Water Use in Maryland
A Workplan to Advance Water Use Science 2017-2020

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Final Report

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Abstract

Authority to manage Maryland's water is vested in the Maryland Department of the Environment under Title 5 of the Environment Article of the Annotated Code of Maryland. Joint location of quantity, quality and sanitary surveys for drinking water systems within the Department's Water Supply Program empowers MDE to coordinate systematic sustainable use and development of the State's water resources. This workplan reviews and identifies the needs and priorities identified for Maryland's Water Supply Program and lays out a workplan to improve the accuracy and utility of water use data in the State that will also help the USGS improve its water use information. This workplan is informed by a review of the current status of the water use program, the challenges and needs identified from water use stakeholders within the state, and the long-term vision of evolving the state permit and management program into a water use information system with the capacity to support statutory and regulatory functions in permitting, management, and enforcement, as well as long-term sustainable resource tracking, planning, and management, for the citizens of Maryland. The workplan is structured to advance two separable but complementary broad goals: improving water use data management, and improving the accuracy of Maryland's water use information.

Table of Contents

Executive Summary

The Maryland Department of the Environment Water Supply Program's policies and regulatory decisions for managing the State's water resources are informed by water use data. The Water Supply Program provides water use data to the USGS on a regular basis. It is of paramount importance for both the Water Supply Program and the USGS to have accurate and reliable water use data so that the State's water resources are managed for the public good which includes ensuring their wise use and sustainability without jeopardizing the State's natural resources. Having accurate and readily accessible water use data is ever important in light of growing demands for water and the impact of climate change on sea level and the hydrologic cycle.

This document describes Maryland's priorities for a workplan to improve the collection, estimation and management of water use data for the State of Maryland. Maryland's proposed Water Use Workplan has been structured to advance State and Federal interests in the Maryland Water Use Program during the period 2017-2020. The workplan reflects Maryland's priorities for improved data collection and management, as well as USGS priorities for improved water use information to support the National Water Use Information Program. The workplan:

- Describes Maryland's water use program;
- Outlines the State's priorities for improving water use data in Maryland; and
- Identifies the steps proposed to address each priority, considering USGS baseline standards for water use data.

The workplan reflects plans and priorities for near-term incremental improvement in water use information, building on the current state of water use data in Maryland. The workplan also reflects USGS priorities for the National Water Use Information Program that were identified through stakeholder meetings sponsored by the Interstate Council on Water Policy (ICWP). For FFY17 these National priorities include:

- Improved data collection, quality assurance, and delivery
- Improved data for irrigation: sources of withdrawals, volumes, and consumptive use (includes irrigation for agriculture and golf courses)
- Improved estimation of public supply deliveries to customer groups or classes, such as commercial, industrial, and domestic.

This workplan reflects State priorities for regulatory and resource management, as well as workplan requirements identified by the USGS Water Use Data and Research Program (WUDR). USGS workplan requirements included:

1. A description of the current State water use program.
2. An outline of State priorities for improving water use data.
3. The steps proposed to address priorities.
4. A description of the collaboration that was part of the Workplan development, or WUDR funding.
5. A description of additional tasks and products that were proposed in the Application for the 2015 WUDR cooperative agreements

The workplan identified strategic priorities addressing two major themes:

1. advancing data management; and
2. improvements in the collection and accuracy of primary and secondary data to improve water use estimates and the information that supports the USGS WURD program.

The outline of water use priorities and the steps proposed to achieve these priorities is summarized in Table ES-1.

Table ES-1 Maryland Water Use Workplan: Priorities & Approach

Priority	Proposed Approach
Improve household estimation • Update "bottoms up" – indoor water use • Estimate separable outdoor water use	• Analyze small CWS daily MOR production data • Stratify on socioeconomic, regional and hydrogeologic attributes • Update residential use against WRF 2016 23-city study
Improve Domestic Self Supply Values • Improved per capita, modified by aquifer yield • Stratify by socioeconomic indicators	• Reevaluate structure and variability in per capita water use from small CWS. • Identify "natural" (regional, economic) clusters of homogenous household water use behavior • Revise DSS per capita by region, socioeconomics, aquifer etc.
Irrigation (reasonable checks and validation) • Estimation methods – crop need models • Compare to DE real-time guidance • Peak, seasonal disaggregation	• Analyze validation alternatives for reported irrigation (e.g. crop needs model, DE irrigation recommendations • Compare to Ag. Census and FRIS estimates
Evaluate Domestic Self Supply Cumulative Aquifer Withdrawals • Well location and aquifer assignment • Tiered hierarchical analysis	• Automate DSS aquifer assignment (Model Builder) from AIS and Well Database • Stratify confidence by estimated error. • Verify random samples within each error strata and iteratively revise assignment rules to target manual well-log verification efforts
Data Systems Management & Upgrades • Clean up tasks • Provide support additional data storage and management • Online permittee submittals?? How to ensure chain of custody w/o paper record	• Added canned reports for pumpage by stream, aquifer, use, use category, basin and range of grid locations • Add support for pumpage by day and by well or well field • Deploy capacity for direct user entry of pumpage • Fix current deficiencies in entry of use percentages and fresh and salt water determination.
Automate Data QA/QC	• Screen and test "reasonableness" checks by sector (e.g. weather sensitivity of irrigation) and between years • Checks with permit applications, economic activity, etc.
Design & Develop Prototype Water Use Data Model (WUDM).	• Design Maryland WUDM (after NEWUD, NJWaTr) • Prototype WUDM by logical joins of feature class tables. Join by permit number, other?
Water Use Data Model Proof-of-concept • Link WSIPS, Wells, AIS to withdrawal-conveyance-use-discharge data model	• Proof of concept demonstration of WUDM for regional assessment of water availability • Demo candidates should test basin & jurisdictional transfers; close water balance. Perhaps at scale of WRE.

1. Background/Introduction

The U.S. Geological Survey (USGS), through its Water Availability and Use Science Program (WAUSP), is the only Federal agency that explicitly collects water-use data as a part of its mission. The WAUSP works with State, local, and Federal partners to consolidate dozens of disparate datasets to create comprehensive reports of water use in the United States every five years. Because of differences in methodology and data quality, USGS water use compilations require significant effort to standardize (to the extent possible) such data between States. The WAUSP products form the basis of the water use component of the National Water Census as called for by the SECURE Water Act (Section 9508, Public Law 111–11).

In response to significant drought and water resource planning challenges in Maryland, the Maryland Water Advisory Committee was established by Executive Order to advise the Governor of Maryland on the development, management, and protection of the State's water resources. The Advisory committee was chaired by Dr. M.G. Wolman and final findings and recommendations were memorialized and reported back to the Maryland Governor (Wolman 2004). Following the Advisory Committee's 2004 final report, a second advisory committee was established to follow up on the 2004 findings and recommendations, prioritizing State actions to implement the committee's recommendations. This evaluation is memorialized in the Committee's final report, "*Water for Maryland's Future: What We Must Do Now*" (Wolman 2008). The Wolman report made seven major recommendations, representing significant changes in the management of Maryland water resources. A number of recommendations institutionalize sustainable planning, and advance information-based management of the State's water resources, emphasizing the comprehensive evaluation of sources of supply in local and regional water and sewer planning.

In 2002 the National Research Council undertook a review of the USGS Water Use Program (NRC 2002). NRC recommended that USGS transform the national water census from a *census and inventory* program into a *water use science* program, with specific recommendations on the use of geospatial data models and statistical estimation methods to enable water use to be managed as the anthropogenic flux in the hydrologic system. A number of these recommendations are already being integrated in WAUSP. Collaborative initiatives between USGS and State water management agencies offer the rich opportunity to advance these goals through the WUDR Program.

Maryland's water use workplan is structured to advance data and information needs for both USGS (for the National Water Use Information Program) and the State of Maryland (for water resource planning, management, and regulatory programs) by building the tools and capacity to support a national water use *science* program seamlessly spanning local to national scales.

The following section provides an overview and description of the current status of Maryland's Water use program. Section 3 describes the development of State priorities for improving water use information. The collaborative development of this draft workplan is briefly described in section 3.1. The advancement of geospatial water use data models is discussed in section 3.2, and the challenges and opportunities to improve water use estimation methods are considered in section 3.3. The section concludes with a tabular summary of priorities for 2017-2020, for the Maryland water use program. Steps initially proposed to advance those priorities are described in section 4. The content and development of the workplan drew upon considerable supporting information, some of which is found in the accompanying Appendices.

2. Description of the Maryland Water Supply Program

Title 5 of the Environment Article of the Annotated Code of Maryland gives MDE the responsibility for leading the development and management of Maryland's' Water Resources:

> "*The Department shall exercise to the fullest extent possible the State's responsibility for its water resources by planning and supervising multiple purpose development and conservation of the waters of the State for the State's best interests and benefit. The Department shall develop a general water resources program which contemplates proper conservation and development of the waters of the State, in a manner compatible with multiple purpose management on a watershed or aquifer basis, or any other appropriate geographical unit.*"

2.1 Maryland's Water Supply Program

Maryland's Water Supply Program (WSP) is a part of the Water Management Administration in the Maryland Department of the Environment (MDE). The mission of the WSP is to ensure that public drinking water systems provide safe and adequate water to all current and future users in Maryland, and that appropriate, planning, and conservation policies are implemented to ensure the maximum beneficial and sustainable use of the state's water resources. This mission is accomplished through proper planning for water withdrawal, protection of water sources that are used for public water supplies, oversight and enforcement of routine water quality monitoring at public water systems, regular on-site inspections of water systems, review of design plans to install or upgrade water treatment, and prompt response to water supply emergencies. In addition to ensuring that public drinking water systems meet federal and State requirements under the Public Water Supply System (PWSS) program, the WSP also administers the wellhead protection program, manages water resources, and issues Water Appropriation and Use Permits for both public and private water users, and commercial and agricultural entities statewide. Because all of these activities reside together in the WSP, Maryland has the unique opportunity to evaluate and regulate public drinking water systems from a broad perspective that includes an evaluation of the resource for both quantity and quality. WSP activities help to ensure safe drinking water for over five million Marylanders.

Public drinking water systems fall into three categories: community, non-transient non-community, and transient non-community. Community water systems (CWS) serve year-round residents, non-transient non-community water systems (NTNCWS) serve non-residents (e.g. school, business, etc.), and transient non-community water systems (TNCW) serve different consumers each day (e.g. campground, restaurant, etc.). During 2014, the number of public water systems remained consistent compared with previous years. In 2014, Maryland had 472 CWS, 535 NTNCWS, and 2,342 TNCWS.

MDE directly regulates community water systems (county and municipal systems, large and small communities, and mobile home parks) and non-transient non-community water systems (businesses, schools, and day care centers that have their own water supply system). Transient non-community water systems (e.g. gas stations, campgrounds, and restaurants that have their own water supply system) are regulated and enforced by the local county environmental health departments through State-County delegation agreements, with the exception of systems in Anne Arundel, Charles, Cecil, Montgomery, Prince George's, and Wicomico Counties, which are directly regulated and enforced by the WSP. Table 1 presents a summary of Maryland's 2014 statistics on public water systems and the populations served by each type of system.

Table 1. Maryland Drinking Water Statistics	
Population of Maryland (July 1, 2014 Census estimate)	5,976,407
Number of individuals served by community water systems	5,079,165
Percent of population served by public water systems	85
Percent of population served by individual wells	15
Number of Public Water Systems	3,349
Number of Community Systems	472
Number of Non-transient Non-community Systems	535
Number of Transient Non-community Systems	2,342
Number of Systems using surface water	59
Number of Systems using only ground water	3,290

2.2 Water Use Appropriation System

Beyond the Public Water Supply System (PWSS) program, all withdrawals of surface water or groundwater must be permitted by the state, with the exception of specific exempted uses. The application process and permit exemptions are summarized in Appendix 5, and described online at: http://www.mde.state.md.us/programs/Water/Water_Supply/Pages/Permitting.aspx. The permitted appropriation process is intended to assure that current and proposed water appropriations are consistent with the purposes and priorities of State and local zoning and development plans, and the inherent resource limitations of the States' water resources. Permittees with annual average water authorized withdrawals greater than 10,000 gpd are required to report monthly withdrawal amounts to the State. Some permittees using 10,000 gpd and less are also required to report water use. Agricultural water users report their monthly use in January for the previous year. Non-agricultural water users report twice yearly, once in January and again in July, for the monthly water use for the previous six-month period. The Water Supply Program mails the forms to the permittees. In calendar year 2015 approximately 1660 agricultural permittees were required to report water use, while approximately 1320 non-agricultural water users were required to report water use. Reported water use was obtained for ninety-five percent of the permittees required to report water for calendar year 2015. Similar and greater compliance levels were achieved in the past five years. The water use data for each permittee is entered into the Water Supply Program's Water Supply Information and Permitting System (WSIPS) data base. Paper records are retained for at least the previous decade. In electronic format the Water Supply Program has monthly water use for permittees extending back to 1979.   WSIPS reported values represent primary data that is also made available to USGS to support the National Water Use Information Program

2.3 Special Use Areas

Maryland has designated several types of Special Use Areas to ensure that regional concerns and special circumstances are inherently reflected in the management and appropriation process.

2.3.1 <u>Water Management Strategy Areas</u>

As of July 2014 MDE has identified five Water Management Strategy Areas (WMSA) where groundwater users are experiencing excessive drawdown, saltwater intrusion or both. Water appropriations in WMSA command additional tracking and oversight, marshalling efforts to limit aquifer withdrawals; redirect withdrawals to another aquifer; or require additional scrutiny such as enhanced water level monitoring to quantify and evaluate risks and impacts from permitted withdrawals. Table 2 summarizes the State's five WMSAs as of July 2014.

