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# WaDE: An Interoperable Data Exchange Network for Sharing Water Planning and Use Data

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**Abstract:** The Water Data Exchange (WaDE) is a project initiated by the member states of the Western States Water Council (WSWC), in cooperation with the Western Governors' Association (WGA), to assist state water agencies when answering local, regional, and national water availability questions. WaDE provides requested information more easily, sustainably, and cost-effectively, by streamlining the publication of water planning, use, and allocation data for access by planners, policy makers, and the public.

This paper presents the background of the WaDE project, how it was envisioned to function, the types of data it will provide, and why access to the information is important for water managers. The goals of WaDE include the establishment of a governance structure, documentation of the current state agency capabilities and methodologies, and the design of a common data format that targets water data products and/or water-quantity information. Many of these foundational products have been developed, such as governance workgroups, databases, web services code, and a prototype mapping application for centralized access. A major milestone, still underway, is the distribution and deployment of the databases and web services code within member states' information technology environments. Lastly, WaDE seeks to encourage the publication of other agency datasets using web services and standardized data formats.

**Keywords:** *Water use, availability, planning, data exchange*

The Western States Water Council (WSWC) is an organization created in 1965 by state governors consisting of appointees of the governors from the eighteen western states (North Dakota to Texas and westward). Since its inception, the WSWC has striven to accomplish its chartered purposes, which include facilitating effective cooperation among western states on the conservation, development, and management of water resources. A lack of water data was identified as a significant hurdle to states interested in collaborating on regional water issues as early as 2006 in the WGA's "Water Needs and Strategies for a Sustainable Future" publication (WGA 2006, 8):

> There is a need for more and better water information, specifically data on water use, efficiencies, and water availability, to facilitate decision-making. While there exists a substantial amount of data on streamflows, much of which is now available on a real-time basis, there is less data and less reliable information related to water quality and ground water and rural water supplies.

As the idea of sharing and publishing water data gained increasing support, it was adopted as a formal priority by the Governors in the "Next Steps" report, a follow-up publication issued in 2008 (WGA 2008, 3):

> State and federal water resource agencies should work together to provide universal access to the water-related data collected by all state, local, and federal agencies, as well as tools and models that better enable the synthesis, visualization, and evaluation of water-related data, including that to be shared with local governments.

Similarly, Western States Federal Agency Support Team (WestFAST), a collaborative body of twelve federal agencies with water management responsibilities in the west, created to support the

WSWC, adopted the objective above as a work plan item as well (WestFAST 2012).

Coincident with these publications was a national shift in the view of water as an integral component of national security in light of energy-water nexus concerns, food security, prolonged drought, and climate change. In 2011, as part of a study on water and energy nexus impacts related to energy transmission planning, the Department of Energy (DOE) and its suite of National Laboratories, led primarily by Sandia National Laboratory, looked to assess current and future water availability in the west (Tidwell et al. 2014). Specifically, using as much state agency generated data as possible, Sandia's "Energy and Water in the Texas and Western Interconnects" study proposed a methodology for evaluating common and alternative water source and supply types. They proposed to estimate the quantity of these that may be available for future energy production on a broad scale using large watersheds, calculate the associated costs of development, and project the increase in demand for water over a 30 year timescale. The results would be shown as mapped "metrics" that would identify areas where new water sources were sufficient to meet future demand, and also areas where scarcity or shortage might occur. To create the water availability metrics, the Sandia research team assembled disparate water data from the states concerning water supply, legal and institutional water availability, water uses, and projected demand. Gathering the data and aggregating them into a comparable dataset was a difficult task and the study allowed for only one "snap-shot" in time of water availability, but the results were incorporated into the long-range energy transmission models utilized by the Western Electric Coordinating Council and the Electric Reliability Council of Texas as a new constraining variable—a water-energy nexus model parameter that had never been explicitly defined in prior model runs.

