit Allocation Limits (Annual and Monthly) and Comparing the Current Year's Data to Historical Data, describe the parts of the QA/QC procedure where each withdrawal site is checked against various factors to identify errors that can be fixed, flagged, and documented, and then the corrected value, as well as the original value, are both uploaded into the final datafile templates, which are loaded into NJWaTr. The withdrawal data for a site are compared to the corresponding permit allocation limits and to the corresponding historical data on an annual and monthly basis. Sites are checked as grouped into their BWA permit(s) and individually on a site-specific basis. Initially, sites are grouped by their BWA permits and reviewed on an annual basis in order to find and correct the more obvious errors. The sites are then examined at finer temporal and spatial scales to identify the less obvious errors. After potential errors are identified, historical data for the site are used to help identify a corrected or "preferred" value for the site. The annual and monthly permit allocation limits can be found in the file SUBJECT ITEMS WITH LIMITS MMDDYYYY TO MMDDYYYY.csv (fig. 2).

Comparing Current Year's Data to Permit Allocation Limits (Annual and Monthly)

Annual sums are calculated by summing the monthly withdrawal values for each site which are then summed by BWA permit (PI ID). The annual BWA permit (PI ID) sums are compared to the annual allocation limit for the permit. For the 10,000-series BWA permits' allocation limits are smaller; no more than 100,000 gallons per day are permitted to be pumped, and pump capacities are less than 70 gallons per minute (State of New Jersey Department of Environmental Protection, Division of Water Supply and Geoscience, Water Allocations and Registrations https://www.state.nj.us/dep/watersupply/a_allocat.html and Water Use Registration Application https://www.state.nj.us/dep/watersupply/pdf/dwr-188.pdf, both accessed August 19, 2019). The sums of the 10,000-series BWA permits are compared against an annual limit of 37 million gallons, as 100,000 gallons per day multiplied by 365 days results in a rounded value of 37 million gallons. For BWA permits with multiple limits, for example the 5000X-series (public-supply permits) the maximum annual allocation limits are culled from the file SUBJECT ITEMS WITH LIMITS MMDDYYYY TO MMDDYYYY.csv, and the grouped BWA permit annual sums from the year of interest's dataset are checked against the maximum allowable annual allocation limits.

The percent differences by permit are calculated, and all permits with a percent difference greater than 25 percent of the annual allocation are flagged to be examined. Percent difference is calculated using the equation

$$\frac{(absValue(|AnnualSumOfAllWithdrawalsInABWAPermit - AnnualAllocationLimitForABWAPermit|))}{absValue(|AnnualAllocationLimitForABWAPermit|)} \times 100,$$

where abs stands for absolute.

Each site associated with the flagged permit is examined, beginning with the largest percent differences. Each site's monthly value is checked for potential typographical and units errors, which are usually easily identifiable at the site-scale level. For sites/permits where a needed correction and (or) revision is not easily identifiable, the sites listed on the permit are compared to associated historical data to determine whether a correction is appropriate using historical data as justification.

Errors found during the annual allocation limit sums procedure check are fixed, flagged, and documented. Both withdrawal values, the original value and the corrected value, are loaded into the final database. The original, raw, "errored" value is loaded as "non-preferred," and the "fixed, corrected" value is loaded as final and "preferred." Any overages (excess over the permitted withdrawals) that are not correctable are retained in the final dataset to be loaded into NJWaTr because withdrawals greater than the BWA permit's allocation limit do happen and do not necessarily constitute an error.

Typically, approximately 10 percent of permits have total withdrawal values greater than their annual allocation limit before corrections are made. For example, analysis of the 2016 data identified that 192 out of 2,262 permits, or about 8 percent, had total withdrawal values greater than their annual allocation limits. The permits and sites listed on the permits were examined for possible errors, and where applicable, values were corrected.

After corrections have been made to monthly withdrawal values that were identified from the comparison of annual withdrawal values and annual allocation limits, the sum of monthly withdrawal values for each permit is re-calculated using the new "preferred" monthly withdrawal values, and the same procedure described in detail above is carried out using monthly allocation permit limits instead of annual allocation permit limits. The monthly allocation limits are contained within the SUBJECT ITEMS WITH LIMITS MMDDYYYY TO MMDDYYYY.csv file. For 10,000-series BWA permits, the monthly limit is 3.1 million gallons per month.

Errors found during the monthly allocation limit sums procedure check are fixed, flagged, and documented. Both withdrawal values, the original value and the corrected value, are loaded into the final database. The original "errored" value is loaded as "non-preferred," and the "fixed, corrected" value is loaded as final and "preferred."

Typically, approximately 1 percent of permit-month withdrawal values are greater than their monthly allocation limits, after the annual allocation limit check but before corrections are made resulting from the monthly allocation limit check. For example, for 2016 data, 166 of 27,144 permit-month combinations had reported monthly withdrawal values that were outside the monthly allocation limits and needed to be examined for possible correction.

