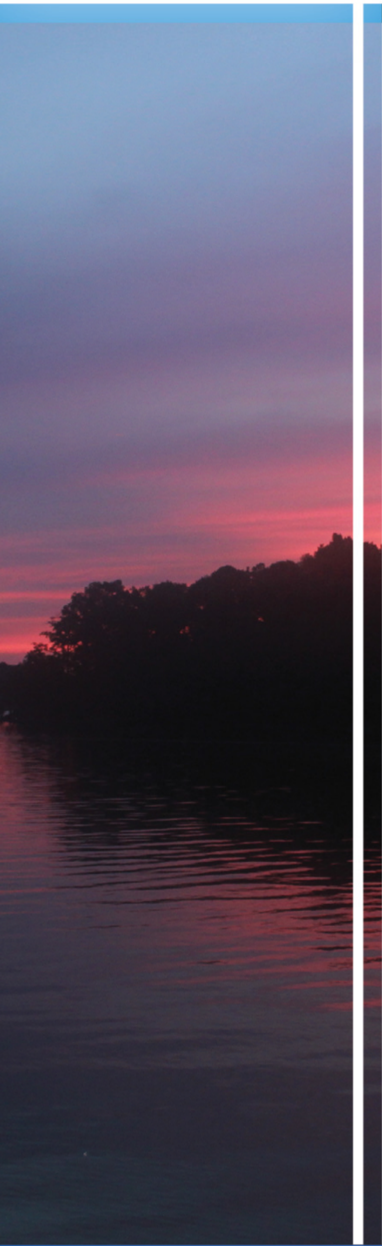

Ohio River Basin Stakeholder Report:

Integrated Water Resources Science and Services

May 2015

Contract #EAJ33C-09-CQ-0034

Cover: Top photo is of Nashville, Tennessee, stakeholder meeting. Side panel photo is of Lake Barkley, Kentucky–Tennessee border. Both photos courtesy of Bob Sneed, USACE.

EXECUTIVE SUMMARY

The Integrated Water Resources Science and Services (IWRSS) is a new business model for interagency collaboration between the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers (USACE), and the National Oceanic and Atmospheric Administration (NOAA). These federal agencies have complementary missions in water science, observation, management, and prediction. The IWRSS agencies are working together to design, develop, and implement a national water modeling and information services framework to infuse new hydrologic science into current water resources management; develop hydrologic techniques and information to support operational water resources decisions; and provide advanced hydrologic services to meet stakeholder needs. The overarching objective of IWRSS is to serve as a reliable and authoritative means of adaptive water related planning, preparedness, and response.

It is critical that IWRSS services meet the needs of water resources managers, water suppliers, planners, and decision-makers. This project was designed and executed to obtain information on priority stakeholder needs in the Ohio River Basin. Similar engagement forums have been held in the mid-Atlantic region (Delaware, Hudson, Potomac, and Susquehanna River Basins) as well as the Russian River Basin, California.[1]

IWRSS sought stakeholder input to:

- Validate existing gaps and identify new needs in water resources services.
- Identify new IWRSS capabilities that could address stakeholder needs.
- Identify (and, where possible, quantify) the socioeconomic benefit of addressing these needs.

Ohio River Basin stakeholders identified water quality and water supply as the highest-priority water resources issues, followed by fish and aquatic habitat (in the Upper Basin) and flooding (in the Lower Basin).

During the forums, stakeholders identified some common gaps across these issues:

- Valuation (of water and ecosystem services).
- Projections and predictions related to climate change.
- Water consumption and withdrawal management.
- Data integration.

Stakeholders then proposed seven pilot projects that would demonstrate how these key information gaps could be filled to address priority issues:

- **Water supply:** (1) Develop a model for a water budget including future climate change scenarios, a common central data portal, and GIS capability. (2) Model future scenarios showing uncertainty in water supply, demand, and ecological requirements due to climate change.
- **Water quality:** (1) Develop a decision support system, initially focused on spill response. (2) Develop a predictive tool that uses climate change and land use data to evaluate, predict, and demonstrate

[1] "Stakeholder Engagement to Demonstrate IWRSS for the River Basin Commissions in the Mid-Atlantic," NOAA National Weather Service, March 2014, and "Integrated Water Resources Science and Services, Russian River Basin Partner Report," NOAA National Weather Service, expected July 2015.

effects of land management practices on water supply and water quality. (3) Develop a method linking river water quality forecasts to major recreational areas and use a smartphone app to alert kayakers and other recreationists about unsafe bacteria levels.

- **Fish and aquatic habitat:** Prepare requirements for a database and data services system to help establish the value of aquatic habitats.
- **Flooding:** Launch a citizen-scientist data collection effort involving schools and leveraging private sector funding to develop data to enhance modeling and raise awareness.

To supplement input obtained at the forums, NOAA contractor Eastern Research Group (ERG) conducted a post-meeting survey of a broader group of stakeholders. The survey corroborated water quality and water supply are the top two priority issues in the Ohio Basin. Most respondents have access to the information they need, but they reported that the information is not adequate or needs improvement. The most common barrier to using the information is that there is not enough information available. Improved water quality was identified as the primary benefit of new or additional IWRSS information.

The IWRSS team consulted with the Ohio River Valley Water Sanitation Commission (ORSANCO) to discuss the seven pilot project ideas generated. Out of the discussion emerged two pilot projects in particular that addressed priority needs, had high potential transferability, high degree of stakeholder support, and represented good candidates to apply or develop IWRSS capabilities:

- A large-scale watershed model.
- A decision support system for spill response.

These projects, by engaging IWRSS capabilities, have high potential to fill in existing gaps and thus improve water resources decision-making in the Ohio River Basin. The results of the stakeholder meetings and survey, in addition to the pilot projects, will inform future investment in information and services provided by IWRSS.

Sunset over Lake Barkley, Kentucky–Tennessee border. ***Photo: Bob Sneed, USACE***

LIST OF ACRONYMS

ADM	Archer Daniels Midland Company
API	application programming interface
BMP	best management practice
DO	dissolved oxygen
DOI	U.S. Department of the Interior
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
EPRI	Electric Power Research Institute
ERG	Eastern Research Group
FEMA	Federal Emergency Management Agency
GIS	geographic information system
HEC-RAS	Hydrologic Engineering Centers River Analysis System
IRIS	Integrated Risk Information System (EPA)
IWRSS	Integrated Water Resources Science and Services
LIDAR	light detection and ranging
MPO	Metropolitan Planning Organization
NGO	non-governmental organization
NOAA	National Oceanic and Atmospheric Administration
NPS	non-point source
NRCS	Natural Resources Conservation Service (USDA)
NWS	National Weather Service (NOAA)
OKI	Ohio–Kentucky–Indiana Regional Council of Governments
ORSANCO	Ohio River Valley Water Sanitation Commission
OWDI	Open Water Data Initiative
PS	point source
TMDL	total maximum daily load
TVA	Tennessee Valley Authority
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service (DOI)
USGS	U.S. Geological Survey

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1.0 INTRODUCTION

Integrated Water Resources Science and Services (IWRSS) is supported by a consortium of federal agencies with complementary missions in water science, observation, management, and prediction: the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers (USACE), and the National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service (NWS). The objective of IWRSS is to design, develop, and implement a national water modelling and information services framework to infuse new hydrologic science into current water resources management, develop hydrologic techniques and decision support applications for operational use, and provide advanced hydrologic services to address growing stakeholder needs.

Toward this end, IWRSS addresses complex water resources problems collaboratively, using a multi-disciplinary approach. Planned IWRSS services include:

- High spatial and temporal resolution "summit to sea" analyses and forecasts for a full spectrum of water budget parameters.
- Short- to long-term river forecasts that quantify uncertainty.
- Static flood inundation map libraries and real-time flood forecast inundation mapping to show the aerial extent and depth of flooding.
- Linking river forecasts and associated flood inundation maps to potential socioeconomic impacts.
- Integrating the access to geospatial water resources information from multiple federal agencies through a single portal.

The purpose of this project was to engage with stakeholders in the Ohio River Basin to understand the need for IWRSS on a regional scale by:

- Validating existing gaps and identifying new needs to address water resources priorities.
- Identifying IWRSS capabilities that could address stakeholder needs.
- Quantifying the socioeconomic benefit of addressing these gaps and developing the business case to demonstrate new IWRSS capabilities to address stakeholder needs.

2.0 METHODOLOGY

IWRSS partners validated gaps and identified new needs for water resources services by (1) holding two stakeholder forums in the Ohio River Basin (see Appendix A for a list of participants, and Appendices B and C for meeting agendas and detailed notes) and (2) conducting a post-meeting survey (see Appendix D for the a copy of the survey report). These efforts provided detailed qualitative information about the gaps and needs of the Upper and Lower River Basin.

2.1 Stakeholder Meetings

On June 25 and 26, 2014, NWS, in cooperation with the Ohio River Valley Water Sanitation Commission (ORSANCO) and in coordination with the IWRSS federal partner agencies, convened two one-day facilitated stakeholder meetings in Nashville, Tennessee, and Cincinnati, Ohio, to obtain input on priority needs for IWRSS services. The Nashville meeting concerned the Lower Basin, defined to include the Tennessee, Cumberland, Wabash, and Green River watersheds. The Cincinnati meeting concerned the Upper Basin—watersheds generally north of the Lower Basin.

The meetings involved 57 representatives from national, regional, state, and local organizations. These participants learned about hydrologic services IWRSS can provide, identified key gaps that IWRSS might fill to inform water resources decision-making, and discussed possible demonstration projects to build capacity for enhanced integrated water resources management in the Ohio River Basin.

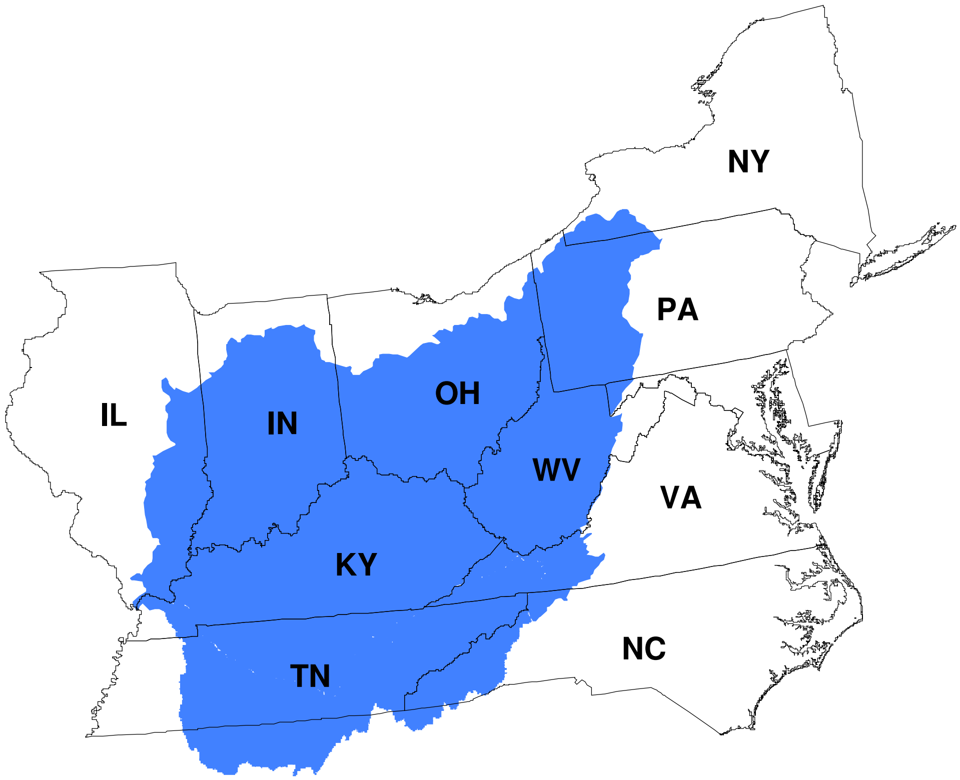

Figure 1. The Ohio River Basin drains portions of 14 states and 204,000 square miles.

2.2 Pre-meeting Issue Identification

The IWRSS team developed a paper describing priority water resources issues for the Ohio River Basin based on a review of EPA, ORSANCO, and USACE reports and in consultation with ORSANCO. The team shared this list of issues with participants before the meetings. As part of the forum registration process, participants were asked to indicate their three highest priorities (with the option of writing in additional suggestions). Priority issues for the Upper Ohio River Basin (along with the number of votes received, in parentheses) are summarized in Table 1, below.

Table 1. Ohio River Basin Priority Issues

Topic	Issues Include:
Water quality (29) #1 issue	• Impacts from runoff by land use conversions and combined sewer overflows. • Water quality effects on threatened and endangered species. • Pharmaceuticals, bacteria, pesticides, nutrient loading, and sedimentation. • Lack of basin-wide stormwater management. • Lack of adequate water treatment/distribution and sewage collection/treatment infrastructure.

Table 1. Ohio River Basin Priority Issues

Topic	Issues Include:
Water supply, water withdrawals, water management (18) #2 issue	• Sufficiency of water supplies in view of projected population increases and climate change. • Bank erosion due to flow regulation at reservoirs, navigation locks, and dams. • Conflicts among water users (i.e., water supply, hydropower, recreation, flood protection, fish and wildlife, and navigation). • Better management of water storage and flows. • Out-of-basin water transfers for water supply and other uses.
Fish and aquatic habitat (14) #3 issue in the Upper Basin	• Lack of ecological connectivity between the rivers/floodplains. • Regulated flow from reservoirs reduces aquatic species habitat diversity and productivity. • Effects of sedimentation on aquatic species including game fish and their food sources. • Invasive species' effects on indigenous aquatic and terrestrial species in the basin. • Changes to river flow regimes, temperature, and nutrient dynamics of the river system, which have affected some fisheries.
Flooding (12) #3 issue in the Lower Basin	• Need for additional flood protection at basin-wide major cities and smaller communities. • Need to update floodplain mapping to better manage development. • Fiscal sustainability of streamflow gages in the basin that are critical to flood warning systems and drought monitoring.
Climate/drought (11)	• Potential effects of climate change on threatened and endangered species habitat, recreational use, water supplies, and agriculture.
Energy production (10)	• Water quality and quantity impacts associated with exploration of the Marcellus shale. • Concerns about impacts of transporting fracking wastes along Ohio River and other waterways. • Hydropower facilities' impact on aquatic life by causing mortality to fish that pass through the facility's turbines. • Diversion of river flow through a hydropower facility.
Maintaining hydrology (5)	• Dredging and maintenance of navigation channels (continually needed for commercial navigation); new commodities and freight prospects in the Ohio River, which place added importance on the navigation system and connections to Gulf Coast ports. • Repair and rehabilitation of aging flood control infrastructure.

2.3 Pre-meeting Survey—Needs, Barriers, and Benefits Identification

To supplement information obtained in stakeholder meetings, ERG also surveyed stakeholders in the Ohio River Basin on water resources information needs, barriers to obtaining useful information, and potential benefits of filling information gaps.[2]

The survey was open from July 1 to August 1, 2014, during which 153 complete responses were collected. It was sent to a list of 435 stakeholders compiled with assistance from ORSANCO and other organizations in the river basin; stakeholders could also respond to the survey via links posted on the ORSANCO website and distributed by the Cumberland River Compact.

Some **key findings** from the survey:

- Most respondents were affiliated with government agencies, had more than 15 years of experience with water resources management issues in the Ohio River Basin, dealt with these issues on a daily basis, and were responsible for providing input into key planning and management decisions.
- The survey corroborated water quality and water supply (including water withdrawals and water management) as the top two priority issues in the Ohio River Basin.
- Most respondents reported that they had access to the information they needed, but found it adequate or in need of improvement.
- Respondents described their access to four types of water resources information: observations, forecasts, uncertainties, and analyses.
    - Observation: Respondents reported using observations to support decision-making over a wide range of time frames, from immediate (30 percent) to over a year (36 percent). One-third of respondents wanted to see new observation information made available for use on an hourly basis.
    - Forecasts: Most respondents indicated that they used forecast information to make decisions over one to three days (36 percent), followed by over a year (28 percent).
    - Uncertainties: Uncertainty information supports decision-making over a longer timeline, either more than a year (34 percent) or one month to one year (25 percent).
    - Most respondents would like to see new uncertainty information made available daily (29 percent) or annually (21 percent).
    - Analyses: For 36 percent of respondents, analyses support decisions made over a timeline of more than a year. Another 30 percent of respondents needed analyses to support decisions over one to three days, and 29 percent needed analyses to support decisions made over one month to one year.

A detailed survey report can be found in Appendix D.

3.0 SUMMARY OF STAKEHOLDER MEETING RESULTS AND SURVEY

This section describes the high-level findings and recommendations of the two stakeholder meetings in the Ohio River Basin. Detailed information for each forum is contained in the forum notes (Appendices B

[2] In 2013, ERG performed a similar survey of four river basins in the mid-Atlantic region: Potomac, Delaware, Susquehanna, and Hudson.

and C) and the survey report (Appendix D), which contains raw survey data and a more detailed analysis of the results.

Nashville, Tennessee, Stakeholder Meeting. ***Photo: Bob Sneed, USACE***

3.1 Top Priorities in the Ohio River Basin

Forum participants identified the following high-priority issues in the survey and confirmed them during the meetings:

Cincinnati (Upper River Basin):	Nashville (Lower River Basin):
• Water quality	• Water quality
• Water supply	• Water supply
• Fish and aquatic habitat	• Flooding

Stakeholders across the Ohio River Basin identified water quality and water supply as the two most pressing issues. Seventy-eight percent of the 153 survey respondents identified water quality as "extremely important" and 52 percent ranked it as the most important issue in the Ohio River Basin. Fifty percent identified water supply (including withdrawals and management) as "extremely important" and one-quarter of all respondents ranked it second in importance.

Water Quality

In the Upper Basin, stakeholders in Cincinnati gave examples of water quality concerns such as water-based recreation in areas where *E. coli* standards not being met; uncertain sources of algal growth; impacts of algal growth on utility operations; maintaining stream gaging; access to real-time data to improve spill response; and determining climate change impacts on long-term water quality. The Lower Basin stakeholders were concerned with rapid land use changes that are affecting water quality. Representatives of the Tennessee Valley Authority (TVA) mentioned water quality and supply concerns related to existing and future operations.

Water Supply

Upper Basin stakeholders mentioned several water supply concerns including water leaving the basin through "cryptic" water transfers and the need for better information to more effectively manage changes in reservoir storage, releases, and dam operations to mitigate spills. In the Lower Basin, better information was also desired in order to better manage and balance increasing water demands versus the supply.

Fish and Aquatic Habitat (Upper Basin) and Flooding (Lower Basin)

Fish and aquatic habitat were another top priority for the Upper Basin as stakeholders expressed concerns over impacts of water temperature change on fish species. Nashville participants were concerned with how to improve real-time inundation mapping and decision-making at the community level before and during flooding events.

Boat ramp construction, Cumberland River, Nashville, Tennessee. *Photo: Bob Sneed, USACE*

3.2 Addressing Gaps in the Ohio River Basin

Stakeholders in Cincinnati and Nashville were asked to determine what questions would need to be answered to address priority issues. The table below summarizes the questions each group identified and the pilot project ideas that could address those questions.

Table 2. Ohio River Basin Priority Issues – Pilot Project identification

Issue	Cincinnati	Nashville
Water quality questions to be answered by pilot projects	Are policies for preparation and emergency response to upstream spills/accidental releases adequate? How can risks and impacts of known/permitted point and non-point discharges be better managed? With increased recreational demands on the river, how can we protect users from poor water quality conditions? Do we know when it is safe for primary or secondary recreational contact (e.g., when bacterial or algal indicators are high)?	If we make these watershed land use changes, what is the impact on local water quality? Can we improve the water quality standards for parameters such as temperature and dissolved oxygen to better protect aquatic resources in a changing climate? How do you decide to invest in point vs. non-point source projects? For example, are significant capital expenditures to upgrade treatment plants more cost-effective than implementation of wide-scale, strategic non-point source controls?
Pilot projects	Decision support system initially focused on spill response Smartphone recreation water quality app	Predictive tool connecting climate and land-use change to evaluate water supply and water quality
Potential benefits identified	• Increases public confidence in safety (spills and recreation), particularly since 5 million people use the main stem of the river for drinking water. • Provides spill risk assessment approach (beneficiaries include community resilience planners, asset management managers, insurance industry, and shipping/other private sectors). • Improves transparency and communication. • Protects public health. • Improves community/public relations (consider the loss of public confidence after the recent West Virginia spill). • Leverages expenditures on the existing Ohio River Community HEC-RAS model (money saved, bigger "bang for your buck").	• Help evaluate operational cost savings and capital investments vs. green infrastructure costs. For example, Cincinnati and Pittsburgh will be spending $3 billion to upgrade wastewater treatment plants. • Will clarify impact of high-growth areas such as industrial agriculture and urban sprawl. • Helps quantify non-point source loads. • Shows that land use change is a key part of the modeling. • Communicates to a broad audience and explains decisions. The tool could identify the option that meets a water quality target at the least cost. • Fosters multi-jurisdictional relationships—local, regional, national. Fosters collaboration between the regulated and un-regulated communities (e.g., treatment plant operators and farmer trading collaboratives). • Supplements (or is an alternative to) TMDL development, possibly helping to delist impaired rivers. TMDLs are static, but this project could produce a "living" TMDL that adapts to conditions over time.

