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Development of the Water-Analysis Screening Tool Used in the Initial Screening for the Pennsylvania State Water Plan Update of 2008

Open-File Report 2008-1106

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

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Conversion Factors and Acronyms

Multiply	By	To obtain
	Area	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
million gallons (Mgal)	3,785	cubic meter (m^3)
	Flow rate	
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Acronyms

7Q10	7-day, 10-year low flow
CAFO	Concentrated Animal Feeding Operation
CWPA	Critical water-planning area
DMR	Discharge monitoring report
GIS	Geographic Information System
Gpcd	Gallons per day per capita
ISC	Initial screening criteria
NAICS	North American Industry Classification System
NHD	National Hydrography Dataset
NW	Net withdrawals
SI	Screening indicator
SIP	Screening indicator as a percentage
WAST	Water-analysis screening tool

Development of the Water-Analysis Screening Tool Used in the Initial Screening for the Pennsylvania State Water Plan Update of 2008

By Marla H. Stuckey

Abstract

The Water Resources Planning Act, Act 220 of 2002, requires the Pennsylvania Department of Environmental Protection (PaDEP) to update the State Water Plan by 2008. As part of this update, a water-analysis screening tool (WAST) was developed by the U.S. Geological Survey, in cooperation with the PaDEP, to provide assistance to the state in the identification of critical water-planning areas. The WAST has two primary inputs: net withdrawals and the initial screening criteria. A comprehensive water-use database that includes data from registration, estimation, discharge monitoring reports, mining data, and other sources was developed as input into the WAST. Water use in the following categories was estimated using water-use factors: residential, industrial, commercial, agricultural, and golf courses. A percentage of the 7-day, 10-year low flow is used for the initial screenings using the WAST to identify potential critical water-planning areas. This quantity, or initial screening criteria, is 50 percent of the 7-day, 10-year low flow for most streams. Using a basic water-balance equation, a screening indicator is calculated that indicates the potential influences of net withdrawals on aquatic-resource uses for watersheds generally larger than 15 square miles. Points representing outlets of these watersheds are colored-coded within the WAST to show the screening criteria for each watershed.

Introduction

The Water Resources Planning Act, Act 220 of 2002 [Water Resources Planning Act of 2002 (P.L. 1776, No. 220)], requires the Pennsylvania Department of Environmental Protection (PaDEP) to update the State Water Plan by 2008. A Statewide Water Resources Committee and six Regional Water Resources Committees have been created to oversee and provide guidance to the process of updating the State Water Plan. The Statewide Water Resources Committee establishes guidelines and policies that will be used as part the State Water Plan update. The State Water Plan update, among other things, will result in the identification of areas where the demand for water exceeds available supplies. These areas will be designated as Critical Water-Planning Areas (CWPA) and will serve as a planning boundary for the creation of a more detailed Critical Area Resource Plan (Pennsylvania Department of Environmental Protection, 2006a).

A water-analysis screening tool (WAST) was developed by the U.S. Geological Survey (USGS), in cooperation with the PaDEP, to provide assistance to the state in the identification of CWPAs. The WAST compares water-use information to an initial screening criteria (ISC), resulting in a screening indicator (SI) for influences of net withdrawals on aquatic-resource uses. The ISC is a percentage of the 7-day, 10-year low-flow statistic (7Q10[1]). A screening indicator as a percentage (SIP) is determined for over 10,000 watersheds across the state, generally larger than 15 mi^2, and is color-coded within the WAST for each watershed at its outlet (termed the "pour point"). This allows for watersheds to be easily identified for further evaluation. After this initial screening of watersheds using the WAST, areas with potential conflicts between water use and aquatic-resource needs will be selected for further evaluation, and CWPAs will be identified.

This report presents the methodology used to develop the WAST and the supporting data used as input into the WAST for the initial screening for the Pennsylvania State Water Plan update. A comprehensive water-use database that includes data from registration, estimation, discharge monitoring reports (DMRs), mining data, and other sources is described. Water-use data were estimated for the following categories: residential, industrial, commercial, agricultural, and golf courses. The ISC are determined using regression equations developed by Stuckey (2006). The assumptions and limitations of the WAST also are presented.

[1]The 7-day, 10-year low flow; the lowest consecutive 7-day mean flow expected on average every 10 years.

