

Stakeholder Engagement to Demonstrate Integrated Water Resources Science and Service (IWRSS)

for River Basin Commissions in the Mid-Atlantic



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Cover: Top photo is of Frenchtown, New Jersey in the Delaware River basin, photo courtesy of Robert J. Owens. Bottom photo is Great Falls in the Potomac River basin, photo courtesy of Jim Palmer.

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 resource 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. The purpose of this project was to engage stakeholders in the Potomac, Delaware, Hudson, and Susquehanna River basins to obtain input on priority needs. Stakeholders in each basin participated in a facilitated forum aimed at:

- Validating existing gaps and identifying new needs in water resources services;
- Quantifying the socioeconomic benefit of addressing these gaps; and
- Identifying new IWRSS capabilities that could address stakeholder needs.

To supplement input obtained at the forums, post-meeting surveys were conducted of a broader group of stakeholders representing 11 sectors. These efforts provided detailed qualitative information about water resources management needs, as well as insights into the socioeconomic benefits of providing these services.

Flooding was the most common and consistently identified priority issue among the basins. Water quality was also consistently cited as a high-priority issue, but it generally ranked lower than flooding, followed by water quantity issues such as water allocation, availability and use (see Table ES-1).

Table ES-1. Highest-Priority Issues in the River Basins

Priority Issue	Potomac	Delaware	Susquehanna	Hudson
Flooding	*	✓*	✓*	✓*
Water quality	✓*	✓	✓*	✓*
Water availability and use (Water supply)	✓*	✓*	✓*	
Drought	*			
Climate change		*		✓

* High-priority issue identified during the stakeholder forums.

✓ High-priority issue identified during the post-forum survey.

Note: Point- and nonpoint-source pollution were included under “water quality.”

Note: Drought was included in some discussions about water availability and use, and climate change issues were mentioned in some discussions about flooding, water quality, and water availability and use.

Water resources information needs identified in the surveys were similar across all four mid-Atlantic river basins. The most commonly identified needs were:

- Improving information about surface hydrology, such as streamflow forecasts, uncertainty information and analyses;
- Improving information about water quality; and
- Reducing barriers to use of information, particularly flood inundation maps and analyses about the impacts of flooding.

When asked to describe the types of information that would fill these needs, respondents suggested:

- Increasing the number surface water monitoring stations (e.g., stream gages) to generate more observations;
- Increasing the spatial resolution of forecasts of stream flow and water quality;
- Providing guidance on how to present uncertainty for all types of information to non-technical audiences;
- Offering access to detailed analyses of topics such as flood inundation and water quality; and
- Creating a single portal for accessing information.

These top needs are primarily associated with the priority areas of flooding, water quality and water availability; the anticipated socioeconomic benefits of addressing them are reduced flood damage, reduced drought damage, and improved water quality benefits (e.g., fisheries, recreation). During the one-day forums, stakeholders first identified water resources priority issues and priority needs for addressing those issues, then proposed demonstration projects that could show how critical gaps could be filled to inform water resources decisions. Participants from the forums proposed 14 demonstration projects that could help meet the critical needs and gaps identified for their priority water resources issues. These proposed projects help to identify commonly needed functionalities across the region that could be met through existing or new IWRSS capabilities.

IWRSS agencies grouped the 14 proposed projects into five major types of capabilities: large-scale watershed model, flood inundation mapping, intensive sub-watershed models, data warehouse, and water quality monitoring. Of these five themes, the large-scale watershed model combined with mapping capabilities (LWMM) was a primary component of the largest number of proposed demonstration projects. The IWRSS agencies also ranked LWMM as the highest priority according to their project ranking criteria (e.g., transferability to other basins; feasibility; strong need identified by stakeholders).

Following the identification of LWMM as the top priority IWRSS need, representatives from the Delaware River Basin Commission (DRBC), Susquehanna River Basin Commission (SRBC) and the Interstate Commission on the Potomac River Basin (ICPRB) were convened. The River Basin Commissions (RBCs): 1) affirmed the process used by IWRSS partners to identify LWMM as the priority need; 2) identified priority subcomponents of a LWMM capability; and 3) described how a LWMM capability could be applied in each basin. Representatives from the RBCs then developed LWMM demonstration project descriptions, drawing on the input gathered at the stakeholder forums as well as their internal knowledge of critical needs. Table ES-2 is a summary of the three demonstration projects suggested by the RBCs for LWMM capability.

Similarities among the demonstration projects included:

- Better modeling of low flow conditions for water supply allocation purposes;
- Better real-time data that could be automatically updated and linked with operational triggers;
- Developing modeling components that could be incorporated into existing basin models;
- Developing water management decision support tools including visualization tools;
- Incorporating climate change scenarios into models; and
- Involving RBCs to help implement and test IWRSS capabilities, and assist with stakeholder engagement.

Table ES-2. Summary of River Basin Demonstration Project Ideas to Apply LWMM Capability

River Basin	Demonstration Project Idea
Susquehanna River Basin Commission	Develop a basin-wide Low Flow Decision Support Tool to: (1) monitor existing hydrologic conditions; (2) track quantitative trigger thresholds; (3) integrate hydro-meteorological forecast information; and (4) facilitate scenario analysis to inform low flow management decision-making.
Delaware River Basin Commission	Develop a coupled freshwater and coastal model for the freshwater/estuarine transition zone between Trenton, New Jersey, and Wilmington, Delaware, that can be integrated into an existing suite of basin models.
Interstate Commission on the Potomac River Basin	Improve storage reservoir release decisions by enhancing existing basin models with real-time upstream withdrawals and discharge data, and better predictions of in-stream flow losses (e.g., evaporation and groundwater interactions).

This stakeholder engagement process resulted in the identification of high value, readily transferable IWRSS capabilities that can inform future decision making by filling key gaps that currently exist on priority water resources issues. Additionally, some information was gathered on the economic value associated with filling these critical needs. Recommendations included:

- Building a business case for IWRSS’ development of an LWMM;
- Implementing the stakeholder engagement approach in other river basins to learn about their priority needs to build on the success of this project;
- Conducting more robust and project-specific economic analyses to show the value of the chosen LWMM demonstration project; and
- Developing a work plan to move forward with a LWMM demonstration project into the implementation stage.

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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 applies a multi-disciplinary approach to address complex water resources problems collaboratively. 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; and
- 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 Potomac, Delaware, Hudson, and Susquehanna River basins to understand the need for IWRSS on a regional scale by:

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

IWRSS partners validated gaps and identified new needs for water resources services by (1) holding stakeholder forums (see Appendix A for agenda) in the Potomac, Delaware, Susquehanna, and Hudson River basins (see Appendix B-E for forum summaries) and (2) conducting a post-meeting survey (see Appendix F). These efforts provided detailed qualitative information about the gaps and needs as well as information for evaluating the socioeconomic benefit of addressing the gaps.



Stakeholder Forum Held in the Delaware River Basin on December 13, 2012, photo courtesy of DRBC.

The resulting needs assessment and gap analyses were used to identify key functionalities that IWRSS could provide for improved water resources management and decision-making. Such functionalities could be demonstrated, along with the social and economic benefits of providing those functionalities, through the design of a demonstration project or projects in the region benefiting all four river basins.

Following a functional analysis of 14 demonstration projects suggested at the forums, and after consultations with the RBCs, consensus was reached between IWRSS partners and the RBCs that a large-scale watershed model with mapping capability (LWMM) would meet identified needs and provide socio-economic benefits. A more detailed description of the priority functions, objectives, and application of a LWMM demonstration project can be found in Appendix G.

RBCs that Participated in the IWRSS Stakeholder Engagement:

- Interstate Commission on the Potomac River Basin (ICPRB),
- Delaware River Basin Commission (DRBC)
- Susquehanna River Basin Commission (SRBC)
- Hudson River Foundation (HRF)*

*While the HRF is not structured as an RBC, it served as convener for the Hudson River Basin

This effort resulted in the development of a “roadmap” to guide the subsequent scoping, funding, and implementation of IWRSS capabilities and one or more demonstration projects to showcase priority capabilities. This “roadmap” consists of: (1) the identification of a LWMM capability for IWRSS to develop; (2) the identification of key functional subcomponents of that capability that meet priority needs of each river basin; (3) demonstration project ideas proposed by the RBCs that could be used to test new IWRSS capability in each basin; (4) an outline of partnership roles between IWRSS and the participating RBCs; and (5) information on the economic and environmental benefits of the project(s) to help build the business case to support implementation. It is hoped that consensus around the demonstration project roadmap will lead to support for implementation, enabling IWRSS partners to address unmet stakeholder needs.

2.0 METHODOLOGY

This section describes the methodology used to engage with stakeholders, gather and analyze information to support the socioeconomic analysis, and identify potential demonstration projects.

To accomplish the goals of this project, the IWRSS team collected and analyzed two basic types of data: (1) information and services needed by stakeholders in the four river basins and (2) socioeconomic benefits of addressing priority service gaps and information needs. To gather these data, the IWRSS team:

- Reviewed existing basin-specific plans, reports, and studies;
- Held four stakeholder engagement meetings; and
- Surveyed stakeholders to explore specific issues in more depth.

2.1 Working with the River Basin Commissions (RBCs)

The IWRSS team held individual kickoff meetings with representatives from each of the river basins to introduce IWRSS, explain the purpose of this project, and get input on forum invitees, stakeholders to be surveyed, and forum logistics. IWRSS also consulted with the RBCs early in the process to inform meeting agendas and survey instruments, and to obtain information that might be useful for the economic analysis.

2.2 Stakeholder Identification

The IWRSS team identified stakeholders using RBC stakeholder lists, basin-specific studies, and suggestions of others that could represent service sectors (see text box for sectors) in their watersheds. As necessary, additional stakeholders — especially those from under-represented sectors — were identified through Web-based searches and input from regional IWRSS partner agencies and RBC staff.

2.3 Stakeholder Meeting and Information Collection

The IWRSS team held stakeholder forums in each of the four basins. Between 20 and 40 stakeholders participated in each forum. Each forum lasted a full day and included large group discussion as well as breakout groups. The IWRSS project team used the same basic agenda (included in Appendix A), but customized the breakout sessions as described below.

In advance of each forum, the IWRSS team worked with RBC staff to identify a list of potential priority water resources issues and polled participants during registration to determine the highest-priority issues for the basin. During the forum, participants divided into groups, depending on the water resources issue of greatest interest, to identify the key decisions, questions, and gaps that IWRSS could address.

IWRSS Stakeholders Include the Following Sectors:

- River commerce
- Emergency management
- Reservoir management
- Agriculture
- Power production (e.g., hydropower, other energy extraction)
- Watershed management
- Fish and wildlife
- Municipal and industrial water supply
- Recreation
- Water quality
- NGOs/environmental groups

For the first breakout session, each group identified up to three key decisions or outstanding questions (event-driven high-impact or high-value routine questions/decisions) that “keep you up at night.” The group then identified key information gaps that were needed to address each question/decision.

For the second breakout session, each group proposed a demonstration project that would address the information gaps for its priority water resources issue. For each proposed demonstration project, the groups developed a short narrative describing the project, identified key benefits, and listed partner organizations and agencies that should be involved.

The IWRSS team documented results from each forum in the form of a summary report, which contained detailed notes from the proceedings and worksheets filled out by the breakout groups. RBCs reviewed the summary reports and posted the report on their websites. These basin-specific reports can be found in Appendix B-E.

2.4 Survey Design and Implementation

After each forum, the IWRSS team conducted a web-based survey of stakeholders, using names from a list of 100 to 300 people per basin representing multiple sectors with interests in water resources management. The survey supplemented the forums by collecting more detailed information on water resources priorities and needs.

The survey contained five topic areas that addressed respondent demographics, priority issues, information access and use, information gaps, and economic benefits of filling information gaps. Surveys were tailored to focus on each basin’s priority issues; the survey questions were otherwise identical. The survey collected information through a mix of scaled and open-ended response questions.

Upon receiving Office of Management and Budget approval through the Paperwork Reduction Act Information Collection Request approval process, the IWRSS team conducted the Web-based surveys. Stakeholders for each river basin received an email invitation to complete the survey and each RBC posted a link to the survey on its website. The surveys were open from April 8 to April 25, 2013, for the Potomac, Delaware, and Susquehanna River basin stakeholders and from June 28 to July 18, 2013, for the Hudson River basin stakeholders.¹ Seven hundred eighty six potential respondents were invited to participate in the survey and 175 stakeholders fully completed the survey. See Appendix F for the survey results, including river basin specific results.

¹ The Delaware and Hudson surveys were re-opened after their official close dates to allow additional respondents to provide input. One late Delaware response was received on May 17, 2013, and one late Hudson response was received on July 22, 2013.

3.0 STAKEHOLDER NEEDS

This section describes the high-level findings and recommendations of the stakeholder meetings and surveys conducted across all four river basins. Detailed information for each river basin forum is contained in the forum reports (Appendix B-E) and the survey report (Appendix F), which contains raw survey data and a more detailed analysis of the results.

3.1 Top Priorities Across River Basins

Forum participants identified the following high-priority issues in a pre-meeting poll and confirmed them during the forum. (The high-priority issues listed below are a generalized version of the detailed priority issues developed for each basin.)

- **Potomac:** flooding, water quality, water availability and use, and drought
- **Delaware:** flooding, water supply, and climate change
- **Susquehanna:** flooding, water quality, and sustainable water use and development (water supply)
- **Hudson:** flooding and water quality (climate change was integrated into both of these topics)

In the survey, respondents rated the importance of each priority issue in their river basin and then the top three most important issues. The survey results showed the following highest priority issues, which are generally consistent with those from the forums (higher-priority issues are listed first).

- **Potomac:** water availability and use, water quality
- **Delaware:** flooding, water supply, water quality
- **Susquehanna:** flooding, water quality, sustainable water use and development (water supply)
- **Hudson:** flooding, water quality, climate change and sea level rise

Table 1 summarizes the highest-priority issues as identified during the forums and surveys.

Table 1. Highest-Priority Issues in the River Basins

Priority Issue	Potomac	Delaware	Susquehanna	Hudson
Flooding	*	✓*	✓*	✓*
Water quality	✓*	✓	✓*	✓*
Water availability and use (Water supply)	✓*	✓*	✓*	
Drought	*			
Climate change		*		✓

* High-priority issue identified during the stakeholder forums.

✓ High-priority issue identified during the post-forum survey.

Note: Point- and nonpoint-source pollution is included under “water quality.”

Note: Drought issues were included in some of the discussions about water availability and use

Similarities

The top priorities across river basins are flooding, water quality, and water availability and use. Flooding is the most common and consistently identified priority among the basins. During the forums, participants in all of the basins identified flooding as a high-priority issue. In the survey, respondents in three of the basins (Delaware, Susquehanna, and Hudson) identified flooding as the top priority.

Participants also identified water quality as a high-priority issue across all of the basins. During the forums, three of the basins (Potomac, Susquehanna, and Hudson) identified water quality as a high priority. In the survey, respondents in all of the basins identified water quality as a high priority, but it was generally ranked less important than flooding. For example, in the Susquehanna, respondents rated “flooding” (70 percent) and “water quality” (52 percent) as “extremely important” when asked to rate importance; when asked to rank the top three issues, 45 percent chose “flooding” and 18 percent chose “water quality” as the number one priority.

Differences

There are several notable differences in the high-priority issues identified across the basins. Water availability was identified as the top-priority issue in the Potomac and a high-priority issue in the Susquehanna, but was not a high-priority issue in either the Delaware or the Hudson. In addition, water supply was only identified as a high-priority issue in the Delaware, while climate change was identified as a high-priority issue in the Hudson survey and both the Delaware and Hudson forums.

The survey results indicate that some of the priority differences between basins may be related to relative number of respondents in each sector. For example:

- For the Hudson, “water quality” was rated as “extremely important” by 64 percent of water quality sector respondents and 75 percent of fisheries and wildlife sector respondents, but only 33 percent of watershed management sector respondents.
- For the Potomac, the high ranking of “water availability and use” and “water quality” may reflect the high percentage of respondents in the watershed management sector (26 percent of total respondents) and the water quality sector (27 percent of total respondents).
- For the Susquehanna, the high ranking of “flooding” (70 percent of total respondents) reflects the high number (44 percent) of respondents in emergency management, a sector expected to focus more on flooding.
- The Delaware survey results showed a broad spread of priority issues among stakeholders across sectors compared to the other basins.



Flooding Along the Susquehanna River, photo courtesy of SRBC.

3.2 Top Needs/Gaps by Priority Area

The water resources information needs and gaps are similar across all four river basins. The most commonly identified needs are improved information and availability of information. These top needs are primarily associated with the priority areas of flooding and water availability.

- **Improved information:** A significant number of respondents (32 to 68 percent, depending on the basin) have access to the information they need for their highest-priority issue, but the information is not adequate or needs improvement. When given four response options: (1) have information, adequate; (2) have information, not adequate; (3) need information, no/limited access; or (4) do not need this information, and considering all four categories of information--observation, forecast, uncertainty and analyses—the highest percentage (49 to 59 percent) of respondents indicated that they have information, but it is not adequate. The most significant gap in information access occurs in the Potomac, Delaware, and Hudson River basins, where 21 to 29 percent of respondents have limited or no access to uncertainty information (e.g., level of confidence in a forecasted flood stage for a tributary stream) and analyses (e.g., high-resolution flood inundation maps).
- **Availability of information:** The most commonly cited barrier to information use was the lack of availability of needed information. In the Potomac River Basin, as in the other basins, 55 to 71 percent of respondents cite lack of availability of surface hydrology and water quality information as a key barrier to observations, forecasts, and uncertainty; 44 to 56 percent cite the same for hydrologic and climatological analyses.

Respondents across all four basins rated new or additional surface hydrology observations, forecasts, and uncertainty information and flood inundation mapping as critical to their work. Hydrologic analyses (Potomac, Delaware, Hudson), information integration (Delaware, Susquehanna), and flood inundation mapping (Susquehanna) were most likely to be rated as “very important” or “critical” for new or additional analyses. When asked to describe the types of information that would fill these information gaps, respondents suggested:

- Increasing the number surface water monitoring stations (e.g., stream gages) to generate more observations.
- Increasing the spatial resolution of forecasts of stream flow and water quality.
- Providing guidance on how to present uncertainty for all types of information to non-technical audiences.
- Offering access to detailed analyses of topics such as flood inundation and water quality.
- Creating a single portal for accessing information.

Full results and additional analysis of the survey responses are contained in Appendix F.

4.0 SOCIOECONOMIC BENEFITS

This section presents the benefits identified for certain types of projects based on information gathered during the stakeholder forums and follow-up surveys. The surveys asked respondents to provide both a description of the benefits that could be derived from new sources of information and for any data on the quantitative value of those benefits. The purpose of asking for this information was to generate estimates of the value of new information being provided by IWRSS. However, the information provided by respondents was broad, general, and sparse. Specifically, respondents to the survey appeared to find it difficult to respond to questions about the value of the benefits. Thus, the data provided did not allow us to generalize benefits for all respondents. Nevertheless, it was possible to provide a summary of the likely benefits (in descriptive terms) and, in some specific cases, provide a quantitative estimate of the benefits.

4.1 Benefits Identified in River Basin Stakeholder Forums

Benefits identified during the basin forums included the potential benefits directly associated with each demonstration project developed by breakout groups. Thus, these benefits were primarily associated with specific priority water resource topics. Below is a list of representative or commonly identified benefits of projects to control flooding, improve water quality, and improve water availability and use that were identified during the stakeholder meetings.

Flooding (Delaware, Potomac, Hudson)

- Better warning systems for flood emergencies to increase evacuation times and emergency response preparations.
- Improve ability to sustain growth and urbanization of coastal and riverine communities.
- Mitigate vulnerabilities by informing infrastructure planning and design specifications (e.g., Department of Transportation (DOT), American Association of State Highway and Transportation Officials (ASHTO) design criteria for culvert sizing).
- More efficient infrastructure designs with better design standards (saving money and hours).
- Minimize combined sewer overflows (CSOs) in recreational areas (avoiding fines/penalties and preventing loss of recreational use) and provide better guidance for public safety (e.g., creation of a warning system for CSO occurrences).
- Enhance ability to conduct scenario planning (land use changes, sea level rise, other climate change impacts) to plan for future flooding events.

Water Quality (Potomac, Susquehanna, Hudson)

- Demonstrate return on investment for each best management practice (BMP) required for total maximum daily loads (TMDLs) in terms of \$/lb of reduced nitrogen, phosphorus, and sediment.
- Demonstrate value of maintenance investments and optimize cost-effective maintenance.
- Restored fisheries could provide significant economic benefits (fishermen, guides, local tourism, fishing tournaments).
- Improve public health, which would avoid higher health care costs.
- Increase revenue to shipping sector.

Water Availability and Use/Water Supply (Delaware, Susquehanna, Potomac)

- Reduce costs for government and industry to perform data collection and prediction in support of water resources management decisions.
- Improve industry (e.g., hydroelectric energy) and government ability to manage their “water inventory” and more appropriately site water-intensive industries to avoid conflicts and water shortages.
- Address impacts between and across jurisdictions (e.g., changes in flow regime and impacts to other users of shared resources).
- Better measure water yield under extreme conditions (e.g., drought, flood); important for agricultural planning and revenues.
- Save money through management decisions (e.g., with accurate and timely forecasts of drought onset, cities save money by preparing for drought earlier and not pumping during drought conditions when water quantity may be restricted and water quality is poorer).

4.2 Benefits Identified in Survey Results

In the surveys, the most commonly cited benefit of improved water resources management in the Potomac, Delaware, and Hudson River basins was improved water quality and the most commonly cited benefit in the Susquehanna River basin was reduced flood damage. Other examples of potential benefits in each basin included:

- **Potomac:** new or additional forecasts and uncertainty information would improve timing of water withdrawals and benefit suppliers and customers.
- **Delaware:** Improved stormwater management would be an important benefit for new or additional observations and analyses. Reduced drought damage would be a key benefit for better forecasts and clearer understanding of uncertainty.
- **Susquehanna:** Respondents cited reduced drought damage as a potential benefit of new or additional uncertainty information and analyses.
- **Hudson:** Improved navigability would be a potential benefit of new or additional forecasts to predict low flows.

As noted above, survey respondents provided a wide range of quantitative and qualitative socioeconomic benefits that could result from filling the above needs and information gaps through potential IWRSS projects. Representative examples appear below and a full list is presented in the survey results.

- **Reduced flood damage (Potomac):** Protection of \$2 billion of personal property from flood damage per year. Reduced losses from unnecessary restrictions and unplanned shortages of \$3 million to \$5 million per event.
- **Improved water quality (Delaware):** New/additional observation information would help protect \$1 billion worth of ecosystem services provided by natural capital, and inform fisheries managers on correlations between fish population trends and water quality parameters that would result in \$250,000 savings per event.
- **Reduced drought damage (Susquehanna):** New/additional analyses would lower the cost of water withdrawals from the Conowingo pool (expensive due to pumping costs, water withdrawal rates),

allowing for more accurate timing of withdrawals — the current cost is \$90,000 per month to operate a single pump.

- **Improved water quality (Hudson):** Reduced impacts on fisheries in terms of population abundance and species composition of various life stages, as well as improved recreational uses; these would have an impact on local economies in the millions of dollars per year.

5.0 DEMONSTRATION PROJECT IDENTIFICATION

This section describes the process used to identify potential projects to demonstrate IWRSS capabilities.

5.1 Summary of Stakeholder-Proposed Demonstration Projects

During the basin forums, each issue-focused breakout group developed at least one project that would help meet the critical needs/gaps identified for their chosen issue. These proposed projects served as the starting point for choosing a single demonstration project that could benefit all four basins. The proposed projects are briefly described below; detailed information on each one appears in the basin forum summary reports (Appendix B-E).

- Develop an integrated storm surge and riverine flood model that includes graphics and 3D visualization tools. This new model would feature an integrated education and outreach component to better communicate local impacts of future storms, including social and environmental impacts. The project would show “on the ground” impacts and would support emergency action planning and scenario planning capabilities.
- Create (1) a probabilistic drought and flood model based on future climate change scenarios in conjunction with a salinity model and (2) an operational storm surge and riverine model to inform “worst-case” scenario planning. Combined, these efforts would improve basin coordination, reservoir management, salinity prediction, ecological sustainability, water availability, environmental protection, and water management, which would ultimately benefit economic growth and energy security.
- Develop a high-resolution hydrologic model to better understand future water-resources impacts at small scales. This project would help address cumulative impacts between and across jurisdictions, improve prediction of extreme flows, and inform decisions involving allocations, conservation, and long-term sustainable use.
- Build a low-flow model that demonstrates proven techniques for predicting future low flows in the Potomac River. This model will help optimize and inform decisions about timing and quantity of water release from reservoirs.
- Develop an improved decision-making tool for city water suppliers. Perform a case study of the Baltimore water supply system to demonstrate how forecasts that predict the probability of restrictions can guide decisions on how much to water to pump (inter-basin pumping) before and after a drought to optimize water quality and minimize costs.
- Develop trigger planning for flooding in urban and rural communities using probabilistic forecasts, temporal/spatial visuals, and thresholds for taking action. The project would include improvements in inundation mapping, better dissemination and communication of forecasts, and metrics to measure success.



Potomac River in Coltons Point, Maryland, photo courtesy of ICPRB.

- Develop a downscaled global climate model in conjunction with a coupled riverine-coastal model to better predict flood frequencies and inform infrastructure planning. The models would provide a wide range of data, including flood frequency, sea-level rise, and storm surge, and serve as a single data portal for this information. In addition, the models would be combined with an improved stream gage network for better calibration and application at the local level.
- Integrate data from federal, state, and local sources into existing models. Combine these data with climate change scenarios in order to better model the timing, volume, and location of water-related impacts in future scenarios. This project would help to assess environmental, social, and economic impacts; use graphics to communicate risk; and inform long-term facility management and planning decisions. Philadelphia was suggested for the demonstration.
- Create an easily accessible “warehouse” of water use data that can compile federal and state water use information at user-specified levels. This project would be a building block for basin-wide water resources management models and tools and provide a wide range of historical information to support water resources planning decisions.
- Create a static flood-inundation map library for the Potomac River in the Washington, DC, metro area provided to the public on a single-source website. Key benefits of this project include reductions in flood-related losses, improved public awareness, and better emergency management response coordination.
- Create a nested monitoring and modeling system to better quantify and understand sediment processes. Potential benefits include more informed decision-making on BMPs and TMDLs, as well as increased public confidence in modeling and monitoring data. Proposed locations include the Anacostia watershed and Four Mile Run.
- Develop a system for improved real-time, in-stream monitoring and measurement of basic water quality parameters to protect and manage critical fisheries habitat. This project would include expanded monitoring of water temperature (with a focus on critical habitats) and predictive aspects (impacts on fish, algae growth, biological indicators) such as air, water, and ground temperature.
- Study the impact of precipitation events on sediment loading and accretion to better predict dredging requirements and prioritize sediment reduction efforts. Perform a study in the New York harbor or Albany harbor to better understand (1) how sediment loads differ based on the location of precipitation events and (2) beneficial sediment accretion within wetlands. This study would also integrate existing and new remote sensing and USGS monitoring data to develop more robust sediment budget information.
- Improve short-term (one- to seven-day) precipitation and streamflow forecasts to support improved operations of multi-purpose reservoirs and optimize Hudson River navigation. Perform a study in the



Stakeholder Forum Held in the Hudson River Basin on June 27, 2013, photo courtesy of HRF.

New York harbor or Albany harbor to better understand the impact of streamflow forecasts on the economics of navigation decisions.

5.2 Identification of Project Themes and Elements

From the 14 projects (listed in Section 5.1), the IWRSS partners identified five major themes (Table 2):

- Large-scale watershed models
- Flood inundation maps
- Intensive sub-watershed modeling
- Water quality monitoring
- Creation of a data warehouse

Categorizing the projects by major theme allowed IWRSS partners to create a common structure for comparison, while ensuring that each element was captured. The more detailed elements of these projects were also captured and compared across projects in a matrix. These elements included project capabilities and data sources, as well as scenarios and specific locations in which these projects might be applicable.

Table 2. Proposed Projects Grouped by Major Theme

Theme	RBC Initial Proposed Projects
Large-Scale Watershed Models	DRBC: probabilistic drought/flood with salinity and climate change
	DRBC: storm surge/riverine flood models with graphic tools
	DRBC: existing data integration with climate change models
	ICPRB: low flow prediction model for water suppliers (2)
	HRF: downscaled climate/riverine-coastal model for flooding
	HRF: sediment loading/precipitation event predictive tool
	HRF: short-term streamflow forecasts
Flood Inundation Maps	ICPRB: flood inundation map library on website
	SRBC: inundation mapping for flood planning
Intensive Sub-watershed Models	ICPRB: small scale high-resolution hydrologic model
	ICPRB: nested monitoring and sediment modeling
Data Warehouse	SRBC: water use data warehouse
Water Quality Monitoring	SRBC: water quality monitoring for fish habitat

IWRSS partners “deconstructed” each of the projects by theme and identified functional subcomponents to better define IWRSS needs (Table 3). Eight of the 14 projects involved modeling at the watershed scale. Five demonstration projects called for the creation of large watershed models for coastal hydrodynamic processes, low-flow decision support, water supply forecasting, and sedimentation studies. Coupled coastal and freshwater models made up a major subcategory of large

watershed model projects. Four projects focused on coupled freshwater coastal models as their primary component. Some of the new information these coupled models might provide included assessment of impacts to infrastructure, effects of storm surge and sea level rise, scenario planning under land use and population change, and salinity modeling under extreme conditions, from floods to droughts. Each group outlined many specific elements, and some elements were common among multiple projects. A few groups proposed coupling these models with a downscaled climate model to account for local climate impacts, and several groups envisioned incorporating graphics and visualization tools.

While some of these coupled riverine-coastal models specified flood inundation modeling and mapping as important inputs for a visualization tool, some demonstration projects focused on flood inundation maps as their main component, though they differed on whether the maps should be provided as a static map library or should incorporate probabilistic forecasts to provide risk-based action planning.

Table 3. Summary of Subcomponents for Each Major Theme

Themes	Primary Subcomponents (# of projects incorporating the component)
Large-Scale Watershed Models (8 projects)	Coupled freshwater coastal model (4)
	Scenarios including sea level rise (4), climate change (4), storm surge (3)
	Reservoir and flow management (3)
	Low flow decision support (3)
	Graphics and visualization tools (3)
	Water supply forecasting (2)
	Probabilistic scenarios (2)
	Modeling drought and flood intensity, duration, and frequency (2)
Flood Inundation Maps (2 projects)	Graphics and visualization tools (2)
	Probabilistic maps (1)
	Static map libraries for Washington, DC (1)
Intensive Sub-watershed Models (2 projects)	High resolution for model (2)
	Un-gaged watersheds (1)
	Provide sedimentation decision support (1)
Data Warehouse (1 project)	Connecting state databases to federal databases, supporting historical rainfall/runoff data, NWS forecasts, and climate forecasts
Water Quality Monitoring (1 project)	Monitoring in critical habitats only, basic water quality parameters, and water, air, and ground temperature

Two projects focused on intensive modeling of a sub-watershed. Although both projects emphasized a high resolution, one project concentrated on understanding long-term water availability by modeling cross-jurisdictional data and inter-basin water transfers in ungaged watersheds, while another focused on a monitoring and modeling project to understand sediment dynamics for decision support.

Another project featured a water quality monitoring effort with a focus on examining basic water quality parameters in critical habitat areas. Yet another group requested a system to connect state and federal databases on water use information with the desire for a continuously updated data warehouse to provide historical and forecast data, along with water resources management models and tools.

5.3 Prioritization of Projects

This initial evaluation of proposed projects provided important information for identifying common needs across the region that IWRSS could address. The next step was to prioritize which of the major project themes and functional subcomponents should be the focus of subsequent IWRSS capability development and demonstration efforts. The IWRSS partners ranked each of the five project themes as high, medium, or low for eight different criteria listed in Table 4.

Table 4. Criteria Used to Rank Subcomponents

Criteria	Description	Scoring
Transferable to other basins	Can the project be applied in multiple basins, or can the protocols/tools be replicated in other areas?	High=transferable to many other basins Medium=transferability in a limited number of basins Low=basin-specific
Meets expressed need	Will the project help inform pressing decisions that need to be made? Are the management issues and gaps to be filled clearly identified by stakeholders at forums or via survey?	High=almost all RBCs mentioned this and it was prominent in the survey Medium=mentioned by some Low=requested by few
Demonstrates IWRSS capability	Project would epitomize why IWRSS was established	High=showcases all IWRSS partners and is innovative combination or creation of IWRSS data/tools Medium=involves limited combination of IWRSS partner data/tools Low=could be accomplished outside of the IWRSS framework
Within IWRSS capability	Project is feasible given availability/accessibility of information and other requirements to inform the project	High=doable with existing data and technologies Medium=would need to generate input or tools not currently available, but could be obtained Low=not possible with information or tools we have today
Has an affordable project budget	Relative estimate of project cost compared to others	High=relatively inexpensive Medium=not too costly Low=expected to be relatively expensive
Local partner/cooperative available	Likelihood of local partner support and commitment and/or existing initiative with which to integrate	High=lots of partners and efforts for collaboration potential Medium=some local partners Low=few partners, or not identified
Measureable economic or environmental benefit	Able to establish performance metrics to evaluate benefit of project based on information from surveys and stakeholder forums	High=yes, many measurable benefits possible Medium=some measurable benefits possible Low=few or not well-articulated measurable benefits
Results available in a desirable timeframe	Estimate of time needed from project design to results and evaluation	High=1-2 year timeframe Medium=3-5 year timeframe Low=more than 5 years

Stakeholder Engagement to Demonstrate IWRSS for RBCs

These rankings were assigned based on an evaluation of information provided by stakeholders within the Delaware, Potomac, Susquehanna, and Hudson River basins during the one-day forums and in response to the broader survey. Ranking results and a more detailed discussion developed of how each theme was specifically evaluated is described below and summarized in Table 5. The possible roles of each IWRSS agency and other federal agencies were also identified and are included as part of the ranking table.