Issue	Cincinnati	Nashville
Water supply questions to be answered by pilot projects	What will future water needs/withdrawals look like and how will competition between users be managed? What will the future water budget look like due to impacts brought on by climate change? Can we develop models that more effectively support source water protection?	What is the optimal hydrologic water balance? What are demand/consumptive use/ withdrawals? Where? When? How can we manage for optimal flows?
Pilot projects	Model for water budget (water in/out) including future climate change scenarios, a common central data portal, and GIS capability	Model and model interpretation (reports, etc.) of future scenarios showing uncertainty in demand and ecological requirements due to climate changes
Potential benefits identified	• Encourages state governments in the basin to buy into integrated resource management. Integrated resource management includes navigation; risk assessment (identifying the most vulnerable infrastructure and communities); reservoir development; resource continuity (e.g., keeping power plants online, delivering fuel such as coal via barges; downscaled results to feed into existing local tools; understanding available supply for growth, export, "recruiting" purposes, etc.; and basis for regulation, conservation, and other tradeoffs with economic initiatives. • Protects the presence of key "economic foundation" companies that rely on consistent industrial water supplies. • Help inform businesses and investors who are looking at available water resources to identify where to invest dollars for energy production.	• Protects source waters, encourages valuation of water as an ecosystem service, and improves management for competing uses. • Is useful for reservoir management in drought (water supply and water quality). • Serves as a planning tool to help cities and municipalities understand water availability for new industries (educate on where to locate construction/investments). • Informs permitting decisions. • Improves reliability of water sources, increasing economic investments/development. • Yields more accurate baseline numbers of industry water use; could help inform policy to address this gap. • Gives local water providers a better background for decision-making. • Could sustain or reduce inter-basin transfers.

Issue	Cincinnati	Nashville
Fish and aquatic habitat (Cincinnati) questions to be answered by pilot projects ***Flooding (Nashville) questions to be answered by pilot projects***	How do we put value on the aquatic/ecosystem services systems? How do we convey that value to the public? How can we address native, exotic, and invasive species and erosion/sedimentation? How can we address connectivity issues in the watersheds (culverts, low dams, roads)?	How can we better support local emergency managers in their decisions (e.g., use of onsite staffing from one agency such as NWS)? How can we create better forecasts? What level of accuracy in light detection and ranging (LIDAR) and other data is needed? How can we make data more reliable? How do we effectively communicate information during events? How can we keep events from getting sensationalized? (Over-sensationalizing creates complacency.)
Pilot projects	Preparation of requirements for database/services that establish the value of aquatic habitats	Citizen-scientist data collection
Potential benefits identified	• Benefits regulatory agencies, local agencies, the scientific community, home owners, local governments, regulated community, non-governmental organizations (NGOs). • Improves convenience and efficiency. • Establishes reliable, accurate, accessible, user-friendly data services	• Makes data better, more complete—better forecasts, improved flood inundation mapping, and improved modeling, which benefit the public, universities, and federal agencies. • Improves public awareness and engagement: if students develop a strong understanding of weather issues at a young age, they can educate their parents. • Promotes cost-sharing through public-private partnerships.

4.0 SUMMARY OF PILOT PROJECTS

At the conclusion of the two stakeholder sessions held on June 25 and 26, 2014, NWS consulted with ORSANCO to discuss the pilot project ideas generated. Out of the discussion emerged two projects in particular that addressed priority needs, had high potential transferability and a high degree of stakeholder support, and represented good candidates to apply or develop IWRSS capabilities:

- A large-scale watershed model.
- A decision support system for spill response.

These projects, by engaging IWRSS capabilities, have high potential to fill in existing gaps to improve water resources decision-making in the Ohio River Basin. To further vet them and get input on their possible benefits, ORSANCO consulted two of its advisory committees (River Users and Power Industry). Comments from ORSANCO's advisory committees validated the choice of these two pilot projects and identified tangible benefits to various river-based sectors.

Project #1: Large-Scale Watershed Modeling

Models to improve the accuracy of water budgets, and also to explore future climate change impacts on water quantity and quality, were discussed at both stakeholder meetings. In particular, industry stakeholders expressed support for this project and believed it could add value in connection to nearterm changes within the power industry, as well as certain technical aspects of industry activities that affect the Ohio River.

The development of a large-scale watershed model would include:

- Decision support/planning (for spill response, etc.)
- Scenarios for climate, land use, industrial, and population change
- Water quality modeling
- Inter-basin transfer quantification
- A GIS database

This large-scale model would support three of the pilot projects proposed by stakeholders at both meetings:

- Water budget analysis, including future climate change scenarios, a common central data portal, and GIS capability.
- Future scenario modeling showing uncertainty in water supply, demand, and ecological requirements due to climate, land use, industrial, and population change.
- Predictive tool development that uses climate change and land use data to evaluate, project, and demonstrate effects of land management practices on water supply and water quality.

To help identify socioeconomic benefits and implementation support needs, the ORSANCO committees were asked the following questions about potential pilot project applications, existing efforts, and potential benefits.

1. How will the pilot project capabilities be applied in the Basin? What problems will they help to solve?

- Regional planning organizations would use the model to guide smart growth decisions—for example, determining where residential, commercial, and industrial development is sustainable and where it is not sustainable from a water resources perspective, or guiding investments in infrastructure.
- State agencies and USACE can better plan and optimize reservoir operations to protect and maintain water quality while meeting other needs such as water supply (consumption, transportation, hydraulic fracturing, etc.), flood control, and fisheries/recreation.
- State and federal agencies can use the model to inform and support inter-basin transfer decision processes.
- Regulatory agencies can use the model for decision-making based on future water budget, including effluent requirements, waste load allocations, and TMDLs to ensure that water quality standards are attained.

2. How will the desired IWRSS capability build on what's already in place?

Many modeling efforts are underway across the Ohio River Basin. Both these and the existing datasets being input into the models create a solid foundation for developing a larger-scale watershed model:

- ORSANCO TMDLs for bacteria (Community Model for flow information).
- Most state agencies use CORMIX to predict plume behavior and thus set effluent limits.

- OHRFC Hydrology and Hydraulics model, climate scenarios for Ohio River Basin, model forcings (MMEFS).
- USACE reanalysis of probable maximum flood scenarios.
- EPA's BASINS provides GIS database and modeling capabilities.
- Better models will be helpful in reducing the mixing zone opportunities for NPDES permits.
- Existing GIS data, land use plans, and population trends developed by local governments (e.g., Nashville Metropolitan Planning Organization).
- Existing climate change models from NOAA and other federal agencies.
- The USACE Huntington District is leading a pilot study to evaluate climate change in the Ohio River Basin. The work includes extensive modeling by NWS to predict hydrologic impacts of climate change. Recommendations might include preparing a basin-wide water management plan. This large-scale watershed model would be a significant step toward that goal.
- Additionally, the Open Water Data Initiative (OWDI) is an ongoing effort that could benefit both Ohio River Basin projects. It is cosponsored by the Federal Geographic Data Committee and Advisory Committee on Water Information Subcommittee on Spatial Water Data. The Subcommittee was tasked to scope and design the OWDI; in doing so, it identified data necessary to support a spill response tool for river systems as use-case in the scoping phase. The OWDI is composed of four interrelated efforts, shown below.

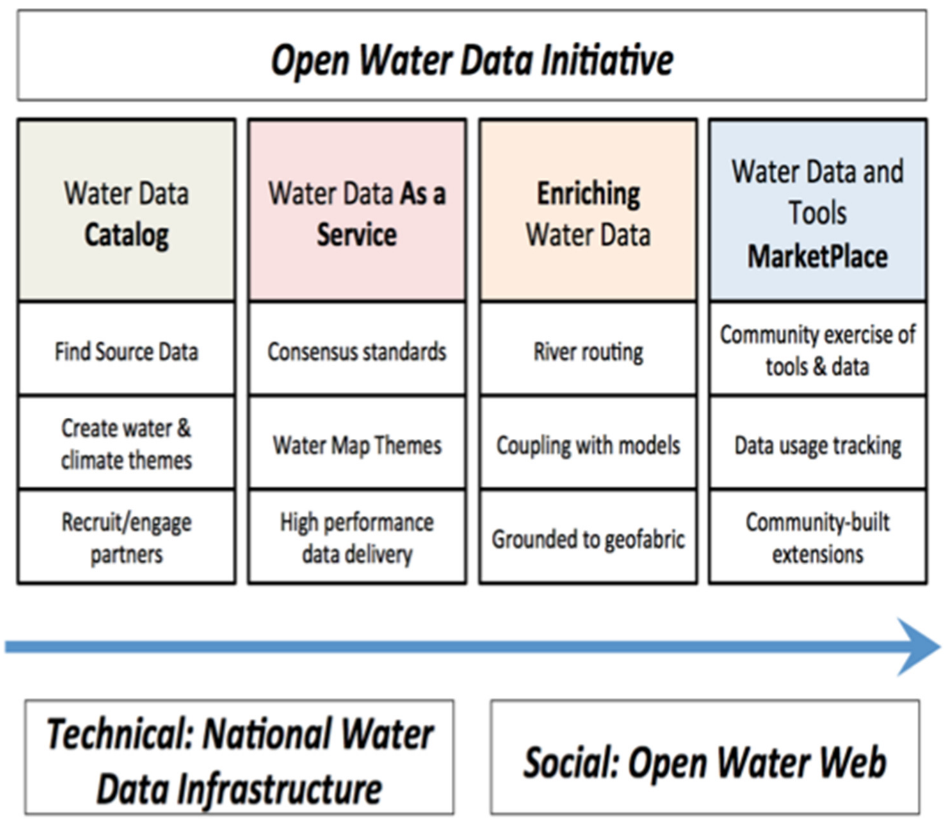

Figure 2. Open Water Data Initiative components. ***Source: Ed Clark, NWS***

3. Who will the stakeholders be (e.g., decision-makers, utilities)?

The primary beneficiaries would be the member states and partner agencies that work together with ORSANCO, including utilities and public water suppliers, as well as other Ohio River Basin states and agencies. More specifically, state water pollution control agencies and EPA (to address TMDLs), municipal planning agencies, state environmental agencies, TVA, shale-gas related industries, other power generation facilities, academics, NGOs, and the U.S. Army Corps (involved with reservoir operations optimization)

4. What are your ideas for generating "the business case" for this project/capability?

While specific dollar amounts have not been estimated, significant cost savings could be realized for efficiencies introduced to power industry operations, pollution control agencies, and shipping/navigation. For example, more targeted/effective TMDLs lead to more efficient actions taken, better understanding of pollution sources, and more cost-effective controls (including non-point source controls), not just further reduction of point sources:

- $4 billion expended on system upgrades in Cincinnati (the water quality benefits of which might be more cost-effectively achieved via other control measures).
- TVA is investing highly in temperature modeling (better modeling better informs decision-making).

Additionally, the positive effects on ecosystems such as reduced hypoxia would have benefits for recreation, fishing, and other users.

5. What is your role in helping to develop, raise awareness, and/or apply an IWRSS pilot project in your basin?

ORSANCO is well positioned to engage stakeholders to facilitate collaboration and achieve buy-in across sectors. They also have extensive knowledge of the river and data to support model development.

Project #2: Decision Support System for Spill Response

Developing modeling and data for a decision support system, initially focused on spill response, is an issue particularly relevant to the Upper Ohio River Basin. Industry stakeholders enthusiastically supported this project and felt it could be easily justified given the potential benefits to millions of people. Several people described developing this project as a “no-brainer,” given that improved communication and responses to chemical spills would positively impact a wide community of stakeholders.

The decision support system would enhance (and reduce the uncertainty of) the existing modeling capabilities of the Ohio River Community Hydrologic Engineering Centers River Analysis System (HEC-RAS) model. The pilot project would also involve the creation of a GIS database with detailed land use data, link to existing databases (e.g., the Integrated Risk Information System [IRIS], a database for toxicity, treatability), and locations of hazardous materials/wastes stored at existing facilities/sites across the entire Ohio River Basin. To maximize usefulness, a common format and set of standards would have to be established for stakeholder data input. Initially, this pilot would support spill response management efforts; however, once established it could be used to make recreational and other water-quality-related decisions.

1. How will the pilot project capabilities be applied in the Basin? What problems will they be used to solve?

- They will enhance knowledge of potential downstream vulnerability, impacts, and treatability of spills.
- A decision support system will facilitate effective spill response by better predicting contaminant flow (fate and transport), making it possible to deploy containment systems more strategically.
- Users will be able to conduct "what if" scenarios to plan for spill response under a variety of conditions; the system will also be usable in emergency response training.
- The system will improve risk management for known/permitted point and non-point discharges.
- The system will help protect users from poor water quality conditions.
- More accurate modeling allows drinking water utilities to better tailor their spill response by modifying treatment, shutting off intakes, switching to other supplies, and issuing advisories to the public.

2. How will the desired IWRSS capability build on what's already in place?

The spill response system will build on the existing Hydrologic Engineering Centers River Analysis System (HEC-RAS) model and/or the ORSANCO Riverine Spill Modeling System (RSMS) (will allow modeling to be extended to tributaries of the Ohio River). Additionally, there could be links to existing GIS databases (e.g., IRIS). ORSANCO recently received a grant from EPA to update their spill model. The Ohio River Community Model group hosted a meeting with the developers at ORSANCO where they discussed the benefits and challenges of incorporating the HEC-RAS output with the updated spill model. Discussions will continue as to the best way to get this information from HEC-RAS into the new spill model.

3. Who will the stakeholders be (e.g., decision-makers, utilities)?

- Public recreational users.
- Utilities (e.g., water suppliers, industrial users) with water intakes along the river that would need to take action in the event of a spill.
- Spill response personnel at a range of levels (local to federal).
- ORSANCO would use the support tool to inform emergency response agencies, municipal and industrial water users, and the news media.
- Source water protection planners.

Nashville, Tennessee, Stakeholder Meeting. ***Photo: Bob Sneed, USACE***

4. What are your ideas for generating "the business case" for this project/capability?

There are many potential qualitative and quantitative benefits of this project, including public health protection, public safety improvement, and improved communication and public confidence in responding agencies. While specific dollar amounts have not been estimated for this particular project, significant cost savings could be inferred from previous spills in the Basin:

- The recent Elk River spill in Charleston, West Virginia, illustrates the severe economic impacts that can occur when a water utility must completely shut down:
    - Researchers at the Center for Business and Economic Research at Marshall University estimated the spill's impacts to the state's economy were $19 million for each business day the "do not use" order was in effect.
    - Greater Cincinnati Water Works spent approximately $113,000 on responding to the Elk River Spill.[3]
- Costs of new regulations related to above-ground storage tanks, created in response to the spill, could be calculated. Improved spill response may help avoid these costs in the future.
- Other benefits are connected to industrial water users and source protection:
- Water utilities can use better information on spill time and concentration prediction to minimize additional treatment.
- Industrial water users suffer impacts when they must shut down their intakes due to spills. Although better modeling doesn't stop a spill from occurring, it will help minimize the amount of time intakes

[3] Estimated by Bruce Whitteberry, Assistant Superintendent, Greater Cincinnati Water Works.

must be closed. It also gives intakes more forewarning, helping in preparations to mitigate spill impacts.

- Improved modeling capability could be a planning tool for source-water protection, used in evaluating potential spill scenarios and developing response plans.
- Additionally, the value of recreational activities along the river that are interrupted during a spill could be calculated.

5. What is your role in helping to develop, raise awareness, and/or apply an IWRSS pilot project in your basin?

ORSANCO plays a key role in spill response events through:

- Coordinating field data collection and sample analysis.
- Running the current (outdated) spill model to estimate travel time and contaminant concentration.
- Providing a central point of communication for state, federal, and local agencies to coordinate response activities.
- Keeping water intakes and the news media informed of the current situation.

As a key user of an improved spill response decision support system, ORSANCO would welcome the opportunity to participate in the development. The Commission has a great deal of experience and expertise in this area that would greatly aid in efforts to develop an effective, valuable spill response tool. It also has a number of stakeholder advisory committees, representing multiple sectors of river users that could be used to enhance the utility of the decision support system.

APPENDIX A: STAKEHOLDER PARTICIPANT LISTS

Integrated Water Resources Science and Services (IWRSS):
A Forum to Discuss This New Federal Initiative

Ohio River Basin—Upper Basin
Cincinnati, Ohio
June 25, 2014

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Integrated Water Resources Science and Services (IWRSS):
A Forum to Discuss This New Federal Initiative

Ohio River Basin—Lower Basin
Cumberland River Compact
Nashville, TN
June 26, 2014

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APPENDIX B: CINCINNATI MEETING AGENDA AND NOTES

Integrated Water Resources Science and Services (IWRSS)
Ohio River Basin—Upper Basin
Stakeholder Forum

U.S. Environmental Protection Agency
26 West Martin Luther King Drive
Cincinnati, OH
Room 30/138

June 25, 2014

Agenda

8:30–9:00 AM	Registration and Coffee
9:00–9:15 AM	Welcome and Introductions
9:15–9:45 AM	Background and Purpose of Meeting
9:45–10:00 AM	Questions and Answers/Discussion
10:00–10:45 AM	Current/Emerging Issues in the Basin *What are the key issues in the river basin now and in the foreseeable future?*
10:45–11:00 AM	Break
11:00–Noon	Key Upcoming Decisions and Information Gaps (Break-out Groups) *What are the key decisions that need to be made to address priority issues and what are the gaps that need to be filled to inform those decisions?*
Noon–1:00 PM	Lunch
1:00–1:45 PM	Report Back on Key Decisions and Key Gaps
1:45–2:45 PM	Brainstorm Solutions (Breakout Groups) *What pilot projects could we propose to fill the gaps and how can we articulate the benefits/make the business case?*
2:45–3:00 PM	Break
3:00–3:45 PM	Lightning Round Report Back (a) Pilot projects to fill key gaps (b) Value of filling the gaps
3:45–4:00 PM	Wrap Up, Next Steps, and Adjourn

Summary of Cincinnati Breakout Group Discussions

Participants in each group are listed below (the full participant list can be found in Appendix A).

Water Quality	Water Supply	Fish and Aquatic Habitat
Bruce Whitteberry	Emily Class	Rich Cogen
Mindy Scott	Scott Kirk	Michael Miller
Greg Nageotte	Brian A. Carr	Kristy Hopfensperger
Scott Jackson	John Menninger	Trent Schade
Elly Best	Ben Haggerty	Judith Petersen
Christina Baysinger	Mike Griffin	Teresa Harten
Mike Ekberg	Gary Springston	
Erich Emery	Bill Caldwell	
John Mangan	Tara Lanier	
Tre Sheldon	Jim Noel	
Jason Heath	Chuck Somerville	
Ted Lozier	Sam Dinkins	
Evelyn Hartzell		
Jim Goodrich		

In preparation for breakout groups, participants generally discussed each of the top three priority issues and expressed their views and questions about how IWRSS might help address the issues they are currently facing, or may face in the future. From this discussion the following topics, concerns, and questions emerged.

Water Quality

- Urban redevelopment in waterfront areas often creates recreational opportunities in areas that do not meet E. coli (and other water quality) standards. It would be useful to have a tool for communicating these safety issues to the public, similar to the one used for Lake Erie.
- A better comprehensive understanding is needed of the algal growth mechanism on the river main stem. This growth can cause operational problems for utilities and impact water quality.
- Having access to high-quality water-velocity data for tributaries would improve spill responses. This could be accomplished with new gages.
- Characteristics of stormwater runoff appear to be changing, but there is limited information on parameters such as total organic carbon and other nutrients.
- Information on green infrastructure and other flood/water pollution mitigation sites (e.g., wetlands, riparian forests) is not aggregated at the local level. A better tracking and inventory system would be useful for local watershed planning.
- More information is needed to evaluate how climate change will impact water temperatures to determine what this means for water quality and aquatic life.
- Bromide levels in the river resulting from Marcellus Shale drilling are a concern. See the February 2014 ORANSCO report titled *Characterization of Dissolved Solids in the Ohio River and Selected Tributaries*.

- USGS and USACE are conducting a study comparing forecasts and hydraulic estimates to determine if gages are doing accurate job of measuring discharge.
- Concern was expressed that stricter air emissions regulations have resulted in power plants going from air-cooled to water-cooled systems, which has resulted in increased impacts on water quality (thermal discharge).
- Concern was expressed over lack of enforcement of private industry pollution.

