Western States Water Survey Report

Survey of Data Collection Practices for Water Resource Monitoring and Water Use in the Western States

October 8, 2024

Table of Contents

Table of Figures

Appendices

Executive Summary

As an attempt to learn more about water resource management strategies and technologies throughout the western states, the North Dakota Department of Water Resources (NDDWR) hired HDR Engineering Inc. (HDR) to engage with water resources agencies across the 17 western states. Agencies were contacted regarding the data collection methodologies and practices that each state deploys for water resource monitoring and water use.

HDR developed a survey in coordination with NDDWR staff and posted the survey via Jotform from April 26, 2024, to June 7, 2024. A total of 126 individuals and 68 agencies were contacted with the request to complete the survey. Each of the 17 western states are represented in the results through responses from 33 individuals from 28 different agencies. Throughout this report, states are referenced by their standard abbreviations.

The survey has limitations due to the small sample size of 33 respondents, which may introduce response bias and miss key viewpoints from other agency representatives who were either unaware of the survey invitation or unable to participate. Despite these issues, the survey provides broad geographical representation, capturing diverse perspectives from all 17 western states.

Based on the survey responses, many of the same issues regarding water resources data exist within most of the western states. A section dedicated to key takeaways and recommendations was developed as part of this report.

Based on the results of the survey, the following key takeaways were developed:

1. Many survey respondents using automated data noted the challenge of ensuring quality control.

2. Many survey respondents highlighted a significant challenge related to the lack of coordination and consistency in data collection and storage across various agencies. The lack of coordination and consistency results in similar data being collected using different methods, formats, or standards. This leads to difficulties utilizing the data in a meaningful way and in many cases creates inefficiencies in establishing state-wide data networks.

3. The results of the survey and research completed by HDR suggest that soil moisture monitoring is conducted by many agencies using many different technologies. Soil moisture data collaboration would benefit multiple agencies including water quality, climatologists, agriculture, and those concerned with water quantity.

4. The results suggest that machine learning or artificial intelligence (AI) has not been widely adopted and there are some ongoing efforts to expand their use.

Based on the results of the survey, the following recommendations were developed:

- **Explore Telemetry Technologies:** Multiple survey responses acknowledged difficulties in guaranteeing the accuracy of water use information provided by individual water users. To address this problem, many states require meter and telemetry devices on points of diversion for certain water use types. It is recommended that ND meet with agencies from other states to discuss their meter/telemetry requirements to learn on methods to improve ND meter and telemetry system (MTS).

- **Adopt AI and Machine Learning Technologies:** Predictive Analytics, among other machine learning techniques, can be used to ensure data quality and indicate anomalies occurring within an existing time series. This could be specifically useful for flow, stage, or any water use data. AI technologies may be in development that could assist in the same fields by reducing human quality control (QC) times and identifying the state of data inaccuracies or shifts in water use. It is recommended that DWR investigate Predictive Analytics and AI technologies for time series data QC.

- **Enhance Multi-Agency Collaboration:** To address the challenges in collecting, verifying, and disseminating data, it is recommended that ND, led by DWR, create a working group regarding water resource-related data. With universities, federal, and state agencies collecting similar datasets, creating a working group to discuss these efforts is warranted. The working group could help the state identify all datasets being collected within its borders, technologies currently being utilized to collect the data, data gaps, and where the datasets are housed. Findings of this working group will likely lead to significant improvement of water data collection within the state. This working group could then work to establish a path forward for data centralization. Universities and agencies that could be included in this working group are included within the Recommendations section.

- **Advance Data Centralization:** By aligning efforts and sharing datasets, agencies could improve the comprehensiveness and utility of water data collection. Following creation of a North Dakota-led, multiagency working group on data collection, the development of a network of networks could take place to work toward data centralization. In many instances, the necessary data needed for decision-making exists across various agencies and websites, making the development of a network of networks extremely useful. This data could be centralized in DWR's MapService, ND Dept of Emergency Services Watch Center, or another similar platform.

- **Confirm National Soil Moisture Network Data:** Following full identification of ND's soil moisture monitoring, ND should work with the team administering the National Soil Moisture Network (National Soil Moisture Network), to ensure that all of ND's data is included in their network. This research is being done to gather information which may be beneficial for the state in the future.

- **Review Resources:** Many survey respondents acknowledged that collecting, verifying, and disseminating data is both costly and labor intensive. To support ongoing data expansion efforts, ND should continue to review resource needs and opportunities for efficiencies as the network is expanded. This will help manage the demands of data handling and ensure the sustainability of these efforts.

Introduction

North Dakota uses Pushing Remote Sensors (**PRESENS**), a system set up to deliver environmental data, including flow and stage, to public databases at the North Dakota Department of Water Resources. The system uses cutting-edge sensor technology to ensure accuracy and integrity of collected data, which helps ND make informed decisions regarding water resource development, planning, and appropriation throughout the state.

To gain additional insights into other effective water data collection methods, the NDDWR hired HDR to engage with water resources agencies in 17 western states regarding the data collection methodologies and practices that each state deploys for water resource monitoring and water use. **Figure 1** illustrates the states surveyed as part of the project.

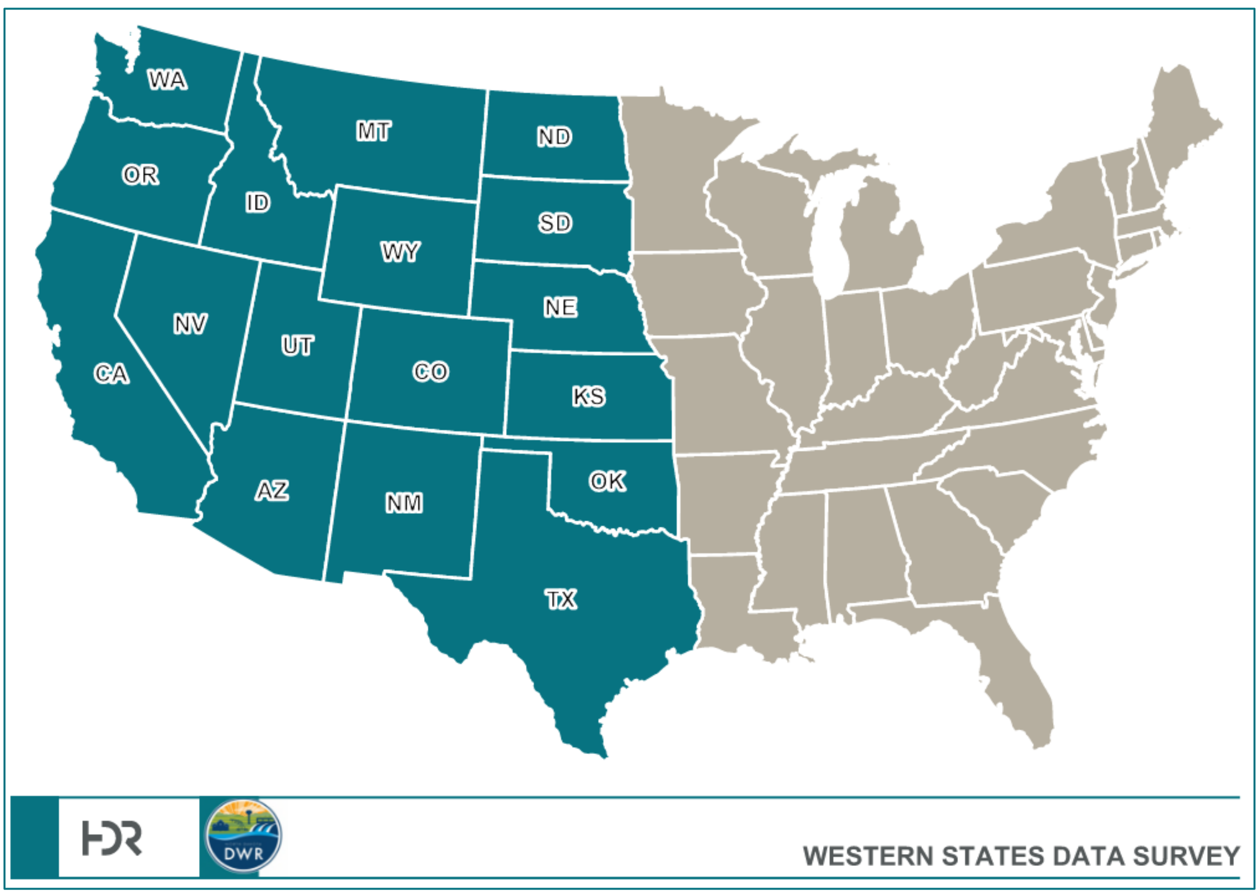

Figure 1. Surveyed States.

The goals of the survey were to identify the methods for collecting real-time and near real-time data and identify technology platforms that are currently used for this purpose, with a specific emphasis on water use data and pumping activities. This information is crucial not only to understand the processes used to maintain the accuracy and integrity of data collection, but also to improve the state's water data management practices. Tasks identified within the project included developing a web-based survey, administering the survey, and creating a report that includes recommendations on how to improve water resource monitoring in the state of North Dakota based on the survey results.

Survey Development

NDDWR and HDR worked collaboratively on developing the survey. NDDWR staff identified categories for survey questions to address:

- water use
- water chemistry
- atmospheric/climatic/soil data
- water flow (discharge)
- stage data (surface and ground water levels)
- artificial intelligence and predictive modeling

Survey questions were drafted in collaboration with NDDWR. The final survey questions are available as part of this report in **Appendix A**.

HDR administered the survey via Jotform, an online service that allows for online form creation. Jotform creates a unique link with the ability to save and exit at any point during the survey. The survey was initially sent to potential contacts via email, with additional follow-up conversations as necessary to encourage participation.

Survey Results

HDR compiled a contact list for the survey by using previously developed contact lists through the Association of Western State Engineers, the National Water Resources Association, and online searches of water use agencies. The survey was sent to 45 individuals, including at least two points of contact for each state. The survey was sent on April 26, 2024, with a request for contacts to participate in the survey or to forward the survey as appropriate. The contacts were requested to complete the survey by May 24, 2024.

Throughout the survey duration, HDR continued to expand on the contact list using references from HDR colleagues, additional contact information provided from survey respondents, and internet searches of agency contact pages. Additionally, state climatologists were added to the survey emails to help fill in information about atmospheric/climatic/soil data. Following requests from several states and in coordination with the NDDWR, the survey closing date was extended until June 7, 2024.

Survey results greatly depended on who was contacted from each state and their expertise level or ability to pass the survey on to colleagues with more suitable experience. In total, HDR reached out to 126 individuals across 68 agencies. All 17 western states were represented in the results through responses from 33 individuals from 28 different agencies. Readers should note that survey results may not be accurate state representations, as responses are submitted by individuals, and that empty columns on numeric figures represent “no response received”. The raw survey responses are available as part of this report in **Appendix B**.

Respondents

In total, 33 unique individuals from 28 agencies responded to the survey from all 17 western states. NDDWR was given a spreadsheet of survey results and individual PDF documents for all survey respondents. In some states, a complete survey response was not obtained. The most complete survey responses came from ND, CA, CO, NV, OK, and WA.

There are some limitations to the survey. With a sample size of only 33 respondents, there is a risk of response bias since the data may not fully represent the perspectives of non-respondents or those unable to participate. Despite including responses from various agencies, key viewpoints from other important representatives might be missing if they were unaware of the survey invitation or unable to respond.

Nonetheless, the survey has several notable benefits. It achieved broad geographical representation by including responses from all 17 western states, which is essential for capturing a diverse range of perspectives. The insights from the 33 respondents contribute to a rich and applicable data set.

The variety of viewpoints influences the discussion of survey results in two main ways: 1. Discussions of an agency’s water data collection practices closely follow the respondent’s language to avoid inferring details not explicitly provided. This may result in varied descriptions of methods where more consistent terminology could be beneficial. 2. The survey highlights overarching trends rather than providing a state-by-state analysis, offering a comprehensive overview of water data collection practices. State-specific examples are included where relevant, with additional details found in Appendix B.

Water Appropriation (Water Use)

Based on NDDWR discussions, the survey largely was based on questions regarding water use data collection and monitoring. Questions 1 through 6 focused directly on water use data collection, storage, and public dissemination.

Water Use Data Collection

Question 1 asked if each state currently collects water use data. It also contained a series of subsections asking how many groundwater and surface water sites are used, if remote data collection or manual self-reporting methods are being used, and about the advantages and challenges of these collection methods. Survey respondents from all states indicated that they collect water use data, with the exception of respondents from MT, shown in **Figure 2.** This information was verified by HDR staff.

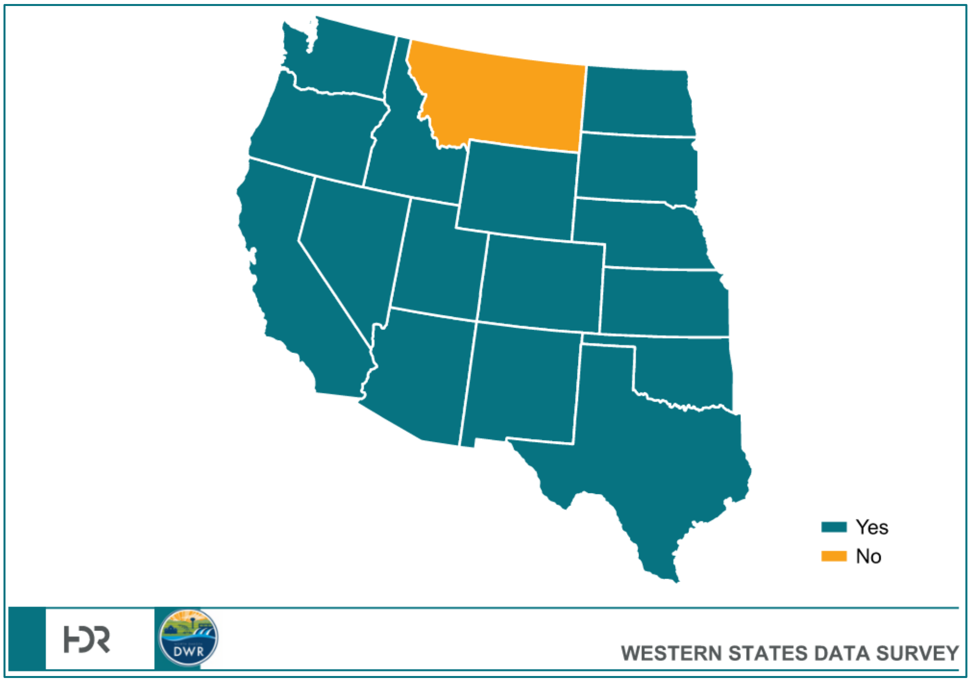

Figure 2. Does your state currently collect water use data?

WATER USE DATA COLLECTION SITES

Respondents provided the number of sites or points of diversion (PODs) that are monitored for water withdrawals for surface water and groundwater uses in Questions 1A and 1B, respectively. Survey respondents from CA reported the highest number of surface water sites/PODs that are monitored for water withdrawals (41,000) while respondents from KS reported the highest number of groundwater sites/PODs (36,000).

Questions 1Cii and 1Cvii asked how many PODs are equipped for automatic and manual data collection, respectively. Survey respondents from CO reported 12,000 PODs equipped with automatic data collection, and all 53,500 PODs in the state are equipped for manual data collection, the highest totals for both methods among all the 17 states represented in the survey.

The responses from these four questions are illustrated in **Figure 3** below. If multiple responses were received per state, online verification was utilized to determine the correct response. If online verification was unsuccessful, the highest response was utilized for the graphic. This approach was taken to handle conflicting numeric responses in all areas of the survey.