Figure 1 MDE Water Management Strategy Areas

TABLE 2 Water Management Strategy Areas

Area	County	Target Aquifer	Issue
1. Annapolis Neck	Anne Arundel	Aquia	Saltwater Intrusion
2. Indian Head	Charles and Prince Georges	Lower & Upper Patapsco	Excessive Drawdown & Saltwater Intrusion
3. Waldorf	Charles	Magothy	Excessive Drawdown
4. Kent Island	Queen Anne	Aquia	Saltwater Intrusion
5. St. Martin's River/Ocean Pines	Worcester	Columbia	Saltwater Intrusion

2.3.2   <u>Tier II watersheds</u>

The Federal Clean Water Act requires states to develop policies, guidance, and implementation procedures to protect and maintain existing high quality waters and prevent them from degrading to the minimum allowable water quality. Tier II waters have chemical or biological characteristics that are significantly better than the minimum water quality requirements. All Tier II designations in Maryland are based on having healthy biological communities of fish and aquatic insects.

Maryland has long had an antidegradation policy, and antidegradation implementation procedures were developed in 2004. The implementation procedures:

- explain how Tier II waters are identified
- identify when the policy applies
- outline the basic antidegradation review process
- explain what must be done if some degradation of a Tier II water is necessary for social and economic reasons

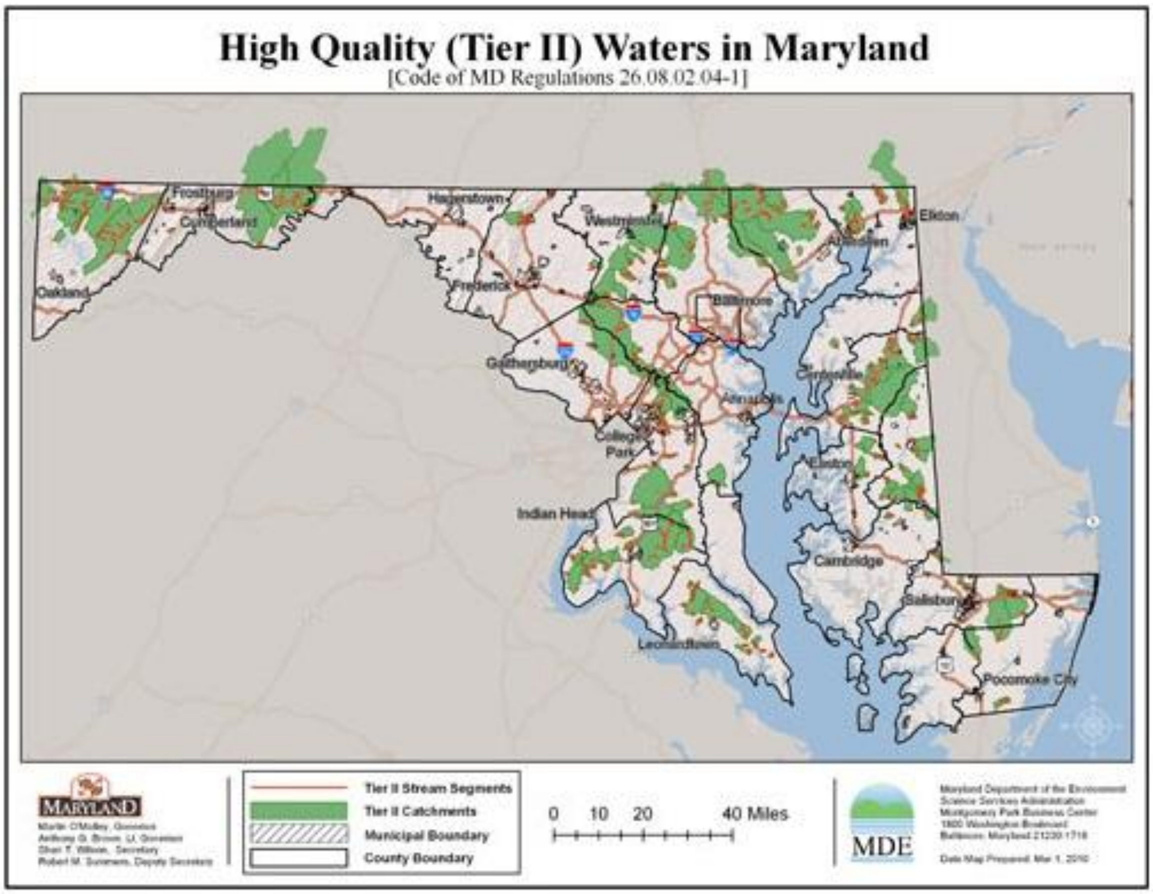

Figure 2 MDE Tier II Waters

Proposed development projects that could potentially impact high-quality waters may, depending on the specific circumstances, be required to satisfy tougher environmental standards in order to obtain state permits or other approvals (for example water and sewer plan amendments). There are currently 235 identified Tier II stream segments, with at least one in every county in Maryland except Baltimore City. The accompanying map shows the current extent and distribution of Tier II waters and catchments.

2.3.3 Areas of No Groundwater Use

MDE's Voluntary Cleanup Program encourages voluntary cleanup and redevelopment of contaminated properties. A description of the program can be found at http://www.mde.state.md.us/programs/Land/MarylandBrownfieldVCP/MDVCPInformation/Pages/programs/landprograms/errp_brownfields/vcp_info/index.aspx . A common outcome of the process is an agreement of the landowner to forego future groundwater use at the property. This decision is recorded in the land records of the County. The Department maintains a map of the properties that have participated in the Voluntary Cleanup Program.

2.3.4 Recharge Easement Areas

A recharge easement area can be required during an individual groundwater appropriation permit review if a particular property (or water service area when an applicant is a public water system) has insufficient recharge to balance the requested appropriation. There have been fewer than a dozen recharge easements agreed to across the State. Such easements are mapped by the Water Supply Program. When permits are reviewed for renewal there is a review to ensure that the easements will continue to be in effect for the duration of the new permit term.

2.4 Water Use Data Management

Maryland's Water use data is currently managed using a relational database system. The Water Supply Information and Permitting System (WSIPS) is a custom designed database management system. WSIPS was conceived as an enterprise database system to support the Maryland Water Supply Program's core workflows, enabling online submission and tracking of permit applications; analysis and approval of the permit applications by MDE staff, and subsequent monitoring of permittee compliance with specified permit conditions over the lifecycle of each permit.

WSIPS replaced the Linux-based Regulatory Analysis and Management System/Water Appropriation Network (RAMS/WAN). In design and scope, WSIPS was conceived to interface with the Public Drinking Water Information System (PDWIS) and its successors, the Safe Drinking Water Information System (SDWIS) which is used to track and report compliance with EPA water quality and Safe Drinking Water Act requirements for public water supply systems, and SDWIS Plus, which holds other information from PDWIS that cannot be stored in

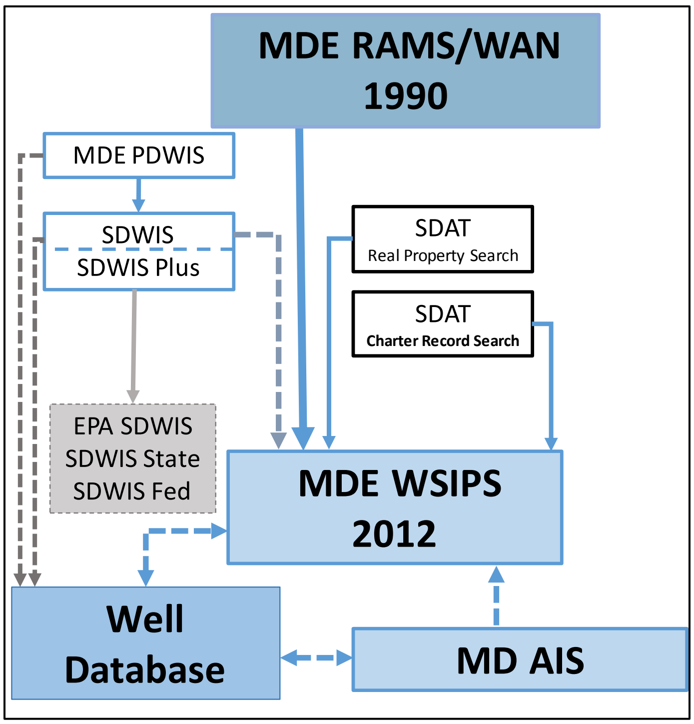

Figure 3Maryland water use data management systems

SDWIS. WSIPS was also developed to provide Map View access to both internal MDE GIS data as well as external data bases. WSIPS provides access to the State Department of Assessment and Taxation (SDAT) Real Property and Charter Record search functions to verify the identity and status of individuals or businesses applying for a permit. WSIPS also provides Map View access to the geospatial data in the Aquifer Information System (AIS) jointly developed by MDE, USGS, and the Maryland Geological Survey.

2.4.1 Related Data Bases

The State also exercises stewardship for a **Maryland well database**, drawn from the historical well completion reports dating back to the 1940's. This database is actually a table in PDWIS and in SDWIS Plus, but is often distributed as a standalone MS Access database and is important enough to consider separately. The well database contains well permit applications and well construction information for individual wells. The lithological record recorded by the well driller – most typically in hand-written notes, is not recorded in digital format, so the well log and regional stratigraphy cannot be directly recovered or reconstructed from these data. However, location, depth, and well yield data provide key information from which the likely aquifer providing supply may be deduced. **Well Completion Records** are the foundation of Maryland's well database, and are either the actual paper well completion reports that are entered into the Maryland well database, or preserved images of those original reports. In addition to the information entered into the Maryland well database, these reports contain the lithologic log prepared by the driller.

Monthly Operating Reports (MOR) are also submitted by community public drinking water systems (CWS) and non-community non-transient public drinking water systems (NCNT), provided those systems provide treatment of the water. This is done as part of the State's oversight and assurance of proper water treatment system operations. MORs report treatment plant operating characteristics to verify proper filter operations, disinfection effectiveness etc. MORs also contain daily production data that provide valuable information capturing daily, seasonal, peak, and interannual patterns of water use. WSIPS is not currently configured with data fields for daily data entry. For this reason, most of this daily MOR water use data is not electronically available for tracking, analysis, estimation, or compliance evaluation.

Capacity Management Plans are required from community water systems operating over 20,000 gpd if they are operating at greater than 80% of their permitted capacity, or more than 80%with a daily average annual withdrawal greater than 20,000 gpd, though all systems with greater than 20,000 gpd average demand are encouraged to complete such a plan. CMPs report the estimated population served for each system, calculate the current and planned demand on the system, estimate the system capacity under various conditions, and determine what additional growth, if any can be sustained by the water system. Detailed instructions on completing a plan are available online at:
http://www.mde.state.md.us/programs/Water/Water_Supply/Pages/CapacityManagement.aspx

Water Resource Element Plans must be completed by local governments as part of their comprehensive plans. This element assesses current and future demands and identifies adequate sources for water supply and capacity for stormwater and wastewater treatment and disposal.

Guidance documents for completing these plans are available from the Maryland Department of Planning.

3. Maryland Water Use Priorities

3.1. Collaborative Stakeholder Input Informed Workplan development

The collaborative development of Maryland's 2017-2020 Water Use Workplan was informed by an assessment of needs and priorities within MDE and among the State's water use stakeholders. This collaborative effort and outreach helped identify additional needs and priorities to support both management and regulatory interests in water use information. A number of stakeholder interests were clearly associated with specific sectoral water use, such as interests in thermal electric water use by the Maryland Power Plant Research Program. Other stakeholders such as the Maryland Department of Planning reflected the cross-sectoral importance of water use and availability, as it affects the State's overall economy and future growth. Stakeholders engaged in the development of the workplan included representatives from:

- USGS Maryland-Delaware-DC Water Science Center
- Maryland Department of the Environment
- Maryland Geological Survey
- Maryland Department of Agriculture
- Maryland Department of Planning
- Maryland Power Plant Research Program
- Maryland DNR
- Baltimore City DPW
- Delaware DEP State Irrigation Extension Specialist
- NJ DEP
- ICPRB staff

Significant concerns were identified that influenced the development of Maryland's water use priorities, and are briefly described here.

Agricultural Irrigation – The quality and reliability of monthly irrigation reporting data is uncertain, due to the use of indirect units (e.g. pumping hours) and specific knowledge of the crops being grown on the farm for the year in question. USGS reported very similar variability in irrigation records they examined, leading them to discard similar data from their analysis (Levin and Zarriello 2013). Reported data may not always be sufficient to gauge compliance. Metering of agricultural irrigation is not required by Maryland, and meters introduce their own idiosyncratic problems with systematic underestimation and overestimation reported as the impellor can be driven by positive and negative pressure surges as systems drain down, and well levels recover. Despite these constraints the need for some additional data or independent information that could serve as a screening level reasonableness check was identified, as a first step in developing tailored, albeit heuristic, QA/QC indicators for reported values.

Regional or local crop models can provide a normative estimate of irrigation needs, but skillful irrigation prediction using crop-models requires additional fine scale site-specific data.

Nevertheless crop models can usefully capture larger meteorological trends and interannual variation, recognizing the confounding effects of planting dates, crop choices, and double cropping (Levin and Zarriello 2013). Compared to western irrigation, meteorological variation is a significant source of variability and uncertainty in Maryland irrigation use, confounding reported values. Even an initial analysis to identify the best consistency checks comparing, e.g., simple crop models, site-specific meteorological data, and weekly (Delmarva) irrigation recommendations from Delaware Extension would significantly improve our understanding of Maryland irrigation water use.