Evaluating annual allocation limits before monthly limits are evaluated allows larger issues and errors to be identified and corrected, which minimizes the number of problem records that are found during the monthly allocation limit check.

Comparing the Current Year's Data to Historical Data

Data for the year of interest are checked against, and compared to, the historical data by BWA permit and by site. The NJWaTr SiteNames, which were linked in a previous step, are taken from the year of interest dataset and used to export a historical dataset from the current version of the main NJWaTr database that contains all the historical data for those SiteNames. The historical data that are exported from the main NJWaTr database are associated with their corresponding BWA (PI ID) permit. Once exported from the main NJWaTr database, these historical data are summed by BWA (PI ID) permit, by year and by month, and the average, maximum, minimum, and standard deviation are computed. These historical statistics are compared to the annual and monthly withdrawal values for the year of interest, which are already summed on a permit basis from previous steps (comparing year of interest data to annual and monthly allocation limits). A percent difference/error is calculated using the sum of the values for sites belonging to a BWA permit for the year of interest and the historical annual average by BWA permit. The absolute value of the overall difference between the value for the year of interest for a BWA permit total and the historical annual average value for a BWA permit also is calculated. A query is set up that looks at any percent difference greater than 99 percent and any overall difference that is greater than 100 million gallons per year. This query occasionally results in a lot of manual checking, so another query extracts all the potential outliers showing the data for the year of interest for all the sites belonging to the permits that vary significantly from their corresponding historical data to further prioritize the list and identify correctable errors. The data for the year of interest's individual sites that are included on each permit are examined to see whether any outliers or typographical errors can be detected, fixed, and documented, as appropriate. Usually, as a result of the previous annual and monthly allocation limits check, the major problems in the dataset have been corrected and, if not corrected, have already been identified as issues that cannot be fixed or altered.

Incorporating Updates to the Historical Dataset

In a continuing effort to improve the database, updates to historical data are made from the new electronic delivery dataset. This includes any historical data (from 2003 to 1 year before the year of interest) that may have been missing or estimated (applies to data from 2003 to 2016 only). The new, updated dataset from the BWA contains withdrawal values for previously missing data that need to be added to the historical database. The old, estimated data value is maintained in the database but becomes a "non-preferred" value, whereas the new, updated value becomes the "preferred" value. New withdrawal values are considered to be updates to null or zero withdrawal values in the dataset and typically result from updated information submitted by the purveyor.

To incorporate the historical updates, first, all historical data are extracted from NJWaTr from 2003 to the year before the year of interest. For example, when working on the 2016 QA/QC procedure, data from 2003 to 2015 were extracted from the NJWaTr database. Using the method code (one of the codes contained in NJWaTr, which designates the source of each data record) to filter the dataset, only data that were classified as estimates are selected to avoid having to rerun the duplicate site verification step and the sites and groups procedure. A check is run on non-estimated, historical data to ensure that the BWA has not made any updates or changes to these records that are marked as "preferred" in the database. These records (site-month-year combination) that already exist in the database as estimates are compared to the latest electronic files matched up by month and year to determine whether data that were previously null have since been replaced by actual values. New, reported withdrawal values are preferred to estimated values and are compiled, formatted, and added to the database. The new, updated withdrawal values are run through the QA/QC checking process to determine whether they exceed allocation limits (monthly and annually) or appear as outliers against monthly historical statistics (minimum, average, and maximum) for that site. Monthly percent difference calculations are re-calculated for those updated data, and any necessary corrections are made and documented. Corrections are made by examining a permit's annual (and later monthly) allocation limit volume values and historical use for that site's monthly period of record in the same manner as described previously for the data for the year of interest.

Note that the old, estimated value and the new, real, and uncorrected value are retained as "non-preferred" withdrawal values within the database, and the new, corrected (if applicable) value is promoted as the "preferred" or "primary" value for that site for that particular month and year. The new,

updated withdrawal values and any corrections are stored in the template in the proper format to be uploaded into the NJWaTr database with the data for the year of interest. An annual data update to the NJWaTr database includes the new, withdrawal values for the year of interest and any updates to the historical data that became available, as well as, if applicable, both of the corresponding, corrected withdrawal values discovered during the QA/QC procedure. For the historical updates, the older, estimated values that are replaced by the newer, withdrawal values become "non-preferred" withdrawal values, and the updates become "preferred" withdrawal values, but both are retained in NJWaTr and remain trackable. The original data for the year of interest, if corrected, also remain in the database as non-preferred, and the corrections become the preferred withdrawal values. As a result, all original data and any corrections or updates can be tracked, and any changes to the data over time can be easily retrieved from the NJWaTr database.