Table 5. Ranking of Major Themes

Project Type	Possible Agency Role	Ranking (High, Medium, or Low) as Described in Table 4							
		Transferable	Meets expressed need	Demo IWRSS capability	Within IWRSS capability	Affordable project budget	Local Partner	Measurable benefit	Results avail. in a desired time frame?
Large-scale watershed model	<p>NWS: link to National Ocean Service (NOS), forecasting</p> <p>USGS: hydrologic and groundwater modeling for low flow conditions, observations (gage network)</p> <p>USACE: hydrologic/hydraulic modeling, coastal models, reservoir regulation and modeling</p> <p>Others: EPA: salinity model; NOS: coastal zone observation, estuary/coastal models</p>	H	H	H	M	M-L	H	H-M	M
Flood Inundation Mapping	<p>NWS: local QA/QC, support siting, manage operational provision, map development, host maps(?)</p> <p>USGS: monitoring, science, map development</p> <p>USACE: models, map development (especially for dynamic mapping)</p>	H	H	H	M-L	M-L	M-H	M-H	M-L
Intensive sub-watershed modeling	<p>NWS: modeling</p> <p>USGS: modeling, observations</p> <p>USACE: modeling</p>	M	M	H	M	M-L	M	H-M	L
Data warehouse compiling state water use info.	Not yet identified	H	L	H	M	H-M	M-L	M-L	M
Water quality monitoring	<p>NWS: predictive aspects based on observed phenomena</p> <p>USGS: monitoring</p> <p>USACE: sediment studies</p>	H	M-L	M-L	M	M	H-M	M	M-L

Projects with a large-scale watershed model as their primary component were given a “high” ranking for transferability, as techniques used to create these models would be applicable for many basins. This component was given a “high” ranking for meeting expressed needs, as stakeholders in most basins identified demonstration projects incorporating this component. While the project component would involve interagency collaboration and was given “high” ranking for demonstrating IWRSS capabilities, it was assigned a ranking of “medium” for being feasible within IWRSS capabilities, as many new tools or inputs might be needed to be developed or obtained to complete a successful project with this component. A “medium to low” ranking was assigned for an affordable project budget and more detailed scoping would be needed to refine this ranking. Since stakeholders identified many potential partners, local partner support was deemed to have a “high” ranking. The large-scale watershed model was deemed to have “high to medium” measureable benefits, based on those outlined at the stakeholder forums and in the survey. Although highly dependent upon the specific project elements, large-scale watershed model projects would have results available in a “medium” timeframe of 3-5 years.



Potomac River, photo courtesy of ICPRB.

Flood inundation mapping projects were given a “high” ranking for transferability, expressed need, and demonstration of IWRSS capabilities since these techniques involve all IWRSS partners, can be replicated in many basins and were desired by a large number of stakeholders. Flood inundation mapping was given a “medium to low” ranking for being feasible within IWRSS capability, especially due to the fact that dynamic maps involving probabilistic information or in coastal areas would require developing new data or techniques. This dynamic aspect also would affect the budget affordability, which was ranked “medium to low.” Many potential partners are available, so the local partner support was given a ranking of “medium to high.” Stakeholders outlined many benefits of flood inundation mapping with the opportunity to gather more information on potential benefits, so a ranking of “medium to high” was assigned for this criterion. Results would not be expected before 3 years from project start, and would be longer for the more complex mapping scenarios, so the timeframe criterion was ranked “medium to low.”

Projects involving an intensive sub-watershed modeling component were rated as “medium” for transferability. Although intensive sub-watershed modeling could be performed in multiple basins, the information needed to complete this modeling might not be available in specific basins. It was only mentioned by a few groups, so it was rated as “medium” for meeting expressed need. Intensive sub-watershed modeling was given a “high” ranking for demonstrating IWRSS capabilities as it is an expressed IWRSS goal to do high-resolution forecasting. A ranking of “medium” was assigned for being within IWRSS capabilities as new data and tools would need to be developed. Accordingly, an affordable project budget was designated “medium to low.” Some local partners were mentioned as possible collaborators during stakeholder forums, so this criterion was ranked as “medium.” Specific economic benefits were outlined, so measureable benefits were ranked “high to medium.” Due to the detailed nature of intensive sub-watershed modeling, the timeframe criterion was ranked “low” because the projects would likely take more than 5 years.

The project that focused on a data warehouse would be very transferrable and was ranked “high.” However, few stakeholders specifically asked for this service, so it was ranked “low” for expressed needs met. Providing a unified source of water information was rated “high” for demonstrating the capability of IWRSS. New data would be involved in compiling the state water use information, so this is within the “medium” level of IWRSS capability. The budget would be relatively affordable, depending on the effort involved in acquiring new data, and thus was given a “high to medium” ranking. The role of local partners in this data warehouse is unclear, so this was given a “medium to low” ranking. Additionally, benefits from this effort would be indirect, so this was also rated “medium to low.” Results might be available in a “medium” timeframe of 3-5 years.

The water quality monitoring component of proposed projects would be transferrable among basins, and was ranked “high.” Only one stakeholder group and a limited number of survey respondents said that water quality monitoring would meet their needs, so this was ranked “medium to low.” Water quality monitoring was given a “medium to low” ranking for the demonstration of IWRSS capabilities because it would not necessarily involve all IWRSS partner agencies. A ranking of “medium” was designated for being within IWRSS capabilities, as new tools or techniques would need to be developed. Water quality monitoring component needs suggest a budget would be a “medium” level of affordability. A number of local partners could support water quality monitoring, and so it was ranked “high” for this criterion. Measureable benefits were not extensively described during stakeholder forums or in the survey, so this was ranked “medium.” Results for the water quality monitoring component would be expected to be available in a timeframe greater than 3 years, and was ranked “medium to low” accordingly.

5.4 River Basin Commission Input

Representatives from the RBCs were reconvened via webcast on December 5, 2013 in order to:

- Describe the process used by IWRSS partners to identify, as the priority need, the development of a LWMM as a demonstration project
- Determine priority subcomponents of a LWMM capability for each river basin
- Identify a proposed project describing how a LWMM capability could be applied in each basin

Three of the four RBCs (Delaware, Susquehanna and Potomac) participated in this meeting. The IWRSS team presented findings from the forums and the survey, the grouping of projects into major themes and functional subcomponents, and the ranking process used by IWRSS partners. The RBCs discussed, and subsequently agreed with, the process for grouping and ranking projects, and confirmed selection of LWMM. The RBCs then selected 3-4 functional components that were the highest priority for filling gaps in their respective basins. After the group discussion, consensus was reached on a LWMM model for drought and flood intensity with capability to:

- Better model low flow to address reservoir optimization, storage, releases and water resources allocation decision-making to prepare for severe drought and ensure adequate stream flow (low flow decision support tool) under climate change scenarios.
- Better predict the timing and magnitude of high flow (under various climate change scenarios). In particular, there was interest in including a coupled riverine/coastal model to predict salt wedge movement under low flow conditions and the convergence of peak riverine flow with oceanic storm surge.

- Build on the models and tools that are already in place and fill specific gaps with information and/or model components that could be integrated into the existing suite of tools; or develop a modeling framework to enable interoperability of an existing system of models with some key gaps filled.
- Provide easy to understand and timely spatial visualization tools for better and time-sensitive communication of risks and results.

Officials from these RBCs participated in one-on-one follow up conversations to flesh-out conceptual proposals for demonstration projects to apply LWMM capability. Appendix G summarizes the results of this consultation process.

5.5 Projects Identified for Collaboration

Refined project descriptions were developed for the Potomac, Delaware and Susquehanna River basins after two rounds of one-on-one follow up conversations. To help identify implementation support needs, each RBC was asked the following questions (common answers to which are provided below):

1. *How will new LWMM capabilities be applied in your basin?*

- LWMM capabilities can be used for better modeling of low flow conditions for water supply planning and allocation purposes, as well as evaluating climate change scenarios.

2. *How will this capability build on what is already in place?*

- RBCs have built a strong foundation; future efforts should involve a high level of RBC involvement in implementation/testing of IWRSS capabilities and assisting with stakeholder engagement to ensure coordination between efforts
- Modeling components could be incorporated into existing basin models rather than creation of a new model would build on capacity already in place

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

- Better, real-time data, automatically updated and linked with operational triggers, would provide economic benefits by optimizing water resources (controlling flood waters and allocating water for water supplies and other uses)

4. *How do you see your role in helping to develop, raise awareness, and/or apply an IWRSS LWMM in your basin?*

- RBCs could play convening role and assist with on-going stakeholder engagement and help implement projects.

As a result of this consultation, the RBCs formulated proposed demonstration projects that they considered high priority, and that the development of IWRSS capabilities could support. Table 6 summarizes these demonstration projects, described in more detail in Appendix G. These LWMM demonstration project ideas illustrate demonstrated needs for IWRSS capability and will be useful in guiding IWRSS activities and future collaboration with the RBCs and stakeholders in the future.

Table 6. Summary of River Basin Projects to Apply LWMM Capability

River Basin Contact	Project Objective
Susquehanna River Basin Commission: John Balay	Develop a basin-wide Low Flow Decision Support Tool to: (1) monitor existing hydrologic conditions; (2) track quantitative trigger thresholds; (3) integrate hydrometeorological forecast information; and (4) facilitate scenario analysis to inform low flow management decision-making.
Delaware River Basin Commission: Bob Tudor	Develop a coupled freshwater and coastal model for the freshwater/estuarine transition zone between Trenton, New Jersey, and Wilmington, Delaware, that can be integrated into an existing suite of basin models.
Interstate Commission on the Potomac River Basin: Carlton Heywood	Improve storage reservoir release decisions by enhancing existing basin models with real-time upstream withdrawals and discharge data and better predictions of in-stream flow losses (e.g., evaporation and groundwater interactions).

6.0 RECOMMENDATIONS FOR FUTURE ACTION

Below are recommendations for building on this effort to engage with water resources stakeholders in the mid-Atlantic region and demonstrate new or improved IWRSS information and services on a regional scale. These recommendations involve digging deeper into socioeconomic benefits of, and making the business case for, developing critical IWRSS capabilities and implementing pilot project(s) to demonstrate those capabilities. The recommendations are based on input from stakeholder forums, stakeholder surveys, follow-up discussions with the RBCs, and lessons learned during this project.

This project resulted in the identification of high value, readily transferable IWRSS capabilities that can inform future decision making by filling key gaps that currently exist on priority water resources issues. Additionally, some information was gathered on the economic value associated with filling these critical needs and lessons were learned about the challenges of collecting this information. The following recommendations outline next steps to further define the future direction and development of IWRSS capabilities.

Build a Business Case for Developing Priority IWRSS Capabilities

- The IWRSS partners should work towards developing the business case for a large-scale watershed model (or models) with mapping capabilities to help fill gaps to meet the highest priority needs identified in the mid-Atlantic region. IWRSS partners should work with mid-Atlantic RBCs and stakeholders to examine how to leverage collaborative partnerships, take advantage of economies of scale and interoperability between project components to demonstrate IWRSS capability going forward.
- IWRSS should further identify and quantify the socio-economic benefits associated with building these capabilities to guide future investment. Preliminarily, areas of future investment appear to be large-scale watershed modeling for low flow, inundation prediction/mapping and complex coastal-riverine hydraulics. Another area of investment would be a common portal for water information, a common theme that was expressed in this region.
- Once *specific* areas of future investments have been identified, developing estimates of the socio-economic benefits will be more tractable than the survey approach utilized under this project. Specifically, IWRSS would need to determine the benefits that would result from providing the information that has been identified and then either perform a valuation project to determine the value of the benefits or find estimates that were developed for other purposes that are applicable. A key to this valuation exercise would be to parse out the amount of the benefit that would be attributable to the information being provided by IWRSS under the new investments.

Expand Needs and Benefits Analysis to Other River Basins and Regions

- The IWRSS partners should expand stakeholder engagement and identification of socio-economic benefits to other parts of the country to capture regional differences in order to determine if the needs identified in the mid-Atlantic are applicable elsewhere. Towards this end, efforts have begun in the Ohio River and Russian River Basins. In addition, the IWRSS partners should identify other critical regions and river basins with either a high level of need and/or robust stakeholder involvement in water resources issues to help identify and develop IWRSS capabilities to support collaborative initiatives.

Conduct more Robust and Project-Specific Economic Analyses to Show the Value of the Chosen Demonstration Project

- The first step for project-specific economic analyses is to identify the process through which benefits are generated from the new information. Specifically, IWRSS partners should map the chain of steps that would occur that lead from provision of new information to a specific benefit.
- Once the steps in generating the benefit from new information have been mapped, IWRSS partners should work to determine the extent to which the benefit would be attributable to the new information. That is, can the IWRSS information take full or only partial credit for the benefit?
- Finally, IWRSS should develop quantitative estimates of the benefit, either based upon a valuation study specific to the IWRSS project or based upon benefit-transfer methods to take values estimated in other contexts and apply those values to the IWRSS project.
- For developing and evaluating future projects, narrow the range and scope of projects under consideration and collect more specific information about benefits and value of information that the projects can produce.

Develop a Plan to Implement Priority IWRSS Capabilities

- Identify pilot projects that can demonstrate these high-priority capabilities (LWMM) in the near term while building a plan for longer-term investment.
- Obtain support for the demonstration project(s) from the participating stakeholders and funding authorities.
- Keep stakeholders engaged during project design and implementation by updating them frequently and providing opportunities for input. Leverage partnerships with RBCs and others to assist with stakeholder engagement.

APPENDIX A: FORUM AGENDA

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

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 <i>What are the key issues in the river basin now and in the foreseeable future?</i>
10:45-11:00 AM	Break
11:00-Noon	Key Decisions and Information Gaps (Break-out Groups) <i>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?</i>
Noon-1:00 PM	Lunch
1:00-1:45 PM	Report Back on Key Decisions and Information Gaps
1:45-2:45 PM	Brainstorm Solutions (Break-out Groups) <i>What demonstration projects could we propose to fill the gaps and how can we articulate the benefits/make the business case?</i>
2:45-3:00 PM	Break
3:00-3:45 PM	Lightning Round Report Back (a) Demonstration projects to fill key gaps (b) Value of filling the gaps
3:45-4:00 PM	Wrap Up, Next Steps & Adjourn

APPENDIX B: DELAWARE RIVER BASIN STAKEHOLDER FORUM REPORT

Integrated Water Resources Science and Services Delaware River Basin Commission Stakeholder Report December 13, 2013

Executive Summary

On December 13, 2013, the NOAA National Weather Service, in cooperation with the Delaware River Basin Commission and in coordination with the IWRSS federal partner agencies (the National Weather Service, the U.S. Geological Survey, and the U.S. Army Corps of Engineers), convened a group of 43 representatives from national, regional, state, and local organizations in West Trenton, New Jersey, for a one-day forum. Over the course of the day, participants engaged in discussions and brainstorming sessions focused on learning about hydrologic services IWRSS can provide, identifying key gaps that IWRSS might fill to inform water resources decision making, and discussing possible demonstration projects to build capacity for integrated water resources management in the Delaware River Basin.

In advance of the meeting, participants were polled to determine the highest-priority resource issues for the basin. This poll indicated that the three issues of greatest interest were water supply, flooding, and climate change impacts.

During the meeting, participants were divided into issue-based groups to identify key decisions, questions, and gaps IWRSS could address. The most commonly identified gaps involved (1) models, forecasts, and analysis; these were followed by (2) data and data integration needs, then (3) communications, including expanded graphics and the conveyance of risk and uncertainty. The modeling-related needs covered a wide range of topics including weather and flood forecasting, upstream saltwater migration, demographics and land use, and economic impacts. They also included providing real-time and downscaled models for local impact assessment, integrating data from numerous sources into models, and integrating the models themselves. Data needs involved accessibility and integration issues, while communication needs focused on visualization tools.

Each group proposed a demonstration project that would demonstrate how some of these key information gaps could be filled to address priority issues. The three demonstration projects are summarized below.

Project #1: Integrate data from federal, state, and local sources into existing models. Combine these data with climate change scenarios in order to better model the timing, volume, and location of water-related impacts in future scenarios. This project would help to assess environmental, social, and economic impacts; use graphic visualizations to communicate risk; and inform long-term facility management and planning decisions. Philadelphia was suggested for the demonstration project.

Project #2: Develop an integrated coastal estuarine and riverine flood model (including storm surge) that produces graphics using 3D visualization tools. The model would produce inundation

graphics depicting the areal extent and depth of flood waters to better illustrate “on the ground” socioeconomic impacts to improve support for emergency action and scenario planning. This new model would also feature an integrated education and outreach component to better communicate local impacts of future storms, including social and environmental impacts.

Project #3: Create (1) a probabilistic drought and flood model based on future climate change scenarios and (2) an operational integrated coastal estuarine and riverine model, including storm surge, to inform “worst-case” scenario planning. Combined, these efforts would improve basin coordination, reservoir management, salinity prediction, ecological sustainability, water availability, environmental protection, and water management, which would ultimately benefit economic growth and energy security.

Delaware River Basin

On December 13, 2013, the NOAA National Weather Service, in cooperation with the Delaware River Basin Commission (DRBC), convened a group of 43 representatives from national, regional, state, and local organizations in West Trenton, New Jersey, for a one-day forum. Over the course of the day, participants engaged in full group discussions and breakout group brainstorming sessions. Together they sought to achieve the following objectives:

- Learn about IWRSS hydrologic services.
- Identify key gaps that IWRSS might fill to inform water resources decision-making for priority water resources issues in the Delaware River Basin.
- Discuss possible demonstration projects to build capacity for integrated water resources management in the Delaware Basin and explore the benefits of such projects.

Following is a summary of the discussion and recommendations from the forum.

Priority Water Resources Issues in the Delaware River Basin

The IWRSS reviewed DRBC's Water Resources Program FY2010–2015 (dated July 14, 2010), and DRBC's Strategy for Sustainable Water Resources — 2060 (dated February 29, 2012), and suggested priority water resources issues. Participants were introduced to these topics during the registration process and asked to indicate their three highest priorities (with the option of writing in additional suggestions). Results of the participant poll were summarized and used to focus the discussion on the three issues of greatest interest (water supply, flooding, and climate change impacts). Each issue, along with the number of votes it received (indicated in parentheses) is presented below.

Population change and distribution (6)

- Population increase and/or re-distribution of population will likely increase the consumptive use of water, increase impervious surface cover, increase pollutant loadings, decrease forest cover, and potentially change use of groundwater and surface water. These changes will have an even greater significance if the population density increases in the upper basin headwater areas.

Energy generation and natural gas development (8)

- The need to reduce once-through cooling at thermal generation facilities will increase the consumptive use of water in the basin. Natural gas development, which consumptively uses water, creates potentially difficult-to-treat wastewater, and causes area-wide land cover issues, was proposed in the forested headwaters.

Ecological flow protection (10)

- Ecological flow analyses will likely affect pass-by flows for water withdrawals and reservoir conservation releases. There may also need to be flow targets in some of the larger tributaries.

Climate change (23)

- Sea level rise will decrease protective wetlands and increase storm surge impact and will affect salinity levels in the tidal river, potentially affecting water purveyors and industries if saline water reaches their intakes.
- Changes in precipitation could result in more intense storms in winter/spring and drought conditions during summer months. Impacts include increasing intensity of floods, flashiness of streams, reduction in snowpack, extended summer drought, increased water temperature, decreased dissolved oxygen, and increased turbidity/sediment load. Reservoir capacity and necessary operational changes will have to be evaluated.

Point and nonpoint pollution (11)

- Major water quality issues include nutrient loading and associated decreases in dissolved oxygen. Greater attention will be needed on the influence of the non-tidal system on the water quality of the estuary.

Flooding (22)

- Reservoir management/storage, flood forecasting and flood warnings, flood mapping, and flood management are key issues for which management schemes need to be in place. For purposes of ensuring a sustainable water supply in the basin, flood mitigation must be taken into account because of its effect on reservoir storage. Ensemble forecasting and nimble reservoir operations will be needed.

Water supply (28)

- Water supply concerns include increased upper basin use, salt water intrusion, salt encroachment at the Philadelphia and NJ American intakes, water quality issues, increased drought, and the need to allocate water for in-stream needs. Integrated water resources management is needed to optimize reservoir operations and to ensure the long-term sustainability of water supplies from both water quantity and water quality perspectives especially in the face of climate change.

Other (1)

- Economic value of water

During the plenary session, Dr. Thomas Graziano (Chief, NWS Hydrologic Services Division) and Carol Collier (Executive Director, DRBC) laid the groundwork for the day by providing an

overview of IWRSS and Delaware River Basin priority issues, respectively. They also discussed the importance of the IWRSS federal partners coordinating with other federal agencies:

- The Federal Emergency Management Agency, to address flood inundation issues and future Flood Insurance Rate Maps
- The U.S. Department of Agriculture, for a conservation evaluation and assessment program

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

- Are there examples of how IWRSS can help solve problems in the Delaware? How exactly will IWRSS benefit the Delaware where three models are currently being used?
- Can a national integrated modeling system be “downscaled” at scales necessary to address issues in the Delaware, for example, optimizing water supply systems for water releases and water allocation to meet multiple objectives?
- How will next steps be determined to answer these questions about direct benefits to the Delaware?
- How certain are funding to provide services and what is the timing of service delivery?
- Is IWRSS tapping into academic consortia? A Memorandum of Understanding and/or coordination through the National Science Foundation are options that could be pursued.
- In the Delaware, there is a need to integrate tidal and non-tidal flood forecasting to address convergence of storm surge and peak flooding from headwaters — is this the type of issue that IWRSS can address?
- Regarding salinity issues for water intakes on the river, NOAA assigns freshwater a “zero” for level of salinity, while Philadelphia views the freshwater/saltwater interface along a salinity gradient. This disconnect could be problematic for consistent modeling of the salinity in the river.

Following is a summary of the first set of breakout group discussions. Each group was asked to take on the following task:

Identify up to three key decisions or outstanding questions (event-driven, high impact or important routine decision/question) that “keep you up at night.” For each question/decision, identify key information gaps that need to be filled to inform these decisions (keeping in mind the capabilities of IWRSS).

Water Supply

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question 1: What will the regular water availability pattern be in the future — both temporal (long-term and short-term) and spatial distribution — and how will extreme climate events impact future water availability?

Gaps:

- Accurate historical data and information to real-time data/information and future predictability
- Assistance with interactive basic modeling — too many models, need to know applicability of each
- Need for readily available, integrated, and easily accessible data and information

Question 2: What are the larger regional implications of future water availability in the Delaware Basin? That is, what are the inter-relationships and inter-dependence between river basins (e.g., optimizing reservoir systems) as each faces future availability issues?

Gaps:

- Readily available, easily accessible and understandable information (intra-basin and inter-basin)
- Information is currently very fragmented among multiple agencies/entities — need to coordinate (need an integrated clearinghouse for models, data and information, and guidance/interpretation on their use)
- Downscale modeling for local application
- Stream gage information (stream gages are being decommissioned when historical data is desperately needed)

Potential Demonstration Project

Philadelphia water supply demonstration project:

- Integrate available data (federal/state/local) from all sources (e.g., daily precipitation and stream flow data for 100 years) into existing models
- Downscale climate outputs to a scale useful for different climate change design scenarios

- Model the timing, location, and volume of water for future climate scenarios; climate model outputs should include daily forecasts of precipitation and streamflow, which will support local model applications and decision support tools
- Assess environmental, social, economic impacts relative to specific design scenarios
- Quantify and communicate risk (with graphic visualizations)
- Inform facility management/long-term planning

Flooding

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question 1: How can water resources be better managed with respect to both flooding and salinity gradient issues (currently and in future)?

Gaps:

- Need to link coastal estuarine models with riverine models (flooding impact of converging peak flows and storm surge)
- Need better mapping of land use and understanding implications of land use trends

Question 2: How can water supply reservoirs be better optimized for flood control?

Gaps:

- Need to improve rainfall forecasts to inform decisions and communicate between reservoirs (i.e., improve accuracy, specificity, temporal resolution, and frequency of issuance to enable better timing for synchronizing basin-wide reservoir releases)
- Improve interagency communication for reservoir management

Question 3: How can we effectively communicate risk?

Gaps:

- Communication of impacts at the local level (local landmarks, infrastructure level)
- Inundation maps linked to socioeconomic impacts — need graphics to communicate impacts effectively

Question 4: How do land use trends affect flooding?

Gaps:

- USDA natural resources inventory in Delaware
- Better projections of flood risk — incorporate USDA information into existing models

Potential Demonstration Project

Integrated storm surge and riverine flood model with visualization tools:

- New model with education/outreach tool built in to communicate the message that all storms are not equal in terms of impacts and areas impacted

- Develop coastal estuarine storm surge model coupled with riverine flood model, including visualization tool for inundation mapping
- Link inundation maps to socioeconomic impacts
- Incorporate 3D visualization to show local impacts

Benefits:

- Will fill a gap — we can't currently show "on the ground" impacts
- Enhanced emergency action planning — communicate flood risk and avoid losses associated with nor'easters and tropical systems
- Enhanced ability to do scenario planning (land use changes, sea level rise, other climate change impacts)

Partners:

- NOAA, USGS, USACE, FEMA, DRBC, USDA, academic/private institutions, local media

Climate Change

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question 1: How will climate variability affect future temperature and other parameters in the main stem and tributaries?

Gaps:

- Connecting models that currently exist and making them more useful for stakeholders
- Determining the best climate change scenario to use for this region
- Risk assessment — gaps exist for socioeconomic impact analysis
- Risk communication — lack of tools to put science in terms that policy makers can translate into decisions and communicate to the public, including integration of tools and processes to communicate impacts and risks associated with climate change
- Impact of demographic shifts

Question 2: How do we value water as an economic resource? (flood and drought)

- What is the impact on the cost of water with climate change?
- Who pays?
- What is the optimal point for capital investment or mitigative action with respect to water resources decisions?

Gaps:

- Economic analysis at multiple levels
- Range of possible impacts to specific structures
- Real-time flood inundation mapping
- Compounding of effects of various processes (flooding plus storm surge)

Question 3: What change in climate is expected in the northeast region specifically and how can models be made more specific for this area?

Gaps:

- Ability to get information out to people “on the ground” who need the information immediately

- Applying past storms to model various future scenarios with climate change

Question 4: What is the “worst drought,” or design drought, that we should use in the future?

Gaps:

- Information to develop metrics to define tipping point for drought

Question 5: How are demographics going to change?

Gaps:

Data needed to answer this question — demographic change scenarios

Question 6: How are wetland areas affected by climate change?

Gaps:

- Better prediction of salinity and water level changes

Question 7: When will there no longer be enough freshwater to keep the salt front from migrating upriver?

Gaps:

- Need to know how much freshwater will be required to keep the salt front from migrating and where the salt line is expected to go
- Costs associated with different climate as well as different management scenarios and actions that might be taken to increase resiliency
- Future conditions with respect to population, sea level rise, and temperature

Question 8: Are current standards adequate given climate predictions?

Gaps:

- Need to define probable/different droughts to run through models to determine impacts
 - Intensity, duration, and frequency variables
 - Streamflow, groundwater, precipitation, and temperature variables
- Need estimates of future water availability for multiple uses and how to balance future demands given climate change impacts

Potential Demonstration Project

Delaware River: create a probabilistic drought/flood model based on future climate change scenarios to predict drought and flood intensity, duration, and frequency in conjunction with a salinity model (with sea level rise/storm surge inputs and other climate-dependent variables such as temperature)

Delaware Bay Estuary: develop an operational, coupled coastal estuarine and riverine model, including storm surge, for worst-case scenario planning, in conjunction with a visualization tool (phase 1 — coastal model and calibration)

Benefits:

- Basin coordination
- Reservoir management
- Salinity prediction
- Ecological sustainability
- Defining limits of water availability
- Protecting sensitive/vulnerable areas
- Energy security
- Better water management leads to economic investment — economic viability and future growth

Partners:

- DRBC, SRBC, DVRPC
- Municipalities including New York City, Philadelphia
- State agencies: PA DEP, other state regulatory and management agencies
- Federal agencies: USDA, EPA, NOAA, USGS, NPS, NFS, FWS
- Water providers, power companies, universities, agricultural community

APPENDIX C: POTOMAC RIVER BASIN STAKEHOLDER FORUM REPORT

Executive Summary

On February 6, 2013, the NOAA National Weather Service (NWS), in cooperation with the Interstate Commission on the Potomac River Basin (ICPRB) and in coordination with the IWRSS federal partner agencies, convened a group of 30 representatives from national, regional, state and local organizations at the USGS Water Science Center in Baltimore, MD, for a one-day forum. IWRSS federal partner agencies include the U.S. Geological Survey and the U.S. Army Corps of Engineers. Over the course of the day, participants engaged in discussions and brainstorming sessions focused on learning about hydrologic services IWRSS can provide, identifying key gaps that IWRSS might fill to inform water resources decision making, and discussing possible demonstration projects to build capacity for integrated water resources management in the Potomac River Basin.

In advance of the meeting, participants were polled to determine the highest priority resources issues for the basin. This poll indicated that the top three issues of greatest interest were: water availability and use, flows and water quality, and drought management. At the meeting, a fourth priority — flood risk management — was added.

During the meeting, participants were divided into issue-based groups to identify key decisions, questions, and gaps that IWRSS could address. The most commonly identified gaps involved (1) data needs followed by (2) models and forecasts, and (3) decision support tools. Data needs centered on data for localized or small scales and at un-gaged sites, historic records, gage accuracy, water withdrawals, and interbasin transfers of water. The modeling and forecast needs included extreme events, hindcasts, and downscaled modeling. Needs involving decision support tools related to water resources decisions and infrastructure management. In addition, communications needs were identified, including public engagement, awareness, and information accessibility.

Each group proposed a demonstration project that would demonstrate how some of these key information gaps could be filled to address priority issues. The four demonstration projects are summarized below.

Project #1: Develop a high-resolution hydrologic model to better understand future water-resources impacts at small scales. This project would help address cumulative impacts between and across jurisdictions, improve prediction of extreme flows, and inform decisions involving allocations, conservation, and long-term sustainable use.

Project #2: Create a nested monitoring and modeling system to better quantify and understand sediment processes. Potential benefits include more informed decision making on best management practices (BMPs) and Total Maximum Daily Loads (TMDLs), and increased public confidence in modeling and monitoring data.

Projects #3 and #4: Develop (1) a model to demonstrate prediction techniques for low-flow scenarios and (2) a tool to improve decision making for city water suppliers. Benefits include more informed water-release decisions and improved management of city water systems during times of drought.

Project #5: Create a static flood-inundation map library for the Potomac River in the Washington, D.C., metro area. Key benefits of this project include reductions in flood-related losses, improved public awareness, and better emergency management response coordination.

Potomac River Basin

On February 6, 2013, the NOAA National Weather Service (NWS), in cooperation with the Interstate Commission on the Potomac River Basin (ICPRB) and in coordination with the IWRSS federal partner agencies (the U.S. Geological Survey and the U.S. Army Corps of Engineers), convened a group of 30 representatives from national, regional, state, and local organizations in Baltimore, Maryland, for a one-day forum. Over the course of the day, participants engaged in full-group discussions and breakout group brainstorming sessions. Together they sought to achieve the following objectives:

- Learn about IWRSS hydrologic services.
- Identify key gaps that IWRSS might fill to inform water resources decision-making for priority water resources issues in the Potomac River Basin.
- Discuss possible demonstration projects to build capacity for integrated water resources management in the Potomac River Basin and explore the benefits of such projects.

Following is a summary of the discussion and recommendations from the forum.

Priority Water Resources Issues in the Potomac River Basin

Based on a review of ICPRB resources and discussion with ICPRB staff, the IWRSS team suggested priority water resources issues, from which participants were asked to indicate their top three highest priorities (with the option of writing in additional suggestions) during the forum registration process. Results of the participant poll were summarized and used to focus the discussion on the four issues of greatest interest (water availability, flows, drought, and floods). Each issue, along with the number of votes it received (indicated in parentheses) is presented below:

Water availability and use (22)

- Availability of surface water and groundwater under current and future conditions
- Cooperative interstate water use
- Maintenance of environmental flows
- Source water protection
- Land use impacts on availability and use

Flows and the impact on water quality (19)

- Point and nonpoint source pollution, including Total Maximum Daily Loads (TMDLs), land use impacts, and wastewater treatment plant discharges and other point sources.
- Stormwater and impervious cover, including nature, extent, and impact of impervious cover and stormwater management efforts to control water quality and quantity impacts.

Drought management (14)

- Geomorphic, ecological, and human impacts associated with droughts.
- Preparedness and response.
- Flow prediction during low flow periods.
- Quantification of risks.

Flood management (10)

- Geomorphic, ecological, and human impacts associated with flooding.
- Preparedness and response.

Climate change (9)

- Effects of potential climate change on water availability and use, extreme events, and water quality.

Potomac river ecosystem (3)

- Harmful impacts on the aquatic ecology resulting from human and natural sources.

During the plenary session, Dr. Thomas Graziano (Chief, NWS Hydrologic Services Division) and Carlton Haywood (Executive Director, ICPRB) laid the groundwork for the day by providing an overview of IWRSS and Potomac River Basin priority issues, respectively. This was followed by two breakout sessions.

For the first breakout session, each group was asked to take on the following task:

Identify up to three key decisions or outstanding questions (event-driven, high impact or important routine decision/question) that “keep you up at night.” For each question/decision, identify key information gaps that need to be filled to inform these decisions (keeping in mind projected capability of IWRSS).

For the second breakout session, each group was asked to develop a demonstration project for their focus area as a potential demonstration project for IWRSS. For each project, the groups were asked to provide a short narrative describing the project, identify key benefits of the project to help make the business case, and determine what partner organizations and agencies would need to be involved.

Water Availability and Use

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question 1: How do we model broad areas in high resolution?

Gaps:

- Localized data at ungaged sites
- Consumptive use
- Ground to surface water transfers
- Recharge variability
- Climate change scenarios
- Population and land use changes
- Cumulative impacts

Question 2: How can we gather and combine data across jurisdictions and beyond reported withdrawals?

Gaps:

1. Policy barriers/reporting requirements
2. Flow estimation methodologies
3. Interbasin transfers
4. Standard formats for tracking data
5. Water equity between jurisdictions and user groups
6. Access to information
7. The ability to fill in or estimate data gaps

Question 3: How does water quality impact water availability and use?

Gaps:

1. Spatial and temporal water quality data (e.g., nitrates and emerging contaminants)
2. Environmental flow restrictions

Potential Demonstration Project

Develop a high-resolution hydrologic model using existing data in a representative watershed to understand the future impacts along the Potomac River basin at small scales

Gaps and data needs for the model:

- Climate change scenarios using downscaled climate models
- Population and land use change forecasts in the watersheds
- Localized data at ungaged watersheds
- Recharge variability
- Interbasin transfer
- Unreported withdrawals
- Cross-jurisdictional data

Benefits:

- Address cumulative impacts between and across jurisdictions (e.g., changes in flow regime)
- Better ability to predict and determine the impacts of extreme flows
- Define long-term sustainable use and future planning for allocations and conservation
- Public awareness

Partners:

- USGS — estimates in ungaged locations (stream flow)
- NOAA, USACE
- Nature Conservancy
- State agencies — Maryland Department of the Environment, Maryland Department of Natural Resources, Maryland Geological Survey
- Cities and counties
- Land trusts

Flows and Impact on Water Quality

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question 1: With respect to land use development impacts, how can we better manage development to control the impacts on flow and water quality? Will low-impact development (LID) and wetlands restoration solve these problems? How to allocate agricultural vs. urban loads?

Gaps:

- Pre- and post-monitoring data at multiple scales
- Understanding sedimentation dynamics and processes

Question 2: Can we demonstrate stream recovery when stormwater is controlled? (Effectiveness of stormwater controls and benefits.)

