Missouri River Basin Needs Assessment Report

Tools for Managing a Precious Resource

Prepared for

Western Water Applications Office

NASA Jet Propulsion Laboratory

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Executive Summary

From October 2022 to May 2023, HDR, Inc. (HDR) partnered with the National Aeronautics and Space Administration's (NASA) Western Water Applications Office (WWAO) to plan and conduct a needs assessment workshop focused on the Missouri River Basin. The workshop's objective was to identify water resource management needs and gaps and then develop use cases that could inform the development of future, co-developed projects. Planning for the needs assessment workshop relied on an internal water resources management survey report completed by SPF Water Engineering (SPF) in 2021. The survey included interviews of water resource management stakeholders in the Missouri River Basin and provided insights into their needs, challenges, potential NASA collaboration areas, and current use of remotely sensed information in water related decision making. This report presents an overview of the Missouri River Basin's physical and socioeconomic characteristics, describes the intent of the WWAO Needs Assessment, identifies the stakeholders who participated in the needs assessment workshop and their roles, and provides a summary of the workshop's findings. It also presents the most significant water management needs identified during the workshop and includes use cases that could aid in the development of future Requests for Information (RFI) from WWAO.

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List of Acronyms

AORC – Analysis of Record for Calibration
API – Applications Programming Interface
ASCII – American Standard Code for Information Interchange
CHPS – Community Hydrologic Prediction System (NOAA)
CyAN – Cyanobacteria Assessment Network
ECOSTRESS – ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station
EMIT – Earth Surface Mineral Dust Source Investigation
EPA – Environmental Protection Agency
ET – Evapotranspiration
GRACE – Gravity Recovery and Experiment
HDF – Hierarchical Data Format
HEC-HMS – Hydrologic Engineering Center-Hydrologic Modeling System (USACE)
HEC-RAS – Hydrologic Engineering Center – River Analysis System (USACE)
HUC – Hydrologic Unit Code
LiDAR – Light Detection And Ranging
LIS – Land Information System
MODIS – Moderate Resolution Imaging Spectroradiometer
NAIP – National Agriculture Imagery Program
NASA – National Aeronautics and Space Administration
NetCDF – Network Common Data Form
NISAR – NASA-ISRO Synthetic Aperture Radar
NLCD – National Land Cover Database
NLDAS – North American Land Data Assimilation System
NOAA – National Oceanic and Atmospheric Administration
NRCS – Natural Resources Conservation Service
NWS – National Weather Service
PRISM – Parameter-elevation Regressions on Independent Slopes Model
RFI – Request for Information
SMAP – Soil Moisture Active Passive Mission
SNODAS – Snow Data Assimilation System
SPoRT – Short-term Prediction Research and Transition Center
SSURGO – Soil Survey Geographic database
SWE – Snow Water Equivalent
SWOT – Surface Water and Ocean Topography Mission
TIF – Tag Image File Format
TMDL – Total Maximum Daily Load
USACE – United States Army Corps of Engineers
USBR – United States Bureau of Reclamation
USDA – United States Department of Agriculture
USFS – United States Forest Service
USFWS – United States Fish and Wildlife Service
USGS – United States Geologic Survey
VIIRS – Visible Infrared Imaging Radiometer Suite
VIRGO – Visualization of In-situ and Remotely-Sensed Groundwater Observations
WWAO – Western Water Applications Office

Introduction

The mission of the National Aeronautics and Space Administration's (NASA's) Western Water Applications Office (WWAO) is to improve how water is managed in the arid western United States by putting NASA data, technology, and tools into the hands of water managers and decision makers. HDR, Inc. (HDR) was tasked with assisting WWAO in this endeavor by helping plan and conduct a needs assessment workshop and companion pre-workshop webinar for the Missouri River Basin. This report presents an overview of the Missouri River Basin and project background, and then provides details of the needs assessment workshop and use case scenarios developed during the event.

Missouri River Basin

SPF Water Engineering, LLC (SPF) conducted a survey and characterization of the Missouri River Basin for NASA WWAO in 2021. This characterization is included below.

The Missouri River Basin (**Figure 1**) is the largest watershed in the United States (U.S.), with a drainage area of 529,350 square miles, covering one sixth of the country. The basin includes portions of ten states and two Canadian provinces. The Missouri River, nicknamed "the Big Muddy," begins its journey in Three Forks, Montana, just west of Bozeman, at the convergence of the Gallatin, Madison, and Jefferson rivers, and continues for more than 2,300 miles before joining the Mississippi River at St. Louis, Missouri. The largest tributaries by runoff are the Yellowstone River in Montana and Wyoming; Platte River in Wyoming, Colorado, and Nebraska; Osage River in Missouri; and Kansas River in Kansas and Missouri.

Figure 1. Missouri River Basin

Despite the length of the river and the vast expanse of the basin, the Missouri River produces annual yields of 40 million acre-feet (MAF), which is significantly less than the yields of the Columbia River (199 MAF). This has resulted in conflicts in the management and use of water within the basin (U.S. Bureau of Reclamation 2016).

The Missouri Basin exhibits large gradients in temperature and precipitation, with precipitation falling more as snow in the western basin and as rain in the eastern basin. Annual rainfall varies from 8 inches per year in the Rocky Mountain foothills (western half of the basin) to over 40 inches per year in parts of Missouri and Iowa (eastern half of the basin). In the portion of the basin east of the 100th meridian, irrigation is practiced in some areas but is not necessary for all crops in wetter years. In arid areas west of the 100th meridian, a mix of ranching, dryland farming, and irrigated agriculture is found (National Research Council [The Missouri River Ecosystem] 2002).

The High Plains, or Ogallala, aquifer underlies much of Nebraska and Kansas and portions of Colorado, Wyoming, and South Dakota. It is the most intensively used aquifer in the U.S., with total withdrawals of approximately 17,500 million gallons per day. The amount of water withdrawn from the High Plains aquifer is almost twice that of the aquifer with the next highest withdrawals and accounts for 23 percent of total withdrawals from all aquifers in the U.S. Irrigation withdrawals accounted for 97 percent of the total withdrawals from the High Plains aquifer in the year 2000 and another 2 percent was withdrawn for public-supply purposes (Maupin and Barber 2000).

The basin was authorized for exploration and settlement by Lewis and Clark's "Corps of Discovery" between 1804 and 1806. In the first half of the nineteenth century, much of the nation's westward exploration and expansion occurred by way of the Missouri River (New World Encyclopedia 2014). Irrigation began in earnest in the basin in the mid-1800s, with many irrigation projects fully developed by the late 1800s. Construction of hydropower dams also began in the basin during the second half of the nineteenth century. The U.S. Army Corps of Engineers (USACE) completed the first dam in the upper basin on the Missouri River at Fort Peck, Montana in 1939. Its primary purpose was to store water for use in supplementing flows downstream of Sioux Falls, Iowa, while maintaining a 6-foot-deep channel (National Research Council [The Missouri River Ecosystem] 2002).

Without a coordinated federal program to control flooding in the early twentieth century, a number of large floods on the Missouri River resulted in significant loss of life and property. After this, several major projects were identified for flood damage reduction in the basin, and Congress passed the 1944 Flood Control Act, which included the Pick-Sloan Plan. This plan affirmed that USACE would be responsible for building and operating the mainstem dams and other flood-control structures in the lower Missouri River and its tributaries in Kansas and Missouri, as well as determining flood-control and navigation storage capacities in all dams in the basin. The USBR would determine irrigation potential and allocate the water dedicated to irrigation, and construct and operate dams on the Missouri upstream from Fort Peck Dam and on upper basin tributaries. Besides the Pick-Sloan dams, the U.S. Natural Resources Conservation Service (NRCS) has constructed hundreds of smaller water projects, such as floodwater retarding dams, channel improvements, and sediment control structures on the Missouri River's tributaries (National Research Council [The Missouri River Ecosystem] 2002).

Project Background

SPF worked with WWAO to characterize water management priorities and challenges, including a survey of entities and organizations with water management interests in the Missouri River Basin. The project was composed of two phases during 2020 and 2021. The first phase identified important water management stakeholders within the Missouri River Basin who could potentially benefit from NASA's remote-sensing research, tools, and data. Stakeholders included federal and state agencies, municipalities, tribal organizations, universities, multi-state coalitions, private companies, and drinking water purveyors/water districts. The second phase identified specific survey participants who represented a cross-section of important water management stakeholders within the basin and were responsive to the survey request. Survey participants were interviewed to establish a deeper understanding of stakeholder water resource responsibilities, concerns, and challenges. SPF conducted 28 interviews with representatives of 28 entities and prepared a report of their findings. WWAO and HDR used the survey report to plan a Missouri River Basin needs assessment workshop, which was held in March 2023.

Needs Assessment Workshop

Building on the stakeholder surveys conducted in 2021, WWAO and HDR planned the Missouri River Basin needs assessment workshop with the goal of identifying water management needs and documenting these needs as use cases. Each use case describes the current state and/or water challenge, the need or gap that must be met to address that challenge, and the desired result if the need is met. The resulting use cases are then used to help form a basis for building water projects that can address key issues within the basin. The use cases may lead to a request for information (RFI) from WWAO where potential partners and stakeholders could propose projects to improve a decision-making process. Representatives of stakeholder organizations identified and/or interviewed as part of the survey were invited to participate in the needs assessment workshop. Invitations were also sent to an additional 200 water stakeholders in the Missouri River Basin. A pre-workshop webinar with approximately 40 participants was held in February 2023 to familiarize potential attendees with both the NASA Earth Science Program and WWAO, and to introduce participants to the upcoming workshop format and approach.

Workshop Format

The Missouri River Basin needs assessment workshop was held March 14 through March 16, 2023, in Omaha, Nebraska at the Omaha Marriott Downtown. Attendees included 25 stakeholder representatives, 7 NASA WWAO technical representatives, and 9 HDR workshop facilitators. **Table 1** lists all stakeholder participants, and **Table 2** lists all workshop facilitators.