Realizing the Sandia study would likely need to be repeated, the WSWC proposed to work with its member states to establish a data exchange framework that could provide the updated information necessary to repeat the study, and thereby support the DOE's water-related national security efforts. The project would also allow the WSWC, WestFAST, and the states to work toward the completion of their stated goal of sharing information with each other and the public. As the Water Data Exchange (WaDE) project got underway, however, it became apparent that the scope of shared data could be expanded to support more than just the water availability figures needed by Sandia. To allow for the publication of the most common state agency datasets, the scope of WaDE was revised to include physical water supply summaries (basin inflows, outflows, natural system uses, etc.), water use summaries by beneficial use category, legal/institutional and regulatory constraints, water allocation information (owners, legal status, beneficial use, priority date, etc.), diversions (locations, volumes or flow rates), consumptive uses, return flows, and any other targeted data that could be made public and also be updated by the state agency on some frequency, as well as accompanying metadata regarding methods used to generate the information.

The DOE and the member states themselves are not the only potential beneficiaries of the WaDE project. Many federal agencies use state agency-supplied data in their day-to-day reports, models and analyses as well.

In a report to congress in 2011, the Federal Interagency Panel on Climate Change and Water Data and Information stated:

> There is a need to modernize hydroclimatic data networks and climate-relevant data collection, data management, mapping, modeling, and information dissemination (FIPCCWDI 2011, *v*).

Their findings identified a wide range of water planning data, such as streamflow and groundwater monitoring networks, reservoir and lake storage, consumptive use, and withdrawal data, as either in need of additional support or inadequate for making long-term decisions about water availability in the U.S., especially with regard to additional stress brought about by a changing climate. The U.S. Geological Survey has also identified these categories of data as an essential part of completing their National Water Census – a program mandated by the Secure Water Act of 2009 – and as a significant data gap (Alley et al. 2013).

WaDE enables the states to support and provide some of the necessary pieces of critical planning such as water withdrawal and use and water allocation information that allow for a more complete national picture of water availability.

The Environmental Protection Agency (EPA) has more recently been reviewing the relationship between water quality and quantity. The WaDE project will make water quantity information more directly available to the EPA and state agencies that are co-regulators of the Clean Water Act, encouraging a tighter integration between what have historically been two very distinct regulatory groups. WaDE will also allow for better decision-making by agencies or groups pursuing an integrated water resource management strategy by facilitating access to published cross-sectoral, water-related data. As an example, a state agency may wish to publish their estimates of physical water supply within a specified basin. This encapsulates the inflows and outflows from the basin, natural system uses, and human withdrawals of water from the reach; however, water supply estimates may not reflect the water that is available for appropriation within that basin. A state agency may wish to also publish what they deem available for appropriation, which would take into account the regulatory, institutional, and legal considerations that are present within the basin. Regulatory considerations include environmental constraints such as minimum instream flow requirements and special management areas. The agency may also wish to elaborate on the different types and relative proportions of different water uses within the basin. These sets of data, which span natural and human uses of water, and include physical, institutional, environmental and legal considerations, will be published and updated via WaDE and will allow integrated water resource management modelers access to the best available information for their modeling efforts.

Finally, one of the primary goals for the WSWC member states and the WGA is to encourage other curators of water data, including the many federal agencies that have water related efforts in the West, to provide easier access. Publication of federal agency data and incorporation of their "dataflows" into a centralized location such as WaDE would facilitate the day-to-day tasks of state and academic researchers and hydrologists. A number of outreach visits were conducted during the initial phase of the WaDE project to encourage federal agencies to begin to share their data using web services and standardized data schemas. A full implementation of the WaDE project will increase the availability of water quantity-related information from state, federal, and other governmental agency partners.

## Governance

The Water Information and Data Subcommittee (Subcommittee) was formed under the direction of the Water Resources Committee of the WSWC. The Subcommittee is comprised of representatives from the states and federal agencies. The Water Resources Committee approved a proposal sponsored by the Subcommittee to begin building the framework that would eventually become the WaDE project. They also agreed to create four workgroups under the direction of the Subcommittee. These four workgroups continue to lay the groundwork for the development of the data exchange and function as its primary governance bodies:

1. State Capabilities Assessment Workgroup: Evaluates the current capabilities of the western states with regard to water allocation, supply and demand data, as well as their current methods of publishing data and their respective IT environments.
2. Methods Workgroup: Documents existing methods and science for estimating targeted water planning data, such as water availability and consumptive use and related definitions.
3. Data Exchange Template (Schema Development) Workgroup: Identifies and defines the data elements necessary for exchanging targeted water data. Using the data elements as a guide, the group refines the data exchange schema (a standard format proposed for the data using eXtensible Markup Language (XML)) that reflects the relationships of the data.
4. Data Exchange Methodology Workgroup: Reviews the existing field of data exchange technologies, evaluates existing state, federal, and academic data exchange collaborations, and makes recommendations for technological approaches.