New residential use – Residential water use patterns are changing (Willis, Stewart et al. 2013, Fidar, Memon et al. 2016), affecting short-term appropriation demands and the cumulative long-term demands on the State resources. Current planning efforts continue to assume 80 gpcd for self-supplied domestic use, and 100 gpcd for predicting total water use for municipal community water systems as default planning values, despite abundant evidence that demographics and the diffusion of water efficient fixtures are changing the pattern and intensity of indoor water use (Fidar, Memon et al. 2010, Tsai, Cohen et al. 2011, Willis, Stewart et al. 2013). Significant interests in improved understanding of residential water use patterns is reflected in the draft workplan.

Along with the broad interest in understanding residential water use, the particular interest in better estimating ***<u>domestic self-supplied</u>*** water use (water use from individual wells that are not required to report any water use data) was a common concern for both MDE and USGS. The default assumption of 80 gpcd used by both USGS and MDE has been unchanged (and untested) for at least two decades. Water managers expressed a strong sense that this value has likely changed, as well as the low likelihood that domestic self-supplied water use would be invariant from Garrett to Wicomico County. Improving domestic-self supplied estimates supports USGS Tier 2 baseline criteria as well as State planning and management activities. Moreover, this estimate has started to become “self-fulfilling” as recent USGS efforts to estimate domestic self-supplied water use from the Piedmont & Blue Ridge, and North Atlantic Coastal Plain aquifer systems derived gross regional estimates for Maryland, based on previously reported estimated values, recapitulating this constant per capita use for both aquifer systems (Maupin and Arnold 2010).

<u>Cumulative aquifer withdrawals from domestic-self-supplied wells</u>

Along with the pragmatic interest in better estimates of currently unreported domestic self-supplied water use, the extent to which unreported domestic self-supplied water use may represent a significant cumulative stress to critical aquifer systems has been a growing concern. The Maryland well completion records could be mined to match known wells with the aquifer they exploit to support the estimation of these cumulative withdrawals. For many wells – especially older wells, the well completion reports provide only approximate location information, and the lithological information recorded manually by the driller has not been transformed into a digital (searchable) format or database. Manual evaluation of well completion records combined with local hydrogeologic knowledge and the review of nearby well records can usually deduce the likely source of supply, but this is a time consuming process for which no resources have been explicitly provided. An initiative to streamline the development of reliable information on the distribution of wells in the State’s aquifer systems and, ultimately, the cumulative unreported withdrawals – particularly, e.g. from the Coastal Plain aquifer systems – supports USGS Tier 1 baseline standards for domestic self-supplied water use, and was identified as a priority for the State.

Beyond these targeted interests in improved water use estimates, priorities for improvements to Maryland's ***water use data management*** were clearly identified. Despite the proliferation of data management systems summarized in section 2, there remains a significant an ongoing need to upgrade and maintain the capability of Maryland's water use management systems. For example, permitted water use and monthly reported water use is effectively managed, but WSIPS was not designed with any data structures to handle daily data, making any analysis of the variability or peaking patterns of water use a challenging non-standard data compilation task. As well, a number of limitations in the current functionality of WSIPS limit MDE's ability to provide usage data by basin, location, use or source stream or aquifer; distinguish fresh, salt or brackish water appropriations; manage usage reports by well or well field, or track interbasin transfers of water that would significantly enhance the use of this data by the National Water Use Information Program.

In addition to programmatic priorities and workflow improvements, the workplan identified the opportunity to migrate the State's water use data management system to an explicit ***water use data model*** built around a withdrawal-conveyance-use-discharge structure. Such a structure logically and hydrologically links permitted withdrawal locations to the spatially distributed patterns of water use and ultimately, discharge. Such a hydrologic characterization of water use reflects the role of water use as the anthropogenic flux in the hydrologic system identified by the National Research Council (NRC 2002). Linking water use data with the natural and infrastructure water use systems provides an integrated conceptual framework to address a rich set of pressing management questions regarding the sustainability of current and projected water use – both in the State of Maryland and for the nation (Roy, Chen et al. 2012, Chen, Roy et al. 2013, Wang, Small et al. 2014, Perrone, Hornberger et al. 2015, Wang, Small et al. 2015).

The workplan priority for a *water use data model* was informed by two examples of water use data management systems developed around a data model with an inherent withdrawal-conveyance structure – not unlike USGS's internal Site-Specific water use data system.

3.2. Water Use Data Model

Consistent with the recommendation of the National Research Council's Review of the USGS Water Use program (NRC 2002) workplan development investigated the database management systems for water use data, considering in particular, the merits of developing a geospatial data model for water use. The current and legacy systems used for managing Maryland water use data were described in section 2.4 and are represented conceptually in Figure 1.

Workplan development was informed by several systems used regionally in northeast states. The New England Water Use Data System (NEWUDS) is an access database built around a data model specifically designed to organize and structure water use information. The system development was led by USGS and the NEWUDS data model is carefully documented in USGS Open File report 01-359 (Tessler 2001). A core feature of the water use data model in NEWUDS is the inherent structure of water withdrawal-conveyance-use-discharge relationships embodied in the relational database. The conceptual data model linking point withdrawals to conveyance and use is also a core feature of the USGS Site Specific Water Use Database systems (SWUDS) although these features are generally not fully populated in most State SWUDS implementations (personal communication with USGS 23 June 2016). The inherent structure and logical relationships that link withdrawal points to conveyance, use, and discharge, highlight the structure that can be integrated into a water use data model. This logical structure reflects the broad range of common interdisciplinary questions various users of water use information are likely to have, and stands in sharp contrast to a relational database in which each permitted withdrawal point is an independent record for census or accounting purposes.

The consistent logical structure to place water withdrawals in the context of spatiotemporal water use empowers the integration of water use in the hydrologic system. Indeed, the NRC recommended USGS consider managing water use data in a geospatial context that would enable seamless coupling of the so-called natural water use system (of streams springs, rivers and lakes) and the infrastructure water use systems (of withdrawals pipes pumps and discharges). A water use data model can provide the geospatial structure to link water use to the natural and infrastructure water use systems as the anthropogenic flux in the hydrologic cycle. Such a logical integrated data management framework empowers the unified management of water resources spanning resource assessments and sustainability analyses, to risk assessment for droughts, spills, and both natural and human caused extreme events.

NJWaTr Water *Resource Management* Data Model –
Investigation of water use data models for Maryland also led us to the New Jersey Withdrawal and Transfer data management system (NJWaTr) used by NJ DEP. NJWaTr is a relational database developed specifically to support regional water resource management (not permitting, compliance, and enforcement) in the State of New Jersey. NJWaTr was developed from the NEWUDS data model, customized and simplified to the dominant water management issues and needs in NJ (Tessler 2003). In contrast to the NEWUDS data model, NJWaTr is strongly oriented to water use and conveyance by HUC, with data associated at the finest scale with uniquely developed NJ 14-digit HUCs. From the smallest HUC-level data, NJWaTr aggregates water use to 20 water use management areas used by NJ DEP to evaluate and manage sustainable use and appropriations. (http://www.nj.gov/dep/njgs/enviroed/HUC11.htm#image). NJWaTr provides another withdrawal-conveyance-use data model, that can enhance the value of water use information by standardizing the representation of water use within the hydrologic system.

Data Management
A water use data model that places water use in the hydrologic cycle offers more than simply intellectual appeal. One of the advantages of developing a data model for water use is the flexibility it provides to dynamically define and integrate logical relationships among existing data management systems. For example, although NEWUDS and NJWaTr were both implemented and developed in Microsoft Access, ArcGIS can readily ingest Access database information. Compared to Maryland's development path from RAMS/WAN to WSIPS with PDWIS and SDWIS connections, a core logical data model for water use can persist across platforms and software upgrades, maintaining logical linkages between existing datasets.

Although considerable development testing and QA/QC would be required to integrate the existing water management systems into a water use data model, these relationships only need be defined logically and can be populated from existing data management systems without interruption. Such a task would require a significant resource commitment in development but represents a rich aspirational goal for near-term and long-term objectives. To evaluate the complexities and benefits more realistically, a demonstration or proof-of-concept example could be developed for a relatively small portion of Maryland, chosen to embody the inherent complexity in defining water use connectivity (e.g. double counting, continuity, etc.). In considering this priority, we note the common independent development of water use data models in other states, motivating the exploration of interest in a joint effort to develop a common water use data model among neighboring states and the larger water use community.

<u>3.3 Improved Water Use Estimation Methods</u>

Improved methods for estimating water use were identified as priorities in several contexts. The common desire to improve the accuracy of estimated water use is a natural shared interest for both MDE and USGS. Improved methods for estimating water use are of obvious interest for water using subsectors for which no reported data are available, such as <u>*domestic self-supplied*</u> wells. Beyond the uncertainty in this water use sector, particular interest in understanding cumulative water use from individual (non-reporting) wells is also of considerable interest to understand the stresses and future sustainability of sensitive aquifer systems – particularly in the Coastal Plain aquifer systems.

In other sectors in which permitted withdrawals are large enough to require reporting, considerable uncertainty may accompany those reported values. This is particularly true in <u>*irrigated agriculture*</u>, where reporting requirement options intended to ease the regulatory burden on agricultural producers result in water use based on a range of indirect units such as hours of pumping or hours of center pivot irrigation operations times a pumping rate, rather than use of a flow meter. Others report inches of water applied each month over a number of acres.

For MDE, reported irrigation water use is also the primary data used for compliance monitoring and enforcement. The uncertain quality of the data poses separate challenges for regulatory enforcement and compliance. Moreover, MDE has keen interests in peak day and maximum day irrigation water withdrawal values for which no reliable independent data are consistently available. For these reasons improved estimates of irrigation water use are of interest to MDE – even as an independent basis for anomaly detection in reported values.

Maryland similarly has considerable interest in improved methods for estimating water use as part of the permit evaluation process for new development. A rich literature on <u>*residential water using behaviors*</u> and changing patterns of domestic water use supports planning and management by municipal water supply utilities. In 2016 the Water Research Foundation (WRF) released a comprehensive study of domestic water use in 23 cities around the Unites States and Canada. In each city 1,000 homes were carefully instrumented to measure water use by fixture (showerheads, washing machines, etc.) to characterize the characteristics of modern residential water use, and the variation among residential water users associated with the diffusion of water efficient fixtures. The WRF report provided an extremely detailed insight into the pattern and variability of modern domestic water use, as well as the conservation effectiveness of water efficient fixtures, the potential for further efficiency gains in 21st century domestic water use, and drought and emergency planning.

One of the important findings of the WRF study is the significant effect of water efficient fixtures on domestic water use, and the change in "typical" (e.g. per capita) water use in domestic residential water use compared to historical per capita assumptions. Using these data provides a bottoms-up approach to develop revised per capita water use estimates for both new construction as well as the continuing efficiency gains to be expected as low flow fixtures continue to diffuse into the residential water use sector as older homes undergo updating and renovation. Combined with estimated outdoor water use (e.g. for lawn irrigation) these data provide a transparent method to estimate new domestic water use. For example, Runfola et al. (2013) found that lawn area, number of bathrooms, and living unit density were sufficient to explain 90% of the variance in individual home water use in Ipswich Massachusetts.

The extensive literature on water use estimation spanning process models, statistical models, and econometric approaches, provides a suite of improved methods for estimating, and validating reported water use data, and predicting future water use in Maryland. Similar methods have been uniformly developed to help populate sector-specific water use estimates in the National Water Use Program (Lovelace 2009, Diehl, Harris et al. 2013, Levin and Zarriello 2013)

Beyond statistical and process based approaches *life cycle assessment methods* have been used to track the material flows of commodities associated with the economic activity between economic sectors. Life Cycle Assessment (LCA) commonly builds on standard economic input-output tables to estimate the direct and indirect material flows underlying each dollar of economic activity. Intuitively we expect increased economic activity in water intensive industries to be associated with increase water use. LCA formalizes this analysis, by extending economic input-output (I/O) analysis to material flow analysis.

In summary, collaborative exploration of needs and opportunities led to the identification of priorities for improving and advancing the Maryland Water Use Program. From a programmatic perspective staff from the MDE Water Management Administration prioritized these activities as follows:

<u>High Priority</u>:

- Irrigation (reasonable checks and validation).
- Data Systems Management & Upgrades.
- Automate Data QA/QC.

<u>Medium Priority</u>:

- Improve household estimation.
- Improve Domestic Self Supply Values.
- Evaluate Domestic Self Supply Cumulative Aquifers withdrawals.

<u>Low Priority</u>:

- Water Use Data Model Proof-of-concept.
- Design & Develop Prototype Water Use Data Model (WUDM).

The following section describes proposed steps to advance each of these priorities.