Development of the Water-Analysis Screening Tool

A water-use database consisting primarily of registrations, DMRs, and available mining data was developed as part of the update process for the State Water Plan. Water use was estimated, where necessary, to complete the database. The ISC used in the statewide initial screening were determined from low-flow regression equations as described by Stuckey (2006). The WAST uses the total withdrawals minus the total discharges, or net withdrawals, of ground water and surface water and the ISC for a watershed to determine a SI for potential influences of net withdrawals on aquatic-resource uses. Watersheds with a negative SI may indicate areas where the net withdrawals are negatively impacting aquatic resources.

Inventory of Water-Use Data

As part of the State Water Plan update, substantial effort has been made to compile a comprehensive water-use database to be used in the statewide identification of CWPAs. All water users withdrawing or using more than 10,000 gal/d averaged over a 30-day period and all public water agencies and hydropower facilities were required to register their water use with PaDEP. The comprehensive water-use database used to perform the initial screening originated from the following information: Act 220 registration, estimation, DMRs, mining data, and "other." These sources of water-use information are described in more detail in the following sections. The 169,700 records that comprise the water-use database are summarized by category in table 1.

The 7,339 registered water users reported water use in agricultural, commercial (which includes golf courses), industrial, water supply, power generation, and mineral extraction. More detailed descriptions of these categories can be found in Ludlow and Gast (2000). Registered water use is from 2003 because the records for that year were more complete than previous years, in part because of the passing of the Act 220 legislation. Water use, especially in the non-residential categories and in agriculture, can differ depending on the amount of precipitation in a given year. Because the precipitation was above average in 2003, the water use reported may be different during periods of drought. Information on registered use was determined by actual days used, rather than average annual use. This may result in a higher value than if water use was calculated on an average annual rate. For example, if a facility used 10 Mgal of water for 180 days, the actual days-used value is 0.06 Mgal/d. The average annual use for the same facility would be 0.03 Mgal/d. Actual days used was utilized in the WAST to capture demands that may only use water during the summer months, such as golf courses and irrigation for agricultural uses.

Table 1. Total water use by source of data.

[Mgal/d, million gallons per day]

Data source	Total number of sources	Total water use (Mgal/d)
Registration	7,339	8,731
Estimation	158,662	196
Discharge monitoring reports	3,453	8,147
Mining	89	85
Other	157	1,059

Unregistered withdrawals were estimated to address data gaps in water-use categories with water use known to be under-reported. The categories requiring estimates were self-supplied residential, industrial, commercial, agricultural, and golf courses. The methodology used to estimate water use is described in more detail in the following section. A total of 158,662 records was estimated as part of this process. The individual quantities estimated are relatively small, averaging 1,238 gal/d. Another category requiring estimation was mining, but because withdrawals for mining vary widely and are dependent on such factors as type of mineral, type of processing, and need for dewatering, a consistent methodology could not be determined.

In addition to withdrawals, flow contributions in the form of discharges also were tabulated. Discharges were compiled for major basins by the Delaware River Basin Commission (DRBC), the Susquehanna River Basin Commission (SRBC), and PaDEP primarily through DMRs. DMRs are monthly reports submitted by wastewater permittees that summarize the quality and quantity of treated water that is discharged. DMRs were compiled from 2000 through 2004, resulting in up to 60 entries for a single facility. Water use was determined for each month using monthly quantities excluding any zero, missing, or unreported months. This resulted in an actual days-used quantity per year. The 2003 actual days-used discharge for each facility was used in the statewide compilation of water use to be consistent with registration water use. In the event that a facility did not have 2003 data, 2002 or 2004 data were used. A sensitivity analysis was done using discharges in the Codorus Creek watershed in York County as a pilot study to determine whether there were any significant differences between the discharges for 2000, 2001, 2002, 2003, and 2004. A Kruskall-Wallis test (Helsel and Hirsch, 2002) was used to compare the datasets, and the results indicated that discharges for all the years are statistically equivalent (p-value = 0.9461).

Active mine operations can withdraw and return large amounts of water to a system. To ensure a balance between the withdrawals and discharges from mining operations, registered mining withdrawals were examined for an associated discharge. If no discharges were found for a particular mining-operation facility, a discharge that assumed 8 percent consumptive use was estimated. For mining-operation facilities involving only mineral preparation, a discharge that assumed 17 percent consumptive use was estimated. Details describing the mining operations for facilities were obtained from registration reports. A consumptive-use factor of 8 percent was obtained from the last water-use compilation for Pennsyl-

vania completed by the USGS (Ludlow and Gast, 2000) and a consumptive-use factor of 17 percent was determined using mining water-use data from the PaDEP water-use database. These additional mining discharges are herein referred to as "mining."