Gaps:

- Monitoring data at sufficiently small scales and over sufficiently long periods (10 years) to better determine the effectiveness of best management practices (BMPs) and develop the business case for them
- Models downscaled for smaller areas, including climatological scenarios for design effectiveness

Question 3: Where is sediment load coming from? This will help properly locate BMPs to most effectively reduce sediment loads. Information on nutrient contribution sources: sediment tracking, loadings, and dynamics (both phosphorus and turbidity TMDLs).

Gaps:

- Improve understanding of sediment dynamics and processes — where sediment goes and what happens to it at all orders of streams within the watershed
- Pre- and post-monitoring data; scales are too large right now
- There is both a monitoring and a modeling gap of backyard and small models, including climate change scenarios
- We can't model it because we don't understand it in the geophysical realm (i.e., where it comes from, where it goes, changes in characteristics)
- We are unsure which BMPs are most effective
- What are the impacts of very large events and floods?

Bottom line: Ensure that we maintain the existing USGS data collection network that we already have. Build on that with targeted studies to answer the questions above.

Potential Demonstration Project

Integrated/nested sediment monitoring and modeling system

- Demonstrate improved understanding of sediment dynamics at more localized scales under real-world conditions. Overall, this is a monitoring study coupled with a new model to help explain what we are observing with monitoring data so that we can extrapolate it to other locations.
- Suggest two locations to show the range of sedimentation issues. Focus on watersheds that are already known for sediment. Potential locations are watersheds that encompass streams on the 303(d) list (EPA designated “impaired and threatened waters”), are located in both the coastal plain and the Piedmont, have a mix of BMPs, and can show the differences between new development (especially LID) and existing urban areas that may be retrofitted. This will allow the monitoring to account for watershed location, pre- and post-development, BMP type and maintenance. Suggest Anacostia watershed and Four Mile Run as good locations to demonstrate.
- The project consists of two parts: a forecast model and a decision model. The decision model would map the forecast and provide benefits information to inform BMP decisions. This model would accurately describe physical processes and predictive effectiveness of controls, taking into account the BMP type and location. The system would be designed with nested sites to reflect a variety of land uses; BMP type, ages, and levels of maintenance; and a range of stream orders.

Benefits:

- Reducing sediment and nutrients is the biggest cost item for Chesapeake Bay restoration
- Return on investment for each BMP for TMDLs, in terms of \$/lb of phosphorus or sediment, is used to determine investment cost-effectiveness.
- System of BMPs that provides location-specific results under actual conditions. The project will provide better information on effective BMPs by better understanding of sedimentation dynamics.
- Demonstrate value of maintenance investments to optimize cost-effective maintenance (based on the assumption that BMPs’ effectiveness goes down over time if they are not well maintained).
- Public health
- Ecosystem benefits — the ultimate goal
- Public confidence — currently public confidence in models and monitoring data is low.

Partners:

- Local governments currently on the hook for Municipal Separate Storm Sewer System (MS4) permits
- State
- Federal: EPA, NWS, and USGS (a natural partner for stream and sediment monitoring)
- Watershed groups and associations

Drought

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question 1: Short-term low-flow forecasting (one to nine days) in the Washington Metropolitan Area (WMA) — should we make a reservoir release? How do we manage the nine-day window, which is the approximate travel time, under low flow conditions, for upper basin reservoir releases to reach users in WMA? If we had better real-time low-flow forecasting from one to nine days with better simulation of physical processes, it would improve our ability to make informed reservoir release decisions and better optimize use of storage.

Gaps:

- Improve the accuracy of low-flow forecasts:
 - Upstream water use and discharge data
 - Better simulation of groundwater contributions during low flow
 - Better simulation of water losses (riparian losses) and evaporation

Question 2: Mid-range probabilistic forecasting (six months/WMA focus) —When is a drought going to end? Is it going to extend into the winter? Answering these questions requires planning for restrictions and similar water decisions. Should we consider water use restrictions? Should we advise less use of reservoirs, even if other sources are more costly? How do we integrate dam releases to ensure that upstream reservoirs fill?

Gaps:

- Need to incorporate longer-term records that include the drought of record in 1930
- Need more stream gages
- Bring in climatological information (climate change)
- Need for site-specific as well as regional levels
- Hindcasts (through 1930) and longer-term historic records: because droughts are a lot less frequent than floods, a longer historic record is required for modeling

Question 3: Long-term drought planning (next 20 years/basin-wide focus) — How much more future storage is needed and do we need to build new reservoirs? What do upstream municipalities need to do for reliable supply? This strategic planning requires going beyond the forecasts and looking at climate and population changes across the basin.

Gaps:

- Historical and future land use and population change

- Uncertainty information and predictions using consistent performance measures
- Water use and discharges (potential to link with USGS water census)
- How do you bring climate change and other issues into these decisions?

Additional discussion item: The quality of the forecast is different from the value of the forecast to users. The value of the forecast is different for operators, forecasters, scientists, and management. There is a need for statistical analyses to help make the best use of model results and to quantify uncertainties. There is a need for partnership between producers/forecasters and the users to ensure the same performance measures. There is also a need to align the NOAA verification system with a user's verification system.

Potential Demonstration Project

Build a low-flow model that demonstrates proven techniques for predicting future low flows in the Potomac River. This model will help optimize and inform decisions about timing and quantity of water release from reservoirs

Benefits:

- Increased reliability and decreased uncertainty of water supply for the WMA during times of low flow
- More effective use of federal agencies' knowledge and experience in coordinating low-flow operations and helping to maintain required flow levels
- Infrastructure benefits, including reduced pumping costs and potentially postponing the need for construction of a new reservoir or other costly capital improvements
- Decreased ecological risk

Partners:

- Washington Suburban Sanitary Commission, Fairfax County Water Authority, USACE Washington Aqueduct Division
- ICPRB
- USACE, NOAA, USGS (participate in building the decision support system)

Note: The group extensively discussed whether this demonstration project could be done accurately enough to be useful to the practitioner. ICPRB has begun work on this issue that could be dovetailed.

Project #2: Improved decision-making tool for city water suppliers. Perform a case study of the Baltimore water supply system to demonstrate how forecasts that predict the probability of

restrictions can guide decisions on how much to water to pump (interbasin pumping) before and after a drought to optimize water quality and minimize costs.

Benefits:

- Costs to develop the model would be offset by improved reliability for the water supply system
- Reduced treatment costs by pumping when the river is higher
- Providing information to minimize uncertainty in pumping costs

Partners:

- City of Baltimore; Susquehanna River Basin Commission (inter-basin transfer)
- Maryland Department of the Environment
- NWS, USGS

Flood-Risk Management

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question 1: What is the water going to do?

Gaps:

- More flow and precipitation gages to allow modeling for smaller and coastal-zone basins
- Faster models to provide timely forecast information
- “Better” (more real-time) weather (precipitation) forecasting capability
- Better definition of forecast-model error
- Complete LIDAR (light detection and ranging) data collection in “vulnerable” areas
- Need inundation mapping in all “vulnerable” areas

Question 2: How do we effectively interact with decision-makers?

Gaps:

- Provide a single and consistent source of flood inundation maps, accessible in real time, that depict the areal extent and depth of flood waters
- Construct a comprehensive list of decision-makers with appropriate contact information
- Provide technical assistance for data and forecast information
- Develop media awareness and contacts so the flood inundation maps, data, and forecasts are widely broadcast and accessible to the public

Question 3: How do we ensure that communities are prepared for, and respond effectively to, a flood?

Gaps:

- Develop a better understanding of the flood-related needs of emergency managers
- Expand outreach and training to communities to ensure that decision-makers can readily access flood inundation maps and understand their utility and limitations thereof

Potential Demonstration Project

Demonstration project: a static flood-inundation map library for the Washington, D.C., metropolitan area for Potomac River flooding (alternate locations can be considered)

The library is developed:

- Using consistent standards for mapping and modeling
- By IWRSS partners in coordination with stakeholders
- With maps and information provided to the public on a single-source website, possibly maintained at the National Water Center, to provide one-stop shopping for the public

Benefits:

- Visibility of the D.C. metropolitan area
- Improved info for evacuation planning
- Reductions in loss of life, property, and critical systems (e.g., infrastructure)
- Improved public awareness
- Improved emergency management response coordination
- Reduced cost of service through single-source maintenance

Partners:

- USACE, USGS, FEMA, and NOAA NWS
- Also ICPRB, states, NPS, media
- Communities (e.g., utilities, planners, emergency management, transportation)

APPENDIX D: SUSQUEHANNA RIVER BASIN STAKEHOLDER FORUM REPORT

Executive Summary

On February 28, 2013, the NOAA National Weather Service, in cooperation with the Susquehanna River Basin Commission, convened a one-day stakeholders' meeting in Harrisburg, Pennsylvania, involving 31 representatives from national, regional, state, and local organizations. This meeting was part of the IWRSS, a national initiative whose federal partner agencies are NOAA's National Weather Service, the U.S. Geological Survey, and the U.S. Army Corps of Engineers.

At this stakeholders' meeting, 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 Susquehanna River Basin.

In advance of the meeting, participants were polled to determine the highest-priority resources issues for the basin. Four issues of greatest interest rose to the top: water quality, sustainable water use, flooding, and the Chesapeake Bay.

During the meeting, participants were divided into issue-based groups reflecting the above priorities (water quality and Chesapeake Bay were combined) to identify key decisions, questions, and gaps that IWRSS could address. The most commonly identified gaps involved (1) models and analysis, followed by (2) data and monitoring and (3) communications needs. The modeling and analysis needs covered a wide range of topics, including modeling scale, accuracy, scenarios, and indices as well as analysis of transport phenomena, permit effectiveness, ground/surface water interactions, and impacts of future climate change and land use scenarios on water resources. Monitoring and data needs included groundwater, temperature, precipitation, streamflow, water use, and data integration. Communications-related needs included effective and consistent public messaging, more lead time to respond to events such as flooding, and addressing information dissemination gaps.

Each issue-based group proposed a demonstration project that would demonstrate how some of these key information gaps could be filled to address priority issues. The three demonstration projects are summarized below.

Project #1: Improved monitoring and measurement of basic water quality parameters to protect and manage critical fisheries habitat. This project would include expanded monitoring of water temperature (focus on critical habitats) and new predictive capabilities (impacts on fish, algae growth, biological indicators) influenced by air, water, and ground temperature.

Project #2: An easily accessible "warehouse" of water use data that can compile water use information at user-specified levels. This project would be a building block for basin-wide water resources management models and tools and provide a wide range of historical information and forecasts to support water resources planning decisions.

Project #3: Risk-based action planning for flooding in urban and rural communities that quantifies certainty through the use of probabilistic forecasts, uses inundation maps to display the areal extent and depth of flood waters, and incorporates user-specified thresholds for taking

mitigative action. The project would include improvements in inundation mapping (including real-time dynamic flood inundation mapping), better dissemination and communication of forecasts, and metrics to measure success.

Susquehanna River Basin

On February 28, 2013, the NOAA National Weather Service, in cooperation with the Susquehanna River Basin Commission (SRBC) and in coordination with the IWRSS federal partner agencies (the U.S. Geological Survey and the U.S. Army Corps of Engineers), convened a one-day stakeholders' meeting in Harrisburg, Pennsylvania, involving 31 representatives from national, regional, state and local organizations. During the stakeholders' meeting, participants engaged in full-group discussions and breakout group brainstorming sessions to achieve the following objectives:

- Learn about hydrologic services that can be provided by IWRSS for the Susquehanna River Basin (IWRSS presentation).
- Identify key gaps that IWRSS might fill to inform water resources decision-making for priority water resources issues in the Susquehanna River Basin.
- Discuss possible demonstration projects to build capacity for integrated water resources management in the Susquehanna Basin and explore the benefits of such projects.

Following is a summary of the discussion and recommendations from the forum.

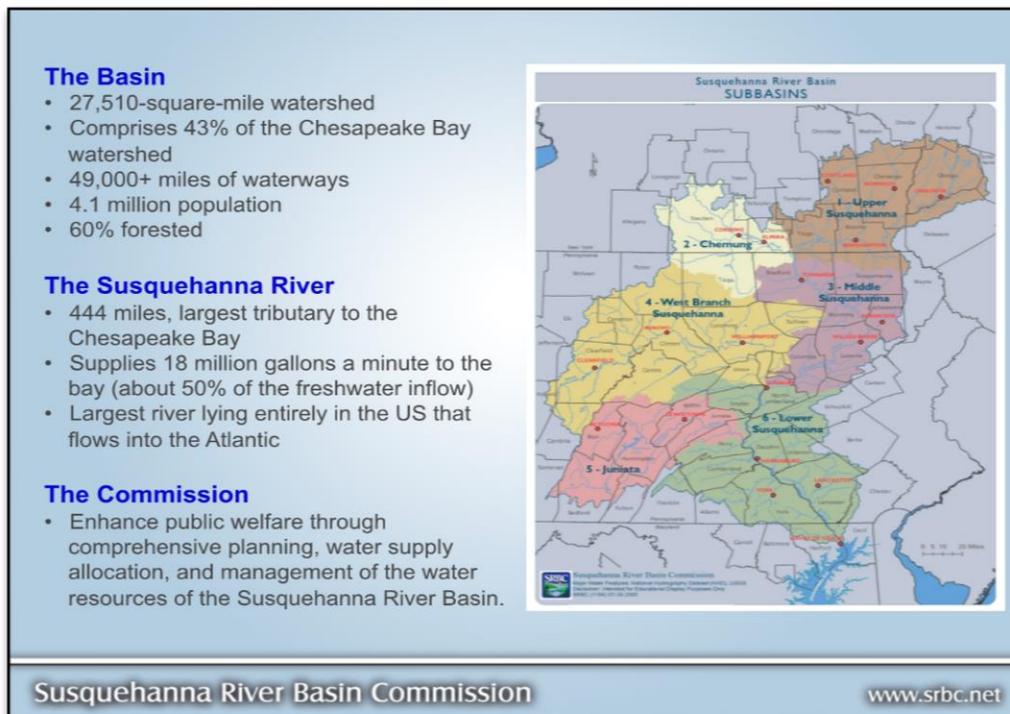


Figure 6-1: Overview of the Susquehanna River, Basin, and Commission

Priority Water Resources Issues in the Susquehanna River Basin

The IWRSS team developed a list of priority water resources issues based on a review of SRBC’s “State of the Susquehanna Report — 2013” and other information from the SRBC website, and in consultation with SRBC. The IWRSS team then shared the list of issues with participants prior to the stakeholders’ meeting. As part of the registration process, participants were asked to indicate their top three highest priorities (with the option of writing in additional suggestions). Each issue, along with the number of votes it received (indicated in parentheses), appears below.

- Water quality (17)
- Sustainable water use (15)
- Flooding (13)
- Chesapeake Bay (13)
- Aquatic ecosystem management (8)
- Other (surface water data modernization) (1)

Results of the participant poll were summarized and formed the basis for the top three issues of greatest interest to be discussed at the meeting: water quality and Chesapeake Bay, sustainable water use, and flooding.

Water quality and Chesapeake Bay

These priorities were combined because most people who voted for one also voted for the other, and because of the overlap between them. They were defined as follows:

Support the designated uses of all water bodies by achieving water quality that meets or exceeds standards. Issues include monitoring, mine drainage, stormwater management, point and nonpoint pollution, mine drainage, and emerging contaminants.

Manage the water resources of the SRB to assist in restoring and maintaining the Chesapeake Bay so it meets or exceeds applicable water quality standards and supports healthy populations of living resources. Issues include flow management, nutrients, and sediments including legacy sediment behind the dams.

Sustainable water use

Sustainable water use was defined as follows:

Meet immediate and future water needs of the basin for domestic, municipal, commercial, agricultural, industrial water supply and recreational activities to

maintain sustainable economic viability, protect in-stream uses, and ensure ecological diversity through regulation and planning.

Highest priority sub-topics under this issue, along with the number of votes received (indicated in parentheses), were:

- Flow (8)
- Drought (7)
- Climate change (7)
- Municipal and industrial water supply (6)
- Regulation of withdrawals and consumptive use (5)

Flooding

Flooding was defined as follows:

Prevent loss of life and significantly reduce future damages from floods within the basin through an integrated system of structural and nonstructural flood damage reduction measures. Issues include sustainable stream gage network, impacts due to climate change, emergency management/response, inundation mapping, and flood damage reduction alternatives for high-risk communities.

Stakeholders' Meeting — Opening Plenary Session

Dr. Thomas Graziano (Chief, NWS Hydrologic Services Division) and Andrew Gavin (SRBC Monitoring and Protection Manager) laid the groundwork for the day by providing an overview of IWRSS and Susquehanna River Basin priority issues, respectively.

In preparation for breakout groups, participants 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 need to address in the future. From this discussion the following topics emerged:

- What is the coordination mechanism between national-level data and services and water resources activities on the regional and local levels? How is information shared and disseminated to ensure consistent messaging and to prevent duplication of efforts?
- Related to the above, participants emphasized the importance of communicating the most accurate technical information in a way that can be easily accessed and understood by local officials and emergency managers who are responsible for deploying equipment and staff in anticipation of flooding events. The group suggested that significant expenditures could be avoided if continually updated probabilities of flooding are provided in such a way that “on-the-ground” impacts are clearly and effectively communicated to the public. It would be particularly useful if lateral inundation zones were depicted (spatially and temporally within the watershed) to predict where and when flooding levels are likely to occur. Inundation maps depicting the areal extent and depth of flood waters would better

inform critical life and property saving decisions and would replace the more generic “low-lying areas” warning, which is not very useful in informing how local resources should be best spent to avoid and/or respond to extreme events.

- The group also noted that, although there are areas of duplication between federal, state, local, and other initiatives, an important part of working in this industry involves knowing about what other agencies are doing and communicating information effectively between agencies to minimize duplication and establish a common operating picture for water resources. The role of federal agencies is often to develop and provide the information that is used by a variety of state and local entities.

Stakeholders’ Meeting — Morning and Afternoon Breakout Sessions

Following is a summary of the breakout group discussions.

For the first breakout session, each group was asked to take on the following task:

Identify up to three key decisions or outstanding questions (event-driven, high-impact or important routine decision/question) that “keep you up at night.” For each question/decision, identify key information gaps that need to be filled to inform these decisions (keeping in mind the capabilities of IWRSS).

For the second breakout session, each group was asked to develop a general scope for a potential project for their priority area to be considered as a possible IWRSS demonstration project. For each project, the groups were asked to provide a short narrative describing the project, identify key benefits of the project to help make the business case for implementing it, and determine what partner organizations and agencies would need to be involved to undertake the project.

Water Quality/Chesapeake Bay

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question 1: What model scale and processes considered therein are adequate for making management decisions?

Gaps:

- Need a model that addresses and is appropriate for local scales
- Need a more accurate model appropriate to needs (e.g., regulation)
- Need monitoring for real-world conditions

Question 2: Do we have adequate quality and quantity of monitoring data to make informed science-based management decisions needed to implement complex Chesapeake Bay TMDLs or complex smallmouth bass issues?

Gaps:

- Need groundwater monitoring (groundwater quality information)
- Need to understand fate and transport (nutrient retention/release)
- Need standards for water well construction
- Need temperature data for smallmouth bass management

Question 3: How does stormwater impact water quality?

Gaps:

- Need to understand Municipal Separate Storm Sewer Systems (MS4) permitting requirements (e.g., numeric limits)
- Need enforcement and clear authority to ensure compliance
- Need monitoring to see if best management practices are working

Question 4: What are the most viable solutions to preserve the sediment trapping capacity of the Lower Susquehanna dams? (Needs are being identified through Lower Susquehanna River Watershed Assessment.)

Gaps:

- Need modeled scenarios of sediment behavior for scenarios identified by the assessment

Potential Demonstration Project

Continuous monitoring data for the Susquehanna River

Continuous monitoring data in the Susquehanna is severely lacking. This project would focus on monitoring for basic water quality parameters on the Susquehanna River in critical habitats. It would provide much-needed information on ecological impacts of various water quality parameters on smallmouth bass and other fisheries or species of interest and concern, and overall water quality issues impacting the health of the Chesapeake Bay. This project would fill monitoring and management gaps and would include:

- Expanded monitoring of water temperature (focus on critical habitats), including real-time/in-stream monitoring and remote sensing
- Predictive aspects of water quality (impacts on fish, algae growth, and biological indicators), including air temperature, water temperature, and ground temperature

Benefits:

- Understanding stressors on smallmouth bass, and other fisheries
- Tracking the impacts of land use changes and new impervious surfaces on waterways
- Restoring a fishery that would provide significant economic benefits (fishermen, guides, local tourism, fishing tournaments)
- Improving regulatory decision-making through information for other Bay-related problems
- Improving and expanding inputs to the Chesapeake Bay model
- Adding an independent scientific perspective
- Tracking climate change impacts on critical habitats
- Adding information that would be useful for triennial review of water quality standards

Partners:

- Fisheries groups (source of reports on locations where smallmouth bass problems occur)
- PA Fish and Boat Commission, PA Department of Environmental Protection, EPA (impairment listing — Region III water quality)
- Vicky Blazer, USGS (currently doing work in this topic)
- SRBC (monitoring)
- U.S. Fish and Wildlife Service
- NOAA (climate data)

Sustainable Water Availability/Water Use

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question 1: Will there be enough water? Concerns include unknown water uses occurring below regulatory thresholds; new applications for water use, which should take into account changes in climate and changes in land use; and aging infrastructure.

Gaps:

- Need information for both short-term and long-term decisions
- Need to clarify perceived versus real data gaps in water use and availability (it is unclear what is really necessary)
- Need to understand how climate impacts will affect water availability
- Need vertical integration of data (how it is acquired and used from federal to local level)
- Need to consider groundwater/surface water interactions

Question 2: Will the water be of sufficient quality?

Gaps:

- Need to better understand the relationship between water quantity and water quality — for example:
 - Relationship between water quality and water usability
 - Effects of lower flows on water quality
- Need sufficient monitoring, modeling, and forecasting of key parameters to better understand and respond to water temperature impacts and other seasonal impacts

Question 3: Do we have the tools necessary to manage basin-wide water resources issues?

For example:

- When can water from the Susquehanna be used for drought conditions, given river water availability and quality during these lower flow periods? Need early warning drought indices to switch to this source earlier and preserve local resources.
- What is the risk and likelihood of forecasted drought?
- What is the level of precision in models? (Need adequate spatial and temporal resolution for localized drought impacts.)

Gaps:

- Need earlier warning drought indices
- Need to be able to predict conditions under which the system reaches unsustainable/critical failure (given future climate and land use)
- Need to communicate public message to reduce water use with scientific integrity, political support, and urgency
- Need a combined voice at a national level to communicate the economic and environmental value of water
- Need in-situ precipitation data
- Need to account for all the bullets under Question 1

Potential Demonstration Project**Data warehouse to support water resources management and planning decisions**

Easily accessible data warehouse that compiles state water use information and can be resolved at user-specified watershed levels. This project would be a building block for basin-wide water resources management models and tools. The warehouse could also include historical rainfall/runoff data, NWS forecasts, and climate forecasts to support water resources planning decisions. It would include the following features:

- Connect state database to federal databases
- Provide better estimates of water uses not measured (e.g., thermal-electric power, evapotranspiration, irrigation, domestic self-supply)
- Provide basin stream statistics
- Continuously update data and provide data recovery features
- Provide for temporal resolution
- Provide sufficient data quality
- Include quantity and quality information

Funding could come from grants by the National Water Census to states for providing an interface between state and federal data.

Benefits:

- Saving time and money typically invested by states and industry to collect data to support modeling and inform water resources management decisions

- Providing a tool to develop water budget on multiple scales and better understand water availability now and in the future
- Supporting sustainability decisions — e.g., water-intensive industries being located appropriately
- Providing public accessibility to water resources data, models, and other information
- Considering and measuring economic value, including:
 - Government and industry receives economic benefits in terms of time and resources saved from data collection
 - Hydroelectric energy (or other industries) can better manage their “inventory” (water in the river is “inventory,” and better water resources models can improve the efficiency with which this inventory is used)
 - Agriculture yield is associated with the cost of water; measure yield performance under certain conditions (e.g., drought, flood)
 - Money saved through management decisions (e.g., with accurate and timely forecasts of drought onset, Baltimore City saves money by preparing for drought earlier and not pumping in drought conditions when water quantity may be restricted and water quality is poorer)
 - Industry would make informed decisions to meet water needs

Partners:

- States
- USGS
- SRBC
- NOAA/NWS
- USACE
- Non-governmental organizations
- Academia
- Municipal/industrial dischargers
- Private industry (insurance)

Flooding

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question 1: From an operational standpoint, on which NWS forecast should I base critical decisions?

- Need to balance operational decisions with forecast accuracy, certainty, and credibility (source of forecast)
- Need to be able to define short-term vs. long-term decisions and forecasts

Gaps:

- Need to communicate levels of confidence in the accuracy of forecasts
- Need to extend lead-time and associated uncertainty

Question 2: How do we provide sustainable funding for stream and rain gages in support of forecasts and warnings?

Gaps:

- Need sufficient data and information to determine if gage network is adequate (network analysis)
- Need to know if the network supports better spatial and temporal resolution of the forecast

Question 3: During flooding, when, where, and how much of an area is going to be affected?

Gaps:

- Need more hydraulic models
- Need user-friendly delivery of static/dynamic inundation mapping
- Need to bridge dissemination gaps
- Need to base maps on best available data
- Need alternative mapping technology

Potential Demonstration Project

Risk-based action planning for flooding in urban and rural communities that quantifies certainty through the use of probabilistic forecasts, uses inundation maps to display the areal extent and depth of flood waters, and incorporates user-specified thresholds for taking mitigative action

Test and evaluate effecting a transition from deterministic forecasting to probabilistic forecasting (or how each can be used) with streamlined risk-based action planning methodologies (spatial and temporal). Trigger planning would provide forecasting thresholds at which certain mitigative actions should be taken.

This project would involve a social science component and technical component, including better inundation mapping and better dissemination and communication of forecast information. The project would also include metrics to measure success and identify any difference the forecasts and communication methods made for users (emergency responders, media, communities, etc.). Also, on a spatial scale, the project would test and evaluate visuals so that decision-makers can see/know the areal extent, depth, and local impacts of flooding expected from upper portions of the watershed.

The project would also consider the different needs of urban and rural/suburban areas.

- **Urban component** — Dynamic inundation maps for larger river flooding with associated probabilities. Visualization tools and triggers for what actions locals should take at each level.
- **Rural/suburban component** — Same as above, but with more focus on improved communication and information dissemination given the lack of Internet access in some places. Include better spatial data and possibly stormwater data. Unlike mainstem issues, focus on the “flashiness” of tributary flooding.

Partners:

- NOAA/NWS
- FEMA
- Local officials
- SRBC

APPENDIX E: HUDSON RIVER BASIN STAKEHOLDER FORUM REPORT

Executive Summary

On June 27, 2013, the NOAA National Weather Service, in cooperation with the NOAA Cooperative Remote Sensing Science and Technology Center at the City College of the City University of New York and the Hudson River Foundation, convened a one-day water resources stakeholders' meeting in New York City, New York, involving 21 representatives from national, regional, state, and local organizations. This meeting was part of the IWRSS, a national initiative whose federal partner agencies are NOAA National Weather Service, the U.S. Geological Survey, and the U.S. Army Corps of Engineers.

At this stakeholders' meeting, participants learned about hydrologic services IWRSS can provide, identified key gaps that IWRSS might fill to inform water resources decisions, and discussed possible demonstration projects to build capacity for enhanced integrated water resources management in the Hudson River Basin.

In advance of the meeting, participants were polled to determine the highest-priority resources issues for the basin. Three issues of greatest interest rose to the top: climate change, flooding, and water quality.

During the meeting, participants were divided into two issue-based groups (flooding and water quality, with climate issues incorporated as a topic for both groups) reflecting the above priorities. The groups were charged to identify key decisions, questions, and gaps that IWRSS could help better inform. The most commonly identified gaps involved (1) models and reliable forecasts, followed by (2) data and monitoring and (3) sediment transport and sedimentation information needs. The modeling and forecasting needs covered a wide range of time scales and topics, including modeling and forecasting to inform short through extended range planning and design decisions for infrastructure, river transport/shipping, emergency planning, and land use. Data and monitoring needs included common/universal measurements and datum, calibration, data integration, and a one-stop portal for data, as well as improved monitoring of ice jams. Sedimentation-related needs focused on modeling sediment erosion and transport for the range of future event frequencies and magnitudes for infrastructure and dredging decision-making and planning, understanding the impact of storm surge on sediment transport and beneficial deposition in wetland areas, information for the prediction of harmful algal blooms, and monitoring of groundwater levels and quality.

The two breakout groups combined to propose demonstration projects to demonstrate how some of these information gaps could be filled to address priority issues. Three demonstration projects were developed, as summarized below.

Project #1: Develop a downscaled global climate model in conjunction with a coupled riverine-coastal model to better predict flood frequencies and inform infrastructure planning. The models would provide a wide range of data, including flood frequency, sea-level rise, and storm surge, and serve as a single data portal for this information. In addition, the models would be combined with an improved stream gage network for better calibration and application at the local level.

Project #2: Study the impact of precipitation events on sediment loading and accretion to better predict dredging requirements and prioritize sediment reduction efforts. Perform a study in the

New York harbor or Albany harbor to better understand (1) how sediment loads differ based on the location of precipitation events and (2) beneficial sediment accretion within wetlands. This study would also integrate existing and new remote sensing and USGS monitoring data to develop more robust sediment budget information.

Project #3: Improve short-term (one- to seven-day) precipitation and streamflow forecasts to support improved operations of multi-purpose reservoirs and optimize Hudson River navigation. Perform a study in the New York harbor or Albany harbor to better understand the impact of streamflow forecasts on the economics of navigation decisions.

Hudson River Basin

On June 27, 2013, the NOAA National Weather Service, in cooperation with the NOAA Cooperative Remote Sensing Science and Technology Center (CREST) at the City College of the City University of New York and the Hudson River Foundation (HRF), and in coordination with the IWRSS federal partner agencies (the U.S. Geological Survey and the U.S. Army Corps of Engineers), convened a one-day water resources stakeholders' meeting in New York City, New York, involving 21 representatives from national, regional, state, and local organizations. During the stakeholders' meeting, participants engaged in full-group discussions and breakout group brainstorming sessions to achieve the following objectives:

- Learn (through an IWRSS presentation) about hydrologic services that IWRSS can provide for the Hudson River Basin.
- Identify key gaps that IWRSS might fill to inform water resources decision-making for priority water resources issues in the Hudson River Basin.
- Discuss possible demonstration projects to build capacity for integrated water resources management in the Hudson Basin and explore the benefits of such projects.

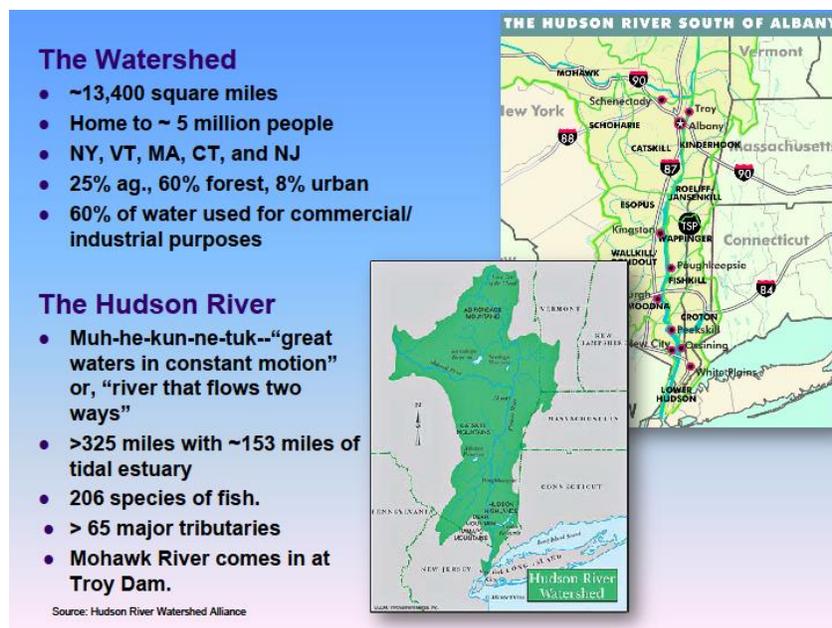


Figure 6-2: Overview of the Hudson River and Basin

Following is a summary of the discussion and recommendations from the forum.

Priority Water Resources Issues in the Hudson River Basin

The IWRSS team developed a list of priority water resources issues based on a consultation with HRF. The IWRSS team then shared the list of issues with participants prior to the stakeholders' meeting. As part of the registration process, participants were asked to indicate their top three

highest priorities (with the option of writing in additional suggestions). Each issue, along with the number of votes it received (indicated in parentheses), appears below.

- Climate change (22)
- Flooding (19)
- Water quality (12)
- Fisheries (9)
- Water supply (8)
- Other (coastal shipping and modeling/forecasting of tides and currents) (2)

Results of the participant poll were summarized and formed the basis for the top three issues of greatest interest to be discussed at the meeting: water quality, flooding, and climate change.

Water quality

Water quality issues include stormwater runoff, sewage discharges, saltwater intrusion, contaminated sediment, and concerns about the impacts associated with hydraulic fracking. Upstream migration of the salt front is an issue for communities like Poughkeepsie that draw drinking water from Hudson River. Nutrients and bacteria from wastewater discharges are also an issue, and wastewater system infrastructure upgrades will be necessary in the near future. Contaminated sediment is an issue affecting water quality and aquatic life. Contaminants of concern include PCBs, pharmaceuticals, endocrine disruptors, and heavy metals such as mercury.

Flooding

Flooding issues include ice jams in the upper watershed during spring thaw, damage from extreme precipitation events (including recent hurricanes and tropical storms such as Irene and Sandy), and storm surge in the lower basin. Growing concerns include the combined effects of riverine peak flooding and coastal storm surge and management of reservoir impoundments to mitigate flooding and prevent catastrophic releases.

Climate change

Climate change issues include increased drought, increased frequency and intensity of flooding associated with sea level rise, and stronger storms. Understanding the scope of these issues and adapting to them is gaining increased attention, including efforts to build community resilience (including infrastructure), conduct species vulnerability assessments, and develop adaptation guidance for local communities.

Stakeholders' Meeting — Opening Plenary Session

Co-sponsors Dr. Reza Khanbilvardi (NOAA CREST) and Clay Hiles (Executive Director, HRF) delivered welcoming remarks and explained the work of their organizations. Dr. Thomas Graziano (Chief, NWS Hydrologic Services Division) then laid the groundwork for the day by

providing an overview of IWRSS. Following his presentation, the facilitator provided an overview of priority issues in the Hudson River Basin.