Priority	Proposed Approach
Improved household estimation • Update "bottoms up" – indoor water use • Estimate separable outdoor water use	• Analyze small CWS daily MOR production data • Stratify on socioeconomic, regional and hydrogeologic attributes • Compare bottom-up residential use from WRF 2016 23-city study
Improved Domestic Self Supply Values • improved per capita, modified by aquifer yield • Stratify by socioeconomic indicators	• Reevaluate structure and variability in per capita water use from small CWS. • Identify "natural" (regional, economic) clusters of homogenous household water use behavior • Revise DSS per capita by region, socioeconomics, aquifer etc.
Irrigation (reasonable checks and validation) • Estimation methods – crop need models • Compare to DE real-time guidance • Peak, seasonal disaggregation	• Analyze validation alternatives for reported irrigation (e.g. crop needs model, DE irrigation recommendations • Compare to Ag. Census and FRIS estimates
Evaluate Domestic Self Supply Cumulative Aquifer withdrawals • Well location and aquifer assignment • Tiered hierarchical analysis	• Automate DSS aquifer assignment (Model Builder) from AIS and Well Database • Stratify confidence by estimated error. • Verify random samples within each error strata and iteratively revise assignment rules to target manual well-log verification efforts
Data Systems Management & Upgrades • Clean up tasks • Provide support additional data storage and management • Online permittee submittals?? How to ensure chain of custody w/o paper record	• Added canned reports for pumpage by stream, aquifer, use, use category, basin and range of grid locations • Add support for pumpage by day and by well or well field • Deploy capacity for direct user entry of pumpage • Fix current deficiencies in entry of use percentages and fresh and salt water determination.
Automate Data QA/QC	• Screen and test "reasonableness" checks by sector (e.g. weather sensitivity of irrigation) and between years • Checks with permit applications, economic activity, etc.
Design & Develop Prototype Water Use Data Model (WUDM).	• Design Maryland WUDM (after NEWUD, NJWaTr) • Prototype WUDM by logical joins of feature class tables. Join by permit number, other?
Water Use Data Model Proof-of-concept • Link WSIPS, Wells, AIS to withdrawal-conveyance-use-discharge data model	• Proof of concept demonstration of WUDM for regional assessment of water availability • Demo candidates should test basin & jurisdictional transfers; close water balance. Perhaps at scale of WRE.

4. Proposed Approaches to Advance Maryland Priorities to Improve Water Use Data

The steps to advance the water use priorities identified in section 3 are described here in greater detail.

1. <u>Improved household estimation</u>
Household water use estimates drive fundamental planning for future growth and development as well as regulatory permit and allocation decisions by MDE. Water use patterns therefore play a central role in the development of municipal and county Water Resource Element Plans (WRE) that are intended to demonstrate adequate water and sewer capacity to sustain planned growth. Household water use also provides a reasonableness check for public water supply estimates reported to MDE that are disaggregated by county and used by USGS in the NWUIP. Water suppliers have driven abundant research on patterns and behaviors in municipal water use to help understand long-term planning, resource needs, infrastructure development, and drought planning and response. (Agthe and Billings 1980, Gallagher, Boland et al. 1981, Boland 1983, Aitken, Mcmahon et al. 1994, Worthington and Hoffman 2008, Arbues, Villanua et al. 2010).

   MDE proposes to improve the estimation of household water use in Maryland, by mining the daily water use information from groundwater-supplied small community water systems that are reported in Monthly Operating Reports (MOR) to the State. These data will be analyzed in a stratified sampling frame to test and evaluate the significant regional and socioeconomic factors that affect household water use patterns. For each CWS, basic information on lot size, house size, and assessed home value, are readily available from the MD Property View and SDAT databases. Data from census block data, CWS Capacity Management plans, and the SDWIS system provide estimates of the population served to support per capita use estimates. A similar analysis performed by NJ DEP found that per capita water use rates were significantly lower in households withdrawing from aquifers with low well yields, implying that adaptive water using behaviors were self-limiting in water stressed areas. We will similarly evaluate whether aquifer yield has a predictable effect on water use, accounting for other demographic and socioeconomic differences between communities.

   The analysis will be structured to sample “representative” variation across small CWS water use, and describe the pattern and variation in water use across regional, climatic, socioeconomic and demographic determinants. We expect this analysis to identify homogenous clusters of similar water using behavior that can be characterized by a well-defined set of household water use “types”. In this way, the current default per capita use rate applied to residential water users may be replaced by distinct water use rates for different regions, incomes, house size, climate, etc.

   This analysis will provide timely new information on household water use to evaluate changes in water using behaviors and the effect of water conserving fixtures on indoor water use. This analysis also informs projections of future water use and the adequacy of supply in the State’s growth areas. The small CWS data analysis will be compared to a “bottom-up” approach for estimating water use (Makki, Stewart et al. 2015) to test specifically how the most recent national data on indoor residential water use synthesized by DeOreo et al. (2016) are manifested in Maryland. Finally, the analysis of daily small CWS groundwater use offers an initial estimate for current per capita water use by domestic self-supplied water users, for which no reported or metered data are available.

2. Improved Domestic Self-Supplied (DSS) Values
   Water use by about 15% of Maryland's population is estimated to be self-supplied from individual wells that are not required to report their water use. Both USGS and MDE use a default value of 80 gpcd to estimate domestic self-supplied water use. – a default value that has remained unchanged for over two decades. To validate and update estimated DSS water use, we will build on the analysis of small CWS MOR data described above, to estimate current representative per capita ground water use estimates for households in different regions or climate divisions within the state, stratified by geology and aquifer, as well as demographic and socioeconomic data (such as house and parcel size). The subset of CWS used to estimate per capita water use will be carefully selected and screened with local managers to best represent the "typical" DSS water user in each stratum. These values will be validated by comparing predicted per capita water use to per capita water use estimated from small CWS that were not used in deriving the estimates, in order to bound the uncertainty in the improved water use estimates and test differences from the current 80 gpcd default rate.

3. Irrigation (reasonable checks and validation)
   Irrigation water use is regionally significant (and can be locally dominant) in Maryland. As a water use category, irrigation represents the largest number of large appropriation permits in the state. Irrigators are not required to report irrigated acreage and crop information, limiting MDE's ability to independently evaluate reported use or perform consistency checks based on crop models. Indeed, Levin and Zarriello (2013) investigated methods to estimate irrigation water use in the humid east and found insufficient data to employ their methods for Maryland. In contrast, Delaware has a robust irrigation research and extension program on the Delmarva peninsula, including the provision of weekly irrigation targets as recommendations for producers using real-time online meteorological data from the online Delaware Environmental Observation System (DEOS http://www.deos.udel.edu/).

   Historically, MDE's reported irrigation data has differed significantly from MD irrigation water use estimated by the NWUIP, which are derived from the USDA Census of Agriculture and the USDA Farm and Ranch Irrigation Survey. For this reason, and for consistency with National irrigation estimates from other states, the USGS irrigation estimates for MD have relied on NWUIP estimates rather than MD Data. To improve regulatory, resource management, and inventory goals, the priority for improving irrigation water use estimation will analyze independent estimates of irrigation water use and evaluate their effectiveness as first-order checks of the "reasonableness" of reported irrigation data. These estimates will include relatively simple crop models that compare typical crop needs with local meteorological conditions, as well as the cumulative irrigation recommendations produced by the University of Delaware each summer. The analysis will also provide consistent automated QA/QC of reported irrigation data, flagging anomalies such as constant reported values from month to month, or duplicate monthly values from year to year. A range of similar reporting anomalies have been described by Levin and Zarriello (2013) [4][4]. For the subset of reported values with acceptable quality, reported values will be compared to site-specific irrigation estimates based on soil, weather and crop needs, as well as the irrigation reported in FRIS and NWUIP estimates. We anticipate that, like Levin and Zarriello (2013), these simpler aggregate estimates will not be a more accurate substitute for currently reported data. However, we expect this analysis to provide a much richer understanding of the sectors and regions in which reported irrigation data can be used with high confidence, and those for which improved irrigation water use estimates will require additional data, such as supplemental reporting requirements, new innovative information (such as remote sensing data) and farm-level outreach through local extension and NRCS specialists. This proposed work is envisioned as the first step in a long-term adaptive management approach to guide continued development of more effective and reliably tools, methods, and collaborations to improve the understanding and management of Maryland's irrigation water use.

4. <u>Evaluate Domestic Self Supply Cumulative Aquifer Withdrawals</u>
   DSS groundwater withdrawals are individually small yet in some counties or regions of the State are significant stresses on the aquifer systems they exploit. (Drummond 2007). Estimating the cumulative DSS stress to an aquifer system requires the application of an estimated DSS water use rate (whether the current or revised estimates proposed above) to the set of wells drafting each aquifer. In principal, these data could be assembled from well completion records that report the location depth and production rate for each well. In practice the reliability of this information is highly variable due to uncertainty in the location of each well, and the aquifer from which groundwater is pumped.

   To improve our understanding of the distribution of wells in each of Maryland's aquifers, MDE proposes to develop a screening-assignment analysis that will iteratively assign well records to the likely aquifer source of supply. Using location and screen depth information in the Maryland Wells Database, local knowledge of aquifer stratigraphy should allow each well to be assigned to its underlying aquifer by matching the depth of the well screens, to the aquifer depth, accounting for local land surface elevation. In practice, many well locations are only approximately known, with many older well records only reporting the quadrangle sheet within which the well is found. Combined with uncertainty about the actual surface elevation of the well, as well as local variation in aquifer depth, the well screen depth below the surface (difference between surface elevation and reported well depth) may have considerable uncertainty, requiring additional data and information to reliably identify the supplying aquifer. More detailed manual evaluation of the well logs recorded in well completion reports (but not digitized) combined with a careful comparison from other local high quality well logs can significantly reduce or eliminate uncertainty enabling a confident aquifer assignment for each well. This manual process is, however quite laborious and time-consuming, and no initiative has currently allocated funds for the consistent systematic linkage of historical well data to specific aquifer systems for the 320,000 records in the Wells Database.

To overcome this challenge, MDE proposes an approach to iteratively automate the screening and assignment of wells to aquifers, starting with the information consistently available in the Wells Database. Well depth, location and the current description of site-specific lithology will be used to characterize the degree of confidence and uncertainty in an aquifer assignment of each well. Based on the uncertainty (or error/agreement between well depth and local aquifer depth) the well completion records will be stratified by the level of confidence with which a unique aquifer assignment may be made. Within each tier or stratum of estimation error, a random sample of well records will be inspected to assess the accuracy of the aquifer assignment (e.g. by confirming the coincidence of screen and aquifer depth, and validating the well yield for the identified aquifer), or identifying additional sorting rules and information that could be used to further resolve the aquifer identity (e.g. comparison to nearby wells and well depths with known aquifer assignments).

We expect a substantial fraction of well-aquifer assignments (e.g. in areas of low relief, or areas with well-established reliance on a dominant aquifer) will be readily and reliably resolved with the simple analysis of basic topographic, well-depth, and aquifer information, that can be automated in an ArcGIS Model Builder script. Beyond this first Tier of well-assignments, we expect the more problematic initial well-aquifer assignments will sort into several different tiers or error types. For example, wells with uncertain locational information in high relief areas may have a mismatch between local well depth and aquifer depth information due to uncertainty in the actual surface elevation of the well. This uncertainty could be evaluated by comparing the local relief to the local range of aquifer depths in order to narrow the candidate aquifer assignments. Similarly, local variation in aquifer depth may not be fully captured in current understanding of regional stratigraphy, but might be well known to local well drillers. Variation of this type might be easily resolved by comparing the well depth to other local wells with known aquifer assignment. The distribution of well-depth aquifer-depth consistency or uncertainty will be used to identify the clusters of well-aquifer uncertainty, and develop further heuristic rules and screening methods to resolve well-aquifer assignments. In this way we will iteratively build aquifer assignments along with estimates of the reliability of those assignments for the Wells Database.

In any ranking and sorting of well-aquifer assignments, the most uncertain tier will contain wells with high locational uncertainty, in areas with multiple productive strata at similar depths. For these most uncertain well assignments manual investigation of the well logs and careful analysis of local stratigraphy and nearby producing wells will be required. While this inevitable investigation remains a time-consuming task, the overarching goal of the stratified screening approach proposed here is to target the manual efforts of experienced knowledgeable technicians to the well-aquifer assignments that are most difficult to resolve by any other means.

Within each error class, a random selection of well assignments will be manually validated to quantify the error rate, and determine if additional screening and review resources need to be targeted to those wells.

Overall this effort is expected to result in nearly complete well-aquifer assignments for the wells in the Wells Database, at least for wells completed since 1969, along with quantitative estimates on the reliability and estimated potential error rate of these assignments. Once completed that information will enable geospatial queries on the wells database by hydrogeologic unit, enabling a compilation of the DSS wells exploiting each aquifer system and a cumulative estimate of the current and projected stresses on critical aquifers from planned, currently unreported water withdrawals.

5. <u>Data System Management & Upgrades</u>
   MDE has identified a number of upgrades and maintenance issues for their current water management system that they feel would enhance the availability, quality and accuracy of data supplied to USGS. For example, it currently requires the user to use ODBC links to the underlying tables in WSIPS to retrieve pumpage reports from more than one permit at a time. If canned reports were developed to allow retrieval of pumpage records by use, source stream or aquifer, basin or range of grid locations, this would make the data more easily accessible for USGS analysis. Adding structures to support pumpage by well or well field would make ground water modeling more feasible. Adding structures that support daily pumpage for some permits would allow for better determination of the effects of pumpage on stream flow. Providing for data entry directly from the permittee would eliminate some errors and would provide better clarity in ensuring that the correct units (gallons, thousands of gallons, gpd) are being reported. These could be achieved by developing precise descriptions of what is needed and having a qualified contractor add this functionality to WSIPS.