An ongoing quality-control program revealed that additional withdrawals and discharges have been missed or not reported. As these water-use facilities are found, they are added to the statewide water-use database and are termed "other." Examples of "other" water use include power generators, water purveyors, mining, and sewage-treatment plants. Some of these facilities may have registered or submitted a DMR, but the reports may have been misplaced, may have included erroneous information, were not filed on time, or were unavailable to staff during times of collection.

Estimated Unregistered Water-Use Data

Unregistered withdrawals were estimated to fill data gaps in water-use categories with water use known to be underreported. These categories are primarily self-supplied users and include residential, industrial, commercial, agricultural, and golf courses water use. The estimated unregistered water use by category is shown in table 2. The methodology used to estimate unregistered water use was modified from procedures developed by Camp, Dresser, and McKee, in cooperation with the DRBC and the PaDEP (David Sayers, Delaware River Basin Commission, written commun., 2005). Water use was estimated using a point approach to represent a larger area, resulting in a unique spatial location necessary for inclusion in the WAST.

Table 2. Estimated unregistered water use by category.

[Mgal/d, million gallons per day]

Estimated unregistered water-use category	Total number of estimated points	Total estimated water use (Mgal/d)
Residential	114,950	20.9
Industrial	3,021	67.8
Commercial, excluding golf courses	36,563	16.5
Irrigation	1,595	39.3
Livestock	2,112	23.0
Golf courses	421	28.8

Residential

Self-supplied residential use refers to households outside of public-water-supply service areas that are assumed to rely on private wells. Data from the 2000 census were used to determine populations outside of the service areas (U.S. Census Bureau, 2000). Service-area boundaries were supplied by PaDEP. Revised 2000 population data were obtained from PaDEP, and blocks with zero populations were removed. A population density (person per square meter) was calculated for each census block. A Geographic Information System (GIS) was used to determine census blocks that were outside the service areas. In cases where the service areas crossed a census block, the population was adjusted by multiplying the population density by the area of the census block outside the service area. Centroids of the census blocks outside of service areas were determined and assigned with associated population attributes. These points represent the combined household population residing in a particular census block.

An attempt was made to determine a water-use factor using statewide data from selected public water suppliers, including population served and quantity of water used. However, there was wide variance in the data, and a conclusive water-use factor could not be determined (Michael Hill, Pennsylvania Department of Environmental Protection, written commun., 2006). A water-use factor of 80 gallons per capita per day (gpcd) was determined by Camp, Dresser, and McKee as part of a pilot study conducted in the Lehigh River watershed (David Sayers, Delaware River Basin Commission, written commun., 2005). This factor was based on data from 21 public water suppliers. Because this value of 80 gpcd was similar to the results of the statewide effort, and a conclusive statewide water-use factor could not be determined, the value of 80 gpcd was applied to each point representing the population residing in one particular census block to determine the estimated water use.

Non-Residential

Non-residential points were assumed to be places of employment outside of public-water-supply service areas. These non-residential points are industrial and commercial facilities relying on private wells or other sources to meet their water needs. Employment data were obtained by PaDEP from the Pennsylvania Department of Labor and Industry. Of the total employment sites included in the Labor and Industry data, 42 percent had either missing or incorrect spatial data. For those sites without valid spatial data, attempts were made to assign latitude and longitude designations on the basis of the centroid of the associated census block. In cases where the service areas crossed a census block, the employment was adjusted by area distribution. Of the employment sites without spatial data, approximately 20 percent did not have census-block information or could not be matched to the 2000 census blocks and were not included in the analysis. A GIS was used to identify those points outside of the service areas. North American Industry Classification System (NAICS) codes

(U.S. Department of Commerce, 2002) were used to identify the industrial (manufacturing) and commercial (non-manufacturing) employment sites (table 3).