The group discussed the following questions related to IWRSS and the purpose of this forum:

- How can IWRSS support water resources research?
- One planned objective of NOAA’s new National Water Center (under construction on campus of the University of Alabama in Tuscaloosa) is to establish an IWRSS proving ground or “sandbox” to promote partnered efforts to develop, test, and validate new water resources models and techniques in an operational setting. A key part of this effort is to partner with academia to facilitate and expedite research to operations and operations to research activities.
- To what degree does IWRSS partner with other sectors impacted by water resources issues (e.g., emergency management)?
- IWRSS partner agencies have done extensive in-person stakeholder engagement as well as surveys with a wide range of stakeholders at the local, state, regional, and national levels. Examples include surveys of emergency managers nation-wide, holding forums at national conferences, and performing service assessments after natural disasters and extreme weather events. A key aspect of IWRSS is to engage a wide range of water resources stakeholders to better inform the design and development of new water resources capabilities. In addition, this forum will be followed by a survey to evaluate the potential benefit of some of the proposed demonstration projects. These surveys will include a much larger group of stakeholders.

In preparation for breakout groups, participants 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 need to address in the future. From this discussion the following topics emerged:

- Climate change:
 - There are distinct trends showing an increase in the frequency of high-precipitation years and an overall increase in amount of precipitation over last 30 years.
 - These trends make it challenging to use long-term averages to create plans for reservoir management and infrastructure design (i.e., “stationarity is dead”).
 - The impacts of climate change on reservoir management are big-picture issues that significantly affect local economies (e.g., water supply, power generation, water levels for fishing or white water rafting).
- Flooding:
 - Docking during flood events is a major challenge to shipping in Albany.

- Early spring runoff causes flooding problems when it builds on already high water levels. For example there was a recent event during which 2 to 3 inches of rain combined with 3 to 4 inches of spring runoff.
- Rain events on snow pack in early January are a common cause of flooding in upstate New York.
- Improved quantitative precipitation forecasts and advance-warning prediction services for weather events (48 to 120 hours) and associated confidence intervals would be ideal for advance tracking and planning for weather systems moving across the country.
- Ice jams are a problem in upstate New York. Developing prediction systems and better tools for addressing release of water upstream of ice jams in real time would be very helpful for emergency managers.
- Locally, in the lower part of the Hudson basin, important issues include stormwater runoff and system overflows.
- An important long-term issue is designing local infrastructure to effectively handle stormwater flooding in the future.
- Planning for extreme events and worst-case scenarios is an increasingly important need. For example, what would be the result of the storm surge of Sandy occurring on the heels of the rains of Irene? What would be the total water level; what people and infrastructure would be affected, and how?
- Summit-to-sea modeling would be very helpful for determining how to build an integrated riverine and coastal (storm-surge) protection system.
- Water quality:
 - Current impacts from fracking are largely outside of the Hudson River Basin.
 - Contaminated sediments are limiting dredging activity and impacting shipping routes.

Because climate change issues have a significant impact on both water quality and flooding, the group decided to break up into only two breakout sessions — water quality and flooding — with climate issues integrated into both discussions.

Stakeholders' Meeting — Breakout Sessions

For the first breakout session, each group was asked to take on the following task:

Identify up to three key decisions or outstanding questions (event-driven, high-impact, or important routine high-value decisions/questions) that “keep you up at

night.” For each decision/question, identify key information gaps that need to be filled to inform these decisions (keeping in mind the capabilities of IWRSS).

For the second breakout session, the two breakout groups combined to develop the general scope of a potential project for each priority area to be considered as a possible IWRSS demonstration project. For each project, the group was asked to provide a short narrative describing the project, identify key benefits of the project to help make the business case for implementing it, and determine what partner organizations and agencies would need to be involved to undertake the project.

Flooding

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question 1: What are the potential impacts of climate change and flooding on sizing of infrastructure (e.g., culverts, roads, bridges, locks, dams, waste water infrastructure)?

- What will a 100-year (0.1% chance) flood look like 20 to 30 years from now?
- Infrastructure needs to be correctly sized in order to accommodate increased flooding levels that may result from climate change
- Probable maximum precipitation (PMP) has a direct financial impact on decisions involving construction, safety, and modernization of dams, water supply systems, and waste water infrastructure (e.g., right-to-know requirements for combined sewer overflows [CSOs])

Gaps:

- Long-term infrastructure impacts:
 - Need downscaled climate models showing impacts of a changing climate on precipitation and river levels
 - Need updated intensity-duration-frequency (IDF) curves and flood frequencies (e.g., one-year, five-year, and 10-year storms)
 - Need to predict dynamic IDF curves 50 years in the future
 - Need to project PMP and probable maximum floods incorporating data from recent extreme storms
- Short-term infrastructure impacts:
 - Need to extend the range and account for uncertainty associated with precipitation forecasts used in operational hydrologic models, and provide streamflow forecasts that quantify the overall forecast uncertainty (atmospheric, hydrologic, anthropogenic, etc.) to better inform decisions and manage risk
 - Need to better predict CSO events based on precipitation forecasts
 - Need more accurate, higher temporal and spatial resolution quantitative precipitation forecasts, on the regional, national, and global scales, that account for precipitation phase (i.e., rain, snow)
 - Need improved observations and forecasts of river icing to inform decisions that reduce downstream impacts

Question 2: How can we provide better and more accurate forecasts for making decisions (e.g., porting or moving ships, amount of cargo, and dredging) that affect ship navigation?

Gaps:

- Need improved data on cross-sectional currents and water surface level
- Need better and more accurate longer-range streamflow forecasts (out through seven days)
- Need to better forecast the impacts of wind on river levels

Question 3: How can we improve county-level and local-level decisions on pre-positioning resources, planning evacuations, and properly sizing infrastructure?

Gaps:

- Need gages, modeling, and inundation maps (depicting both the areal extent and depth of flooding) to properly inform local decisions related to flooding, including future events that could occur under different climate-change scenarios
- Need common datum and universal measurements: too much information with different datum often results in reduced usefulness of the data and miscommunication about potential impacts
- Need a “one-stop shop” for integrated access to water data from federal agencies, NGOs, and others (this gap is applicable to all of the flooding questions)

Question 4: How do we make land-use decisions under different climate-change scenarios? How do we evaluate negative water health trends, including the trend of “migration toward mediocrity,” where the low-quality waters are improved but high-quality waters continue to degrade?

Gaps:

- Need better forecasting for low flow and to produce forecasts of water quality
- Need to evaluate the impacts of nutrient loads and related land-use/land-cover changes

Water Quality

Key Decisions/Questions and Gaps That IWRSS Could Fill

Question 1: In the future, how will an increase in precipitation frequency and intensity influence how often and in what locations we will need to dredge (dredge forecasting)? How much material will be dredged and, depending on the level of sediment contamination, what are the options for disposal?

Gaps:

- Need integration of weather data and future atmospheric predictions (storm duration, intensity, droughts) to model sediment transport. Modeling sediment transport requires an understanding of watershed conditions, hydrology, channel erosion rates, sediment loading, etc., for each of the major tributaries.
- Need to calibrate the sediment transport model, which requires better sediment science (long-term monitoring, scenario testing for different management schemes, research). Existing modeling efforts include the Contamination Assessment and Reduction Project for contaminant forecasts used by USACE, and USGS for long-term monitoring to help calibrate sedimentation rates. Need to extend funding for monitoring for calibration efforts.
- How do particle sizes change in relation to flooding and what impact do droughts have on sediment transport?
- How do changes in coastal morphology/bathymetry (in addition to stream geomorphology) affect sediment transport?
- Need to better understand how much sediment is pushed upriver or downriver into the estuary from extreme storm surge events (e.g., Sandy) or when combined with extreme precipitation events (e.g., Irene/Lee).

Question 2: How will rising sea levels and increased stormwater infiltration influence water table height and groundwater quality (e.g., increased salinity, contamination)?

Gaps:

- Need monitoring to better understand the impact of best management practices (BMPs) on groundwater and flooding. USGS is no longer conducting groundwater monitoring in New York City
- Need groundwater monitoring in the Five Boroughs for groundwater quality and quantity.

Question 3: What spectrum of events (e.g., frequent storms with less than 1 inch of precipitation, large events, superstorms, or combination of events) should be considered when planning future infrastructure (e.g., treatment plants; nuclear power plants; roadway, culvert, and

bridge design; shoreline stabilization) and waterfront development? How can facility planners use this information to prevent water quality degradation?

Gaps:

- Need to combine flood inundation mapping with infrastructure mapping to assess socioeconomic impacts and identify which facilities will be flooded or overwhelmed to determine which structures should be elevated, enclosed, replaced, or relocated.
- Need flood inundation mapping specifically around flood-vulnerable facilities, in coastal zones, and in areas not close to gages (>1 mile, extended areal coverage from limited gages).
- Need to know facilities and land uses where there is both a high pollution generation potential and a high level of vulnerability to flooding (this could be cross-referenced with EPA industrial discharge permits).
- Need more likely scenarios of extreme events or combinations of extreme events (e.g. coastal surge plus flooding from precipitation).
- Need to know the changing frequency of smaller events (e.g., if stormwater BMPs are designed to manage the one-year design storm, what does that storm look like in 20 years?) as well as the predicted 2080 100-year storm event, which is important for designing storm infrastructure.

Question 4: Can we better predict harmful algal blooms?

Gaps:

- Tools to predict harmful algal blooms and inform decisions that mitigate their environmental impact

Potential Demonstration Projects

Demonstration Project #1

Develop a downscaled global climate model to better predict flood frequencies and inform infrastructure planning

Develop a downscaled global climate model and a coupled riverine-coastal model in the Hudson River Basin/New York State to show the impact of climate change on vulnerable infrastructure in New York City. Combined, the models would provide a wide range of data, including flood frequency, sea-level rise, and storm surge, and would serve as a single data portal for this type of information. Combine the modeling system with an improved gage network for better calibrating the model at the local level.

This project would fill the following gaps:

- Need forward-looking information with a global model
- Need input to DOT and others for infrastructure vulnerability studies
- Need a single data portal for flooding, sea-level rise, and storm surge information
- Need criteria that private firms can use for planning and design
- Need inundation forecasts for updating emergency management and evacuation maps
- Need to demonstrate multi-agency collaboration, particularly for post-Sandy infrastructure planning (e.g., \$20 million USACE study)
- Need a model that actually runs fast

Benefits:

- Provide better warning systems for flood emergencies to increase evacuation times and emergency response preparations (Day [1970] estimates that a four-hour warning leads to a 10 percent reduction in the costs of flood damage; the City of New York's [2013] *A Stronger, More Resilient New York* report estimated \$19 billion in damages from Hurricane Sandy)
- Mitigate vulnerabilities by informing infrastructure planning and design specifications (e.g., DOT, ASHTO design criteria for culvert sizing)
- Save money by better prioritizing infrastructure projects and increasing infrastructure longevity through flood resilience
- Minimize CSOs in recreational areas (flood avoidance) and provide better guidance for public safety (e.g., creation of a warning system for CSO occurrences)
- Reduce flood damage costs

- Reduce costs of treatment to improve quality of water supply and for public health
- Reduce costs and damages to recreational boaters
- Develop more efficient infrastructure designs (saved man-hours) with better standards
- Improve our ability to successfully maintain growth and urbanization of coastal communities

Partners:

- HRECOS, Stevens Institute, and possibly the Beacon Institute (data collection)
- New York Department of Transportation
- New York State Department of Environmental Conservation
- NOAA-CREST
- New York Open Data Initiative (New York departments put information online)
- New York climate clearinghouse
- SUNY-Stonybrook
- Northeast Coastal Ocean Forecast System

Demonstration Project #2**Better understand the impact of precipitation events on sediment loading and accretion to better manage sediment reduction projects**

Perform a study in the New York harbor (thousands ships per year) or Albany harbor (350 ships per year) to better understand (1) how sediment loads differ based on the location of precipitation events within the basin and (2) opportunities for beneficial sediment accretion, particularly within wetlands. This study would integrate existing and new USGS monitoring and remote sensing data to develop improved sediment budget information. This project would fill the dredging gap.

Benefits:

- Improved ability to plan for capital costs of future dredging and disposal (about 70 to 80 percent of the sediment dredged from the Hudson is contaminated; disposal costs are estimated at \$100/cubic yard)
- Increased revenue to shipping sector
- Prioritized investment in sediment reduction projects

Partners:

- Sediment transport working group (USGS and academia)
- New York State Department of Environmental Conservation
- Port Authority
- Soil and Water Conservation Districts
- Hudson River Demonstration
- Consortium of ship owners in Albany, New York
- Canal Corporation

Demonstration Project #3

Improve short-term (one- to seven-day) streamflow forecasts

Improve short-term (one- to seven-day) streamflow forecasts to support improved operations of multi-purpose reservoirs and optimize Hudson River navigation. Perform a study in the New York harbor or Albany harbor to better understand the impact of streamflow forecasts on the economics of navigation decisions.

Benefits:

- Save approximately \$2 million each year in shipping costs (more accurate four- to five-day water level forecasts could help move thousands more tons of cargo, which would have savings/benefits for shippers and customers)
- Increased revenue to shipping sector
- Reduce flood damage costs
- Increase efficiency in hydropower production and reduce downstream risk (flooding vs. downstream uses vs. operations)

Partners:

- Port Authority
- Hudson River Pilots
- Consortium of ship owners in Albany, New York
- Canal Corporation

APPENDIX F: RESULTS AND ANALYSIS OF STAKEHOLDER SURVEY

STAKEHOLDER ENGAGEMENT TO DEMONSTRATE INTEGRATED WATER RESOURCES SCIENCE AND SERVICES (IWRSS) FOR RIVER BASIN COMMISSIONS IN THE MID-ATLANTIC

*Survey Results for the Potomac, Delaware,
Susquehanna, and Hudson River Basins*

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1. OVERVIEW

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), U.S. Army Corps of Engineers (USACE), and National Oceanic and Atmospheric Administration 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 applies a multi-disciplinary approach to address complex water resource problems collaboratively. Planned IWRSS services include: a) high spatial and temporal resolution “summit to sea” analyses and forecasts for a full spectrum of water budget parameters; b) extended range river forecasts that quantify uncertainty; c) static flood inundation map libraries and real-time flood forecast inundation mapping to show the aerial extent and depth of flooding; d) linking river forecasts and associated flood inundation maps to potential socioeconomic impacts; and e) integrating the access to geospatial water resources information from multiple federal agencies through a single portal.

This report describes the results of four surveys conducted by Eastern Research Group, Inc. (ERG) to identify priority hydrologic information needs and gaps and to characterize the benefits of IWRSS providing that information. The surveys covered stakeholders in four river basins: Potomac, Delaware, Susquehanna, and Hudson. The stakeholders covered by these surveys include government and private sector water resources decision makers whose interests include hydropower, emergency management, reservoir management, watershed management, agriculture, fish and wildlife, river commerce, municipal and industrial water supply, recreation, and water quality.

Key Themes Across the Basins

Across the four basins, the surveys found:

- **Priority water resources issues:** Flooding is a top cross-basin priority. This priority appears in the set of priority issues for each basin and respondents in three out of four river basins chose this as their number one priority. The exception is the Potomac River Basin, respondents indicated that “water availability and use” is their number one priority issue.
- **Water resources information needs:** Most respondents have access to the information they need but it is not adequate for their work; information access is particularly limited for uncertainty information and analyses, and for surface hydrology information in particular. Lack of access to key information is most significant for the Potomac, Delaware and Hudson River basins where 21 to 29 percent of respondents have limited or no access to uncertainty information and analyses.
- **Water resources information gaps:** Respondents across all four basins rated new or additional surface hydrology observations, forecasts, and uncertainty information and flood inundation mapping as critical to their work. When asked to describe the types of information that would fill these information gaps, respondents suggested:
 - Increasing the number surface water monitoring stations (e.g., stream gages) to generate more observations

- Increasing the spatial resolution of forecasts of stream flow and water quality
- More information about uncertainty for all types of information and guidance for presenting it to non-technical audiences
- Detailed analyses of topics such as flood inundation and water quality offered through a single portal for each access.
- ***Economic benefits of addressing information gaps:*** New or additional surface hydrology information and flood inundation mapping are expected to result in significant economic benefits through reduced flood damage and improved water quality. Additionally, respondents in the Delaware and Susquehanna River basins expect new or additional information to result in reduced drought damage.

The findings are discussed in greater detail below and full survey results are found in the appendices. These surveys are part of a larger project that ERG is performing for NOAA's NWS to identify information needs and scope out potential demonstration projects for providing desired information.

River Basin Commission Stakeholder Surveys

These stakeholder surveys have several objectives: a) identify priority issues for decision-making; b) identify gaps in information needed for decision making; and c) obtain stakeholder perceptions of the importance and economic value of needed information. The survey instruments were structured around five topic areas (described in more detail below) that addressed respondent demographics, priority issues for each basin, information access and use, information gaps, and economic benefits of filling information gaps. The instrument collected this information through a mix of scaled and open-ended response questions.

The surveys were identical for all four river basins except for the insertion of basin-specific priority issues. The priority issues were developed with stakeholders during a series of stakeholder meetings hosted by the four river basin commissions² and the IWRSS program. The river basin commissions also produced lists of contact information for stakeholders representing eleven sectors in each basin for the survey sample. The survey instrument is provided in Appendix A.

Upon receiving Office of Management and Budget (OMB) approval to conduct the surveys through the Paperwork Reduction Act (PRA) Information Collection Request approval process, the data collections were implemented as web-based surveys. Stakeholders for each river basin received an email invitation to complete the survey and a link to the survey was posted on each river basin commission's website. The surveys were open from April 8, 2013 to April 25, 2013 for the Potomac, Delaware, and Susquehanna River basin stakeholders and from June 28, 2013 to July 18, 2013 for the Hudson River basin stakeholders.³ The surveys were open during different timeframes due to scheduling of stakeholder meetings. Seven hundred eighty six potential respondents received a direct invitation to participate in the survey. Table 1 summarizes the survey responses by river basin.

² For the Hudson River basin, NOAA Cooperative Remote Sensing Science and Technology Center (CREST) and Hudson River Foundation and the City College of New York co-hosted the stakeholder forum.

³ The Delaware and Hudson surveys were re-opened after their official close dates to allow additional respondents to provide input. One late Delaware response was received on May 17, 2013 and one late Hudson response was received on July 22, 2013.

Table 1. IWRSS Survey Respondents

Category	Potomac	Delaware	Susquehanna	Hudson
Surveys sent out via email	276	193	224	93
Clicked into the survey link	104	87	102	52
From emails sent	95	78	94	46
From non-email source [a]	9	9	8	6
Did not continue past intro page	23	19	21	10
Incompletes	28	23	26	12
Incomplete before Question 20 [b]	14	11	18	7
Submits	53	45	55	30
From emails sent	50	38	49	28
From non-email source [a]	3	7	6	2

[a] Refers to respondents who arrived at the survey via a river basin commission website.

[b] This is a subset of the “Incompletes.” Question 20, regarding barriers-to-use of types of observation information, is midway through the ‘Information Access and Use’ section.

Between 51 and 58 percent of the respondents who accessed the survey submitted a completed survey. Nevertheless, many of those who did not “submit” the survey answered some questions. ERG used both complete surveys (where the respondent reached the end of the survey and clicked the “submit survey” button) and partial surveys (where the respondent closed out of the survey before completion) in the data analysis. In other words, any response received was included in the analysis of each question. For transparency, charts in the appendices provide the actual number of responses to each question.

Demographics

The surveys began with a brief set of demographic questions to collect information on the respondent’s primary sector of interest, employment affiliation, interest in issues facing the river basin, interest in issues related to water resources management, frequency of working with water resources management issues, and extent to which their job responsibilities include providing input to strategic planning; program, facility, operations or financial management; or project planning decisions on water resources information.⁴ The demographic characteristics of the respondents are fairly consistent across the four basins, a few key findings include:

- **Primary sector:** Most respondents in the Potomac, Delaware, and Hudson River basins selected “water quality” (27, 21, and 29 percent, respectively) and “watershed management” (26, 18, and 14 percent, respectively) as their primary sectors; while respondents in the Susquehanna River basin selected “emergency management” (44 percent).

⁴ This last question also acted as a screening question, as only respondents who answer “Yes” are later asked to describe the economic value of impacts or benefits of new or additional information.

- **Affiliation:** More than 50 percent of respondents in all four basins are affiliated with government agencies; in the Potomac, Delaware, and Hudson most of those are state and federal agencies, in the Susquehanna most are local government.⁵
- **Interest in water resources issues:** Across all four basins, over 80 percent of respondents have been interested in and working on water resources issues for over 5 years and over 50 percent deal with relevant water resources issues on a daily basis.

Priority Issues

During the stakeholder meetings, each river basin developed a set of priority water resources issues facing their basin. The paraphrased priority issues for each basin are shown in Table 2. Detailed priority issues for each basin are available in the Appendices.

Table 2. Priority Issues by River Basin

River Basin	Priority Issues
<i>Potomac River Basin</i>	<ul style="list-style-type: none"> • Water availability and use. • Flows and the impact on water quality. • Drought. • Potomac River ecosystem. • Flooding. • Climate change impacts on water resources.
<i>Delaware River Basin</i>	<ul style="list-style-type: none"> • Population change and distribution impact on water availability. • Energy generation and natural gas development water quality and quantity impacts. • Protection of flows for ecological health. • Climate change impacts on water resources. • Point- and nonpoint-source pollution. • Flooding. • Water supply.
<i>Susquehanna River Basin</i>	<ul style="list-style-type: none"> • Sustainable water use and development (water supply). • Water quality. • Flooding. • Chesapeake Bay. • Aquatic ecosystem management.
<i>Hudson River Basin</i>	<ul style="list-style-type: none"> • Flooding. • Water supply. • Climate change and sea level rise. • Water quality. • Fisheries and aquatic habitat.

⁵ While many respondents were associated with government agencies, the survey results are not skewed by federal agency, especially IWRSS partner agency, responses. ERG utilized the email domain of the respondent to tabulate responses to key questions by federal versus non-federal respondents and found comparable responses.

Survey respondents were asked to rate the importance of each priority issue in their river basin and then asked to rate the top three most important issues. In each basin, the priority issue that was rated as “extremely important” by the most respondents was also the issue rated as the number one priority by the most respondents. In each basin, the top priority issue is:

- **Potomac:** Water availability and use (59 percent said it was “extremely important,” 44 percent listed it as the “#1 Priority”)
- **Delaware:** Flooding (53 percent “extremely important,” 24 percent “#1 Priority”).
- **Susquehanna:** Flooding (70 percent “extremely important,” 45 percent “#1 Priority”).
- **Hudson:** A tie between flooding and water quality (Each priority scored: 44 percent “extremely important,” 26 percent “#1 Priority”).

Information Access and Use

This set of questions asked respondents to rate the degree to which they have access to four categories of information, as follows:

- **Observations:** Data collected using scientific instruments. Examples include meteorological observations such as air temperature, dew point, and precipitation and surface hydrology observations such as river discharge/streamflow, river velocity, and soil moisture.
- **Forecasts:** Meteorological, climatological, and hydrologic information for future times at given locations derived from a model. Examples include meteorological forecasts of atmospheric pressure, atmospheric freezing levels, and wind speed and surface hydrology forecasts of river discharge/streamflow, river stage/elevation, and river velocity.
- **Uncertainty:** Quantification of uncertainty that arises from several sources, including model structure, parameters, initial conditions, and data used to drive and evaluate the model. For example, the probability of exceeding a flood level quantifies the model and data uncertainty for a river level forecast at a given time and location.
- **Analyses:** Public alerts, guidance, estimates, maps, and information derived from the evaluation and integration of meteorological, hydrologic, and climatological data.

Respondents were asked about their access to information about observations, forecasts, uncertainty, and analyses; barriers to use of information; the timeframe for use of information; and, how often each category of information should be updated.

- **Access to information:** A significant number of respondents (32 to 68 percent) have access to the information they need for their highest priority issue, but the information is not adequate or needs improvements. The most significant gap in information access occurs in the Potomac, Delaware and Hudson River basins where 21 to 29 percent of respondents have limited or no access to uncertainty information and analyses.
- **Barriers to use of information:** The most commonly cited barrier to information use across basins and information categories is the lack of availability of needed information. For example, in the Potomac River Basin 55 to 71 percent of respondents cite lack of availability of surface hydrology and water quality information as a key barrier to use of observations, forecasts and uncertainty and 44 to 56 percent cite the same for hydrologic and climatological analyses.
- **Timeframe for use:** Varies by river basin and information type; for example over 50 percent of respondents in the Potomac would use information for decisions (across information categories)

over a 1 year time frame while those in the Susquehanna were more likely to use shorter time frames (i.e., 1 to 3 days) (reflecting emergency response representation in the Susquehanna).

- **Timeframe for updates:** Respondents tend to prefer to have access to updated observation and forecast information more often than estimates of uncertainty and analyses. For example, respondents in the Delaware River Basin would prefer to have updated observation and forecast information on an hourly basis (25 and 35 percent, respectively), and uncertainty and analyses information on a monthly basis (23 and 22 percent, respectively).

Information Gaps

Next, respondents were asked to rate how important new or additional information would be to their work. For this set of questions the four categories of information (observations, forecasts, uncertainty, and analyses) are broken into several different types (or subcategories) of information. Examples of these information types are presented in Table 3.

Table 3. Examples of information subcategories

Information Category/Type	Examples
Observations, Forecasts, Uncertainty:	
<i>Surface Hydrology Information</i>	<ul style="list-style-type: none"> • Evapotranspiration, river discharge/streamflow, river stage/elevation, runoff, soil moisture
<i>Groundwater Hydrology Information</i>	<ul style="list-style-type: none"> • Depth to water table, aquifer thickness, aquifer yield
<i>Water Quality Information</i>	<ul style="list-style-type: none"> • Dissolved oxygen, nutrients, pH, turbidity, water temperature
<i>Drainage Basin Management Information</i>	<ul style="list-style-type: none"> • Reservoir elevation, reservoir storage, dam releases
<i>Meteorology Information</i>	<ul style="list-style-type: none"> • Air temperature, atmospheric pressure, dew point, potential evaporation, precipitation, wind speed
<i>Snow/Ice Information</i>	<ul style="list-style-type: none"> • River ice, snow depth, snowmelt, soil frost depth
Analyses:	
<i>Public Alerts</i>	<ul style="list-style-type: none"> • Flood watches and warnings
<i>Meteorological Analyses</i>	<ul style="list-style-type: none"> • Flash flood guidance, radar-based precipitation estimates, satellite-based and/or derived precipitation estimates
<i>Hydrologic Analyses</i>	<ul style="list-style-type: none"> • Discharge that has been exceeded X percent of the time for a designated period, record low flow/stage/or pool for a specified period of record, seven-day minimum flow with a recurrence interval of 10 years
<i>Climatological Analyses</i>	<ul style="list-style-type: none"> • Precipitation frequency estimates, probable maximum precipitation
<i>Flood Inundation Mapping</i>	<ul style="list-style-type: none"> • Map displaying spatial extent and depth of flood waters
<i>Information Integration</i>	<ul style="list-style-type: none"> • Single portal integrating the full spectrum of federal water resources information

Within each of the four categories of information, respondents were asked to rate (on a five point scale from “Not at all important” to “Critical”) the importance of each new or additional type/subcategory of information to their work. Overall, surface hydrology was most likely to be rated “very important” or “critical” for new or additional observations, forecasts, and uncertainty information. Hydrologic analyses (Potomac, Delaware, Hudson), information integration (Delaware, Susquehanna), and flood inundation mapping (Susquehanna) were most likely to be rated as “very important” or “critical” for new or additional analyses information.

Then respondents were asked: “For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making.” Several trends emerged in the written comments in response to the request for respondents to describe the new or additional information that they need:

- **Observations:** Responses focused on adding more surface water monitoring and gaging stations to provide additional observations of surface water and water quality.
- **Forecasts:** Respondents indicated a need for increased spatial resolution of stream flow and water quality forecasts.
- **Uncertainty:** Comments on uncertainty are difficult to summarize because many respondents focused on the importance of the information and how it would be used. Those that provided specific descriptions mentioned surface hydrology, water quality, groundwater, reservoir elevation, and improved communication around uncertainty for both data users and non-scientists.
- **Analyses:** Of primary interest are additional analyses of flood inundation, water quality planning, and future climate change impacts. Also, respondents would like tools such as a single “clearinghouse” for information and water quality alerts mobile applications for recreational users.

Economic Benefit of Filling Information Gaps

Finally, for each category of information (observations, forecasts, uncertainty, and analyses), respondents were asked if they would experience any of nine types of impact or benefit as a result of new or additional water resources information, and, if so, to describe the impact and estimate the cost avoided or benefit gained per year or event. The potential impacts or benefits cited by respondents included:

- Reduced flood damage.
- Reduced drought damage.
- Improved wastewater management or treatment.
- Improved stormwater management or treatment.
- Improved drinking water supply or treatment.
- Improved water quality.
- Improved navigability.
- Increased efficiency of hydroelectric power generation.
- Improved timing of water withdrawals and releases to optimize flow management.
- Other types of impacts.

The most commonly cited benefit in the Potomac, Delaware, and Hudson River basins was improved water quality and the most commonly cited benefit in the Susquehanna River basin was reduced flood damage. Other examples of potential benefits in each basin included:

- **Potomac:** Improved timing of water withdrawals would be a benefit of new or additional forecasts and uncertainty information.

- **Delaware:** Improved stormwater management would be an important benefit for new or additional observations and analyses. Reduced drought damage would be a key benefit for forecasts and uncertainty.
- **Susquehanna:** Respondents chose reduced drought damage as a potential benefit of new or additional uncertainty information and analyses.
- **Hudson:** Improved navigability would be a potential benefit of new or additional forecasts and uncertainty information.

Respondents whose job description involved “providing input to strategic planning; program, facility, operations or financial management; or project planning decisions on water resources information” were also asked to provide a description of the economic value of the benefits of new or additional information through open-ended questions. Only a few respondents in each basin provided a specific example of the economic value of the benefit specific services or information (e.g., new information will result in \$2 million in avoided flood damage per event). These descriptions provide a potential basis for developing more precise estimates through further stakeholder discussions. For context, the basin-specific sections that follow provide examples of the type of impact described by respondents; the full responses for each basin can be found in the detailed survey results in the appendices.

Report Organization

The next four sections present high level summary results for each river basin including: response rate, respondent demographics, basin priorities, information access and use, new or additional information needed, and the economic benefits of providing new or additional information. Detailed results from each survey are presented in the appendices.

2. POTOMAC RIVER BASIN RESULTS SUMMARY

Survey invitations were sent to 276 stakeholders with 81 surveys being submitted (53 complete). Of these 81 total responses, 75 were from individuals on the mailing list or colleagues to whom those emails were forwarded; the other six responses came from “untracked” participants (i.e., those who arrived at the survey via a link on the RBC website).

Respondent Demographics

Just over half of the respondents in the Potomac River Basin indicated water quality (27 percent) or watershed management (26 percent) as their primary “sector.” A majority of respondents (78 percent) are affiliated with a government agency. Fifty-two percent of respondents have been interested in issues in the Potomac River Basin for more than 15 years. Seventy-two percent of respondents have been interested in issues related to water resources management for more than 15 years and 68 percent deal with these issues on a daily basis.

Priority Issues

Respondents were asked to rate importance of six priority issues facing the Potomac River basin and rank their top three issues. The top priorities are “water availability and use” and “flows and the impact on water quality.” When asked to rate importance, over half of respondents rated “water availability and use” (59 percent) and “flows and the impact on water quality” (54 percent) as “extremely important.” When asked to rank the top three issues, 44 percent chose “water availability and use” and 25 percent chose “flows and the impact on water quality” as the number one priority.

Information Access and Use

Respondents were asked about their access to information (observations, forecasts, uncertainty, analyses), barriers to use of information, and timeframe for use of information. Across all types of information:

- 49 to 50 percent (uncertainty, observations) of respondents have the information but it is not adequate or needs improvement, 23 percent have limited or no access to uncertainty information.
- The most common barrier is “not enough information available.” Fifty-five to 71 percent of all respondents cited this barrier for surface hydrology and water quality information, and 49-56 percent of respondents cited this barrier for hydrologic and climatological analyses.
- Fifty-one to 62 percent of respondents are using information for decision making for timeframes greater than 1 year.
- Thirty-nine to 44 percent of respondents would like to see new observations and forecasts hourly or daily, and 25 to 32 percent would like to have new analyses or uncertainty information annually.

Information Gaps

Respondents were asked to rate the importance of new or additional information for decision making. Most respondents indicated that surface hydrology information is the most important for observations (44 percent), forecasts (34 percent), and uncertainty (32 percent); and, information integration (24 percent) for analyses.

Respondents were then asked to describe, for the information types rated as very important or critical, the additional or new information needed for decision making. Brief summaries of their comments are presented below.

Observations

New observation information needed for decision making includes: expanded stream gage networks (including additional, smaller stream segments) with increased observations of surface water variables and water quality; and high spatial resolution observations of water quantity and interaction with surface waters for ground water.

Forecasts

New forecast information needed for decision making includes: improved spatial and temporal resolution of forecasts; additional stream gages in key locations (for development and use of forecasts); the relationship between the information types and climate change; and the relationship between land uses, stream flow, and water quality.

Uncertainty

New uncertainty information needed for decision making includes: surface hydrology and water quality. Respondents note that the uncertainty information supports decision making and improves credibility of decisions.

Analyses

New analysis-related information needed for decision making includes: flood inundation mapping; water quality planning; and understanding future climate change impacts. Many comments focused on use of information integration to support decision making, planning, and other project work.

Economic Benefit of Filling Information Gaps

Respondents were asked if they would experience a type of benefit from new/additional information and if so, to describe benefit and estimate economic value of the benefit. The top types of benefits and an example of the estimated economic value are presented below.

Observations

Most respondents indicated that they would experience “improved water quality” (59 percent) and “improved stormwater management” (46 percent). One commenter noted that new or additional information would lead to the protection of \$2 billion of personal property from flood damage, per year.

Forecasts

The top three benefits are “improved stormwater management” (53 percent), “improved water quality” (53 percent) and “improved timing of water withdrawals and releases” (53 percent). New or additional information would lead to avoided costs of stormwater overflows and malfunctions of \$25,000 to \$250,000 per event, and avoided costs of \$410 to \$15,000 per household from shortages to surficial aquifer suppliers.

Uncertainty

The top two benefits are “improved water quality” (44 percent) and “improved timing of water withdrawals” (41 percent). New or additional information would lead to the above benefits through

improved understanding of relative benefits and risks of best management practice (BMP) implementation, improved interpretation of observations and forecasts, and improved drought operations of Washington D.C. water utilities.

Analyses

The top benefit is “improved water quality” (55 percent). New or additional analyses would lead to improved water quality through improved targeting of BMPs, and reduced treatment costs, in addition to other benefits.