6. <u>Automate Data QA/QC</u>
   MDE is aware of a variety of data anomalies that can and have entered the Water Use System. Many of these anomalies are recognized by experienced reviewers as they are encountered in permit applications and renewals. Yet many the system workflows remain prone to errors in data entry or reporting for which flags and consistency checks could be automated. Automating QA/QC and consistency checks would raise the floor for the quality and reliability of Maryland's water use data, and suggest robust and extensive QA/QC checks that can be integrated as part of routine system maintenance and enhancement. To implement this process, MDE proposes to begin the development of a QA/QC automation cycle to capture record, test and evaluate simple data checks and flags in the State permit database. These will be initially evaluated and implemented for test data sets and illustrated for WRA staff to determine the action and resolution (e.g. manual correction with dated identification of editor; compilation of anomalies to be manually evaluated or returned to permittee for verification; etc.) Initial QA/QC automation will also usefully quantify the frequency and type of the most commonly occurring anomalies to help revise and refine the ongoing QA/QC process. The potential effects on water use estimates by system, county etc. will also be evaluated to quantify the potential improvement in accuracy to be realized from updating and automating this data management task. Finding potential problems as near as possible to the time the data is initially reported makes it more likely that the data can be verified and, if needed, corrected. Checks of the year to year and month to month consistency of the data would flag sudden changes and implausible invariance in reported values.

7. Design and Develop Prototype Water Use Data Model (WUDM)
   To advance the development of a Water Use Data Model, MDE proposes to convene a working group of knowledgeable data model practitioners. This will include State and USGS professional staff who developed AIS, and USGS personnel who worked on NEWUDS and NJWaTr. Expertise will also be sought from other State water program staff who have worked on similar systems for their states, as well as Academic experts who developed ArcHYDRO and the ArcHYDRO Groundwater model. Part of this activity may include the organization of a small conference or workshop on Water Use Data Models in order to engage the larger State and USGS communities with the shared common interest in advancing a robust withdrawal-conveyance-discharge schema for water use data. Outcomes from this activity would be an initial blueprint for requirements and data structures, feature classes to enable a seamless linkage between water use data models and the natural and infrastructure water systems. With the benefit of these core criteria and principles, a water use data model spanning the existing water data management systems will be defined. The goal for this prototype system is to build on the relational databases already in place (e.g. WSIPS, AIS) to provide the logical definitional elements and feature classes that provide basic functionality for water use data management and water sustainability analysis.
   The initial design of this prototype hybrid data model will be vetted and reviewed by participants in the system requirements scoping workshop, as the first cycle of a continuous improvement process. We envision this community of water use data modelers contributing to the development of a community data model for water use, developed to serve the joint interests of State water management programs and the NWUIP, designed and developed to seamlessly complement the ArcHYDRO and ArcHYDRO Groundwater data models.

8. WUDM Proof of Concept
   The linkage and integration of a formal WUDM advances the integrated analysis of water use within the hydrologic system. As a consequence, it naturally advances USGS goals to place water use in the context of HUC-8 watersheds. Moreover, as the anthropogenic flux in the hydrologic cycle, a WUDM linked to hydrologic and infrastructure systems embodies consumptive use and return flow estimates – which were not included in recent USGS water census data collection.

   To demonstrate these advantages as well as the broader capabilities of an integrated WUDM, MDE proposes to develop a proof-of-concept WUDM demonstration, for a small region or system in the State of Maryland. The WUDM proof-of-concept demonstration might be selected from area known to MDE to have “manageable complexity”. By manageable complexity we suggest a system in which the overall number of withdrawals, conveyances, uses and discharge is well understood, yet the complexity of those uses (e.g. seasonality, peaking, irregular patterns of use, interbasin and interjurisdictional transfers, significant losses or consumptive uses, etc.) is understood and sufficient to test the logical consistency and continuity of logical relational data schema. The proof-of-concept system might be selected to correspond to geographic or municipal boundaries for a CWS, in which the system’s Capacity Management Plan and Water Resource Element Plan could be evaluated within the data management system (analogous to the HUC-11 water resource reports produced by NJWaTr – see Appendix 3).

Acronyms and Abbreviations

AIS – Aquifer Information System
CMP – Capacity Management Plan
CWS – Community Water System
DEOS – Delaware Environmental Observation System
DSS – Domestic Self Supplied
EIOLCA – Economic Input-Output Life Cycle Assessment modeling
FRIS – Farm and Ranch Irrigation Survey
gpd – gallons per day
gpcd – gallons per capita per day
LCA – Life Cycle Assessment
MCPAIS – Maryland Coastal Plain Aquifer Information System
MDE – Maryland Department of the Environment
MOR – Monthly Operating Report
NEWUD – New England Water Use Data Model
NJWaTr – New Jersey Withdrawal and Transfer data management system
NTNCWS – Non-Transient Non-Community Water Supply
NRC – National Research Council
NWUIP – National Water Use Information Program
NWIS – National Water Information System
ODBC – Open Database Connectivity
PDWIS – Public Drinking Water Information System
PWSS – Public Water Supply System
RAMS – Regulatory Analysis and Management System
SDAT – State Department of Assessment and Taxation
SDWIS – Safe Drinking Water Information System
SWUDS –Site-Specific Water Use Database
TNCWS – Transient Non-Community Water Supply
WAN – Water Appropriation Network
WAUSP – Water Availability and Use Science Program
WMSA – Water Management Strategy Area
WMA – Water Management Administration
WRE – Water Resource Element plans
WRF – Water Research Foundation
WSIPS – Water Supply Information and Permitting System
WSP – Water Supply Program
WUDM – Water Use Data Model

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Appendix 1 Water Use Data Models

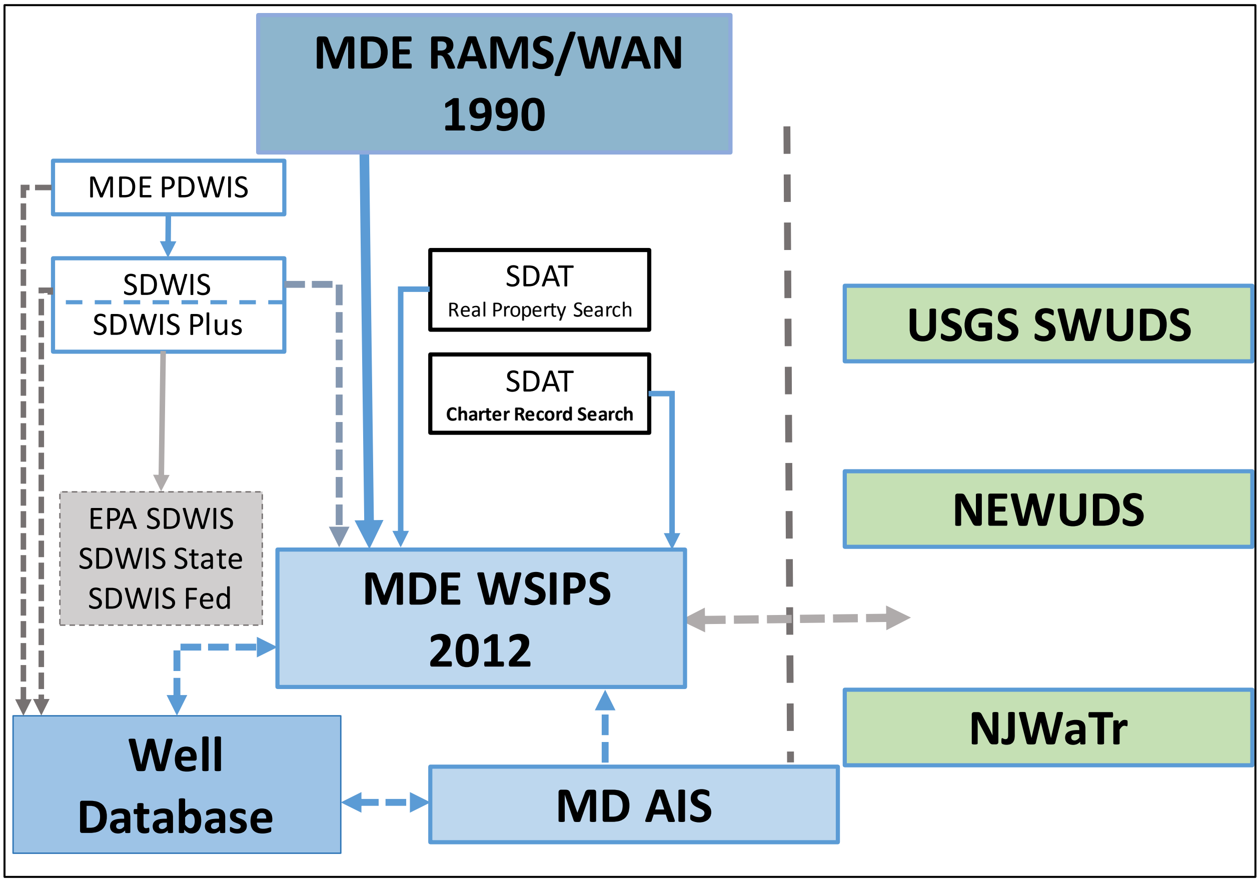


Figure 4 MD Water Use Data Models

This figure provides an over view of active and legacy water use database management systems in Maryland (in blue). These systems include those used by the Water Supply Program for managing water appropriation permits as well as systems used for reporting and compliance with EPA Safe Drinking Water Act requirements for water systems. These systems represent the current information infrastructure used for regulatory, management, and planning purposes.

Other water use database management systems investigated in the preparation of this workplan are shown in green on the right-hand-side of the figure. These represent database management systems that were specifically developed around a water use data model (as opposed to the enterprise workflow design of WSIPS). These systems indicate the parallel, independent efforts underway in other states to develop a water use data model built around a withdrawal-conveyance-use-discharge paradigm. These systems represent development templates that bridge permit-regulatory function and water management priorities. The NEWUDS and NJWaTr provide evocative models that can help prototype a water use data model that integrates water use data management integrated in geospatial hydrologic data models, as the anthropogenic flux in the hydrologic system.