Estimating Nulls and Missing Data

The final step in the QA/QC procedure of the year of interest's withdrawal data is to estimate any nulls or missing data from the electronic dataset using historical data. As previously mentioned, this step of the QA/QC procedure ended with the 2016 data and is included here to describe how data were estimated from 2003 to 2016. Null data are culled from the dataset for the year of interest and matched to the exported historical data, by site and month. The null value is estimated using available, preferred historical data for the month and site. The historical data from 2003 to 1 year before the year of interest include updates, corrections, and inclusions from the previous step and are made up of preferred, withdrawal values and non-estimated, withdrawal values only. This allows each site and month combination to have a historical average value per month composed of as many years of available data as possible, without including any estimates in the resulting calculation. Once the monthly historical average is calculated per site, that value replaces any null values in the dataset for the year of interest, using a monthly, site-specific estimation. The new estimated, withdrawal values are marked "estimated" and included in the formatted dataset that are uploaded into the NJWaTr database. Only gaps of missing data in that year of interest's monthly dataset are estimated. For sites having a whole year of missing monthly records, the site's monthly records are not estimated or included, and the sites are assumed to be either proposed sites with data coming online in the future or sites that are potentially in a non-operational status for that year.

The new dataset with the estimated withdrawal values is again compared to the monthly and annual allocation permit total withdrawal values to verify no overages were introduced with the estimations. An overage might indicate the null withdrawal values should have been entered as zero. Corrections are made by examining a permit's annual (and later monthly) allocation limit values and using that sites' historical monthly period of record data as supporting evidence. Any necessary and appropriate corrections are made and documented.

Aquifer Storage and Recovery (ASR) and Surface-Water Returns Data

Aquifer storage data track the storage of available unused water that is pumped from a useable and accessible source and stored for later use, typically in an aquifer. Potential sources of stored water include groundwater from other aquifers, surface water that has been treated, or treated wastewater. Aquifer recovery data track the removal of this stored water from the aquifer for use at a later date (New Jersey Department of Environmental Protection, 2017). Surface-water return data track water taken from surficial sources, utilized by humans (including industrial, agricultural, and other uses), and then returned to the surface-water system (U.S. Geological Survey, 2013).

Data for aquifer storage and recovery and surface-water returns are obtained from three text files in the electronic data delivery received from NJDEP BWA (fig. 2). Aquifer storage data are acquired from a file titled WATER STORED UNITS MI 01012003 TO MMDDYYYY.csv. Aquifer recovery data are acquired from a file titled WATER RECOVERED ASR UNIT MI 01012003 TO MMDDYYYY.csv (fig. 2). Surface-water returns data are acquired from a file titled WATER RETURNED UNITS MI 01012003 to MMDDYYYY.csv (fig. 2). The only difference to the file nomenclature over time is that the date at the end of the file name will change as subsequent years are added to the dataset.

Though different in context and meaning, these three types of data are handled similarly. The monthly data for the year of interest are retrieved and transformed from a wide-table format (January through December) into a long-table format of monthly data by site and corresponding permit (as for the withdrawal data, described earlier). The data are stored as monthly values, and each site must be associated with its corresponding transfer conveyance parts. A conveyance is the process of transferring water from one place to another and has a "from" side (source) and a "to" side (destination). For example, a transfer may be from a groundwater well or a surface water site to an aquifer for storage, and then from the aquifer to the user. To process these data, the associations must be made between the "from" and "to" sides to link the volume of stored water to its source and its destination.

For aquifer storage and recovery sites, the conveyance sides "from" and "to," which become the From and To Site-Names in NJWaTr, are made up of either the Drinking Water Service Area permit number that is assigned to that particular ASR site or the original site identifier information contained in either the file WATER STORED UNITS MI 01012003 TO MMDDYYYY.csv or the file WATER RECOVERED ASR UNIT MI 01012003 TO MMDDYYYY.csv, with "_ASR" appended to the end. The "from" and "to" sides of the

conveyance, and the corresponding From and To SiteNames, switch depending on whether the data are storage transfers or recovery transfers.

Storage transfers are associated with their conveyance sides—the "from" side of the conveyance, titled the FromSite SiteName in NJWaTr, becomes "ASR_storage," and the "to" side of the conveyance, titled the ToSite SiteName in NJWaTr, is created by using the associated SiteName (garnered from site identifier information contained in the file entitled WATER STORED UNITS MI 01012003 TO MMDDYYYY.csv) and attaching "_ASR" to the end. The example in figure 12 shows the file titled WATER STORED UNITS MI 01012003 TO MMDDYYYY.csv in its raw, wide format as delivered in the original electronic file dataset (fig. 2). The PREF_ID_NUM and the SUBJECT_ITEM_DESIGNATION fields are used to create the ToSite Sitename with "_ASR" appended to the end (fig.12, enlarged insets). The example in figure 13 shows the resulting From and To SiteNames that become associated with the storage transfer conveyance. These From and To SiteNames are associated with their corresponding aquifer storage monthly transfer volumes and are uploaded as such into the NJWaTr database.