Table 1. Needs Assessment Workshop Stakeholder Participants

Organization	Name	Position
Nebraska Department of Environment and Energy	Tara Anderson	Water Quality Standards Coordinator
	Bridger Corkill	Engineer
	Dane Pauley	Water Quality Certification Coordinator
Nebraska Department of Natural Resources	Jesse Bradley	Senior Hydrogeologist
	Shuhai Zheng	Head of Engineering and Technical Services
North Dakota Department of Water Resources	Clay Carufel	-
	Joe Nett	Hydrologist Manager
United States Geological Survey	Brenda Densmore	Associate Director for Hydrologic Investigations
University of Missouri-Extension	Dan Downing	Extension Specialist
South Dakota State University	Nathan Edwards	Mesonet Operations Manager
	John McMaine	Water Management Engineer
U.S. Army Corps of Engineers	Alex Flanigan	Hydraulic Engineer
	Ryan Larsen	Civil Engineer
	Rachel Schulz	Hydrology Section Chief
United States Bureau of Reclamation	Kevin Foley	Civil Engineer - Hydrologic
Valmont Industries	John Kastl	Vice President, Mechanical Value Stream
Montana Department of Natural Resources and Conservation	David Ketchum	Hydrologist
Coalition to Protect the Missouri River	Shane Kinne	Executive Director
National Oceanic and Atmospheric Administration	Doug Kluck	Central Region Climate Services Director
Audubon Great Plains	Melissa Mosier	Platte River Program Manager
Institute of Arctic and Alpine Research, University of Colorado Boulder	Karl Rittger	Research Associate
Kansas Water Office	Richard Rockel	Water Resource Planner
City of Omaha	Jim Theiler	Public Works Assistant Director
Missouri Department of Conservation	Matt Vitello	Policy Coordinator
Wyoming Department of Environmental Quality / Water Quality Department / Watershed Protection	David Waterstreet	Watershed Program Manager

Table 2. NASA and HDR Workshop Facilitators

Organization	Name	Position
	NASA	
WWAO	Indrani Graczyk	Program Manager
WWAO	Sharon Vasquez-Ray	Stakeholder Engagement Lead
WWAO	Stephanie Granger	Program Strategist
WWAO	Amber Jenkins	Information Architecture Lead
WWAO	Amber McCullum	Impact and Transition Lead
NASA	Bailing Li	Assistant Research Scientist
NASA	Renato Prata de Moraes Frasson	Research Scientist
	HDR	
HDR	Kristen Veldhouse	Project Manager
HDR	Julie Molacek	Strategic Communications Coordinator
HDR	John Engel	Senior Water Resources Engineer
HDR	Josh Jackson	Water Resources EIT
HDR	Paul Woodward	Senior Water Resources Engineer / Planner
HDR	Nathan Rossman	Hydrogeologist
HDR	Matt Pillard	Environmental Project Manager
HDR	Creighton Omer	Senior Water Resources Engineer
HDR	Matt McConville	Dams, Levees, and Civil Works Business Class Lead

The first day of the workshop included a welcome and introductions, an overview of WWAO and NASA capabilities, a description of the needs assessment process and the use case methodology, and an overview of outcomes from the Missouri River Basin survey that was completed in 2021. Day 1 was also used to determine focus areas around which breakout groups would be organized on Day 2. Ahead of the workshop, the WWAO team had pre-determined a set of six tentative focus areas based on the Missouri River Basin survey report and feedback gathered during the pre-workshop webinar. Guided by HDR and WWAO, participants were able to use these as a basis from which to determine a final set of focus areas that represented their areas of greatest interest and concern.

It is worth noting that climate change was one of the six pre-determined focus areas. When discussing whether to include climate change as a focus area on Day 2, participants expressed mixed opinions. All agreed that climate change was of extremely high priority, but the conundrum was whether to include it as its own focus area or to incorporate it into each of the other focus areas. Ultimately, participants decided to keep climate change as its own focus area.

However, at the end of Day 1, when each attendee was asked to rank their focus group preference for Day 2, all ranked climate change low on the list. It turned out that, in practice, climate change was best accounted for within the context of the other focus areas. Thus, the five remaining focus areas were as follows:

- Watershed Health and Management
- Water Availability
- Agriculture and Irrigation
- Water Quality
- Water Infrastructure

On Day 2, breakout groups were assigned to each focus area and meetings were held concurrently for most of the day. Brainstorming and prioritizing potential use cases occurred during the first hour of the day, with the remainder of the morning and most of the afternoon dedicated to use case development. The final hour of the day allowed participants to switch focus area breakout tables if they chose to do so to provide their thoughts on other use cases developed during the day.

Use cases were developed using the use case template in **Table 3**. The use case methodology was designed to provide step-by-step instructions for participants to build use cases that could lead to an RFI from WWAO. Project proposals could then be submitted to the RFI that address the identified needs or gaps. NASA WWAO and HDR facilitated the breakout group discussions. This information was used to complete the use case tables in the Use Cases section.

Table 3. Use Case Template

Priority	Use Case Element	Description
Must Haves	Current State or Water Management Challenge	Describe the current decision-making process and the data and models used to support decision-making, or the water management challenge where lack of information precludes progress.
	Desired Result	Describe desired improvements to the decision-making process or the water management challenge described above.
	Need/Gap	Describe the information needed to achieve the desired result (e.g., consumptive use, snow water equivalent, streamflow, vegetation health, etc.). Note: needs should be agnostic to specific solutions.
	Information requirements	To the extent possible, describe the data characteristics needed to improve the decision (e.g., spatial resolution, temporal resolution, accuracy, latency, and data formats). Include necessary modifications to existing models.
	Partner Potential	Identify the primary organization that would partner with WWAO to develop/implement a potential project to address the need (should it be selected). Provide name(s) and contact information. Primary partner: <Contact Info/Phone number here> Other interested parties: <Contact info and phone numbers>

Priority	Use Case Element	Description
Supports Needs Prioritization by WWAO	Description/Decision Context	Describe the decision to be made, how the decision is made, and who makes the decision with as much detail as possible, including information about what data are used to inform the decision-making process and who is currently responsible for producing and/or interpreting the data.
	Obstacles to addressing the need	Describe obstacles (e.g., technical, institutional, cultural, financial) to addressing the need.
	Priority (MI, VI, I)	Provide a rough estimate of the priority (MI, VI, or I) for the need. If possible, briefly describe your rationale for the prioritization. **MI**—**Most Important**—Refers to needs that are critical to sustain the Missouri River Basin's socio-economic and/or environmental viability. These are the highest priority needs that should be considered. **VI—Very Important**—Refers to needs that, if addressed, would contribute substantially to advancing the Missouri River Basin's socio-economic and/or environmental viability, second only to MI. Every effort should be made to address these needs if resources are available or if they can be addressed opportunistically. **I—Important**—Refers to high value needs that should be addressed if resources allow.
Supports Needs Prioritization by WWAO	Description/Decision Context	Describe the decision to be made, how the decision is made, and who makes the decision with as much detail as possible, including information about what data are used to inform the decision-making process and who is currently responsible for producing and/or interpreting the data.
	Obstacles to addressing the need	Describe obstacles (e.g., technical, institutional, cultural, financial) to addressing the need.

The third and final day of the workshop was spent refining and ranking use case topics before reporting the results of each breakout group to the plenary. The report-out was followed by a discussion on how, or if, use cases could be consolidated. Finally, WWAO reported on the next steps that would occur following the workshop.

Use Cases

This section provides descriptions of the use cases developed during the Missouri River Basin needs assessment workshop. A total of 21 use cases were developed during breakout sessions, shown in **Table 4**. The ranking column in **Table 4** shows how each focus area breakout group ranked the use cases in order of importance. Of these use cases, five were developed for Watershed Health and Management, three were developed for Water Availability, four were developed for Agriculture and Irrigation, six were developed for Water Quality, and three were developed for Water Infrastructure.

Table 4. Use Cases by Category with Ranking

Use Case Topic	Use Case Ranking (1 = most important)
A: Watershed Health and Management	
A-1: Identification of Habitat Corridors, Habitat Complexes, and Connections	2
A-2: Measure Channel Characteristics to Identify Changes in Watershed Health	3
A-3: Identification of Temperature Changes and Riparian Habitat in Headwater Streams	5
A-4: Refining Harmful Algal Bloom Satellite Data to Capture Smaller Waterbodies and Near-Shore Areas	1
A-5: Evaluating Contributing Factors to Evaluate Wetland Sustainability	4
B: Water Availability	
B-1: Measurement of Surface Water Storage and Elevation	3
B-2: Improved Runoff Forecasting	2
B-3: Improved Reservoir Yield Estimates	1
C: Agriculture and Irrigation	
C-1: Improved Consistent and Temporal Coverage of Soil Moisture and Temperature at Depth	2
C-2: Improved Spatial and Temporal Analyzed Evapotranspiration Information from Remotely Sensed Data – Enhance OpenET	1
C-3: Understanding Spatial and Temporal Change in Groundwater/Aquifer Levels	3
C-4: Soil Health/Carbon Sequestration	4
D: Water Quality	
D-1: Improved Temperature Measurements for Protection of Aquatic Life	4
D-2: Detection of Metals in Water Bodies	6
D-3: Determining Impact of Land Cover/Land Use Changes to Water Quality	1
D-4: Monitoring Water Quality	2
D-5: Identification of Land Applied Biosolid	5
D-6: Methods to Develop Automated Wetland Delineation	3
E: Water Infrastructure	
E-1: Improve River Forecasting through Collection and Application of More Refined Model Inputs	1
E-2: Infrastructure Condition Assessment	2 (tied)
E-3: NASA Water-Related Data Portal	2 (tied)

The final set of 21 use cases are described in the following sections and include completed templates for each use case.

Category A: Watershed Health & Management

Use Case A-1: Identification of Habitat Corridors, Habitat Complexes, and Connections

Missouri River Basin water managers and environmental scientists rely on landowners to provide information on habitats or complete field studies, which are costly to an agency in terms of both time and resources. Stakeholders were interested in a comprehensive dataset to assist in defining habitat corridors and connections for determining suitability as conservation areas for potential resource investment. Additionally, having land cover mapping data on an annual basis would provide historical data on the changes to habitats and help identify issues with the overall health of an ecosystem.