WSIPS
Selected Table Relationships

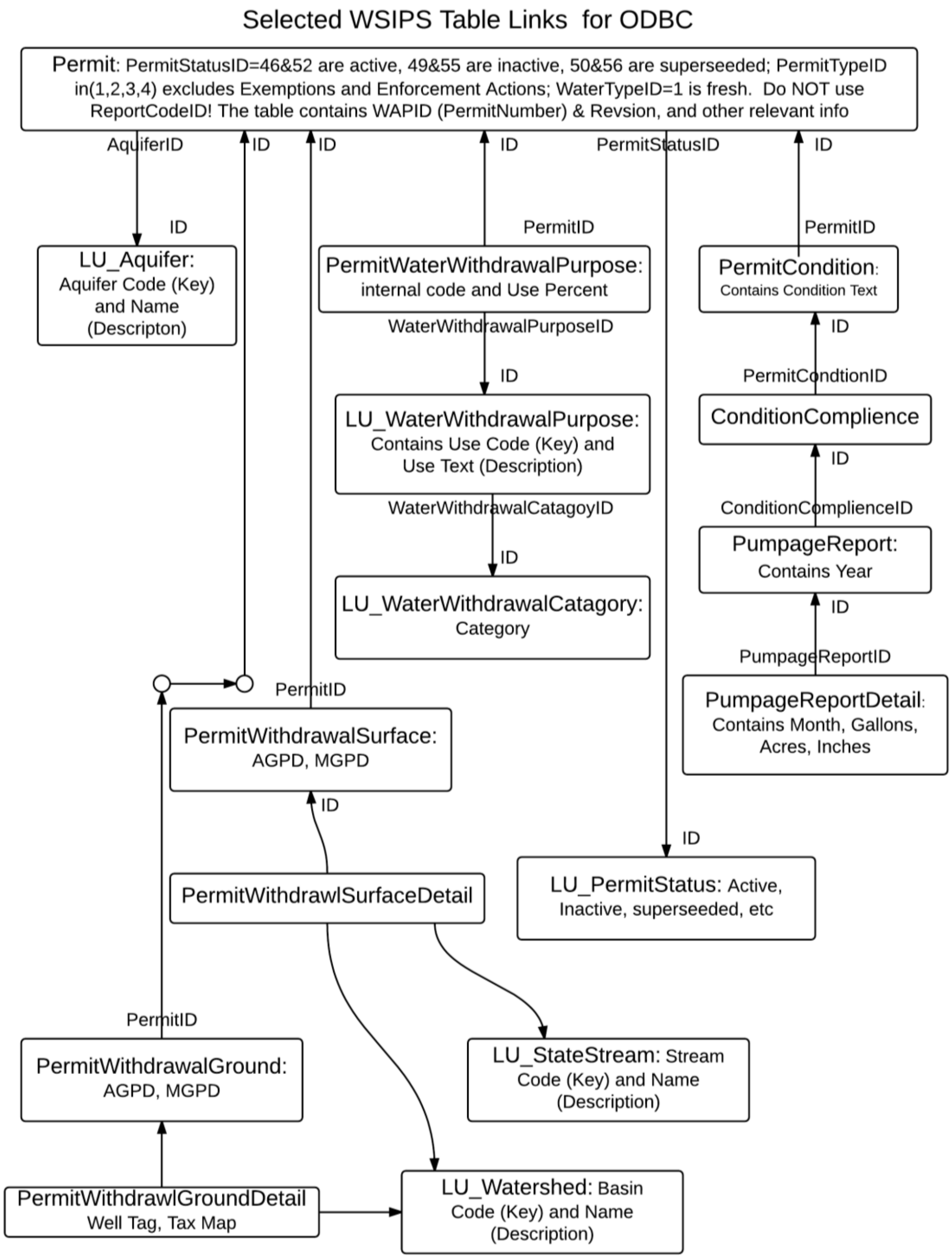


Figure 5 Selected WSIPS Table Links

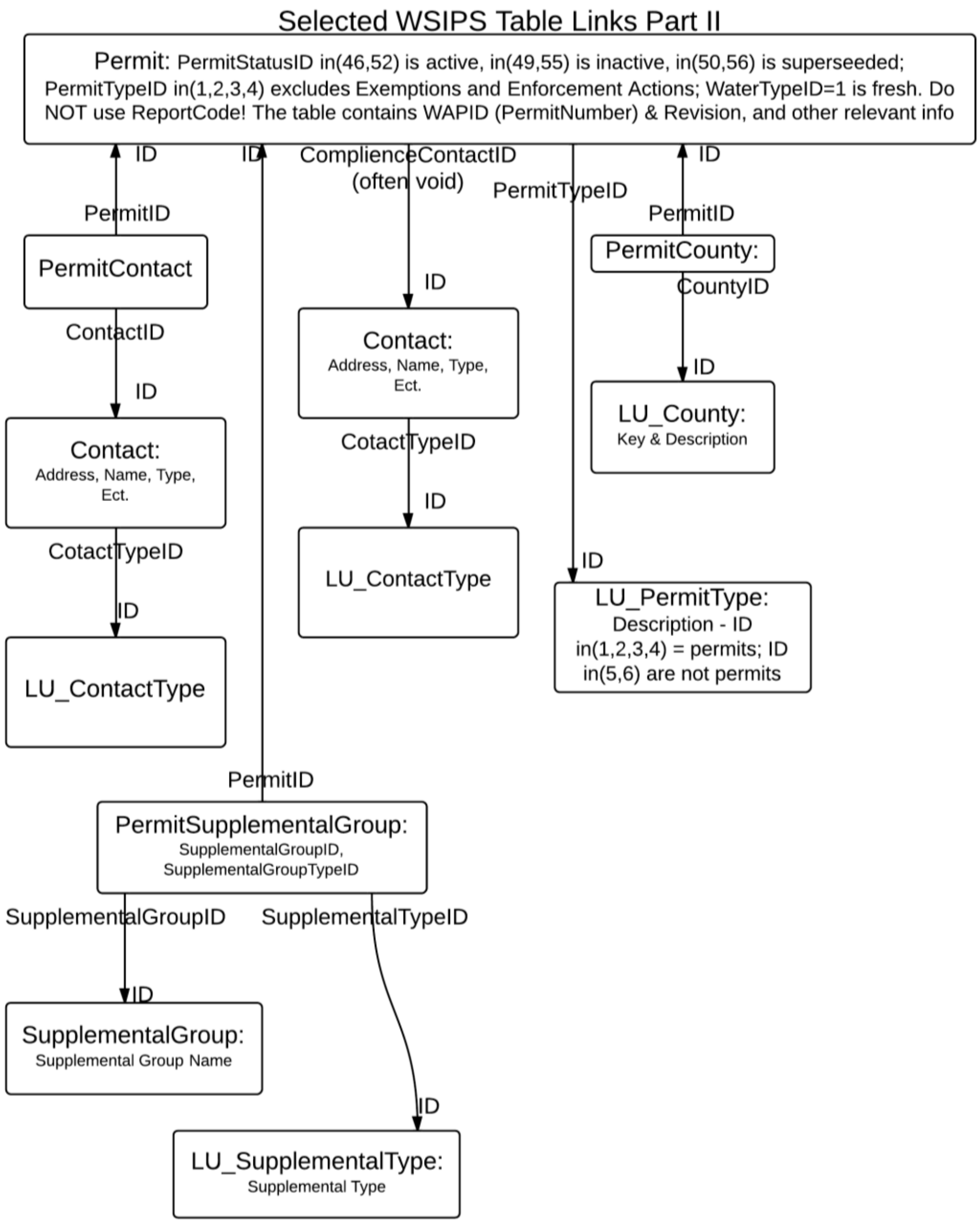
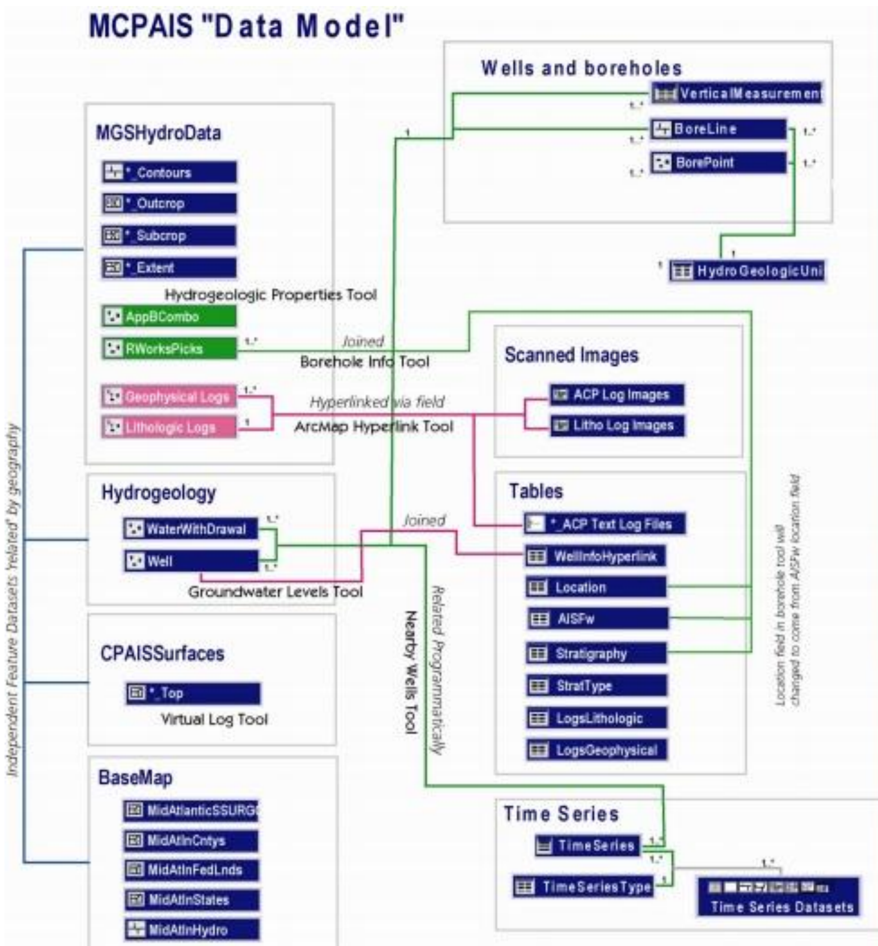


Figure 6 Selected WSIPS Table Links Part II

Maryland Coastal Plain Aquifer Information System

courtesy of A.W. Staley, MD Geological Survey

Figure 7 MD Coastal Plain Aquifer Information System


MCPAIS "Data Model"
Wells and boreholes
VerticalMeasuremen
BoreLine
BorePoint
HydroGeologicUni
MGSHydroData
*_Contours
*_Outcrop
*_Subcrop
*_Extent
Hydrogeologic Properties Tool
AppBCombo
RWorksPicks
Joined
Borehole Info Tool
Geophysical Logs
Lithologic Logs
Hyperlinked via field
ArcMap Hyperlink Tool
Scanned Images
ACP Log Images
Litho Log Images
Hydrogeology
WaterWithDrawal
Well
Groundwater Levels Tool
Joined
Tables
*_ACP Text Log Files
WellInfoHyperlink
Location
AISFw
Stratigraphy
StratType
LogsLithologic
LogsGeophysical
Location field in borehole tool will changed to come from AISFw location field
CPAISSurfaces
*_Top
Virtual Log Tool
Nearby Wells Tool
Related Programmatically
Independent Feature Datasets 'related' by geography
BaseMap
MidAtlanticSSURG
MidAtlnCntys
MidAtlnFedLnds
MidAtlnStates
MidAtlnHydro
Time Series
TimeSeries
TimeSeriesType
Time Series Datasets

NJWaTr Data Model

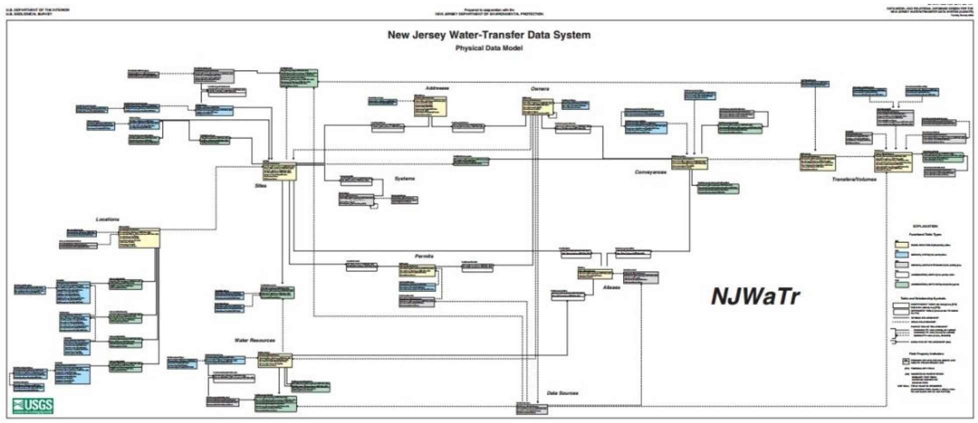


Figure 8 NJWaTr Data Model
PDF accessible online at: http://pubs.usgs.gov/of/2003/ofr03197/pdf/ofr03-197_full.pdf

The data model implemented for every NJ HUC-11 watershed, supports standardized assessment of available water resources and a summary of water balance stresses including consumptive and non-consumptive uses by major water use sectors. The Figure to the right is an example of a standard HUC-11 watershed report that is automatically populated by the system.

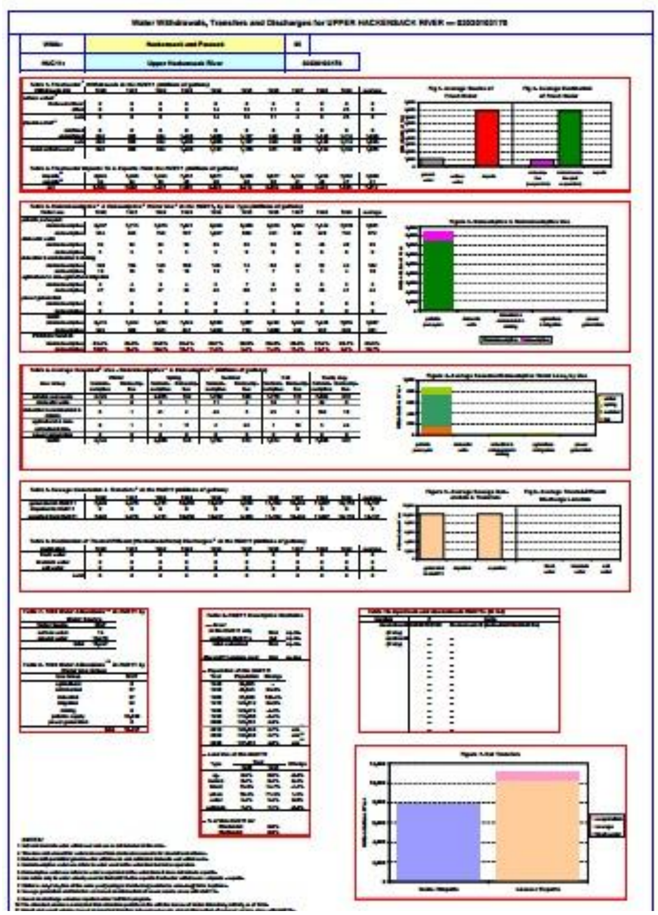


Figure 9 source: www.nj.gov/dep/njgs/enviroed/HUC11.htm

New Jersey HUC-11 watersheds are aggregated into 20 water management areas spanning the State. The NJWaTr system is designed and used to track and evaluate water use as a water management system, *not* a regulatory permit compliance system

Appendix 2 EIOLCA models

Blackhurst et al. (2010) used life cycle Analysis (LCA) based on the US Economic input-Output (I/O) table to estimate the direct and indirect withdrawals of water supporting each sector of the U.S. Economy. Details of economic I/O LCA analysis can be found online in the e-book by Hendrickson at – www.eiolca.net . The basic EIOLCA approach extends traditional macroeconomic I/O analysis by developing a water requirements matrix F corresponding to the national economic I/O Table, A , in which each elements of $A=(a_{ij})$ correspond to the dollars of input from economic sector *i* required to produce one dollar of output from economic sector *j*. Given a vector of final economic output for every sector of the U.S. economy (e.g. sector contributions to GDP) considered as a final demand, x , The vector of total direct plus indirect water use by economic sector, w , required to satisfy the final demand x , can be computed as

$$w=(I-A)^{-1}Fx \tag{1.1}$$

Using this approach based on the U.S. National I/O table, Blackhurst et al. (2010) estimate the direct and indirect water use for each economic sector and can identify, e.g. the sectors of the economy with the greatest direct or indirect water use. In this context indirect water use refers to the embodied water used by all of the economic sectors that provides inputs to a particular sector. Total embodied water use per dollar of output, or unit of output adjusted for price can similarly be computed. For example, Electric power generation is the single largest water use in the USGS 2000 water use census, but grain and cotton farming have significantly higher water use intensity (gal/$ of output). Indeed, power generation and supply is only the 7th most water intensive industry sector requiring 450 gallons of water per dollar of output, compared to 1400 gallons of water per dollar of output for grain farming.

LCA based on the national economic I/O tables could also be used to estimate state water use, using state and county I/O tables that are routinely used in regional planning. Imposing state or county boundaries on the embodied water of indirect water use poses additional methodological challenges for disaggregated EIOLCA, but the consistency with which national and regional sector-specific economic data are compiled motivates an examination of the potential utility of standardized EIOLCA to derive consistent estimates of water use by sector, to complement the USGS pentannual estimates of national water use by state and county.