Water Supply

- America's Watershed Initiative is working on a report card for the Mississippi River Basin. One goal is to grade the economic potential of the watershed. The report card identified as an issue the lack of understanding of "cryptic" water transfers (i.e., water leaving the basin through products, livestock, energy, etc.).
- More research is needed on stream flashiness. Degree of flashiness (extreme short-term high water levels after a storm) is important for terrestrial and aquatic biota. Research, though limited, suggests that flashiness can be decreased by managing vegetation.
- Sediment accumulation caused by bank erosion is impacting reservoir management. Sedimentation from erosion also impacts aquatic life.
- Source water protection is critical for protecting drinking water supplies. It includes identifying potential contamination sources upstream of public water supplies (e.g., above-ground storage tanks in West Virginia).
- Effluent releases are becoming increasingly important for maintaining streamflow during low flow periods. This means that flow in the river depends on the quality of effluent coming out of treatment plants. This trend will likely be more pronounced due to climate change.
- The Indiana Silver Jackets are conducting an erosion study in Indiana to capture changes in bank erosion based on intensity of events. This effort ties back to existing infrastructure (e.g., power lines) and involves sediment transport.
- More information is needed to implement management changes in reservoir storage, releases, and dam operations to mitigate spills. Should more water be stored to lower flows during a spill? Or should higher flows be used to dilute the spill?
- Climate change will alter the hydrologic cycle and uniquely impact different areas of the Ohio River Basin. Tools are needed to better predict how these changes will impact different areas of the Basin.

Fish and Aquatic Habitat

- Temperature change impacts on species are a major concern.
- More attention needs to be paid to ecological connectivity and more research is needed to evaluate the importance of certain species (e.g., cold water fish) to the ecosystem. Solutions are needed for managing these species; for example, structural changes may be needed to allow species to survive.
- Some portions of the Ohio River Basin contain globally significant species (e.g., mussels in the Green River). What are some ways to preserve these populations?

- Research on invasive species in riparian areas is needed to determine how they can affect the amounts of water and sediment. There are big differences in transpiration rates between invasive and native species.

Water Quality

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question #1: Are policies for preparation and emergency response to upstream spills/accidental releases adequate?

Gaps:

- Better knowledge of downstream travel time, contaminant concentrations, and resulting impacts (i.e., human and aquatic community health effects, treatability, etc.) of upstream spills.
- Spatial information on potential sources of spills (e.g., high risk land uses, transportation crossings, key outfall/discharge locations).
- Better understanding of downstream vulnerability (e.g. at drinking water intakes, sensitive habitats).

Question #2: How can risks and impacts of known/permitted point and non-point discharges be better managed?

Gaps:

- Need reservoir storage/release and dam operation procedures to optimize for water quality considerations (currently, releases are determined based on only flood control and navigation-related objectives).
- Need more stream gages and land use information over a wider area (e.g., in upstream tributaries).

Question #3: With increased recreational demands on the river, how can we protect users from poor water quality conditions? Do we know when it is safe for primary or secondary recreational contact (e.g., when bacterial or algal indicators are high)?

Gaps:

- Need a tool linking short-term weather forecast to create local water quality forecasts to warn and inform public recreational users of water quality conditions for primary and secondary contact.

Potential Pilot Project, Benefits, and Partners

Pilot Project: Develop a decision support system initially focused on spill response.

This project would focus on enhancing existing modeling capabilities of the Ohio River Community Hydrologic Engineering Centers River Analysis System (HEC-RAS) model and reducing uncertainty by 1) increasing the number of stream gages measuring flow and velocity, 2) generating better topographic/bathymetric information, 3) expanding coverage to upstream tributaries, and 4) adding a water quality component. The pilot project would also involve the creation of a GIS database with detailed land use data, location and performance of green infrastructure (from local, state, and federal agencies that have funded the green infrastructure), link to existing databases (e.g., Integrated Risk Information System (IRIS) database for toxicity, treatability), and locations of hazardous materials/wastes stored at existing facilities/sites across the entire Ohio River Basin. To be useful, a common format and set of standards would have to be established for stakeholder data input. Initially, this pilot would support spill response management efforts; however, once established it could be used to make recreational and other water quality-related decisions.

Key benefits of this project:

- Increases public confidence in safety (spills and recreation), particularly since 5 million people use the main stem of the river for drinking water.
- Provides a spill risk assessment approach—beneficiaries include community resilience planners, asset management managers, insurance industry, and shipping/other private sectors.
- Improved transparency and communication.
- Public health protection.
- Community/public relations (consider the loss of public confidence after the recent West Virginia spill).
- Leverages expenditures on existing Ohio River Community HEC-RAS model (money saved, bigger “bang for your buck”).

Key partners:

- FEMA (risk assessment)
- State agencies
- Water utilities (intake locations)
- ORSANCO (communication with states, drinking water, and industries)
- EPA
- Coast Guard (data on barges)
- Ohio Kentucky Indiana (OKI) Regional Council of Governments

Data sources:

- Electric Power Research Institute (EPRI)
- Shipping companies
- Railroads
- Chemical companies

Pilot project: Smartphone recreation water quality app (suggested in plenary). Link short-term weather predictions with projected river water quality forecasts at key recreational locations. Provide access to this “surf report” in a public smartphone app designed for kayakers and other secondary contact recreationists to predict if safe bacteria levels will likely be exceeded.

Water Supply

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question #1: What will future water needs/withdrawals look like and how will they be managed (i.e., competition between users given unknowns in the future water budget)? Users include agriculture, development, river commerce, and energy production. Variables include climate change impacts, land use changes, and withdrawal levels.

Gaps:

- Information on total consumptive use, including nomadic water withdrawals and dead end sources (e.g., fracking).
- Information on inter-basin transfers.
- Lack of central storage for individual state plans, policies, etc. Currently each state has its own individual water use plan.
- Better predictive tools for water use, which will require current and future information on agricultural, development, commerce, and energy production user requirements.

Question #2: What will the future water budget look like due to impacts brought on by climate change?

Gaps:

- Better climate change predictive tools (including the science and assumptions that go into the models), e.g., meteorological and hydrologic tools.
- An economic valuation of water.
- Need improvement for state-level drought response plans (overall watershed plan needed).
- Water requirements to support ecosystems.

Question #3: Can we develop models that more effectively support source water protection?

Gaps:

- Information on where the potential contaminants exist.
- Need to identify, quantify, and rank contaminants based on risk (e.g., storage tanks, locating those sources).
- Improved hydrologic modeling for spill scenarios.
- Communication gap across states, regions, localities.
- Assessments of non-point runoff (impacts treatability of water supply).

Potential Pilot Project, Benefits, and Partners

Pilot project: Develop a model for water budget (water in/out) including future climate change scenarios, a common central data portal, and GIS capability.

Critical to the development of the model would be determining appropriate inputs:

- Stream flow data, aquifer levels, recharge, precipitation data, snow water content, etc.; outflow from industrial, agriculture, inter-basin transfers including cryptic transfers, municipal supplies, and sewage treatment systems. (There are significant unknowns associated with cryptic inter-basin transfers.)

Some potential outputs include:

- Streamflow under various scenarios (droughts, floods, extremes vs. average)
- Water budget (source, use, surplus numbers)
- Forecasting based on future climate scenarios
- All outputs would be probabilistic in nature
- Downscaled climate model results

Key benefits of this project:

- State governments in the basin would buy into integrated resource management. Integrated resource management includes:
  - Navigation
  - Risk assessment—identify the most vulnerable infrastructure and communities
  - Reservoir development
  - Resource continuity—e.g., keeping power plants online and delivering fuel (e.g., coal via barges)
  - Downscaled results to feed into existing local tools
  - Understanding available supply for growth, export, “recruiting” purposes, etc.
  - Basis for regulation, conservation, and other tradeoffs with economic initiatives

Additional examples of potential benefits include:

- If a city loses industrial supply due to drought, such a condition would impact the presence of key “economic foundation” companies.
- Businesses and investors are looking at available water resources to identify where to invest dollars for energy production.

Key project partners:

- NOAA (climate, weather, temperature, precipitation data)
- USGS (streamflow data, groundwater)
- USACE (initial project underway to identify at risk infrastructure)
- State departments of natural resources
- FEMA (existing models focused on higher flow)
- EPA (looking at impacts of water quality on species)
- State agencies (have the data)
- ORSANCO

- Academia (partner with academia to ground truth information, data entry, etc.)
- U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) farm and ranch irrigation survey (coming out 2015)

Fish and Aquatic Habitat

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question #1: How do we put value on the aquatic/ecosystem services systems? How do we convey that value to the public?

Gaps:

- Evaluation of watersheds, backwater wetlands, inundated pools – do not know ecological services they provide.
- Overlay data state and federal agencies have collected about populations over the years with flow data, temperature, topography, etc.

Question #2: How can we address native, exotic, and invasive species and erosion/sedimentation?

Gaps:

- Monitoring, including citizen-scientists.
- Overlay data state and federal agencies have collected about populations over the years with flow data, temperature, topography, etc.
- Climate change information (study ongoing).

Question #3: How can we address connectivity issues in the watersheds (culverts, low dams, roads)?

Gaps:

- Need overlay of barriers (structures such as dams, culverts, roads) that restrict flow and disrupt connectivity (from local agencies).
- Need climate change information (study ongoing).

Potential Pilot Project, Benefits, and Partners

Pilot project: Prepare requirements for the database/services that establish the value of aquatic habitats.

There could be many applications for the database or data service where existing data would be collected and standardized:

- Ecosystem service studies
- Water quality assessments
- Scenic river designations
- Ecosystem health assessments
- Navigation

- Flood management

There would need to be acceptable standards for the data (e.g., Ohio Data Credibility Law). Accessibility to the data would also be critical.

Key benefits of this project:

- Beneficiaries include regulatory agencies, local agencies, scientific community, home owners, local governments, regulated community, non-governmental organizations (NGOs).
- Convenience and efficiency.
- Reliability, accuracy, accessibility, and user-friendliness of data services.

Key project partners:

- Fish and wildlife (state and federal)
- DOT
- IWRSS partners
- EPA
- State and regional planning agencies (e.g., OKI)
- NGOs (e.g., The Nature Conservancy) and other end users

APPENDIX C: NASHVILLE MEETING AGENDA AND NOTES

Integrated Water Resources Science and Services (IWRSS)
Ohio River Basin—Lower Basin
Stakeholder Forum

Cumberland River Compact
2 Victory Avenue—Suite 300
Nashville, Tennessee

June 26, 2014

Agenda

8:30–9:00 AM	Registration and Coffee
9:00–9:15 AM	Welcome and Introductions
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1:45–2:45 PM	Brainstorm Solutions (Break-out Groups) *What pilot projects could we propose to fill the gaps and how can we articulate the benefits/make the business case?*
2:45–3:00 PM	Break
3:00–3:45 PM	Lightning Round Report Back (a) Pilot projects to fill key gaps (b) Value of filling the gaps

3:45–4:00 PM Wrap Up, Next Steps, and Adjourn

Summary of Nashville Breakout Group Discussions

Participants in each group are listed below (the full participant list can be found in Appendix A).

Water Quality	Water Supply	Flooding
Dorie Bolze Tania Datta Paul Davis Sam Dinkins Timothy Hall Mekayle Houghton Mary Mullusky Randy Payne Trent Schade Bob Sneed	Amanda Bowen Craig Carrington Dixie Cordell Gwen Griffith George McKillop	Alfred Kalyanapu Kelie Hammond James LaRosa Larry Vannozzi Ken Weidner Shannon Williams

In preparation for breakout groups, participants generally discussed each of the top three priority issues and expressed their views and questions about how IWRSS might help address the issues they are currently facing, or may face in the future. From this discussion the following topics, concerns, and questions emerged.

Water Quality

- Water quality is a rapidly changing issue because land use is changing and urbanization and industrial uses are increasing. When looking at costs and benefits of making changes to land use, it would be useful to have predictive tools to inform planning. How much improvement could we make in urban streams? Which areas are most likely to be successfully restored to provide the greatest benefit?
- Thermal impacts of Tennessee Valley Authority (TVA) operations are a daily issue/concern—specifically, temperature due to discharge from thermal plants and low dissolved oxygen (DO) levels. Both are monitored but TVA is always looking to improve. Model improvements are important for hydrothermal management.
- USACE is involved in water temperature and DO issues, such as those described above. USACE actively manages its upstream releases to provide the right cooling water to TVA plants at the right time. Those agencies work closely with the thermal modeling group in Knoxville. Dam safety issues have complicated management for water temperature.
- The federal Clean Water Act does directly address non-point sources (NPS) of pollution. Education is a part of the solution, but only goes so far. Sediments and nutrients are the biggest concern. Right now, the focus is on showing water quality improvements. Point source dischargers make up a relatively small part of the watershed pollutants, but NPS are tough to deal with. Note: A pilot NPS/point source trading program is underway in the Ohio Basin. One idea is to come up with a trading project that is “BMP ready” once nutrient criteria are established. This would be a proactive approach so that a program is in place in time for the development of nutrient standards. The program has tested some pilot trades, but it is a couple of years away from being operational.

Water Supply

- TVA has multiple concerns including:
  - Permitting program: TVA can permit any permanent intake structures in their region. Its biggest concern is temporary (e.g., agricultural) withdrawals and how those withdrawals impact the permitted uses.
  - Drought impacts: The Cumberland River and its basin are considered a water-rich region, but the drought of 2007 had some significant impacts, with reservoirs falling below their intakes. What should we do when this occurs? Could we develop a tool to predict future drought and adjust intake levels accordingly?
  - TVA is currently operating without management plans for "outlier" events.
- A USACE reallocation study on water supplies is currently underway. What happens when the population grows to the point where there need to be some tradeoffs? The ability to predict the required capacity of a new reservoir is needed to account for competing needs (e.g., water supply contracts with municipalities).
- Currently there is no integrated water supply plan in place for water allocation purposes.
- Better and more integrated information is needed on users, supply, etc., to balance demand vs. supply.
- Climate change will complicate efforts to predict demand and supply. Example: The city of Denver conducted a study on water supply in which a 5-degree increase in average temperature resulted in a 40 percent gap in supply vs. demand. Such information would be valuable in the Lower Basin for future planning.

Flooding

- Stakeholder groups should be more fully engaged to better inform communities that have a difficult time making decisions regarding flooding (e.g., anticipating water levels, knowing how much water is flowing, knowing how much rain is falling).
- Real-time downscaled inundation mapping capability is needed to show how a certain amount of rainfall in one area would impact specific downstream areas.
- What does a community need to do to get coverage for real-time inundation mapping? USGS and NWS did this in 2010 in certain localities. USACE, along with its contractor AMEC, made some hard copy books with stage levels at intersections, critical areas that local emergency managers carried in the trunks of their cars. IWRSS could use this as a starting point to improve upon and modernize them.

Water Quality

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question #1: If we make these watershed land use changes, what is the impact on local water quality? Water quality is not often accounted for when weighing advantages/disadvantages of land use decisions, *especially* outside jurisdictional boundaries regulated by Municipal Separate Storm Sewer System permits.

Gaps:

- We need a "video game," user-friendly app, or interface that a local planner or town manager can use to visualize potential land use scenarios at a small scale.
- Information on the cost/value of water quality.
- Higher-resolution land cover data, directly connected impervious area, buffer quality, etc.
- Quantitative loading/waste data on agricultural inputs.
- Future scenarios (e.g., uncertainly around climate change).
- Lack of information to advocate and educate.

Question #2: Can we improve the water quality standards for parameters such as temperature and DO to better protect aquatic resources in a changing climate?

Gaps:

- Ability for policy to handle adaptive management.
- Need for a new end point for criteria.
- Biological information.
- Ability to predict how future climate or land use inputs, future withdrawals, etc., may shift baseline parameters; need more long-term predictions.
  - Will native river temperatures be warmer in the future and what does this mean for electric plant operations?
  - What is the environmental cost of a one-degree temperature change in the reservoir? TVA has good real-time info currently, but is looking for 2D or 3D models.
  - What if there are more frequent and longer droughts and USACE doesn't have supplemental flow to release?
  - What if the number of inputs or volume withdrawn changes (e.g., shift to new and higher-water-demanding crops due to climate change)?

Question #3: How do you decide to invest in point vs. non-point source projects? For example, are significant capital expenditures to upgrade treatment plants more cost-effective than implementation of wide-scale, strategic non-point source controls?

Gaps:

- Quantification of non-point loads to help evaluate where the real risk to public health is (point or non-point). We know dry weather flows are an issue, but don't have a good grasp on stormwater loads.
- Data on organic loadings and emerging contaminants.
- BMP effectiveness.
- Tools or mechanisms for trading (e.g., trading pilot program for Miami River).

Potential Pilot Project, Benefits, and Partners

Pilot project: Predictive tool connecting climate and land-use change to evaluate water supply and water quality.

The project would create a predictive tool connecting regional climate and localized land-use changes to evaluate impacts on water supply and water quality. A user-friendly interface for this tool will give us the capability to visualize and quantify the impact of various watershed land use and treatment scenarios to better inform local decision-makers on the true cost of land use decisions. It will include a mechanism for cost comparisons to help evaluate investment options in pollution reduction approaches. This project is envisioned as a living, adaptable mechanism to supplement (or provide an alternative to) the static total maximum daily load (TMDL) process.

Key benefits of this project:

- Helps to evaluate operational cost savings and capital investments vs. green infrastructure costs. For example, Cincinnati and Pittsburg will be spending $3 billion to upgrade wastewater treatment plants.
- The tool helps us understand the impact of high-growth areas such as industrial agriculture and urban sprawl.
- The tool helps quantify non-point source loads.
- Shows that land use change is a key part of the modeling and helping to answer the question about the impact of future land use on water resources (both quality and quantity)—is the result good or bad?
- Helps communicate to a broad audience and explain decisions. The tool helps show the option that meets a water quality target at the least cost.
- Foster multi-jurisdictional relationships—local, regional, national. Fosters collaboration between the regulated and un-regulated communities (e.g., treatment plant operators and farmer trading collaboratives).
- Supplements (or is alternative to) TMDL development, possibly helping to delist impaired rivers. TMDLs are static, but this project could produce a "living" TMDL that changes and adapts to conditions over time.

Key partners:

- EPA (to develop modeling).
- GIS data owners (counties, regions with information about land-use, soil-type, temperature, precipitation, flow)
- Cumberland River Compact
- Harpeth River Watershed Association
- USDA NRCS
- Metro Nashville
- TVA

Water Supply

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question #1: What is the optimal hydrologic water balance?

Gaps:

- Better quantification/understanding of currently reported water balance.
- Understanding of optimal flows for streams, not just flow minimums.
- Uncertainty levels around USGS water projections (5-year), USDA county-level consumptive factors (yearly).
- Information on source of groundwater and groundwater levels, stream, etc.

Question #2: What are demand/consumptive use/withdrawals? Where? When?

- What/how much water is being taken out and where is it being put back in?
- How will upstream withdrawals and demand impact downstream users and reservoirs?
- How does this impact power generation?

Gaps:

- Accurate population growth rates, water consumption rates, land use changes
- A better quantification of unreported withdrawals and returns

Question #3: How can we manage for optimal flows?

- How do we project optimal water supply given population growth to inform project decisions (e.g. inter-basin transfers, additional reservoir)?
- How do we manage flows currently and in the future for flow targets/species of concern?

Gaps:

- Same gaps as Question #1.
- Climate projections to assist with future regional planning for drought situations, future hydrologic conditions (extremes).
- Build out projections to predict future water demand, future water quality.

Potential Pilot Project, Benefits, and Partners

Pilot Project: Model and model interpretation (reports, etc.) of future scenarios showing uncertainty in demand and ecological requirements due to climate changes.

This project would model different downscaled climate change scenarios (low, medium, high emissions) and, for each scenario, show how the range of factors under local control (e.g., population growth, industry changes for major water users and estimate of their use) that influence water supply. There is potential overlap with current modeling efforts with the Nashville Metropolitan Planning Organization (MPO) and TVA.

Key benefits of this project:

- This will allow for protection of source waters, valuation of water as an ecosystem service, and better management for competing uses.
- Would be useful for reservoir management in drought (water supply and water quality).
- Planning tool to help cities and municipalities understand water availability for new industries (educate on where to location construction/investments).
- Can inform permitting decisions.
- Can improve reliability of water sources, increasing economic investments/development.
- Could get more accurate baseline numbers of industry water use, and help inform policy to address this gap.
- Local water providers would receive better background for decision-making.
- Could sustain or reduce inter-basin transfers.

Key project partners:

- Nashville MPO and Cumberland River Compact (MPO's goal is to use regional planning process to inform comprehensive planning process)
- NWS (climate, drought modeling)
- USGS (drought reports, stream gauges)
- USACE (watershed modeling)
- USFWS (information about in-stream flows)
- State and local governments (plans)
- USDA (information about ecosystem services of agriculture, provide current water use estimates)
- U.S. Forest Service (ecosystem services of forests)

Flooding

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question #1: How can we better support local emergency managers in their decisions? What is the best way to do this (e.g., use of onsite staffing from one agency such as NWS)?

Gaps:

- Slow pace of implementation of new capabilities.
- Information is not accessible.

Question #2: How can we create better forecasts? What level of accuracy in light detection and ranging (LIDAR) and other data is needed? How can we make data more reliable?

Gaps:

- Monitoring networks (stream gauge, soil moisture, precipitation, evaporation, water quality).
- Inundation mapping and graphical warning system.
- Better and more accessible spatial data (e.g. bathymetry).
- HEC-RAS improvements (to account for wind).
- Probability (risk) information (forecasts and inundation maps) connected to FEMA Hazus analyses (property damages due to flooding).