MON_YEAR	PREF_ID_NUM	SUBJECT_ITEM_ID	JAN_RESULT	FEB_RESULT	MAR_RESULT	APR_RESULT	MAY_RESULT	JUN_RESULT	JUL_RESULT	AUG_RESULT	SEP_RESULT	OCT_RESULT	NOV_RESULT	DEC_RESULT	SUBJECT_ITEM_DESIGNATION
2003	5057	WSWL69723	6.372	4.987	6.159	5.419	4.42	0.921	0	0	1.866	6.17	5.033	5.362	3700000640
2004	5057	WSWL69723	5.541	4.929	5.226	5.199	4.455	4.266	0	0	3.324	5.405	4.787	4.521	3700000640
2005	5057	WSWL69723	5.689	4.649	5.168	4.846	4.561	3.93	0	0	3.621	4.687	4.543	4.684	3700000640
2006	5057	WSWL69723	4.869	1.982	0	5.423	5.344	5.141	0	0	0	6.107	6.554	7.157	3700000640
2007	5057	WSWL69723	6.702	5.644	0.411	6.846	2.087	0	0	0	5.21	6.815	5.912	5.463	3700000640
2008	5057	WSWL69723	5.496	4.715	4.448	4.853	4.608	2.001	0	0	3.908	5.459	4.477	4.519	3700000640
2009	5057	WSWL69723	5.253	5.592	5.312	4.818	4.455	3.134	0	0	4.177	3.583	4.145	5.42	3700000640
2010	5057	WSWL69723	4.906	3.673	5.418	5.387	4.314	3.805	0	0	3.197	6.395	6.117	5.447	3700000640
2011	5057	WSWL69723	6.263	6.644	7.878	6.44	7.471	3.946	0	0	4.91	6.514	5.996	6.451	3700000640
2012	5057	WSWL69723	6.559	7.153	6.302	7.541	7.206	1.522	0	0	5.565	6.574	6.422	7.017	3700000640
2013	5057	WSWL69723	5.759	5.833	6.572	6.845	6.667	3.884	0	0	3.777	2.165	0	0	3700000640
2014	5057	WSWL69723	0	0	0	0	3.008	6.885	0	0	4.98	6.732	6.166	6.216	3700000640
2015	5057	WSWL69723	5.945	5.765	6.87	7.361	4.042	0	0	0	4.686	6.825	7.527	6.54	3700000640
2016	5057	WSWL69723	5.298	5.95	6.028	6.473	3.164	0	0	0	0	7.435	7.858	7.859	3700000640
2017	5057	WSWL69723	6.596	6.046	7.512	5.006	4.925	0	0	0	0	6.632	7.955	6.773	3700000640
2018	5057	WSWL69723	6.64	6.637	7.304	7.245	3.444	0	0	0	4.524	6.511	6.606	6.205	3700000640
2019	5057	WSWL69723	6.123	6.089	6.572	5.406	4.011	0	0	0	3.849				3700000640

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SUBJECT_ITEM_DESIGNATION
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Figure 12. Example of raw data from the file WATER STORED UNITS MI 01012003 TO MMDDYYYY.csv as received in the electronic dataset delivery from the Bureau of Water Allocation. Insets show enlarged columns PREF_ID_NUM (BWA Permit) and SUBJECT_ITEM_DESIGNATION (NJPermit), which make up the "to" side (To SiteName) of the conveyance for stored water transfers. (BWA, Bureau of Water Allocation; MON, Monitoring; PREF, Preferred)

SiteName_From	SiteName_To
ASR_storage	BWA:5057:3700000640_ASR

Figure 13. Example of the "from" and "to" NJWaTr SiteNames for the conveyance of a stored water transfer. The "to" side of the conveyance SiteName is derived from the fields provided in the raw data from the file WATER STORED UNITS MI 01012003 TO MMDDYYYY.csv received in the electronic dataset delivery from the BWA. (BWA, Bureau of Water Allocation; ASR, Aquifer Storage and Recovery)

Recovered water transfers are associated with their transfer conveyance sides. The "from" side of the conveyance, titled FromSite SiteName in NJWaTr, is created by using the associated SiteName (garnered from site identifier information contained in the file WATER RECOVERED ASR UNIT MI 01012003 TO MMDDYYYY.csv) and attaching "_ASR" to the end. The "to" side of the conveyance, titled ToSite SiteName in NJWaTr, becomes the associated Drinking Water Service Area, to which that stored water is delivered and used. If the Drinking Water Service Area is unknown, the ToSite SiteName becomes "ASR_recovered" as a holder until more information becomes available. The example in figure 14 shows the file WATER RECOVERED ASR UNIT MI 01012003 TO MMDDYYYY.csv in its raw, wide format as delivered in the original electronic file dataset (fig. 2). The PREF_ID_NUM and the SUBJECT_ITEM_DESIGNATION fields are used to create the FromSite Sitename with "_ASR" appended to the end (fig.14, enlarged insets). The example in figure 15 shows the resulting From and To SiteNames that become associated with the recovered water transfer conveyance. These From and To SiteNames are associated with their corresponding aquifer recovered water monthly transfer volumes and are uploaded as such into the NJWaTr database.