Use Case Element	Description
Current State or Water Management Challenge	Currently habitat areas are identified and acquired through landowner-initiated discussions. While there is existing data that includes species range maps and species occurrences, it is difficult for agencies to define habitat types and make decisions on suitability without a comprehensive dataset. Additionally, data is not aggregated.
Desired Result	The Missouri River Basin would benefit from a comprehensive dataset that aids in identifying conservation areas and/or management areas that decision makers can use to make acquisition decisions.
Need/Gap	Stakeholders need data for determining what is measurable to assist in defining habitat types.
Information Requirements	Land cover mapping should be acquired annually in the late spring or early summer. The annual data cadence was defined as a goal, but no specific timing was identified for receipt of data. Data should be provided in a shapefile or GeoTIFF and could include: • Canopy height • Vegetation height • Inundated vegetation • Vegetation density Spatial resolution for data could begin at 30m and ultimately be refined to 10m or less, if possible.
Partner Potential	Primary partners: State Department of Natural Resources, United States Fish and Wildlife Service (USFWS), and State game, fish, and parks. Other interested parties: Audubon, The Nature Conservancy, and Pheasants Forever.
Description/ Decision Context	The decision to be made is the strategic acquisition of property for conservation purposes.

Use Case Element	Description
Obstacles to Addressing the Need	Institutional obstacles include each agency's resources (technical, financial, and personnel) available to apply the data for their decision-making. Cultural obstacles may be individual landowner privacy concerns.
Priority (MI, VI, I)	**VI—Very Important**—Habitat diversity contributes to watershed health and the overall health of an ecosystem. Active habitat fragmentation threatens species viability.
Current Workflow	There is no real integration of data and existing data are currently disconnected between agencies.

Potential Data Sources	• Species presence data
	• Land cover
	• Flow data
	• Species range
	• Southeast Conservation Blueprint
	• Satellite-based data from:
	    • Landsat
	    • Sentinel-2
	    • MODIS
	    • VIIRS
	    • EMIT

Participants	USFWS, State agencies, non-governmental organizations, and not--for-profit conservation agencies.

Use Case A-2: Measure Channel Characteristics to Identify Changes in Watershed Health

Basin water managers discussed the importance of measuring channel characteristics to identify areas where intervention may be necessary to protect water quality, prevent flooding, control erosion, and maintain habitat quality. Currently, there is not enough specific, historical data to make proactive decisions based on channel migration changes. Water managers would benefit from having better channel migration data and land use change information to determine if, when, and how intervention is necessary.

Use Case Element	Description
Current State or Water Management Challenge	Management agencies must make decisions on utility impacts and/or restoration/stabilization efforts based on locations of channel changes. Currently there is little data on channel location or migration over time, resulting in reactionary management strategies by agencies.
Desired Result	Stakeholders would benefit from a better understanding of the rate of channel migration change. It would allow them to make more informed decisions regarding prevention, stabilization, and rehabilitation.
Need/Gap	There is a need to measure the rate of channel migration change on a vertical and horizontal scale over time as well as land use changes over time.
Information Requirements	Temporal information on an annual basis in the early winter.

Use Case Element	Description
	Spatial resolution data at 30m, 10m, and 1m should be provided when available. Data types include optical or elevation data for stream channel location and/or stream height or flow volumes. Geographic data for the entire watershed for land use changes.
Partner Potential	Primary partner: NRCS and United States Geological Survey (USGS). Other interested parties: State resource agencies and county or local soil and water conservation districts.
Description/ Decision Context	Determination to incorporate best management practices, permit requirements, and/or infrastructure location decisions.
Obstacles to Addressing the Need	Incorporation of data into policies/decision trees.
Priority (MI, VI, I)	**VI—Very Important**—This use case addresses socio-economic decisions and associated infrastructure costs.
Current Workflow	Current stream stabilization efforts are reactionary.
Potential Data Sources	Infrastructure inventories by public or private entities. Remotely sensed data from: • Landsat • Sentinel-2 • MODIS • VIIRS • LiDAR • SWOT
Participants	State or local transportation agencies, public or private infrastructure—such as rail, gas, water, wastewater, power, and fiber entities—and land use decision makers.

Use Case A-3: Identification of Temperature Changes and Riparian Habitat in Headwater Streams

Water managers need additional tools to justify their decisions related to headwater streams, help meet evolving regulatory requirements, protect aquatic ecosystems, make fair and equitable decisions for water/recreational users, and assist with their long-term planning. Two factors that assist in making headwater stream decisions are changes to temperature and riparian habitat. Stakeholders monitor temperature changes for varying reasons. State departments of environmental quality, game, and fish departments, and/or non-profits, such as Trout Unlimited, may desire to monitor temperature changes to determine when to initiate annual releases/stocking programs. However, measuring temperature changes is difficult as there are often not enough monitoring devices, and they are not always placed in ideal locations. Likewise, riparian habitat conditions and changes in riparian habitat are used to inform wildlife management decisions.

Use Case Element	Description
Current State or Water Management Challenge	Identifying temperature and riparian habitat changes in headwater streams would assist in justifying land and water use decisions in

Use Case Element	Description
	headwater streams. It would also assist in determinations for species promulgation, release times, and release locations.
Desired Result	Temperature and riparian habitat change data would provide a basis for informed decision-making relative to water use, fishery management, and wildlife management.
Need/Gap	There is a need to identify streamflow frequency, stream temperature, canopy cover, and herbaceous vegetation density. Stream temperature may need to be measured by air temperature or snow temperature as a proxy.
Information Requirements	Temporal information should include: • Streamflow frequency as often as possible, ideally daily or weekly. • Short-term stream temperature as frequently as possible, ideally daily or weekly. Air or snow temperature could be measured as a proxy. • Long-term stream temperature to retroactively determine changes to date, ideally on a monthly basis. • Canopy cover on a seasonal basis, such as annually during the summertime. • Herbaceous vegetation density on a seasonal basis, such as annually during summertime. Spatial resolution should include: • Streamflow frequency: 1m • Stream temperature: 1-5m • Canopy Cover: 3m • Herbaceous vegetation density: 1m Geographic information should include: • HUC12; 3rd order stream and lower
Partner Potential	Primary partner: USGS. Other interested parties: State departments of environmental quality; State game, fish, and parks; and Trout Unlimited.
Description/ Decision Context	Identification of timing for water use and fish and wildlife decisions.
Obstacles to Addressing the Need	Data to support decision making.
Priority (MI, VI, I)	**I—Important**—This use case was viewed as important because it would provide additional information to support tools used currently for decision making.
Current Workflow	Based on best available data (site collected) and best professional judgement.
Potential Data Sources	USGS stream gages, state departments of natural resources stream gages, National Oceanic and Atmospheric Administration (NOAA) weather information, and United States Department of Agriculture (USDA)/NRCS data. Remotely sensed data from: • Landsat

Use Case Element	Description
	• Sentinel-2 • MODIS • VIIRS • LiDAR
Participants	US Forestry Service (USFS), State game, fish, parks departments, and USDA/NRCS.

Use Case A-4: Refining Harmful Algal Bloom Satellite Data to Capture Smaller Waterbodies and Near-Shore Areas

Detecting harmful algal blooms early helps water managers take quick action to better manage them before they negatively impact public health and the surrounding environment. Careful monitoring of the size, location and intensity of harmful algal blooms helps agencies know if and when to issue public health warnings or initiate mitigation measures.

Traditional monitoring is time- and money-intensive for agencies. Remote-sensing data could help provide earlier warning of harmful algal blooms, or supplement public reports or direct sampling of waterbodies and near-shore areas, at minimum. Current satellite-data based monitoring systems, like the Cyanobacteria Assessment Network (CyAN), were cited as a resource, with this use case building on improvements temporally and spatially.

Use Case Element	Description
Current State or Water Management Challenge	Agencies rely only on reports and/or direct sampling of waterbodies and near-shore areas to issue public health warnings for harmful algal blooms.
Desired Result	Near-real time data for smaller water bodies could better support an early warning system for public use areas.
Need/Gap	Current data are measured at 10m resolution. A 1-3m resolution is needed for near-shore areas and smaller water bodies.
Information Requirements	1-3m resolution data at a weekly occurrence is reasonable in supporting the desired result. For latency, near real time data are preferred.
Partner Potential	Primary partner: Environmental Protection Agency (EPA) Office of Research and Development. Other interested parties: State departments of environmental quality.
Description/ Decision Context	Water managers need additional data to provide earlier issuance of public health warnings for harmful algal blooms.
Obstacles to Addressing the Need	Data for smaller water bodies are needed to make accurate decisions in a timely manner.
Priority (MI, VI, I)	**MI—Most Important**—Supports a public health decision that builds on existing tools.
Current Workflow	Harmful algal blooms are currently reported via public and/or agency visual observations, and sometimes symptoms from contact initiate warnings.
Potential Data Sources	Satellite-based imagery from Sentinel-2 and Landsat. Improved spatial and temporal resolution of existing data preferred.

Participants	State public health organizations and State game, fish, and parks departments.

Use Case A-5: Evaluating Contributing Factors to Evaluate Wetland Sustainability

Water managers need additional data to prioritize wetland conservation and preservation. The enhanced mapping of wetland/upland vegetation boundaries will aid in determining the volume of water necessary to sustain wetland viability. With this threshold defined, managers may make informed decisions on granting water use appropriations and limit withdrawals to ensure wetland sustainability.

Use Case Element	Description
Current State or Water Management Challenge	Currently, stakeholders use aerial imagery, such as the National Agriculture Imagery Program (NAIP) and/or Sentinel data, to define a surface area and determine volume of water when making permit decisions. Information to make decisions on how much water can be appropriated from a wetland for other uses is lacking.
Desired Result	Tools that aid in identifying a sustainable water yield from a wetland to prioritize conservation/preservation.
Need/Gap	Delineation of wetland boundaries (edge between wetland vegetation and upland vegetation) over time.
Information Requirements	• Temporal Resolution: Two data products per year to identify wetland extent in early spring (pre growing season) and again in late fall (post growing season). • Spatial Resolution: 1m is desirable. • Latency: Not an urgent need, this can be months after data is collected. • Geographic: Refined based on partner needs.
Partner Potential	Primary partner: USGS. Other interested parties: State departments of natural resources, water use agencies, and USFWS.
Description/ Decision Context	The data would support surface water permitting decisions.
Obstacles to Addressing the Need	Data to support decision-making as to the viability of the resource affected by the permit decision.
Priority (MI, VI, I)	**MI—Most Important**—Refers to needs that are critical in order to support socio-economic decisions (permitting).
Current Workflow	Assessments are made based on best professional judgement and/or with a site visit and review of best available data.
Potential Data Sources	Aerial imagery from NAIP. Satellite-based imagery from Sentinel-2 and Landsat.
Participants	State surface water permitting agencies.