Question #3: How do we effectively communicate information during events? How can we keep events from getting sensationalized? (Over-sensationalizing creates complacency.)

Gaps:

- Lack of situational awareness on the part of people reporting on events.
- Communications protocols are clear for dam breaks but not so much for other events.

Potential Pilot Project, Benefits, and Partners

Pilot project: Citizen-scientist data collection.

Install weather stations with soil moisture sensors at schools and universities to create more complete networks. The project would be implemented with an engaged school district that has bought into the idea of collecting meteorological and soil moisture data. The schools would host and run the stations with the assistance of universities and/or qualified climate scientists. Mill Creek and Whites Creek watersheds were mentioned as potential pilot watersheds. The project would likely work best in basins of 100 square miles or less. Like some previous collaborative efforts in the state, the private sector could provide funding for the installation of the stations (e.g., the Nestlé monitoring and engagement effort). Some considerations/challenges would be placement of sensors, maintenance, and data quality.

Key benefits of this project:

- Better/more complete data: better forecasts; improved flood inundation mapping; and improved modeling, which benefits the public, universities, and federal agencies.
- Improved public awareness and engagement: If students develop a strong understanding of weather issues at a young age, they can educate their parents.
- Cost sharing: private-public partnerships.

Key project partners:

- IWRSS partners
- Local governments
- Local schools and universities
- Private sector
- Any groups in the target watershed (e.g., Mill Creek and Whites Creek)

APPENDIX D: STAKEHOLDER SURVEY

IWRSS Stakeholder Survey

Ohio River Basin Results *August 27, 2014*

A consortium consisting of the U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers (USACE), and the National Oceanic and Atmospheric Administration (NOAA) supports Integrated Water Resources Science and Services (IWRSS). These IWRSS partner agencies are collaborating to design, develop and implement a national water modeling and information services framework to:

1. Infuse new hydrologic science into current water resource management;
2. Develop hydrologic techniques and information to support operational water resources decisions; and
3. Provide advanced hydrologic services to meet stakeholder needs.

On behalf of NOAA, ERG conducted a survey to allow stakeholders in the Ohio River Basin to articulate and prioritize water resources information needs, describe barriers to obtaining useful information, and identify the potential benefits of filling information gaps.[4] Results of the survey will inform future investment in information and services provided by IWRSS.

The survey was open from July 1 to Aug 1, 2014 and received 153 complete responses. Invitations and reminders were emailed to a list of 435 stakeholders compiled with assistance from the Ohio River Valley Water Sanitation Commission (ORSANCO) and other organizations in the river basin;[5] stakeholders could also respond to the survey via links posted on the ORSANCO Web site and distributed by the Cumberland River Compact.

In addition to complete submissions, there were 36 incomplete survey responses. ERG reviewed them and found that the respondents had only filled out the first six questions of the survey; this provided information on their background and sectors of interest but did not answer any of the substantive questions. It is not clear why respondents submit partial responses, they may have decided that the survey didn't interest them, that it would take too long, or they forgot they started the survey and completed a full response at a different time. As a result, the partial responses are not included in this summary.

Some ***key findings*** from the survey include:

- Respondents are primarily interested in water quality and watershed management, are affiliated with government agencies, have more than 15 years of experience with water resources management issues in the Ohio River basin, deal with these issues on a daily basis, and are responsible for providing input into key planning and management decisions.
- The top two priority issues in the Ohio River basin are water quality and water supply (water supply includes water withdrawals, and management).
- Most respondents have access to the information they need, but it is not adequate or needs improvement. The most common barrier to using the information is that there is not enough information available.

[4] In 2013, ERG performed a similar survey of four river basins in the mid-Atlantic region: Potomac, Delaware, Susquehanna, and Hudson.

[5] While the total response rate appears low at 35 percent, this is consistent with national trends of decreasing response to Web-based surveys.

- The primary benefit of providing new or additional information is improved water quality.

The survey results, tabulated by question, are provided in Appendix A. This memorandum summarizes the key findings by topic.

1 DEMOGRAPHICS

Respondents were asked to identify their primary and secondary sectors of interest, affiliation, years of experience in the Ohio River basin and water resources management, the frequency with which they deal with water resources issues, and whether their job entails providing input to strategic planning; program, facility, operations or financial management; or project planning decisions.

The most common primary sectors chosen by respondents were water quality (27 percent), followed by watershed management (16 percent), and fish and wildlife (14 percent). Secondary sectors of interest included water quality (57 percent) and watershed management (58 percent). See Figure 1 and Figure 2.

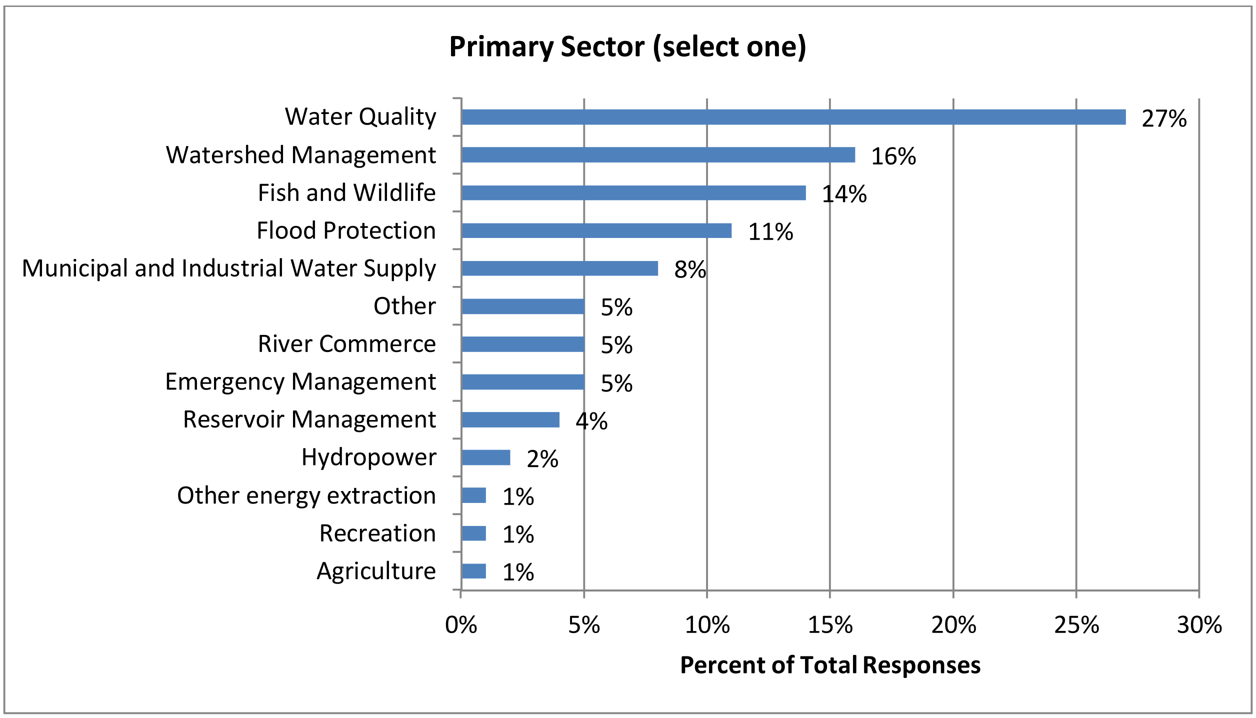


Figure 1: Responses to the question "Please select the PRIMARY sector in which your work or interest is focused."

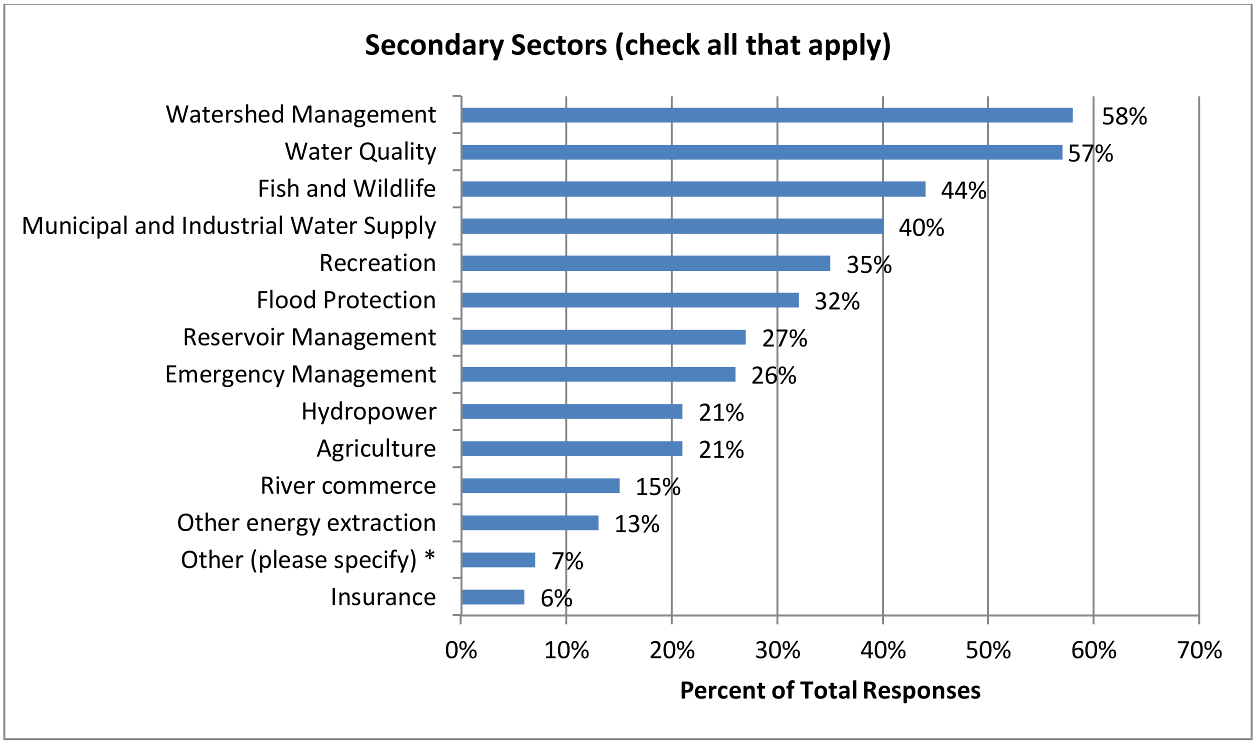


Figure 2: Responses to the question "Please indicate any other sectors in which you work or that you are concerned about (please check all that apply)."

Most respondents (67 percent) are affiliated with federal, state, or local government; of these, the largest group, about one-third of all respondents, is affiliated with state government (31 percent). See Figure 3. The respondents to this survey also have significant experience with water resources issues in the Ohio River basin: 56 percent have more than 15 years experience in this river basin and 68 percent have more than 15 years of experience in water resources management. See Figure 4.

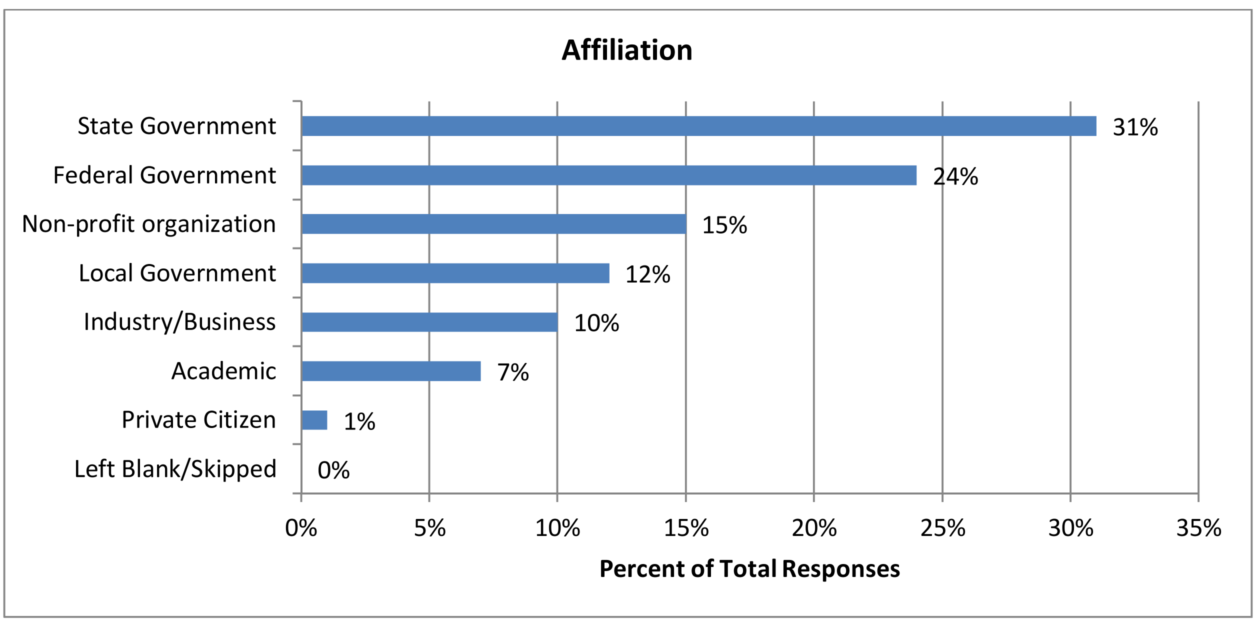


Figure 3: Responses to the question "Please select the affiliation that best describes you work or interest in the Ohio River Basin."

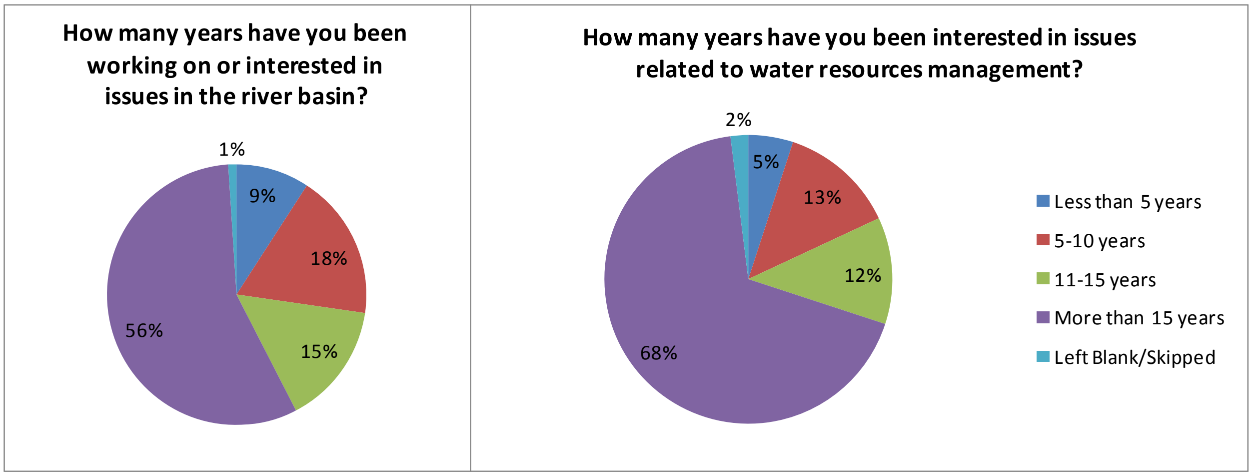


Figure 4: Summary of respondent years of experience with the Ohio River basin and issues related to water resources management.

Further, a majority (63 percent) of the respondents deal with water resources management issues on a daily basis (see Figure 5), and 88 percent have job responsibilities that include providing input to strategic planning; program, facility, operations or financial management; or project planning decisions.

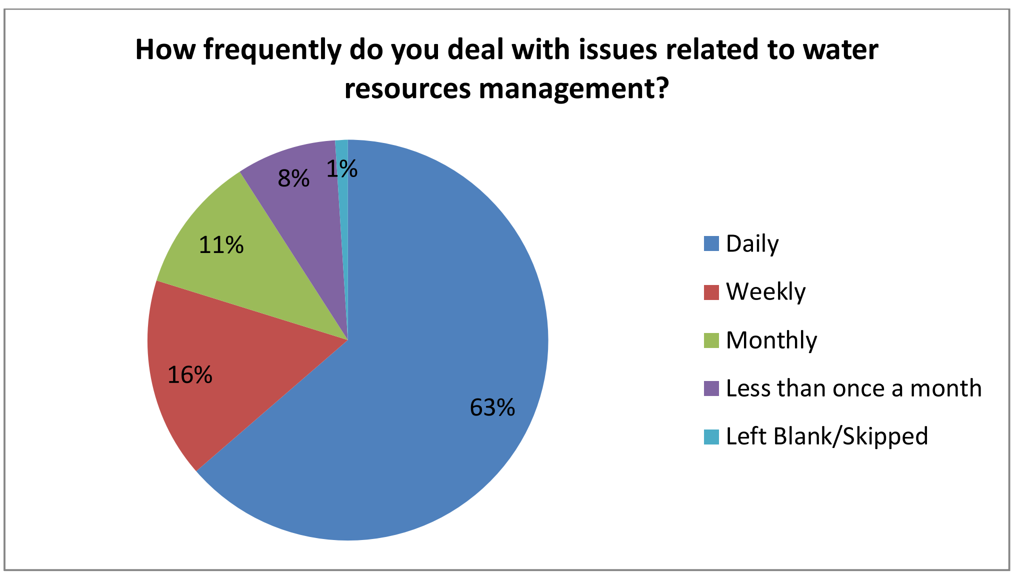


Figure 5: Summary of the frequency with which respondents deal with issues related to water resources management.

2 PRIORITIES

ERG conducted Web-based research and consulted with ORSANCO to identify seven water resources management priority issues facing the basin. The priority issues are summarized in Table 1.

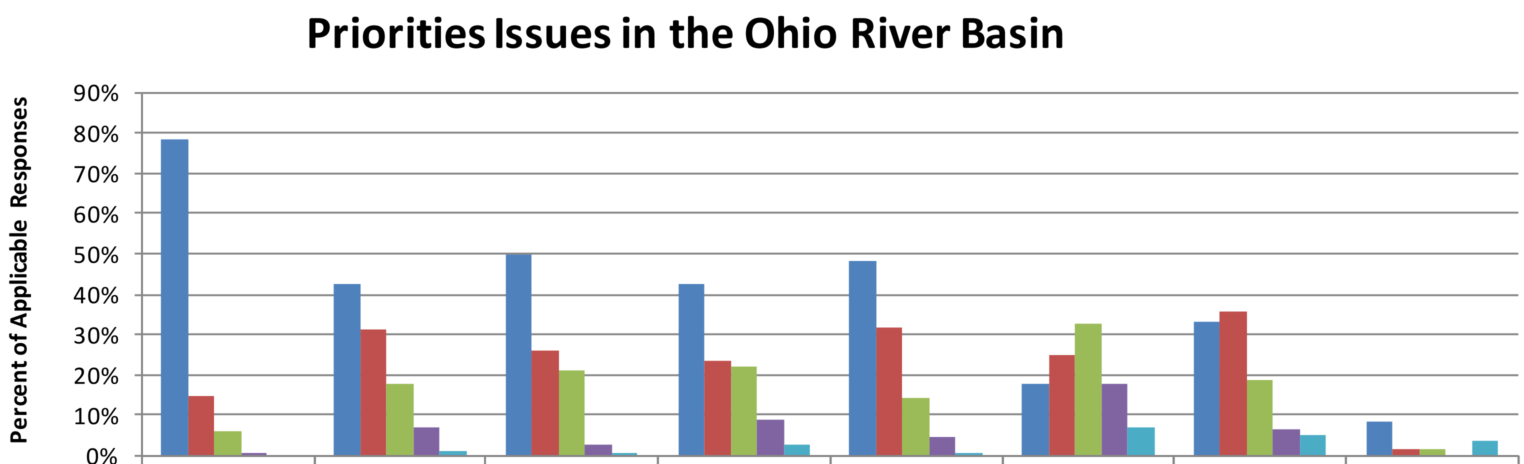
Table 1. Ohio River Basin Priority Issues

Topic	Issues Include:
Water Quality	• Impacts from runoff by land use conversions and combined sewer overflows • Water quality effects on threatened and endangered species • Pharmaceuticals, bacteria, pesticides, nutrient loading, and sedimentation • Lack of basin stormwater management • Need for water treatment/distribution and sewage collection/treatment infrastructure
Maintaining Hydrology	• Dredging and maintenance of navigation channels is continually needed for commercial navigation. New commodities and freight prospects in the Ohio River place added importance on the navigation system and connections to Gulf Coast ports • Repair and rehabilitation of aging flood control infrastructure is a major concern
Water Supply, Water Withdrawals, Water Management	• Sufficiency of water supplies in view of projected population increases and climate change • Bank erosion due to flow regulation at reservoirs, navigation locks, and dams • Conflicts among water users (i.e., water supply, hydropower, recreation, flood protection, fish and wildlife, and navigation) • Better management of water storage and flows • Out-of-basin water transfers for water supply and other uses
Flooding	• Need for additional flood protection at basin-wide major cities and smaller communities • Need to update floodplain mapping to better manage development • Fiscal sustainability of streamflow gages in the basin that are critical to flood warning systems and drought monitoring
Fish & Aquatic Habitat	• Lack of ecological connectivity between the rivers/floodplains • Regulated flow from reservoirs reduces aquatic species habitat diversity and productivity • Effects of sedimentation on aquatic species including game fish and their food sources • Invasive species effects on indigenous aquatic and terrestrial species in the basin • Changes to river flow regimes, temperature and nutrient dynamics of the river system has affected some fisheries
Energy Production	• Water quality and quantity impacts associated with exploration of the Marcellus shale • Concerns about impacts of transporting fracking wastes along Ohio River and other waterways • Hydropower facilities' impact on aquatic life by causing mortality to fish that pass through the facility's turbines • Diversion of river flow through a hydropower facility
Climate/Drought	• Potential effects of climate change on threatened and endangered species habitat, recreational use, water supplies and agriculture.