Appendix 3 Well-Aquifer Association

Example

Groundwater well information was retrieved from the USGS NWIS system, Figure A3-1 shows the locations of NWIS wells in Worcester County, MD. With significant variability, the shallow wells in Worcester County exploit the Senepuxent aquifer with an average well depth just under 35 feet. In contrast, much deeper (300-500 ft) nearby wells are drawing water from the Manokin aquifer, with wells at intermediate depths exploiting the Chesapeake and Ocean City formations. For comparison the shallow well in Wicomico County withdraws water from the Parsonburg formation.

Figure 10 Well retrievals from USGS NWIS

Table A6-1 Well Depth & Aquifer

Aquifer (aquifer code)	Depth (feet)
Worcester County	
Sinepuxent (112SNPX)	34.1 ± 19.8
Manokin (112MNKN)	412.2 ± 80.7
Ocean City (122OCNC)	243
Chesapeake (122CSPK)	100
Wicomico County	
Parsonburg (112PRBG)	25

This arbitrary sample suggests how location and estimated well depth could be used to begin to deduce the likely aquifer exploited by each well.

Appendix 4 NWIS Maryland Aquifer Codes

NWIS Code	Aquifer/Formation
100CNZC	CENOZOIC ERATHEM
110AFCL	ARTIFICAL FILL
110ALVM	QUATERNARY ALLUVIUM
110CLVF	COLLUVIAL FAN DEPOSITS
110CLVM	COLLUVIUM
110MNWS	MOUNTAIN WASH
110QRNR	QUATERNARY SYSTEM
110TRRC	TERRACE DEPOSITS
111BRRR	BARRIER SAND
111HLCN	HOLOCENE SERIES
111LLND	LOWLAND DEPOSITS
111SPOL	SPOIL
111TDLM	TIDAL MARSH DEPOSITS
112BRND	BRANDYWINE FORMATION
112BVDM	BEAVERDAM SAND
112CLMB	COLUMBIA FORMATION
112IRSR	IRONSHIRE FORMATION
112KILD	KENT ISLAND FORMATION
112MTCV	MINOR TERRACE DEPOSIT AND COLLUVIUM
112OMAR	OMAR FORMATION
112PCPC	PLEISTOCENE-PLIOCENE SERIES
112PLSC	PLEISTOCENE SERIES
112PMLC	PAMLICO FORMATION
112PRBG	PARSONSBURG FORMATION
112RDGV	RED GRAVELLY FACIES
112SDLD	SUNDERLAND FORMATION
112SLBR	SALISBURY AQUIFER
112SNPX	SINEPUXENT FORMATION
112TLBT	TALBOT FORMATION
112UPLD	UPLAND DEPOSITS
112WCML	WICOMICO FORMATION
112WLSN	WALSTON SILT
120TRTR	TERTIARY SYSTEM
120UPLD	UPLAND GRAVEL
121BRMR	BRYN MAWR FORMATION
121BVDM	BEAVERDAM SAND
121PLCN	PLIOCENE SERIES
121WLSN	WALSTON SILT
122CLVR	CALVERT FORMATION
122CPNK	CHOPTANK FORMATION
122CSLD	CHESWOLD AQUIFER
122CSPK	CHESAPEAKE GROUP
122FDBG	FEDERALSBURG AQUIFER
122FRDC	FREDERICA AQUIFER
122MNKN	MANOKIN AQUIFER

NWIS Code	Aquifer/Formation
122MOCN	MIOCENE SERIES
122OCNC	OCEAN CITY AQUIFER
122PCMK	POCOMOKE AQUIFER
122PNSK	PENSAUKEN FORMATION
122SMRS	ST MARYS FORMATION
122YRKN	YORKTOWN FORMATION
123OLGC	OLIGOCENE SERIES
124ECPC	EOCENE-PALEOCENE SERIES
124EOCN	EOCENE SERIES
124NNJM	NANJEMOY FORMATION
124PMNK	PAMUNKEY GROUP
124PNPN	PINEY POINT FORMATION
125AQRC	AQUIA AND RANCOCAS AQUIFER
125AQUI	AQUIA FORMATION
125BRGS	BRIGHTSEAT FORMATION
125HRRS	HORNERSTOWN FORMATION
125MRLB	MARLBORO CLAY
125MTPN	MATTAPONI (?) AQUIFER
125PLCN	PALEOCENE SERIES
125RCCS	RANCOCAS FORMATION
125VNCN	VINCENTOWN FORMATION
200MSZC	MESOZOIC ERATHEM
210CRCS	CRETACEOUS SYSTEM
211CRCSU	UPPER CRETACEOUS SERIES
211EGLS	ENGLISHTOWN FORMATION
211MCVL	MERCHANTVILLE FORMATION
211MGTY	MAGOTHY FORMATION
211MLEG	MARSHALLTOWN AND ENGLISHTOWN FORMATIONS, UNDIVIDED
211MLRL	MOUNT LAUREL SAND
211MNMT	MONMOUTH FORMATION
211MRSL	MARSHALLTOWN FORMATION
211MTWN	MATAWAN FORMATION
211RRTN	RARITAN FORMATION
211SVRN	SEVERN FORMATION
217ARDL	ARUNDEL FORMATION
217CLCK	CANAL CREEK AQUIFER IN THE PATAPSCO FORMATION
217CRCSL	LOWER CRETACEOUS SERIES
217LPLT	LA PLATA AQUIFER
217NNMR	NONMARINE CRETACEOUS AQUIFER
217PPSC	PATAPSCO FORMATION
217PPSCU	UPPER PATAPSCO AQUIFER IN THE PATAPSCO FORMATION
217PPSCL	LOWER PATAPSCO AQUIFER IN THE PATAPSCO FORMATION
217PTMC	POTOMAC GROUP
217PTXN	PATUXENT FORMATION
217WLDF	WALDORF AQUIFER
217WSTD	WESTWOOD AQUIFER
220DIBS	JURASSIC DIABASE
230TCBM	TRIASSIC BASEMENT ROCKS, UNDIFFERENTIATED
230TRSC	TRIASSIC SYSTEM

NWIS Code	Aquifer/Formation
231BLBF	BALLS BLUFF SILTSTONE
231BLRN	BULL RUN FORMATION
231DIBS	DIABASE DIKES AND SILLS
231GBRG	GETTYSBURG SHALE
231LBRG	LEESBURG LIMESTONE CONGLOMERATE MEMBER OF BULL RUN FORMATION
231MNSS	MANASSASS SANDSTONE
231NOXF	NEW OXFORD FORMATION
231NOXFB	NEW OXFORD FORMATION BASAL CONGLOMERATE
231NWRK	NEWARK GROUP
231TRSCU	UPPER TRIASSIC SERIES
300AMPB	AMPHIBOLITE LITHOFACIES OF THE WISSAHICKON FORMATION,UNDIVIDED
300BCMV	BACHMAN VALLEY FORMATION
300BLDR	BOULDER GNEISS OF WISSAHICKON FORMATION
300BLMR	BALTIMORE GABBRO COMPLEX
300CCKV	COCKEYSVILLE MARBLE
300DDHL	DRUID HILL AMPHIBOLITE MEMBER OF JAMES RUN FORMATION
300ELCC	ELLICOTT CITY GRANODIORITE
300GBRC	GABBROIC ROCK, UNDIFFERENTIATED
300GBSP	GABBRO AND SERPENTINITE AT GRAY HILL
300GEMR	GNEISSES,ON GARRET ISLAND,NEAR ELK MILLES,& ROLLING MILL,UNDIVIDED
300GLFD	GUILFORD QUARTZ MONZONITE
300GLLS	GILLIS FORMATION
300GLPF	GILPINS FALLS MEMBER OF JAMES RUN FORMATION
300GLRM	GLENARM SERIES
300GPDR	GUNPOWDER GRANITE
300GRGN	GEORGETOWN MAFIC COMPLEX
300GRNC	GRANITIC ROCK, UNDIFFERENTIATED
300IJMV	IJAMSVILLE FORMATION
300IJVM	IJAMSVILLE FORMATION-MARBURG SCHIST,UNDIFFERENTIATED
300JMSR	JAMES RUN FORMATION
300KNSG	KENSINGTON QUARTZ DIORITE
300LBRN	LIBERTYTOWN METARHYOLITE
300LFPF	LITTLE NORTHEAST CR.,FRENCHTOWN,PRINCIPIO FURNACE MBRS,JAMES RUN FM
300LPLC	LOWER PELITIC SCHIST OF WISSAHICKON FORMATION
300MBAB	METAGABBRO AND AMPHIBOLITE
300MCGM	METACONGLOMERATE OF WISSAHICKON FORMATION
300MFIC	MAFIC BRECCIA
300MGAB	METAGRAYWACKE WITH AMPHIBOLITES OF WISSAHICKON (?) FORMATION
300MGCK	METAGRAYWACKE OF WISSAHICKON FORMATION
300MQMG	MUSCOVITE QUARTZ MONZONITE GNEISS
300MRBG	MARBURG FORMATION
300MWSG	MOUNT WASHINGTON AMPHIBOLITE
300NBCK	NORBECK QUARTZ DIORITE
300OELL	OELLA FORMATION
300PCSC	PELITIC SHIST OF WISSAHICKON (?) FORMATION
300PGMT	PEGMATITE DIKES
300PLCG	PELITIC GNEISS OF WISSAHICKON (?) FORMATION
300PLGV	PLEASANT GROVE SCHIST
300PLZC	PALEOZOIC ERATHEM

NWIS Code	Aquifer/Formation
300PMZA	PEGMATITE QUARTZ, MONZONITE GNEISS AND ALASKITE GNEISS
300PNRN	PINEY RUN FORMATION
300PRDP	PORT DEPOSIT GNEISS
300PRTB	PRETTYBOY SCHIST
300PSAB	PELITIC SCHIST WITH AMPHIBOLITES OF WISSAHICKON (?) FORMATION
300PZPC	EARLY PALEOZOIC-LATE PRECAMBRIAN ERATHEMS,UNDIFFERENTIATED
300QZQZ	QUARTZ GABBRO AND QUARTZ DIORITE GNEISS
300RELY	RELAY GNEISS MEMBER OF JAMES RUN FORMATION
300SGFM	SUGARLOAF MOUNTAIN QUARTZITE
300SLVR	SILVER RUN LIMESTONE
300SMCK	SAMS CREEK METABASALT
300STRS	SETTERS FORMATION
300UFGB	ULTRAMAFIC AND GABBROIC ROCKS
300UHBP	FELSITE,HAPPY VALLEY BR.,BIG ELK CR.,PRINCIPIO CR.MBRS,JAMES RUN FM
300UMFC	ULTRAMAFIC ROCKS
300UPPC	UPPER PELITIC SCHIST OF WISSAHICKON FORMATION
300URBN	URBANA FORMATION
300VLCC	VOLCANIC COMPLEX OF CECIL COUNTY
300WDCK	WOODSTOCK QUARTZ MONZONITE
300WKFD	WAKEFIELD MARBLE
300WSCK	WISSAHICKON FORMATION
307JMSR	JAMES RUN FORMATION
307RELY	RELAY GNEISS MEMBER OF JAMES RUN FORMATION
310DNKD	DUNKARD GROUP
310PRMN	PERMIAN SYSTEM
317PRMNL	LOWER PERMIAN SERIES
320PSLV	PENNSYLVANIAN SYSTEM
321CNMG	CONEMAUGH FORMATION
321MNGL	MONONGAHELA FORMATION
321PSLVU	UPPER PENNSYLVANIAN SERIES
324ALGN	ALLEGHENY FORMATION
324PSLVM	MIDDLE PENNSYLVANIAN SERIES
324PSVL	POTTSVILLE FORMATION
324PVAG	POTTSVILLE-ALLEGHENY FORMATIONS,UNDIFFERENTIATED
330MSSP	MISSISSIPPIAN SYSTEM
331GRBR	GREENBRIER FORMATION
331MCCK	MAUCH CHUNK FORMATION
331MSSPU	MISSISSIPPIAN, UPPER
337MSSPL	MISSISSIPPIAN, LOWER
337POCN	POCONO GROUP
337PRSL	PURSLANE SANDSTONE
337RCKL	ROCKWELL FORMATION
340DVNN	DEVONIAN SYSTEM
341BRLR	BRALLIER FORMATION
341CMNG	CHEMUNG FORMATION
341DVNNU	DEVONIAN, UPPER
341HMPR	HAMPSHIRE FORMATION
341HRRL	HARRELL SHALE
341JNGS	JENNINGS FORMATION