The activities of the four workgroups and the coordination and reporting for the WaDE project in general are coordinated by the WSWC.

## Outreach, Participation, and Data Schema Review

Site visits to 15 of the 18 member western states were conducted to explain the WaDE project to state agency staff, garner support, and to define and refine the data schema originally developed by the Data Exchange Template Workgroup. Several federal agencies, including the Natural Resource Conservation Service, the Bureau of Reclamation, and the U.S. Geological Survey, were also visited to discuss the adoption of a common format for publishing data controlled by their respective offices, which would greatly improve state agency access and facilitate their water planning processes. The site visits resulted in broad support of the project and several adjustments to the proposed data schema, such that it would provide a better "fit" for more state agency data. These included semantic changes to accommodate what the states defined as "available water," as well as determining a hierarchy among data elements or relationships utilized by the states within the databases that house their information. Some information that had not been deemed relevant was re-introduced into the schema, while some data elements originally thought to be important were removed.

## Categories of Data

There are two categories of data targeted for publication by the WaDE project. Both require a different solution for the implementation in the exchange. Phase 1 of the WaDE project targets the first category of data, termed "derived" or "value added" data. These can be described as data that are not direct measurements, but rather reflect interpretations, evaluations, models, or decisions based on other datasets. Examples include water availability summaries or metrics (e.g., an evaluation of the actual or relative volume of water that may be available for a given timeframe within a watershed or other delineation), water use summaries (including a breakdown by beneficial use category or sector), water appropriations (including water rights/permit owners, legal status, priority dates, volumes or flow rates for a given timeframe), regulatory information, and general water planning data. "Derived" data products are usually generated from other datasets, such as a streamgage time series, reservoir storage stage, or meteorological data, to arrive at a conclusion. An important piece of information that must be captured for "derived" data is the methodology used by the agency to arrive at their final calculation so that others can understand the context of that estimate. WaDE workgroup members determined that this category of data would benefit the states more directly and immediately, and gave it priority over Phase 2.

Phase 2 of the WaDE project involves the incorporation of a second category of data, termed "measured" data, i.e. a dataset containing measurements of some parameter taken over a period of time. Although some measurements may still be derived from other measured values, they can be quantified as a specific measurement at a specific time, which can be evaluated along with other measurements over that same time period. Examples of data that fit within this category include streamgage data, groundwater level, snow depth, reservoir elevation, and precipitation data. Recommendations from WaDE workgroup members concerning "measured" data are based on recent work conducted by the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUASHI). CUASHI has established a framework for hydrologic measurement data called Water Mark-up Language, widely known as WaterML, to transfer hydrologic measurement and sensor data using a common format (Open Geospatial Consortium 2007). Recognizing that much of the state and federal data that would be shared within the WaDE framework would be of this category, workgroup members recommended that the WSWC's state and federal partners be encouraged to adopt the WaterML 2.0 schema – the most recent Open Geospatial Consortium approved version – in preparation for Phase 2.