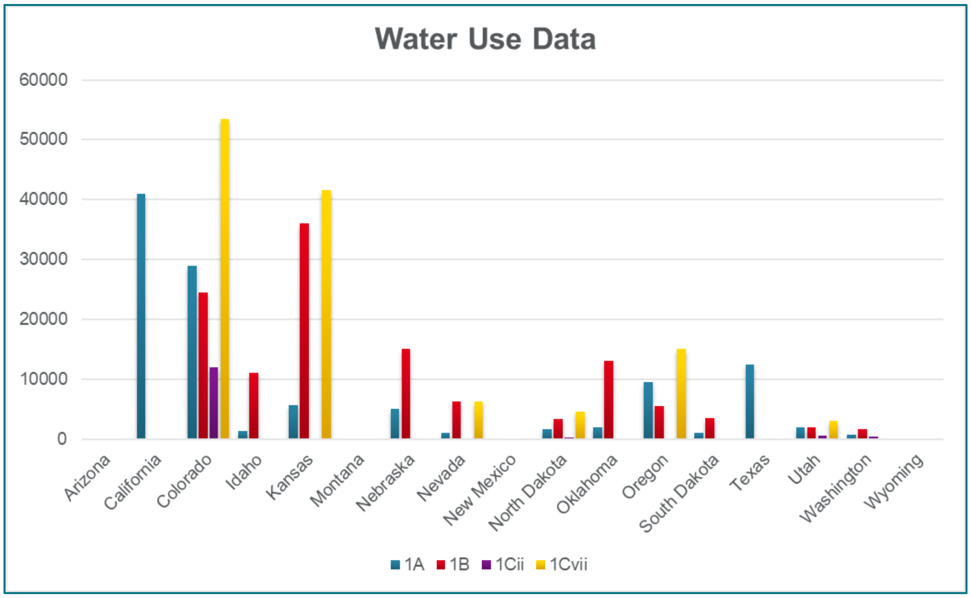

Figure 3. 1A) How many surface water sites/PODs/locations are monitored for water withdrawals?
1B) How many groundwater sites/PODs/locations are monitored for water withdrawals?
1Cii) How many sites/PODs/locations are equipped for automatic data collection?
1Cvii) How many sites/PODs/locations are equipped for manual data collection?
**States not accompanied by a bar indicate that the state did not respond to the respective question. It does not indicate a value of 0 unless otherwise noted.*

WATER USE DATA COLLECTION METHODS

Question 1C asked respondents if their state uses automatic or manual technologies to collect water use information. Survey respondents from WY did not answer this section. Of the 16 states represented through responses, 10 utilize automatic data collection methods. Those states include AZ, CA, CO, ID, NE, NM, ND, TX, UT, WA. Respondents from all responding states indicate that they utilize manual data collection methods, with the exception of MT.

AUTOMATIC WATER USE DATA COLLECTION METHODS

Question 1Ci focused on automatic data collection technologies. Respondents from CO indicated that they use cellular modems that upload data directly to their REST API proprietary software or is requested from Sutron AutoPoll. Data is also collected from other entities using REST API or web services. They also use stage discharge recorders connected to satellite (GOES). It was reported that their remote data collection network has not extended into groundwater, other than monitoring wells. This is consistent with other responses, indicating that remote data collection technologies are more widely used for surface water data collection, rather than groundwater. They also indicated that currently 30-50% of their surface water monitoring sites are equipped with remote sensors and that the state is pushing to expand their remote monitoring network.

Respondents from both NE and NM indicated that local entities, such as natural resource districts or irrigation districts, aid in collecting water use information throughout the state. The respondent from NE also indicated that surface water data is collected for all canal diversions using mainly Sutron equipment. The respondent from NM indicated the methods to collect surface and groundwater data varies throughout the state. The Lower Rio Grande is monitored using telemetry, while the Middle Rio Grande is monitored using compact flow measurement (combination of gauged flow at various points and human measurement).

Respondents from ND indicated that a combined meter and telemetry system (MTS) is required by the permit holder on any Industrial Water Depot and must produce at least one reading per day to DWR hosted web services. Metering is required for all uses except fish, wildlife and domestic, and recreation. Respondents from TX indicated that water use is reported by the individual water users, many of which have multiple PODs and utilize remote data collection. Respondents from WA also indicate a requirement for water users to monitor and report water usage themselves. Remote radio-head technology is used in one area of the state where water users were required to install meters because remote was less expensive at the time.

Respondents from CA reported using a combination of telemetry devices, such as cellular and satellite, in tandem with manually read meter data. Groundwater use is not formally regulated by the state, but local agencies track basin-scale use and report it annually. The DWR manages remote stream gauge data and has a well-established telemetry system and requirements for their sensors and gauging stations. Respondents from eight states reported the use of telemetry, often in tandem with mechanical meters, making it the most common form of automatic data collection used throughout the study area. All methods reported are listed below.

- Telemetry devices (cell services, satellite, radio, Sutron equipment) – CA, CO, ID, NE, NM, ND, UT, WA
- Flowmeters – NE, ND
- Pressure transducers – CO, ID
- Data loggers – CO, UT
- Radar (downlookers) – CO
- Bubblers – CO
- Acoustic / Acoustic doppler – ID
- Compact flow measurement – Some areas of NM, such as in the Middle Rio Grande

AUTOMATIC WATER USE DATA COLLECTION ADVANTAGES AND CHALLENGES

Question 1Ciii asked about the advantages and challenges associated with the technologies stated in Question 1Ci. Reported advantages and challenges are listed below.

Advantages:

- Large volumes of collected data increase overall knowledge of water use in the state (ND).
- Automatic data collection allows for real-time administration of rivers, increasing efficiency and effectiveness (CO, ID, NM, ND, TX).
- Automatic data collection reduces manual data entry errors, increasing accuracy (WA).
- Automatic collection is easily scalable once the system is operational (ND).
- Automatic data collection provides transparency to water use (UT).
- Remote data collection requires less driving, saving time (CO).
- Real-time data collection allows agencies to have a better understanding of where water withdrawals are occurring (ND).

Challenges:

- There are currently no consistent requirements for diversion telemetry (CA).

- There are high costs associated with service providers, upkeep, and maintenance (CO, ID, NE, NM, UT).
- There are high costs associated with the purchase of proprietary software.
- Automatic data collection sometimes provides difficulty in ensuring data quality (CO, NM, ND).
- Remote areas are a challenge if there is no satellite connection (CO).
- Remote systems can occasionally experience long downtimes associated with system failures, software bugs, and infrastructure issues (CO, ND).
- Remote collection still requires occasional travel for startup and to check on equipment (CO, NM, UT, WA).
- Agencies have to make sure the staff understands the equipment (ID, NM, ND).

AUTOMATIC WATER USE DATA COLLECTION ACCURACY

Question 1Civ asked what methods have been implemented to ensure accuracy and integrity of automatically collected data. Reported methods are listed below.

- Frequent site visits and spot checks by water and well commissioners and agency employees are required (CO, ID, ND).
- Diverters are required to maintain specific measurement devices, with periodic updates required (CA).
- QA/QC checks take place after a period of time to ensure accuracy (CO).
- Data is reviewed by agency staff or water commissioners (CO, ID, NM, ND, UT).
- Groundwater data is collected and verified by Natural Resources Districts (NE).
- Research is done at universities to continually improve data collection technology (NM).
- Water users are required to have a meter and to report their readings to cross check agency readings (TX).
- Staff assumes automatic data is accurate unless the equipment has failed (WA).

FUTURE AUTOMATIC WATER USE DATA COLLECTION METHODS

Question 1Cvii asked what automatic data collection methods are being considered for future use. Reported technologies are listed below.

- Adopting cellular-based technologies to enhance real-time data collection (CA).
- Adding telemetry to include all high hazard dams (NE).
- Expanding telemetry systems to include groundwater monitoring wells to manage aquifer systems more accurately (NE, NM).
- Requiring telemetry systems in situations that require more reliable data (WA).
- Upgrading surface water gauging stations and water diversions to allow for operational decisions to be made in a shorter time, decreasing water waste (NM).
- No future technologies are being considered at this time (CO, TX).

MANUAL WATER USE DATA COLLECTION METHODS

Question 1Cvi focused on manual data collection technologies. Respondents from seven states reported the use of flowmeters, often reported by the water user, making it the most common form of manual data collection used throughout the study area. All methods reported are listed below.

- Self-reporting – CO, KS, NV, ND, OK, OR, SD, TX, UT, WA
- Flowmeters – CO, NV, ND, OK, OR, TX, UT
- Staff gauges – CO, ID
- Ultrasonic flow measurement – NE
- Flumes – CO
- V-notch weirs – CO

MANUAL WATER USE DATA COLLECTION ADVANTAGES AND CHALLENGES

Question 1Cviii asked about the advantages and challenges associated with the methods stated in Question 1Cvi. Respondents from OR noted that adding different reporting and data search options would make it more convenient for water use reporters, such as dropdown menus and allowing pictures, likely leading to higher quality data. Reported advantages and challenges are listed below.

Advantages:

- In-person data collection can provide more context to the data being reported (CO).
- There are minimal maintenance costs associated with low upkeep requirements (ID, OR, UT, WA).
- Self-reporting requires less staff time and saves money (KS, NV).
- Self-reporting builds customer relationships and provides a forum for questions and discussion (NV).
- Self-reporting provides the state with the ability to monitor certain areas and keep a historic record of how much water is being used (ND).

Challenges:

- Manual collection methods provide little consistency of measurement (CA, NE, OK, UT).
- Self-reported data depends on the water user's ability to properly read and maintain meters (KS, ND).
- Misreporting is sometimes a problem with user-reported data (CO, OR, TX).
- Travel to remote locations costs time and money (NV).
- Data accuracy is hard to guarantee between site visits (CO).
- State agencies do not have the staff to check every POD (ID, NE).
- QA/QC and physical verification of reported data are difficult (OR, WA).

MANUAL WATER USE DATA COLLECTION ACCURACY

Question 1Cix asked what methods have been implemented to ensure accuracy and integrity of manually collected data. Reported methods are listed below.

- Water and well commissioners routinely take readings to create annual records as accurately as possible (CO).
- QC checks are used by water commissioners before publishing water use data (CO).
- Staff reviews manually submitted data and contacts water users to correct submitted data (CO, ID, KS, NE, NV, ND, OR, SD, TX, UT, WA).
- Penalties and fines are in place to deter misreporting and failure to report (KS).

- Submitted data is compared to historical records (NV).

FUTURE MANUAL WATER USE DATA COLLECTION METHODS

Question 1Cx asked what manual data collection methods are being considered for future use. One notable response from OR described developing an internal web based application to track completed work and share data collected on items such as groundwater levels, surface water hydrology, well construction locations, and dam safety construction and location. Respondents from most states reported none or to continue with current methods; however, reported improvements are listed below.

- Using more widespread flowmeters to improve accuracy within a larger area (ND).
- Merging new data reporting methods with existing methods can ensure more accurate and efficient collection (NV).
- Requiring statewide self-reporting through administrative mechanisms (NV).
- Requiring statewide metering through administrative mechanisms (OK).
- Implementing internally developed web-based tracking applications (OR).

Water Use Data Management

Questions 2 through 6 focused primarily on how each state stores water use data, serves it to the public, and ensures its accuracy. Based on the responses to Question 2, illustrated in **Figure 4**, a majority of respondents indicated that their agency uses proprietary software and/or state servers to manage and store the collected data. Respondents from NV and NM also reported that their agencies use physical forms and specialized software, respectively.

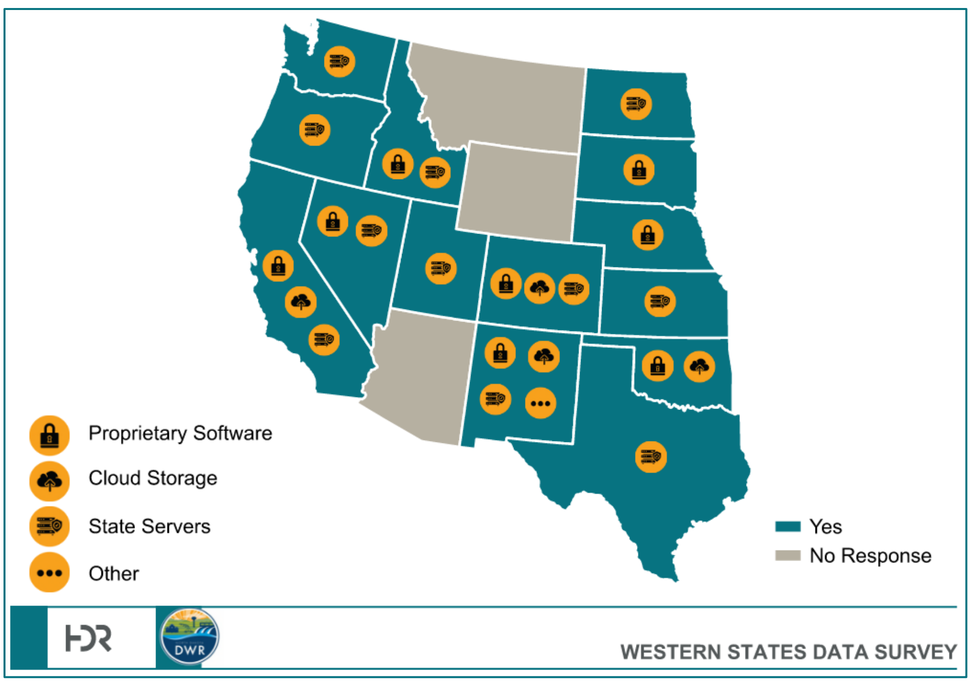

Figure 4. How does your state currently store and manage the collected water use data?

Responses to Question 3, illustrated in **Figure 5**, indicate that proprietary software and state servers will continue to be used for future data management, but more states are looking into cloud storage as an alternative.

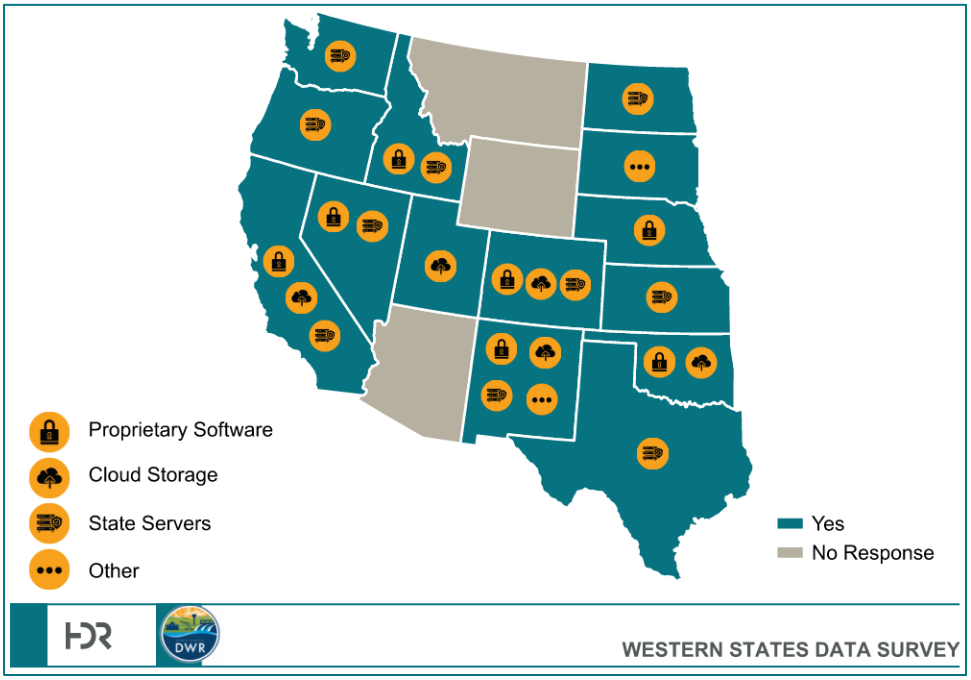

Figure 5. What is your state considering for future storage and management of water use data?

WATER USE DATA ACCESS

Question 4 asked respondents whether their state's water use data was publicly available and Question 4A asked by what means it is available. Responses to Question 4 and Question 4A are shown in **Figure 6**. Respondents from all the states provided a response that indicated that water use data is available to the public. Overall, web-based platforms are the most common method of delivery, but most states also grant access from written requests. Respondents from CA and NM indicate that the public is also allowed to request to review physical copies of data.

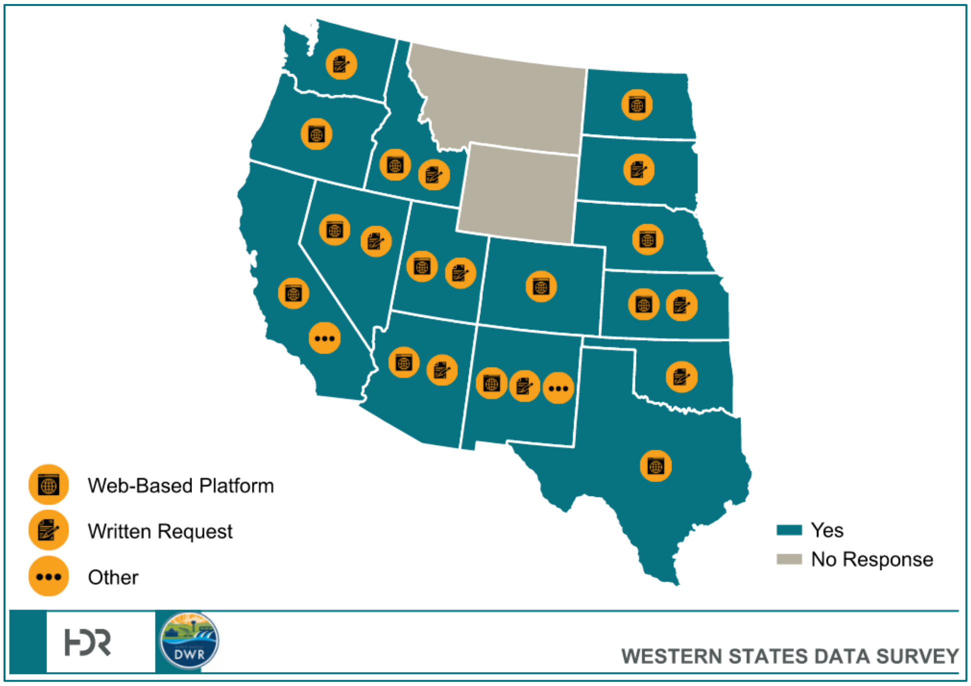

Figure 6. Is collected water use data publicly available? If so, through what means is it available?