Category B: Water Availability

Use Case B-1: Measurement of Surface Water Storage and Elevation

Workshop attendees would like to better quantify water storage and elevation in ungaged lakes/reservoirs and provide additional data for surface water bodies that are gaged.

Stakeholders interested in this topic focused on managing reservoirs; therefore, this use case originated from and focused on the concept of managing reservoir releases before runoff events. However, there are several stakeholders who would benefit from better measurement of surface water storage, including power producers and conservation groups.

Use Case Element	Description
Current State or Water Management Challenge	To prepare for a runoff event, stakeholders need to know how to manage reservoir releases. However, it is challenging to quantify water that is coming from upstream as well as the available water capacity in the system (reservoirs). There is a lack of information on gaged surface water bodies, including lakes and reservoirs. There should be a specific emphasis on remote prairie potholes, sandhills lakes, playa lakes, mountain lakes, stock ponds, and more, including reservoirs that may be ungaged. Currently, manual measurements can be used to verify gage data and there is no information at ungaged surface water bodies. Gaps occur at gaged locations when gages stop functioning.
Desired Result	The desired result is to better quantify water storage and elevation in ungaged lakes/reservoirs. Gaged locations would benefit from stage information where bathymetric data already exists to increase accuracy of storage volume estimates.
Need/Gap	Topographic data of water bodies at low stage would be used to define water body bathymetry and develop stage/storage/area relationships. Accurate remotely sensed water surface elevation data would then be used to determine stored volumes of water and additional storage available. This data is most important on prairie pothole lakes or ungaged surface water bodies.
Information Requirements	Daily data with relatively high accuracy on elevation/vertical, sub-inch accuracy discussed, but one-foot accuracy would be a great improvement over existing information. Data formats could be variable, such as ASCII or NetCDF. Latency of sub-weekly to weekly is desired.
Partner Potential	Primary partner: State agencies (natural resources or water agencies), USBR, and USACE. Other interested parties: Playa Lakes Joint Venture, power producers that run hydropower reservoirs, and conservation groups, such as Delta Waterfowl, Ducks Unlimited, and Pheasants Forever.
Description/ Decision Context	Water management decisions relating to reservoir operations are made by USACE and USBR; therefore, they will be most interested in this data. Currently, reservoir bathymetry is surveyed via instrumentation mounted on boats or operated manually. Such surveys produce depth measurements along cross-sections, which can be sparse, leading to inaccurate volume measurements. Additionally, ungaged water bodies, which are more likely to have no information on bathymetry, also lack water levels, hindering their management. Bathymetry measurements

Use Case Element	Description
	from Light Detection and Ranging (LiDAR) are currently only helpful for relatively shallow depths.
Obstacles to Addressing the Need	Vertical resolution should be of relatively high accuracy to limit error. Identifying locations of smaller and numerous lakes/ponds or surface water bodies is challenging based on sheer number and spatial distribution. Additionally, overall cataloging or inventory of surface water bodies, including geometry (depths/bathymetry) for quantifying total water storage (stage-volume curves), may be an obstacle due to the volume of data. Some agencies working across states would need to host the data for holistic use across the basin. The algorithm would need to run in near real-time for downstream users (i.e., input to rainfall-runoff models) and workflow would require efficient access to satellite data to be useful.
Priority (MI, VI, I)	**VI—Very Important**—The magnitude of the downstream impacts of the improvements to these datasets are hard to quantify at this time, but it could be very important as input to models dealing with the other two use cases in Category B, Water Availability. Resources are available and this data can be gathered opportunistically.
Current Workflow	Little to no data exists on ungaged storage sites, so often their potential storage is not reflected in runoff predictions. For gaged locations, data from most recent bathymetric surveys (often years to decades old) are used to estimate storage volumes.
Potential Data Sources	Local or regional studies on prairie pothole lakes, sandhill lakes, mountain lakes, playa lakes, stock ponds, and more may provide local data on geometry to help quantify storage volumes (or stage-storage relationships). This would be useful for populating a database with characteristics where LiDAR bathymetric data is unavailable or not accurate. The surface water and ocean topography (SWOT) sensor could catalog surface water bodies along with surface height or elevation, area, and changes in volume. NISAR is a possible future source of information on water extent and height at relatively high resolution that may be beneficial for detecting smaller bodies of water.
Participants	Reservoir owners and operators, emergency management officials, and state and local flood control officials.

Use Case B-2: Improved Runoff Forecasting

The highly uncertain models and methods for forecasting runoff events mean that stakeholders are making short- and long-term decisions on reservoir operations, floodplain management, and emergency response with incomplete or too infrequent data on key factors such as rainfall, snowpack, soil moisture, land cover, land use, streamflow measurements, and presence of frozen ground. The information requirements in this use case focus on more frequent datasets (hourly, sub daily, or daily) to improve runoff forecasts that will allow water managers to make better operational decisions in the short term, such as mitigating flood threats, as well as long-term- operational planning to ensure reservoir storage is managed to provide adequate supplies for its authorized purposes.

Use Case Element	Description
Current State or Water Management Challenge	Multiple models are currently used for forecasting river flows, flooding events, and reservoir operations, but forecasts are highly uncertain. Additionally, long-term forecasting of water supply, including mountain snow melt, is challenging. HEC-HMS (USACE) or CHPS (National Weather Service [NWS]) modeling packages are currently used to predict runoff from the watershed. HEC-RAS (USACE) or flow from rating curves (NWS) is used to route/simulate channel flows based on runoff estimates. Current input for developing predictive model inputs includes NWS precipitation products, NWS SNODAS gridded snowpack data (daily and hourly—daily is validated), soil moisture (representative basin value aggregated from gridded or lumped parameter model output), and infiltration based on gridded soil type hydraulic conductivity (SSURGO). More robust data sets are needed, both spatially and temporally, as typically there are hourly to daily outputs.
Desired Result	Improved data to better predict watershed runoff, resulting in lowered uncertainty of forecasts for improved confidence in operational decision-making and adaptive management.
Need/Gap	There is a need for more representative (spatially and temporally) input data sources for use in basin-wide models for predicting runoff, including precipitation, snowpack depth, soil moisture and temperature, land cover/use, and soil type-based infiltration rates. More streamflow measurements are needed for calibration of models; both new gaging locations and keeping existing gages operational should be emphasized. Additionally, more accurate meteorological data, spring-time precipitation forecasting (seasonal), and soil temperature data for improving infiltration would be useful. Overland flow and channel routing information would be useful but is not considered as important as other types of parameters.
Information Requirements	• Precipitation – Rainfall: Intensity, hourly to daily. • Precipitation – Snowfall: Intensity and accumulation, hourly to daily. Daily accumulated. 1km spatial resolution data would be preferred, especially to help with characterizing mountain snow volumes. • Soil moisture: Daily, consistent with precipitation data (1km). • Land cover/use: Annually, at a regional scale (10s of kilometers). • Streamflow measurements: Sub-daily. • Frozen ground: depth in terms of inches. There is no preferred spatial resolution, but the finer resolution (<2km) the better to improve accuracy of depth of frozen ground that impacts infiltration.

Use Case Element	Description
Partner Potential	Primary partners: USBR, USACE, NWS River Forecast Center, NRCS, and South Dakota State University (SDSU) Mesonet. Other interested parties: Kansas Water Office, State water management agencies, navigators, reservoir operators, power companies, municipalities, levee sponsors, public, emergency responders, and users/landowners involved with floodplains.
Description/ Decision Context	Runoff forecasts are used by stakeholders to make decisions on managing reservoir releases, floodplain management, emergency response and flood fighting, and for long-term (seasonal to annual time scale) reservoir operations and water management to meet multi-use water use objectives.
Obstacles to Addressing the Need	Assimilating, processing, and accessing high-resolution, high-frequency data is a technical challenge. Methods utilizing new data sources for flood forecasting have to be vetted, tested, and integrated over time before implementation. Soil temperature data can possibly be estimated using air temperature, but more measurements to verify these estimates (or to rely on separately) are needed. This is not possible to measure remotely when soils are snow covered. Soil temperature could be modeled, and the outputs from that modeling could be used as input to the basin-wide runoff models.
Priority (MI, VI, I)	**MI—Most Important**—This is considered most important because of the severity and breadth of possible flooding impacts, including the threat of human loss of life and economic impacts. Likewise, a large swath of the population is dependent on responsible management of the surface water storage in the basin to serve multiple purposes.
Current Workflow	The current process involves assembling hydrologic data (referenced above) from a number of sources with variability in the data type, quality, and resolution.
Potential Data Sources	Existing streamflow measurements for model calibration. Data from SWOT and more gages would be helpful. SDSU Mesonet data could be used as ground truth of weather variables for correlating or validating remote sensing data. Common grid and standards between Mesonet sensors and remote sensed data are needed to assist calibration/validation. The Mesonet data can bridge the time lapse gap between satellite flyovers. Existing gridded weather data products (PRISM, AORC, NLDAS). High resolution SMAP- or GRACE-based soil moisture estimates at root zone. Future NISAR estimates of soil moisture.
Participants	Federal, state, and local agencies engaged in flood mitigation and water supply planning activities.

Use Case B-3: Improved Reservoir Yield Estimates

As noted in Use Case B-1, stakeholders in the Water Availability breakout group focused on managing reservoirs. Therefore, use cases in this group focused primarily on reservoir management. These agencies have inadequate evapotranspiration data and unreliable groundwater measurement or modeling data to simulate reservoir losses. These types of losses are often estimated as residual quantities from water balance calculation. Better information to reflect reservoir losses will allow reservoir operators to better manage storage to serve authorized purposes.