3. DELAWARE RIVER BASIN RESULTS SUMMARY

Survey invitations were sent to 193 stakeholders; 68 surveys were submitted, of which 44 were complete responses. Of these 68 responses, 60 were from individuals on the mailing list or colleagues to whom those emails were forwarded; the other eight responses came from “untracked” participants (i.e., those who arrived at the survey via a link on the RBC website).

Respondent Demographics

The two most common sectors identified as the respondent’s primary sector in the Delaware River Basin were “water quality” (21 percent) and “watershed management” (18 percent). Just over half of the respondents are affiliated with a branch of government: 31 percent federal government and 22 percent state government. Fifty-three percent of respondents have been working on or interested in issues in the Delaware River basin for more than 15 years. Most respondents (96 percent) have also been working on or interested in issues related to water resources management for more than 5 years. About 85 percent of respondents deal with issues related to water resources management on a daily or weekly basis.

Priority Issues

Respondents were asked to rate importance of seven priority issues facing the Delaware River basin and rank their top three issues. The top priority issue is “flooding.” When asked to rate importance, over half of respondents rated “Flooding” (53 percent) and “Water Supply” (52 percent) as “extremely important.” When asked to rank the top three issues, 24 percent chose “Flooding” and 18 percent chose “Point- and nonpoint-source pollution” as the number one priority.

Information Access and Use

Respondents were asked about their access to information (observations, forecasts, uncertainty, analyses), barriers to use of information, and timeframe for use of information. Across all types of information:

- Forty-five to 49 percent of respondents indicate that the information they have is not adequate or needs improvement. However, 42 and 46 percent of respondents have adequate access to observations and forecasts, respectively, while only 22 and 28 percent of respondents have adequate access to uncertainty and analyses, respectively.
- The most frequently identified barrier to use of information is lack of information — 45 to 52 percent for observations, 41 to 70 percent for forecasts, 31 to 50 percent for uncertainty, and 29 to 46 percent for analyses — followed by insufficient accuracy or resolution.
- In using observation information for decision making 42 percent of respondents are using it over a 1 year time frame while 37 percent use it immediately and 35 percent over 1 to 3 days; for forecasts 42 percent use the information over a 1 to 3 day time period; for uncertainty information 38 percent use it over 1 month to 1 year and another 36 percent over 1 week to 1 month; and for analyses 42 percent use the information 1 month to 1 year, and 41 percent over 1 year.
- Respondents would like to see new observation and forecast information made available hourly (25 and 35 percent, respectively) and new uncertainty and analyses information monthly (23 and 22 percent, respectively).

Information Gaps

Respondents were asked to rate the importance of new or additional information for decision making. The most important category of information is surface hydrology for observations (59 percent), forecasts (50 percent) and uncertainties (39 percent); the most important category is flood inundation mapping for analyses (33 percent).

Respondents were then asked to describe, for the information types rated as very important or critical, the additional or new information needed for decision making. Brief summaries of their comments are presented below.

Observations

New observation information needed for decision making includes: more observations data through additional monitoring stations; integration of currently available data for the basin in one location; and information that supports targeted conservation activities or management of development.

Forecasts

New forecast information needed for decision making includes: streamflow forecasts in smaller tributaries or estuarine zones to support planning water uses and response to high or low flow; forecasts of impacts (such as climate change and pollutants) at the basin level with comparisons to other levels (state, regional, coastal, national).

Uncertainty

New uncertainty information needed for decision making includes: flood forecasts; groundwater; surface temperature; reservoir elevations; and precipitation. Most comments repeat data needs stated in response to earlier questions or explain how the data would be used or why it is important.

Analyses

The comments on new analyses needed for decision making are difficult to summarize because each comment describes a specific topic; one trend that appears a few times is a need for a single “portal” or “clearinghouse” for the information.

Economic Benefit of Filling Information Gaps

Respondents were asked if they would experience a type of benefit from new or additional information and if yes, to describe benefit and estimate economic value of it. The top types of benefits and an example of the estimated economic value are presented below.

Observations

The top two benefits are “improved water quality” (86 percent) and “improved stormwater management” (76 percent). New or additional observation information would inform fisheries managers on correlations between fish population trends and stormwater management (\$100,000 avoided cost per year) and water quality parameters (\$250,000 avoided costs per event).

Forecasts

The top two benefits are “improved water quality” (74 percent) and “reduced drought damage” (68 percent). New or additional forecast information could lead to improved water quality by helping protect \$1 billion worth of ecosystem services provided by natural capital.

Uncertainty

The top benefit is “improved water quality” (73 percent). New or additional uncertainty information could lead to improved drinking water supply to 9 million users in New York City through increased reliability.

Analyses

The top benefit is “improved water quality” (68 percent). New or additional analyses of flood frequency and impacts and integrated reservoir management would reduce flood damage by helping to identify possible improvements to water resources planning.

4. SUSQUEHANNA RIVER BASIN RESULTS SUMMARY

Survey invitations were sent to 224 stakeholders; 81 surveys were submitted, of which 55 were complete responses. Of these 81 responses, 73 were from individuals on the mailing list or colleagues to whom those emails were forwarded; the other eight responses came from “untracked” participants (i.e., those who arrived at the survey via a link on the RBC website).

Respondent Demographics

Forty-four percent of respondents in the Susquehanna River Basin selected “emergency management” as their primary sector. Just over half of the respondents are affiliated with a local government agency (52 percent), and 28 percent are affiliated with federal government. Nearly half of respondents (46 percent) have been working on or interested in the Susquehanna River basin for 5 to 15 years. Fifty-three percent have been working on or interested in issues related to water resources management for more than 15 years. About half of respondents (49 percent) work with issues related to water resources management on a daily basis.

Priority Issues

Respondents were asked to rate importance of five priority issues facing the Susquehanna River basin and rank their top three issues. The top priority is “flooding.” When asked to rate importance, over half of respondents rated “flooding” (70 percent), “water quality” (52 percent), and “sustainable water use and development” (52 percent) as “extremely important.” When asked to rank the top three issues, 45 percent chose “flooding” and 31 percent chose “sustainable water use and development” as the number one priority.

Information Access and Use

Respondents were asked about their access to information (observations, forecasts, uncertainty, analyses), barriers to use of information, and timeframe for use of information. Across all types of information:

- 32 to 47 percent of respondents have access to the information but it is not adequate or needs improvement to meet their needs. Another 50 percent have adequate access to observations and forecasts, and 38 to 43 percent have adequate access to uncertainty and analysis information.
- Most respondents, 26 to 59 percent, identify the lack of availability of information as the most common barrier to use; the second most common barrier is not knowing where to get the information.
- Forty-two percent of respondents would use observation information to support decisions over an immediate timeframe (42 percent), forecast information over 1 to 3 days (38 percent), uncertainty over 1 to 3 days (32 percent), and analyses over 1 to 3 days (32 percent) or >1 year (32 percent).
- Most respondents would prefer to see new observation and forecast information on an hourly basis (27 percent and 41 percent, respectively), and uncertainty and analyses information on a daily basis (38 and 28 percent, respectively).

Information Gaps

Respondents were asked to rate the importance of new or additional information for decision making. For observations (33 percent), forecasts (30 percent) and uncertainties (17 percent) the most important category of information is surface hydrology. For analyses the most important category is flood inundation mapping (21 percent).

Respondents were then asked to describe, for the information types rated as very important or critical, the additional or new information needed for decision making. Brief summaries of their comments are presented below.

Observations

New observation information needed for decision making includes increased spatial resolution at the sub-watershed level; more observations of surface water, water quality, and groundwater; flood inundation observations; and impacts of development on water quality and aquatic species.

Forecasts

New forecast information needed for decision making includes increased spatial resolution of forecasts and more frequent or more easily available forecasts of water quality, streamflow, and flooding.

Uncertainty

One trend that emerges regarding gaps in uncertainty information is a need for better communication around uncertainty. For example, “a clear statement of all the limiting conditions/assumptions set up in the model” and “improved method of conveying uncertainty that is understandable by non-scientists.”

Analyses

New analyses needed for decision making include flood inundation mapping to update old maps and increase the resolution in mapped areas and integrated information that is readily available and easy to communicate to the public.

Economic Benefit of Filling Information Gaps

Respondents were asked if they would experience a type of benefit from new/additional information and if yes, to describe benefit and estimate economic value of it. The top types of benefits and an example of the estimated economic value are presented below.

Observations

The top two benefits are “improved water quality” (67 percent) and “reduced flood damage” (62 percent). New or additional observation information could reduce flood damages at a rate of \$4 saved per every \$1 spent on mitigation.

Forecasts

The top two benefits are “reduced flood damage” (55 percent) and “improved drinking water supply” (55 percent). New or additional forecast information would lead to reduced flood damage through increased lead time for evacuations, mobilization of personnel and operation of flood control reservoirs.

Uncertainty

The top two benefits are “reduced flood damage” (48 percent) and “improved timing of water withdrawals and releases” (43 percent). New or additional uncertainty information would lead to reduced flood damage through improved model performance with greater spatial resolution for mapping, and improved planning of exit routes.

Analyses

The top two benefits are “reduced flood damage” (62 percent), “reduced drought damage” (48 percent). New or additional analyses would lead to improved water quality and reduce the costs of nonpoint-source practices to meet water quality TMDL, which currently cost \$250 million.

5. HUDSON RIVER BASIN RESULTS SUMMARY

Survey invitations were sent to 93 stakeholders; 42 surveys were submitted, 30 of which were complete. Of these 42 total responses, 39 were from individuals on the mailing list or colleagues to whom these emails were forwarded; the other three responses came from “untracked” participants (i.e., those who arrived at the survey via a link on the RBC website).

Respondent Demographics

Forty-three percent of the respondents in the Hudson River Basin indicated water quality (29 percent) or watershed management (14 percent) as their primary sector. Another 12 percent indicated fisheries and wildlife. About half of respondents (54 percent) are affiliated with a government agency. Fifty-five percent of respondents have been working on or interested in issues in the Hudson River basin for more than 15 years. Sixty-four percent of respondents have been interested in issues related to water resources management for more than 15 years and 62 percent deal with these issues on a daily basis.

Priority Issues

Respondents were asked to rate importance of five priorities facing the Hudson River basin and rank their top three issues. The top priority issues are “flooding” and “water quality,” although priority issues vary by sector. For example, while “flooding” and “water quality” were both rated as “extremely important” by 44 percent of respondents, “flooding” was rated as “extremely important” by 67 percent of watershed management sector respondents and 71 percent of other sector respondents. In comparison, “water quality” was rated as “extremely important” by 64 percent of water quality sector respondents and 75 percent of fisheries and wildlife sector respondents, but only 33 percent of watershed management sector respondents. When asked to rank the top three issues, 26 percent of respondents chose “flooding,” another 26 percent chose “water quality,” and another 23 percent chose “climate change and sea level rise.” Again, “flooding” was ranked a top priority more often by those in watershed, emergency, and reservoir management and other sectors, while “water quality” was ranked a top priority by those in water quality and recreation sectors.

Information Access and Use

Respondents were asked about their access to information (observations, forecasts, uncertainty, analyses), barriers to use of information, and timeframe for use of information. Across all types of information:

- Respondents have inadequate information or lack access to information about observations (66 percent), forecasts (68 percent), uncertainty (39 percent) and analyses (50 percent). Another 21 to 29 percent of respondents have no or limited access to uncertainty and analysis information.
- Lack of availability is the most common barrier to use across all information types and subcategories (20 to 65 percent).
- Respondents would use observation information for decision making over a timeframe greater than 1 year (39 percent) or less than 1 day (36 percent), forecast information over 1 to 3 days (43 percent), uncertainty information over more than 1 year (32 percent), and analyses over one month to one year (38 percent) or greater than one year (38 percent).
- Respondents would like to see updated observations, forecasts and uncertainty hourly or daily and new analyses annually, monthly, or weekly.

Information Gaps

Respondents were asked to rate the importance of new or additional information for decision making. For observations (79 percent), forecasts (73 percent) and uncertainties (48 percent) the most important category of information is surface hydrology. For analyses the most important category is hydrologic analyses (52 percent).

Respondents were then asked to describe, for the information types rated as very important or critical, the additional or new information needed for decision making. Brief summaries of their comments are presented below.

Observations

New observation information needed for decision making includes: expanded stream gage networks (including additional, smaller stream segments) with increased observations of surface water variables and water quality; and improved spatial and temporal resolution. Respondents also requested observations of salinity, dissolved oxygen, and bacterial contamination.

Forecasts

New forecast information needed for decision making includes increased spatial and temporal resolution of forecasts related to river flows, and improved accuracy. Responses also discussed how the information could be used, for example, for improved planning, management, and communication.

Uncertainty

New uncertainty information needed for decision making includes specific needs such as uncertainties related to oxygen levels, stream flow, temperature, and salinity at specific locations. Respondents also described the overall benefits of uncertainty information for communication, decision making, and planning.

Analyses

The comments on new analyses needed for decision making fall into two categories: examples of specific analyses and the format of the information. In terms of specific analyses, respondents mentioned long term trends analyses of water quality (especially the position of the salt front), statistical distributions of high and low parameters, water quality alerts for recreational users, and flood inundation mapping. In terms of information format, several respondents note that they need analyses that provide clear, straightforward results that can be communicated to and understood by the public.

Economic Benefit of Filling Information Gaps

Respondents were asked if they would experience a type of benefit from new/additional information and if yes, to describe benefit and estimate economic value of it. The top types of benefits and an example of the estimated economic value are presented below.

Observations

The top category is “improved water quality” (68 percent). New or additional observation information could lead to tens of millions of dollars in avoided costs to the wastewater treatment plants as a result of the development of better strategies to anticipate and deal with storm water.

Forecasts

The top two categories are “improved water quality” (47 percent) and “improved navigability” (47 percent). New or additional forecast information for water quality parameters such as harmful algal blooms would lead to more efficient operation of water supply plants and result in several million dollars of savings each year.

Uncertainty

The top three categories are “reduced flood damage” (37 percent), “improved water quality” (37 percent) and “Improved navigability” (37 percent). New or additional uncertainty information would lead to improved wastewater management, which would result in reduced impacts on fisheries in terms of population abundance and species composition.

Analyses

The top benefit is “improved water quality” (50 percent). New or additional analyses could improve wastewater treatment plant operation and save tens of millions of dollars.

APPENDIX A: IWRSS Stakeholder Survey Instrument

IWRSS is supported by a consortium consisting of U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers (USACE), and the National Oceanic and Atmospheric Administration (NOAA) (the “IWRSS partner agencies”). These 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;
- 3) Provide advanced hydrologic services to meet stakeholder needs.

It is critical that IWRSS services meet the needs of watershed planners and decision-makers. We are currently looking for opportunities to develop and demonstrate IWRSS. That’s why we need your participation in this effort! As practitioners, you are faced with both routine and emergency decisions that require optimization of limited water resources for sustainable supplies, adequate water quality, and the mitigation of socioeconomic impacts associated with extreme weather events, including floods and droughts. You know what information you need to support sustainable water resource management decisions. We need your expertise and advice so we can design and deliver practical, useful and high-value services. By participating in this effort, you will help shape the future direction of IWRSS.

The purpose of this survey is to provide an opportunity for you to articulate and prioritize your water resources information needs, describe how your information needs support decision making, and describe the benefit of filling your gaps in information. Results of the survey will drive future investment in information and services provided by IWRSS.

As a stakeholder in the **[RIVER BASIN]** River Basin, you have valuable insight into the key issues and decisions facing the region, as well as the types of information you need. We ask that you base your answers on your own experience, expertise, and/or role in your organization.

Survey and Navigational Instructions

Move forward or backward one page at a time by clicking on the Next Page or Previous Page buttons. (DO NOT use your browser’s Back or Forward buttons.)

Move from field to field by either clicking with your mouse or using the Tab key.

Use the pop-up explanation boxes. Phrases in blue font have explanatory pop-ups associated with them. Mouse over the blue type and you should see a box with information that could help you answer the question.

If you have any questions during the survey, you can email ERG from any page using the link in the bottom corner.

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

- Water Quality
- Hydropower
- Fish and Wildlife
- Other Energy Extraction
- Emergency Management
- River Commerce
- Reservoir Management
- Municipal and Industrial Water Supply

- Watershed Management
- Recreation
- Agriculture
- Other (please specify)

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

- Water Quality
- Hydropower
- Fish and Wildlife
- Other Energy Extraction
- Emergency Management
- River Commerce
- Reservoir Management
- Municipal and Industrial Water Supply
- Watershed Management
- Recreation
- Agriculture
- Other (please specify)

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

- Federal Government
- State Government
- Local Government
- Industry/Business
- Non-Profit Organization
- Academic
- Private Citizen

4) How many years have you been working on or interested in issues in the [RIVER BASIN] River basin?

- Less than 5 years
- 5 - 10 years
- 11 - 15 years
- More than 15 years

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

- Less than 5 years
- 5 - 10 years
- 11 - 15 years
- More than 15 years

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

- Daily
- Weekly
- Monthly
- Less than once a month

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?

- Yes, my job responsibilities include at least one of these tasks
- No, my job responsibilities do not include any of these tasks

II. Priorities.

For the purposes of this survey, we are using, as a starting point, the water resources priorities identified by the [RIVER BASIN COMMISSION]. The list of priorities, with examples of each is provided below.

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.")

	Not important at all 1	Slightly important 2	Important 3	Moderately important 4	Extremely important 5
ISSUE 1	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ISSUE 2	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
ISSUE 3	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
...	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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

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

III. Information Needs.

Next, we would like to ask you about the types of information you need to make decisions about the issue you ranked as your top priority issue.

We would like to focus on four categories of information provided by IWRSS partner agencies:

- > Observations: Data collected using scientific instruments. Examples include meteorological observations such as air temperature, dew point, and precipitation and surface hydrology observations such as river discharge/streamflow, river velocity, and soil moisture.
- > Forecasts: Meteorological, climatological, and hydrologic information for future times at given locations derived from a model. Examples include meteorological forecasts of atmospheric pressure, atmospheric freezing levels, and wind speed and surface hydrology forecasts of river discharge/streamflow, river stage/elevation, and river velocity.
- > Uncertainty: Quantification of uncertainty that arises from several sources, including model structure, parameters, initial conditions, and data used to drive and evaluate the model. For example, the probability of exceeding a flood level quantifies the model and data uncertainty for a river level forecast at a given time and location.
- > Analyses: Public alerts, guidance, estimates, maps, and information derived from the evaluation and integration of meteorological, hydrologic, and climatological data.

[In the previous section, you indicated that your highest priority issue is: [Insert highest priority issue here.]

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

	I do not need this type of information	I have adequate information to meet my needs	I have the information, but it is not adequate or needs improvement	I need this type of information by currently have no or very limited access to it.
Observations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Forecasts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Uncertainty	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Analyses	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

[In Question 11, if respondent DID NOT select “I do not need this type of information”, for:

- a) Observations then ask: Q12 – Q13,
 - b) Forecasts then ask: Q14 – Q15,
 - c) Uncertainties then ask: Q16 – Q17,
 - d) Analyses then ask: Q18 – Q19;
- Otherwise go to [END].]

Observation Information Details

You indicated that you use or are interested in using observation information for decision making.

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

- Immediate
- 1 day
- 1 to 3 days
- 3 to 5 days
- 5 to 7 days
- 1 week to 1 month
- 1 month to 1 year
- > 1 year
- None of the above

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

- Every 15 minutes or less
- 15 minutes to 1 hour
- Hourly
- Daily
- Weekly
- Monthly
- Quarterly
- Annually
- None of the above

Forecast Information Details

You indicated that you use or are interested in using forecast information for decision making.

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

- Immediate
- 1 day
- 1 to 3 days
- 3 to 5 days
- 5 to 7 days
- 1 week to 1 month
- 1 month to 1 year
- > 1 year
- None of the above

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

- Every 15 minutes or less
- 15 minutes to 1 hour
- Hourly
- Daily
- Weekly
- Monthly
- Quarterly

- Annually
- None of the above

Uncertainty Information Details

You indicated that you use or are interested in using uncertainty information for decision making.

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

- Immediate
- 1 day
- 1 to 3 days
- 3 to 5 days
- 5 to 7 days
- 1 week to 1 month
- 1 month to 1 year
- > 1 year
- None of the above

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

- Every 15 minutes or less
- 15 minutes to 1 hour
- Hourly
- Daily
- Weekly
- Monthly
- Quarterly
- Annually
- None of the above

Analyses Information Details

You indicated that you use or are interested in using analyses information for decision making.

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

- Immediate
- 1 day
- 1 to 3 days
- 3 to 5 days
- 5 to 7 days
- 1 week to 1 month
- 1 month to 1 year
- > 1 year
- None of the above

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

- Every 15 minutes or less
- 15 minutes to 1 hour
- Hourly
- Daily
- Weekly
- Monthly
- Quarterly
- Annually
- None of the above

[In Question 11, if respondent selected “I have the information, but it is not adequate or needs improvement” or “I need this type of information by currently have no or very limited access to it,” for:

- a) Observations then ask: Q20,
 - b) Forecasts then ask: Q21,
 - c) Uncertainties then ask: Q22,
 - d) Analyses then ask: Q23;
- Otherwise go to [END].]

Barriers to Use 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?

	Not available in a format that I can use	Don't know where to get the information	Accuracy is not sufficient	Resolution is not sufficient	Not enough information available	Don't understand how information can be used	I don't use this type of information
Surface hydrology information	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Groundwater hydrology	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Water quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Drainage basin management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Meteorology	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Snow/ice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

21) 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 forecast information?

	Not available in a format that I can use	Don't know where to get the information	Accuracy is not sufficient	Resolution is not sufficient	Not enough information available	Don't understand how information can be used	I don't use this type of information
Surface hydrology information	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Groundwater hydrology	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Water quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Drainage basin management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Meteorology	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Snow/ice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

22) 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 uncertainty information?

	Not available in a format that I can use	Don't know where to get the information	Accuracy is not sufficient	Resolution is not sufficient	Not enough information available	Don't understand how information can be used	I don't use this type of information
Surface hydrology information	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Groundwater hydrology	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Water quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Drainage basin management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Meteorology	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Snow/ice	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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

	Not available in a format that I can use	Don't know where to get the information	Accuracy is not sufficient	Resolution is not sufficient	Not enough information available	Don't understand how information can be used	I don't use this type of information
Public alerts	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Meteorological analyses	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hydrologic analyses	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Climatological analyses	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flood inundation mapping	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Information integration	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

IV. Importance for Decision Making and Economic Value

Next we would like to ask you about the importance of different types of information to your decision making and the economic value of having additional and/or new information to support your decision making on your top priority issue.

We are trying to understand the economic value which may be realized through information provided by IWRSS partner agencies (NOAA, USGS, USACE). For example, improved data can a) help communities provide advanced notice of flood events to reduce personal property damages; b) help planners make more informed decisions about water resources capital investments or c) help operators improve the efficiency of hydropower generation.

Your responses in this section are critical to this effort; the IWRSS partner agencies need your feedback about the value of this information in order to build a business case for making new information available. Accurate, detailed answers to the following questions will help the IWRSS partner agencies add new and improved information to the suite of products and services already offered.

[In Question 11, if respondent selected "I have the information, but it is not adequate or needs improvement" or "I need this type of information by currently have no or very limited access to it," for:

- a) Observations then ask: Q24- Q27,
- b) Forecasts then ask: Q28-Q31,
- c) Uncertainties then ask: Q32-Q35,
- d) Analyses then ask: Q36-Q39;

Otherwise go to [END].]

Observation Information Details

24) If additional or new observation information were available that meets your decision-making needs, how important would this information be to making decisions in the course of your work?

	Not Important	Minor Importance	Somewhat Important	Very Important	Critical
Surface Hydrology	<input type="radio"/>				
Groundwater Hydrology	<input type="radio"/>				
Water Quality	<input type="radio"/>				
Drainage Basin Management	<input type="radio"/>				
Meteorology	<input type="radio"/>				
Snow/ice	<input type="radio"/>				

Please consider the types of information you indicated would be 'Very Important' or 'Critical' for making decisions in the course of your work: [PROMPT RESPONSES TO PREVIOUS QUESTION]

25) For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making. _____

[If the respondent answered “No” to Question 7, then skip Q26 – Q27.]

26) Would you experience any of the following impacts or benefits from using additional or new observational information from IWRSS partner agencies? If you would experience these impacts or benefits, please describe a monetary estimate of the value.

	No, this is not something that I would experience	Yes, this is something that I would experience
Reduced flood damage (property damage, injury or loss of life, lost business, recovery costs)	<input type="radio"/>	<input type="radio"/>
Reduced drought damage	<input type="radio"/>	<input type="radio"/>
Improved wastewater management or treatment	<input type="radio"/>	<input type="radio"/>
Improved stormwater management or treatment	<input type="radio"/>	<input type="radio"/>
Improved drinking water supply or treatment	<input type="radio"/>	<input type="radio"/>
Improved water quality	<input type="radio"/>	<input type="radio"/>
Improved navigability (shipping, recreation)	<input type="radio"/>	<input type="radio"/>
Increased efficiency of hydroelectric power generation	<input type="radio"/>	<input type="radio"/>
Improved timing of water withdrawals and releases or its management	<input type="radio"/>	<input type="radio"/>
Other type of impact?	<input type="radio"/>	<input type="radio"/>

27) For those impacts or benefits you selected as "yes" above, please provide a description in the appropriate box below of the cost avoided or the benefit gained per year or per event; or describe the capital investment decisions dependent upon this information. For example, the additional or new information that would be provided by the IWRSS partner agencies could "help protect \$2 billion of personal property from flood damage each year" or "eliminate the need to build a multi-billion dollar water treatment facility."

Forecast Information Details

28) If additional or new forecast information were available that meets your decision-making needs, how important would this information be to making decisions in the course of your work?

	Not Important	Minor Importance	Somewhat Important	Very Important	Critical
Surface Hydrology	<input type="radio"/>				
Groundwater Hydrology	<input type="radio"/>				
Water Quality	<input type="radio"/>				
Drainage Basin Management	<input type="radio"/>				
Meteorology	<input type="radio"/>				
Snow/ice	<input type="radio"/>				

Please consider the types of information you indicated would be 'Very Important' or 'Critical' for making decisions in the course of your work: [PROMPT RESPONSES TO PREVIOUS QUESTION]

29) For the information types you rated as very important or critical, please describe the additional or new forecast information that you need for your decision making.

[If the respondent answered "No" to Question 7, then skip Q30 – Q31.]

30) Would you experience any of the following impacts or benefits from using additional or new forecast information from IWRSS partner agencies? If you would experience these impacts or benefits, please describe a monetary estimate of the value.

	No, this is not something that I would experience	Yes, this is something that I would experience
Reduced flood damage (property damage, injury or loss of life, lost business, recovery costs)	<input type="radio"/>	<input type="radio"/>
Reduced drought damage	<input type="radio"/>	<input type="radio"/>
Improved wastewater management or treatment	<input type="radio"/>	<input type="radio"/>
Improved stormwater management or treatment	<input type="radio"/>	<input type="radio"/>
Improved drinking water supply or treatment	<input type="radio"/>	<input type="radio"/>

	No, this is not something that I would experience	Yes, this is something that I would experience
Improved water quality	<input type="radio"/>	<input type="radio"/>
Improved navigability (shipping, recreation)	<input type="radio"/>	<input type="radio"/>
Increased efficiency of hydroelectric power generation	<input type="radio"/>	<input type="radio"/>
Improved timing of water withdrawals and releases or its management	<input type="radio"/>	<input type="radio"/>
Other type of impact?	<input type="radio"/>	<input type="radio"/>

31) For those impacts or benefits you selected as "yes" above, please provide a description in the appropriate box below of the cost avoided or the benefit gained per year or per event; or describe the capital investment decisions dependent upon this information. For example, the additional or new information that would be provided by the IWRSS partner agencies could "help protect \$2 billion of personal property from flood damage each year" or "eliminate the need to build a multi-billion dollar water treatment facility."

Uncertainty Information Details

32) If additional or new uncertainty information were available that meets your decision-making needs, how important would this information be to making decisions in the course of your work?

	Not Important	Minor Importance	Somewhat Important	Very Important	Critical
Surface Hydrology	<input type="radio"/>				
Groundwater Hydrology	<input type="radio"/>				
Water Quality	<input type="radio"/>				
Drainage Basin Management	<input type="radio"/>				
Meteorology	<input type="radio"/>				
Snow/ice	<input type="radio"/>				

Please consider the types of information you indicated would be 'Very Important' or 'Critical' for making decisions in the course of your work: [PROMPT RESPONSES TO PREVIOUS QUESTION]

33) For the information types you rated as very important or critical, please describe the additional or new uncertainty information that you need for your decision making.

[If the respondent answered “No” to Question 7, then skip Q34 – Q35.]

34) Would you experience any of the following impacts or benefits from using additional or new uncertainty information from IWRSS partner agencies? If you would experience these impacts or benefits, please describe a monetary estimate of the value.

	No, this is not something that I would experience	Yes, this is something that I would experience
Reduced flood damage (property damage, injury or loss of life, lost business, recovery costs)	<input type="radio"/>	<input type="radio"/>
Reduced drought damage	<input type="radio"/>	<input type="radio"/>
Improved wastewater management or treatment	<input type="radio"/>	<input type="radio"/>
Improved stormwater management or treatment	<input type="radio"/>	<input type="radio"/>
Improved drinking water supply or treatment	<input type="radio"/>	<input type="radio"/>
Improved water quality	<input type="radio"/>	<input type="radio"/>
Improved navigability (shipping, recreation)	<input type="radio"/>	<input type="radio"/>
Increased efficiency of hydroelectric power generation	<input type="radio"/>	<input type="radio"/>
Improved timing of water withdrawals and releases or its management	<input type="radio"/>	<input type="radio"/>
Other type of impact?	<input type="radio"/>	<input type="radio"/>

35) For those impacts or benefits you selected as "yes" above, please provide a description in the appropriate box below of the cost avoided or the benefit gained per year or per event; or describe the capital investment decisions dependent upon this information. For example, the additional or new information that would be provided by the IWRSS partner agencies could "help protect \$2 billion of personal property from flood damage each year" or "eliminate the need to build a multi-billion dollar water treatment facility."

Analyses Information Details

36) If additional or new analyses information were available that meets your decision-making needs, how important would this information be to making decisions in the course of your work?

	Not Important	Minor Importance	Somewhat Important	Very Important	Critical
Public alerts	<input type="radio"/>				
Meteorological analyses	<input type="radio"/>				
Hydrologic analyses	<input type="radio"/>				
Climatological analyses	<input type="radio"/>				
Flood inundation mapping	<input type="radio"/>				
Information integration	<input type="radio"/>				

Please consider the types of information you indicated would be 'Very Important' or 'Critical' for making decisions in the course of your work: [PROMPT RESPONSES TO PREVIOUS QUESTION]

37) For the information types you rated as very important or critical, please describe the additional or new analyses information that you need for your decision making.

[If the respondent answered “No” to Question 7, then skip Q38 – Q39.]

38) Would you experience any of the following impacts or benefits from using additional or new analyses information from IWRSS partner agencies? If you would experience these impacts or benefits, please describe a monetary estimate of the value.

	No, this is not something that I would experience	Yes, this is something that I would experience
Reduced flood damage (property damage, injury or loss of life, lost business, recovery costs)	<input type="radio"/>	<input type="radio"/>
Reduced drought damage	<input type="radio"/>	<input type="radio"/>
Improved wastewater management or treatment	<input type="radio"/>	<input type="radio"/>
Improved stormwater management or treatment	<input type="radio"/>	<input type="radio"/>
Improved drinking water supply or treatment	<input type="radio"/>	<input type="radio"/>
Improved water quality	<input type="radio"/>	<input type="radio"/>
Improved navigability (shipping, recreation)	<input type="radio"/>	<input type="radio"/>
Increased efficiency of hydroelectric power generation	<input type="radio"/>	<input type="radio"/>
Improved timing of water withdrawals and releases or its management	<input type="radio"/>	<input type="radio"/>
Other type of impact?	<input type="radio"/>	<input type="radio"/>

39) For those impacts or benefits you selected as "yes" above, please provide a description in the appropriate box below of the cost avoided or the benefit gained per year or per event; or describe the capital investment decisions dependent upon this information. For example, the additional or new information that would be provided by the IWRSS partner agencies could "help protect \$2 billion of personal property from flood damage each year" or "eliminate the need to build a multi-billion dollar water treatment facility."

Additional or New Information Details

40) Are there any other types of information beyond *observations, forecasts, uncertainty, and analyses* that you would rank as needing improvement and critical for informing decisions?

- Yes, there are.
- No, there are not. [Go to END.]

41) Please describe the other types of information that you would rank as needing improvement and critical for informing decisions on: _____

[If the respondent answered “No” to Question 7, then skip Q42 – Q43.]

42) Would you experience any of the following impacts or benefits from using additional or new information from IWRSS partner agencies? If you would experience these impacts or benefits, please describe a monetary estimate of the value.

	No, this is not something that I would experience	Yes, this is something that I would experience
Reduced flood damage (property damage, injury or loss of life, lost business, recovery costs)	<input type="radio"/>	<input type="radio"/>
Reduced drought damage	<input type="radio"/>	<input type="radio"/>
Improved wastewater management or treatment	<input type="radio"/>	<input type="radio"/>
Improved stormwater management or treatment	<input type="radio"/>	<input type="radio"/>
Improved drinking water supply or treatment	<input type="radio"/>	<input type="radio"/>
Improved water quality	<input type="radio"/>	<input type="radio"/>
Improved navigability (shipping, recreation)	<input type="radio"/>	<input type="radio"/>
Increased efficiency of hydroelectric power generation	<input type="radio"/>	<input type="radio"/>
Improved timing of water withdrawals and releases or its management	<input type="radio"/>	<input type="radio"/>
Other type of impact?	<input type="radio"/>	<input type="radio"/>

43) For those impacts or benefits you selected as "yes" above, please provide a description in the appropriate box below of the cost avoided or the benefit gained per year or per event; or describe the capital investment decisions dependent upon this information. For example, the additional or new information that would be provided by the IWRSS partner agencies could "help protect \$2 billion of personal property from flood damage each year" or "eliminate the need to build a multi-billion dollar water treatment facility."

OMB Control Number: 0648-0342

Public reporting burden for this collection of information is estimated to average 30 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other suggestions for reducing this burden to Thomas Graziano, NOAA National Weather Service, 1325 East-West Highway, SSMC2 Rm.13426, Silver Spring, MD 20910.