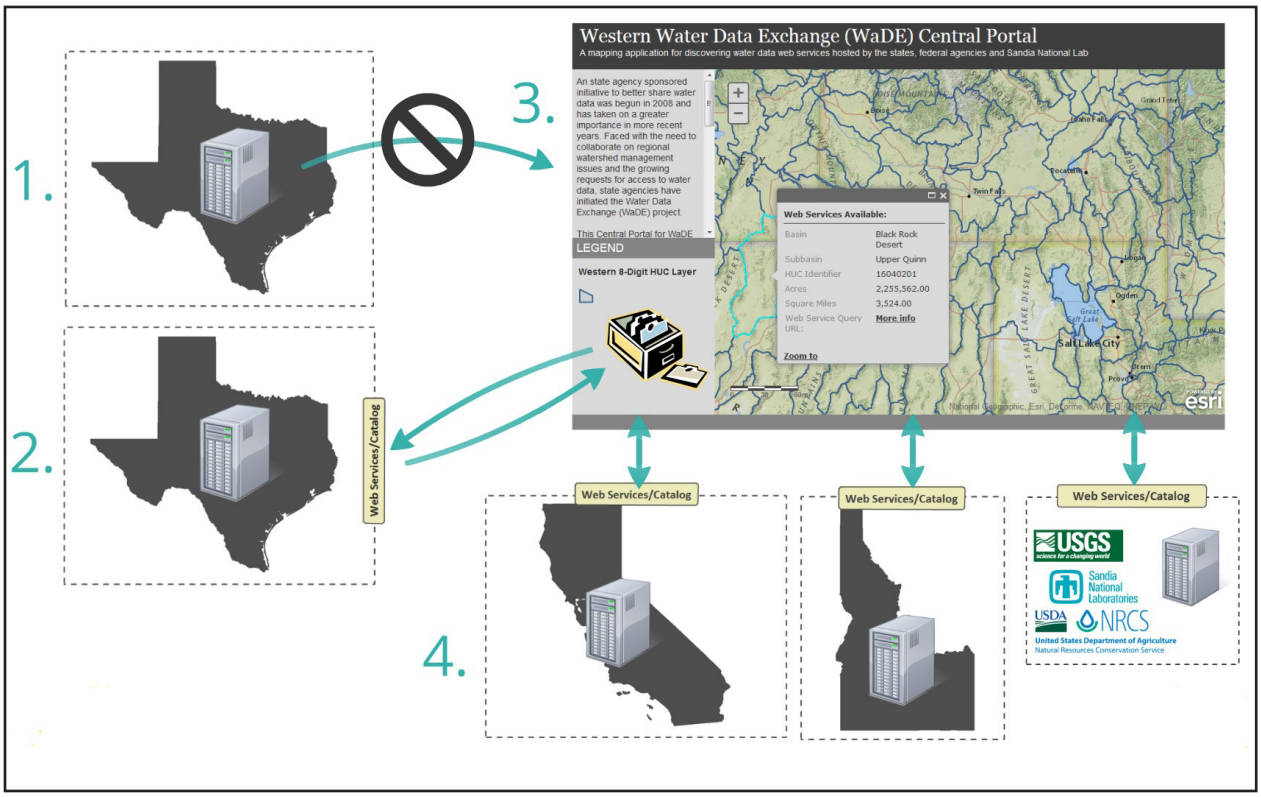


**Figure 1.** Conceptual Framework of the Water Data Exchange (WaDE).

## System Design

WaDE employs an innovative, distributed database framework, wherein partners control and maintain their datasets locally (ensuring that published data are the best available), while making them discoverable via a centralized web mapping application using web service requests. When a client requests a set of data, they are transferred using platform-independent XML, which can be directly incorporated into models and modeling software. It provides a state-to-state, state-to-fed, fed-to-state data exchange that is entirely open and accessible to the public. The design of the system is such that data flows in either an automated, computer-to-computer fashion or as requested. Data owners or partners control what data are shared and oversee quality control of published estimates. Participants benefit by being able to access other agency data, while having their own published in a common format via web service using a centralized data portal, which facilitates data discovery.

Figure 1 is a conceptual diagram of the WaDE system architecture. Partners that supply data to the WaDE interface will include state and federal partners, as well as organizations that house significant datasets dealing with water planning or management. The data exchange design has some key components:

1. Each state operates a "node" on the exchange network infrastructure that is based on their in-house databases. Databases are *not* transferred away from any state agency; instead, nodes respond in the same manner when queried with a web browser address of the same format. This arrangement allows the WaDE retrieval system to query all relevant nodes at once without having to build a custom interface for each. Nodes also manage security and access to the data. Node databases and software need not be identical as long as the responses are similar.
2. Each state maintains both a core set of defined web services as well as a "catalog" of the data housed within the node. The use of a catalog allows other partners to be able to discover data without having to search through entire datasets. Once a

user has narrowed in on the data that they want via the catalog, it can be used as a gateway to retrieve what is available on a particular node.