Use Case Element	Description
Current State or Water Management Challenge	Reservoir yield estimates are prepared using the RiverWare modeling software, which uses estimates of groundwater exchange and reservoir evaporation and measured data for the other water budget variables. Yields are highly dependent on estimated evaporation. Many reservoirs are operated to provide water to users for long periods of time—even in times without inflows (i.e., during periods of shortage or drought). Evaporative volumes become large over these long time periods and decreased inflow, or times of shortage, amplify the importance of accurate data. Groundwater losses are estimated as the last residual to close the reservoir water budget.
Desired Result	Stakeholders desire better estimates of reservoir yield for long-term planning. This includes the reservoir's water budget and downstream transit (or conveyance) losses on the way to the end user.
Need/Gap	Evapotranspiration measurements from the entire reservoir surface is a data gap. Another data gap is local groundwater level data near the reservoir, including downstream channel and canals used for conveyance.
Information Requirements	• Evapotranspiration: spatial resolution across reservoir surface—approximately 500m is adequate, but a finer resolution would be helpful; monthly temporal resolution; latency is relatively unimportant. • Groundwater levels: any reliable measurement or modeling data of groundwater levels would be an improvement. Stakeholders would be interested in integrating with or validating against remote sensing data (which would be surficial expression).
Partner Potential	Primary partner: State water planning agencies, municipalities, USBR, and USACE. Other interested parties: Kansas Water Office and communities relying on reservoir water for drinking, irrigation, recreation, etc.
Description/ Decision Context	Reservoir yields are estimated with RiverWare modeling software and used to develop long-term (seasonal and beyond) operational plans to manage storage water for release and delivery to serve a multitude of end users. Usually, updated calculations of firm yield are driven by requests from users who would like to have more water delivered for increased use. Currently, estimates of groundwater exchange and evaporation are used in the model, while other water budget variables are based on measured data. Reservoir yield and operational planning are highly dependent on estimated evaporation.

Use Case Element	Description
	Evaporation data is typically calculated via land surface-temperature sensing instruments (remote sensing), and then requires other meteorological data inputs (wind, air temp, humidity, net radiation) and modeling to compute evaporation estimates. USBR currently calculates this for their facilities. USBR has the capability of incorporating groundwater data into calculations of reservoir losses. Kansas Water Office is interested in updating firm yield calculations as well. Water security and water availability planning across Kansas involves reservoir yield calculations.
Obstacles to Addressing the Need	Collection of groundwater in-situ data comes with many institutional, technical, and financial challenges.
Priority (MI, VI, I)	**VI—Very Important**—This effort would support long-term planning and is considered less important than flood response and reservoir operations for the many competing uses.
Current Workflow	Currently, reservoir evaporation is estimated from meteorological data inputs with little to no spatial variability across reservoir area. Groundwater (seepage) losses in the reservoir/receiving streams are typically estimated as the residual in water balance computations.
Potential Data Sources	VIRGO, Landsat, and MODIS for groundwater. GRACE-based modeled groundwater estimates. Sentinel-3 and future NISAR observations for estimates of subsidence related to groundwater recharge and extraction.
Participants	Water users relying on reservoir storage water for drinking water supplies, irrigation, hydropower, recreation, navigation, etc.

Category C: Agriculture and Irrigation

Use Case C-1: Improved Consistent and Temporal Coverage of Soil Moisture and Temperature at Depth

A better understanding of soil moisture and temperature will provide basin stakeholders with a better understanding of watershed hydrologic conditions. Producers can use this information to better plan for and adjust to seasonal conditions. Water managers, emergency management officials, and governmental agencies will use this information to better monitor and map drought conditions and inform decisions on allocation of resources to mitigate drought conditions.

Use Case Element	Description
Current State or Water Management Challenge	Currently, these measurements are point based and distributed sparsely. Distributed values generated on this point data have poor resolution and only describe the surface conditions. The information helps risk management for producers (what to plant and what to pay), pre-irrigation season scheduling support, pasture health, and drought monitoring/mapping (producer economic impact). Groups like the National Drought Mitigation Center (U.S. Drought Monitor) make decisions on drought severity based on this data. Other decision-makers include State water managers, emergency management agencies, and other local irrigation districts.

Use Case Element	Description
Desired Result	Improved, consistent, and temporal coverage of soil moisture and temperature depth would provide an improvement in seeing soil depth, spatial resolution, and temporal resolution. Enhanced data will better inform drought monitoring/mapping, pasture/forage forecasting, water quality and nitrate leaching, and planning for irrigated and dryland producers. It will also help inform risk management forecast/prediction and watershed water balance tracking.
Need/Gap	Gridded data set of soil moisture, soil temperature, frozen soil, and frost depth conditions with quarter section to section spatial resolution.
Information Requirements	Soil moisture at 6, 20, and 40 inches and all root zone depths, if possible. Gridded datasets as well as finished product mapping at quarter section resolution (500-800m) would be most useful. Monthly snapshots of these data are desired. An after-snowmelt and before planting snapshot would be the most useful if monthly data collection is not possible. An alternative (based on data latency) would be post-harvest data and then track precipitation balance through the winter (precipitation balance of runoff versus infiltration, snow water equivalent and sublimation) to derive spring conditions. Could verify using NASA SPORT-LIS data. Soil temperature map at depths through root zone (topsoil and subsoil). Diurnal temperature to 8 inches, a daily minimum/maximum with weekly summation, and field level resolution are preferred. This would help predict frost depth on a 4km grid and have it available at freeze/thaw and pre-planting.
Partner Potential	Primary partner: USDA (contact through USDA-Agricultural Research Service or NOAA). Other interested parties: National Drought Mitigation Center and High Plains Regional Climate Center. Users would include producers (dryland, irrigated and livestock), drought monitoring, State water management, universities, hydrologic modelers (NWS and USACE), private irrigation scheduling, crop insurance, and emergency management.
Description/ Decision Context	Producers use soil moisture information for determining crop types, planting density, and irrigation requirements for the upcoming season. In addition, this information can be used to inform cover crop decisions based on fall soil moisture levels. As an example, dairy farms where corn is cut for silage may plant cover crops that salvage nitrogen and produce forage. Producers could use fall soil moisture and targeted soil moisture in the spring to manage cover crop moisture usage. The National Drought Mitigation Center uses soil moisture as part of their drought monitoring and mapping process, and determination of drought severity. Emergency managers and the engineering community use soil moisture and temperature in estimates of soil infiltration/runoff in predicting streamflow.

Use Case Element	Description
Obstacles to Addressing the Need	Technological challenges may exist to gather data at depth. May require a surrogate remote sensed data element that can be correlated to physical measurements. Data latency given the spatial resolution and required processing to a usable product poses an additional challenge.
Priority (MI, VI, I)	**VI—Very Important**—Based on agrarian nature of the basin, heavy reliance on irrigation, and frequent presence of drought conditions that impact a wide range of basin participants.
Current Workflow	Currently, information is limited to point physical measurements that are used to represent broader regional estimates. This interpolation leads to inaccuracies—particularly important in instances of drought emergency or disaster declarations.
Potential Data Sources	Potential data sources include: • SDSU Mesonet or other weather stations • Producer field level data (future possibility) • GRACE • SMAP • MODIS • LANDSAT • VIIRS
Participants	State water management agencies, universities, hydrologic modelers (NWS and USACE), crop insurance agencies, and emergency management.

Use Case C-2: Improved Spatial and Temporal Analyzed Evapotranspiration Information from Remotely Sensed Data – Enhance OpenET

OpenET is used by many water managers using satellite and weather station data to make field level decisions. However, OpenET data has a 14-day information delay that water managers would like to see reduced through remotely sensed data. Increased spatial resolution would assist water managers in determining irrigation needs, crop water usage, irrigation scheduling, and evaporative losses in managing water delivery. Finally, an evapotranspiration dataset would add in the development and calibration of modeling tools.

Use Case Element	Description
Current State or Water Management Challenge	Irrigation and water management decisions are made at the field level and used to support a State's consistent administration of water. Irrigation producers make their field decisions, and State administrators (and other water managers) decide water allocation. However, they typically are using outdated, temperature-based analytical methods, such as the Blainey Criddle method (which ignores humidity), for crop consumption or evapotranspiration (ET). Field measurement of ET rates occurs at specific weather station locations with limitations in both their spatial and temporal resolution. The challenge for producer-level data is spatial and temporal resolution. The challenge for field level data is accurate broad-based coverage. OpenET daily timestep is available in raster format, but volume of data limits its inclusion in a geodatabase.

Use Case Element	Description
Desired Result	A spatial and temporal product that feeds into ongoing water balance, determining an ET rate applied over specified period. This would assist dryland and rangeland producers to determine how much soil water has been depleted and would enhance ongoing predictions and forecasts for field level decisions. It would also help with better flash drought predictions.
Need/Gap	There is a need to achieve a daily return of remote-sensed data to provide an ET result to users. Data latency and post-processing is an obstacle to meeting this need. The spatial resolution need would be a quarter section (805m) spacing.
Information Requirements	The desired temporal resolution is daily, and the desired spatial resolution is a quarter section (805m). OpenET data would be improved by reducing data latency.
Partner Potential	Primary partner: OpenET.
Description/ Decision Context	Daily to weekly decisions are made on range management, crop irrigation and delivery, and irrigation scheduling including demand estimates. Currently, these are made based on meteorological data and forecasts, and generalized reference ET or crop coefficient data. State administrators allocate water to appropriators based on crop consumptive use, which is based on analytic approaches and estimates.
Obstacles to Addressing the Need	Data latency and post-processing is an obstacle to meeting this need.
Priority (MI, VI, I)	**MI—Most Important**—ET is a critical factor in managing water and its uses throughout the basin. Current methods and simplified analytic approaches based on generalized data and coefficients. Finally, there is an opportunity to build on the OpenET framework to meet this need.
Current Workflow	The OpenET workflow is described in detail on their website: https://openetdata.org/methodologies/. The reported data latency for daily ET data is 12–16 days. However, access to the daily data is not currently available until an Application Programming Interface (API) is released.
Potential Data Sources	OpenET and site weather stations.
Participants	The primary user is dryland and irrigated land producers. All potential users include State water agencies, USBR, irrigation companies, data service providers, crop consultants, university extension offices, rangeland advise, golf courses, and the USDA economic outlook.

Use Case C-3: Understanding Spatial and Temporal Change in Groundwater/Aquifer Levels

Groundwater supplies are a substantial source of water in large portions of the Missouri River Basin. Understanding changes in groundwater and aquifer levels and the timing of those changes is critical for decision making to manage this resource.