WATER USE DATA STORAGE ADVANTAGES AND CHALLENGES

Question 5 asked respondents to describe the advantages and challenges associated with their state's current water use data storage practices. High-level summaries of the advantages and challenges are included below, many of which seem to be the same from state to state.

Advantages:

- Serving water use data from a website provides transparency and makes it easier to distribute (CO, ID, ND, UT).
- Serving the data and building relationships with the public is easy for staff (NV).

Challenges:

- Respondents indicated that provisional data and data accuracy being served readily can prove to be a challenge (CO, OK).
- Data is often available on antiquated systems, making data acquisition difficult (CA, SD).
- The cost to maintain web-based platforms is often overlooked and requires much more staff time than anticipated (ID, ND, OR).
- Some of the data needed to get the full picture on water use is not available in the same platform that the data is being served in (NE, NM, WA). Based on the responses, it is assumed necessary assumptions regarding water availability were not included in the same platform as information on water use.
- Having the data publicly available can present challenges in terms of the public accessing and understanding the information (NV, UT).

One notable challenge provided by respondents from WA is that water rights, which require multiple measuring devices due to the complexity of the water right, can cause issues on knowing exactly whether or not a water right is being met or exceeded. It was noted that a one-to-one relationship between gages and uses significantly reduced the risk of overuse by water users.

WATER USE DATA COLLECTION CHANGES

Question 6 asked respondents what they would change about their state's data collection for more accurate and reliable information regarding water use data. A summary of the responses is provided below.

- Respondents from states that require self-reporting indicated that some level of metering or monitoring would be an improvement to their network (CA, OK, SD).
- Education and collaboration between agencies to help with data sharing and collection (NM, ND).
- Higher frequency of field inspections and verification (ID, NV).
- Technology improvements for telemetry and increasing the amount of telemetry used. One example of a technology upgrade includes switching from battery to solar with rechargeable batteries (CA, ID).
- Database upgrades and requirements on additional metadata (OR, TX, UT, WA).

Water Chemistry

The water chemistry portion of the survey focused primarily on the methodologies states are using to collect, validate, and store surface and groundwater chemistry data.

Water Chemistry Data Collection

Question 7 and its subsections were written to key in on what type of water chemistry data each state is collecting, both surface and subsurface. Respondents in all states indicated that their state collects water chemistry data with the exception of NM as illustrated in **Figure 7.**

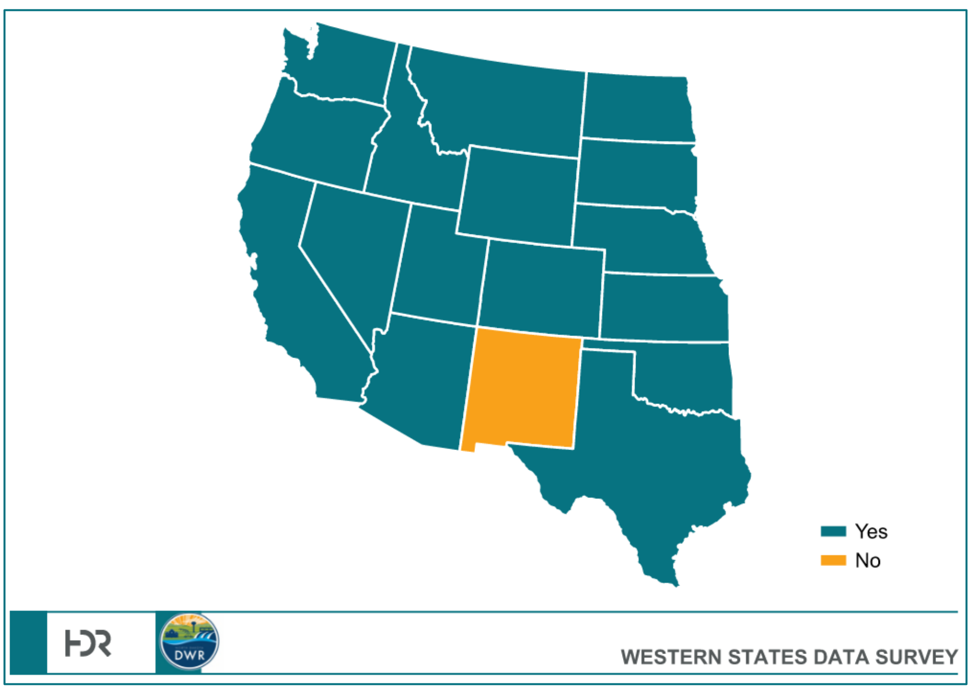

Figure 7. Does your state currently collect water chemistry data?

SURFACE WATER CHEMISTRY DATA COLLECTION

Question 7A focused on what types of surface water chemistry data each state collects. Survey responses indicated that states collect data on constituents associated with the Clean Water Act, with additional constituents as they deem necessary. Collected field meter readings, chemical and biological parameters, pollutants, and project-specific constituents vary by state. Some respondents reported that chemistry data collection within their state varies by waterbody.

SURFACE WATER CHEMISTRY DATA COLLECTION SITES

Questions 7Ai, 7Aii, and 7Aiii focused on the number of surface water chemistry collection sites located within each state, the number of sites operated solely by the United States Geological Survey (USGS), and the number of sites that are funded cooperatively or entirely by state agencies, respectively. Respondents from WA reported zero surface water chemistry sites operated solely by the USGS and OR reported zero sites funded by state entities. Responses to these questions are scaled logarithmically for visual purposes and shown in **Figure 8.**

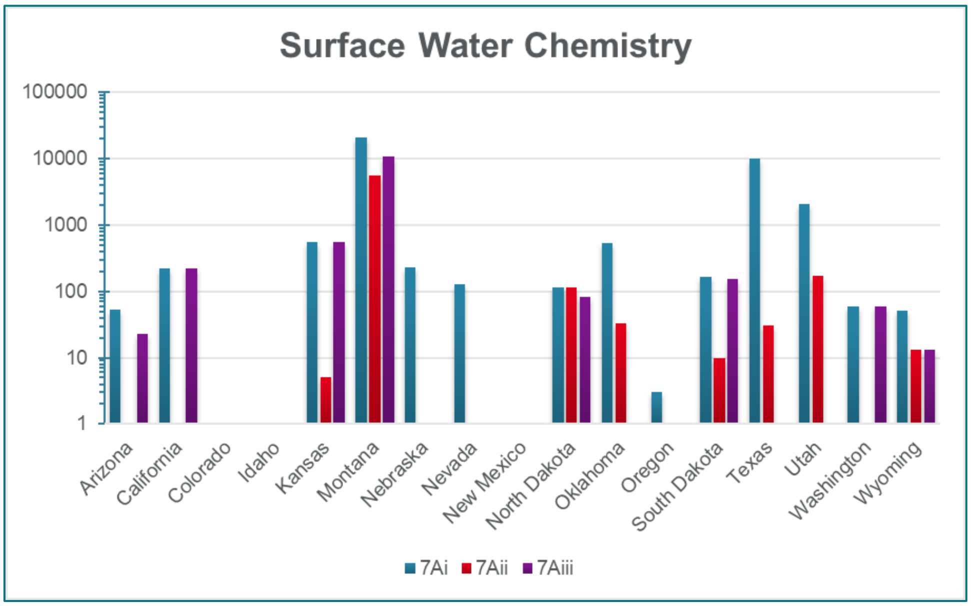

Figure 8. 7Ai) How many surface water chemistry monitoring sites does your state currently have?
7Aii) How many are solely operated by the USGS?
7Aiii) How many are cooperatively or completely funded by state entities?

**States not accompanied by a bar indicate that the state did not respond to the respective question. It does not indicate a value of 0 unless otherwise noted.*

GROUNDWATER CHEMISTRY DATA COLLECTION

Question 7B focused on what types of groundwater chemistry data each state collects. Survey responses indicated that states collect data on constituents associated with the Clean Water Act and the Safe Drinking Water Act, with additional constituents as they deem necessary. Collected field meter readings, chemical and biological parameters, pollutants, and project-specific constituents vary by state. Some respondents reported that chemistry data collection within their state varies by waterbody.

GROUNDWATER CHEMISTRY DATA COLLECTION SITES

Questions 7Bi, 7Bii, and 7Biii focused on the number of groundwater chemistry collection sites located within each state, the number of sites operated solely by the USGS, and the number of sites that are funded cooperatively or entirely by state agencies, respectively. Respondents from AZ, CA, SD, and WY reported zero groundwater chemistry monitoring sites operated solely by the USGS and ND reported zero sites funded by state entities. Responses to these questions are scaled logarithmically for visual purposes and shown in **Figure 9.**

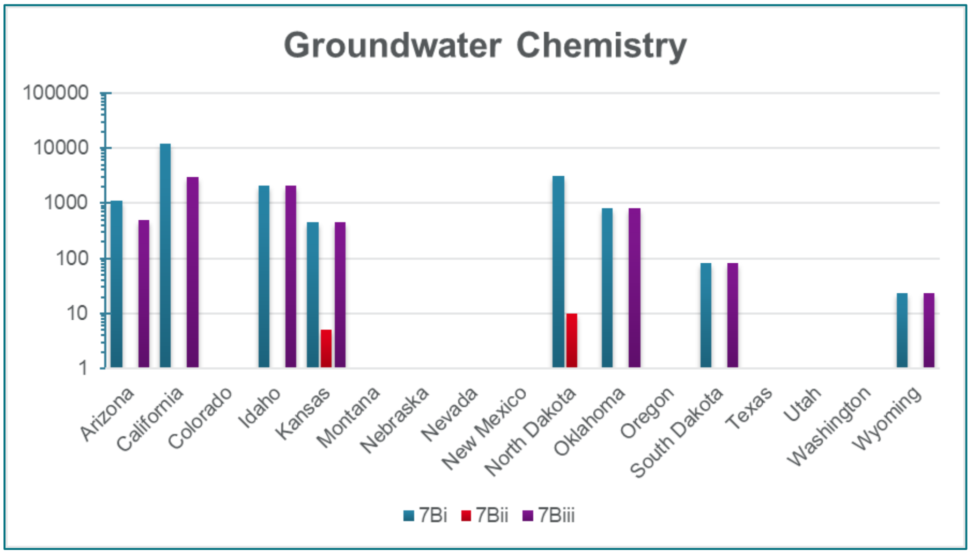

Figure 9. 7Bi) How many groundwater chemistry monitoring sites does your state currently have? 7Bii) How many are solely operated by the USGS? 7Biii) How many are cooperatively or completely funded by state entities?

**States not accompanied by a bar indicate that the state did not respond to the respective question. It does not indicate a value of 0 unless otherwise noted.*

WATER CHEMISTRY DATA COLLECTION METHODS

Question 8 asked what water chemistry data collection methods are currently in use by each state. The most common methods for sampling include grab samples, which may be accompanied by a purging process to ensure accuracy, as well as real-time meters and sensors to grab ambient water conditions. Ambient water conditions include pH, temperature, dissolved oxygen, specific conductance, minerals, nitrate, and other constituents. Reported methods are listed below.

- Grab samples using standard sampling procedures –AZ, CA, ID, MT, ND, OR, SD, WY
- Sensors/sondes – KS, MT, OK, SD, WA, WY
- Field meters – ID, NE, OK, OR, SD
- Grab samples with purging – AZ, ID, OK, SD
- Equal width increment – AZ, MT, WY
- Equal depth increment – AZ, WY
- Depth integrated samplers – MT
- Bailers – OK

AUTOMATIC WATER CHEMISTRY DATA COLLECTION METHODS

Question 8A asked what automatic water chemistry data collection methods are currently in use by each state. Respondents from 15 different states answered this section. Within this group, respondents from five states reported that their agency does not use automatic technologies at all. The most common technologies include telemetry and sensors to grab ambient water conditions. Reported methods are listed below.

- Telemetry – MT, OK, OR, UT
- Sensors/sondes – MT, OK, WA
- USGS stations – KS, TX
- Contractor – AZ, NV
- Data loggers – MT, WA
- Meters – SD

One notable undertaking in the state of Nevada is the development of a tool that detects harmful algal blooms using satellite data provided from National Oceanic and Atmospheric Administration (NOAA).

AUTOMATIC WATER CHEMISTRY DATA COLLECTION ADVANTAGES AND CHALLENGES

Question 8B asked about the advantages and challenges associated with the methods stated in Question 8A. Reported advantages and challenges are listed below.

Advantages:

- Access to real-time data allows for quick decision making (KS, OK).
- System is easy to install and set up (MT).
- Profilers and sensor strings in lakes provides the ability to capture stratification and turn-over events that occur in between sampling events that may be missed otherwise (OK).
- Large amounts of data can be used to develop hydrologic models to evaluate water quality (TX).

Challenges:

- Data is largely collected at a large basin scale, so smaller subwatershed data is generally not available (KS).
- Bottles need to be replaced frequently in automatic data samplers due to low space (MT).
- Programming, troubleshooting, and maintaining new equipment is difficult (OK, TX, UT).
- Sensors have experienced performance problems during high-flow and turbidity events on rivers (WA).

WATER CHEMISTRY DATA COLLECTION ACCURACY

Question 8C asked what methods have been implemented to ensure accuracy and integrity of collected data. Respondents indicated that Standard Operating Procedures and Quality Assurance Plans are developed by states to maintain compliance with regulations. Respondents from SD and UT indicated that they get assistance from universities as well. Reported methods are listed below.

- Data undergoes pre- and post-upload verification by labs, consultant companies, Arizona Department of Environmental Quality (ADEQ) database coordinator, Water Quality database, and the EPA Water Quality Exchange database (AZ).
- Drinking water data is regulated under Title 22 and clean-up sites are state and federally regulated (CA).
- Field checks are conducted to ensure technicians are following standard operating procedure and equipment is calibrated (ID, OK, OR, UT, WY).
- Quality-control samples are grabbed and reviewed. Results that are suspect are flagged. (KS, NE, TX)
- Instrument results are compared with lab-analyzed samples to ensure readings are correct (MT).
- Groundwater databases are reviewed at the end of every season (SD).
- Manually entered data goes through automated validation checks (TX).

FUTURE WATER CHEMISTRY DATA COLLECTION METHODS

Question 9 asked what collection methods are being considered for future use. Respondents from most states reported none or to continue with current methods; however, reported improvements are listed below.

- Increase the scale of pesticide and polyfluoroalkyl substances (PFAS) testing (ID).
- Sample for DNA for biological monitoring (KS).
- Use drones to capture algal coverage types to aid in modeling efforts at sites that require it (MT).
- Expand in-situ sensors to monitor groundwater trends in order to quantify climate impacts on recharge (OR).
- Install nitrate sensors at wells with historically high nitrate levels (SD).
- Explore a replacement for existing database (WA).
- Increase the footprint of current monitoring technologies (ND, UT).

Water Chemistry Data Management

Questions 10 and 11 focused on the storage of water chemistry data, shown in **Figure 10** and **Figure 11**, respectively. The former asks about the current state of storage and the latter asks about future storage plans. Currently, most respondents indicated that their state uses state servers to store their data with proprietary software following closely behind. STORET and WISKI are also used by a couple of states to manage their water chemistry data. In the future, respondents indicated that their state plans to keep its storage practices relatively the same.