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APPENDIX B: Potomac River Basin Detailed Survey Results

Potomac River Basin

Responses

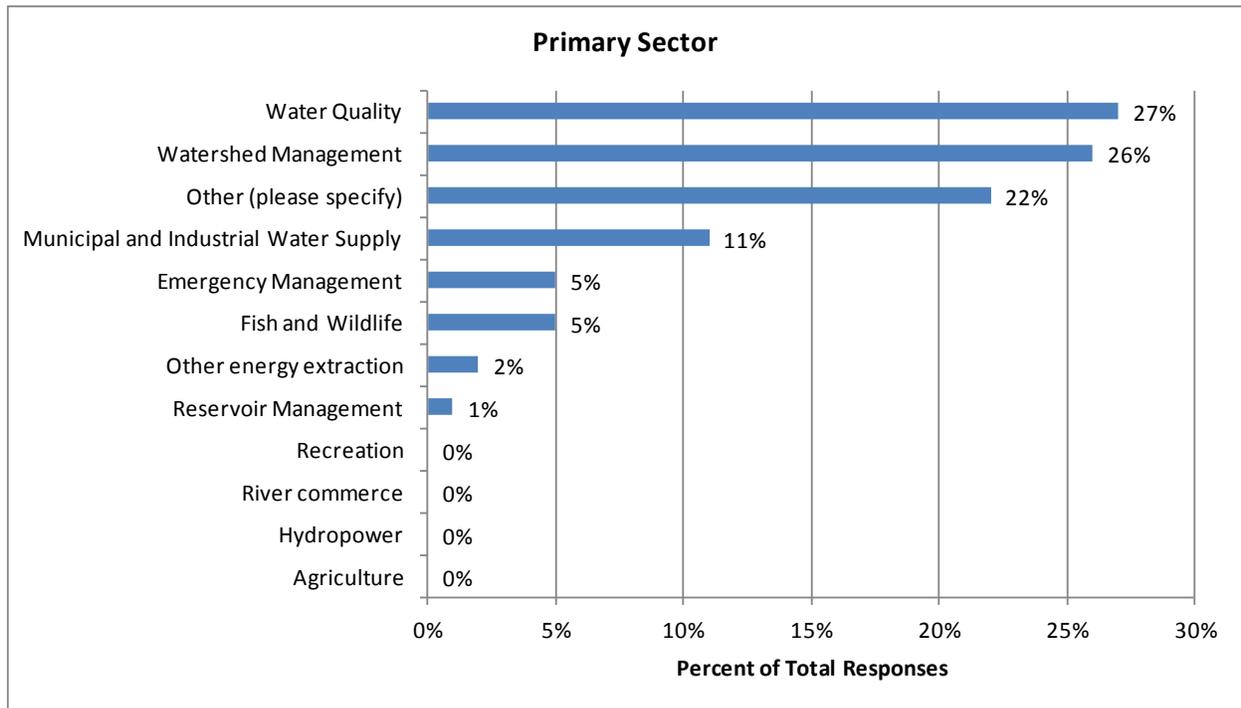
Personalized survey invitation emails were sent to 276 people. ERG received 81 total responses, including 53 complete surveys (i.e., respondent reached the end of the survey and hit submit) and 28 incomplete surveys (i.e., respondent closed out of the survey before completing). Of these 81 total responses, 75 were from individuals on the mailing list or colleagues to whom those emails were forwarded; the other 6 responses came from “untracked” participants (i.e., those who arrived at the survey via a link on the RBC website). To the maximum extent possible, the incomplete surveys were included in the results presented below.

Respondent Demographics

Respondents were asked to select the primary sector in which their work or interest is focused in the Potomac River basin, see Figure 6-3. Half of respondents indicated that their work or interest was primarily focused on water quality (27 percent) or watershed management (26 percent). Twenty-two percent, however, specified an “other” sector (other than a categorized response option). Their verbatim responses were:

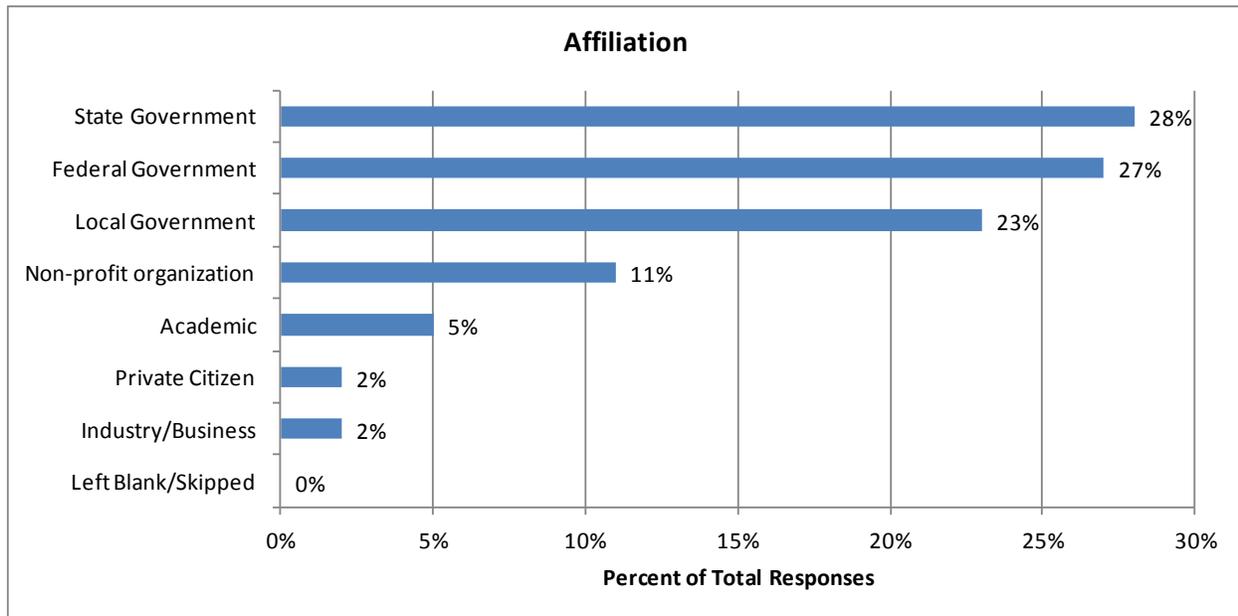
- Broad, state of PA- partner in River basin mgt
- Conservation for nature and people
- Ecosystem indicators
- Fisheries and ecosystem management
- Flooding
- Floodplain management (2)
- Forest management
- Instream Flow Protection
- Land Conservation and Management (NPS)
- NHD, WBD, tide-referenced shoreline, bathy
- Planning
- State government
- Stormwater Management
- Surface water quantity
- Water Quantity
- Water Resource Management (2)

Figure 6-3. Responses to “Please select the primary sector in which your work or interest is focused in the Potomac River Basin.”



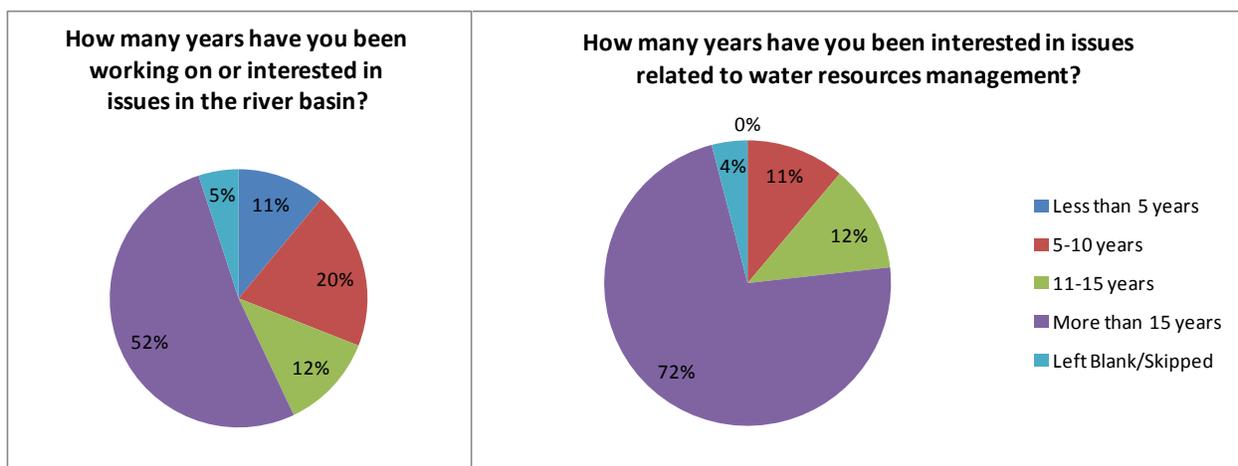
Respondents were asked to indicate the affiliation that best describes their work or interest in the Potomac River basin, see Figure 6-4. The majority of respondents (78 percent) are affiliated with a government agency (federal, 28 percent; state, 27 percent; local, 23 percent); 11 percent are affiliated with a non-profit organization.

Figure 6-4. Responses to “Please select the affiliation that best describes your work or interest in the Potomac River Basin.”



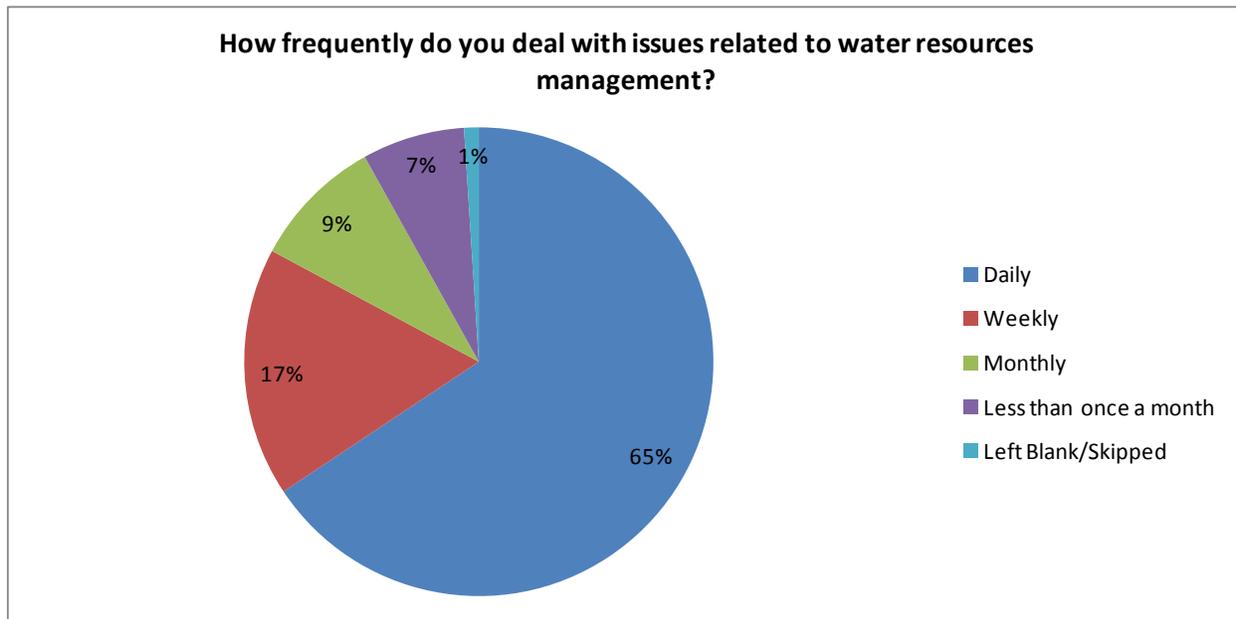
Respondents were asked to indicate how many years they have been working on or interested in issues in the Potomac River basin and how many years they have been interested in issues related to water resources management, see Figure 6-5. Half of respondents have been working on or interested in issues in the Potomac River basin for more than 15 years. Accordingly, over half (75 percent) have also been working on or interested in issues related to water resources management for more than 15 years.

Figure 6-5. Number of years respondent has been working on or interested in issues in the river basin and water resources management.



The survey asked how frequently respondents deal with issues related to water resources management, see Figure 6-6. Over 75 percent of respondents deal with such issues on a daily or weekly basis.

Figure 6-6. Frequency of dealing with water resources management issues.



Almost all respondents (91 percent) have job responsibilities that include providing input to strategic planning; program, facility, operations or financial management; or project planning decisions on water resources information.

Priority Issues

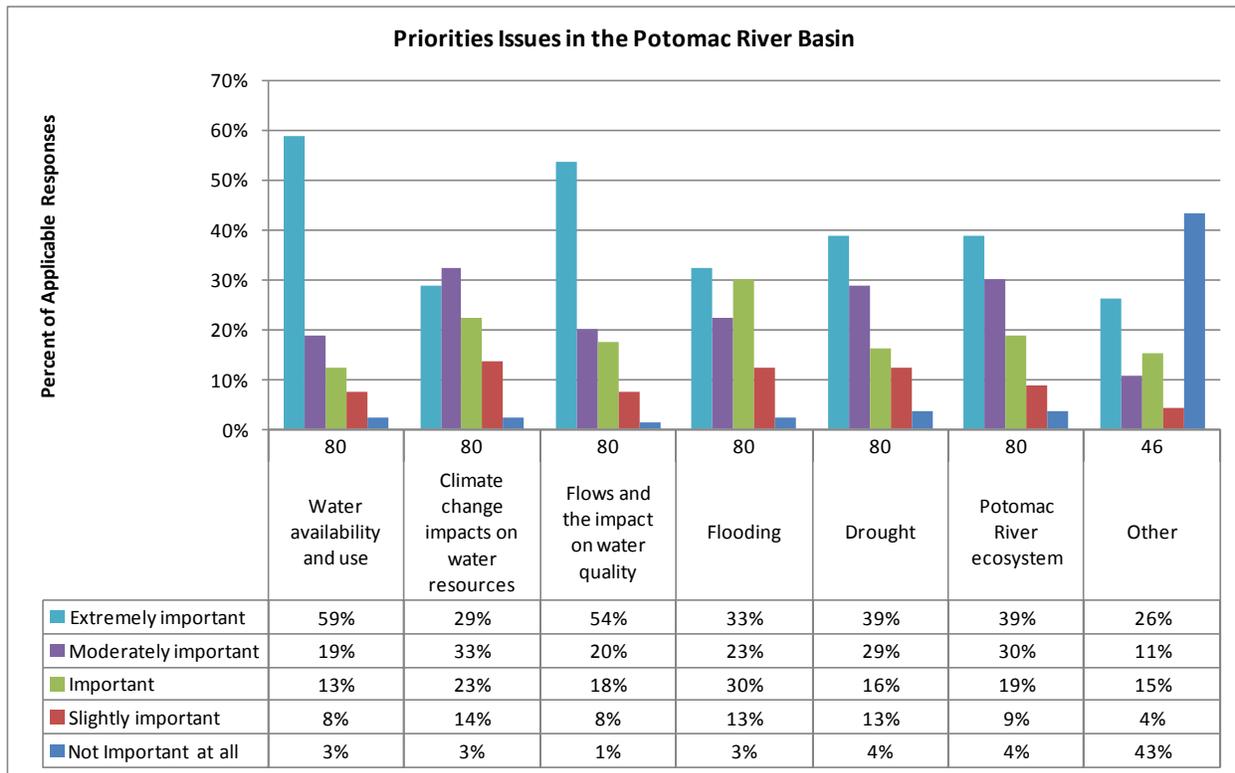
Prior to the survey, priority issues facing the Potomac River basin were identified as follows:

- **Water availability and use:** This issue includes availability of surface water and groundwater under current and future conditions for all uses, maintenance of environmental flows, and source water protection.
- **Climate change impacts on water resources:** This issue includes the effects of potential climate change on water availability and use, extreme events, and water quality.
- **Flows and the impact on water quality:** This issue includes water quality and quantity relationships with respect to point- and nonpoint-source pollution, land use impacts, Total Maximum Daily Loads (TMDLs), wastewater treatment plant discharges and other point sources, stormwater and impervious cover.
- **Flooding:** This issue includes geomorphic, ecological, and human impacts associated with flooding, and flood management, preparedness and response.
- **Drought:** This issue includes geomorphic, ecological, and human impacts associated with droughts; drought management, preparedness and response; flow prediction during low flow periods; and quantification of drought risks.
- **Potomac River ecosystem:** This issue includes harmful impacts on aquatic ecology resulting from human and natural sources.

Respondents were asked to indicate the importance of these issues and to rank the top three issues that they think are the most important, see Figure 6-7. Over half of respondents identified “water availability and use” and “flows and the impact on water quality” as extremely important. In addition, between 55 and 69 percent indicated that the remaining issues (“climate change impacts on water resources,” “flooding,” “drought,” and the “Potomac River ecosystem”) were moderately or extremely important. Respondents were also invited to describe any additional concerns that they would rank as one of their top three most important issues. Many of the “other” priority issues identified in verbatim responses probably could be included under the pre-determined priority issues. These verbatim responses were:

- Environmental stressor identification.
- Health of biological indicators - benthic macroinvertebrates, fish, crayfish, etc.
- Impact of Agriculture and Forest Lands on Water quality.
- Interbasin transfers and surface water-groundwater interactions.
- Invasive species. (2)
- Invasive fishes.
- Land use.
- Land use patterns and development pressure on habitat and fisheries resources.
- Nutrient and Sediment loads to the Tidal Potomac.
- Our program is driven by regulatory compliance with Clean Water Act programs.
- Please note that I am offering these opinions broadly - I do not live or work in the Potomac River Basin. I respond based on the importance of these issues to me in any river basin. Same for the question below.
- Presume it's captured under "ecosystem," but water as a habitat for fish species and associated food chain/ecosystem dynamics.
- Recreation.
- Sediment and nutrient inputs of agriculture, sediment impacts from unpaved roads.
- The primary issue is how urban activities affect local streams and Potomac water quality; I'm assuming that's covered by your "flows and the impact on water quality."
- TMDLs.
- Water quality.
- Water quality: nutrients.

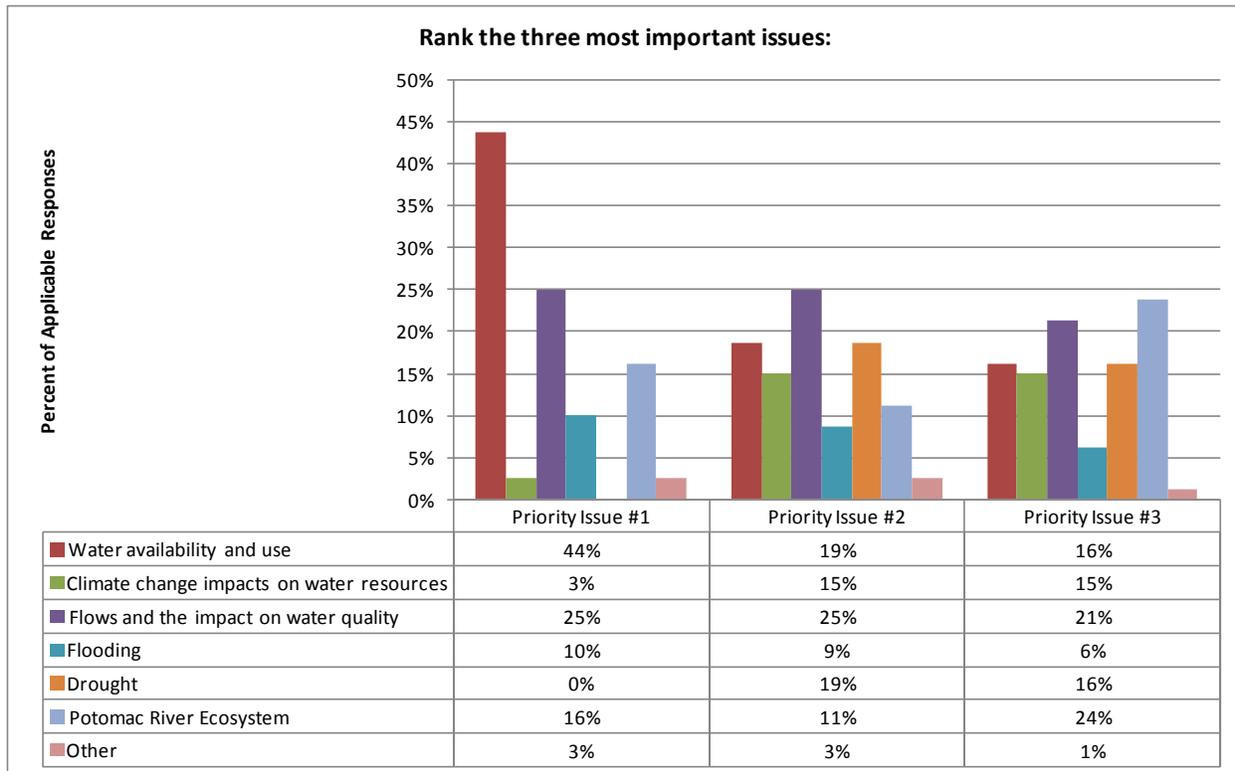
Figure 6-7. Responses to “Please indicate the importance of each of the following issues.”



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 81 survey responses. Those who skipped the question or never saw the question are not included here.

When ranking the most important issues facing the Potomac River basin, 44 percent identified “water availability and use” as most important. Another quarter of respondents indicated “flows and the impact on water quality” as the most important. The Potomac River ecosystem was the third most commonly identified issue. See Figure 6-8.

Figure 6-8. Responses to “Looking at the issues as a group, please rank the three most important issues that you think are facing the Potomac River Basin.”

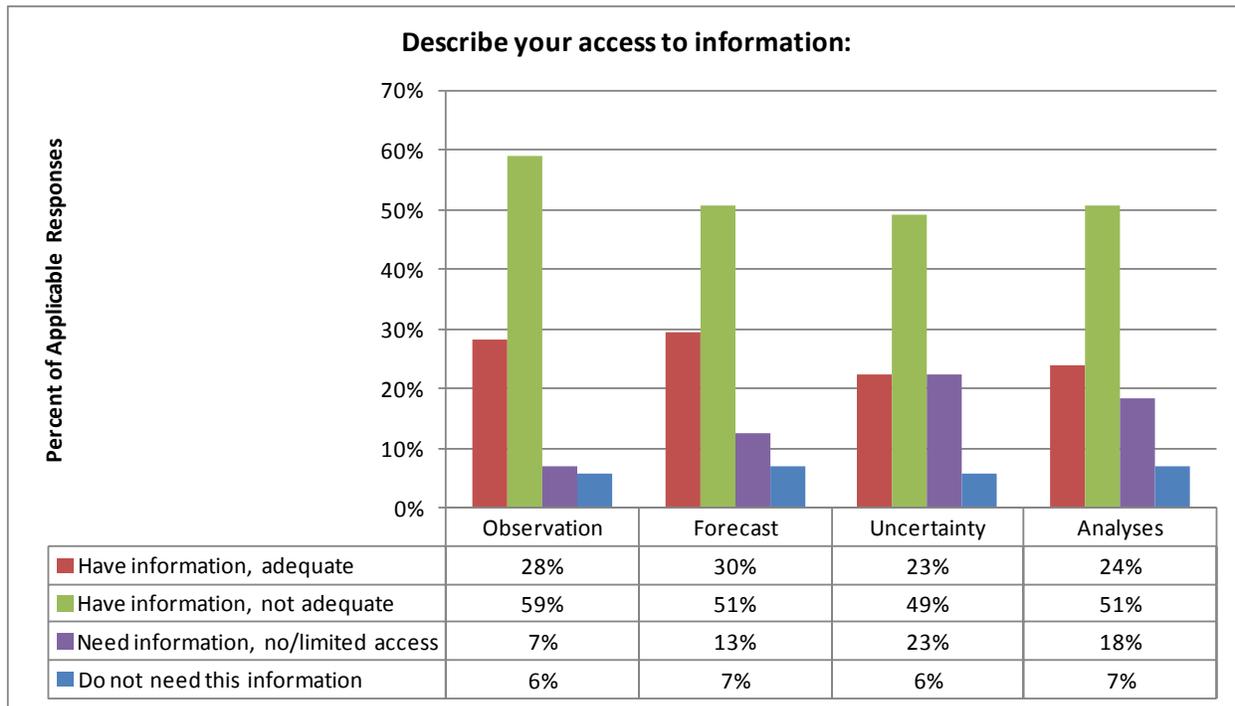


Note: There were 80 responses to this question.

Information Access and Use

Respondents described their access to observations, forecasts, uncertainty, and analyses information needed for informing decisions, see Figure 6-9. Across all types of information (observation, forecast, uncertainty, analyses), 23 to 30 percent of respondents have adequate information and 49 to 59 percent indicated that they have information but it is inadequate. While only 7 percent lack access to observation information, 23 percent lack access to uncertainty information. Very few respondents (6-7 percent) do not need the specific information.

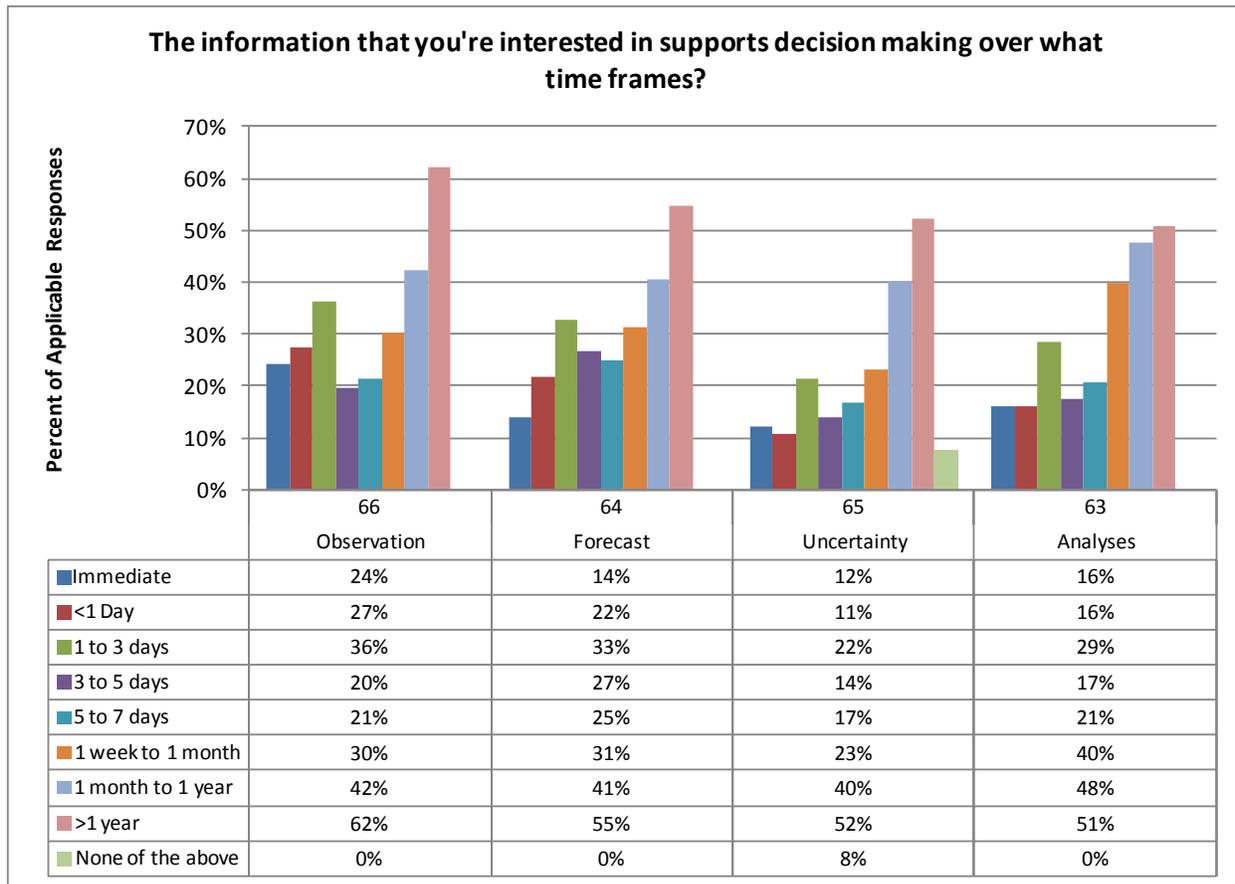
Figure 6-9. Responses to “For your highest priority issue, describe your access to the following types of information needed for informing decisions.”



Note: There were 71 responses to this question.

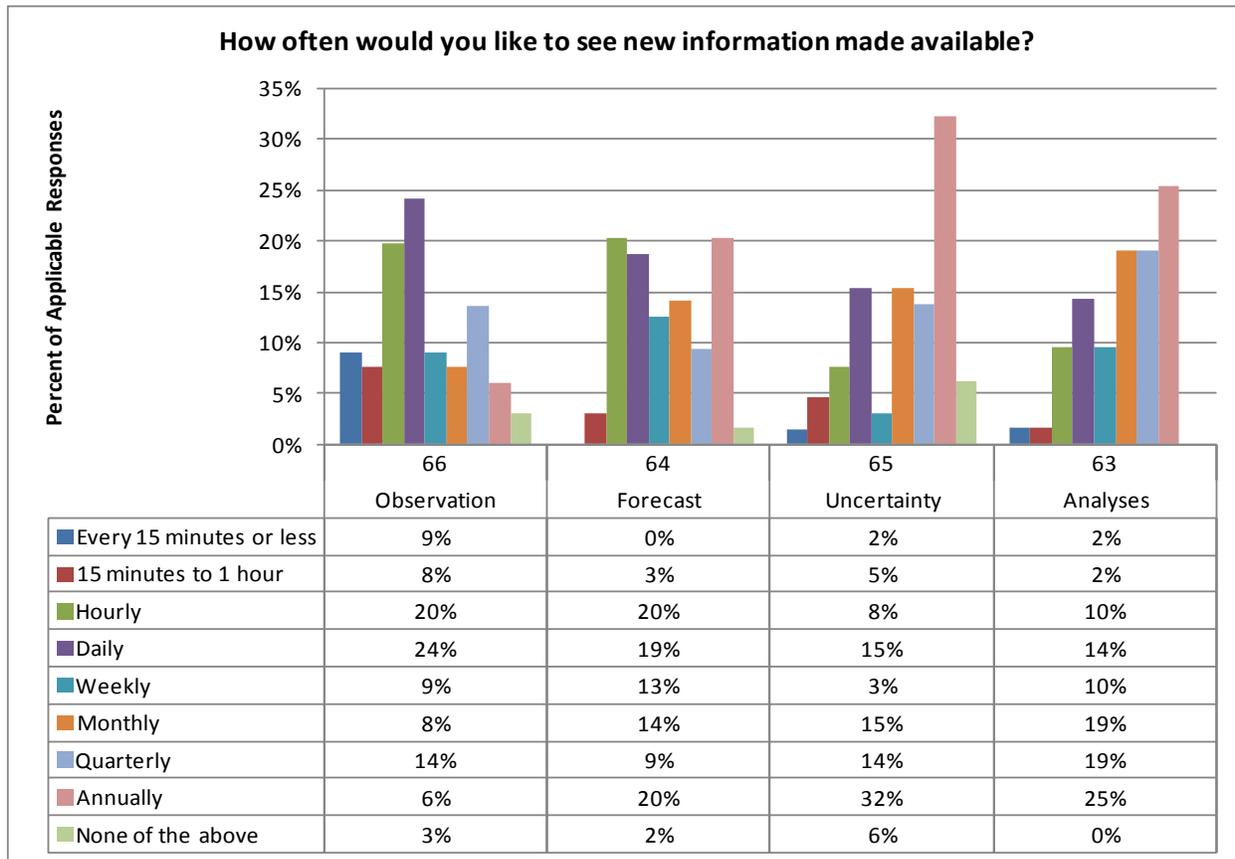
Respondents were also asked to indicate the decision-making time frames that would be supported by the information in which they were interested, see Figure 6-10, and how often they would like to see new information made available for use, Figure 6-11. Regarding timeframes, most respondents selected 1 month to 1 year and more than a year, regardless of information type. Respondents would like to see new or additional observation information made available hourly or daily; forecast information available hourly, daily or annually; uncertainty information available yearly; and analyses information available annually, monthly or quarterly.

Figure 6-10. Summary of the time frame for using information regarding observations, forecasts, uncertainty, and analyses for decision making.



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 81 survey responses. Those who never saw the question (i.e., incomplete or not applicable) are not included here.

Figure 6-11. Summary of respondent preferences for new observation, forecast, uncertainty, and analyses information to be available.



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 81 survey responses. Those who never saw the question (i.e., incomplete or not applicable) are not included here.

Respondents were asked to identify barriers to use for subsets of the four information categories (observations, forecasts, uncertainty and analyses).

For observations, forecasts, and uncertainties:

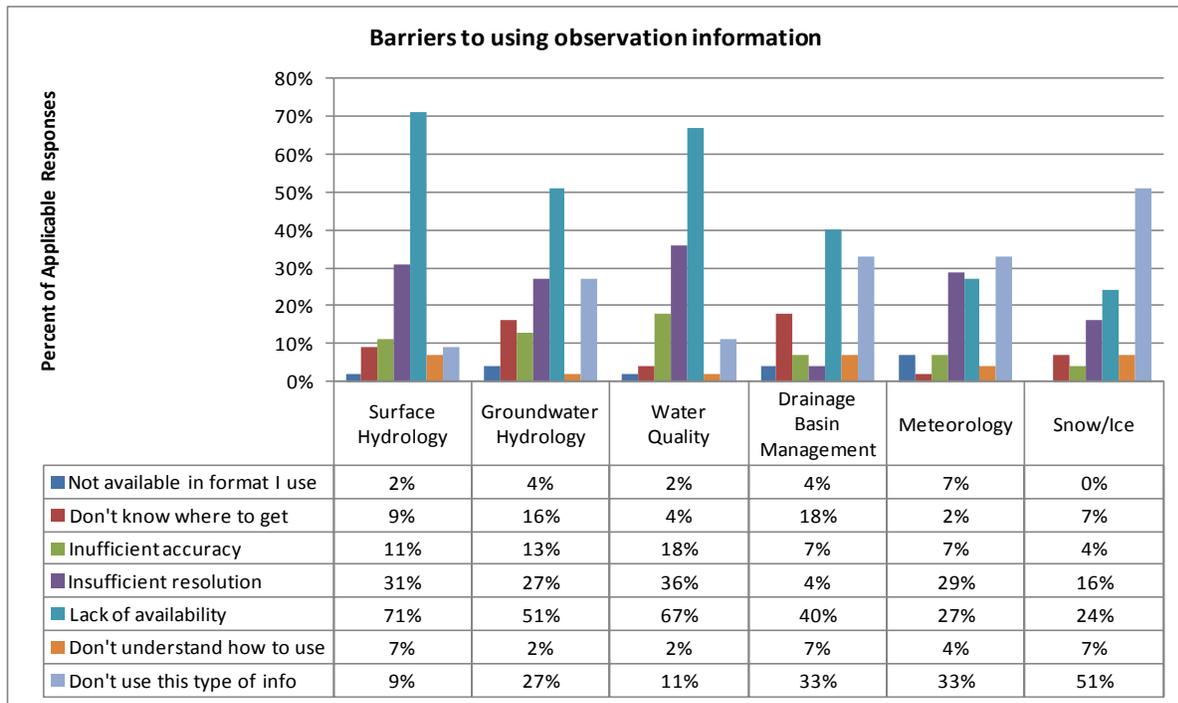
- Surface hydrology.
- Groundwater hydrology.
- Water quality.
- Drainage basin management.
- Meteorology.
- Snow/ice.