Use Case Element	Description
Current State or Water Management Challenge	USGS or state agencies collect data periodically using static water level monitoring wells, or in some cases continuously recording monitoring wells. Regional aquifer mapping is typically completed annually and months after data is collected. This spatial and temporal scale may be suitable for planning and activities; however, decision makers are often facing issues with much shorter timescales, such as well interference, water level changes, and need for water use restrictions to protect existing uses.
Desired Result	Ultimately, water managers would have increased resolution of spatial and temporal groundwater elevation, storage, and drawdown data to make decisions. It is unknown if it is possible to forecast a change in groundwater storage.
Need/Gap	The gap is the continuous (weekly, or monthly at a minimum) representation of groundwater levels. Current annual snapshots from field measurements lack temporal resolution. There is a temporal gap and limited spatial resolution in GRACE results.
Information Requirements	GRACE groundwater storage anomaly correlated to field measured groundwater levels from existing monitoring wells.
Partner Potential	Primary partner: Nebraska Department of Natural Resources and Kansas Division of Water Resources. Other interested parties: Stakeholders with aquifer management authority.
Description/ Decision Context	Groundwater management authorities currently rely on months to years old data, with limited additional seasonal data, to manage aquifer levels. Decisions to curtail or allocate uses have significant economic impacts, but public drinking and industrial supplies are often dependent on active management of the groundwater aquifer.
Obstacles to Addressing the Need	Timely collection and processing of data, correlation to field measurements, and processing for use by stakeholders to provide meaningful benefit likely requires weekly or monthly, at a minimum, time scale.
Priority (MI, VI, I)	**VI—Very Important**—Ranked as very important based on the role groundwater resources play within the basin, in particular the economic impact of irrigated agriculture and public drinking and industrial water supply. Also, existing monitoring data is available to correlate to GRACE observations.
Current Workflow	Data measurement accuracy is within a tenth of a foot. Data feeds into groundwater models and eventually stream depletion.
Potential Data Sources	GRACE remote sensed data correlated to existing groundwater monitoring data. Sentinel-3 and future NISAR estimates of subsidence.
Participants	State and local groundwater management agencies.

Use Case C-4: Soil Health/Carbon Sequestration

While stakeholders saw the value in better measuring soil carbon change, it was unknown if NASA's products could capture and quantify this data. The stakeholder group discussed how historical poor soil health does not allow corn and soybeans to weather too much water in the spring and too little in the summer, as both can commonly cause crop insurance losses in the same year. The focus area breakout group was not able to fully develop this use case during the workshop; further exploration of this topic is needed.

Use Case Element	Description
Current State or Water Management Challenge	NRCS has a soil health initiative, and states in the U.S. are building upon these initiatives to capitalize on the economic benefits of their adoption. A defensible, economically efficient approach for estimating carbon sequestration is desired to market carbon credit. The current soil health/carbon sequestration measurement is soil sampling and lab testing to determine carbon credit/change.
Desired Result	Create a broad, remotely sensed grid representing soil carbon change.
Need/Gap	There is not a ground-level baseline of soil carbon. The only validation of soil carbon credit is soil sampling and lab testing. There is no broad observation or measurement of carbon sequestration currently.
Information Requirements	Information requirements are fairly unknown since there is not a soil carbon baseline. There is a need to predict carbon content through the soil profile based on surficial observations. There is a potential use of land subsidence measurements, which will see an increase in non-compacted, healthier soils. Measurements of subsidence could be correlated to field measurements to develop estimates of carbon change. It is recommended that this should be tried on range and pastureland first.
Partner Potential	Primary partner: NRCS, State conservationists and NASA HARVEST and ACRES programs. Other interested parties: Private agriculture agencies, investors, carbon credit markets.
Description/ Decision Context	In the carbon credit market, validation of carbon credits purchased/sold is required for long-term market viability. For overall soil health, data would be used to prioritize investments in soil management approaches that provide tangible benefits.
Obstacles to Addressing the Need	Limited existing soil carbon data (temporally and spatially) to validate remotely sensed data. Granularity of single field scale data requirements is an additional challenge.
Priority (MI, VI, I)	**I—Important**—Growing in importance from an overall soil health aspect, but also the growing carbon credit market and potential economic impacts.
Current Workflow	Current soil health/carbon sequestration requires site specific field data collection, soil sampling, and lab testing to determine carbon credit/change.
Potential Data Sources	Imaging spectroscopy.
Participants	NRCS, soil conservation districts, individual producers, corporations and individual investors involved in carbon credit market.

Category D: Water Quality

Use Case D-1: Improved Temperature Measurements for Protection of Aquatic Life

Stakeholders discussed how water temperature is used to monitor and protect aquatic species throughout the basin. Currently, there is limited availability of temperature measurements, specifically for aquatic species monitoring. Existing data lacks temporal and spatial resolution. The stakeholders determined this data would be beneficial to differentiate between native cold and warm water aquatic species. Availability of better data could be used for comparison across water bodies throughout the basin.

Use Case Element	Description
Current State or Water Management Challenge	Water managers are responsible for monitoring water temperatures. While there are many reasons this data is collected, one key reason is that improved temperature measurements would help protect aquatic life and the overall ecosystem. Better data would set a baseline expectation for species needs and collected data could be used to compare standards across water bodies. A major challenge to using this data effectively would be determining the parameter(s) needed to sustain life.
Desired Result	Enable the evaluation of the effects of climate change in aquatic life, which is impacted by stream temperature.
Need/Gap	There is a need to differentiate between viable habitats for native cold and warm water species and measure temperature in streams. However, data with the needed temporal and spatial characteristics are missing and collection of in-situ data for validation is expensive.
Information Requirements	Information requirements include: • Resolution: 5m to resolve intermittent rivers • Frequency: Seasonal; Three to five measurements per season • Length of data: 2–10 years. For this application, data latency is not critical.
Partner Potential	USFWS; tribes; environmental groups; universities/academies; State game, fish, and parks; and recreationalists.
Description/ Decision Context	Data will be used to make decisions based on potential improvements to aquatic life and differentiate between cold water and warm water streams.
Obstacles to Addressing the Need	Availability of data with adequate time series length. Validation of data. Spatial and temporal data collection.
Priority (MI, VI, I)	**I—Important**—Useable data already exists, and this would help differentiate between cold water and warm water species.
Current Workflow	No current workflow.
Potential Data Sources	Sentinel 2, Landsat, and ECOSTRESS can be used for temperature estimation for wider waterbodies; however, the spatial resolution does not meet the identified needs.
Participants	USFWS; tribes; environmental groups; universities/academies; State game, fish, and parks; and recreationalists.

Use Case D-2: Detection of Metals in Water Bodies

The stakeholders developed this use case to identify alternative means to detect heavy metals via remote sensing. Heavy metals most commonly enter water bodies through industrial and consumer waste and through mining activities. Current detection methods use in-situ data and cannot always capture and trace heavy metals to their origins. Having remotely sensed data of trace concentrations of metals at a high resolution in near real-time would allow for timely response to leaks.

Use Case Element	Description
Current State or Water Management Challenge	Heavy metals often enter water bodies by industrial and consumer waste and through mining activities. Detecting trace metals/heavy metals in water bodies is crucial to human health, as heavy metals can cause toxicities in humans. Additionally, heavy metal pollutants can have a significant negative impact on aquatic and mammal life. The current state of mining's reliance on in-situ data causes blind spots in detecting trace heavy metals.
Desired Result	Ability to detect trace metals in water in timely fashion to respond to leaks.
Need/Gap	Rather than in-situ data collection, remotely sensed retrieval of trace metals would be beneficial. The remotely sensed data should differentiate and quantify naturally occurring metals versus introduced metals.
Information Requirements	Near real-time information at 5m is preferred to more accurately respond to metals/heavy metals detected in water bodies.
Partner Potential	Public water supply districts, USFWS and State/local health departments
Description/ Decision Context	Decision support tools to aid in real-time response to contaminants.
Obstacles to Addressing the Need	Stakeholders were unaware if remotely sensing trace metals was achievable given current technology. Solids (suspended/dissolved/total) might be a more feasible target.
Priority (MI, VI, I)	**I—Important**—While trace metals can be detrimental to human health, given the technology uncertainties and limitations this use case was rated as Important.
Current Workflow	Relies on in-situ data that causes blind spots in detecting trace heavy metals.
Potential Data Sources	Potential data sources are unknown.
Participants	Public water supply districts, USFWS and State/local health departments

Use Case D-3: Determining Impact of Land Cover/Land Use Changes to Water Quality

The stakeholders recognize that land cover and land use data currently exist, primarily through the National Land Cover Database (NLCD), a widely known and commonly used data source. One NLCD limitation is that it is updated approximately every 3 years. In addition, the spatial resolution is 30m. NLCD's temporal and spatial resolution make it somewhat coarse for identifying land use and land cover changes that occur on an annual basis (or more frequently).

Water managers desire more frequent observation/collection of land use changes and with increased spatial resolution (i.e., 5m) to better track riparian evolution.

Use Case Element	Description
Current State or Water Management Challenge	Land use and land cover changes have a far-reaching impact on water quality and ultimately human health. While land use and land cover information are used to inform watershed management, watershed protection plans, city planning, recreation, and zoning, there is currently a lack of data, lack of frequently updated data, and lack of resources for entities to process and use that data for planning purposes.
Desired Result	More frequent observation to quantify land use change to determine its impact on watershed health/water quality through remote sensing methods.
Need/Gap	Agencies typically evaluate land use changes every one to three years. Water managers need more frequent observations of land use at a higher resolution than is currently being provided. Additionally, this data needs to be paired with quality measurements.
Information Requirements	The desired resolution for land cover and land use is 5m to enable tracking of riparian evolution, streets, roofs, etc. Ideally data is collected and provided on an annual or seasonal basis for water quality, and monthly for baseflow data.
Partner Potential	State departments of agriculture, NRCS, environmental planning and zoning offices.
Description/ Decision Context	The Nebraska Department of Environment and Energy and similar entities/agencies could use this data to provide better water management plans and best management practices. This data could also inform local land use planning.
Obstacles to Addressing the Need	Obstacles include the lack of infrastructure and resources to provide data more often than every 3 years. Additionally, defining how the product should be delivered (via GIS layer, or a new tool /software) is key. The level of detail and frequency of land use and land cover data will require processing large data volumes and require large amounts of data storage. There may also be a perception that more frequent monitoring at fine spatial resolution is invasive and could cause privacy concerns.
Priority (MI, VI, I)	**MI—Most Important**—Land cover/land use data used to determine Total Maximum Daily Loads (TMDL) are updated every 3–5 years, which is too out-of-date for water managers to use in their decision-making process.
Current Workflow	Uses data that is often outdated and updated only once every 1–3 years.
Potential Data Sources	Use existing data sources but provide for more frequent data collection and at higher resolution.
Participants	State departments of agriculture, NRCS, environmental planning and zoning offices.