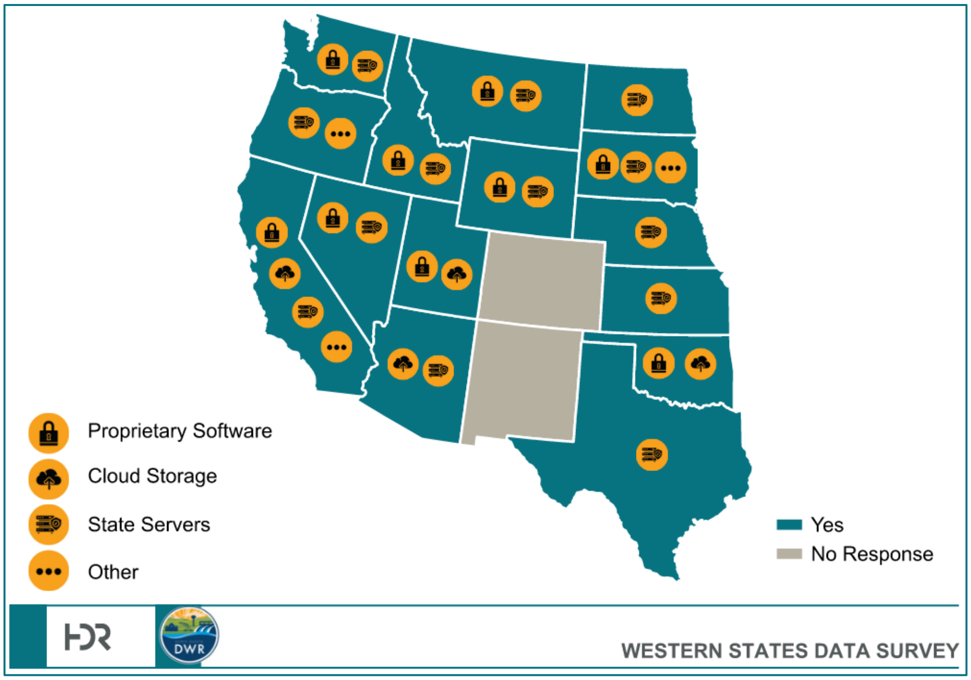

Figure 10. How does your state currently store and manage the collected water chemistry data?

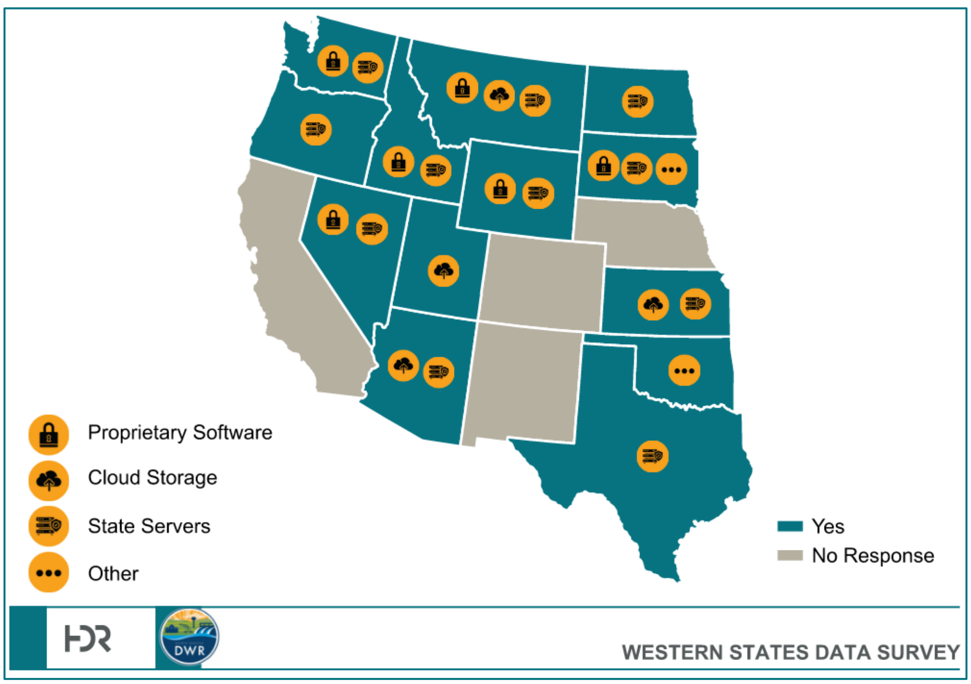

Figure 11. What is your state considering for future storage and management of water chemistry data?

WATER CHEMISTRY DATA ACCESS

Question 12 and its responses indicated that every state has water chemistry data available to the public. Question 12A confirmed that nearly every state offers data access through a web-based platform, and many also offer the data from a written request. Data from Question 12 and 12a are shown in **Figure 12** below.

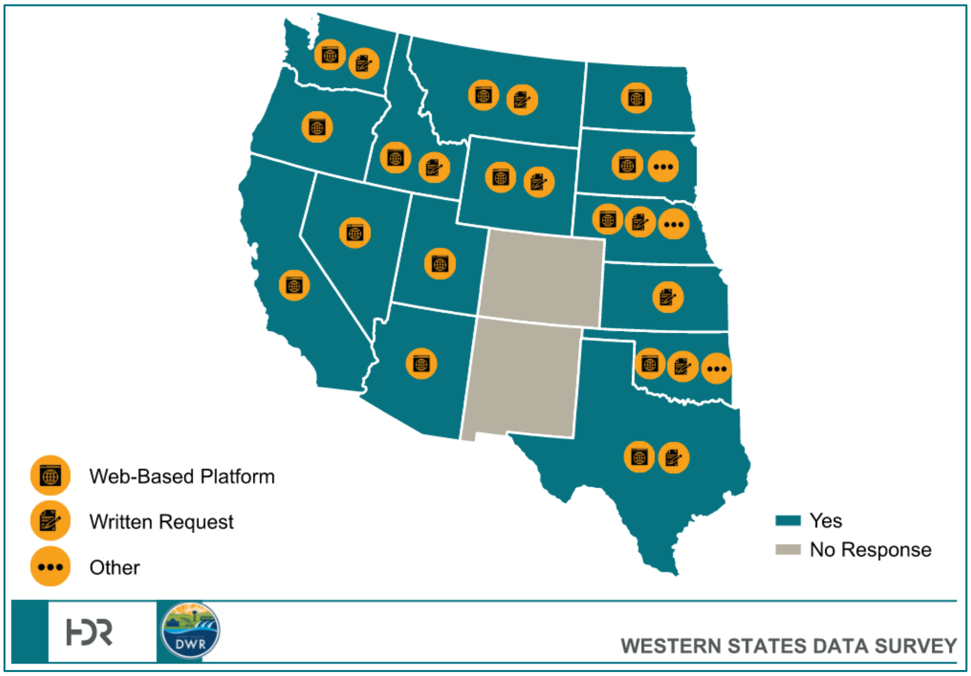

Figure 12. Is collected water use data publicly available? If so, through what means is it available?

WATER CHEMISTRY DATA STORAGE ADVANTAGES AND CHALLENGES

Question 13 asked respondents to describe the advantages and challenges associated with their state's current water chemistry data storage practices. High-level summaries of the advantages and challenges are included below, many of which seem to be the same from state to state.

Advantages:

- Web-based platforms allow for easy public access (AZ, MT, ND).
- Databases can be capable of comparing quality data against quality criteria and running statistical tests to determine the status for Clean Water Act reporting (NV).
- Data users have access to a large amount of data (CA, MT, SD).
- Data can be organized by sites, schedule, parameter, equipment, etc. which gives a high degree of functionality to the data user (WA).

Challenges:

- Inability to handle continuous data (AZ).
- It is challenging to get support from IT departments to help with software modifications, server maintenance, and firewall configuration (ID, KS, OK, WA).
- Operating, updating, and enhancing databases have high costs (NV, ND).
- Integrity cannot be guaranteed for data collected before a Quality Assurance Project Plan (QAAP) was put in place (MT, TX).

WATER CHEMISTRY DATA COLLECTION CHANGES

Question 14 asked respondents what they would change about their state's data collection for more accurate and reliable information regarding water chemistry data. A summary of the responses is provided below.

- Introduce automated methods for data collection and QA checks, including well drilling information and water level data (OK).
- Add the ability to capture continuous data with automated processes to handle aggregation, outlier identification, and reporting (ND, WA).
- Adopt a statewide data standard for harmful algal bloom data (CA).
- Increase the number of pesticide and PFAS testing sites (ID).
- Increase the frequency of sampling at each site (KS).
- Establish sites at a subwatershed scale (KS).
- Put more focus on making the data useful and easy to understand (MT).
- Use tablets in the field to record measurements, discharge data, etc. to improve the speed and accuracy of data entry (NE).
- Upgrade databases and data import procedures to increase efficiency and make data more readily available to the public (NV).
- Fund and develop means for data integration across agencies (OR).

Atmospheric/Climatic/Soil

The goal of this section of the survey was to understand the methodologies used to collect, validate, and store atmospheric, climatic, and soil data within each state. Climatologists in each state were contacted as part of the survey, but the response was limited.

Atmospheric Data Collection

Question 15 and its subsections focused on atmospheric data. Question 15 asked respondents whether or not their states collect atmospheric data. Responses were received from 14 states, with no respondents from KS, TX, and UT. **Figure 13** shows the responses to Question 15. The survey respondent from OR indicated that their agency does not collect some form of atmospheric data.

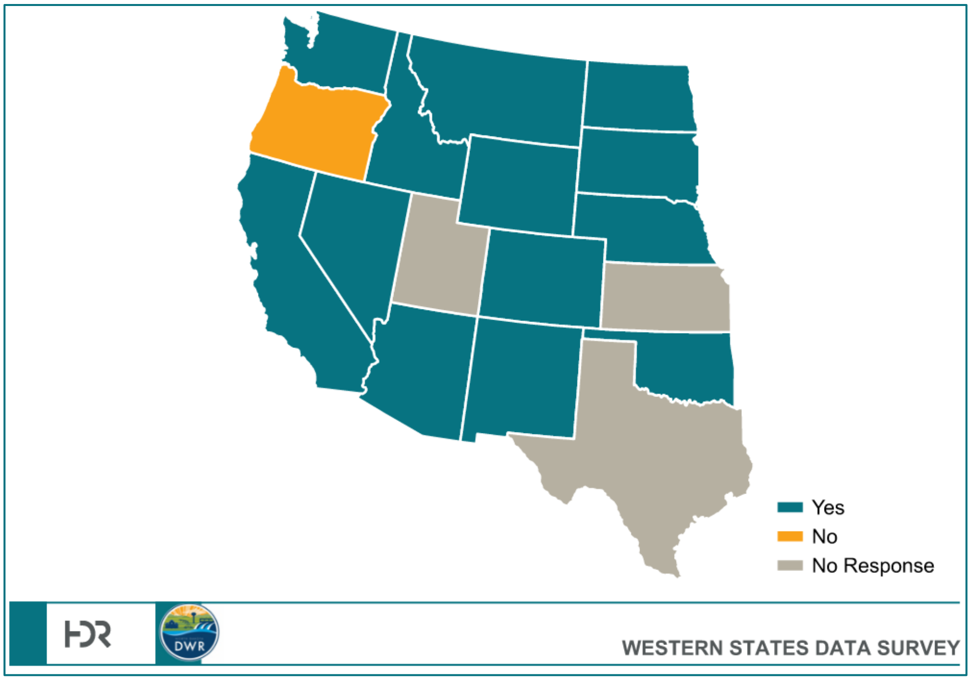

Figure 13. Does your state currently collect atmospheric data?

ATMOSPHERIC DATA COLLECTION PARAMETERS

Question 15A asked respondents what types of atmospheric data their state collects. The question was formatted so a respondent could mark as many boxes as necessary. Responses were received from respondents in 13 states, shown in **Figure 14**. Of the states that collect atmospheric data, most collect precipitation, barometric pressure, and temperature data. The results indicate snow data is not collected in warmer areas.

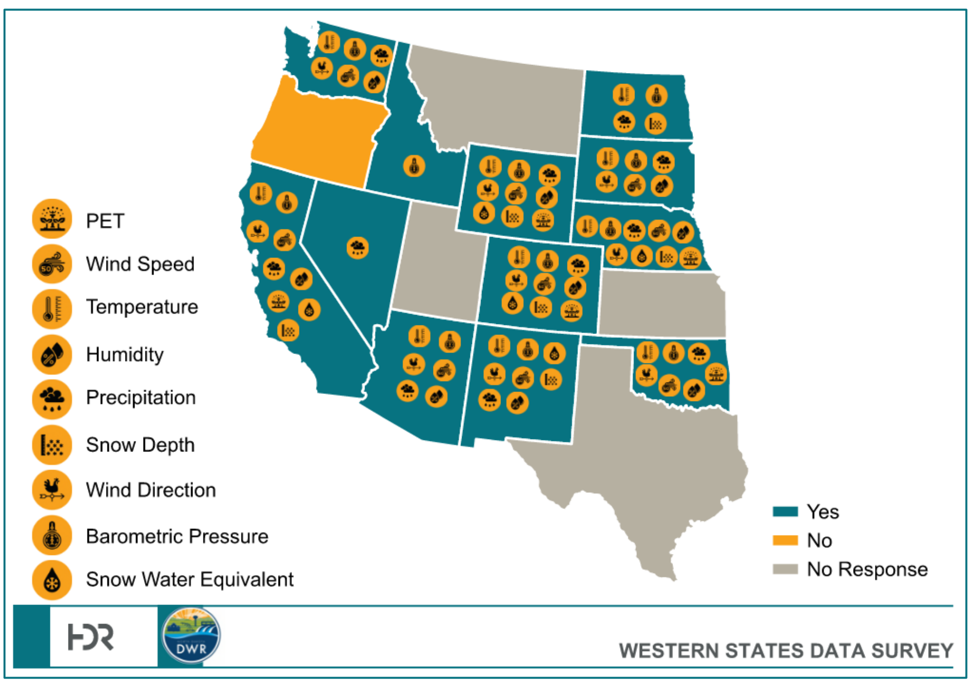

Figure 14. What atmospheric data does your state collect?

ATMOSPHERIC DATA COLLECTION METHODS

Question 15B asked what methodologies are being used to collect atmospheric data in each state. Methodologies that were reported are listed below.

- Mesonet Network –CO, NE, OK, SD
- Weather stations – CA, CO, NM, OK
- Automated sensors – CA, ND, WA
- Precipitation gages – NV
- California Irrigation Management Information System (CIMIS) – CA
- SNOTEL – CO
- Community Collaborative Rain Hail and Snow Network (CoCoRHaS) – CO
- Pressure transducers – ID

Many state-operated networks are part of the **National Mesonet Network**[1]. The National Mesonet is a central repository for real-time collection and dissemination of non-federal surface, boundary layer, and tropospheric atmospheric weather observations in the United States. Respondents from CO, NE, OK, and SD all referenced the Mesonet network. A survey respondent from MT indicated to contact the **Montana Climate Office**[2]. In referencing this Climate Office's website, Montana's Mesonet Network has over 100 weather, soil, moisture, and snow monitoring stations.

ATMOSPHERIC DATA COLLECTION SITES

Questions 15C, 15Ci, and 15Cii focused on the number of atmospheric data collection sites located within each state, the number of sites operated solely by the USGS, and the number of sites that are funded cooperatively or entirely by state agencies, respectively. Respondents from ND, OK, and WY reported zero sites operated solely by the USGS. Responses to these questions are scaled logarithmically for visual purposes and shown in **Figure 15.**

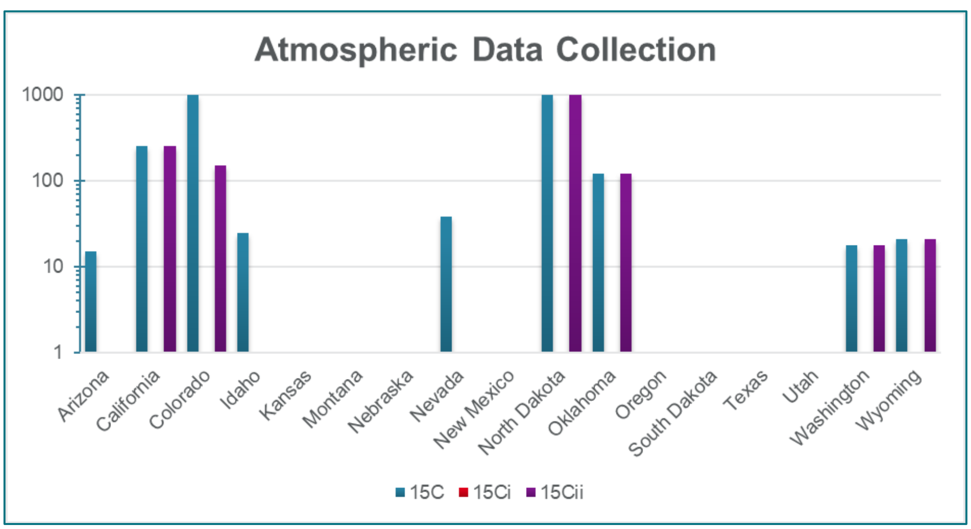

Figure 15. 15C) How many atmospheric data collection sites does your state currently have?
15Ci) How many are solely operated by the USGS?
15Cii) How many are cooperatively or completely funded by state entities?

**States not accompanied by a bar indicate that the state did not respond to the respective question. It does not indicate a value of 0 unless otherwise noted.*

AUTOMATIC ATMOSPHERIC DATA COLLECTION METHODS

Question 15D asked what automatic data collection methods are currently in use by each state. The most common technologies include data loggers and cellular connection to grab ambient conditions. Respondents from CA noted partnership with NOAA and the University of California that includes the use of a research-grade network for atmospheric rivers. Sites include stations equipped with disdrometers, MicroRain radars, snow level radars, and gap-filling radars. Reported methods are listed below.