And for analyses:

- Public alerts.
- Meteorological analyses.
- Hydrologic analyses.
- Climatological analyses.
- Flood inundation mapping.
- Information integration.

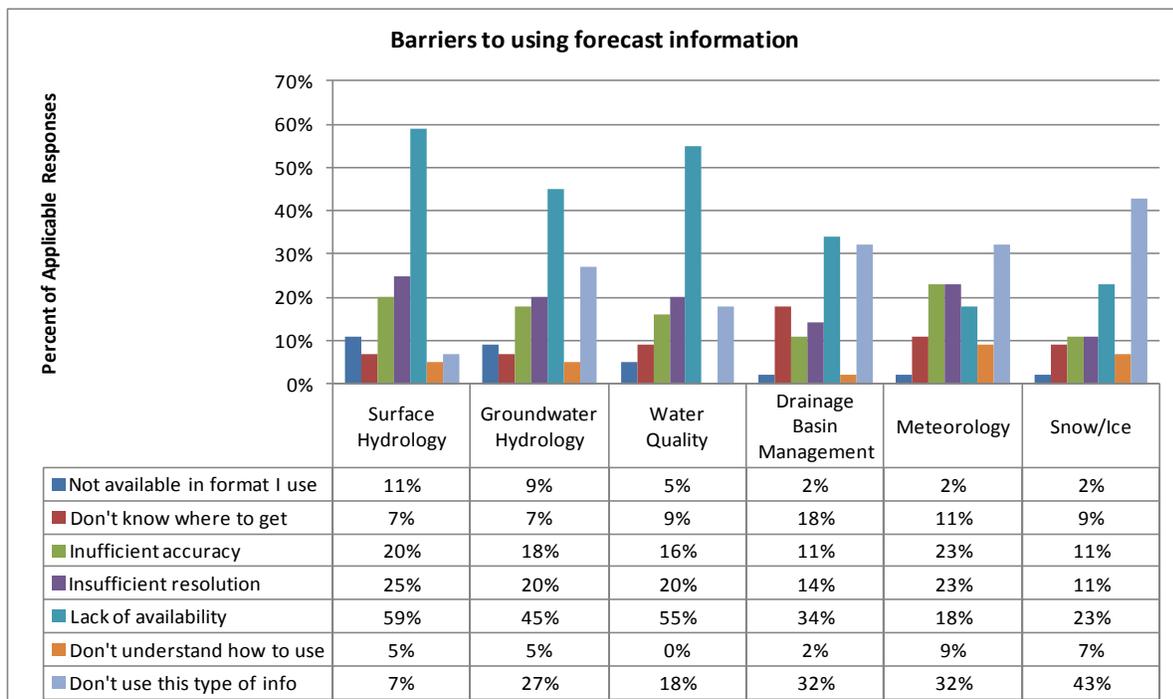
Results show that barriers to use are fairly consistent across the four information types. For example, lack of availability is the most common barrier to use. Insufficient resolution and accuracy are also common barriers to use. For observation, forecast, and uncertainty information, 29-33 percent of respondents do not use drainage basin management information or meteorology information, and 43-51 percent of respondents do not use snow/ice information. See Figure 6-12 through Figure 6-15.

Figure 6-12. “What are some of the barriers to using the following types of observation information?”



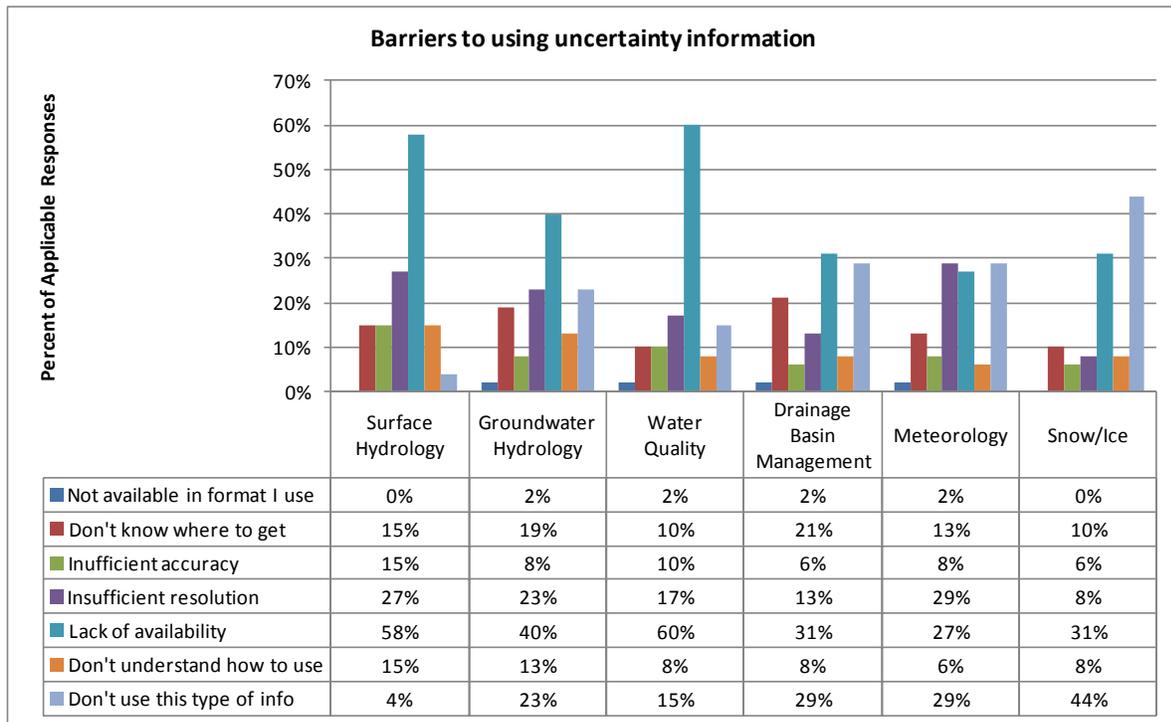
Note: There were 45 responses to this question.

Figure 6-13. “What are some of the barriers to using the following types of forecast information?”



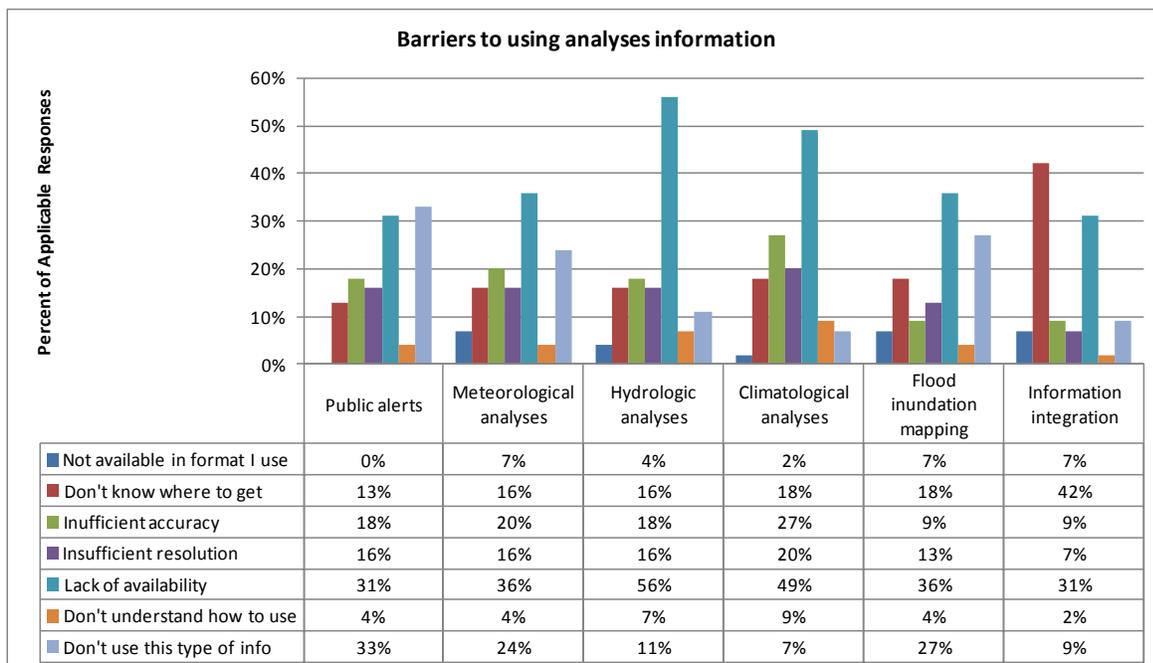
Note: There were 44 responses to this question.

Figure 6-14. “What are some of the barriers to using the following types of uncertainty information?”



Note: There were 48 responses to this question.

Figure 6-15. “What are some of the barriers to using the following types of analyses?”



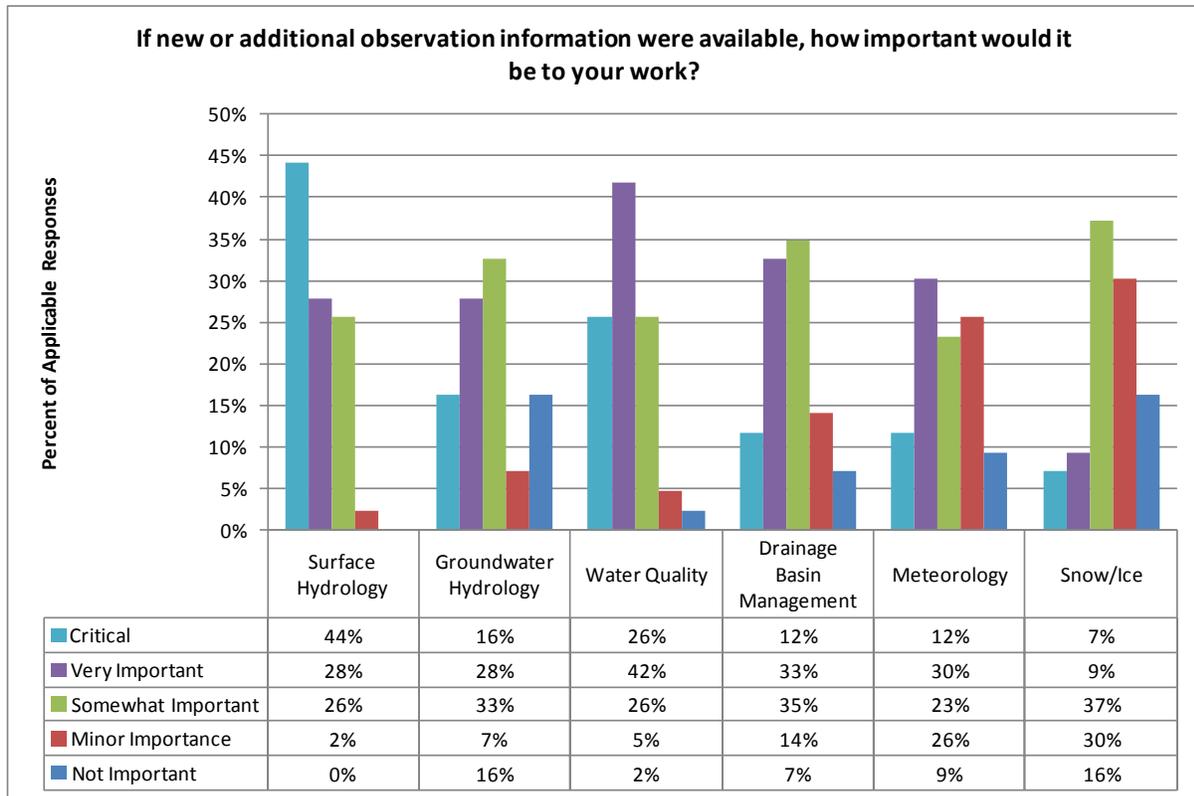
Note: There were 45 responses to this question.

Note:

Additional Information Needed

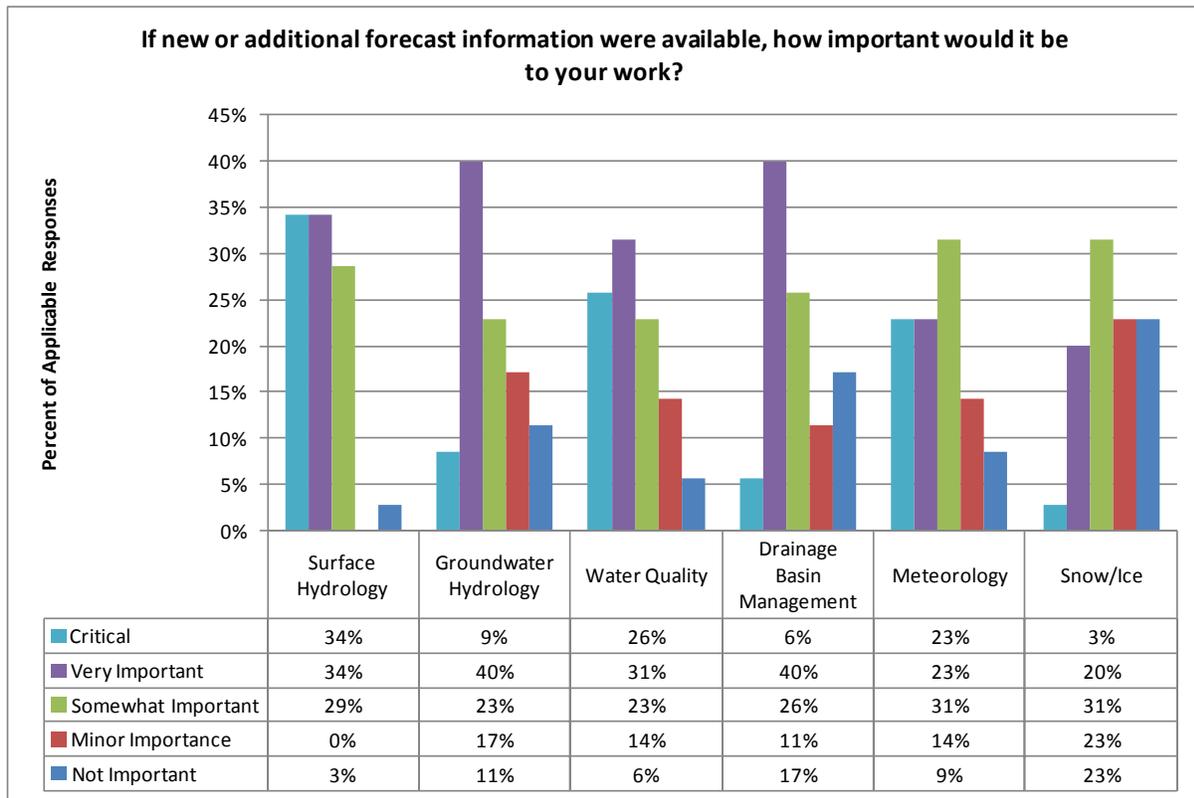
Respondents were asked if new or additional information were available, how important it would be to their decision making. For observations, forecasts, and uncertainty the subcategories of surface hydrology and water quality information were rated as the most important (when combining “critical” and “very important” responses). Under analyses, respondents rated hydrologic analyses and information integration as the most important. See Figure 6-16 to Figure 6-19.

Figure 6-16. Importance of new or additional observation information.



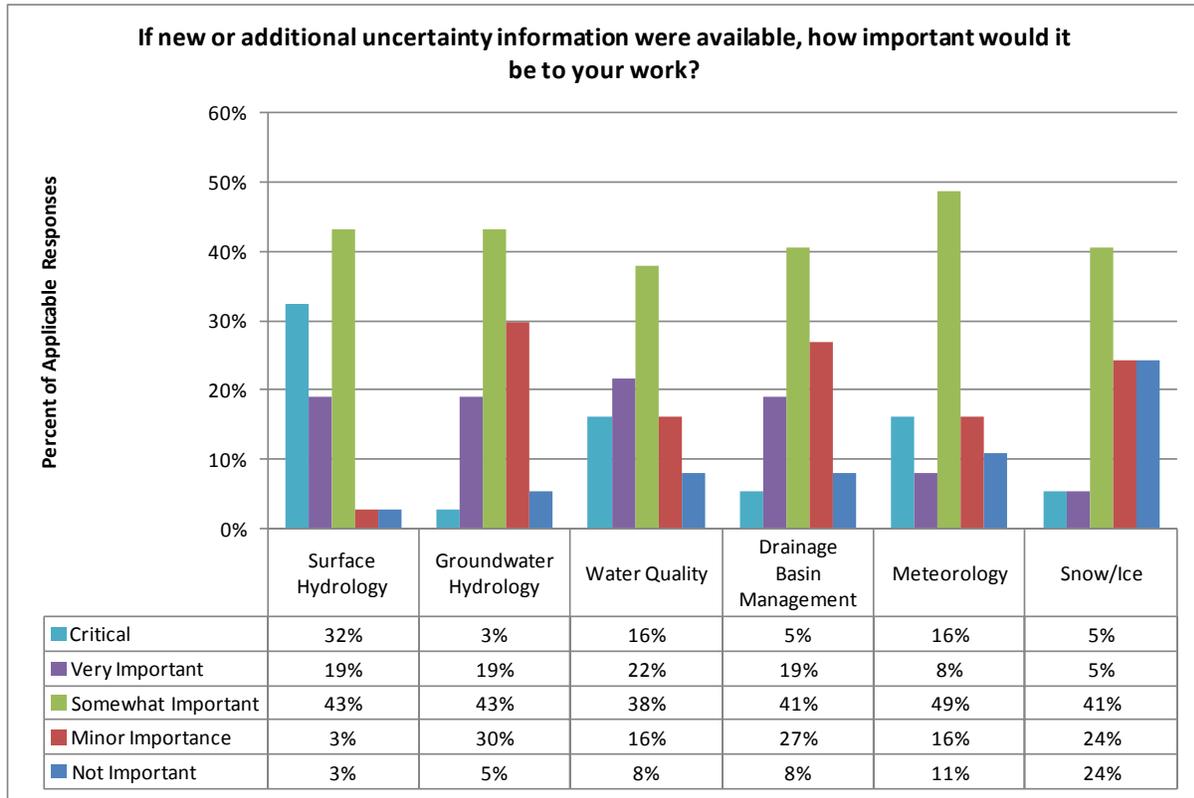
Note: There were 43 applicable responses to this question.

Figure 6-17. Importance of new or additional forecast information.



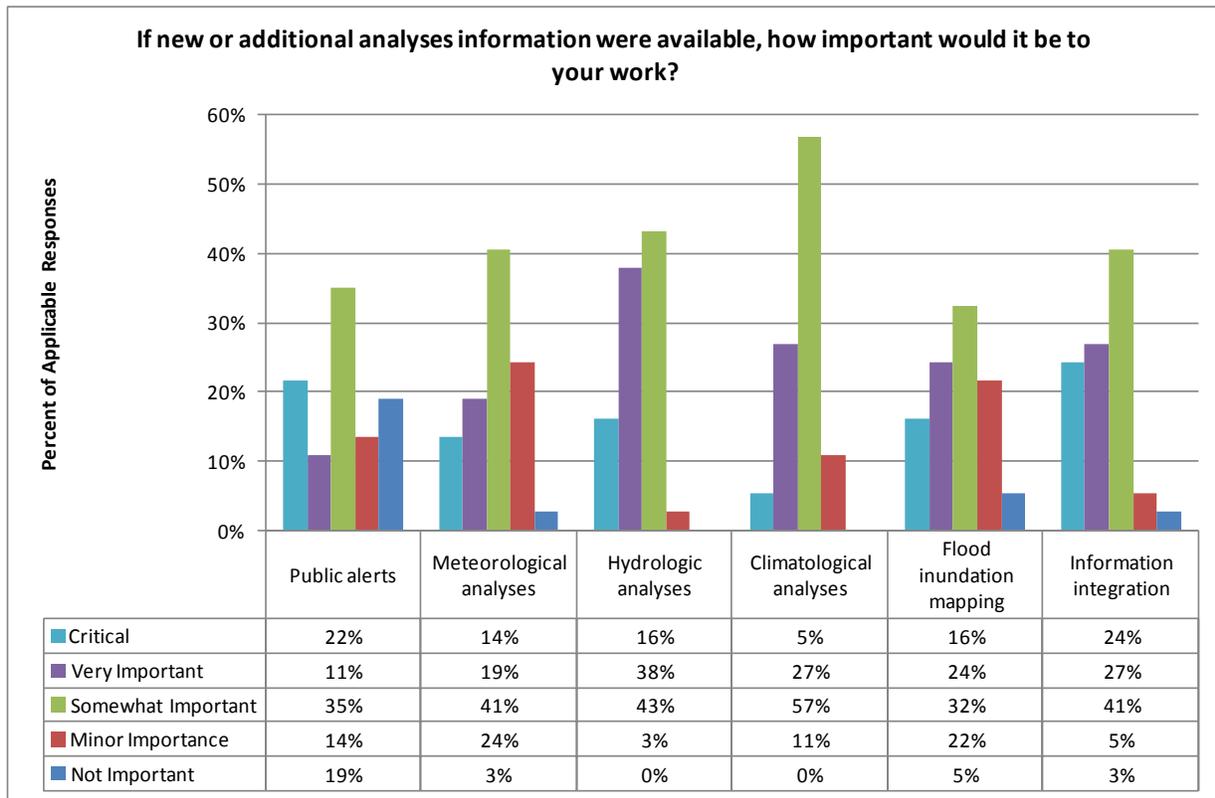
Note: There were 35 applicable responses to this question.

Figure 6-18. Importance of new or additional uncertainty information.



Note: There were 37 applicable responses to this question.

Figure 6-19. Importance of new or additional analyses information.



Note: There were 37 applicable responses to this question.

Summary of Open Comments

After respondents rated the importance of new or additional information types needed for decision making, they were asked to describe the additional or new information for those types identified as very important or critical. This section summarizes the written comments in response to that question by category of information — observations, forecasts, uncertainty, and analyses.

For observations, forecasts and uncertainties the most important subcategory of information is surface hydrology, followed by water quality; for analyses, the most important subcategory is information integration. See Table 4 for a summary of responses by category.

Table 4. Number of respondents indicating that new or additional information is “Very important” or “Critical” to their decision making.

	Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/ice	Public alerts	Meteorological analyses	Hydrologic analyses	Climatological analyses	Flood inundation mapping	Information integration	Provided Description
Observations	31	19	29	19	18	7	--	--	--	--	--	--	28
Forecasts	24	17	20	16	16	8	--	--	--	--	--	--	29
Uncertainty	19	8	14	9	9	4	--	--	--	--	--	--	24
Analyses	--	--	--	--	--	--	12	12	20	12	15	19	26

Based on a review of the written comments from respondents the following new or additional information would be useful:

- **Observations:** expanded stream gage networks (including additional, smaller stream segments) with increased observations of surface water variables and water quality; and high spatial resolution, observations of water quantity and interaction with surface waters for ground water.
- **Forecasts:** improved spatial and temporal resolution of forecasts, additional stream gages in key locations (for development and use of forecasts), the relationship between the information types and climate change, and the relationship between land uses, stream flow, and water quality.
- **Uncertainty:** It is difficult to identify trends in this category because responses focus on other information categories, how they would use uncertainty information, and why the information is important. Responses focus on surface hydrology and water quality, noting that the uncertainty information supports decision making and improves credibility of decisions.
- **Analyses:** This category is also difficult to summarize due to the uniqueness of each comment. Many comments focused on use of information integration to support decision making, planning, and other project work. Desirable topics for analyses include flood inundation, water quality planning, and understanding future climate change impacts.

The remainder of this section provides a summary of the written comments by information category (observations, forecasts, uncertainty, analyses) and a table presenting raw written comments by number and type of information types rated as “very important” or “critical.”

Observations

Twenty-eight respondents provided comments in response to this question, the comments focused on surface hydrology and water quality information. The primary theme in the responses relating to these two topics is simply a need for more observations; respondents mention expanded stream gage networks that could provide more real-time monitoring of surface water and water quality as well as more local information from specific stream segments. Several respondents also offered specific comments on groundwater hydrology information; respondents are interested in higher spatial resolution, water quantity, and interaction with surface waters. The following table, Table 5, summarizes the written responses by the information types marked as “very important” or “critical” to decision making (indicated with a check mark). The responses have been lightly edited for misspelled words and grammatical errors, non-substantive comments have been removed, and comments are ordered from most to least check marks.

Table 5. Summary of written responses to “For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making,” by information type.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/ice	For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making.
✓	✓	✓	✓	✓	✓	Real time monitoring of SW, GW Quantity and Quality, real time water budgets for watersheds, daily precipitation and snow/ice data for past 10 years.
✓	✓	✓	✓			More localized information would be useful for stream segments in Gaithersburg.
✓	✓	✓		✓		In DC groundwater flow is critical in understanding stream flow and the overall water quality condition in streams, but little robust information is available concerning linking surface hydrology, groundwater and water quality.
✓	✓	✓		✓		More sites to cover spatial variability.
✓	✓		✓	✓		Higher spatial resolution for surface hydrology, groundwater hydrology, drainage basin management, and meteorology for shorter time steps.
✓		✓	✓	✓		Ability to link surface hydrology to impacts on fisheries sustainability/health.
		✓	✓	✓	✓	Public attitude and wants/needs.
✓	✓	✓				Additional data on water quantity (flow) for both headwater streams and larger streams, additional water quality sampling stations with more samples taken. More information on groundwater in WV.
✓	✓	✓				Some of the groundwater goes toward this basin at its Western limits; some from there (on the surface) must travel toward this Basin. How much?
✓	✓	✓				Observations.
✓		✓		✓		- stream water quality data from "continuous" monitors (sondes) - % alteration in flow metrics from baseline conditions - precipitation estimates by HUC12 catchments - incident radiance estimates by region Note: a lot of the meteorological data are collected but are only available to the analyst in bulk for a price
✓		✓	✓			Surface hydrology - gage network expansion. Water quality - expanded and integrated monitoring network across jurisdictions that includes biological monitoring.
✓		✓	✓			Better understanding of what monitoring data is telling us about land use particularly in regards to geomorphology.
✓			✓	✓		When hurricanes approach we need to make decisions on action levels in Washington DC. How can forecasting integrate with decision making?
✓				✓		Spatially disaggregated water withdrawal and water return data. Daily timestep, updated daily.
✓				✓	✓	Need automated stream gages along the Potomac River at Williamsport, MD, Shepherdstown, WV 7 Harpers Ferry, WV.
	✓	✓	✓			All of these are critical, however the ones I marked as Very Important are ones where we need more data.
✓	✓					Current groundwater data is simply insufficient to allow for accurate prediction of groundwater levels, land use effects on groundwater, and ground and surface water interactions.
✓	✓					ET data - at daily timestep; stream flow data at additional locations; groundwater level data at additional locations; soil moisture data would help us forecast flows.
✓		✓				New observations for surface hydrology and water quality.
✓		✓				More real-time station. Easier access to larger data sets. Data availability in multiple formats.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/ice	For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making.
✓		✓				Denser data network would allow better understanding of river flow dynamics. Denser water-quality data network would enhance understanding of relations between water quality and stream biota.
✓		✓				Water temperatures.
✓		✓				Hydrology: river discharge/streamflow, river stage/elevation. Water quality: nutrients, sediments, temperature.
		✓	✓			Longer range projections are needed, out to 50 years. Water quantity needs to be addressed as well.
			✓	✓		Integrated watershed observations that characterize ecosystem condition for better understanding watershed effects on fisheries.
		✓				We need more information on water quality from small urban catchments, particularly as retrofit BMPs may be implemented to see if improvements really result.

Forecasts

Twenty-nine respondents provided written comments describing new or additional forecast information. The comments focused on surface hydrology and water quality, several respondents highlight the need for improved spatial and temporal resolution of forecasts and also acknowledge that a lack of stream gages in key locations is hampering effective forecasting and use of forecast information. Several respondents expressed an interest in the relationship between these information types and climate change, and the relationship between land uses, stream flow, and water quality. See Table 6.

Table 6. Summary of written responses to “For the information types you rated as very important or critical, please describe the additional or new forecast information that you need for your decision making,” by information type.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/ice	For the information types you rated as very important or critical, please describe the additional or new forecast information that you need for your decision making.
✓	✓	✓	✓	✓	✓	More river gages and area specific meteorology would help in determinations for flood evacuations.
✓	✓	✓	✓	✓	✓	For both surface hydrology and water quality, the resolution of the forecast data and density of forecasts need improvements. Surface water forecasts, such as the river forecast models, are lacking in many basins. Accurate models are hampered by lack of gaging stations in many basins. Water quality forecasts are essentially non-existent.
✓	✓	✓	✓	✓	✓	Direct line to park superintendents so they know immediately the repercussions that could occur to park visitors and resources
✓	✓	✓	✓	✓	✓	The impact of fracking and development- impervious surfaces and forest being cut down for the development.
✓	✓	✓	✓	✓	✓	How these relate to climate change.
✓	✓	✓	✓	✓		With respect to surface hydrology, it is critical that flow data is generated at subwatershed scale/or urban sewershed scale, if proper planning is to be realized. This is because, a number of urban-based TMDLs are developed at this scale, yet there is

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new forecast information that you need for your decision making.
						little flow data to support the development of these TMDLs (and by extension- water quality improvement plans).
✓	✓		✓	✓	✓	Seasonal flows, seasonal fluctuation in GW storage, better prediction equals more reaction time.
	✓	✓	✓	✓	✓	Forecasts are too general, and do not include specific information for my region.
✓	✓	✓	✓			Modeling of future water quantity and quality in the area.
✓	✓	✓	✓			Please refer to our workgroup’s well-id'd detailed recommendations from the forum at the USGS office. It is better stated than I can do here. Again, this is Carlton Haywood's working group, with unanimous findings and recommendations provided to the larger/full group.
✓	✓	✓	✓			Knowing about future expectations would inform decision making on the part of the City.
✓	✓	✓				Better linkage between flow and water quality.
✓	✓			✓		Most important need is for consistent reliable verification and confidence limit information on forecast products; especially for extreme events with smallest observed sample sizes.
✓	✓			✓		More accurate streamflow forecasts are critical to efficient use of reservoirs; understanding of groundwater hydrology important for forecasting low flows; better meteorological forecasts important for both short-term and long-term flow forecasts.
✓	✓		✓	✓		Higher spatial and temporal resolutions.
✓	✓		✓			During extreme low flows they are important for determining when to conduct ecological monitoring during extreme low flows. Even during "normal" years, the predictions can be useful in scheduling routine monitoring.
	✓	✓	✓			Want to see longer range water quantity projections.
✓		✓		✓		Flooding from the Potomac River Basin to Washington DC area parks. Tidal storm surge floods that come from the Chesapeake Bay during hurricanes that will hit DC.
✓				✓	✓	Unable to provide daily full time series forecast services for Williamsport, MD, Harpers Ferry, WV & Shepherdstown, WV because of lack of stream gage observations.
✓	✓					New forecasts for surface hydrology and impacts of water quality changes.
✓			✓			Live watershed maps that are updated regularly online to forecast predictions of flooding.
✓				✓		Daily ensemble flow forecasts (and associated hindcasts) out for ~6-12 months.
✓				✓		Climate change info.
✓				✓		1-predicted meteorological variables (rainfall, dew point temperature, air temperature, solar radiation, cloud cover, wind speed, wind direction) gridded over entire Potomac River basin. Predicted evaporation and streamflow.
		✓	✓			Integrated water quality and watershed management information - how is land use and water quality/quantity affecting available habitat for fisheries.
		✓				Ecological forecasts linking abiotic changes and living resource response in an operational format like a weather forecast.
		✓				We need better models of future water quality impacts based on different management scenarios.
		✓				Significant tributary water quality data.

Uncertainty

Twenty-four respondents provided written comments in response to the question, it is somewhat difficult to identify trends in the responses because the responses either don't describe uncertainty information, or they focus on describing how the information would be used and why it is important rather than describing what it would look like. For example, several responses note that uncertainty information is useful for decision making around water quantity management and preparation for flooding or drought and that it is important because it improves the credibility and defensibility of the decision. In terms of information types, the responses focus on surface hydrology and water quality. See Table 7.

Table 7. Summary of written responses to “For the information types you rated as very important or critical, please describe the additional or new uncertainty information that you need for your decision making,” by information type.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new uncertainty information that you need for your decision making.
✓	✓	✓	✓	✓	✓	Each element is so important in National Parks toward the safety of visitors and protection of resources.
✓	✓	✓	✓			In addition to the reported water quality violation types, need more information regarding potential sources of the pollution and recommended remedies (Example: low ph).
✓	✓	✓	✓			Please see the answers for the "forecast" portion - the uncertainty of current observations and future conditions is extremely important to be able to assess any likely future impacts.
✓	✓	✓	✓			Linkage between seasonal drought patterns and cyclical water quality changes.
✓	✓		✓	✓		Explicit quantification/estimates.
✓				✓	✓	Additional stream gages would be critical in notifications for a flood. Meteorology and Snow/Ice would help predict and event.
✓	✓			✓		In order to make good use of streamflow forecasts in water supply management, uncertainties need to be quantified.
✓		✓	✓			Please refer to top response/and recommendations provided at the Baltimore USGS offices mtg. Thank you.
✓			✓	✓		Where's it going to flood given the amount of precipitation in the watershed, temperatures, etc.?
✓				✓	✓	Need way to effectively convey the uncertainty in river forecasts. Social science leadership is important to getting the NWS's message delivered to the public to encourage them to take action to save their lives and property during floods.
✓	✓	✓				Our agency makes decisions allocating and approving surface water & groundwater withdrawals. Therefore, any data that helps us to understand how much water is available at a given point and how much can be safely taken is very important. Also very important is information on water quality. As part of the multi-barrier concept, it is crucial to utilize and maintain high quality sources.
✓	✓					Bounds of uncertainty need to be well quantified for the information and interpretation to be scientifically valid and credible.
✓		✓				Water quality - expanded and integrated monitoring network including biological monitoring could increase resolution while decreasing uncertainty.
✓		✓				Need accuracy in predicting events from drought to floods.
✓				✓		DC needs to make decisions to respond to potential flooding. Better uncertainty

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/ice	For the information types you rated as very important or critical, please describe the additional or new uncertainty information that you need for your decision making.
						description allows us to make decisions with more confidence.
✓				✓		Need to understand the uncertainty associated with met and flow forecasts if we are to use such in defensible operations decision making and planning.
				✓	✓	Need accurate & timely forecast information.
✓		✓				Each case is unique, however, in public setting, knowing the uncertainty accompanying any measurement is critical in communicating risks, protecting public health and gaining a modicum of public confidence in where public dollars are spent, and nowhere is this more important than water quality and flow.
✓		✓				Uncertainty estimates for surface hydrology forecasts are frequently omitted from the most readily forecasts. Clear presentation of this data would be most helpful in decision making.
			✓	✓		Why isn't population growth/water usage listed?
			✓	✓		Water quality and watershed management as indicators of future projection of ecosystem health.
✓						Consistent verification information and confidence limits for individual gauge forecasts (not aggregate "skill scores" by region, for individual forecasts for each forecast time horizon (e.g. daily to seasonal).
				✓		Uncertainty associated with surface hydrology information and water quality.
				✓		EPA's current watershed model does not have uncertainty estimates associated with it, yet it is being used to support wasteload allocations in individual permits. If models are to be used in this context, they need error measurements associated with them.