MON_YEAR	PREF_ID_NUM	SUBJECT_ITEM_ID	JAN_RESULT	FEB_RESULT	MAR_RESULT	APR_RESULT	MAY_RESULT	JUN_RESULT	JUL_RESULT	AUG_RESULT	SEP_RESULT	OCT_RESULT	NOV_RESULT	DEC_RESULT	SUBJECT_ITEM_DESIGNATION
2008	5057	WSWL69723				0	0	8.81	18.994	16.897	0.404	0	0	0	3700000640
2009	5057	WSWL69723	0	0	0	0	0	0.645	18.253	16.414	3.465	0	0	0	3700000640
2010	5057	WSWL69723	0	0	0	0	0	0.734	20.412	19.411	3.143	0	0	0	3700000640
2011	5057	WSWL69723	0	0	0	0	0	1.403	19.666	19.615	8.538	0	0	0	3700000640
2012	5057	WSWL69723	0	0	0	0	0	4.257	22.349	23.013	8.329	0	0	0	3700000640
2013	5057	WSWL69723	0	0	0	0	0	3.417	17.938	24.641	11.852	0	0	0	3700000640
2014	5057	WSWL69723	0	0	0	0	0	0	4.315	5.674	0	0	0	0	3700000640
2015	5057	WSWL69723	0	0	0	0	0	0.683	21.95	22.062	6.086	0	0	0	3700000640
2016	5057	WSWL69723	0	0	0	0	0	1.381	20.987	21.744	6.579	0	0	0	3700000640
2017	5057	WSWL69723	0	0	0	0	0	3.08	24.609	21.243	6.897	0	0	0	3700000640
2018	5057	WSWL69723	0	0	0	10.154	0	3.778	7.783	26.029	10.937	0	0	0	3700000640
2019	5057	WSWL69723	0	0	0	0	0	0	20.162	21.516	7.292				3700000640

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SUBJECT_ITEM_DESIGNATION
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Figure 14. Example of raw data from the file WATER RECOVERED ASR UNIT MI 01012003 TO MMDDYYYY.csv as received in the electronic dataset delivery from the Bureau of Water Allocation. Insets show enlarged columns PREF_ID_NUM (BWA Permit) and SUBJECT_ITEM_DESIGNATION (NJPermit) that make up the "from" side (From SiteName) of the conveyance for recovered water transfers. (BWA, Bureau of Water Allocation; NJ, New Jersey; MON, Monitoring; PREF, Preferred)

SiteName_From	SiteName_To
BWA:5057:3700000640_ASR	DW Service Area 0xxx001

Figure 15. Example of the "from" and "to" NJWaTr SiteNames for the conveyance of a recovered water transfer. The from side of the conveyance SiteName is derived from the fields provided in the raw data from the file WATER RECOVERED ASR UNIT MI 01012003 TO MMDDYYYY.csv received in the electronic dataset delivery from the Bureau of Water Allocation. (BWA, Bureau of Water Allocation; ASR, Aquifer Storage and Recovery; DW, Drinking Water)

Note that the From SiteName of the recovered water transfer is the same as the To SiteName from the stored water transfer conveyance (the source of the recovered water is the repository of the stored water), and the To SiteName of the recovered water transfer becomes the distribution to its Drinking Water Service Area. Once the aquifer storage and recovery transfers are associated with their corresponding From and To SiteNames and their monthly transfer data for the year of interest, these data can be checked. When complete, the storage and recovery data can be matched against each other on a monthly or yearly basis to track net amounts.

Surface water that is returned to its source is associated with its transfer conveyance sides; the "from" side of the conveyance, titled the FromSite SiteName in NJWaTr, becomes the corresponding BWA Use Area that is associated with its SiteName (garnered from site identifier information contained in the file WATER RETURNED UNITS MI 01012003 TO MMDDYYYY.csv), and the "to" side of the conveyance, titled the ToSite SiteName in NJWaTr, becomes "Return Flow." The example in figure 16 shows the file WATER RETURNED UNITS MI 01012003 TO MMDDYYYY.csv in its raw, wide format as delivered in the original electronic file dataset (fig. 2). The PREF_ID_NUM and the SUBJECT_ITEM_DESIGNATION fields are used to create the FromSite SiteName with "BWA Use Area" appended to the beginning (fig.16, enlarged insets). The example in figure 17 shows the resulting From and To SiteNames that become associated with the surface-water returns transfer conveyance.