Respondents were asked to rate each of the priorities on a scale from 1 to 5, where 1 is "Not Important at All," 2 is “Slightly Important,” 3 is “Important,” 4 is “Moderately Important,” and 5 is "Extremely Important," and then identify their top three issues across all seven priorities. Looking across priority issues, respondents were most likely to rate water quality as being extremely important (78 percent). The next most important issues, in terms of the percent of respondents that rated them extremely important, were water supply, withdrawals and management (50 percent) and fish and aquatic habitat (48 percent). See Figure 6.

Looking at each priority issue, respondents tended to rate issues as extremely or moderately important; fewer than 10 percent of respondents rated any particular issue as not important at all. For example, for water quality, maintaining hydrology, water supply, flooding, and fish and aquatic habitat over 40 percent of respondents rated the issue as extremely important. For the remaining two issues, about one-third of respondents rated climate/drought as moderately important (a “4” on the five-point scale), while roughly the same amount rated energy production as important only (a “3” on the five-point scale).

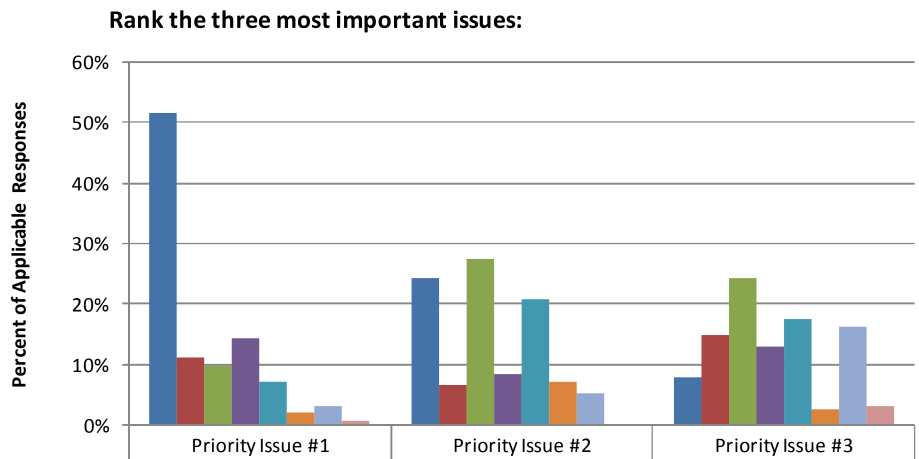
Respondents also suggested other priority issues that were not on the list, including: invasive aquatic species, recreational uses, and outreach and education. A complete list of other issues is provided in the Appendix.



	Water Quality	Maintaining Hydrology	Water Supply, Withdrawals, Management	Flooding	Fish & Aquatic Habitat	Energy Production	Climate, Drought	Other
	153	153	153	153	153	153	153	25
Extremely important	78%	42%	50%	42%	48%	18%	33%	8%
Moderately important	15%	31%	26%	24%	32%	25%	36%	2%
Important	6%	18%	21%	22%	14%	33%	19%	2%
Slightly important	1%	7%	3%	9%	5%	18%	7%	0%
Not Important at all	0%	1%	1%	3%	1%	7%	5%	4%

Figure 6: Summary of respondent ratings of seven priority issues in the Ohio River basin.

The respondents also ranked their top three most important issues, in order of importance where 1 indicates the most important issue. Consistent with the results above, 52 percent of respondents selected water quality as the most important issue. Water supply was the most likely priority to be selected as the #2 and # 3 priority issues. See Figure 7.



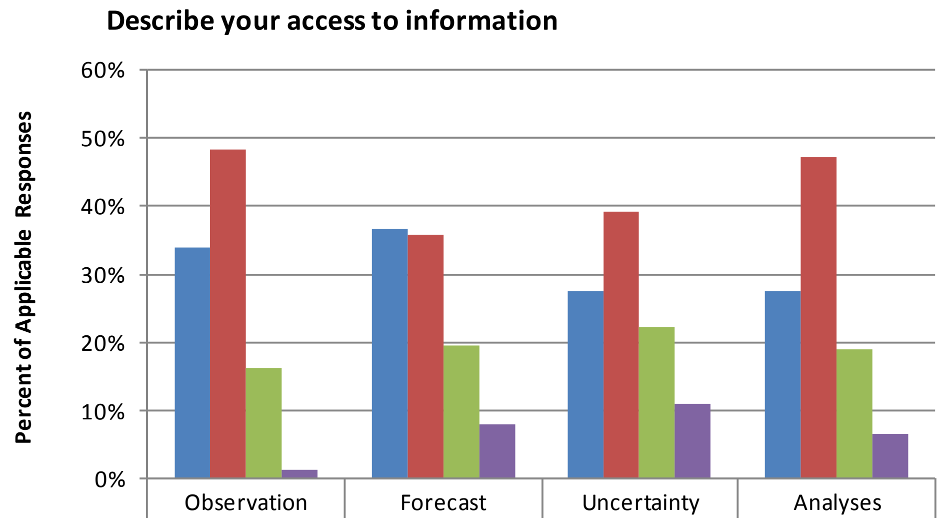
	Priority Issue #1	Priority Issue #2	Priority Issue #3
Water Quality	52%	24%	8%
Maintaining Hydrology	11%	7%	15%
Water Supply, Withdrawals, Management	10%	27%	24%
Flooding	14%	8%	13%
Fish & Aquatic Habitat	7%	21%	18%
Energy Production	2%	7%	3%
Climate, Drought	3%	5%	16%
Other	1%	0%	3%

Figure 7: Respondent ratings of the top three most important priority issues.

3 ACCESS TO AND USE OF INFORMATION

Respondents described their access to four types of water resources information: observations, forecasts, uncertainties, and analyses. For each of those four types of information, respondents were asked to describe the timeline for decision making based on the information, their preferred timing for information updates, and barriers to use.

Overall, most respondents indicated that they have access to the information, but for many of them the information is not adequate or needs improvement. For example, 82 percent of respondents have access to observations, but 48 percent indicate that the information needs improvement. See Figure 8.



	Observation	Forecast	Uncertainty	Analyses
Have information, adequate	34%	37%	27%	27%
Have information, not adequate	48%	36%	39%	47%
Need information, no/limited access	16%	20%	22%	19%
Do not need this information	1%	8%	11%	7%

Figure 8: Summary of respondent access to observations, forecasts, uncertainty information, and analyses.

3.1 Observations

Respondents are using observation information to support decision making over a wide range of time frames from immediate (30 percent) to over 1 year (36 percent). See Figure 9. One third of respondents would like to see new observation information made available for use on an hourly basis (see Figure 10).

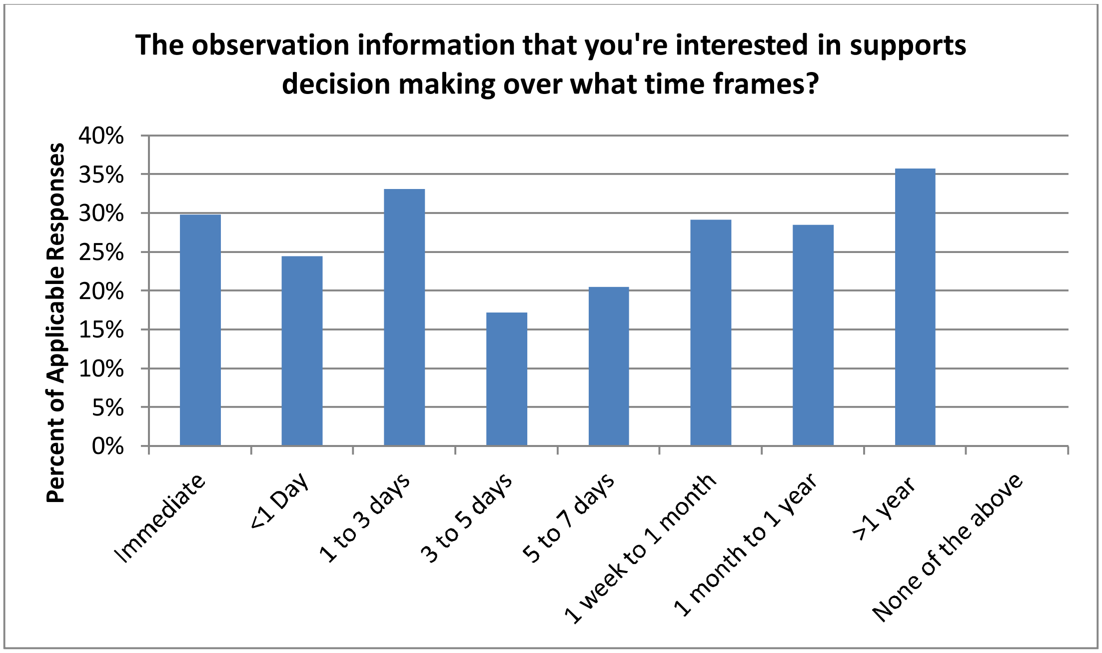


Figure 9: Summary of respondent use of observation information for decision-making.

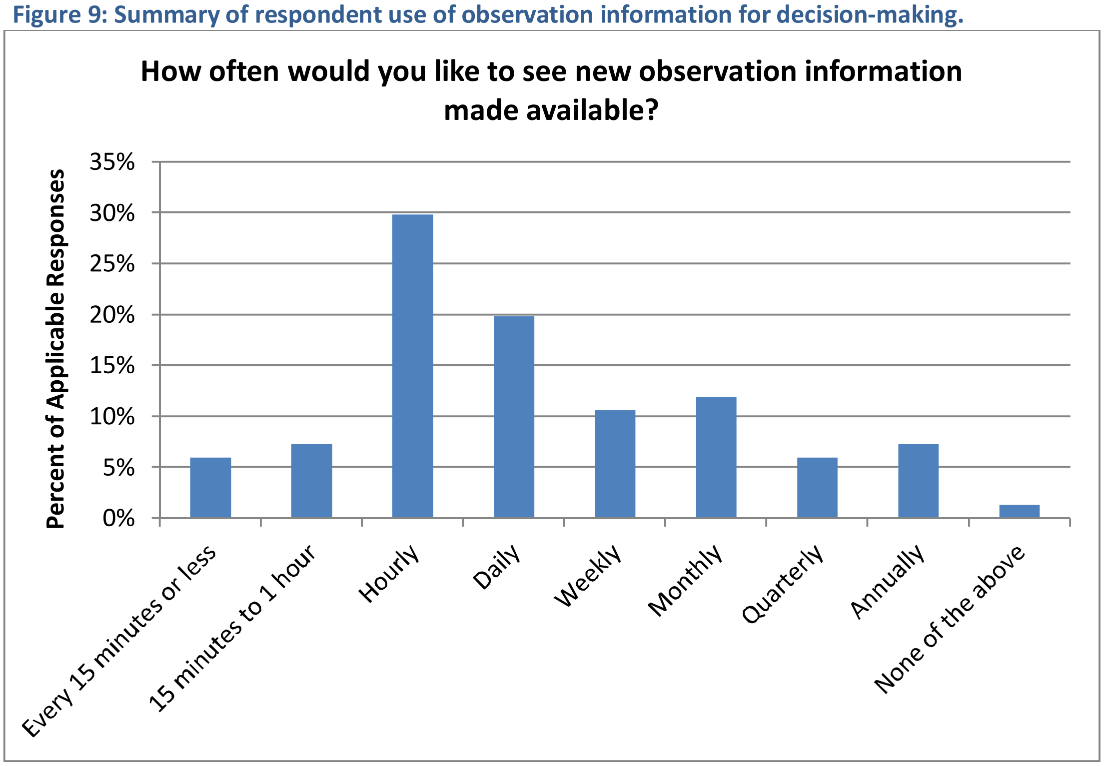
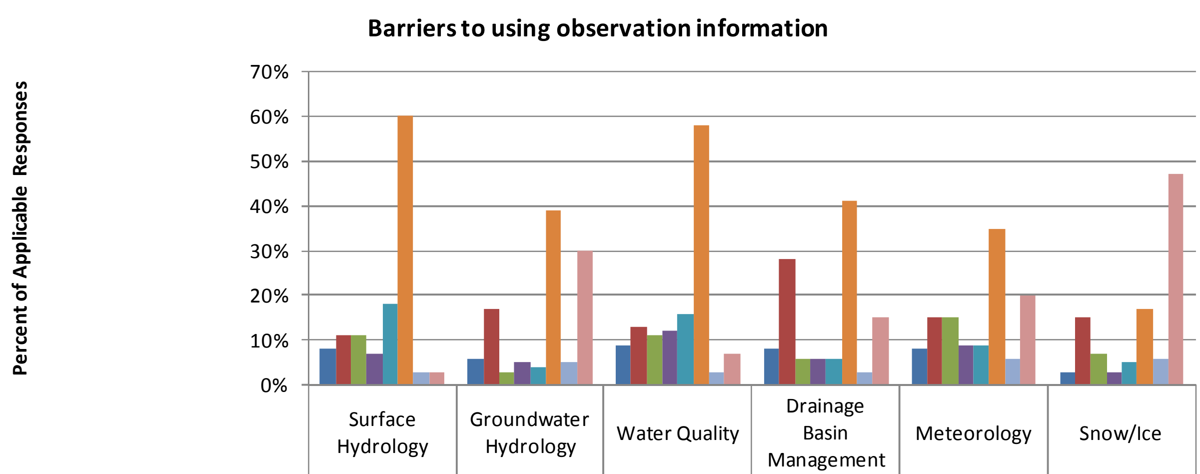


Figure 10: Summary of desired frequency of observation information updates.

Respondents that indicated that a particular type of information is unavailable or needs improvement were asked to describe the current barriers to using the information. For observation information, the most common barrier to use was lack of information available on surface hydrology (60 percent), water quality (58 percent), drainage basin management (41 percent), groundwater hydrology (39 percent), meteorology (35 percent), and snow/ice (17 percent); note, however, 47 percent do not use snow/ice melt information. See Figure 11.



	Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice
Not available in format I use	8%	6%	9%	8%	8%	3%
Don't know where to get	11%	17%	13%	28%	15%	15%
Insufficient accuracy	11%	3%	11%	6%	15%	7%
Insufficient consistency	7%	5%	12%	6%	9%	3%
Insufficient resolution	18%	4%	16%	6%	9%	5%
Lack of availability	60%	39%	58%	41%	35%	17%
Don't understand how to use	3%	5%	3%	3%	6%	6%
Don't use this type of info	3%	30%	7%	15%	20%	47%

Figure 11: Responses to the question "What are some of the barriers to using the following types of observation information."

3.2 Forecasts

Most respondents indicated they are using forecast information to make decisions over a time frame of 1-to-3 days (36 percent) followed by a time frame of over 1 year (28 percent). See Figure 12. Thirty-two percent would like to see new forecast information made available for use daily followed by hourly (25 percent). See Figure 13.

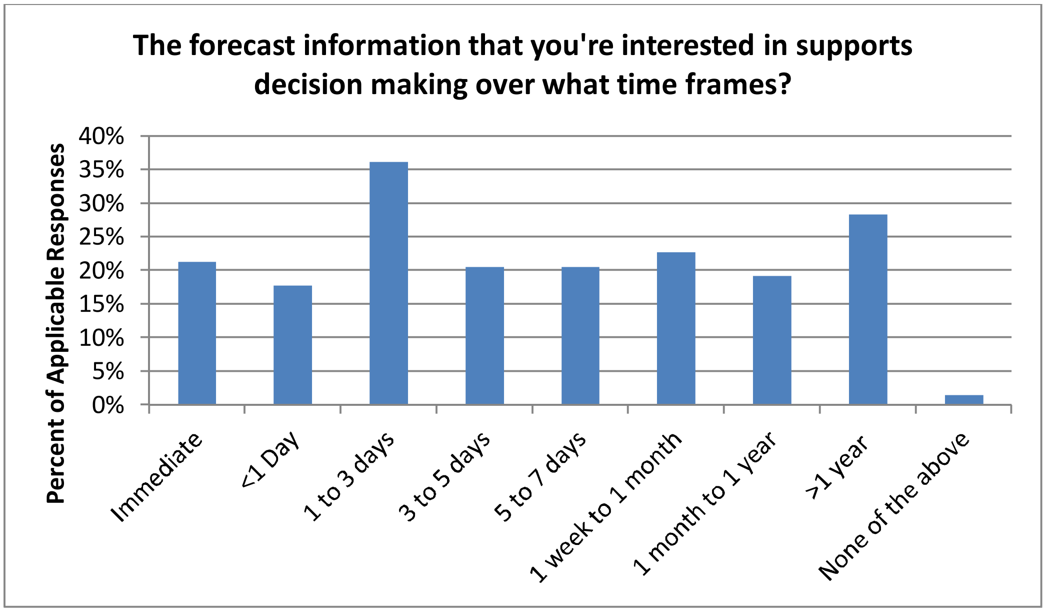


Figure 12: Summary of respondent use of forecast information for decision-making.

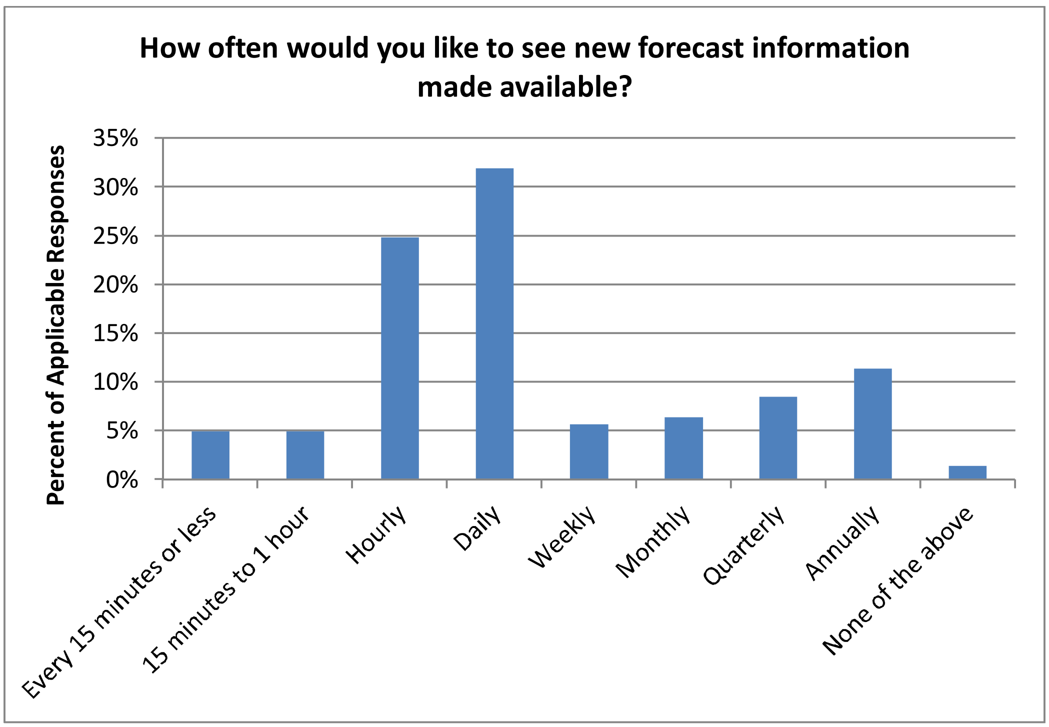
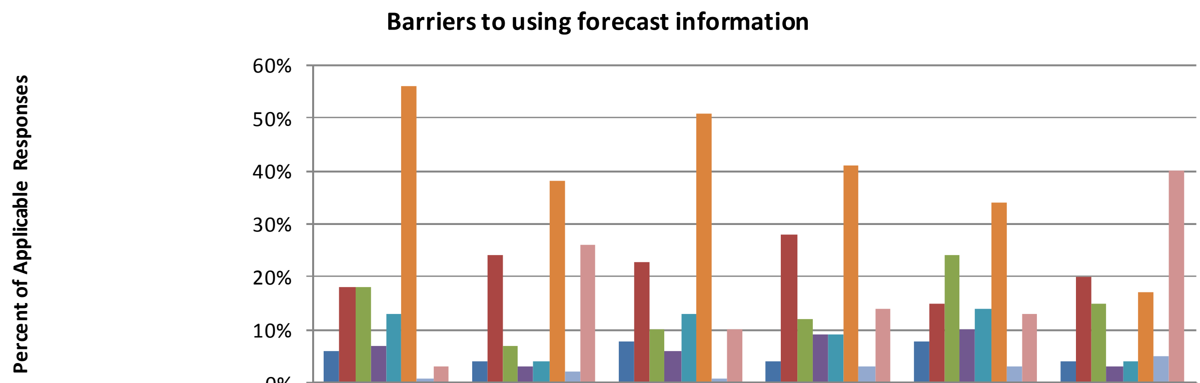


Figure 13: Summary of desired frequency of forecast information updates.