3. The WaDE Central Portal with a corresponding centralized catalog has the ability to consume the summary information available in partner catalogs, display that information on a searchable map interface, compile a user's request for specific data, request the data from the respective nodes, and return a report or dataset to the user. The portal is a key piece in demonstrating the value of the data flow. The central catalog would allow the portal to perform quickly, for ease-of-use by the client.
4. As more partners deploy the WaDE database and enable their web services, the value of the information shared and the ability to perform a more regional analysis also grows. As Phase 2 begins, federal partners also begin to share their datasets using web services that can be accessed from the WaDE Central Portal.

Based on feedback gathered during outreach visits and reviews within the workgroups, the WSWC has developed a preliminary draft schema and defined services that their state partners will implement as they plug into the WaDE framework (WaDE schema version 0.2). As the components are deployed by each partner agency, suggested changes to the schema will be documented and evaluated by the workgroups for incorporation into the next official schema version.

## Types of Services

After a careful evaluation of many options and approaches for sharing data, WSWC and its workgroups made the recommendation to use a combination of Representational State Transfer (REST) and Simple Object Access Protocol (SOAP) web services for the exchange of information between partners (WSWC 2012). The majority of the web services will be shared using REST, with some SOAP services as needed to gather information about participating nodes and to retrieve information about data available at each node. Both the SOAP and the REST services offered by WaDE are modeled after and adhere to the specifications for services used by the Environmental Protection Agency's (EPA) National Environmental Information Exchange Network (NEIEN) program (NEIEN 2010, 2012).

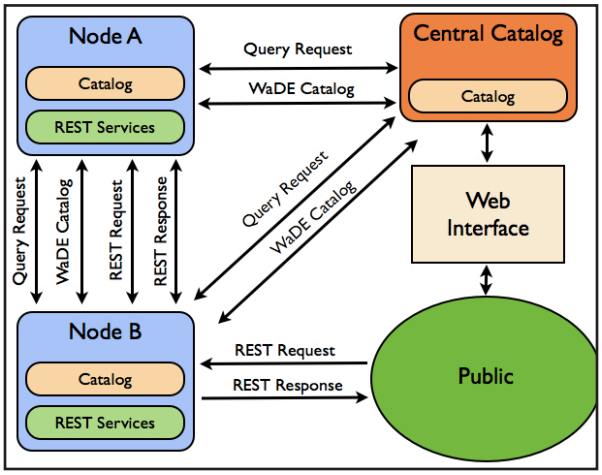


**Figure 2.** WaDE Web Service Types between Nodes.

Figure 2 provides examples of transactions between nodes, the public, and the central catalog that would require either REST or SOAP.

## Publishing and Discovery via the Central Portal

Easy access and discovery of water-related datasets is of paramount importance. A major step of the WaDE project was to build a prototype web-mapping application to access the results from the Sandia study and other sample data gathered from state agencies. The prototype used REST-based URL requests to query databases residing at an emulated node. The queries were returned to the user by super-imposing web browser stylesheets over the returned raw XML data for human readability. This Central Portal demonstration was created to show how the different components that comprise the WaDE system function together to provide the user with an easy-to-navigate and responsive dashboard-like interface.

Figure 3 is a screenshot of the prototype application, showing some of the Sandia results and the sample state-hosted data side-by-side. The WSWC anticipates continued refinement and customization of the interface as more and more states are brought into the data exchange.