- Data loggers – OK, WA, WY
- Cellular – AZ, CO
- Radar – CA
- PRESENS - ND

AUTOMATIC ATMOSPHERIC DATA COLLECTION ADVANTAGES AND CHALLENGES

Question 15Di asked about the advantages and challenges associated with the methods stated in Question 15D. Advantages and challenges are listed below.

Advantages:

- Snow level radars are relatively inexpensive and are very useful for decision-making and situational awareness in forecasting (CA).
- Automatic collection provides consistent measurements, timeliness, and lower human error (ND, OK).

Challenges:

- There are high costs and maintenance associated with automatic collection equipment (ND).
- Remote collection practices lead to an inability to conduct in-field QA/QC (WA).
- Lack of available power and cellular connection, as well as difficult site access, are other challenges (WY).

ATMOSPHERIC DATA COLLECTION ACCURACY

Question 15Dii asked what methods have been implemented to ensure accuracy and integrity of collected data. Methods include automatic and manual QA/QC analyses and routine site maintenance including calibration and replacement of gages (AZ, CO, NV, OK). Others include performance audits and recertification (WA, WY).

FUTURE ATMOSPHERIC DATA COLLECTION METHODS

Question 15E asked what collection methods are being considered for future use. Respondents from most states reported none or to continue with current methods; however, reported improvements include expanding networks of all-weather precipitation gages, temperature sites, and pressure sites (CO, ND). Adding soil volumetric water sensors and mini-sodar as well as replacing existing data acquisition systems are other improvements (OK, WA, WY).

Soil Moisture Data Collection

Question 16 and its subsections are related to soil moisture monitoring within each state. Based on the responses, many different agencies collect this data. In some cases, it falls upon the universities in each state. Given the broad range of those collecting this type of data, the response was limited. Respondents from 11 different states answered this section. Of this group, respondents from AZ, ID, OR, SD, and WY reported that their agency does not collect soil moisture data, shown below in **Figure 16**.

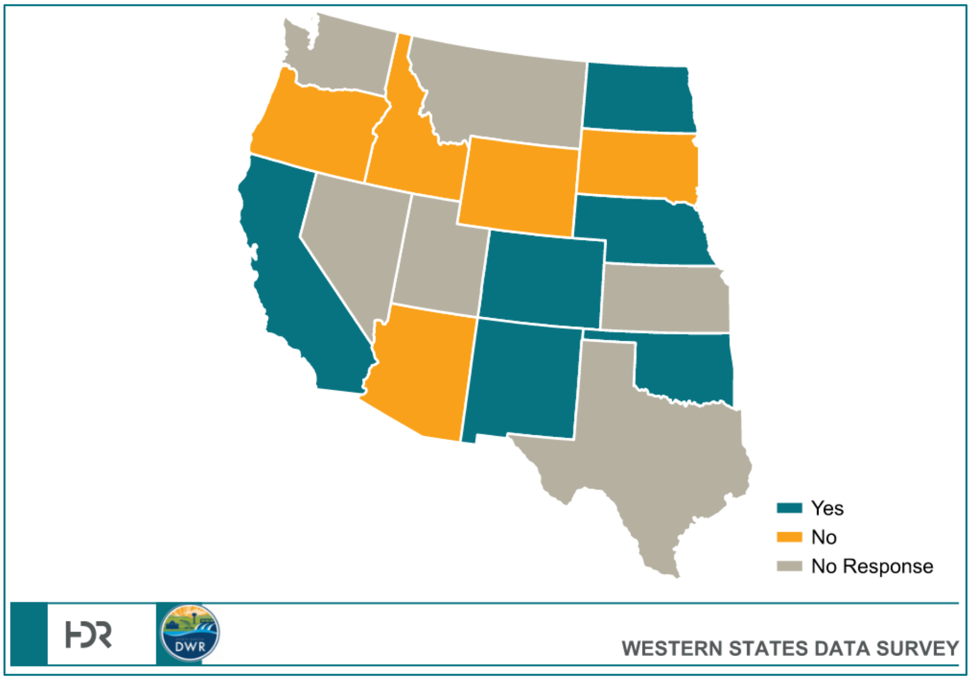

Figure 16. Does your state currently collect soil moisture data?

SOIL MOISTURE DATA COLLECTION METHODS

Question 15B asked what methodologies are being used to collect soil moisture data in each state. Many state-operated networks are part of the National Mesonet Network, similar to atmospheric data collection. The most common methodologies include automatic sensors at multiple depths and collection at existing weather stations.

HDR was made aware of a national effort to compile soil moisture data through the **National Soil Moisture Network**[3], which is being developed by a team at The Ohio State University. The existing network includes the National Resource and Conservation Servies SCAN network, many state Mesonet networks, and other statewide efforts to create a comprehensive network, illustrated in **Figure 17**. Each data source in the National Soil Moisture Network references the original data network and includes multiple soil horizons.

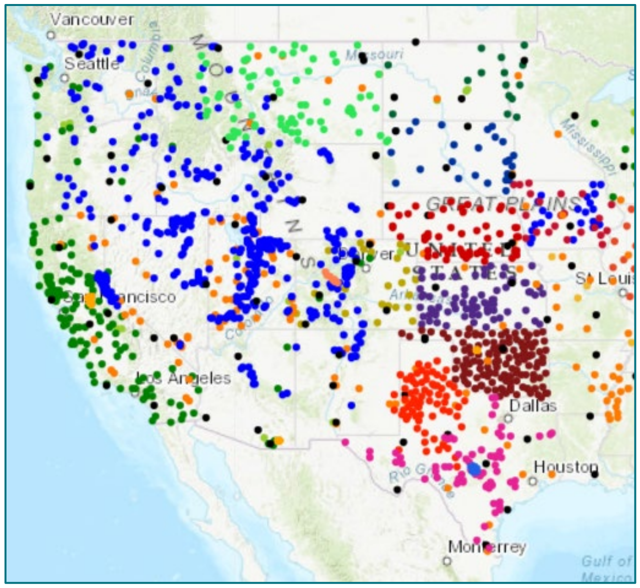

Figure 17. National Soil Moisture Network.

SOIL MOISTURE DATA COLLECTION SITES

Questions 16B, 16Bi, and 16Bii focused on the number of soil moisture data collection sites located within each state, the number of sites operated solely by the USGS, and the number of sites that are funded cooperatively or entirely by state agencies, respectively. Respondents from ND and OK reported zero sites operated solely by the USGS. Responses to these questions are shown in **Figure 18.**

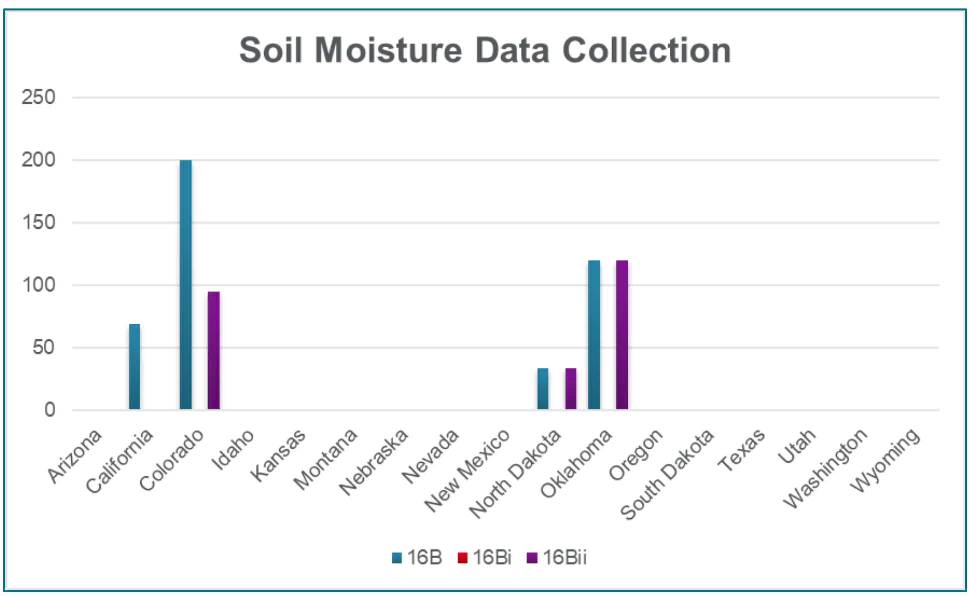

Figure 18. 16B) How many soil data collection sites does your state currently have?
16Bi) How many are solely operated by the USGS?
16Bii) How many are cooperatively or completely funded by state entities?

**States not accompanied by a bar indicate that the state did not respond to the respective question. It does not indicate a value of 0 unless otherwise noted.*

AUTOMATIC SOIL MOISTURE DATA COLLECTION METHODS

Question 16C asked what soil moisture data collection methods are currently in use by each state. Responses to this question were limited. Received responses indicated that ND uses automated soil moisture sensors at five depths with PRESENS units, while other states use telemetry and automated sensors (CA, CO, NE, OK).

AUTOMATIC SOIL MOISTURE DATA COLLECTION ADVANTAGES AND CHALLENGES

Question 16Ci asked about the advantages and challenges associated with the methods stated in Question 16C. Reported advantages include consistent measurements and access to real-time data (ND, OK). Challenges include high cost and maintenance requirements (ND).

SOIL MOISTURE DATA COLLECTION ACCURACY

Question 16Cii asked what methods have been implemented to ensure accuracy and integrity of collected data. Reported methods include automated and manual quality assurance methods and state QAAP data validations (OK, WY).

FUTURE SOIL MOISTURE DATA COLLECTION METHODS

Question 16D asked what collection methods are being considered for future use. Respondents from most states did not respond to this question; however, respondents from ND reported expanding network footprints. A respondent from CO also reported a proposed "network of networks" that incorporates soil data collected from other entities throughout the state.

Atmospheric, Climatic, and Soil Moisture Data Management

Questions 17 and 18 asked respondents how their state currently stores and manages atmospheric, climate, and soil data, as well as what the state is considering for the future, respectively. Based on limited responses to Question 17, respondents indicated that state servers are predominately being used. It should also be mentioned that many of the states' networks are stored in the National Mesonet, so responses to certain parameters of this question may be a combination of state and federal sources. Responses labeled "other" referenced federal and university servers, which likely implies the Mesonet Network. Limited responses to Question 18 indicate that states do not feel a need to change their current data management practices. **Figure 19** and **Figure 20** illustrate the responses to Questions 17 and 18.

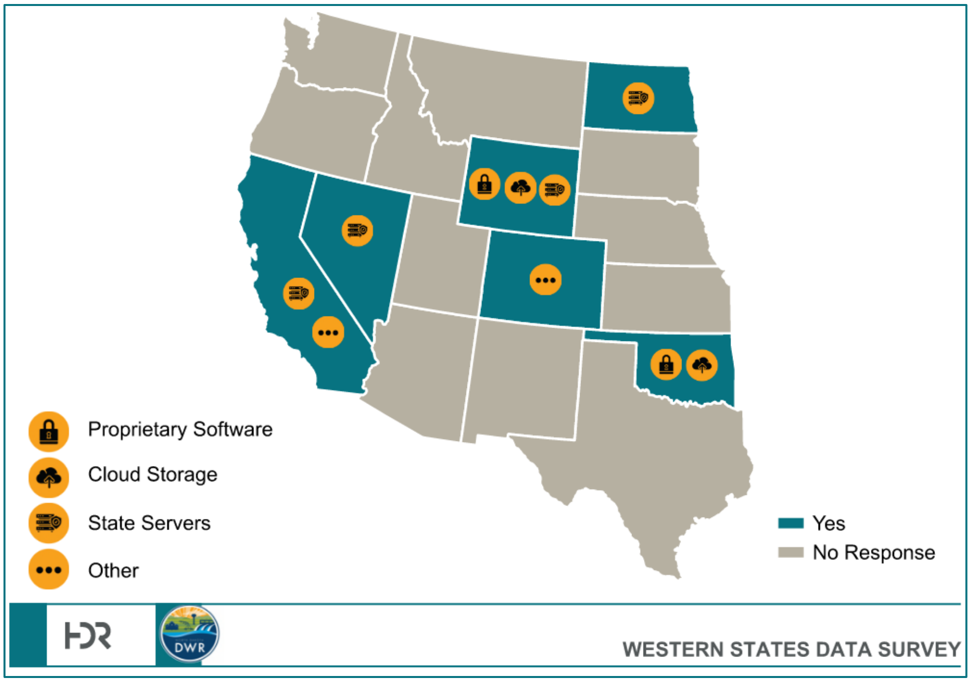

Figure 19. How does your state currently store and manage the collected atmospheric/climatic/soil data?

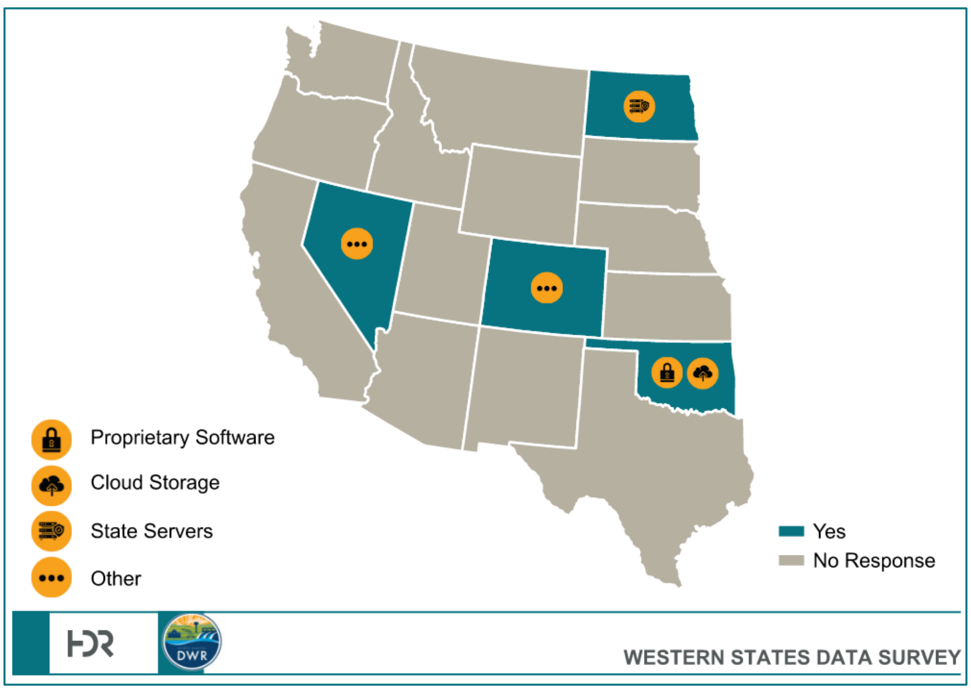

Figure 20. What is your state considering for future storage and management of collected atmospheric/climatic/soil data?

ATMOSPHERIC, CLIMATIC, AND SOIL MOISTURE DATA ACCESS

Question 19 was broken into two parts asking respondents if collected atmospheric, climatic, and soils data was publicly available in their state and by what means it was made available. Based on the responses, all states except for ID have publicly available data. Data from Question 19 and 19a are shown in **Figure 21**.

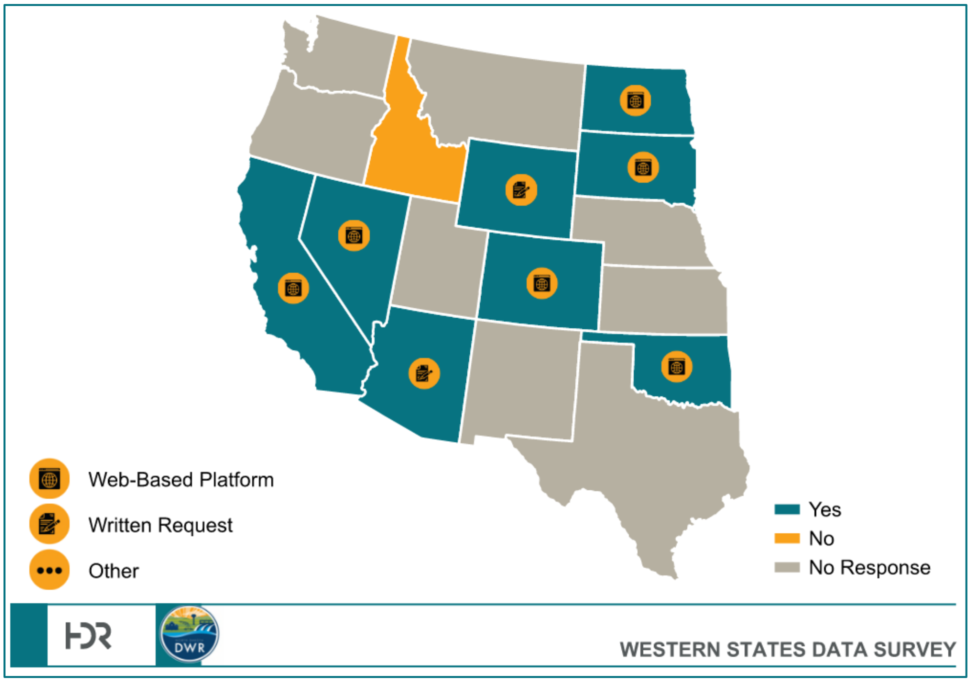

Figure 21. Is collected atmospheric/climatic/soil data publicly available? If so, through what means is it available?