Respondents who indicated that a particular type of information is unavailable or needs improvement were asked to describe the current barriers to using the information. For forecast information, the most common barrier cited was lack of available information for surface hydrology (56 percent), water quality (51 percent), drainage basin management (41 percent), groundwater hydrology (38 percent), meteorology (34 percent), and snow/ice (17 percent; note, however that 40 percent do not use snow/ice melt information). Other common barriers included not knowing where to get the information and perceived insufficient accuracy of the information. See Figure 14.



	Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice
Not available in format I use	6%	4%	8%	4%	8%	4%
Don't know where to get	18%	24%	23%	28%	15%	20%
Insufficient accuracy	18%	7%	10%	12%	24%	15%
Insufficient consistency	7%	3%	6%	9%	10%	3%
Insufficient resolution	13%	4%	13%	9%	14%	4%
Lack of availability	56%	38%	51%	41%	34%	17%
Don't understand how to use	1%	2%	1%	3%	3%	5%
Don't use this type of info	3%	26%	10%	14%	13%	40%

Figure 14: Responses to the question "What are some of the barriers to using the following types of forecast information."

3.3 Uncertainties

For many respondents, uncertainty information supports decision making over a longer timeline, either more than a year (34 percent) or 1-month-to-1-year (25 percent). However, a significant percentage of respondents also work with shorter time frames, such as 1-to-3 days (24 percent). See Figure 15. Respondents would like to see new uncertainty information made available daily (29 percent) or annually (21 percent). See Figure 16.

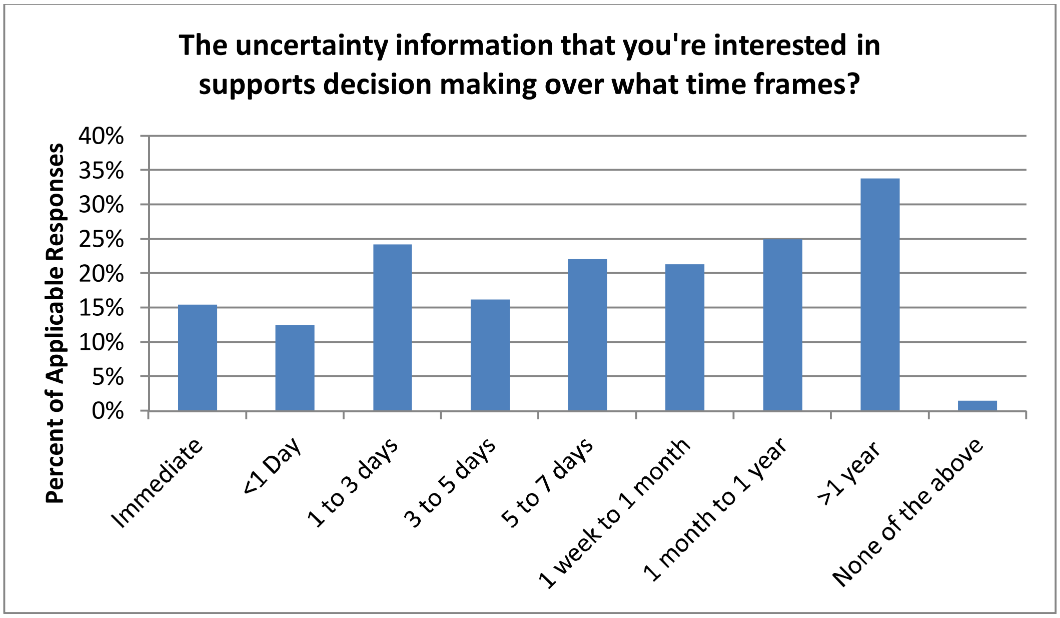


Figure 15: Summary of respondent use of uncertainty information for decision-making.

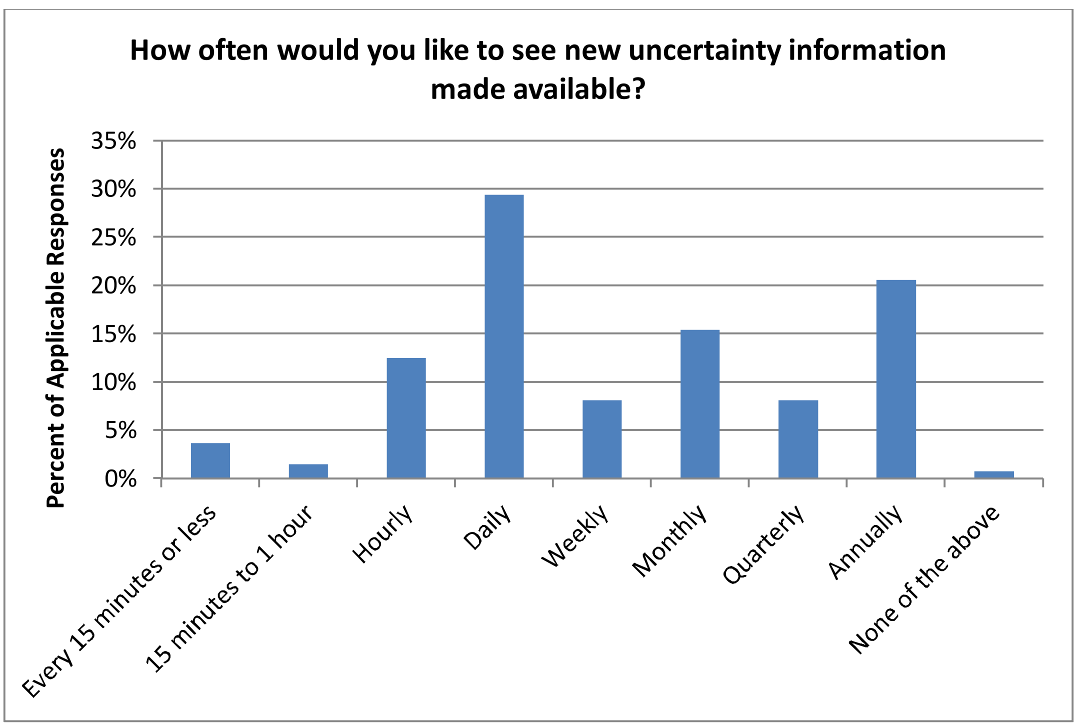
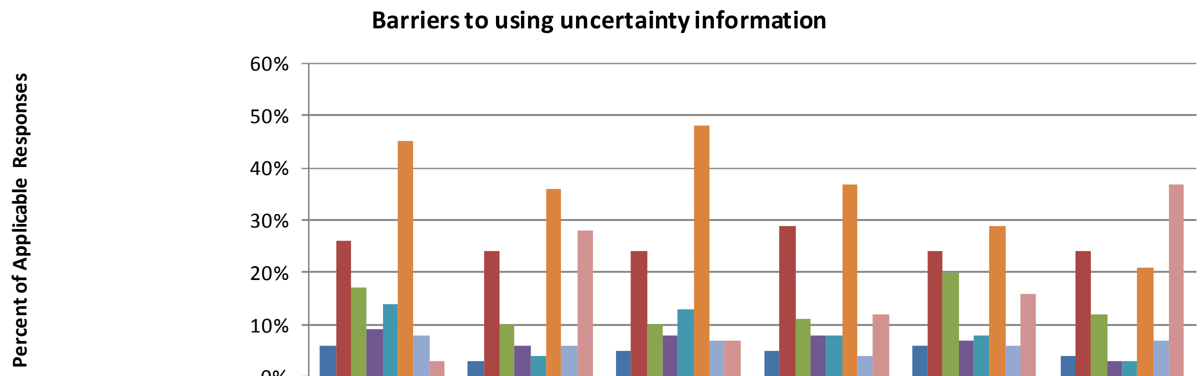


Figure 16: Summary of desired frequency of uncertainty information updates.

Respondents that indicated that a particular type of information is unavailable or needs improvement were asked to describe the current barriers to using the information. For uncertainty information, the most common barrier to use is that there isn't enough information available for surface hydrology (45 percent), water quality (48 percent), drainage basin management (37 percent), groundwater hydrology (36 percent), and meteorology (29 percent). The other key barrier for many of these information types is that respondents do not know where to get the information. See Figure 17.



	Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice
Not available in format I use	6%	3%	5%	5%	6%	4%
Don't know where to get	26%	24%	24%	29%	24%	24%
Insufficient accuracy	17%	10%	10%	11%	20%	12%
Insufficient consistency	9%	6%	8%	8%	7%	3%
Insufficient resolution	14%	4%	13%	8%	8%	3%
Lack of availability	45%	36%	48%	37%	29%	21%
Don't understand how to use	8%	6%	7%	4%	6%	7%
Don't use this type of info	3%	28%	7%	12%	16%	37%

Figure 17: Responses to the question "What are some of the barriers to using the following types of uncertainty information."

When asked if their organization has a formal mechanism or decision model that uses uncertainty information, 41 percent of respondents replied "no," but 22 percent indicated that their organization uses a qualitative approach and 22 percent indicated that their organization has a formal mechanism in place. Those using a qualitative approach described the approach in terms of providing a range of possibilities for forecasts, defining a best case or worst case scenario, or determining how concerned to be about a long term forecast. Those using a formal model described statistical models for risk and uncertainty as well as in-house analyses of water withdrawals or drought forecasting. Full responses to this question are provided in the Appendix; see question 17b.

3.4 Analyses

For 36 percent of respondents, analyses support decisions made over a timeline of more than a year; see Figure 18. Another 30 percent of respondents need analyses to support decisions over a time frame of 1-to-3 days, and 29 percent need analyses to support decisions made over a 1-month-to-1-year time frame. Respondents would like to see new analyses made available hourly (20 percent), daily (17 percent) or annually (17 percent), see Figure 19.

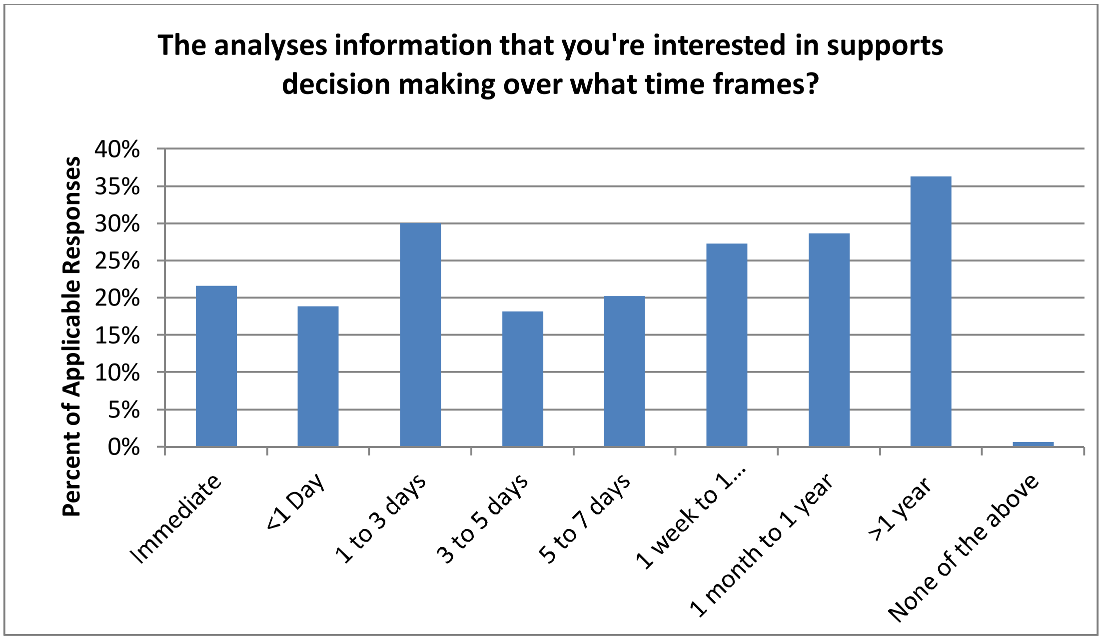


Figure 18: Summary of respondent use of analyses for decision-making.

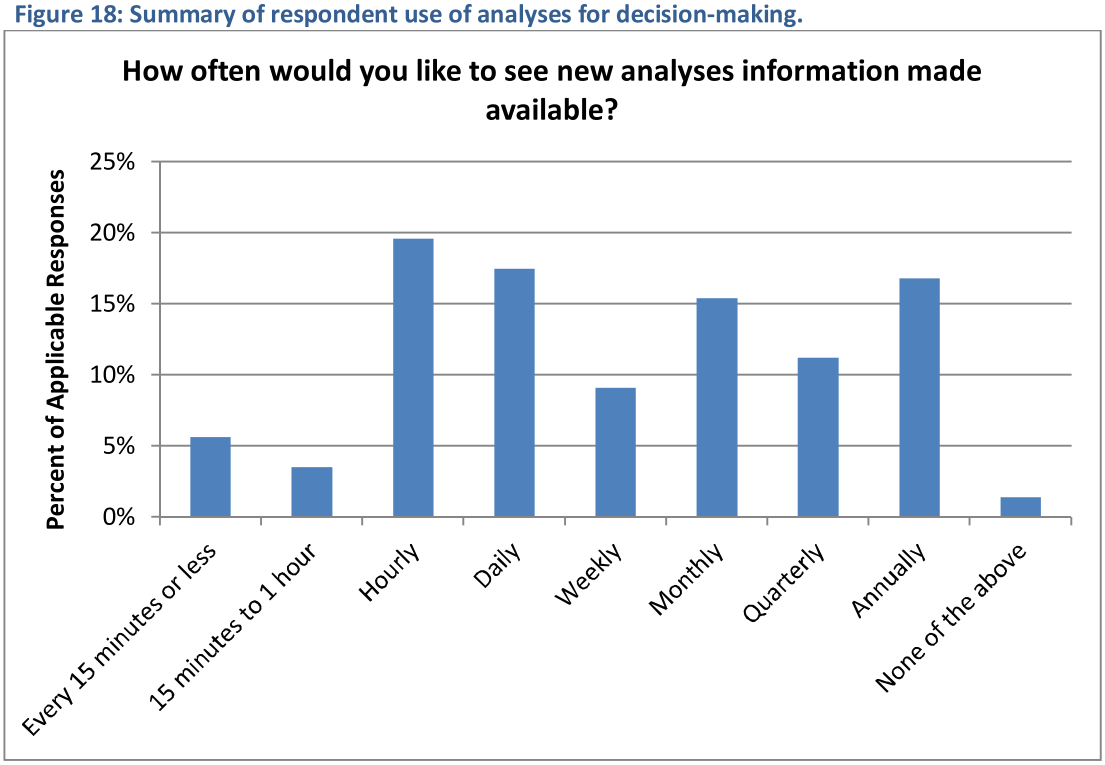
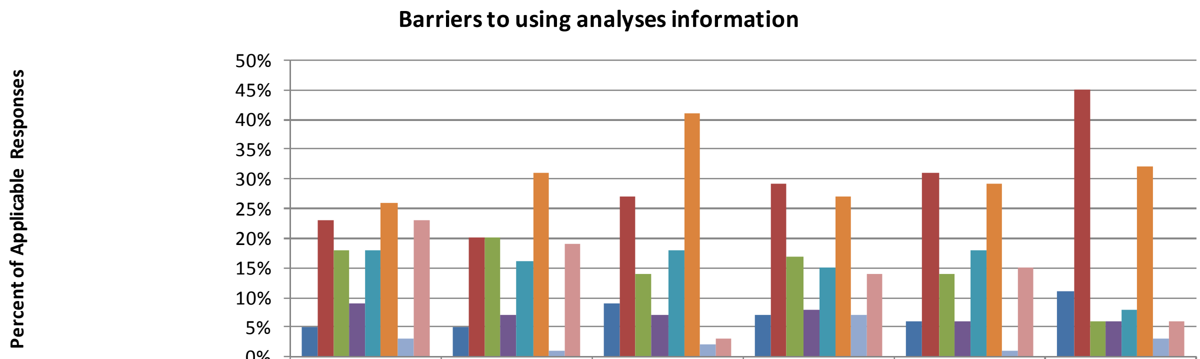


Figure 19: Summary of desired frequency of uncertainty information updates.

Consistent with the above findings, a key barrier to use of analyses was lack of information available, particularly for hydrologic analyses (41 percent), meteorological analyses (31 percent), and public alerts (26 percent). For most of these analyses, not knowing where to get the information was a key barrier to use, particularly for information integration (45 percent), flood inundation mapping (31 percent) and climatological analyses (29 percent). See Figure 20.



	Public alerts	Meteorological analyses	Hydrologic analyses	Climatological analyses	Flood inundation mapping	Information integration
Not available in format I use	5%	5%	9%	7%	6%	11%
Don't know where to get	23%	20%	27%	29%	31%	45%
Insufficient accuracy	18%	20%	14%	17%	14%	6%
Insufficient consistency	9%	7%	7%	8%	6%	6%
Insufficient resolution	18%	16%	18%	15%	18%	8%
Lack of availability	26%	31%	41%	27%	29%	32%
Don't understand how to use	3%	1%	2%	7%	1%	3%
Don't use this type of info	23%	19%	3%	14%	15%	6%

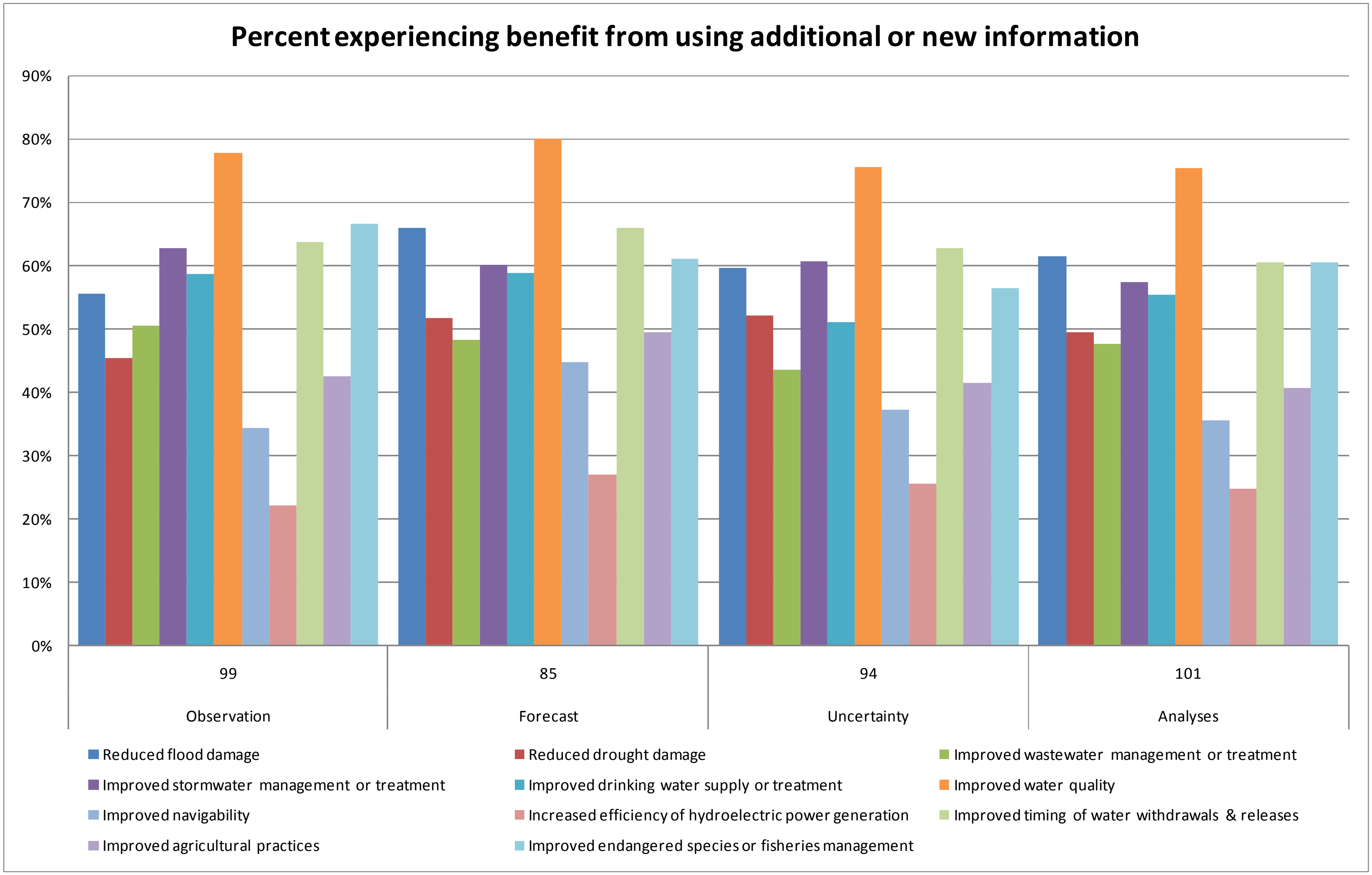
Figure 20: Responses to the question "What are some of the barriers to using the following types of analyses."