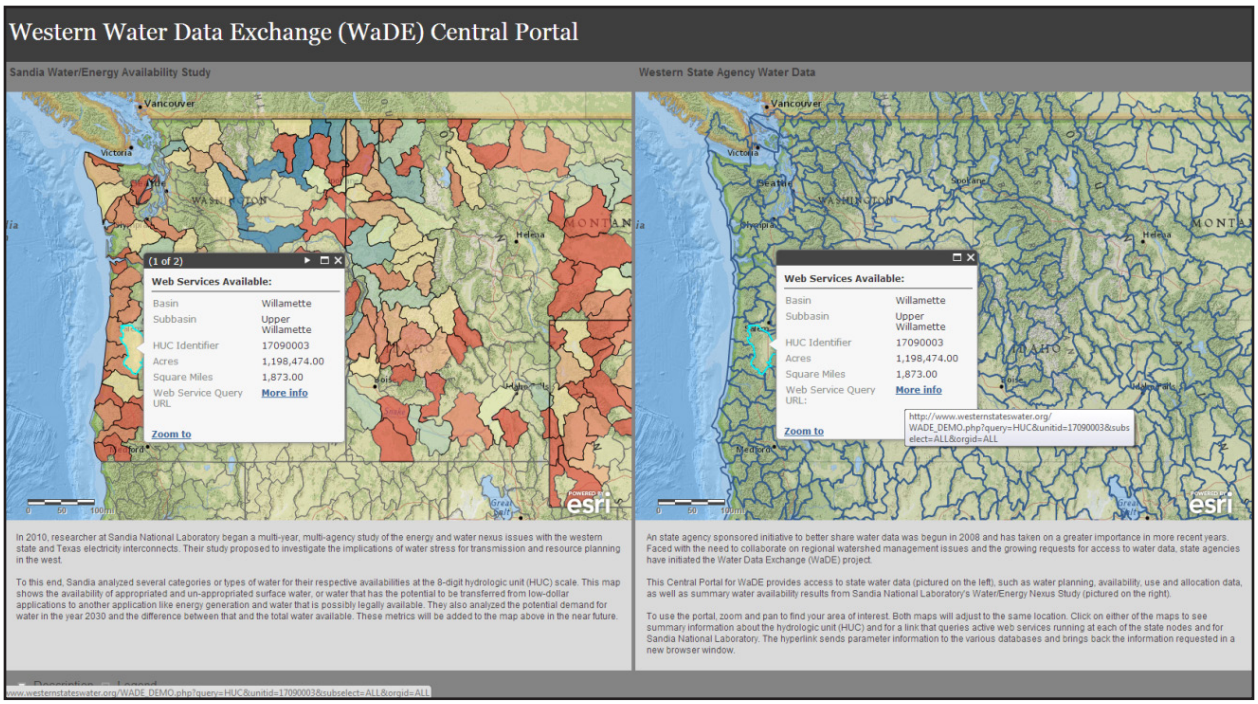


**Figure 3.** Prototype WaDE Central Portal Application.

## Potential Data Challenges

One of the greatest challenges to a full implementation of WaDE was identified during both the outreach visits and the work conducted by the State Capabilities Assessment Workgroup. The primary hurdle for WaDE is the lack of consistent sets of summary-level water planning data targeted by the schema that are generated on a complete spatial (statewide) and temporal (seasonal/annual) scale and interval. A goal of the Sandia study was to generate a Westwide snapshot of water availability based on a uniform hydrologic basin scale and the best available state data. When the Sandia team began to contact the state water agencies for the necessary information,they found a wide variety of outputs and methods, most of which only covered certain portions of the state or that were generated for different timeframes. This led to the use of water "metrics" that utilize state-generated data when available, but defaulted to a streamgage/streamflow analysis of water availability when it was not. However, physical presence of water flowing in a stream in the watershed is not necessarily an indicator of water availability. There are many other considerations for permitting, including the institutional and legal limitations, the public interest, and environmental considerations such as instream flow requirements and endangered species habitat.

Another limitation is simply that some states define the term "water availability" differently. Most of the states use the term water availability when referring to a series of tasks performed during the permitting process, which is usually ad hoc and site-specific.

There are also spatial and temporal differences between state water planning programs. Most of the states that summarize their water supply, availability, or water use data optimize the process by using their own planning program delineations that have been used by the agency since their early basin analyses. The state may use hydrologic unit codes (HUCs), counties, regional planning areas, or some combination of these for summarizing information depending on how the planning program has evolved over the years. Most of the states use a variation of a hydrologic basin with an additional customization of administrative or jurisdictional boundaries. The states that use more refined watershed delineations have the ability to aggregate their data to a larger scale, but the reverse is not always the case. The states also use

differing timeframes for summarizing their data – some on a monthly basis, some use a calendar year, and others use the traditional "water year."