MON_YEAR	PREF_ID_NUM	SUBJECT_ITEM_ID	JAN_RESULT	FEB_RESULT	MAR_RESULT	APR_RESULT	MAY_RESULT	JUN_RESULT	JUL_RESULT	AUG_RESULT	SEP_RESULT	OCT_RESULT	NOV_RESULT	DEC_RESULT	SUBJECT_ITEM_DESIGNATION
2003	2285P	WSIN73125	7.2	12.2	15.1	10.8	15.1	15.1	15.8	15.1	15.8	15.8	11.5	14.4	POND 1
2004	2285P	WSIN73125	10.7	10.2	11.7	10.8	7.2	10.8	15.1	15.8	10.8	15.1	15.1	15.8	POND 1
2005	2285P	WSIN73125	15.1	15.1	16.55				12.9	18	13.7	15.1	15.1	15.1	POND 1
2006	2285P	WSIN73125	15.1	14.4	16.6	14.4	15.8	15.8	14.4	16.5	14.4	12.2	9.4	14.4	POND 1
2007	2285P	WSIN73125	10.8	7.9	15.1	15.1	15.8	15.1	15.1	12.9	13.6	15.8	15.1	12.9	POND 1
2008	2285P	WSIN73125	15.1	15.1	15.1	15.1	14.4	10.8	15.1	14.4	15.1	12.2	13.6	10.8	POND 1
2009	2285P	WSIN73125	3.6	11.5	12.2	8.6	13.6	10.8	16.5	12.9	15.1	15.8	14.4	10.8	POND 1
2010	2285P	WSIN73125	12.9	12.9	15.8	15.1	5.7	14.4	14.4	15.8	15.1	14.4	15.1	10	POND 1
2011	2285P	WSIN73125	0	11.5	15.8	15.1	15.1	15.8	14.4	12.2	15.1	14.4	15.1	13.6	POND 1
2012	2285P	WSIN73125	14.4	15.1	15.1	8.6	15.8	15.1	15.1	16.5	13.6	16.5	15.1	12.9	POND 1
2013	2285P	WSIN73125	15.8	14.4	15.8	12.6	12.6	11.5	15.8	15.8	14.4	16.56	14.4	14.4	POND 1
2014	2285P	WSIN73125	13.6	15.1	15.1	15.8	15.1	15.1	15.8	15.1	15.1	16.6	13.7	15.1	POND 1
2015	2285P	WSIN73125	10.8	3.6	8.64	15.84	14.4	15.84	9.36	13.68	7.92	15.12	14.4	9.36	POND 1
2016	2285P	WSIN73125	0	0	0	15.1	15.1	15.8	6.48	16.56	10.8	15.12	14.4	5.76	POND 1

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SUBJECT_ITEM_DESIGNATION
POND 1
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Figure 16. Example of raw data from the file WATER RETURNED UNITS MI 01012003 TO MMDDYYYY.csv as received in the electronic dataset delivery from the Bureau of Water Allocation. Insets show enlarged columns entitled PREF_ID_NUM (BWA Permit) and SUBJECT_ITEM_DESIGNATION (NJPermit) that make up the "from" side (From SiteName) of the conveyance for surface-water return transfers. (BWA, Bureau of Water Allocation; NJ, New Jersey; MON, Monitoring; PREF, preferred)

SiteName_From	SiteName_To
BWA Use Area:2285P:POND 1	Return Flow

Figure 17. Example of the "from" and "to" NJWaTr SiteNames for the conveyance of a surface-water return transfer. The "from" side of the conveyance SiteName is derived from the fields provided in the raw data from the file WATER RETURNED UNITS MI 01012003 TO MMDDYYYY.csv received in electronic dataset delivery from the Bureau of Water Allocation. (BWA, Bureau of Water Allocation)

The ASR and surface-water returns monthly data records are checked and quality assured as described below. The aquifer storage and recovery data are matched to each other using their corresponding From and To SiteNames and checked against each other. For the ASR data, a month within the year is compared to all other months within that year for those matched storages and recoveries, and the monthly records are compared to previous years' ASR data by site, to elicit any units issues or gross typographical errors. For the surface-water returns data, a month within the year is compared to all other months within that year, and all months are compared to previous years' surface-water returns data, by site, to elicit any units issues or gross typographical errors. For example, the surface-water return value for March 2015 is compared to all the other surface-water return values for the rest of the months in 2015 and any other monthly value for that site provided in previous years' datasets. Corrections and (or) updates are made, where appropriate, and documented with the proper QA/QC flags.

Wastewater Discharge Data

The wastewater discharge data, which come from the New Jersey Pollutant Discharge Elimination System (NJPDES), contain multiple measurements for each site for any given month. Each of these measurements is assigned a method code in the original dataset received from NJPDES. These method codes describe the different types of measurements made and are used to evaluate the data. A list of the possible method codes accompanying the wastewater data is show in table 3. The large amount of wastewater data must be reduced and ranked such that priority can be assigned to the best, most accurate method available in the dataset for that site/month combination. The value for the method that has the highest rank for each site/month combination is the one retained and subsequently loaded into the NJWaTr database. Possible measurement methods, their codes and descriptions, and the ranking list, which prioritizes the different measurement methods, are shown in table 3.

The wastewater data from NJDPES have units different from those stored in NJWaTr, and conversions are done to change units to millions of gallons per month. Some of the discharge volume values must be deleted because letters, symbols, or other characters are in the volume field.