An attempt was made to determine a water-use factor using statewide data from registered industrial and commercial facilities, including number of employees and quantity of water used. However, there was wide variance in the data, and a conclusive water-use factor could not be determined (Michael Hill, Pennsylvania Department of Environmental Protection, written commun., 2006). Water-use factors of 665 gal/d per employee and 42 gal/d per employee for industrial and commercial sites, respectively, were determined by Camp, Dresser, and McKee as part of a pilot study conducted in the Lehigh River Watershed (David Sayers, Delaware River Basin Commission, written commun., 2005). These factors were based on data from 16 and 21 public water suppliers, with standard deviations of 815 gal/d and 57 gal/d for industrial and commercial facilities, respectively. Because the water-use factors developed by Camp, Dresser, and McKee were similar to the results of the statewide effort and new values could not be determined, these water-use factors were used to estimate water use for industrial and commercial sites. These water-use factors were applied to known and approximate locations outside of public-water-supply service areas. Duplicate values for the same non-residential facility may exist as a result of both registration and estimation. Insufficient information from the Labor and Industry data resulted in the inability to check for duplicate values on a statewide basis. Before a watershed is identified as a CWPA, verification would be needed to ensure there are no duplicate values for estimated unregistered facilities with large registered withdrawals outside of service areas.

Irrigation

Irrigation water use was estimated for the top 10 counties identified from the 2002 agriculture census (U.S. Department of Agriculture, 2004) that accounted for about 60 percent of irrigated water use in the state. Irrigation water use in Lancaster, Franklin, Adams, Erie, Berks, Schuylkill, Lebanon, Chester, Lycoming, and York Counties was estimated. Water use was estimated for points within these counties on the basis of total irrigated cropland, which was determined using a ratio of irrigated cropland to total cropland as reported in the 2002 agricultural census (U.S. Department of Agriculture, 2004). Data were compiled for the 2002 agricultural census through the use of mailed questionnaires to farm and ranch owners and operators. Land-use categories were used to determine the

Table 3. North American Industry Classification System used in estimation of non-residential water use.

North American Industry Classification System (NAICS)	Description
Manufacturing	
31-33	Manufacturing
Non-manufacturing	
22	Utilities
23	Construction
42	Wholesale Trade
44-45	Retail Trade
48-49	Transportation and Warehousing
51	Information
52	Finance and Insurance
53	Real Estate and Rental and Leasing
54	Professional, Scientific, and Technical Services
55	Management of Companies and Enterprises
56	Administrative and Support and Waste Management and Remediation Services
61	Educational Services
62	Health Care and Social Assistance
71	Arts, Entertainment, and Recreation
72	Accommodation and Food Services
81	Other Services (except Public Administration)
92[1]	Public Administration

[1]NAICS code 99 was used in the Labor and Industry database but did not have a corresponding NAICS code in the Workforce Investment Area Data; after discussion with Pennsylvania Department of Environmental Protection, data from NAICS code 92 was substituted for NAICS code 99.

location of cropland within the counties. Total cropland for Lancaster, Franklin, Adams, Berks, Schuylkill, Lebanon, and Lycoming Counties was determined from row crops (Pennsylvania State University, 2003); total cropland for Erie and York Counties was determined from row crops, grain, hay, seeds, and other crops (U.S. Department of Agriculture, 2006); and total cropland for Chester County was determined from row crops, grain, hay, and seeds (U.S. Department of Agriculture, 2006). The areas of cropland computed using these geospatial data layers were compared to the 2002 agriculture census total cropland for the counties, and the two areas were within 12 percent. The cropland was then determined in a GIS for the subbasins used in the WAST, and the centroids of the subbasins were generated.

As a result of the GIS analysis described in the preceding paragraph, each centroid point has a corresponding amount of cropland representing a portion of the total cropland for the county. This cropland amount was then adjusted on the basis of a ratio of total cropland to irrigated cropland (table 4) determined from the 2002 agriculture census (U.S. Department of Agriculture, 2004). Water use was then estimated using a water-use factor based on irrigated cropland in acres generated by Dr. Albert R. Jarrett from the Pennsylvania State University in conjunction with PaDEP (Dr. Albert Jarrett, Pennsylvania State University, written commun., 2007). The water-use factors for the counties with estimated water use are provided in table 4. These water-use factors were determined on the basis of the growing season, using a 31-day August average with average precipitation. Actual water used for irrigation during drought years may be greater than the quantities determined using the water-use factors shown in table 4 and may need to be further evaluated before a watershed is identified as a CWPA.

Livestock

Water use for livestock was estimated for the top 12 counties that accounted for about 60 percent of water used for livestock in the state (Dr. Albert Jarrett, Pennsylvania State University, written commun., 2007). These included Lancaster, Franklin, Lebanon, York, Berks, Bradford, Adams, Cumberland, Chester, Somerset, Perry, and Snyder Counties. An analysis of land use and locations of Concentrated Animal Feeding Operations (CAFOs) showed that the majority of these locations were in land-use areas categorized as row crops (Pennsylvania State University, 2003). The livestock areas were therefore assumed to be located in the row-crop areas, and row crops were determined in a GIS for the subbasins used in the WAST. The percentage of row-crop area within each subbasin to total county row-crop area was determined for each subbasin. The centroids of the subbasins with row crops were determined. Each centroid was assigned a water-use quantity representing a particular subbasin on the basis of the percentage of row-crop area and water-use factors for the county. The water use required for livestock per county is shown in table 5 (Dr. Albert Jarrett, Pennsylvania State University, written commun., 2007).