Each state has a specific methodology for estimating their important figures such as physical supply, legal availability, and water use data. They also have their own models for capturing water permitting/rights data. Some states use the drought of record to decide whether water can be appropriated, others use statistical analyses. Some use sophisticated decision support tools to support their appropriations while others generate hydrologic models to review applications on a case-by-case basis. This is one of the reasons why the WaDE portal, at the current time, allows for data discovery using custom delineations used by the states, but does not apply any internal shading or coloring. It is also one of the reasons why each estimate is closely accompanied by metadata that describe the method from which the value was derived. Given these differences in approach, a primary concern for the development of the WaDE portal is to impose a strong end-use agreement or disclaimer that informs incoming clients that different states (or potentially even regions within a state) are using different methods to create estimated values. It is the intention of the WaDE program to portray the data and methods that the states currently have, while also pointing the state agencies in a direction that will help to create a more uniform and spatially complete picture of water availability and use in the west in the future. Discussions among the various workgroups and amongst WSWC members regarding the adoption of a common Westwide water availability metric and methodology are ongoing. Until that time, WaDE will serve as a template for state agencies when they are evaluating their programs or considering new data products.

## Conclusion

Whether addressing population growth, national security, drought, climate change, or meeting our growing energy needs, questions surrounding water availability in the west will increase and become more important in the coming years. WaDE allows its partners to share and publish important water planning and use data and methods to their customers easily, and in a common, defined format that minimizes the difficulties and costs of data collection. WaDE will also dovetail with other ongoing national water efforts, such as the U.S. Geological Survey's National Water Census, positioning the states to proactively provide water use estimates and other necessary data. Other potential customers of the data exchange range from large organizations such as the Government Accountability Office, with their recent water-energy nexus work, and the Department of Energy, to research institutions, non-governmental organizations, the EPA, water district managers, and even farmers, journalists, and politicians concerned about ongoing drought. The accomplishment of Phase 1 of the WaDE project will be a major step toward improved access to "derived" data products like water availability and use summaries, while Phase 2 will provide greater access and discoverability to "measured" hydrologic measurement data. Finally, the tangible step of sharing water data and methodologies between state agencies signals a paradigm shift toward more cooperative and collaborative regional watershed and water resource management.

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## References

Alley, W.M., E.J. Evenson et al. 2013. *Progress Toward Establishing a National Assessment of Water* Availability and Use: U.S. Geological Survey Circular 1384, 34.

Federal Interagency Panel on Climate Change and Water Data and Information. 2011. *Report to Congress – Strengthening the Scientific Understanding of Climate Change Impacts on Freshwater Resources of the United States*, 49.

National Environmental Information Exchange Network (NEIEN). 2010. *Data Exchange Design Rules and Conventions (EDRC) for the Exchange Network*. Available at http://www.exchangenetwork.net/exchange-design-rules-and-conventions-edrcs/.

National Environmental Information Exchange Network (NEIEN). 2012. *Exchange Network REST Guidance: Optimize Your REST Services and Simplify Their Usability*. Available at http://www.exchangenetwork.net/news/en-governance-releases-rest-guidance/.

Open Geospatial Consortium (OGC). 2007. *CUAHSI WaterML*. Available at http://portal.opengeospatial.org/files/?artifact_id=21743.

Tidwell, V., et al. 2014. *Mapping Water Availability and Cost in the Western United States*. Available at http://energy.sandia.gov/?page_id=1741.

Western States Water Council (WSWC). 2012. *WaDE Flow Configuration Document*. Available at http://www.westernstateswater.org/wp-content/uploads/2012/11/WADE_FCD_v02.pdf.

Western Governors' Association (WGA). 2006. *Water Needs and Strategies for a Sustainable Future*. Available at http://www.westgov.org/reports/doc_download/83-water-needs-and-strategies-for-a-sustainable-future.

Western Governors' Association (WGA). 2008. *Water Needs and Strategies for a Sustainable Future: Next Steps*. Available at http://www.westgov.org/wswc/water%20needs%20&%20strategies-6%2708%20final.pdf.

Western States Federal Agency Support Team (WestFAST). 2012. *WestFAST Agencies: 2012 Work Plan*. Available at http://www.westgov.org/wswc/westfast/workplan/westfast_2012_workplan.pdf.