Once the data are formatted and converted to the correct units, a SiteName is generated from the NJPDES permit number, concatenated with the discharge pipe number or monitoring location, for example, NJPDES:NJ0024716.002A. This SiteName becomes the "to" side of the conveyance, also known as the ToSite in NJWaTr, and the "from" side of the conveyance, also known as the FromSite in NJWaTr, is the NJPDES permit number associated with its corresponding Sewer Service Area (SSA), for example, SSA:NJ0024716.

After associating the sites with their conveyance parts, the wastewater discharge volume values are evaluated to determine whether any monthly discharges for the year of

Table 3. Wastewater method code abbreviations, descriptions, and ranks, as associated with data received from the New Jersey Pollutant Discharge Elimination System.

[N/A, Not Available]

Method abbreviation	Method description	Rank
01MOTO	Monthly total	1
01MOAV	Monthly average	2
01DAAV	Daily average	3
01WKAV	Weekly average	4
01QTAV	Quarterly average	5
01YRAV	Yearly average	6
06MOAV	N/A	7
01DAAVMN	Daily average minimum	8
12MORLAV	N/A	9
01WKAVMX	Weekly average maximum	10
01QTTO	N/A	11
01DAMX	Daily maximum	12
01MOMX	Monthly maximum	13
01RPINMX	Instantaneous maximum	14
01RPMX	Maximum	15
01YRMX	Yearly maximum	16
01QTMX	Quarterly maximum	17

interest exceed the historical average for each month for that site by greater than 50 percent. If any site-month-year combination is discharging more than 50 percent of historical averages for a month, the site-month-year record will be flagged. The flag becomes part of the record uploaded into NJWaTr as part of the template in both the "Column comment" field and the "QA flag" field. Wastewater data are never changed or corrected once the proper unit conversions are made.

Lastly, the checked and potentially flagged wastewater discharge volume values and their FromSite and ToSite SiteNames are compiled into a template to be loaded in the NJWaTr database. For new wastewater sites, new From Site and To Site SiteNames are generated, and other geographical information that describes the site location, as well as other identifying information, are added to the templates to be uploaded into the NJWaTr database.

Final Processing of All Quality Assured Data, Including New Sites

Once the data have been checked and processed with appropriate documentation, the various data types—withdrawal, aquifer storage and recovery, surface-water returns, and wastewater—are loaded into templates that are then uploaded to the main NJWaTr database. These templates include the withdrawal/discharge volume data, as well as all accompanying information for new sites. This accompanying information includes new conveyances (associating the "from" side From SiteName with the "to" side To SiteName), any site aliases, site permits, site-location information, resource information, specialized regional area information, Census Block information, water-use type category, and owner information. The site aliases include SUBJECT_ITEM_DESIGNATIONs (also known as NJPermit) and NWIS Site Numbers. The site permits include BWA permit numbers (also known as PI IDs or PREF_ID_NUMs) or NJPDES permit numbers, as appropriate. Site location information includes longitude and latitude, the 14-digit Hydrologic Unit Code (HUC14), the minor civil division (MCD) code, the Geographic Names Information System (GNIS) code, the county code, and the state code. The site resource information includes whether the site is a surface-water or groundwater site, the aquifer in which the groundwater site is drilled and from which the groundwater site is withdrawing, the confinement status for the groundwater site, whether or not the groundwater site is located in a critical area, and the geologic formation information for that site. Specialized regional area information includes whether the site is in the Highlands or Pinelands Preservation Areas or in either of New Jersey's Critical Areas.

After the various templates have been completed and approved, they are uploaded to the NJWaTr database. The NJWaTr database is considered complete for that year of interest, and this new version of the NJWaTr database becomes the current approved version for water-use data for New Jersey.

Glossary

AllocationPreProcessor A part of the Allocation Tool that parses out the different groups to which each site belongs.

BWA Permit (Also known as **PI ID** and **PREF_NUM_ID**) A permit number assigned by the New Jersey Department of Environmental Protection Bureau of Water Allocation, that is given to a site or group of sites that share the same owner. An owner may have more than one BWA permit. A BWA permit can be made up of groundwater or surface-water sites and (or) groups. An example of a public supply BWA permit is 5057.

BWA_UID (Also known as **NJEMS ID** and **SUBJECT_ITEM_ID**) A unique identifier assigned by the New Jersey Department of Environmental Protection Bureau of Water Allocation, that is a concatenation of the 4-letter **SUBJECT_ITEM_CATEGORY_CODE** and a 5- or 6-digit numerical **SUBJECT_ITEM_ID,** which can be found in the file SUBJECT ITEMS also known as SOURCES BY PI MMDDYYYY TO MMDDYYYY.csv from the original electronic dataset. An example of a BWA_UID for a well is WSWL960664.

BWA Use Area An area that defines where the withdrawn water is used. For withdrawal sites, it is analogous to the **To SiteName** in NJWaTr.

From SiteName A site name used in NJWaTr for a water-use site that serves as the source of the conveyance of water transferred from one place to another.

GNIS Code A Geographic Names Information System code given to physical and cultural features across the United States.

HUC14 A 14-digit Hydrologic Unit Code that defines a subwatershed's drainage area boundaries.