ATMOSPHERIC, CLIMATIC, AND SOIL MOISTURE DATA STORAGE ADVANTAGES AND CHALLENGES

Questions 20 received limited responses, but based on these responses and discussions with experts, soil moisture is a particularly challenging variable to assess and get data on at a useful frequency. Respondents from CO and ND noted that the biggest advantage is the data being freely available to the public. Challenges noted include server costs, maintenance, and limited staff and resources (CO, ND, OK). Difficulty analyzing multiple samples due to soil data being housed in project-specific files was a challenge brought up by respondents from AZ. Based on the information provided from The Ohio State University, there are many different agencies collecting this data for different purposes without much coordination. In addition to the disconnect between agencies collecting soil moisture data, cost was also noted as being a factor with storing data.

ATMOSPHERIC, CLIMATIC, AND SOIL MOISTURE DATA COLLECTION CHANGES

Question 21 asked respondents what they would change about their state's data collection for more accurate and reliable information regarding atmospheric, climatic, and soil moisture data. Limited responses were received, but respondents from CO and ND noted that better integration of datasets between state agencies would help these datasets reach their full potential. Respondents from ND also noted that deployment of more soil moisture sensors at various depths and locations would help the state better understand soil water content and dynamics.

Water Flow and Stage

The goal of this section of the survey was to document the methodologies each state uses to collect, validate, and store surface and groundwater flow and stage data.

Water Flow Data Collection

Question 22 asked respondents if their state currently collects flow data. Respondents from all states, with the exception of KS, answered this question. All 16 respondents indicated that their state collects flow data, shown below in **Figure 22**.

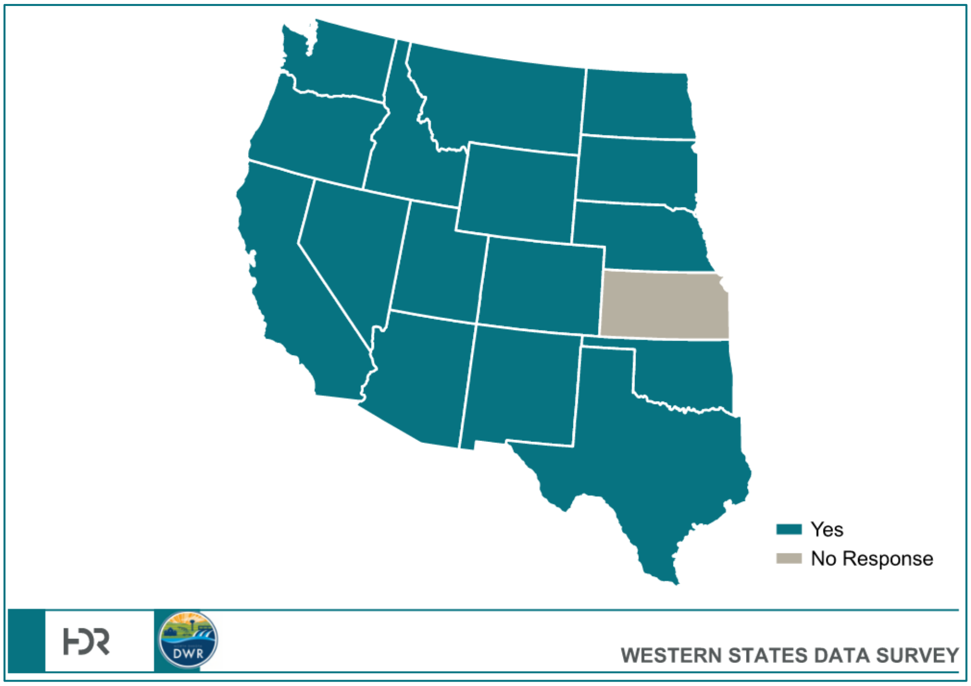

Figure 22. Does your state currently collect surface water flow data?

WATER FLOW DATA COLLECTION SITES

Questions 22Ai, 22Aii, and 22Aiii focused on the number of surface water flow collection sites located within each state, the number of sites operated solely by the USGS, and the number of sites that are funded cooperatively or entirely by state agencies, respectively. Respondents from AZ and WA reported zero sites operated solely by the USGS. Responses to these questions are scaled logarithmically for visual purposes and shown in **Figure 23.**

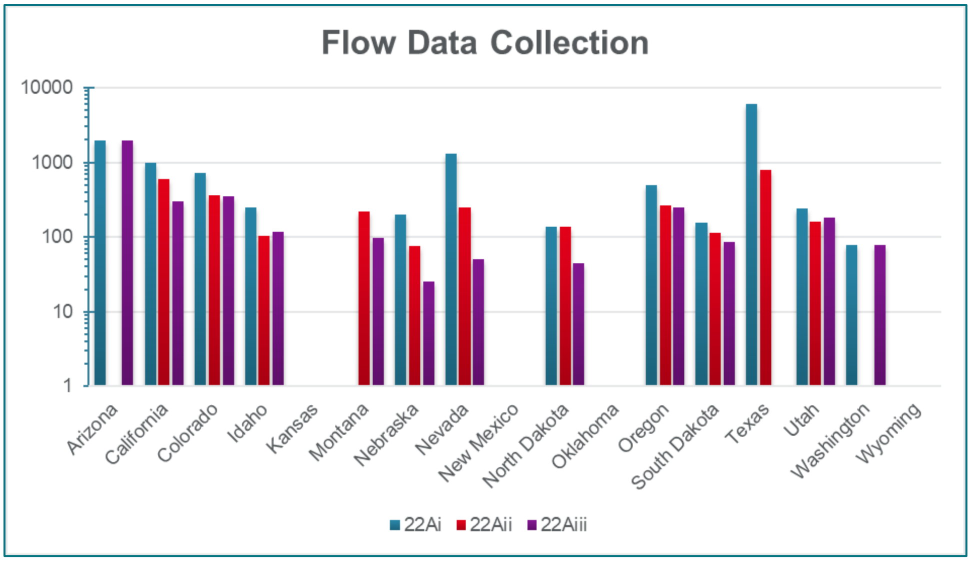

Figure 23. 22Ai) How many flow data collection sites does your state currently have?
22Aii) How many are solely operated by the USGS?
22Aiii) How many are cooperatively or completely funded by state entities?

**States not accompanied by a bar indicate that the state did not respond to the respective question. It does not indicate a value of 0 unless otherwise noted.*

WATER FLOW DATA COLLECTION METHODS

Question 22A asked respondents what methods are used in their state to collect flow information. Responses indicated that states tend to use the same methods for collecting flow data as they use for collecting withdrawal data. A variety of automatic and manual methods were discussed. The use of stage-storage curves to calculate flow based on reported stage data was also indicated by respondents from CO, ID, NE, ND, OR, and WA. USGS partnership is also common throughout the responding states (CA, ID, MT, ND, OR, SD).

AUTOMATIC WATER FLOW DATA COLLECTION METHODS

Question 22Aiv focused on automatic data collection technologies. Reported methods primarily include different types of telemetry (AZ, CA, CO, ID, MT, NE, ND, OK, OR, SD, UT, WA) and remote data loggers (AZ, ID, UT). This is similar to automatic technologies reported for use in collecting water withdrawal data.

AUTOMATIC WATER FLOW DATA COLLECTION ADVANTAGES AND CHALLENGES

Question 22Av asked about the advantages and challenges associated with the technologies stated in Question 22Aiv. Many of these advantages and challenges are the same as those noted for automatic water use data collection technologies. Reported advantages and challenges are listed below.

Advantages:

- Automatic technologies give the ability to collect real-time data (CO, ND).
- Automatic technologies do not require significant staff travel (NV).
- Automatic collection technologies allow for the collection of storm flow samples that can be used to identify the presence of water in desert streams (AZ).

Challenges:

- Automatic technologies occasionally lack accuracy (CO, NE).
- There are high costs associated with automatic data collection (ID, NE, NV, ND).
- Remote sites provide difficulties, accessing and scheduling, maintenance, making it more time consuming (CO, NE, OR).

AUTOMATIC WATER FLOW DATA COLLECTION ACCURACY

Question 22Avi asked what methods have been implemented to ensure accuracy and integrity of automatically collected data. Many of these advantages and challenges are the same as those noted for automatic water use data collection technologies. QA/QC checks, audits, regular equipment recalibration, and training of staff on state and federal guidelines were discussed throughout the responses.

FUTURE AUTOMATIC WATER FLOW DATA COLLECTION METHODS

Question 22B asked what automatic data collection methods are being considered for future use. Respondents from many states indicated that their state does not intend on altering its current collection strategies, but a notable change was Montana's use of drones for collection of LiDAR and bathymetric surveys. Other changes include implementing doppler and radar technologies in ID and WA to improve data accuracy, incorporating surface water velocity data collection programs in OR and WA, and implementing continuous sampling in AZ.

Water Stage Data Collection

Question 23 asked respondents if their state currently collects stage data. Survey respondents from CA, KS, and WY did not submit a response to this question. Responses to Question 23 are shown below in **Figure 24.**

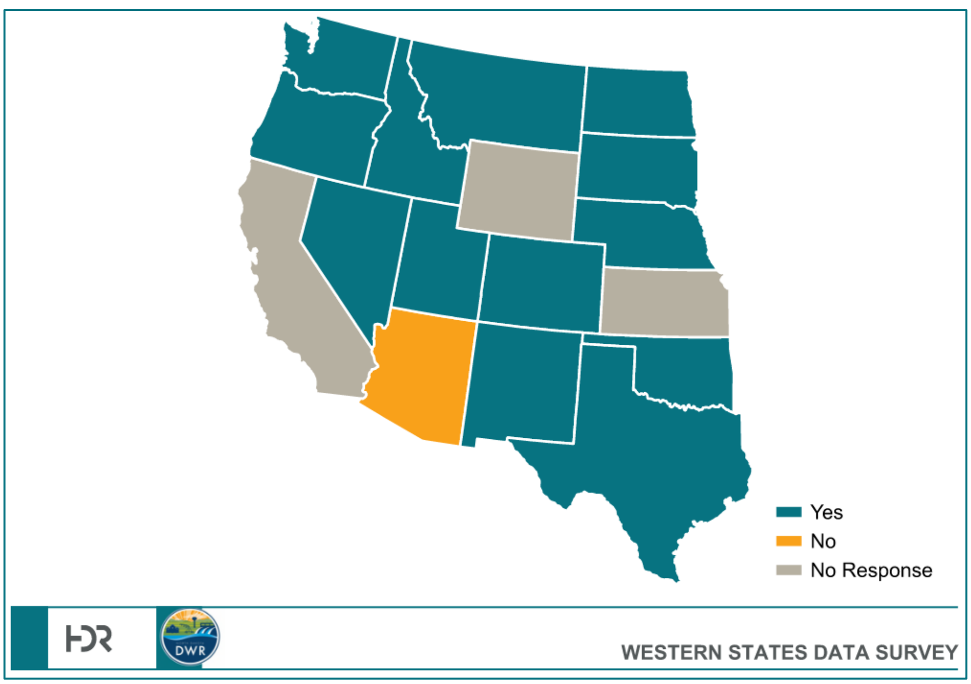

Figure 24. Does your state currently collect surface water stage data?

WATER STAGE DATA COLLECTION SITES

Questions 23Ai, 23Aii, and 23Aiii focused on the number of surface water stage collection sites located within each state, the number of sites operated solely by the USGS, and the number of sites that are funded cooperatively or entirely by state agencies, respectively. Responses to these questions are shown in **Figure 25.**

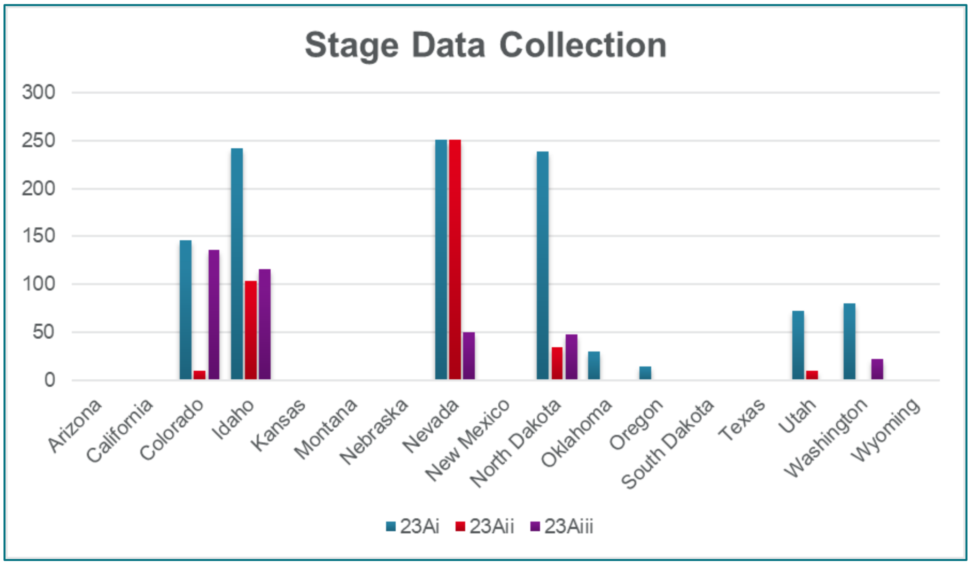

Figure 25. 23Ai) How many stage data collection sites does your state currently have?
23Aii) How many are solely operated by the USGS?
23Aiii) How many are cooperatively or completely funded by state entities?
**States not accompanied by a bar indicate that the state did not respond to the respective question. It does not indicate a value of 0 unless otherwise noted.*

WATER STAGE DATA COLLECTION METHODS

Question 23A asked respondents what methods are used in their state to collect stage information. Responses indicated that states tend to use the same methods for collecting stage data as they use for collecting withdrawal and flow data. A variety of automatic and manual methods was discussed in this section.

AUTOMATIC WATER STAGE DATA COLLECTION METHODS

Question 23Aiv focused on automatic data collection technologies. Reported methods primarily include different types of telemetry, mechanical meters, and remote data loggers. This is similar to automatic technologies reported for use in collecting water withdrawal and flow data.

AUTOMATIC WATER STAGE DATA COLLECTION ADVANTAGES AND CHALLENGES

Question 23Av asked about the advantages and challenges associated with the technologies stated in Question 23Aiv. Many of these advantages and challenges are the same as those noted for automatic water use and flow data collection technologies. Advantages include the ability to collect real-time data and less need for staff travel. Challenges include lack of accuracy, high costs, maintenance, and difficult site access.

AUTOMATIC WATER STAGE DATA COLLECTION ACCURACY

Question 23Avi asked what methods have been implemented to ensure accuracy and integrity of automatically collected data. Many of these advantages and challenges are the same as those noted for automatic water use and flow data collection technologies. Regular QA/QC checks and calibrations, agency transparency, contractual requirements, and following state and federal guidelines were discussed in the responses.

FUTURE AUTOMATIC WATER STAGE DATA COLLECTION METHODS

Question 23B asked what automatic data collection methods are being considered for future use. Many of the noted methods are the same as those noted for automatic flow data collection technologies. Respondents from many states indicated that their state does not intend on altering its current collection strategies at all.

Groundwater Level Data Collection

Question 24 asked respondents if their state currently collects groundwater level data. Survey respondents from OR, TX, and WY did not submit a response to this question. Respondents from the other 14 states indicated that their state collects groundwater level data, shown in **Figure 26**.