Golf Courses

According to an extensive search by DRBC in conjunction with PaDEP, 421 golf courses did not register water use in 2003 (David Sayers, Delaware River Basin Commission, written commun., 2006). These golf courses account for about 60 percent of all golf courses in the state. Using registered golf courses as a reference, a consistent methodology was determined to estimate water use at the unregistered courses. Water used at each registered golf course varied widely and depended on such factors as expanse of facility and grounds,

Table 4. Water-use factors used in the estimation of irrigation water use.

County	Rank	Irrigated lands[1] (acres)	Total cropland[1] (acres)	Ratio of irrigated land to total cropland	Water-use factor[2] (gallons per day per acre)
Lancaster	1	6,051	333,009	0.01817	2,467
Franklin	2	2,712	191,112	.01419	1,836
Adams	3	2,656	135,040	.01967	1,867
Erie	4	2,302	106,364	.02163	2,506
Berks	5	1,914	173,223	.01105	2,653
Schuylkill	6	1,876	78,347	.02394	2,727
Lebanon	7	1,857	102,547	.01811	2,512
Chester	8	1,846	124,322	.01485	2,689
Lycoming	9	1,770	103,763	.01706	997
York	10	1,689	222,789	.00758	2,245

[1]U.S. Department of Agriculture (2004).

[2]Dr. Albert Jarrett, Pennsylvania State University, written commun., 2007.

Table 5. Estimated water required for livestock for selected counties.

[Mgal/d, million gallons per day]

County	Rank[1]	Water required[1] (Mgal/d)
Lancaster	1	8.771
Franklin	2	3.469
Lebanon	3	2.248
York	4	1.868
Berks	5	1.860
Bradford	6	1.710
Adams	7	1.660
Cumberland	8	1.287
Chester	9	1.231
Somerset	10	1.130
Perry	11	1.060
Snyder	12	1.055

[1]Dr. Albert Jarrett, Pennsylvania State University, written commun., 2007.

amenities, and number of holes. A relation between the number of holes and the water used on registered golf courses statewide was developed to estimate water use at the unregistered golf courses; a water-use factor of 4,270 gal/d per hole was used. Further analysis could be applied to refine the water-use factor to a smaller scale, basing it on counties or census information rather than on the entire state.

Consumptive Use

Consumptive use is the part of withdrawn water that is consumed and is removed from the immediate water system (Solley and others, 1998). The water may be consumed by humans or livestock, or incorporated into products or crops, making it unavailable for immediate use. Consumptive use is incorporated into the database through related registered withdrawal and discharge points. The difference between the amount of water a facility withdraws and the amount returned as a discharge is essentially the consumptive use.

However, the estimated withdrawals do not have corresponding estimated discharges, because discharges, as a whole, were not estimated. All estimated withdrawals, with the exception of residential, are assumed to have a consumptive use of 100 percent. Although that assumption may be realistic for some water-use categories, such as irrigation where historically most of the water applied is evapotranspired, it may not be realistic for all categories. Estimated residential water use was adjusted to account for consumptive use of 10 percent, resulting in 90 percent of the water used being returned to the system. Previous studies in Pennsylvania support a consumptive-use factor of 10 percent for self-supplied residential, including the last compilation completed by the USGS (Solley and others, 1998) and an analysis done by DRBC (David Sayers, Delaware River Basin Commission, written commun., 2007).