Use Case D-4: Monitoring Water Quality

This use case was developed with the idea of supplementing existing water quality data with higher resolution and more frequent temporal distribution. Collection of remotely sensed water quality parameters (i.e., suspended/total sediments, e-coli, nutrients, chlorophyll, algae, and metals) could supplement existing in-situ measurements—at a basin scale—and be used for comparison with industry standards. These measurements could be used by regulatory agencies to issue more timely public health warnings.

Use Case Element	Description
Current State or Water Management Challenge	Determine water quality along basins, rotation of in-situ sampling of water quality parameter to cover entire basin within required frequency.
Desired Result	Stakeholders would like to supplement in-situ measurements with remotely sensed information on physical, chemical, and biological parameters, such as E-coli, metals, sediment, nutrients, and chlorophyll.
Need/Gap	There is a need for spatially-temporally complete measurements of suspended/total sediments, E-coli, nutrients, streamflow, chlorophyll, algae, and metals.
Information requirements	5m resolution at a monthly or weekly cadence.
Partner Potential	USBR, state departments of agriculture, county soil environmental districts, and local municipalities
Description/ Decision Context	Measurements for harmful water quality issues are compared with industry standards and used by regulatory agencies to issue public health warnings. More and better water quality data would assist these agencies in issuing earlier warnings. Compare measurements with standards and issue warnings depending on comparison. Regulatory agencies.
Obstacles to addressing the need	Agencies/employees have intrinsic biases that limit the vision of what is possible for data collection. There is also some resistance to the adoption of new technologies and integrating them into existing processes/policies. Additionally, agencies have limited IT resources to integrate new technologies.
Priority (MI, VI, I)	**MI—Most Important**—Data collection of these elements could have a beneficial impact to human and animal life (e.g., e-coli, metals) to issue early warnings.
Current Workflow	Current workflow unknown.
Potential Data Sources	Optical imagery and imaging spectroscopy
Participants	USBR, state departments of agriculture, county soil environmental districts, and local municipalities.

Use Case D-5: Identification of Land Applied Biosolid

Stakeholders were largely in agreement that land applied biosolids data collection is lacking or even non-existent. These can result in sludge deposits that could be a source of per- and polyfluorinated substances (PFAS), E-coli, nutrients, and organic matter that can contaminate surface and/or groundwater. Observation of these areas could help identify erosion/leaching risk that can lead to contamination. It could also identify locations of concentrated animal feeding operations, treatment plants, and more.

Use Case Element	Description
Current State or Water Management Challenge	Sludge deposits can be a source of contaminants, introducing per-and polyfluorinated substances (PFAS), E-coli, nutrients, and organic matter into surface or groundwater. Currently, there are no observational

Use Case Element	Description
	capabilities, other than some permits requiring periodic reporting on these contaminants. Better identification of land applied biosolid would be applicable to many stakeholders, including concentrated animal feeding operations, treatment plants, and more.
Desired Result	Ultimately, observations would lead to identification of surface area and erosion/leaching risk that can lead to contamination. It would also assist with identifying future locations for deposits that are safer.
Need/Gap	Observations are largely lacking or non-existent.
Information Requirements	Location/size of applications, soil morphology, composition, porosity, terrain slope, and other parameters that go into soil loss equations. There would also need to be information on erosion potential.
Partner Potential	Dairy industry, health departments, EPA, state governments, NRCS, USDA, and sources of byproducts.
Description/ Decision Context	This would lead to earlier identification of contaminants for making decisions on safer locations for future deposits.
Obstacles to Addressing the Need	Stakeholders were concerned that remote sensing may not capture the data needed to help with decision making, and therefore this approach might not be feasible
Priority (MI, VI, I)	**I—Important**—Stakeholders were concerned that this may not be feasible with remote sensing and therefore concluded that it should be a lower priority.
Current Workflow	Assumed there is no current workflow; no existing data.
Potential Data Sources	Permit required reporting (limited).
Participants	Dairy industry, health departments, EPA, state governments, NRCS, USDA, and sources of byproducts.

Use Case D-6: Methods to Develop Automated Wetland Delineation

Water managers currently rely heavily on the National Wetlands Inventory (NWI) to identify the types, sizes, and locations of wetlands. NWI is based on relatively old data, some collected as far back as the 1980s. It is widely understood that NWI undercounts wetlands and is outdated due to tile drains in crop lands. The stakeholders are interested in improved collection of wetlands data via remote sensing to assist with monitoring hydrophytic vegetation, water surface dynamics, and detection of location and geometry of wetlands. The desire is the ability to capture wetland bodies as small as one acre.

Use Case Element	Description
Current State or Water Management Challenge	Location and size of wetlands is based on infrequently updated inventory that began with 1980s aerial imagery. This method is known to undercount wetlands and is an outdated method due to tile drains for crop lands.
Desired Result	Remote sensing would assist with monitoring the presence of hydrophilic vegetation, water surface dynamics, detection of location, and geometry of wetlands.
Need/Gap	Currently, water managers rely on NWI-based photography to delineate wetlands, missing ephemeral wetlands and inundation dynamics.
Information Requirements	Improve the temporal frequency of NWI, produced by USFWS, tracking bodies as small as one acre in size.

Use Case Element	Description
Partner Potential	USFWS, Nebraska Department of Environment and Energy, and state and local fish and game agencies.
Description/ Decision Context	Regulatory and permitting officials, along with USFWS would use this data to locate wetlands.
Obstacles to Addressing the Need	Potentially, remote sensing data could confuse wetlands with lagoons, and maybe have other false detections. Additionally, remote sensing may not identify specific wetland types.
Priority (MI, VI, I)	**I—Important**—While this information already exists and is readily available, information is old and delineating wetlands takes significant manual labor from agencies.
Current Workflow	Uses infrequently updated data, most of which was collected in the 1980s.
Potential Data Sources	Augment new, more frequently collected data with existing data sources.
Participants	Dairy industry, health departments, EPA, state governments, NRCS, USDA, and sources of byproducts.

Category E: Water Infrastructure

Use Case E-1: Improve River Forecasting through Collection and Application of More Refined Model Inputs

Missouri River Basin stakeholders would like to improve river forecasting through more refined model inputs, ultimately resulting in less manipulation/assumptions by water managers in using modeling tools to get the output they need to make water management decisions. Precipitation measurements are a key information requirement. There are radar gaps (as noted for southeast Montana) and not enough refined resolution at the desired frequency. Stakeholders noted that NWS sends hourly observed precipitation data to USACE.

Use Case Element	Description
Current State or Water Management Challenge	System operations and emergency response are dependent on accurate river forecasting. Current river forecasting does not fully meet the needs of forecasters, system operators, or affected entities.
Desired Result	Stakeholders would like to improve the accuracy of river forecasts in terms of stage, arrival, and duration and ultimately decrease the variance between forecast and observed river conditions.
Need/Gap	Various needs include: • Current precipitation measurements (observed and forecasted) • Past and current air temperature • Landcover • Soil condition data, including soil type, soil moisture, frozen state • Current surface water extents • Snowpack • Albedo
Information Requirements	Information requirements include: • Observed precipitation measurements: ◦ Address radar gaps (southeast Montana for example)

Use Case Element	Description

	• Improve resolution of precipitation measurements to 2km, with hourly resolution or less, and available within 4 hours of occurrence with an accuracy 0.1 inch
	• Forecasted precipitation measurements—derivative of weather model.
	• Past and current air temperature at 2 km: accuracy within 1 degree Fahrenheit, at an hourly occurrence
	• Forecast temperature: improve useful forecast duration
	• Landcover: monthly vegetative cover at 30m with 2- to 3-day latency. NLCD type classification and format is preferred.
	• Impervious area: collected annually and is more important in developing urban areas. The ability to assess directly connected impervious area is desired.
	• Soil condition data:
	  • Soil type: remoted sensed at 30m resolution
	  • Moisture: percent saturation within first foot on a daily basis, available the next day
	  • Frozen state: measure for the top 2 inches on a daily basis
	• Current surface water extents: Measured by acre on a daily to weekly basis
	• Snowpack: 1 km desired particularly in mountainous regions. If not in a mountainous region, 2 km is adequate. Both should be measured daily. Also needed are snow water equivalent estimates (SWE) that are more accurate than SNODAS.
	• Albedo: daily to weekly; daily to weekly on 2 km grid. (Model requirement; already available)

Partner Potential	Primary partner: NOAA NWS River Forecast Center Other interested parties: USACE, USGS, NRCS, USBR, North Dakota Department of Water Resources, Montana Department of Natural Resources and Conservation, South Dakota Department of Natural Resources, Nebraska Department of Natural Resources, Wyoming State Engineer's Office, and Kansas Water Office.
Description/ Decision Context	Decisions are made regarding high or low river conditions. High river condition decisions include reservoir operations, evacuations, flood fighting locations and allocation of resources. Low river condition decisions involve water supply, allocation, water rights, and water treatment. Decisions are made based on the current forecast (peak stage, minimum stage), which has limitations. USACE, USBR and RFC produce forecasts interpreted by numerous stakeholders/affected parties in their water management activities.

Use Case Element	Description
Obstacles to Addressing the Need	Obstacles may be technical in terms of data availability (i.e., radar gaps) and differing model input needs. Another obstacle may be the volume of data and latency required. Institutional and financial obstacles may include the ability of hydrologists/meteorologists/modelers to incorporate the data into forecasting tools in a timely manner. There may also be resource constraints for time and computing.
Priority (MI, VI, I)	**MI—Most Important**—Priority ranking based on breadth of users within the basin that rely upon accurate forecasting to make decisions.
Current Workflow	Data gathering occurs at the beginning of the workflow. Users gather grids (clip desired spatial extents using large datasets from USACE Cumulus). The model sequence includes runoff models, reservoir models, river models, and consequence models. The desired process is to have similar datasets that do not require manipulation—aside from clipping—to the desired area. Rainfall, temperature, and snowpack are currently applied as gridded estimates. Frozen ground and soil moisture are currently qualitative, so improvements are particularly needed in this area. Air temperature is used as a proxy for solar radiation. In the future, solar radiation data would be beneficial.
Potential Data Sources	Data is available from different public sources (NWS, NRCS, NOAA, NASA, USBR, USACE, etc.); however, the spatial resolution and consistency in data format varies, requiring significant manipulation before use.
Participants	This use case applies broadly to federal, state, and local entities with responsibility in watershed management, flood control, and reservoir operations.