NWIS Code	Aquifer/Formation
341PRKD	PARKHEAD SANDSTONE
341WDMN	WOODMONT FORMATION
344DVNNM	DEVONIAN, MIDDLE
344HMLN	HAMILTON GROUP
344MNNG	MAHANTANGO FORMATION
344MRCL	MARCELLUS SHALE
344NDMR	NEEDMORE SHALE
344RMNY	ROMNEY FORMATION
344TIOG	TIOGA METABENTONITE
347DVNNL	DEVONIAN, LOWER
347HDBG	HELDERBERG GROUP
347KYSR	KEYSER LIMESTONE
347ORSK	ORISKANY GROUP
347RDGL	RIDGELEY SANDSTONE
347SRVR	SHRIVER CHERT
350SLRN	SILURIAN SYSTEM
351SLRNU	SILURIAN, UPPER
351TNLY	TONOLOWAY LIMESTONE
351WLCK	WILLS CREEK SHALE
352BMBG	BLOOMSBURG FORMATION
354CLNN	CLINTON GROUP
354KEFR	KEEFER SANDSTONE
354MCKZ	MCKENZIE FORMATION
354RCSR	ROCHESTER SHALE
354RSHL	ROSE HILL FORMATION
354SLRNM	SILURIAN, MIDDLE
357SLRNL	SILURIAN, LOWER
357TCRR	TUSCARORA SANDSTONE
360CRDF	CARDIFF METACONGLOMERATE
360MRGR	MORGAN RUN FORMATION
360ODVC	ORDOVICIAN SYSTEM
360PCBM	PEACH BOTTOM SLATE
360SKVL	SYKESVILLE FORMATION
360SKVLG	SYKESVILLE FORMATION, GNEISS MEMBER
360SKVLS	SYKESVILLE FORMATION, SCHIST MEMBER
361JUNT	JUNIATA FORMATION
361MRBG	MARTINSBURG SHALE
361ODVCU	ORDOVICIAN, UPPER
364CBBG	CHAMBERSBURG LIMESTONE
364NMRK	NEW MARKET LIMESTONE
364ODVCM	ORDOVICIAN, MIDDLE
364RPRK	ROW PARK LIMESTONE
364STPL	ST PAUL GROUP
367BKMN	BEEKMANTOWN GROUP
367GROV	GROVE LIMESTONE
367ODVCL	LOWER ORDOVICIAN SERIES
367PBGS	PINESBURG STATION DOLOMITE
367RCKR	ROCKDALE RUN FORMATION
367SNNG	STONEHENGE LIMESTONE

NWIS Code	Aquifer/Formation
370ARBY	ARABY FORMATION
370CMBR	CAMBRIAN SYSTEM
370DDHL	DRUID HILL AMPHIBOLITE MEMBER OF JAMES RUN FORMATION
370GPDR	GUNPOWDER GNEISS
370HLFD	HOLOFIELD LAYERED ULTRAMAFITE
370LCRV	LOCH RAVEN SCHIST
370PRCK	PETERS CREEK SCHIST
370PRHL	PERRY HALL GNEISS
370RPBG	RASPEBURG AMPHIBOLITE
371CCCG	CONOCOCHEAGUE LIMESTONE
371CMBRU	CAMBRIAN, UPPER
371ELBK	ELBROOK FORMATION
374CMBRM	CAMBRIAN, MIDDLE
377ANTM	ANTIETAM FORMATION
377CHLH	CHILHOWEE GROUP
377CMBRL	LOWER CAMBRIAN SERIES
377FDCK	FREDERICK LIMESTONE
377HRPR	HARPERS FORMATION
377LUDN	LOUDOUN FORMATION
377SKVL	SYKESVILLE FORMATION
377SKVLG	GNEISS MEMBER, SYKESVILLE FORMATION
377SKVLS	SCHIST MEMBER, SYKESVILLE FORMATION
377TMSN	TOMSTOWN DOLOMITE
377WSBR	WAYNESBORO FORMATION
377WVRN	WEVERTON FORMATION
400BLMR	BALTIMORE GNEISS
400CTCN	CATOCTIN METABASALT
400GBGG	GRANODIORITE AND BIOTITE GRANITE GNEISS
400GNSS	GNEISS COMPLEX
400MTRL	METARHYOLITE AND ASSOCIATED PYROCLASTIC SEDIMENTS
400PCMB	PRECAMBRIAN ERATHEM
400SFRN	SWIFT RUN FORMATION
400SGTS	SLAUGHTERHOUSE GNEISS
400SMCK	SAMS CREEK FORMATION
410SKVL	SYKESVILLE FORMATION
BASEMENT	BASEMENT
BEDROCK	BEDROCK

Appendix 5 Maryland Water Use Appropriation Permits

3.15 WATER APPROPRIATION AND USE PERMIT

- *Question: Am I planning to perform an activity that withdraws water from the State's surface and/or underground waters?*

Why do I need this approval?

In order to conserve, protect, and use water resources of the State in the best interests of the people of Maryland, it is necessary to control the appropriation or use of surface and underground waters.
This permit is required for any activity that withdraws water from the State's surface and/or underground waters unless exempted below.

What laws or regulations give MDE the legal authority to issue this approval?

STATE: Environment Article, Title 5, §5-203 and §5-501 through §5-516 and §5-5B-01 through §5-5B-05, Annotated Code of Maryland; COMAR 26.17.06 and COMAR 26.17.07.

What is the process to get this approval?

1) Obtain local land use zoning approvals and check for consistency with county water and sewer plan.
2) Submit application for technical review and include:
a. Map of project location and service area or structure;
b. For subdivisions: a preliminary plat with lot sizes;
c. Explanation of water use;
d. Average daily use calculated on an annual basis;
e. For groundwater withdrawal, average daily use during the month of highest use; and
f. For surface water, maximum daily use.
3) Submit plans and specifications for any facility or structure or conduct and submit special evaluations as requested.
4) A site inspection may be performed by the Department to obtain additional information.
5) Appropriation requests for an annual average withdrawal of more than 10,000 gallons per day (gpd) (as a new request or increase) will receive a detailed package of instructions for completing the application. These instructions may include aquifer testing, other technical analysis and are provided after the applicant completes the one-page form. Agricultural users are provided technical assistance by MDE in the permitting process. All applicants proposing a new use of increase of 10,000 gpd will be required to include certified notification of contiguous property owners and certification of compliance with Business Occupations and Professions, Article 12, §205, Annotated Code of Maryland (water conservation technology).
6) Requests for an annual average withdrawal of more than 10,000 gpd as a new request or increase are advertised for a public information hearing.

Forms for notice of exemptions, locations of water management strategy areas and permit applications can be downloaded from the MDE website at:http://www.mde.state.md.us/waterpermits/pages/forms.aspx

Before I apply for this approval, do I need to get any approvals from the local or federal government?

County planning and zoning approval;
County water and sewer plan approval;

Is this approval directly related or contingent on other approvals?

3.14 Well construction permit
3.18 or 3.19 Wetlands permit
3.25 Waterway construction permit

Are there any other requirements?

EXEMPTION: Uses exempt from the water appropriation and use permit process are:
1) Extinguishing a fire;
2) Agricultural use under 10,000 gallons/day;
3) Individual domestic use except withdrawals for heating and cooling;
4) Temporary dewatering during construction if:
a) The duration of the dewatering including intermittent non-pumping periods is expected to be less than 30 days; and
b) The average water use does not exceed 10,000 gallons/day.
5) Other users of ground water less than 5,000 gpd as an annual average:
a. that is not for a community water system, as defined by the Safe Drinking Water Act; or;
b. that is not within a water management strategy area; and
c. the user files a notice of exemption with MDE at least 30 days prior to the beginning of the use or prior to the expiration date for an existing permitted use.
APPROVALS
PRE-APPROVAL: An applicant must provide satisfactory proof that the proposed withdrawal of water is reasonable and the impacts on the water resource and other users are acceptable. In addition, the proposed use must be consistent with the local planning and zoning requirements and the county water and sewer plan.
POST APPROVAL: The project must meet withdrawal limits and may be required to meet periodic reporting, environmental and other requirements specific to the permit.

How long should I expect it to take to get this approval once I submit a complete application?

Appropriation Requested	Turnaround Time
Under 10,000 gallons per day	90 days
10,000 gallons per day or more	18 months

Once I get this approval, how long will it last?

Maximum of twelve years

How much will this approval cost?

No fee.

Do I need to know any additional information?

The approved withdrawal must begin within two years of approval. Permits are subject to a review every three years and are not transferable to new ownership without written authorization by the Department.

Who do I contact with additional questions?

John Grace
Water Supply Program
John.Grace@maryland.gov
(410) 537-3714

Appendix 6 MDE Water Use Codes and Categories

Maryland's water use codes and categories as of 1 September 2016 are summarized in the following Table. The codes and categories are continuously revised and updated. For this reason, information presented below includes codes and categories found on historical permits that are no longer used for new permits. Similarly, the categories undergo updating and some categories were not available for older permits. For example, Livestock Watering would now be coded as either Poultry (Evaporative), Poultry (Foggers), Dairy Animal Watering, and/or, Other Livestock Watering. Some MDE water use categories do not obviously map to USGS water use categories. For example, the Commercial Drinking/Sanitary category could capture both potable and wastewater. Moreover, the USGS Commercial category is defined as commercial uses from a Public Water Supply. MDE's water use categories are associated with individual permits. For this reason, MDE's commercial permitted water uses do not correspond to USGS commercial uses in Public Supply, despite sharing the "commercial" industrial activity sector designation. The USGS water use categories for MDE water use categories with ambiguous or uncertain correspondence are left blank in the following table.

Water Use Code	Water Use	Water Use Category	USGS Water Use Category	Active (Is this code available for new permits?)
1110	Livestock Watering	Agricultural	Livestock	FALSE
1111	Poultry (Evaporative)	Agricultural	Livestock	TRUE
1112	Poultry (Foggers)	Agricultural	Livestock	TRUE
1113	Dairy Animal Watering	Agricultural	Livestock	TRUE
1114	Other Livestock Watering	Agricultural	Livestock	TRUE
1120	Farm Potable Supplies	Agricultural	Self-Supplied Domestic	TRUE
2020	Crop Irrigation	Agricultural	Irrigation-Crop	TRUE
2050	Nursery Irrigation	Agricultural	Irrigation-Crop	TRUE
2060	Sod Farm Irrigation	Agricultural	Irrigation-Crop	TRUE
6010	Food Processing (Onsite)	Agricultural		TRUE
6020	Aquaculture & Aquarium	Agricultural	Aquaculture	TRUE
2010	Irrigation (Undefined)	Non-Agricultural Irrigation		TRUE
2030	Golf Course Irrigation	Non-Agricultural Irrigation	Irrigation - Golf Courses	TRUE
2040	Lawn & Park Irrigation	Non-Agricultural Irrigation		TRUE
4020	Small Intermittent Irrigation	Non-Agricultural Irrigation		TRUE
1060	Industrial Drinking/Sanitary	Industrial & Mining		TRUE
1130	Mining Potable Supplies	Industrial & Mining		TRUE

3030	Industrial Wash & Separation Processes	Industrial & Mining	Mining	TRUE
3040	Mine Construction and Dewatering (Mining Only)	Industrial & Mining	Mining	TRUE
3060	Industrial Heating & cooling Water	Industrial & Mining		TRUE
3090	Sand & Gravel Washing	Industrial & Mining	Mining	TRUE
3100	Product Manufacturing	Industrial & Mining		TRUE
3150	Industrial (Undefined)	Industrial & Mining		TRUE
3170	Mining Operations (Undefined)	Industrial & Mining	Mining	TRUE
4040	Water Well Drilling Operations	Industrial & Mining	Mining	TRUE
4050	Other Well Drilling Operations (Excluding Fracking)	Industrial & Mining		TRUE
4060	Fracking Operations for Gas & Oil	Industrial & Mining	Fracking	TRUE
5010	Fossil Fueled Power Generation	Power	Thermoelectirc	TRUE
5011	Fossil Fueled Power – Once Thru Cooling	Power	Thermoelectirc	TRUE
5012	Fossil Fueled Power – Cooling Tower Blowby	Power	Thermoelectirc	TRUE
5013	Fossil Fueled Power – Boiler Blowby	Power	Thermoelectirc	TRUE
5014	Fossil Fueled Power – Pollution Control	Power		TRUE
5015	Fossil Fueled Power – Other Uses	Power	Thermoelectirc	TRUE
5020	Nuclear Power Generation	Power	Thermoelectirc	TRUE
5030	Hydroelectric Power Generation	Power	Hydroelectric Power	TRUE
5040	Geothermal Power Generation	Power		TRUE
1010	Government Run Water Supply	Water Supply	Public Supply	TRUE
1020	Private Water Supplier	Water Supply	Public Supply	TRUE
1080	Trailer Park/Apartment Bldg/Condo	Water Supply	Public Supply	TRUE
1030	Commercial Drinking/Sanitary	Commercial & Institutional		TRUE
1040	Institutional Drinking/Sanitary	Commercial & Institutional		TRUE
1041	Educational Drinking/Sanitary	Commercial & Institutional		TRUE
1042	Social Drinking/Sanitary	Commercial &		TRUE

		Institutional		
1043	Religious Drinking/Sanitary	Commercial & Institutional		TRUE
1044	Fire & Rescue Drinking/Sanitary	Commercial & Institutional		TRUE
	Government Drinking/Sanitary	Commercial & Institutional	Commercial	TRUE
1046	Undefined Drinking/Sanitary	Commercial & Institutional		TRUE
1050	Recreational Drinking/Sanitary	Commercial & Institutional		TRUE
1100	Sewage Treatment Plants (All Uses)	Commercial & Institutional	Wastewater Treatment	TRUE
3050	Commercial Heating & Cooling Water	Commercial & Institutional	Commercial	TRUE
3070	Commercial Washing Processes	Commercial & Institutional	Commercial	TRUE
3080	Laboratories	Commercial & Institutional	Commercial	TRUE
3160	Commercial (Undefined)	Commercial & Institutional	Commercial	TRUE
1070	Subdivisions with Individual Wells	Water Supply	Domestic Self-supply	TRUE
1090	Residential Heat Pumps	Other		TRUE
6030	Permanent Dewatering of Buildings	Other		TRUE
6040	Wildlife Ponds and Recreational	Other		TRUE
6050	Environmental Enhancement	Other		TRUE
6060	Ground Water Cleanup	Other		TRUE
4010	Hydrostatic Testing & Fire Protection	Other	Public Supply	TRUE
4030	Construction Dewatering	Other		TRUE
4070	Food Processing	Industrial & Mining	Industrial	TRUE

END