Initial Screening Criteria

The ISC were established in cooperation with the CWPA Subcommittee, a subcommittee of the Statewide Water Resources Committee, for purposes of identifying potential CWPAs. CWPAs are areas where existing or projected withdrawals are likely to cause irreparable or unmitigated impacts to reasonable and beneficial withdrawal and non-withdrawal uses (Pennsylvania Department of Environmental Protection, 2006b). Cumulative unmitigated net withdrawals in CWPAs exceed, or result in, at least one of the following values or conditions (Pennsylvania Department of Environmental Protection, 2006b):

- Repeated acute dewatering,
- 5 percent mean annual habitat loss for Class A trout streams underlain by carbonate bedrock,
- 5 percent mean annual habitat loss for Class A trout streams in noncarbonated areas,
- 10 percent mean annual habitat loss for Class B trout streams underlain by carbonate bedrock,
- 15 percent mean annual habitat loss for Class C and D trout stream underlain by carbonate bedrock,

On the basis of an analysis by the Pennsylvania Fish and Boat Commission for the CWPA Subcommittee and PaDEP, it was determined that a percentage of the 7Q10 may be used for the initial screenings to satisfy the requirements listed above (Leroy Young, Pennsylvania Fish and Boat Commission, oral commun., 2005). This quantity, or the ISC, was determined to be 50 percent of the 7Q10 flow for all streams except those designated as a Class A trout stream in areas of carbonate bedrock; 30 percent of the 7Q10 flow is used for those streams. Trout-stream classifications and requirements are shown in table 6. The 7Q10 is computed by regional regression equations developed by the USGS (Stuckey, 2006). All 7Q10 values determined using the regression equations are greater than zero. After the initial screening using a percentage of 7Q10, if a watershed is prioritized for further study, the ISC will be reevaluated using other methods where applicable. For example, a percentage of mean annual habitat loss as determined using Pennsylvania Instream Flow Incremental Methodology developed by SRBC (1998) could be compared to the ISC and used in the WAST.

Regulated flow from flood-control reservoirs and other lakes and ponds may alter downstream streamflow. Conservation releases or pass-by flows requiring permits were not included in the initial screening using the ISC as a percentage of 7Q10. In addition, net withdrawals and the ISC were computed as stand-alone values in the initial screening without

Table 6. Trout-stream classifications and requirements[1] for Pennsylvania streams.

[cm, centimeter; kg/ha, kilogram per hectare; —, does not apply]

Stream classification	Trout species	Total biomass of species	Total biomass less than 15 cm	Species percentage of total trout biomass
A	Wild brook	30 kg/ha or greater	0.1 kg/ha or greater	75% or greater
	Wild brown	40 kg/ha or greater	.1 kg/ha or greater	75% or greater
	Mixed wild brook and brown	40 kg/ha or greater	.1 kg/ha or greater	less than 75% brook trout and less than 75% brown trout
	Wild rainbow	—	2.0 kg/ha or greater	—
B	Brook	20 kg/ha or greater and less than 30 kg/ha	—	—
	Brown or mixed brown and brook	20 kg/ha or greater and less than 40 kg/ha	—	—
C	All species	10 kg/ha or greater and less than 20 kg/ha	—	—
D	All species	less than 10 kg/ha	—	—

[1] Russel Greene, Pennsylvania Fish and Boat Commission, written commun., 2008.

regard to the effects or implications from the conservation releases, pass-by flows, or other mitigation efforts. Information on the actual quantity, timing, and operation of conservation releases would be collected as part of the detailed verification required before a watershed is designated as a CWPA. Because conservation releases and pass-by flows are an important component of the water balance for a particular watershed, efforts should be made to compile known releases into a statewide database.

Water-Analysis Screening Tool

The WAST is a watershed-based geospatial program developed by the USGS to evaluate potential influences of net withdrawals on aquatic-resource uses. The WAST is used as an initial screening for the state as part of the process of identifying CWPAs and can later be used to refine the inputs for a particular watershed to more closely replicate actual conditions. The WAST has two primary inputs: net withdrawals and the ISC, both defined in previous sections. Assuming the surface-water and ground-water resources are one resource, total withdrawals include both surface-water and ground-water withdrawals, and assuming unmitigated withdrawals for initial screening purposes, the potential influence of net withdrawals on aquatic-resource uses is defined as the SI. A basic water-balance equation is used in the determination of SI, as shown in equation 1.

$$SI = ISC - NW , \quad (1)$$

where:

SI is a screening indicator of the potential influence of net withdrawals on aquatic-resource uses for a watershed, in million gallons per day;

ISC is the initial screening criteria for a watershed as determined by a percentage of the 7Q10, in million gallons per day;

and

NW is the net withdrawal for a watershed as determined by total withdrawal minus total discharge, in million gallons per day.