Use Case E-2: Infrastructure Condition Assessment

Agencies who manage levees, dams, canal systems, and other water infrastructure do not have the resources to inspect the conditions of the infrastructure they manage regularly, resulting in reactionary management practices. There is a particular need for more infrastructure condition data after flood events, which are becoming more frequent in the Missouri River Basin due in part to climate change. While basin-wide infrastructure observation data is the ultimate desired result, stakeholders noted that they would be willing to focus on specific, pre-defined infrastructure that is considered critical.

Use Case Element	Description
Current State or Water Management Challenge	Decisions on infrastructure condition, such as deficiencies and needed repairs, rely on infrequent physical inspection data. For example, levees undergo some level of field inspection each year and a more comprehensive inspection every 5 years. These physical inspections take time and are not as comprehensive as is needed.
Desired Result	Ideally, collecting infrastructure terrain and position data occurs at a routine interval, such as annually, and after major flood events occur so that changes can be identified and rectified more readily.

Use Case Element	Description
	The primary desired result would be to collect data basin wide. This data would be available online with means to extract the desired terrain dataset using a shapefile input. The secondary desired result would be to obtain coverage for specific, pre-defined infrastructure (dams, levee systems, canal systems etc.), thus limiting the spatial extent of what is required. Scope at dams may include dam embankment, auxiliary spillway, upstream sediment deposition, and downstream reaches to assess channel and land use changes. This framework would also apply to critical infrastructure, such as bridges and utility crossings.
Need/Gap	A terrain dataset to extract features such as levee crest profiles, levee cross sections, dam crest profiles, auxiliary spillway profiles, and sections to provide comparison to the previous year's dataset (or most recent pre-event dataset) to identify issues such as settlement and sloughing.
Information Requirements	Information requirements include: • Spatial Resolution: Preferred 1-foot-cell resolution terrain; a maximum 3-foot-cell resolution is required due to width of features being captured. For example, levee top width varies between approximately 10 and 15 feet. • Temporal Resolution: Annually. • Accuracy: Horizontal – 1 foot. Vertical – 0.1 foot to 0.5 foot. Accuracy might vary based on risk. • Latency: 1–2 months for annual collection. 2–3 days for event-driven data. • Data Format: TIFF, NetCDF (multiple acceptable formats).
Partner Potential	Primary partner: USGS Earth Resources Observation and Science Center. Other interested parties: USACE Omaha District.
Description/ Decision Context	The general decision is where to allocate maintenance and/or emergency resources. These decisions are made by the infrastructure owners based on immediate needs identified during periodic data collection and inspection efforts or during emergencies. Owners include USACE, USBR, and a variety of local project sponsors (levee districts, natural resource districts, counties, and municipalities). Current decisions are often reactive rather than proactive.
Obstacles to Addressing the Need	Technical obstacles may be the spatial extent and resolution for basin wide data collection. Vegetative cover limiting remotely sensed data accuracy, requiring ground-truthing to achieve a bare-earth surface. Institutional obstacles may be low trust in the Federal Government (fear of regulation or otherwise), as well as a lack of understanding or trust in the data itself.
Priority (MI, VI, I)	**MI—Most Important**—This information would be critical in emergency response scenarios. Less-served communities could benefit tremendously where current resources do not allow for regular or any inspection.

Use Case Element	Description
Current Workflow	As an example of current workflow for levees, physical inspection may be performed once annually to document visible deficiencies, such as erosion, rodent holes, etc. Survey of identified cross sections and other features are obtained periodically.
Potential Data Sources	Drone-based LiDAR or other mobile data collection methods.
Participants	Infrastructure owners such as USACE, USBR, state agencies, and local levee sponsors (districts, counties, municipalities).

Use Case E-3: NASA Water-Related Data Portal

All water managers in the WWAO service area would benefit from a single, front-end portal to reduce the amount of data manipulation necessary due to numerous and various data sources. During the group report out session on Day 3, stakeholders had a broader conversation about the need for a one-stop-shop data source rather than using multiple (siloed) data sources. Currently the USGS data site is the most complete, but the general consensus is that, while there are many good existing tools, there is not a single, preferred source of information that all stakeholders use and that would be a good partner in developing and hosting this portal.

Use Case Element	Description
Current State or Water Management Challenge	Data collection is cumbersome due to multiple sources, data format limitations and variability, varying spatial extents and resolutions, and difficulty in accessing and downloading desired datasets.
Desired Result	Ultimately, stakeholders would like to remove barriers to data acquisition by developing a front-end portal that allows access to publicly available data that can be selected easily (based on spatial, data type, temporal period, and other user inputs) and downloaded for use by third parties (federal, state, local agencies, etc.). This would allow spatial flexibility by using a user-supplied shapefile (polygon) and navigation by Hydrologic Unit Code (HUC). It would also allow for varying spatial extents to be defined in multiple ways, as one can on waterdata.usgs.gov. Tools to use as examples include USACE Cumulus, waterdata.usgs.gov, and USGS EarthExplorer. As an example, a desired dataset is soil moisture, not the raw spectral analysis data that was obtained. The portal would allow navigation by both map and data type. The portal would be publicly available via login. It would be open to all, but users would need to establish an account.
Need/Gap	Access to all publicly available, analysis-ready, hydrometeorological data from NASA.
Information Requirements	Datasets include, but are not limited to: • Soil moisture • Albedo • Snow water equivalent • LiDAR • SMAP products • SWOT products

Use Case Element	Description
	A site to host data for the U.S. would be a requirement. It is recommended to begin with NASA Level 3 and Level 4 data. Data formats may include NetCDF, GeoTIFF, and others. The site should be updated with additional datasets a minimum of once per week or as data becomes available. The site could include a social chat tool to allow users to post questions about data needs, where/how to find certain datasets, etc.
Partner Potential	Primary partners: NASA WWAO, USACE and USGS. Other interested parties: Esri.
Description/ Decision Context	There should be open collaboration with NASA and USACE HEC to align data availability and formats with model data input needs. Software development can be tailored to use data that NASA can readily provide. This could be approached as a pilot study.
Obstacles to Addressing the Need	There is an overlap with other NASA assets and other public agencies. Additionally, should a site or portal be stood up, there will need to be extensive outreach for awareness and training for website users.
Priority (MI, VI, I)	**MI—Most Important**—This would remove barriers to data access that currently exist and would allow full utilization of the suite of NASA data already being collected to the benefit of all—both within the Missouri River Basin and nationwide.
Current Workflow	The current workflow requires cumbersome searching, downloading, and manipulation of multiple data sources.
Potential Data Sources	USACE and USGS data serving websites may provide website structure/functionality that could be applied to this case.
Participants	This use case applies broadly to federal, state, and local entities with responsibility in watershed management, flood control, reservoir operations, etc. Extends beyond the Missouri River Basin to users nationwide.

Summary and Conclusions

NASA's WWAO Missouri River Basin needs assessment workshop was held in-person in March 2023. This report presents an overview of the Missouri River Basin and summarizes the workshop and its outcomes. During the workshop, stakeholder participants worked together to identify key water management needs and to develop use cases that described these needs in detail.

The workshop's overarching goals were to identify opportunities where remote sensing data could complement existing systems and facilitate key water management decisions, discuss data needs and information gaps in the Missouri River Basin, identify ways in which NASA may be able to assist in meeting these needs, and develop use case scenarios for the Missouri River Basin. During the workshop, use cases were developed in five breakout groups, with each group having a unique focus area. The ability to discuss needs and challenges, both as a large group and in smaller focused breakout groups, meant that stakeholders were able to develop thoughtful use cases they could then prioritize based on importance. Stakeholders collaborated on focus areas associated with watershed health and management, water availability, agriculture and irrigation, water quality, and water infrastructure. A total of 21 use cases were developed, which are documented in this report.

Common themes identified in the workshop and expressed in several use cases was the need for remotely sensed data with enhanced spatial and temporal resolution for use in estimating water supplies, as well as remotely sensed data of the basin's natural resources linked to water management decisions (stream channels, wetlands, water storage, riparian habitat, land use, etc.). However, limited resources (people and financial) were identified as obstacles to addressing these needs and the resulting use cases.

Stakeholders also discussed the need to remove barriers to data acquisition. This would mean providing a one-stop-shop website for water managers, since data is hosted on several different portals in several different formats and data sources. A front-end portal or website could host publicly available data, which would be selected easily based on spatial, data type, temporal period, and other user inputs, and downloaded for use by third parties. While beneficial to stakeholders, implementation would be challenging since no one agency owns all the data that would be included in the portal. Additionally, an agency would need to identify significant resources to host and maintain such a portal.

On the last day of the workshop, participants discussed whether any use cases could be combined. As such, participants noted the following potential use case combinations:

- Wetland delineation use case from the Water Quality focus area and the stream health use case from the Watershed focus area.
- River forecasting use cases from the Water Availability and the Water Infrastructure focus areas.
- Runoff use cases from the Watershed Health and Management and Water Availability focus areas.

During the same discussion, participants pointed out that additional use cases could be explored within the water infrastructure focus area, including ice cover and ice jams as well as sedimentation in reservoirs and throughout rivers.

Many stakeholders found significant value in the workshop—the average rating from the post-workshop evaluation survey for venue/event platform, speakers, quality of sessions, number of sessions offered, and date(s) of the event was 4.6 out of 5. Additionally, stakeholders noted their appreciation of the ability to collaborate with different agencies and discuss ideas. The most noted item to improve future workshops was that participants would like both a larger stakeholder group in attendance and a more diverse range of Missouri River Basin stakeholders.

Several stakeholders made the comment that WWAO's needs assessment workshop was the only opportunity they had to collaborate with other water managers in the basin. As a result, post-workshop communication included the names and organizations of workshop participants so that future collaborations could occur. It should be noted that only 25 stakeholders out of the almost 200 stakeholders invited were in attendance. As the largest watershed in the United States, there are many voices that were not heard in the workshop, which in turn affects use case development. To capture additional water managers in the basin, it may be worthwhile to host another needs assessment workshop in the northern part of the basin. Continued collaboration between water managers in the Missouri River Basin and NASA will bring more informed, data-driven water management decisions to the basin.

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