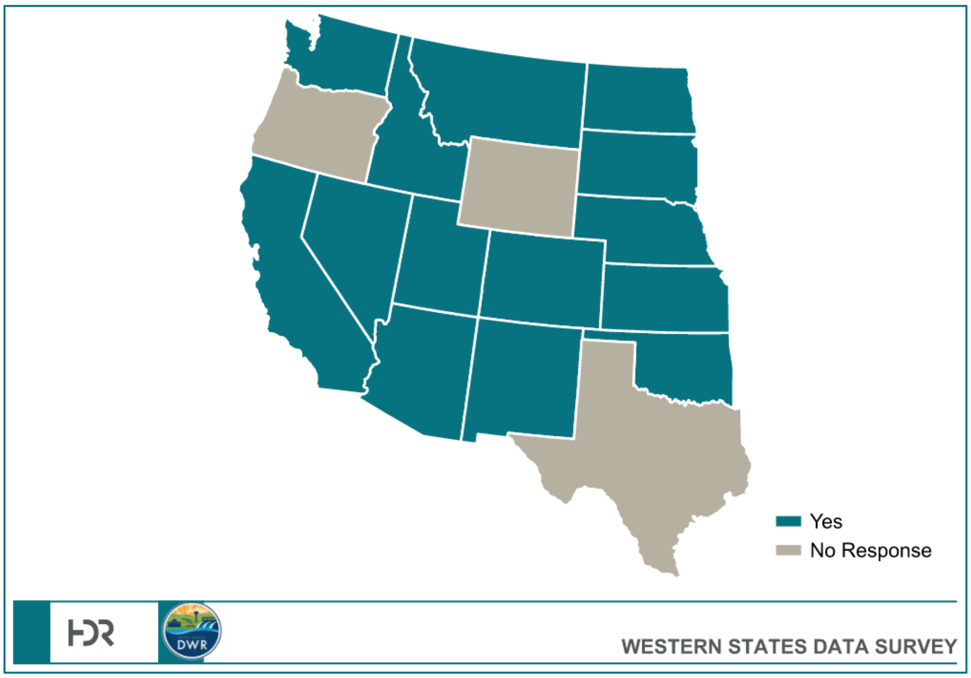

Figure 26. Does your state currently collect groundwater level data?

GROUNDWATER LEVEL DATA COLLECTION SITES

Questions 24Ai, 24Aii, and 24Aiii focused on the number of groundwater level collection sites located within each state, the number of sites operated solely by the USGS, and the number of sites that are funded cooperatively or entirely by state agencies, respectively. Respondents from CO and WA reported zero sites operated solely by the USGS. Respondents from ND, NE, and NV reported zero sites funded by state entities. Responses to these questions are scaled logarithmically and shown in **Figure 27.**

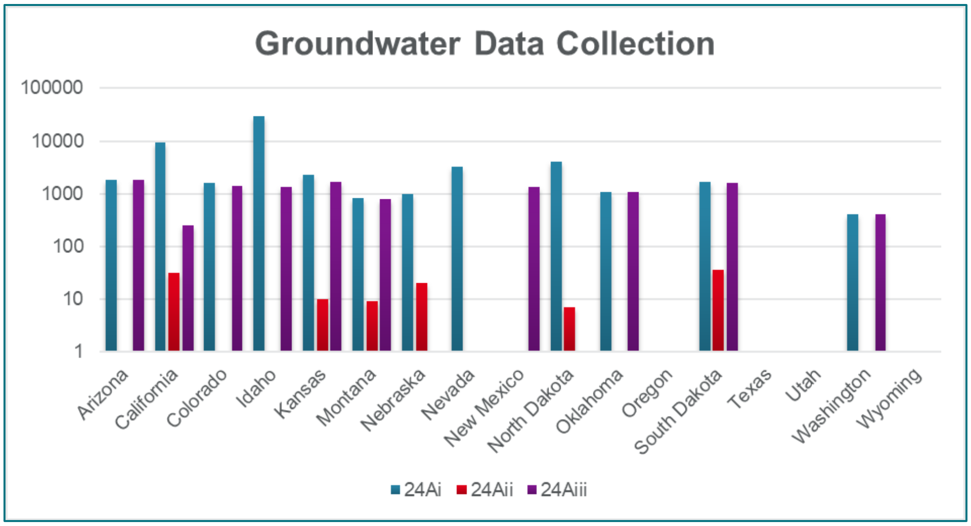

Figure 27. 24Ai) How many groundwater data collection sites does your state currently have?
24Aii) How many are solely operated by the USGS?
24Aiii) How many are cooperatively or completely funded by state entities?
**States not accompanied by a bar indicate that the state did not respond to the respective question. It does not indicate a value of 0 unless otherwise noted.*

GROUNDWATER LEVEL DATA COLLECTION METHODS

Question 24A asked respondents what methods their state uses to collect groundwater level information. Networks of monitoring wells are regularly measured using both automated and manual methods listed below. Many states also require well owners to report on levels or utilize USGS gage data. Common collection methods are listed below.

- Telemetry –ID, KS, MT, NM, ND, OK
- Pressure transducers & data loggers –AZ, CA, ID, SD
- Tape (electric/steel) – AZ, CO, ID, KS, MT, SD
- Drillers logs/reports – AZ, CA, CO
- Meters – AZ, CO

Respondents from OK also noted the use of discrete measurements over a brief timeframe to develop potentiometric surface maps of their aquifers. There are 100-300 sites taking high-density water-level measurements at each aquifer. In addition, a dense network of continuous water-level recorders is used to characterize the aquifer.

AUTOMATIC GROUNDWATER LEVEL DATA COLLECTION METHODS

Question 24Aiv focused on automatic data collection technologies. Reported methods primarily include different types of telemetry, such as remote data loggers attached to pressure transducers. ND was the only exception, with survey respondents from this state reporting the use of PRESENS.

AUTOMATIC GROUNDWATER LEVEL DATA COLLECTION ADVANTAGES AND CHALLENGES

Question 24Av asked about the advantages and challenges associated with the technologies stated in Question 24Aiv. Notable advantages and challenges are listed below.

Advantages:

- Telemetered sites allow for high-frequency data and daily status checks (CA, ND).
- Data collection is more efficient and often yields better quality data (ID, MT, SD).
- PRESENS is a cost-effective option of collecting real-time data (ND).

Challenges:

- There are handling challenges associated with the raw level data file type (AZ).
- There is limited capability to geographically verify data (AZ).
- There can be a high cost of equipment, installation and maintenance, and staff training (CO, ID, ND, SD).
- Equipment failure due to livestock, weather, and vandalism is possible (CO, OK).
- Difficult to work with cell service providers (MT).

AUTOMATIC GROUNDWATER LEVEL DATA COLLECTION ACCURACY

Question 24Avi asked what methods have been implemented to ensure accuracy and integrity of automatically collected data. Many of these advantages and challenges are the same as those noted for automatic water use, flow, and stage data collection technologies. QA/QC checks, audits, periodic site visits, redundant measurements, and reviews of historical data were discussed throughout the responses.

FUTURE AUTOMATIC GROUNDWATER LEVEL DATA COLLECTION METHODS

Question 24B asked what automatic data collection methods are being considered for future use. Respondents from some states indicated that their state does not intend on altering its current collection strategies, but respondents from many states mentioned that their state is expanding its networks and telemetered sites.

Flow, Stage, and Groundwater Level Data Management

Questions 25 and 26 asked respondents how their state currently stores and manages flow, stage, and groundwater level data, as well as what the state is considering for the future, respectively. Based on responses to Question 25, states are predominantly using state servers. Responses to Question 26 indicate that states do not feel a need to change their current data management practices. **Figure 28** and **Figure 29** illustrate the responses to Questions 25 and 26.

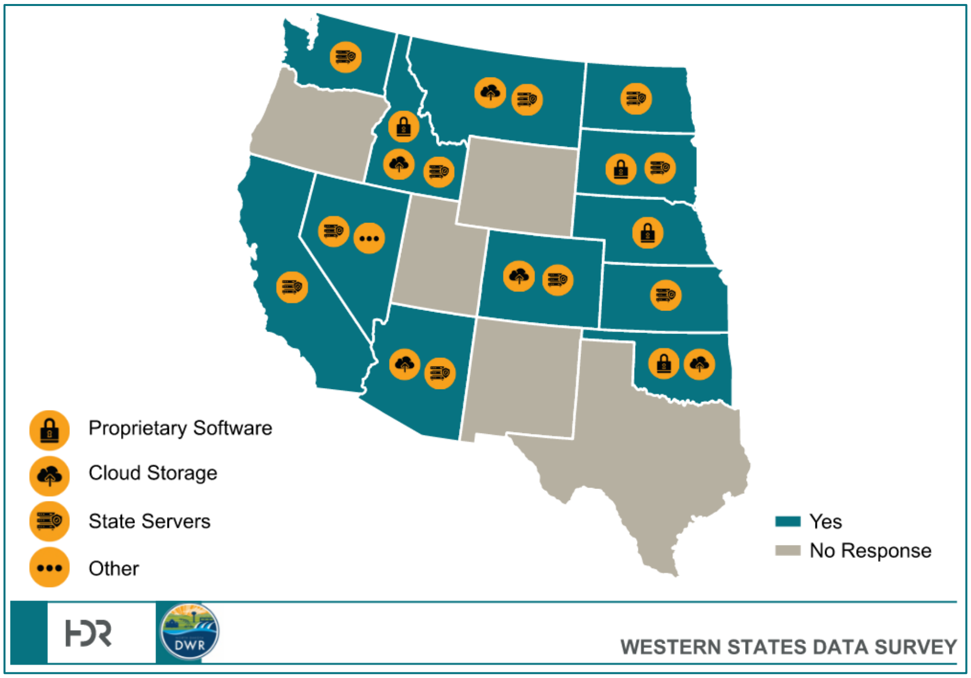

Figure 28. How does your state currently store and manage the collected water flow, stage, and groundwater level data?

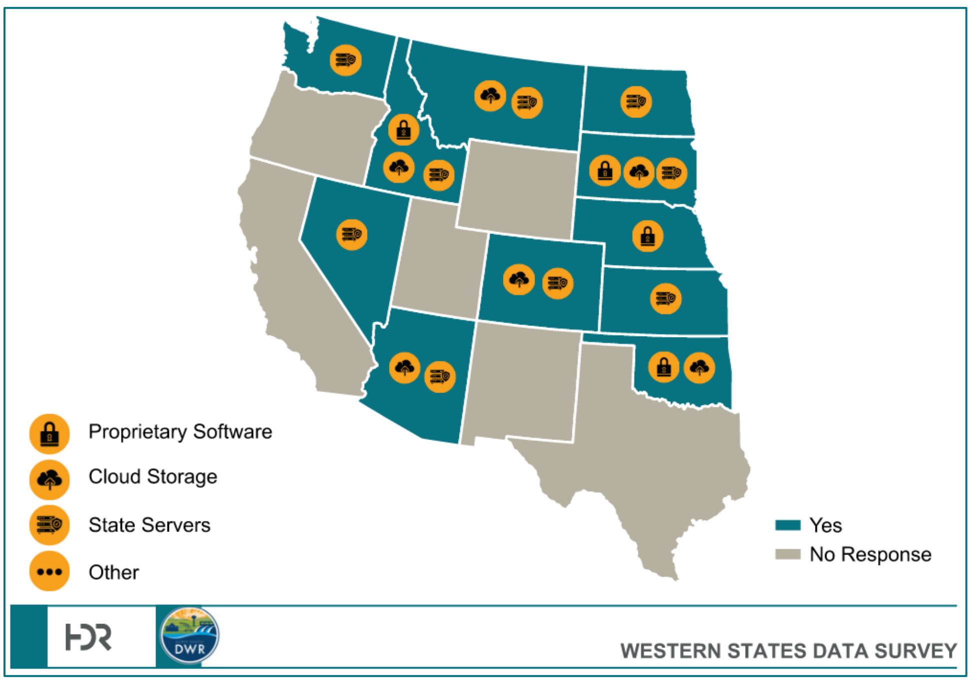

Figure 29. What is your state considering for future storage and management of water flow, stage, and groundwater level data?

FLOW, STAGE, AND GROUNDWATER LEVEL DATA ACCESS

Question 27 was broken into two parts asking respondents if the collected flow, stage, and groundwater level data was publicly available in their state and by what means it was made available. All respondents indicated that this data was publicly available. Respondents from most states indicated that the data is available through web-based platforms rather than written request. Data from Question 27 and 27a are shown in **Figure 30**.

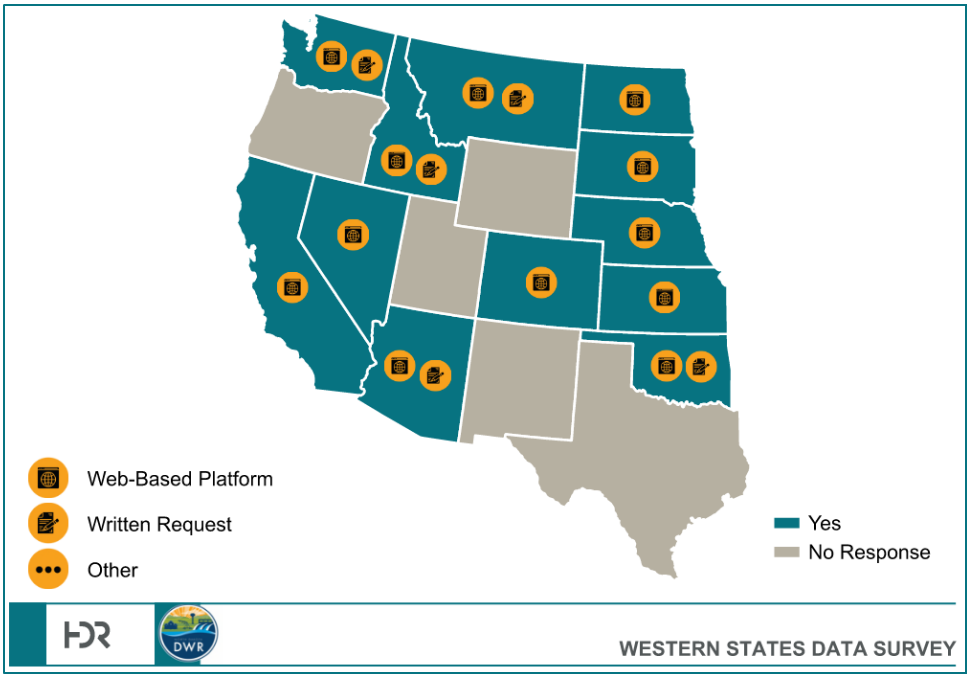

Figure 30. Is collected water flow, stage, and groundwater level data publicly available? If so, through what means is it available?

FLOW, STAGE, AND GROUNDWATER LEVEL DATA STORAGE ADVANTAGES AND CHALLENGES

Question 28 asked about the advantages and challenges associated with current data storage and management practices regarding flow and stage data. High-level summaries of the advantages and challenges are included below, many of which seem to be the same from state to state. Many of the responses are similar to the responses to Question 5. The survey respondents from OK indicated that that the state implements national data standards.

Advantages:

- Serving water use data from a website provides transparency and makes it easier to distribute (ID, MT. ND).
- Helping water related agencies better understand the availability of water resources (NV).

Having a long period of records for comparative analysis.

Challenges:

- IT support challenges to maintain serving the data to the public (ID, OK).
- Provisional data and data accuracy being readily served can prove to be a challenge (CO).
- The cost of continuing to maintain the web-based platforms is often overlooked and requires much more staff time than anticipated (MT, ND).
- The cost of collecting the data is expensive and certain pieces of equipment are typically unavailable (NV).

- Having the data publicly available can present challenges in terms of the public accessing and understanding the information (OK).
- Uploading large amounts of data can be cumbersome (WA).

FLOW, STAGE, AND GROUNDWATER LEVEL DATA COLLECTION CHANGES

Question 29 asked respondents what they would change regarding their state's flow and stage data collection efforts and the responses were extremely similar. A summary of the responses is included below:

- Add more monitoring sites (ID, ND).
- Look more into or increase automated data collection (AZ, CO, SD, WA).
- Find more steel tapes for ground water monitoring (KS, NV).
- Implement automated QC through machine learning or other methods (ND, OK).
- Increase staffing to assist with data collection and QC of data (NV).

Artificial Intelligence and Predictive Modeling

Artificial intelligence (AI) and predictive modeling response in the survey was limited. The only response that indicated using artificial intelligence other than researching its capabilities was provided by the Kansas Geological Survey (KGS). KGS has hired staff with experience in artificial intelligence and machine learning to identify relationships and patterns within lithology, water level, water quality, and pumping data.

Responses to the current use of predictive modeling was slightly more complete than that of artificial intelligence. Current uses of predictive modeling provided by study respondents include:

- AZ – Use of a linear regression model from Predictive Analytics to prevent Maximum Contaminant Level violations in public water systems.
- NE – Use of a state-wide network of groundwater models for estimating impacts on water levels.
- NV – Use of models and analytical methods to predict conflict or other effects on existing rights.
- ND – Use of automated processes around data collection activities and quality control procedures. Current setup could implement AI in the future.
- WY – Use of air quality predictive analytics.

Recommendations and Key Takeaways

The survey conducted across 17 western states provides valuable insights into the diverse methodologies and practices employed for water resource monitoring and management. By focusing on real-time and near real-time data collection, the survey aimed to uncover effective strategies and technologies used in the field, with a particular emphasis on enhancing the accuracy and integrity of water resource data.