4 BENEFITS OF FILLING INFORMATION GAPS

For each of the four types of information (observation, forecasts, uncertainty, and analyses) respondents were asked whether they would experience any of ten potential benefits from using additional or new water resources information. The potential benefits included:

- Reduced flood damage (property damage, injury or loss of life, lost business, recovery costs)
- Reduced drought damage
- Improved wastewater management or treatment
- Improved stormwater management or treatment
- Improved drinking water supply or treatment
- Improved water quality
- Improved navigability (shipping, recreation)
- Increased efficiency of hydroelectric power generation
- Improved timing of water withdrawals and releases or its management
- Improved agricultural practices
- Improved endangered/threaten species or fisheries management

Figure 21 provides an overview of the benefits of new or additional information for observations, forecasts, uncertainty information, and analyses. Improved water quality was the most prominent benefit across the four categories.



Note: The number above each information type represents the total number of respondents anticipating potential benefits of new or additional information of that type.

Figure 21: Summary of potential benefits of new or additional information for observations, forecasts, uncertainty information, and analyses.

4.1 Observations

Respondents indicated that the top three potential benefits of providing new or additional observation information were improved water quality (77 percent), improved management of endangered species or fisheries (66 percent), improved timing of water withdrawals, releases and management (63 percent), and improved stormwater management (62 percent). See Figure 22.

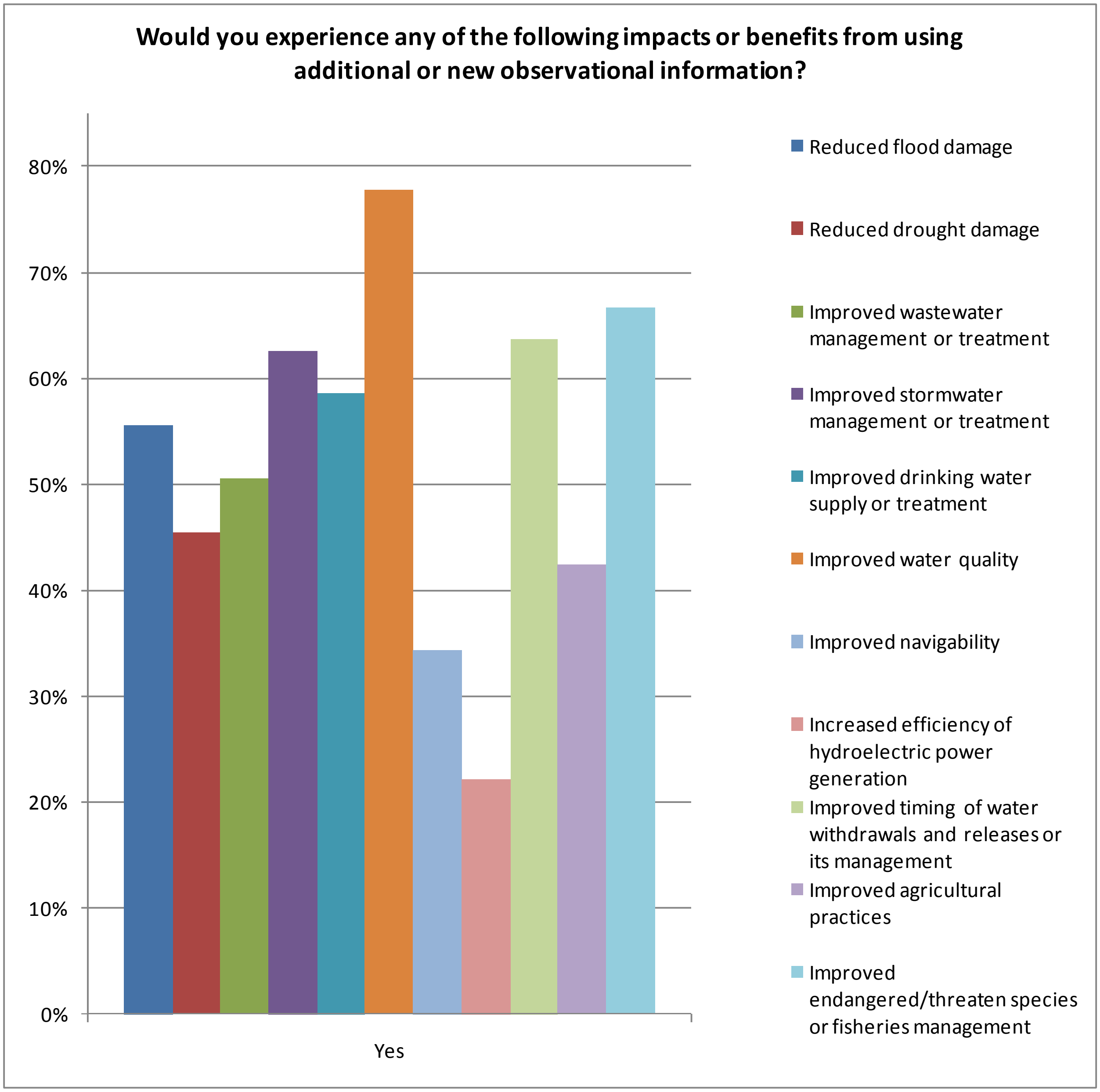


Figure 22: Summary of benefits of using new or additional observation information.

4.2 Forecasts

Respondents identified the top three potential benefits of providing new or additional forecast information as improved water quality (68 percent), reduced flood damage (56 percent), and improved timing of water withdrawals, releases and management (56 percent). See Figure 23.

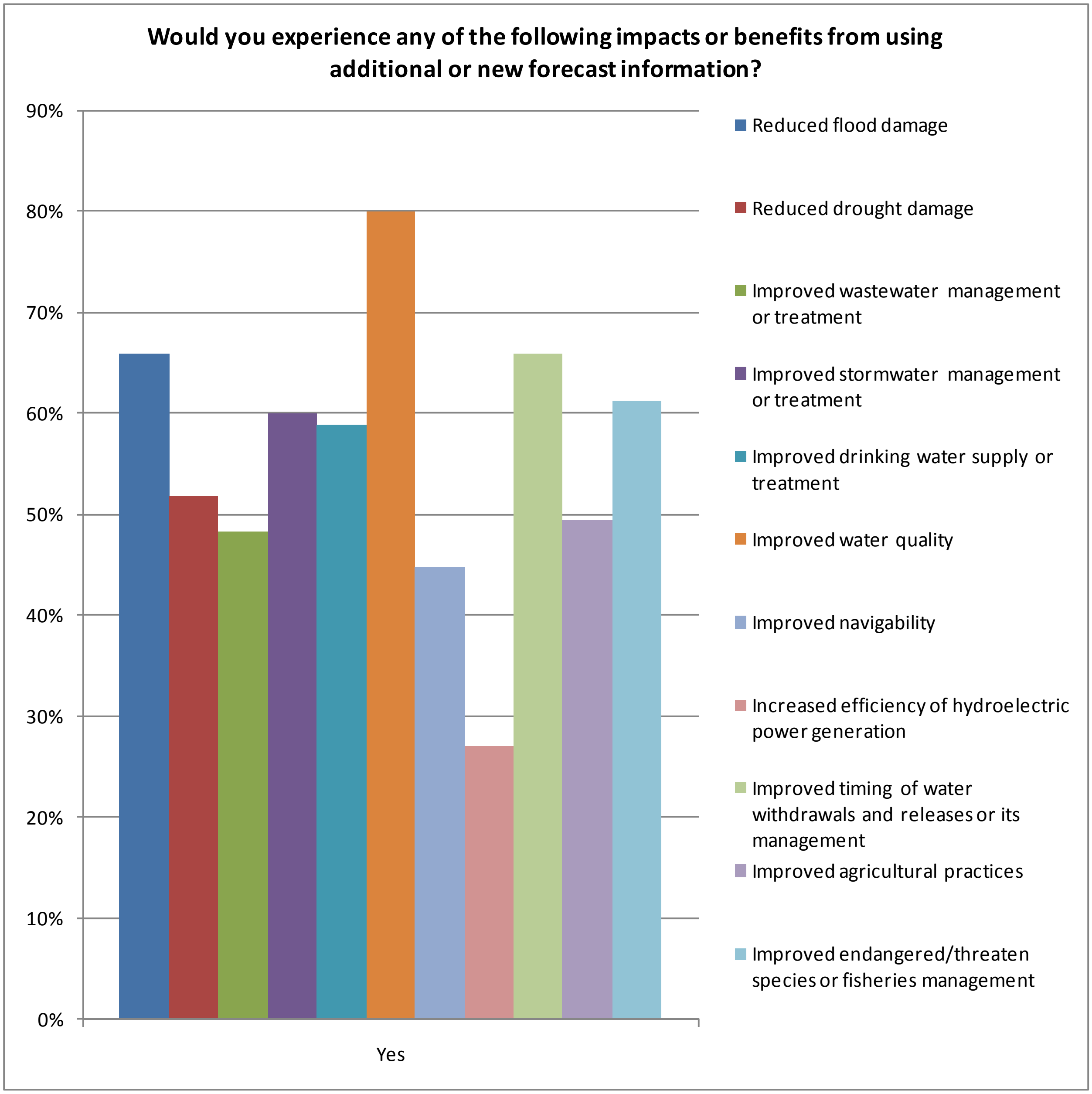


Figure 23: Summary of benefits of using new or additional forecast information.

4.3 Uncertainties

The top three potential benefits of providing new or additional uncertainty information was improved water quality (71 percent), improved timing of water withdrawals, releases and management (59 percent), improved stormwater management (57 percent), and reduced flood damage (56 percent). See Figure 24.

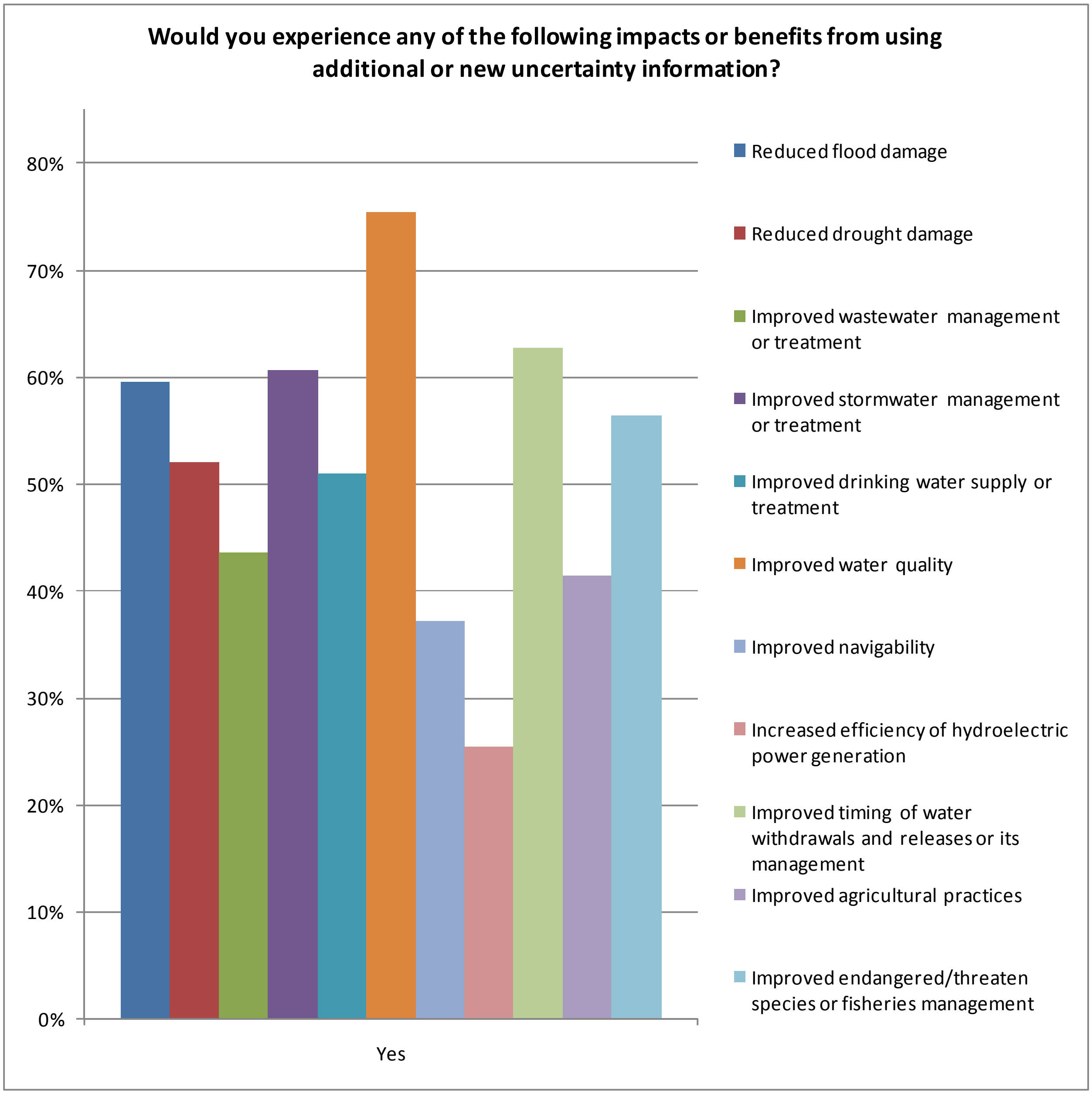


Figure 24: Summary of benefits of using new or additional uncertainty information.

4.4 Analyses

Respondents indicated that the top three potential benefits of providing new or additional analyses were improved water quality (76 percent), reduced flood damage (62 percent), improved timing of water withdrawals, releases and management (61 percent), and improved endangered species or fisheries management (61 percent). See Figure 25.

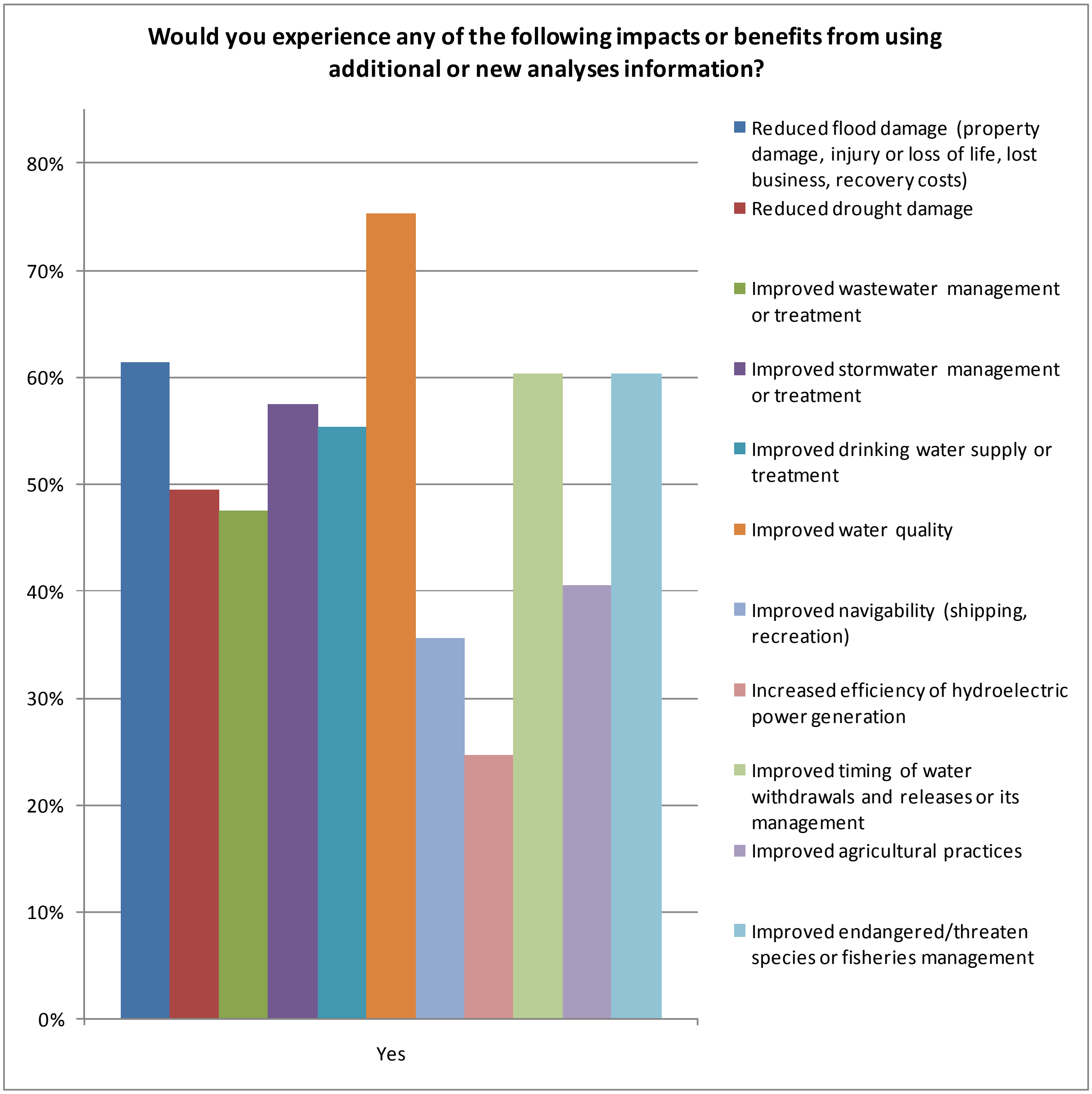


Figure 25: Summary of benefits of using new or additional analyses.

Appendix A
Survey Responses by Question

IWRSS Stakeholder Survey

Ohio River Basin Results, by Question

1) From the following list, please select the PRIMARY sector in which your work or interest is focused in the Ohio River basin? (Check one)

Sector	Count	Percent
Agriculture	1	1%
Recreation	1	1%
Other energy extraction	2	1%
Hydropower	3	2%
Reservoir Management	6	4%
Emergency Management	7	5%
River Commerce	7	5%
Other	8	5%
Municipal and Industrial Water Supply	13	8%
Flood Protection	17	11%
Fish and Wildlife	22	14%
Watershed Management	24	16%
Water Quality	42	27%
Total	**153**	**100%**

Other Responses
Basin planning for both quality & quantity
Biological assessment
Forestry
Regulatory
Scientific data and studies for those sectors
State Regulatory staff for water supply
USGS is involved in a number of areas
Monitoring

2) Please indicate any other sectors in which you work or that you are concerned about in the Ohio River basin? (Please check all that apply)

Sector	Count	Percent
Water Quality	87	57%
Fish and Wildlife	68	44%
Emergency Management	40	26%
Reservoir Management	42	27%
Watershed Management	88	58%
Agriculture	32	21%
Hydropower	32	21%
Other energy extraction	20	13%
River commerce	23	15%
Municipal and Industrial Water Supply	61	40%
Recreation	54	35%
Insurance	9	6%
Flood Protection	49	32%
Other (please specify)	11	7%
Total	**153**	**100%**

Other Responses
Aquatic Invasive Species
Asian carp
Climate adaptation and resilience
Ecosystems services
Mapping What & Where
Scientific data and studies for those sectors
Stormwater Management
Stormwater runoff
Water pollution
Conservation organization
Ecosystem services
Effects of climate change
Permitting

3) Please select the affiliation that best describes your work or interest in the Ohio River basin? (Check one)

Affiliation	Count	Percent
Left Blank/Skipped	0	0%
Private Citizen	2	1%
Academic	10	7%
Industry/Business	15	10%
Local Government	19	12%
Non-profit organization	23	15%
Federal Government	36	24%
State Government	48	31%
Total	**153**	**100%**

4) How many years have you been working on or interested in issues in the Ohio River basin?

Years	Count	Percent
Less than 5 years	14	9%
5-10 years	28	18%
11-15 years	23	15%
More than 15 years	86	56%
Left Blank/Skipped	2	1%
Total	**153**	**100%**

5) How many years have you been interested in issues related to water resources management?

Years	Count	Percent
Less than 5 years	8	5%
5-10 years	20	13%
11-15 years	18	12%
More than 15 years	104	68%
Left Blank/Skipped	3	2%
Total	**153**	**100%**

6) How frequently do you deal with issues related to water resources management?

Frequency	Count	Percent
Daily	97	63%
Weekly	25	16%
Monthly	17	11%
Less than once a month	13	8%
Left Blank/Skipped	1	1%
Total	**153**	**100%**

7) Do your job responsibilities include providing input to strategic planning; program, facility, operations or financial management; or project planning decisions on water resources information?

	Count	Percent
Yes	135	88%
No	18	12%
Total	**153**	**100%**

II. Priorities

8) How important are each of the following issues? (Please indicate the importance (to you) of each the following issues on a scale from 1 to 5; where 1 is "Not Important at All" and 5 is "Extremely Important.")