SI is calculated at pour points across the state representing watersheds generally larger than 15 mi^2. To correlate and compare estimated SIs between different watersheds with differing drainage areas and natural flows, a dimensionless SIP is computed. SIP is determined using equation 2.

$$SIP = [(ISC - NW) / ISC] \times 100 , \quad (2)$$

where:

SIP is the screening indicator of the potential influence of net withdrawals on aquatic-resource uses for a watershed, as a percentage;

ISC is the initial screening criteria for a watershed as determined by a percentage of the 7Q10, in million gallons per day;

and

NW is the net withdrawal for a watershed as determined by total withdrawal minus total discharge, in million gallons per day.

The pour points are displayed in the WAST and color-coded on the basis of the SIP as determined from equation 2. Green is used for watersheds where net withdrawals are less than the ISC, indicating the potential of adequate water to meet the demands of aquatic-resource uses. Yellow is used for watersheds where net withdrawals are greater than the ISC, indicating potential areas of conflicts with aquatic-resource uses. Some of these potential conflict areas may eventually become designated CWPAs. White is used for watersheds that can not conclusively be labeled as having a high or low potential for conflicts with aquatic-resource uses.

Assumptions

At times of severe drought, it is assumed that the only flow in a stream is attributed to ground-water base flow, which is sustained by ground-water discharge. Gaining reaches in a stream are those in which ground-water discharge is supplementing the natural streamflow. Losing reaches in a stream are those in which streamflow is exiting the stream channel and entering the ground-water system. The ISC may need to be adjusted in areas of losing reaches because the 7Q10 as computed from regression equations assumes gaining reaches.

A one-to-one relation between ground water and surface water is assumed; that is, if 1 gal is pumped from ground water, it is assumed to be equivalent to 1 gal removed from a stream. This assumption does not factor in ground-water storage, the time-response delay due to the distance a well is from a stream, or the loss due to ground-water evapotranspiration.

The water-use data, based on 2003 data, are assumed to be comparative to water-use data recorded during other years. Because 2003 was a year with above-average precipitation and streamflow, the actual water use may change during drought conditions, particularly in the categories of industrial, commercial, and agricultural. The water-use factors used to estimate irrigation water use were based on a year with average precipitation.

Methodology used in the placement of water-use points using the centroid approach for estimated residential, commercial, and industrial use assumes a uniform distribution of population within the census blocks. Methodology used in the placement of water-use points using the centroid approach for estimated agricultural use assumes a uniform distribution of irrigated land within the row crops. In addition, livestock is assumed to be within areas of row crops.

Estimated water use for commercial, industrial, agricultural, and golf courses is assumed to be 100 percent consumptive, in which no water is returned to the system. Although that may be realistic for some water-use categories, such as irrigation where historically most of the water applied is evapotranspired, this assumption may not be realistic for the other categories. Estimated residential water use was assumed to have a 10-percent consumptive use on the basis of previous studies in Pennsylvania. Depending on the number of residential sand mounds, which return less water to the water system than septic systems because of evaporation, and the number of households with private wells that are connected to a public sewer system, the consumptive-use factor for estimated residential use within a particular watershed may be higher. Lack of comprehensive maps outlining the service areas for sewage-treatment plants hinders establishing the relation between public-water-supply service areas and sewage-treatment-plant service areas.

Limitations and Accuracy

Aquatic resources depend on water quantity and quality. Clean and abundant water is necessary for most users of water, from ecological uses to water purveyors. The WAST only identifies watersheds with areas of concern based on net withdrawals. There may be watersheds not identified by the WAST where there may be potential conflicts with aquatic resources because of the quality of the available water. Water quality can limit the types of uses of the available water.

The WAST includes watersheds with drainage areas of generally about 15 mi^2 to about 2,000 mi^2. Watersheds outside of this range may have aquatic-resource concerns not captured by the WAST. Not all watersheds within this range of drainage areas are included in the WAST because of the automated processing used to generate the pour points. Watershed boundaries may have errors in the delineations because of problems with the underlying National Hydrography Dataset (NHD) or the digital elevation model. GIS processing involved in the WAST used the centerline flow from the NHD, which can result in skewed watershed delineations near major rivers. Incorrect watershed delineations could result in inaccuracies in the calculations of ISC, SI, and SIP.

Surface-water and ground-water resources and drainage-basin divides are not differentiated in the screening tool and, therefore, all relevant water use in a watershed may not be captured. In areas where there are probable discrepancies between the divides, such as areas with karst topography or coal-mining areas, the results of the WAST should be reviewed carefully.