The survey findings reveal that, despite operating independently, states face similar challenges, which include:

- **Water Use Self-Reporting Challenges**: Many respondents indicated there is difficulty guaranteeing the accuracy of water use information reported by an individual water user. The respondent from OR even mentioned that water users have acknowledged it is not in their best interest to be honest about their use. Respondents from ND, CA, and TX indicated there are meter requirements for some water users, while respondents from ID, OK, and SD brought up the possibility of requiring metering in the future. The respondent from WA indicated that while their state requires water users to measure their diversion, it is still difficult to confirm compliance with the water permit. This respondent added that a larger automatic collection footprint would give staff more time to enforce permit requirements. HDR investigated telemetry monitoring programs and identified that CA is currently working on a pilot project to evaluate real-world conditions for telemetered water monitoring and test their new data system, the California Water Accounting, Tracking, and Reporting System (Cal-WATRS). The pilot project will run from 2025 to 2028 with the goal of developing efficient data reporting structures and reducing reporting burdens.
- **Quality Control Challenges**: Many respondents pointed out difficulties in maintaining quality control with automated data systems. This suggests a need for improved protocols and regular validation procedures to ensure data reliability.
- **Data Centralization and Access Challenges:** Survey respondents indicated that integrating water data from multiple sources into one central system and making this information accessible to all relevant stakeholders (e.g., policymakers, the public, etc.) can be complex and resource intensive.
- **Data Collection and Storage Disconnects**: The survey revealed a significant issue with data collection and storage practices across different agencies. Addressing these disconnects could lead to more integrated and streamlined data management systems, enhancing overall data accessibility and utility.

Specific survey responses highlight water data collection practices and technologies that may serve as effective models to tackle these challenges. While these responses are not fully developed recommendations, they are presented as insights for DWR to investigate further or implement within ND. These practices and technologies are grouped into categories and include:

- **Water Quantity Technologies**:
    - OR's suggestion to add different reporting and data search options, such as dropdown menus and allowing pictures, that would make it more convenient for water use reporters, likely leading to higher quality water use data.
    - WA's note that a one-to-one relationship between gages and water rights significantly reduced the risk of overuse by water users with complex water rights.
    - MT's use of drones for collection of LiDAR and bathymetric surveys.
    - OK's use of discrete measurements over a brief timeframe to develop potentiometric surface maps of their aquifers.

- **Water Quality Technologies**:
    - NV's development of a tool that detects harmful algal blooms using satellite data provided from National Oceanic and Atmospheric Administration (NOAA).
    - ID's note of an expanded PFAS testing program.
    - KS's note of biological monitoring through DNA sampling.

- **Atmospheric Technologies**:
    - CA uses snow level radars for decision-making purposes and situational awareness for forecasting, indicating that they are relatively inexpensive.
    - CA's partnership with NOAA and the University of California that includes the use of a research-grade network for atmospheric rivers.

- **Data Collection and Distribution**:
    - Multiple states indicating they get assistance from universities in collection and analysis of a variety of data.

Recommendations

Based on these collective water data collection practices and technologies, the following recommendations are proposed:

- **Explore Telemetry Technologies:** Multiple survey responses acknowledged difficulties in guaranteeing the accuracy of water use information provided by individual water users. To address this problem, many states require meter and telemetry devices on points of diversion for certain water use types. HDR researched telemetry monitoring programs and found that CA is running a pilot project from 2025 to 2028 to evaluate real-world conditions for telemetered water monitoring and test their new data system, the California Water Accounting, Tracking, and Reporting System (Cal-WATRS). With its goal of developing efficient data reporting structures and reducing reporting burdens, this pilot project offers one approach on how to improve other telemetry networks. ND currently requires water users to utilize meter and telemetry devices but does not provide specific guidance on technologies. It is recommended that ND meet with the following agencies to discuss their meter/telemetry requirements to learn about methods to improve ND's meter and telemetry system (MTS):

- California Department of Water Resources
    - Colorado Division of Water Resources
    - Nebraska Department of Natural Resources
    - Washington Department of Ecology

- **Adopt AI and Machine Learning Technologies:** Predictive modeling, among other machine learning techniques, can be used to ensure data quality and indicate anomalies occurring within an existing time series. This could be specifically useful for flow, stage, or any water use data. Several tools have been developed in the space of time series data analytics, such as IBM's Predictive Analytics Program. Survey respondents from AZ and WY mentioned the use of Predictive Analytics. The survey respondents from AZ specifically referenced using this tool for mean contaminant levels, but additional conversations on how the tool performs may be warranted to help guide the DWR on more applications for its use. While not specifically mentioned in the survey, AI technologies may be in development that could assist in the same fields by reducing human quality control efforts and identifying the state of data inaccuracies or shifts in water use.

- **Enhance Multi-Agency Collaboration:** To address the challenges in collecting, verifying, and disseminating data, it is recommended ND, led by DWR, create a working group regarding water resource-related data. With universities, federal, and state agencies collecting similar datasets, creating a working group to discuss these efforts is warranted. This effort could help inform on data gaps within the state and make water managers within the state more aware of data available. Universities and agencies that could be included in this working group include the following:
    - University of North Dakota (state)
    - North Dakota State University (state)
    - North Dakota Department of Environmental Quality (state)
    - North Dakota Department of Water Resources (state)
    - North Dakota Department of Agriculture (state)
    - North Dakota State Climatologist (state)
    - North Dakota Department of Emergency Services (state)
    - National Weather Service (federal)
    - United States Army Corps of Engineers (federal)
    - United States Bureau of Reclamation (federal)
    - United States Geological Survey (federal)
    - National Oceanic and Atmospheric Administration (federal)

  The working group could help the state identify all datasets being collected within its borders, technologies currently being utilized to collect the data, data gaps, and where the datasets are housed. Findings of this working group would likely lead to significant improvement of water data collection within the state, increase awareness of the existence of the data, and improve accessibility to the data. This working group could then work to establish a path forward for data centralization.

- **Advance Data Centralization:** The widespread use of soil moisture monitoring among agencies presents an opportunity for better coordination and data integration. By aligning efforts and sharing datasets, agencies could improve the comprehensiveness and utility of water data collection. During the implementation of this survey, HDR contacted the National Integrated Drought Information System (NIDIS) to gain more information on which states are currently collecting soil moisture data for the purposes of water resource monitoring. NIDIS provided information on the network being assimilated by The Ohio State University and mentioned it is a national dataset many agencies are interested in, but there has been little agency-to-agency coordination. This network curated by The Ohio State University, along with a "network of networks" being developed by CO, appear to be the only projects identified by the survey and through additional research, working toward data centralization. Following creation of a North Dakota-led, multiagency working group on data collection, the development of a network of networks could take place to work toward data centralization. In many instances, the necessary data needed exists across various agencies and websites, making the development of a network of networks extremely useful. This data could be centralized in an architecture similar to DWR's MapService or another like platform.
- **Confirm National Soil Moisture Network Data:** Following full identification of ND's soil moisture monitoring, ND should work with the team administering the National Soil Moisture Network (National Soil Moisture Network) to ensure all of ND's data is included in their network. Much of this research is being done to gather information which may be beneficial for the state in the future. This concept could be applied to other federal or regional data networks identified by the working group formed as part of the Enhance Multi-Agency Collaboration recommendation.

- **Review Resources:** Many survey respondents acknowledged that collecting, verifying, and disseminating data is both costly and labor intensive. To support ongoing data expansion efforts, ND should continue to review resource needs and opportunities for efficiencies as the network is expanded. This will help manage the demands of data handling and ensure the sustainability of these efforts.

The survey covered a broad range of topics related to water data collection and management, demonstrating high-level trends and potential future directions for the state to consider. For states interested in delving further into specific aspects such as water quality or availability, a study could be considered to gather precise technological information. Additionally, conducting research early in the year can likely avoid conflicts with fieldwork and increase participant availability, leading to more comprehensive and actionable data.

By leveraging the findings from this survey, DWR and water resources agencies in neighboring states can refine their water data management practices, enhance the effectiveness of their water resource monitoring, and ultimately make more informed decisions regarding water resource development and planning.

Appendix A

(Final Survey)

NDDWR Western States Water Survey

The North Dakota Department of Water Resources (DWR) is seeking to engage with water resource agencies in the 17 western states regarding the data collection methodology and practices each state deploys for water resource monitoring and water use. A primary focus for this survey will be to identify real-time and near real-time data and the technology platforms that are currently being developed and deployed to address respective initiatives, particularly the efforts surrounding the collection of water use data and pumping activities. Additionally, it would be advantageous to better understand what challenges other states face and how they currently or plan to address them. The results of the survey will be shared with all western states in order to provide benefits to all. We thank you in advance for your participation as we believe this effort will be beneficial to all states in understanding current best practices.

1. What state are you responding on behalf of?

Please Select

Contact Information

a. Name *

b. Organization Represented *

c. Phone Number *

d. Email Address *

Water Use

The goal of this section of the survey is to document and understand the methodologies used to collect, validate, and store surface and groundwater use data within each state.

1.) Does your state currently collect water use data?

- Yes
- No

a.) How many surface water sites/points of diversion/locations are monitored for water withdrawals?

e.g., 23

b.) How many groundwater sites/points of diversion/locations are monitored for water withdrawals?

e.g., 23

c.) Are automatic (remote data collection) or manual (self-reporting, meter readers, etc.) collection methods used?

- ○ Automatic
- ○ Manual
- ○ Both
- ○ None

2. How does your state currently store and manage the collected water use data?

- ☐ Propriety Software
- ☐ State Servers
- ☐ Cloud Storage
- ☐ Other

3. What is your state considering for future storage and management of water use data?

- ☐ Proprietary Software
- ☐ Cloud Storage
- ☐ State Servers
- ☐ Other

4. Is collected water use date information publicly available?

◯ Yes

◯ No

5. What are the current advantages and challenges associated with the current data storage and management practices in your state, regarding water use data?

6. What would your state change about your data collection for more accurate and reliable information, regarding water use data?

Water Chemistry

The goal of this section of the survey is to document and understand the methodologies used to collect, validate, and store surface and groundwater chemistry data within each state.

7. Does your state currently collect water chemistry data?

◯ Yes

◯ No

a.) What types of surface water chemistry data does your state collect?

- How many surface water chemistry monitoring sites does your state currently have?

e.g., 23

- How many are solely operated by the USGS?

e.g., 23

How many are cooperatively or completely funded by state entities?

e.g., 23

b.) What types of groundwater chemistry data does your state collect?

- How many groundwater chemistry monitoring sites does your state currently have?

e.g., 23

- How many are solely operated by the USGS?

e.g., 23

How many are cooperatively or completely funded by state entities?

e.g., 23

8. What methodologies are used to collect water chemistry data in your state?

a.) What automatic technologies (remote data collection) does your state use for water chemistry data collection?

- What are the advantages and challenges associated with each technology?

- How does your state ensure accuracy and integrity of the collected data?

9. What data collection methods are you considering for future use?

10. How does your state currently store and manage the collected water chemistry data?

- [ ] Proprietary Software
- [ ] Cloud Storage
- [ ] State Servers
- [ ] Other

11. What is your state considering for future data storage and management of water chemistry?

- [ ] Proprietary Software
- [ ] Cloud Storage
- [ ] State Servers
- [ ] Other

12. Is collected water chemistry data information publicly available?

- ( ) Yes
- ( ) No

13. What are the current advantages and challenges associated with the current data storage and management practices in your state, regarding water chemistry data?

14. What would your state change about your data collection for more accurate and reliable information, regarding water chemistry data?

Atmospheric/Climatic/Soil Data

The goal of this section of the survey is to document and understand the methodologies used to collect, validate, and store atmospheric, climatic, and soil data within each state.

Atmospheric Data Collection

e.g. temperature, precipication, barometic pressure

15. Does your state currently collect atmospheric data?

- ○ Yes
- ○ No

a.) What atmospheric data do you collect? Please check all that apply.

- ☐ Temperature
- ☐ Precipitation
- ☐ Barometric Pressure
- ☐ Windspeed
- ☐ Humidity
- ☐ Snow Depth
- ☐ Snow Water Equivalent
- ☐ PET
- ☐ Wind Direction
- ☐ Other

b.) What methodologies are used to collect atmospheric data in your state?

c.) How many atmospheric data collection sites does your state currently have?

e.g., 23

- How many are solely operated by the USGS?

e.g., 23

How many are cooperatively or completely funded by state entities?

e.g., 23

d.) What automatic technologies (remote data collection) does your state use?

- What are the advantages and challenges associated with each technology?

- How does your state ensure accuracy and integrity of the collected data?

e.) What data collection methods are you considering for future use?

Soil Data Collection

16. Does your state currently collect soil moisture data?

- ◯ Yes
- ◯ No

a.) What methodologies are used to collect soil data in your state?

b.) How many soil data collection sites does your state currently have?

e.g., 23

- How many are solely operated by the USGS?

e.g., 23

How many are cooperatively or completely funded by state entities?

e.g., 23

c.) What automatic technologies (remote data collection) does your state use?

- What are the advantages and challenges associated with each technology?

- How does your state ensure accuracy and integrity of the collected data?

d.) What data collection methods are you considering for future use?

17. How does your state currently store and manage the collected atmospheric/climatic/soil data?

- [ ] Proprietary Software
- [ ] Cloud Storage
- [ ] State Servers
- [ ] Other

18. What is your state considering for future storage and management of atmospheric/climatic/soil data?

- [ ] Proprietary software
- [ ] Cloud storage
- [ ] State servers
- [ ] Other

19. Is collected atmospheric/climatic/soil data information publicly available?

- Yes
- No

20. What are the current advantages and challenges associated with the current data storage and management practices in your state, regarding atmospheric/climatic/soil data?

21. What would your state change about your data collection for more accurate and reliable information, regarding atmospheric/climatic/soil data?

Water Flow and Stage Data

The goal of this section of the survey is to document and understand the methodologies used to collect, validate, and store surface and groundwater flow and stage data within each state.

Surface Water Flow Data Collection

22. Does your state currently collect flow data?

- Yes
- No

a.) What methodologies are used to collect flow data in your state?

- How many flow data collection sites does your state currently have?

e.g., 23

- How many are operated solely by the USGS?

e.g., 23

How many are cooperatively or completely funded by state entities?

e.g., 23

- What automatic technologies (remote data collection) does your state use?

What are the advantages and challenges associated with each technology?

How does your state ensure accuracy and integrity of the collected data?

b.) What data collection methods are you considering for future use?

Surface Water Stage Data Collection

23. Does your state currently collect stage data?

- ◯ Yes
- ◯ No

a.) What methodologies are used to collect stage data in your state?

- How many stage data collection sites does your state currently have?

e.g., 23

- How many are solely operated by the USGS?

e.g., 23

How many are cooperatively or completely funded by state entities?

e.g., 23

- What automatic technologies (remote data collection) does your state use?

What are the advantages and challenges associated with each technology?

How does your state ensure accuracy and integrity of the collected data

b.) What data collection methods are you considering for future use?

Groundwater Data Collection

24. Does your state currently collect groundwater levels?

- ○ Yes
- ○ No

a.) What methodologies are used to collect groundwater levels in your state?

- How many groundwater collection sites does your state currently have?

e.g., 23

- How many are solely operated by the USGS?

e.g., 23

How many are cooperatively or completely funded by state entities?

e.g., 23

- What automatic technologies (remote data collection) does your state use?

What are the advantages and challenges associated with each technology?

How does your state ensure accuracy and integrity of the collected data?

b.) What data collection methods are you considering for future use?

25. How does your state currently store and manage the collected water flow, stage, and groundwater level data?

- [ ] Proprietary Software
- [ ] Cloud Storage
- [ ] State Servers
- [ ] Other

26. What is your state considering for future storage and management of water flow, stage, and groundwater level data?

- [ ] Proprietary Software
- [ ] Cloud Storage
- [ ] State Servers
- [ ] Other

27. Is collected water flow, stage, and groundwater level data information publicly available?

- ( ) Yes
- ( ) No

28. What are the current advantages and challenges associated with the current data storage and management practices in your state, regarding water flow and stage data?

29. What would your state change about your data collection for more accurate and reliable information, regarding water flow, stage, and groundwater level data?

Artificial Intelligence (AI) and Predictive Modeling

The goal of this section of the survey is to document and understand the current and future use of artificial intelligence and predictive modeling to enhance water resource data collection practices within each state.

30. Please describe if your state has been implementing, is in the process of, or plans to implement AI as it relates to leveraging the state's data collection activities in making water resource management decisions.

31. Please describe any advances your state has made as it relates to water resources predictive modeling capabilities as a result of the water-related data collection efforts.

Additional Comments

32. Does your state have any additional water-related data collection efforts that have not been covered by the survey?

33. Do you have any comments related to this survey?

34. Do you have anything else you would like to inform us about related to your state's water resource efforts?

Comments or Questions

If you have any comments or questions, please reach out to Chris Korkowski, PE via phone at 701-557-9734 or email at christopher.korkowski@hdrinc.com.

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