	Water Quality	Maintaining Hydrology	Water Supply, Withdrawals, Management	Flooding	Fish & Aquatic Habitat	Energy Production	Climate, Drought	Other
Not Important at all	0%	1%	1%	3%	1%	7%	5%	4%
Slightly important	1%	7%	3%	9%	5%	18%	7%	0%
Important	6%	18%	21%	22%	14%	33%	19%	2%
Moderately important	15%	31%	26%	24%	32%	25%	36%	2%
Extremely important	78%	42%	50%	42%	48%	18%	33%	8%

9) If you selected "Other" above, please use this space to describe your priority water resources issue.

Aquatic Invasive Species
Asian Carp and other ANS issues
Contact Recreation
Educating the public and elected officials about the importance of water quality and wildlife
Farm field runoff. It may be able to be lumped under impacts from runoff by land use conversions, but that sounds more like recent conversions
Hydropower and forecasting long and short term water availability
Improving biological assessment
Invasive species impact to the aquatic resources of the Ohio River Basin.
Maintaining ecosystem services.
Maintenance of L/D structures to protect water resources. Almost all the other issues will be WAY worse if the dams are not repaired and maintained.
Management of floodplains and land uses by county and municipal jurisdictions, administered outside of State or Federal authorities but instrumental in stormwater issues, flooding and water quality.
Outreach & Education
Recreational use of the rivers public access to the rivers.
Relationship with ground water
Riparian Corridor Protection
The unknown.
Public use
Thermal pollution

10) Looking at the issues as a group, please rank the three most important issues that you think are facing the Ohio River Basin, in order of importance; where 1 is the most important issue.

Priority Issue	Priority Issue #1		Priority Issue #2		Priority Issue #3	
	Count	Percent	Count	Percent	Count	Percent
Water Quality	79	52%	37	24%	12	8%
Maintaining Hydrology	17	11%	10	7%	23	15%
Water Supply Withdrawals, Management	15	10%	42	27%	37	24%
Flooding	22	14%	13	8%	20	13%
Fish & Aquatic Habitat	11	7%	32	21%	27	18%
Energy Production	3	2%	11	7%	4	3%
Climate, Drought	5	3%	8	5%	25	16%
Other	1	1%	0	0%	5	3%
Total	**153**	**100%**	**153**	**100%**	**153**	**100%**

III. Information Needs.

11) For your highest priority issue, describe your access to the following types of information needed for informing decisions.

	Observation		Forecast		Uncertainty		Analyses	
	N	Percent	N	Percent	N	Percent	N	Percent
I do not need this type of information	2	1%	12	8%	17	11%	10	7%
I have adequate information to meet my needs	52	34%	56	37%	42	27%	42	27%
I have the information, but it is not adequate or needs improvement	74	48%	55	36%	60	39%	72	47%
I need this type of information but currently have no or very limited access to it	25	16%	30	20%	34	22%	29	19%
Total	**153**	**100%**	**153**	**100%**	**153**	**100%**	**153**	**100%**

Observation Information Details

12) The observation information that you're interested in supports decision making over what time frames? Please check all that apply.

Time Frame	N	Percent
Immediate	45	30%
<1 Day	37	25%
1 to 3 days	50	33%
3 to 5 days	26	17%
5 to 7 days	31	21%
1 week to 1 month	44	29%
1 month to 1 year	43	28%
>1 year	54	36%
None of the above	0	0%
Total	**153**	**100%**

13) How often would you like to see new observation information made available for use?

Time Frame	N	Percent
Every 15 minutes or less	9	6%
15 minutes to 1 hour	11	7%
Hourly	45	30%
Daily	30	20%
Weekly	16	11%
Monthly	18	12%
Quarterly	9	6%
Annually	11	7%
None of the above	2	1%
Total	**153**	**100%**

Forecast Information Details

14) The forecast information that you're interested in supports decision making over what time frames? Please check all that apply.

Time Frame	N	Percent
Immediate	30	21%
<1 Day	25	18%
1 to 3 days	51	36%
3 to 5 days	29	21%
5 to 7 days	29	21%
1 week to 1 month	32	23%
1 month to 1 year	27	19%
>1 year	40	28%
None of the above	2	1%
Total	**153**	**100%**

15) How often would you like to see new forecast information made available for use?

Time Frame	N	Percent
Every 15 minutes or less	7	5%
15 minutes to 1 hour	7	5%
Hourly	35	25%
Daily	45	32%
Weekly	8	6%
Monthly	9	6%
Quarterly	12	9%
Annually	16	11%
None of the above	2	1%
Total	**153**	**100%**

Uncertainty Information Details

16) The uncertainty information that you're interested in supports decision making over what time frames? Please check all that apply.

Time Frame	N	Percent
Immediate	21	15%
<1 Day	17	13%
1 to 3 days	33	24%
3 to 5 days	22	16%
5 to 7 days	30	22%
1 week to 1 month	29	21%
1 month to 1 year	34	25%
>1 year	46	34%
None of the above	2	1%
Total	**153**	**100%**

17) How often would you like to see new uncertainty information made available for use?

Time Frame	N	Percent
Every 15 minutes or less	5	4%
15 minutes to 1 hour	2	1%
Hourly	17	13%
Daily	40	29%
Weekly	11	8%
Monthly	21	15%
Quarterly	11	8%
Annually	28	21%
None of the above	1	1%
Total	**153**	**100%**

17b) Does your organization use a formal mechanism or decision model with uncertainty information?

Response	N	Percent
No, my organization does not currently have an approach for using this information. [Please describe below]	63	41%
No, my organization uses a qualitative approach. [Please describe below]	33	22%
Yes, my organization uses a formal mechanism or decision model. [Please describe below]	33	22%
Skipped	24	16%
Total	**153**	**100%**

No, my organization does not currently have an approach for using this information. [Please describe below]
For reservoir management decision-making, we use a formal decision model, which includes inherent uncertainties related to various model parameters or inputs (such as rainfall observations or soil moisture states). These uncertainties are not quantified, or explicitly included, in the model outputs.
This information would be useful in making manpower decisions during flood conditions.
We do not possess this expertise.
We understand the forecasts have an inherent uncertainty factor. Forecast information is used as "guidance", and is not considered "absolute".
We use it to inject caution into our strategies
No, my organization uses a qualitative approach. [Please describe below]
1. What are the variations in sediment loading related to rainfall frequency and intensity? (This affects cooling water impacts on industrial piping wear and plugging. How is the water quality impact measured regarding sanitary and industrial sewage bypasses during storm events? This affects industrial discharge quality in once through cooling water systems.
A description of the uncertainty helps us to determine how concerned to be over potentially forecast outcomes--especially long term forecasts.
Based on COE AND NWS INFO
Based on historical frequencies
Peer Review
The marine department does this work predominantly, I am aware of the work but able to describe the approach to level I think you are requesting.
This centers mostly on interpretation of biological and water quality data - based on inference and variability in reference conditions.

Use information in making permit and water quality assessment decisions.
We rely upon NOAA for river flows and forecasts
We understand that there is inherent uncertainty in all we do, and thus are always considering that in our decision-making. For example, in flood forecasting and warning, we provide a range of possibilities with an understanding that we can never know exactly what will happen.
When making future projections for decision-making, we use a loose best case and worse case concept, and then plan for a "no regrets" strategy for decision making in most cases.
Yes, my organization uses a formal mechanism or decision model. [Please describe below]
A formal model is used for drought monitoring; separate sets of models are used for long-term water supply planning.
Developed in-house, surface water withdrawals are analyzed using a cumulative impact analysis that is essentially a water budget on a daily time-step. This allows the evaluation of a proposed withdrawal's (and its operating rules) potential impact on the existing system, and permit decisions are made based upon that analysis.
GIS based
Identifying/approving/permitting and assisting in the funding of regional approaches to water and wastewater needs is a critical statewide goal. It is well documented that regional water solutions are more sustainable, more energy efficient, economies of scale less costly for all tax payers, and less impactful to the environment. It's critical that the process involve a broad range of stakeholders. It cannot be, nor can it have the appearance of being, a top-down process. In TN, we are collaborating with federal, local and NGO partners to: 1) define "regional approaches"; and 2) provide economic incentives through SRF loan ranking for regional projects. Obtaining the very best hydrologic data for all of our state's surface and groundwater sources is critical in the process to best understand reliable yields of water bodies against growth projections.
ORSANCO Organics Detection System
Predicted flood stage to determine if sampling is safe and/or appropriate for collection of biological samples.
Pre-schedule of flow releases to max generation and value from available water
Risk models for life loss and flood damages
Several statistical "bootstrap" methods have been developed. Also, ensemble forecast technology has been very useful to us over the past 4 years and continued improvements would be welcome.
Strategic Habitat Conservation: an adaptive, iterative process of biological planning, conservation design, conservation delivery, monitoring, and research.
Use internal USACE software with risk and uncertainty models pulled into it
USEPA uses several uncertainty approaches, e.g., in HSPF studies (see: Report EPA/600/R-12/058F (Sept. 2013)
USGS has a number of QA/QC standards and methods that include uncertainty.
Varies by project.
We do whatever Louisville does.
We execute lower Ohio and Mississippi River flood control using a dynamic routing model.
We have participated in a Spill Management Information system program in conjunction with the Vanderbilt University and the Army COE for spills in the source water.
We need to forecast if the river level will be above 30 feet so we can make a call to cancel or continue with our Ohio River Paddlefest
We use our on statistical models based on historical data for forecasts with some statistical uncertainty included, however we do not account for climate changes, population change, etc. uncertainties.
Within my academic research we work on decision models with uncertainty.
(blank)
Don't know, different groups use various statistical or modeling approaches

Analyses Information Details

18) The analyses information that you're interested in supports decision making over what time frames? Please check all that apply.

Time Frame	N	Percent
Immediate	31	22%
<1 Day	27	19%
1 to 3 days	43	30%
3 to 5 days	26	18%
5 to 7 days	29	20%
1 week to 1 month	39	27%
1 month to 1 year	41	29%
>1 year	52	36%
None of the above	1	1%
Not Applicable	10	7%
Total	**153**	**100%**

19) How often would you like to see new analyses information made available for use?

Time Frame	N	Percent
Every 15 minutes or less	8	6%
15 minutes to 1 hour	5	3%
Hourly	28	20%
Daily	25	17%
Weekly	13	9%
Monthly	22	15%
Quarterly	16	11%
Annually	24	17%
None of the above	2	1%
Not Applicable	10	7%
Total	**153**	**100%**

IV. Barriers to Use and Benefits Section

20) You indicated that the observation information you need for informing decisions needs improvement or is unavailable. What are some of the barriers to using the following types of observation information?

Type of Information	N (total = 99)					
	Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice
Not available in a format that I can use	7	6	8	7	7	3
Don't know where to get the information	10	16	12	26	13	14
Accuracy is not sufficient	10	3	10	6	13	7
Consistency is not sufficient	11	7	18	9	14	5
Resolution is not sufficient	17	4	15	6	8	5
Not enough information available	56	37	53	38	31	16
Don't understand how information can be used	3	5	3	3	5	6
I don't use this type of information	3	28	6	14	18	45
Not applicable	54	54	54	54	54	54

21) If the observation information you needed were made available, would you experience any of the following benefits from using the additional or new observational information?

Types of impacts or benefits	N (total = 99)				
	Yes	No	Skipped	Not Applicable	Total
Reduced flood damage (property damage, injury or loss of life, lost business, recovery costs)	55	40	4	54	153
Reduced drought damage	45	50	4	54	153
Improved wastewater management or treatment	50	44	5	54	153
Improved stormwater management or treatment	62	32	5	54	153
Improved drinking water supply or treatment	58	37	4	54	153
Improved water quality	77	17	5	54	153
Improved navigability (shipping, recreation)	34	57	8	54	153
Increased efficiency of hydroelectric power generation	22	68	9	54	153
Improved timing of water withdrawals and releases or its management	63	29	7	54	153
Improved agricultural practices	42	49	7	55	153
Improved endangered/threaten species or fisheries management	66	27	6	54	153
Other type of impact?	10	39	50	54	153

22) If you selected "yes" for "other type of benefit," please provide a brief description. [Open-ended]

Ability to forecast water quality for recreation
Better understanding of limiting factors to biological assemblages.
Improved ability to accurately report on attainment of beneficial uses.
Improved water quality modeling (i.e. TMDLs). And Improved decision-making to target placement of best management practices.
Improved communication to/within state and federal water pollution regulatory agencies
Needed for sport fish management

Possibly reduce cost to upgrade aging infrastructure as a result of dam hazard reclassification

23) You indicated that the forecast information you need for informing decisions needs improvement or is unavailable. What are some of the barriers to using the following types of observation information?

Type of Information	N (total = 85)					
	Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice
Not available in a format that I can use	5	3	6	3	6	3
Don't know where to get the information	14	20	18	21	12	16
Accuracy is not sufficient	14	6	8	9	19	12
Consistency is not sufficient	11	5	9	14	15	5
Resolution is not sufficient	10	3	10	7	11	3
Not enough information available	44	31	41	31	27	14
Don't understand how information can be used	1	2	1	2	2	4
I don't use this type of information	2	21	8	11	10	33
Not applicable	68	68	68	68	68	68

24) If the forecast information you needed were made available, would you experience any of the following benefits from using the additional or new observational information?

Types of impacts or benefits	N (total = 85)				
	Yes	No	Skipped	Not Applicable	Total
Reduced flood damage (property damage, injury or loss of life, lost business, recovery costs)	56	27	2	68	153
Reduced drought damage	44	39	2	68	153
Improved wastewater management or treatment	41	40	4	68	153
Improved stormwater management or treatment	51	28	6	68	153
Improved drinking water supply or treatment	50	31	3	69	153
Improved water quality	68	12	5	68	153
Improved navigability (shipping, recreation)	38	43	4	68	153
Increased efficiency of hydroelectric power generation	23	56	6	68	153
Improved timing of water withdrawals and releases or its management	56	26	3	68	153
Improved agricultural practices	42	38	5	68	153
Improved endangered/threaten species or fisheries management	52	26	7	68	153
Other type of impact?	6	34	45	68	153

25) If you selected "yes" for "other type of benefit," please provide a brief description. [Open-ended]

Ability to let public know whether or not water quality is safe for recreation
Forecast information should be provided consistently with how flood risk information is provided and documented. For example, frequency and magnitude of rain events/storms is not consistent with frequency/magnitude of flood on a watercourse.
Improve public safety
Improved derivation of water quality criteria.
Ability to do correction action and groundwater clean up when contamination found.
Improved response to emergencies involving loss of electrical power to water and wastewater utilities

26) You indicated that the uncertainty information you need for informing decisions needs improvement or is unavailable. What are some of the barriers to using the following types of observation information?

Type of Information	N (total = 94)					
	Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice
Not available in a format that I can use	5	3	4	4	5	4
Don't know where to get the information	23	21	21	24	21	22
Accuracy is not sufficient	15	9	9	9	17	11
Consistency is not sufficient	14	9	12	12	10	5
Resolution is not sufficient	12	4	11	7	7	3
Not enough information available	40	32	42	31	25	19
Don't understand how information can be used	7	5	6	3	5	6
I don't use this type of information	3	25	6	10	14	33
Not applicable	59	59	59	59	59	59

27) If the uncertainty information you needed were made available, would you experience any of the following benefits from using the additional or new observational information?

Types of impacts or benefits	N (total = 94)				
	Yes	No	Skipped	Not Applicable	Total
Reduced flood damage (property damage, injury or loss of life, lost business, recovery costs)	56	35	3	59	153
Reduced drought damage	49	41	4	59	153
Improved wastewater management or treatment	41	48	5	59	153
Improved stormwater management or treatment	57	31	5	60	153
Improved drinking water supply or treatment	48	41	4	60	153
Improved water quality	71	20	3	59	153
Improved navigability (shipping, recreation)	35	52	7	59	153
Increased efficiency of hydroelectric power generation	24	63	6	60	153
Improved timing of water withdrawals and releases or its management	59	29	6	59	153
Improved agricultural practices	39	49	6	59	153
Improved endangered/threaten species or fisheries management	53	37	4	59	153
Other type of impact?	6	44	44	59	153

28) If you selected "yes" for "other type of benefit," please provide a brief description. [Open-ended]

Ability to convey to the public the reliability of forecasts
Because of the "science" behind flood prediction and monitoring, the public does not believe there is accurate depiction of risk. Less uncertainty in determining frequency and magnitude (more gages, better modeling, etc.) would improve acceptance and belief in risk communication tools.
Better prediction of effects on biological assemblages. More precise indicators and criteria.

29) You indicated that the analysis information you need for informing decisions needs improvement or is unavailable. What are some of the barriers to using the following types of observation information?

Type of Information	N (total = 101)					
	Public alerts	Meteorological analyses	Hydrologic analyses	Climatological analyses	Flood inundation mapping	Information integration
Not available in a format that I can use	5	5	9	7	6	11
Don't know where to get the information	21	19	26	27	30	43
Accuracy is not sufficient	17	19	13	16	14	6
Consistency is not sufficient	14	10	10	12	9	9
Resolution is not sufficient	17	15	17	14	17	8
Not enough information available	24	30	39	25	28	31
Don't understand how information can be used	3	1	2	7	1	3
I don't use this type of information	21	18	3	13	15	6
Not applicable	52	52	52	52	52	52

30) If the analysis information you needed were made available, would you experience any of the following benefits from using the additional or new observational information?

Types of impacts or benefits	N (total = 101)				
	Yes	No	Skipped	Not Applicable	Total
Reduced flood damage (property damage, injury or loss of life, lost business, recovery costs)	62	33	6	52	153
Reduced drought damage	50	46	5	52	153
Improved wastewater management or treatment	48	45	8	52	153
Improved stormwater management or treatment	58	35	8	52	153
Improved drinking water supply or treatment	56	37	8	52	153
Improved water quality	76	19	6	52	153
Improved navigability (shipping, recreation)	36	57	8	52	153
Increased efficiency of hydroelectric power generation	25	66	9	53	153
Improved timing of water withdrawals and releases or its management	61	31	9	52	153
Improved agricultural practices	41	50	9	53	153
Improved endangered/threaten species or fisheries management	61	33	7	52	153
Other type of impact?	5	42	0	52	153

31) If you selected "yes" for "other type of benefit," please provide a brief description. [Open-ended]

Better able to gauge the measures for specific Ohio R. projects - better benchmarking.
Cost savings and efficiency in hydrologic and hydraulic modeling are needed. Risk communication depends on comprehensive and timely analysis of flooding. Better ways to predict the impact of flooding, runoff, and development's impact are need

32) Are there any other types of information beyond observations, forecasts, uncertainty, and analyses that you believe need improvement and are critical for informing decisions?

	Count	Percent
No, there are not.	128	84%
Yes, there are.	25	16%
Total	153	100%

33) Please describe the other types of information that you believe need improvement and are critical for informing decisions: ____

Bacterial conditions
Better and more consistent chemical, physical, and biological data to form a more detailed assessment of the Ohio R. at multiple scales. Current scale of assessment is at pool level which is too coarse for emerging management needs.
Better historical information on the timing and details of policy decisions. I am sure that the information is available --- it just is not publicly accessible.
Better information on the integration and use of such information as pertains to policy development/implementation.
Better regional predictions for climate change impacts on water resources and aquatic habitat.
Condition of the infrastructure - what dam gates are out of operation; what hydropower turbines are out of operation; what levees are not up to standards or where they are breaching; what dams are high risk.
Consistently collected network of fish and aquatic habitat information at a broad scale
Explanations of the relevance and significance of information is also needed to accompany the data and analyses. How to apply the information to behaviors and decisions is equally important.
Future changes (plus or minus) in flow discharge due to climate change induced precipitation.
GIS Map information on location of potential accidental spills and water utility characteristics
I would like to see the three agencies work together more efficiently when reporting all the observations. Examples, flow gauges, water quality, meteorological, stream gauges, etc.
Information about engagement of stakeholders to help develop path forward for rehabilitating, renewing, or removing hydrologic management infrastructure.
Information intended to educate the public and elected officials on the importance of maintaining water quality and habitat
Lots of different agencies performing inundation-mapping studies. We would like to make sure there is one consistent go-to place for the static inundation mapping results
Ohio River water depth and bottom material in the river channel; riparian zone width and maturity along Mainstream Ohio River and flood plain tributaries.
Quick information sharing across the board with emergency management, before public dissemination!
Risk assessment tools that can be used by individual property owners, communities and watersheds need to be developed to support hazard mitigation.

Statewide daily rainfall data at good resolution
Statistical and physical models and their assumptions. Forecasts might be great, but not if I don't know how they were made.
Water quality, pollution control standards adequate to protect aquatic and human health; recreational use; fish consumption
We need information on what kinds of data and tools are needed for water resource issues because we supply those scientific data, studies, and tools
What (quality) are the upstream river water users discharging and what is the frequency and volume of such?
Good and timely info
Not specific to water quality, but detailed information on watershed water budgets, including all inputs and outflows (specifically including embedded water) would be useful in management recommendations