The registered water use was determined from 2003 registrations because that year was the most complete compared to previous years. However, this does not necessarily mean that the 2003 registrations capture all the water users in the state. Estimates were used to fill in these data gaps and build a comprehensive water-use database. Additional water users not captured as part of the registration process or estimation can only be identified at a local scale. The use of 100-percent consumptive use for estimated water use, with the exception of the residential category, may result in a lower SI than expected for a watershed because no water is returning to the system.

The WAST was developed to provide an initial screening of the potential influence of net withdrawals on aquatic-resource uses. From this initial screening, areas of the state can be identified that have potential conflicts between water-use demands and aquatic-resource needs and further work can be

prioritized. Further investigation into the water use, ISC, and mitigation efforts would be needed before a watershed can be designated as a CWPA. The accuracy of the WAST depends on the accuracy of the input data, specifically the water-use information and the ISC. Data from each watershed should be carefully examined for accuracy.

Summary

The WAST was developed by the USGS to provide assistance to PaDEP in the identification of critical water-planning areas as required by the Water Resources Planning Act. The WAST compares water-use information to an ISC based on the 7Q10, resulting in a SI for potential influences of net withdrawals on aquatic-resource uses. The SIP is displayed in the WAST by a range of colors at pour points representing the outlets of watersheds generally larger than 15 square miles. Green is used for watersheds where net withdrawals are less than the ISC, indicating the potential of adequate water to meet the demands of aquatic-resource uses. Yellow is used for watersheds where net withdrawals are greater than the ISC, indicating potential areas of conflicts with aquatic-resource uses. Some of these potential conflict areas may eventually become designated CWPAs. White is used for watersheds that can not conclusively be labeled as having a high or low potential for conflicts with aquatic-resource uses.

A comprehensive water-use database that includes data from registration, estimation, DMRs, mining data, and other sources was developed as input into the WAST. The registered water-use data and DMRs were reported in actual days used rather than as an annual average. This allows for a more direct comparison between water use and the 7Q10. Estimated water use includes data from the following categories: residential, industrial, commercial, agricultural, and golf courses. Consumptive use is assumed to be 100 percent for all estimated water-use categories except residential, which uses a 10-percent consumptive-use factor.

The WAST was developed to provide an initial screening of the potential influence of net withdrawals on aquatic-resource uses. Users should familiarize themselves with the assumptions and limitations described in this report before assessing the results displayed in the WAST. The accuracy of the WAST depends on the accuracy of the input data, specifically the water-use information and the ISC. Data from each watershed should be carefully examined for accuracy.

References Cited

Helsel, D.R., and Hirsch, R.M., 2002, Statistical methods in water resources: U.S. Geological Survey Techniques of Water-Resources Investigations, book 4, chap. A3, 522 p.

Ludlow, R.A., and Gast, W.A., 2000, Estimated water withdrawals and use in Pennsylvania, 1995: U.S. Geological Survey Fact Sheet 174-99, 4 p.

Pennsylvania Department of Environmental Protection, 2006a, The Pennsylvania State Water Plan and Act 220 of 2002: 3920-FS-DEP 3155, 2 p.

Pennsylvania Department of Environmental Protection, 2006b, Guidelines for identification of Critical Water Planning Areas: Document 392-2130-014, 17 p.

Pennsylvania State University, 2003, Pennsylvania land cover, 2000: accessed September 12, 2007, at *http://wiz.pasda.psu.edu/uci/MetadataDisplay.aspx?entry=PASDA&file=palanduse2000.xml&dataset=464*.

Solley, W.B., Pierce, R.R., and Perlman, H.A., 1998, Estimated use of water in the United States in 1995: U.S. Geological Survey Circular 1200, 71 p.

Stuckey, M.H., 2006, Low-flow, base-flow, and mean-flow regression equations for Pennsylvania streams: U.S. Geological Survey Scientific Investigations Report 2006-5130, 84 p.

Susquehanna River Basin Commission, 1998, Instream flow studies Pennsylvania and Maryland: Susquehanna River Basin Commission Publication 191, 309 p.

U.S. Census Bureau, 2000, United States Census 2000: accessed August 22, 2007, at *http://www.census.gov/main/www/cen2000.html*.

U.S. Department of Agriculture, 2004, 2002 Census of Agriculture Pennsylvania: National Agricultural Statistics Service, Agricultural Statistics Board.

U.S. Department of Agriculture, 2006, 2002 MidAtlantic Cropland Data Layer: National Agricultural Statistics Service, Agricultural Statistics Board.

U.S. Department of Commerce, U.S. Census Bureau, 2002, North American Industry Classification System – United States, 2002: Springfield, Va., 1419 p.