MCD Code A minor civil division is a code defined by the U.S. Census Bureau that signifies a town, township, or district.
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NJEMS ID (Also known as **BWA_UID** and **SUBJECT_ITEM_ID**) Another name for BWA_UID, as used in the NJWaTr database site file. See **BWA_UID**.

NJPermit (Also known as **SUBJECT_ITEM_DESIGNATION**) Another name for **SUBJECT_ITEM_DESIGNATION,** as used in the USGS NJWSC's internal database of water-use sites. See **SUBJECT_ITEM_DESIGNATION.**

NJWaTr SiteName A site name given to a site, mandatory for inclusion into the NJWaTr database. A SiteName is made up of the **BWA permit** and the **SUBJECT_ITEM_DESIGNATION.** An example is BWA:10000W:4500061135, where 10000W is the **BWA permit** and 4500061135 is the **SUBJECT_ITEM_DESIGNATION**.

NWIS Site Number A 15-digit number (representing longitude and latitude) given to a groundwater site or an 8-digit number (representing downstream order number) given to a surface-water site by the USGS NJWSC Database Administrator that indicates entry into the National Water Information System (NWIS). A unique identifier for a site in the USGS NWIS database.

PI ID (Also known as **BWA Permit** and **PREF_NUM_ID**) Another name for BWA Permit, as used in the electronic dataset received from the New Jersey Department of Environmental Protection Bureau of Water Allocation. See **BWA Permit**.

PREF_NUM_ID (Also known as **BWA Permit** and **PI ID**) Another name for BWA Permit, as used in the electronic dataset received from the New Jersey Department of Environmental Protection Bureau of Water Allocation. See **BWA Permit**.

SUBJECT_ITEM_CATEGORY CODE A code assigned by the New Jersey Department of Environmental Protection Bureau of Water Allocation, to indicate the category to which the site belongs, for example WSWL is used for a well and WSIN is used for a surface-water intake site. When combined with the **SUBJECT_ITEM_ID**, it makes up the **BWA_UID**, also known as **NJEMS ID**.

SUBJECT_ITEM_DESIGNATION (Also known as **NJPermit**) The State Well Drilling Permit Number or Surface Water Intake Number/Name, as assigned by the NJDEP BWA and used to identify sites in the electronic dataset received from the New Jersey Department of Environmental Protection Bureau of Water Allocation.

SUBJECT_ITEM_ID (Also known as **BWA_UID** and **NJEMS ID**) Another name for BWA_UID, as used in the electronic dataset received from the New Jersey Department of Environmental Protection Bureau of Water Allocation. See **BWA_UID**.

To SiteName A site name used in NJWaTr for a water-use site that serves as the destination of the conveyance of water transferred from one place to another.

References Cited

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Appendix 1 Selected Publications that Include Data from New Jersey Water Transfer Data System (NJWaTr)

Simulated effects of allocated and projected 2025 withdrawals from the Potomac-Raritan-Magothy aquifer system, Gloucester and Northeastern Salem Counties, New Jersey
U.S. Geological Survey Scientific Investigations Report 2011–5033
Prepared in cooperation with the New Jersey Department of Environmental Protection
By: Emmanuel Charles, John P. Nawyn, Lois M. Voronin, and Alison D. Gordon
https://doi.org/10.3133/sir20115033
https://pubs.er.usgs.gov/publication/sir20115033

Simulated effects of groundwater withdrawals from the Kirkwood-Cohansey aquifer system and Piney Point aquifer, Maurice and Cohansey River Basins, Cumberland County and vicinity, New Jersey
U.S. Geological Survey Scientific Investigations Report 2017–5144
Prepared in cooperation with the New Jersey Department of Environmental Protection
By: Alison D. Gordon and Debra E. Buxton
https://doi.org/10.3133/sir20175144
https://pubs.er.usgs.gov/publication/sir20175144

Estimated use of water in the Delaware River Basin in Delaware, New Jersey, New York, and Pennsylvania, 2010
U.S. Geological Survey Scientific Investigations Report 2015–5142
By: Susan S. Hutson, Kristin S. Linsey, Russell A. Ludlow, Betzaida Reyes, and Jennifer L. Shourds
https://doi.org/10.3133/sir20155142
https://pubs.er.usgs.gov/publication/sir20155142

Simulated effects of projected 2010 withdrawals on ground-water flow and water levels in the New Jersey Coastal Plain—A task of the New Jersey Water Supply Plan, 2006 revision
U.S. Geological Survey Scientific Investigations Report 2007–5134
Prepared in cooperation with the New Jersey Department of Environmental Protection
By: Alison D. Gordon
https://doi.org/10.3133/sir20075134
https://pubs.er.usgs.gov/publication/sir20075134

Hydrogeology of, and Simulation of Ground-Water Flow In, the Pohatcong Valley, Warren County, New Jersey
U.S. Geological Survey Scientific Investigations Report 2006–5269
Prepared in cooperation with the U.S. Environmental Protection Agency
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