Analyses

Twenty-six respondents provided written comments on the types of new or additional analyses that they need for their decision making. The comments are somewhat difficult to summarize because each comment describes a fairly unique information need; many of the comments focus on some type of information integration or synthesis of analyses in order to support decision making, planning, and other project work. In terms of specific topics for analyses, several comments focus on flood inundation, water quantity planning, and understanding future climate change impacts. See Table 8.

Table 8. Summary of written responses to “For the information types you rated as very important or critical, please describe the additional or new analyses that you need for your decision making,” by analysis type.

Public alerts	Meteorological analyses	Hydrologic analyses	Climatological analyses	Flood inundation mapping	Information integration	For the information types you rated as very important or critical, please describe the additional or new analyses that you need for your decision making.
✓	✓	✓	✓	✓	✓	Flood inundation mapping would be the most critical, this tool would allow me to better relay the impact a flood would have on a property. The others would allow me to do my job better and in a more efficient manner.
✓	✓	✓	✓	✓	✓	Each element is so important in National Parks toward the safety of visitors and protection of resources.

Public alerts	Meteorological analyses	Hydrologic analyses	Climatological analyses	Flood inundation mapping	Information integration	For the information types you rated as very important or critical, please describe the additional or new analyses that you need for your decision making.
✓	✓	✓	✓	✓	✓	All of these areas need to be improved for better DC management of flood risks.
✓	✓	✓	✓	✓	✓	Need full flood threat graphic that encompasses all the myriad of warnings, watches, storm surge, flash flood, river flood, coastal flood, etc... all in one easily understandable product.
✓	✓	✓		✓	✓	Alerts are important.
✓	✓	✓	✓	✓		Need early warning systems to alert water intakes.
	✓	✓	✓	✓	✓	All analyses assist in decision making.
	✓	✓	✓	✓	✓	All aspects of ecosystem health and management, particularly integration of this information to inform fishery management decisions.
✓	✓	✓	✓		✓	Hydrologic data - precipitation data at subwatershed scale.
✓		✓	✓	✓		More analyses related to more sites.
✓		✓		✓	✓	Any information that we could share with public water suppliers pertaining to public alerts, hydrologic analysis, flooding, or information would be helpful in planning and operating public water systems.
✓		✓			✓	Information integration is critical so that the users can have the information quickly and be able to respond.
✓				✓	✓	If the analysis indicates a local threat, that needs to be conveyed to the public ASAP.
	✓	✓			✓	Easy access to these different types of analytical results would make my project-specific analyses much more cost-effective and versatile.
	✓	✓		✓		Not so much new analysis, but specific analysis for my region and local conditions.
		✓	✓		✓	New assessments of the quality of freshwater resources in this area, as well as how climate change may impact the freshwater resources, would be very valuable in my work.
✓			✓			You can't forecast without analysis. We need to improve our understanding of climate fluctuations, need more gages to see what flow changes may be happening in least human impacted watersheds - i.e., to compare with flow changes that are results of land-use changes.
	✓				✓	Information integration, single portals, for multiple data types would be very helpful. Clear concise analysis of weather patterns including range of expected conditions, changes expected for predictions, etc.
		✓			✓	Water quantity combined with population and water use growth analysis out at least 50 years.
		✓			✓	Please refer to top response/and recommendations provided at the Baltimore USGS offices mtg. Thank you.
		✓	✓			Current water quality loading models are pretty good from hydrologic standpoint, but more localized data is needed. Also, the models are only beginning to take the impact of climate change on changing hydrology into effect. This needs to be done for future forecasting purposes.
		✓		✓		Current data on hydrological analysis and flood inundation mapping.
				✓	✓	Synthesis products that show ecosystem change as a result of differing scenarios.
				✓	✓	Gaging station compilation, QL-2 LiDAR.
					✓	Information integration - single portal for information could lead to increased efficiency in decision making and ensure that critical information is not overlooked during planning process.

Public alerts	Meteorological analyses	Hydrologic analyses	Climatological analyses	Flood inundation mapping	Information integration	For the information types you rated as very important or critical, please describe the additional or new analyses that you need for your decision making.
	✓					More readily available statistics.

Other

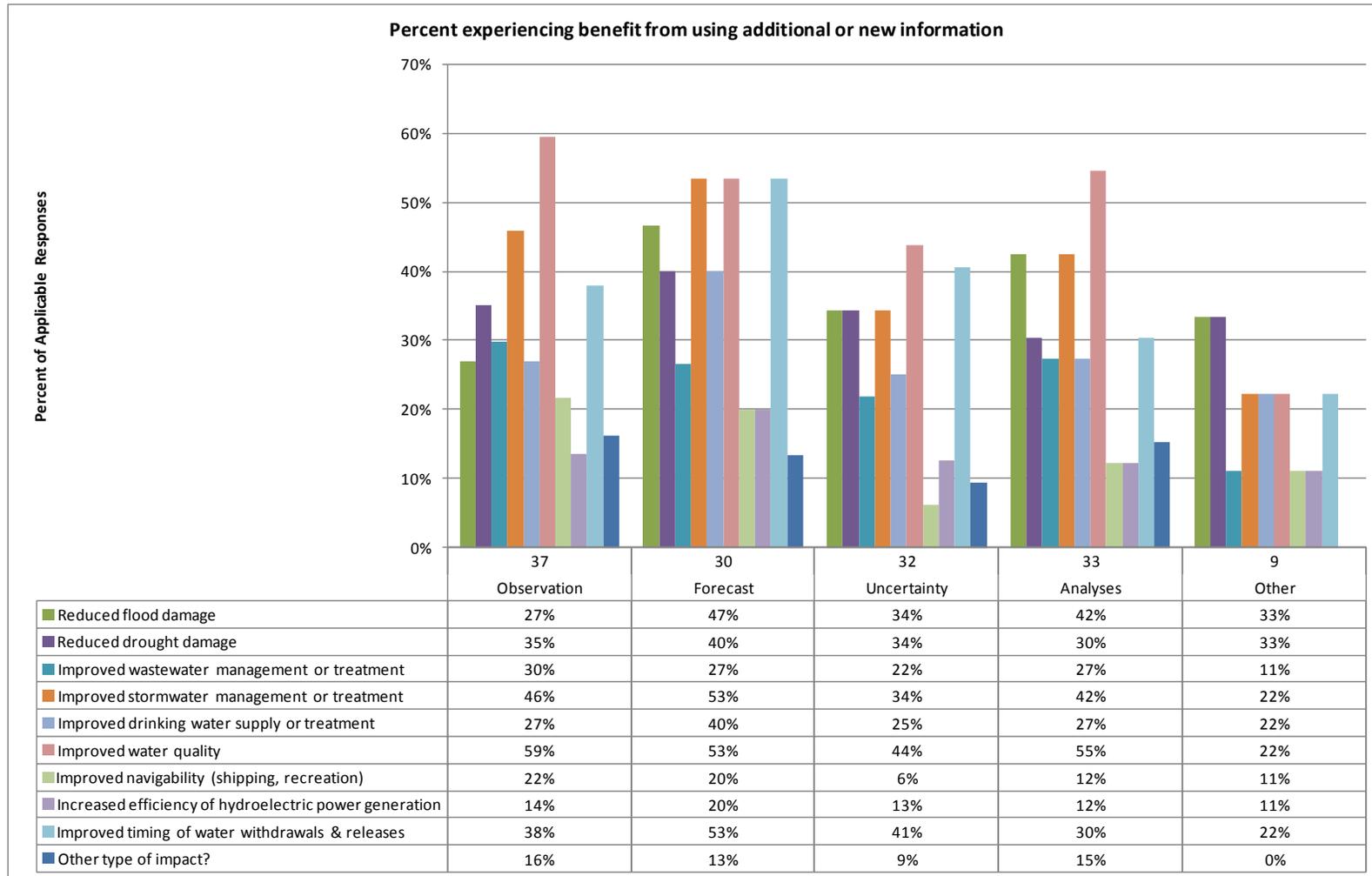
Ten respondents indicated that they would rank “other” types of information as needing improvement and critical for informing decisions on their top priority issue. They provided the following written comments to describe the other types of information that they need for their decision-making:

- An incredibly broad question, but two that come to mind are management practice effectiveness and fisheries ecosystem science.
- During a flood we need to bring together the best expertise from these entities to advise DC area agencies on flood response levels during the days leading to the flood and throughout the flood event. We need best science for best decision making for the difficult to forecast events (especially for storm surge like Katrina and Sandy).
- Information beyond the instrumental record, e.g. mid Atlantic tree ring surrogates. Scenario information for possible futures.
- Modeling of runoff; Determining rating curves for smaller streams
- More information can always be provided and will always be appreciated.
- Need improved accuracy of NWS low flow forecasts. Current models are calibrated for flood forecasting. In the Potomac Basin, high priority is low flow management for consumptive water use.
- Sediment sampling, transport and analysis.
- Tools for integrating observations, forecasts, and system operations within a framework that accounts for uncertainty and supports further analyses.
- Topographic surface, impervious surface

Economic Impacts or Benefits

Respondents were asked if they would experience any of a set of impacts or benefits from using additional or new information from IWRSS partner agencies, see Figure 6-20. The most commonly anticipated benefits of new observation information are reduced flood damage, improved water quality, and improved stormwater management or treatment. For forecasts, stormwater management and water quality are cited by most respondents followed by improved timing of water withdrawals and releases. For uncertainty, the two most common benefits are improved water quality and improved timing of water withdrawals and releases. And for new or additional analyses, respondents expect improved water quality, improved stormwater management, and reduced flood damage.

Figure 6-20. Responses to “would you experience any of the following impacts or benefits from using additional or new information from IWRSS partner agencies?”



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 81 survey responses. Those who never saw the question (i.e., incomplete or not applicable) are not included here. These totals DO include those who saw but skipped the question.

Summary of Open Comments

Respondents who indicated that they would experience any of a set of impacts or benefits from using additional or new information from IWRSS partner agencies were then asked to describe the benefit and estimate the cost avoided or benefit gained per year or per event.

Observations

By providing new or additional observation information for the Potomac River Basin nine types of benefits would be realized: reduced flood damage, reduced drought damage, improved wastewater management/treatment, improved stormwater management/treatment, improved drinking water supply/treatment, improved water quality, improved navigability, improved timing of water withdrawals/releases, and other impacts. Specifically:

- **Reduced flood damage:** Protection of \$2 billion of personal property from flood damage per year.
- **Reduced drought damage:** Improved management of the D.C. water supply during drought, avoided damage to the trout fishery.
- **Improved wastewater management/treatment:** Avoided cost of \$2 billion to build a water treatment facility, improved ability to identify and prioritize environmental stressors, and new/additional information will help the Chesapeake Bay Program Partnership (CBPP) make more informed decisions in the cleanup effort.
- **Improved stormwater management/treatment:** Identify BMPs, identify and prioritize environmental stressors, help the CBPP make more informed decisions, and support investment decisions.
- **Improved drinking water supply/treatment:** Improved management of D.C. water supply during drought (see second bullet above).
- **Improved water quality:** Through tracking of pollutions sources, prioritizing actions and outreach efforts, better targeting of BMPs and other efforts, limiting the number of closures of recreational opportunities and allow more staff time for analysis instead of measurement. Also, improved ability to identify and prioritize environmental stressors, and help the CBPP make more informed decisions.
- **Improved navigability:** New/additional observation information would provide knowledge for buoy maintenance of NOAA Potomac River buoys.
- **Improved timing of water withdrawals/releases:** Better knowledge of timing of required releases from a State of Maryland dam, and improved management of the D.C. water supply during drought (see second bullet above).
- **Other impacts:** Better projections of TMDL-related improvements, long term impact on integrated watershed planning decisions, improved ecosystem health and function, improved ability to assess biological resources and prioritize conservation activities.

Forecasts

By providing new or additional forecast information for the Potomac River Basin ten types of benefits would be realized: reduced flood damage, reduced drought damage, improved wastewater management/treatment, improved stormwater management/treatment, improved drinking water

supply/treatment, improved water quality, improved navigability, increased efficiency of hydroelectric power generation, improved timing of water withdrawals/releases, and other impacts. Specifically:

- **Reduced flood damage:** Reduced loss of life and flood affects in D.C., increased lead time for warning systems and road closures, and support for planning to avoid damage to infrastructure.
- **Reduced drought damage:** Reduced losses from unnecessary restrictions and unplanned shortages of \$3 million to \$5 million per event. Also, support better planning for agricultural entities; improved drought detection leads to fewer drought days, more timely investment in supply-demand balance and improved reliability, and avoided damage to river biota from low water.
- **Improved wastewater management/treatment:** Avoided costs of overflows and malfunctions of \$25K to \$250K per event. Also, help mitigate nutrient loads to the bay.
- **Improved stormwater management/treatment:** New/additional forecast information will result in reduced capital costs for CSO abatement on the order of ~\$100 million. Additionally, it will support better predictions for sizing management facilities and discharges to mitigate flooding and runoff, support road design that addresses water, and improved guidance of investment in the city.
- **Improved drinking water supply/treatment:** New/additional forecast information would decrease shortage costs by ~\$50,000 per day and have potential avoided capital costs of ~\$10 million. Also, it would help ensure adequate water supplies and improve drought operations of water supply utilities in the DC metro area.
- **Improved water quality:** Improved guidance of investment in the city.
- **Improved navigability:** Improved recreation industry.
- **Increased efficiency of hydroelectric power generation:** New/additional forecast information would result in a 2-5 percent increase in discretionary power generation, 2.5–5 cents per kilowatt hour.
- **Improved timing of water withdrawals/releases:** New/additional forecast information would result in avoided costs of \$410 to \$15,000 per household from shortages for surficial aquifer suppliers. Additionally, it would improve drought operations of water supply utilities in the D.C. metro area.
- **Other impacts:** Improved ability to estimate impact of future conditions on natural resources, improved planning abilities, and provides the opportunity to assess future threats and opportunities.

Uncertainty

By providing new or additional uncertainty information for the Potomac River Basin eight types of benefits would be realized: reduced flood damage, reduced drought damage, improved wastewater management/treatment, improved stormwater management/treatment, improved drinking water supply/treatment, improved water quality, improved timing of water withdrawals/releases, and other impacts. Specifically:

- **Reduced flood damage:** Improved evacuation prediction reduces costs associated with evacuations.

- **Reduced drought damage:** Improve drought operations of D.C. water utilities, improve understanding of natural variability, and to improve level of comfort with decisions based on observations and predictions.
- **Improved wastewater management/treatment:** Support CBPP informed decision making, and limit potential of by-passing.
- **Improved stormwater management/treatment:** Help the city manage expectation, reduce pollution loads, and support CBPP decision making.
- **Improved drinking water supply/treatment:** Reduced risk to drinking water.
- **Improved water quality:** Improve understanding of relative benefits and risks of BMP implementation, understand natural variability, reduce impacts to aquatic life, support CBPP decision making, and help the city manage expectations.
- **Improved timing of water withdrawals/releases:** Support appropriate interpretation and application of observation and forecast information, improve drought operations of D.C. water utilities.
- **Other impacts:** Support use of observation and forecast information.

Analyses

By providing new or additional analyses information for the Potomac River Basin eight types of benefits would be realized: reduced flood damage, reduced drought damage, improved wastewater management/treatment, improved stormwater management/treatment, improved drinking water supply/treatment, improved water quality, improved timing of water withdrawals/releases, and other impacts. Specifically:

- **Reduced flood damage:** Improved analysis, especially storm surge, will improve warning, and reduce loss of life and property.
- **Reduced drought damage:** Understand effects of drought on biota, and improve drought operations by DC metro area water utilities.
- **Improved wastewater management/treatment:** Improved preparation and planning for high flow events; more comprehensive, integrated analysis of ecosystem responses to stream degradation/restoration; and, improved understanding of environmental services lost when streams are degraded.
- **Improved stormwater management/treatment:** Protection of infrastructure; more comprehensive, integrated analysis of ecosystem responses to stream degradation/restoration; and, improved understanding of environmental services lost when streams are degraded.
- **Improved drinking water supply/treatment:** Protection of infrastructure and human health.
- **Improved water quality:** Reduced treatment costs, understand the effects of water quality changes on biota, improve targeting of BMPs and other efforts; more comprehensive, integrated analysis of ecosystem responses to stream degradation/restoration; and, improved understanding of environmental services lost when streams are degraded.
- **Improved timing of water withdrawals/releases:** Improved drought operations by D.C. metro area water utilities.
- **Other impacts:** Improved expectations for TMDL-related reductions in nutrients and sediments, ability to perform ecosystem analysis, and better research papers and simulations.

Other Information

By providing new or additional information for the Potomac River Basin three types of benefits would be realized: reduced flood damage, reduced drought damage, improved wastewater management/treatment, improved stormwater management/treatment, improved drinking water supply/treatment, improved water quality, improved navigability, increased efficiency of hydroelectric power generation, improved timing of water withdrawals/releases, and other impacts. Specifically:

- ***Improved wastewater management/treatment:*** Help the CBPP make informed decisions.
- ***Improved stormwater management/treatment:*** Help the CBPP make informed decisions.
- ***Improved water quality:*** Help the CBPP make informed decisions.

APPENDIX C: Delaware River Basin Detailed Survey Results

Delaware River Basin

Responses

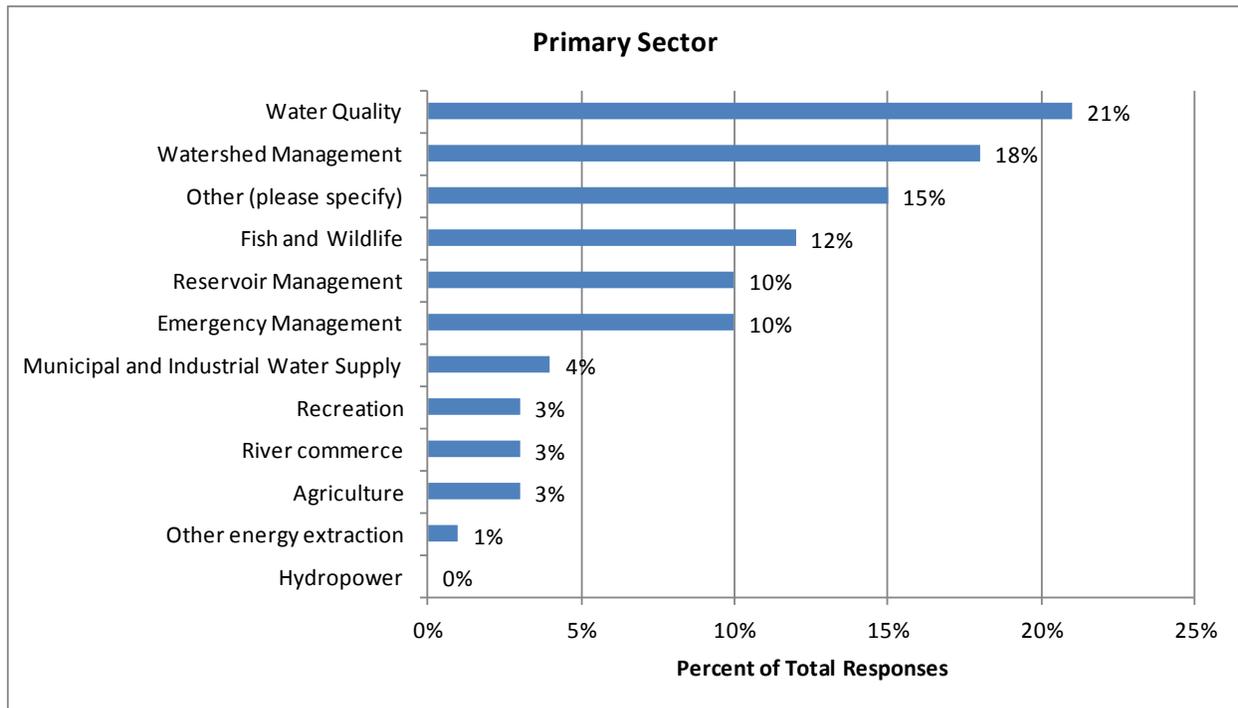
Personalized survey invitation emails were sent to 193 people. ERG received 68 total responses, including 45 complete surveys (i.e., respondent reached the end of the survey and hit submit) and 23 incomplete surveys (i.e., respondent closed out of the survey before completing). Of these 68 total responses, 60 were from individuals on the mailing list or colleagues to whom those emails were forwarded; the other 8 responses came from “untracked” participants (i.e., those who arrived at the survey via a link on the RBC website). To the maximum extent possible, the incomplete surveys were included in the results presented below.

Respondent Demographics

Respondents were asked to select the primary sector in which their work or interest is focused in the Delaware River basin, see Figure 6-21. The focus of respondents’ work or interest in the Delaware River basin was varied among respondents. In descending order, respondents identified their primary focus as water quality (21 percent), watershed management (18 percent), “other” (15 percent), fish and wildlife (10 percent), reservoir management (10 percent), etc. Fifteen percent, however, specified an “other” sector (other than a categorized response option). Their verbatim responses were:

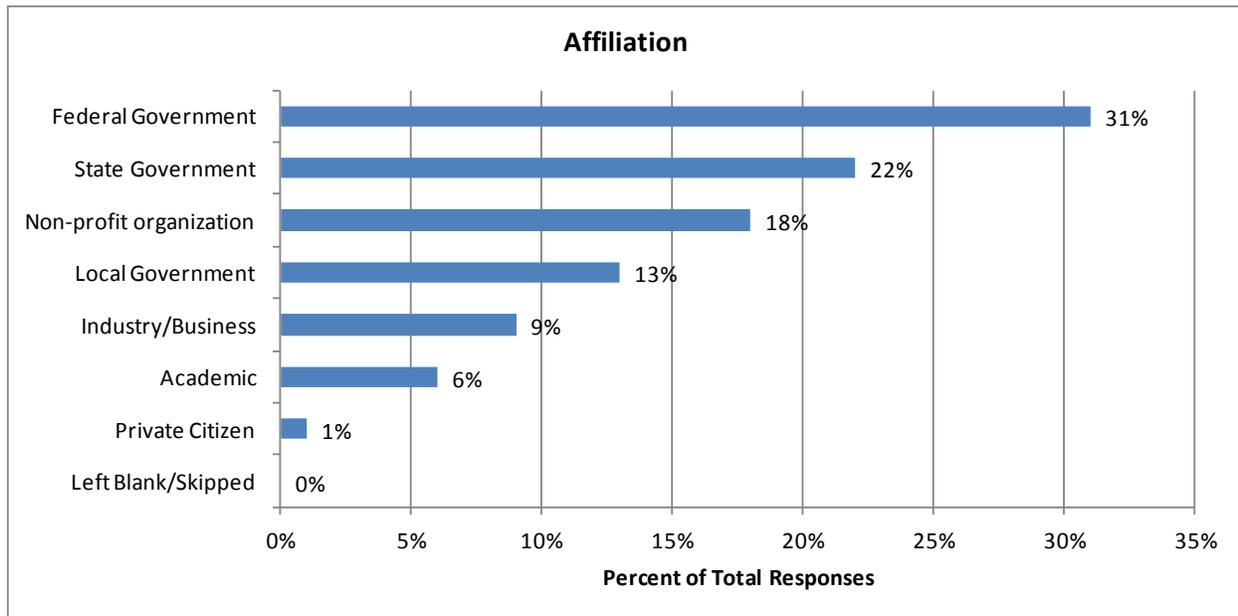
- Dam safety and flood risk mitigation
- Data (streamflow and water-quality) collection and analysis
- Electric generation/cooling water
- Flood and drought management
- Flood control
- Floodplain Management
- NGOs working in the watershed
- Streamflow
- Surface water hydrology
- US Gov. -- water resources & management

Figure 6-21. Responses to “Please select the primary sector in which your work or interest is focused in the Delaware River Basin.”



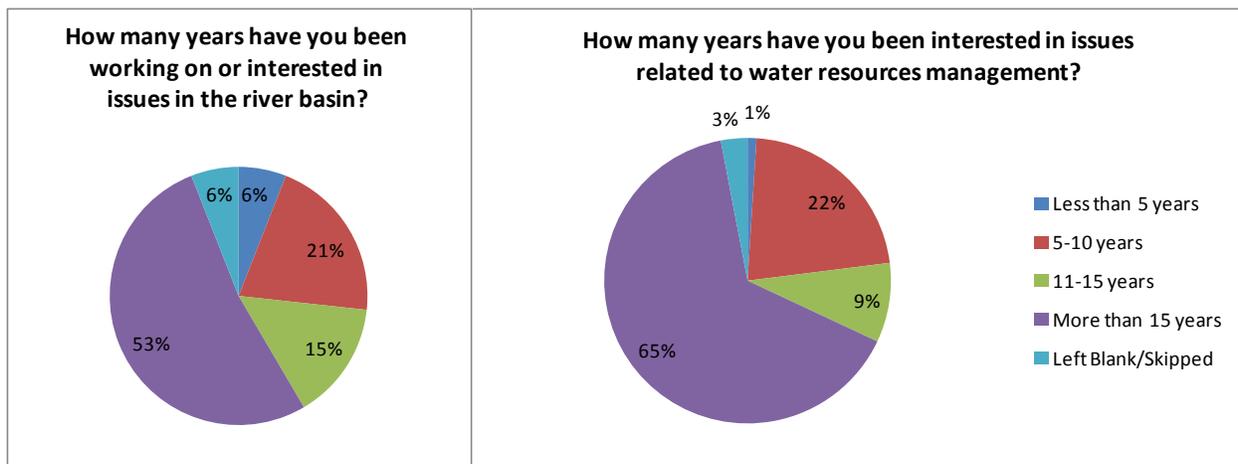
Respondents were asked to indicate the affiliation that best describes their work or interest in the Delaware River basin, Figure 6-22. Nearly a third of respondents (31 percent) are affiliated with the federal government. Another 22 percent are affiliated with state government and 18 percent are affiliated with a non-profit organization.

Figure 6-22. Responses to “Please select the affiliation that best describes your work or interest in the Delaware River Basin.”



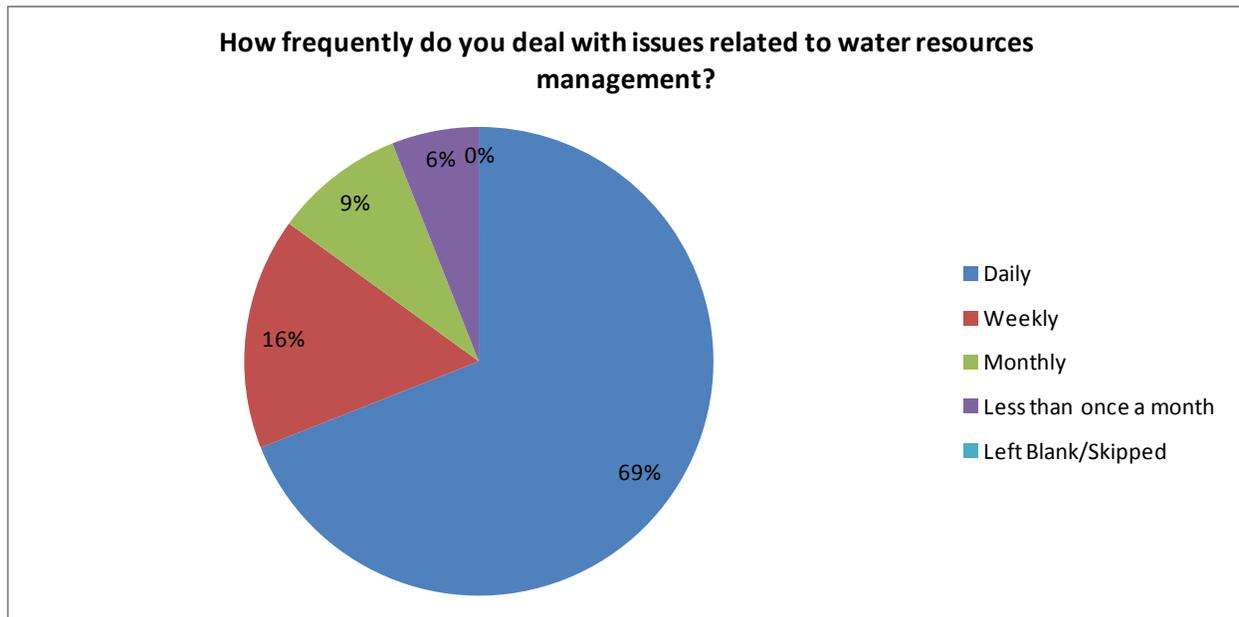
Respondents were asked to indicate how many years they have been working on or interested in issues in the Delaware River basin and how many years they have been interested in issues related to water resources management, see Figure 6-23. Slightly more than half (53 percent) of respondents have been working on or interested in issues in the Delaware River basin for more than 15 years. Most respondents have been working on or interested in issues related to water resources management for more than 5 years.

Figure 6-23. Number of years respondent has been working on or interested in issues in the river basin and water resources management.



The survey asked how frequently respondents deal with issues related to water resources management, Figure 6-24. About 85 percent of respondents deal with issues related to water resources management on a daily or weekly basis.

Figure 6-24. Frequency of dealing with water resources management issues.



Almost all respondents (90 percent) have job responsibilities that include providing input to strategic planning; program, facility, operations or financial management; or project planning decisions on water resources information.

Priority Issues

Prior to the survey, priority issues facing the Delaware River basin were identified as follows:

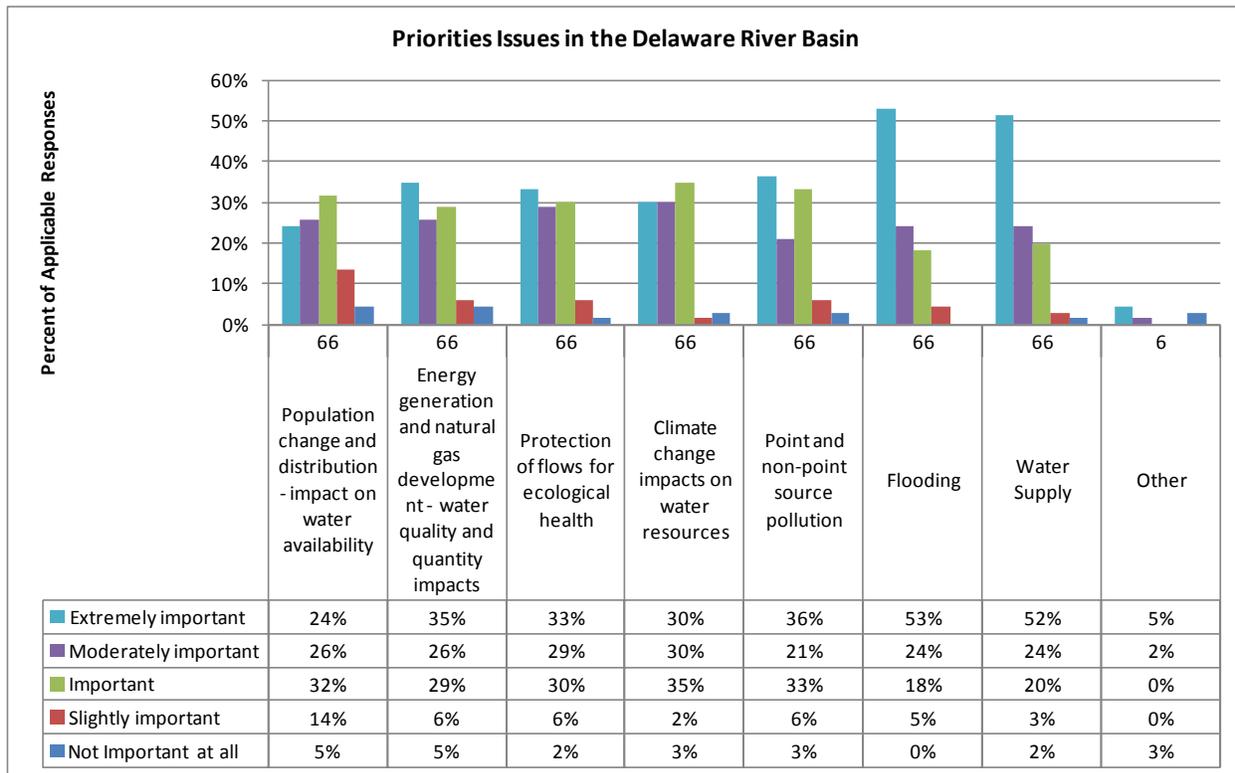
- **Population change and distribution — impact on water availability:** Population increase and/or re-distribution will likely increase the consumptive use of water, increase impervious surface cover, increase pollutant loadings, decrease forest cover and potentially change use of water resources.
- **Energy generation and natural gas development — water quality and quantity impacts:** The need to reduce once-through cooling at thermal generation facilities will increase the consumptive use of water in the basin. Natural gas development creates potentially difficult-to-treat wastewater and causes area-wide land cover issues.
- **Protection of flows for ecological health:** Ecological flow analyses will likely affect pass-by-flows for water withdrawals and reservoir conservation releases. There may also need to be flow targets in some of the larger tributaries.

- **Climate change impacts on water resources:** Sea level rise will decrease protective wetlands, increase storm surge impact and affect salinity levels in the tidal river. Changes in precipitation could result in more intense storms in winter/spring and drought conditions during summer months.
- **Point- and nonpoint-source pollution:** Point- and nonpoint-source pollution contributes to nutrient loading and associated decreases in dissolved oxygen. Greater attention will be needed on the influence of the non-tidal system on the water quality of the estuary.
- **Flooding:** Reservoir management/storage, flood forecasting and flood warnings, flood mapping and flood management are key issues for which management schemes need to be in place.
- **Water supply:** Water supply concerns include increased upper basin use, salt water intrusion, salt encroachment at water supply intakes, water quality issues, increased drought, need to allocate water for in-stream needs.

Respondents were asked to indicate the importance of these issues and to rank the top three issues that they think are the most important, see Figure 6-25. Priority issues were varied among respondents in the Delaware River basin. “Flooding” and “Water Supply” were both rated as extremely important by about half of respondents. However, between 49 and 60 percent of respondents also rated all of the remaining priority issues as either moderately or extremely important. Very few respondents identified a priority issue that wasn’t a predetermined response option. These few verbatim responses were:

- Addressing “legacy” pollutants.
- Competing usage, recreational usage, run-off issues.
- Economic Value of Water.
- Ridge line protection within watershed (water quality and land erosion).
- Stormwater management.

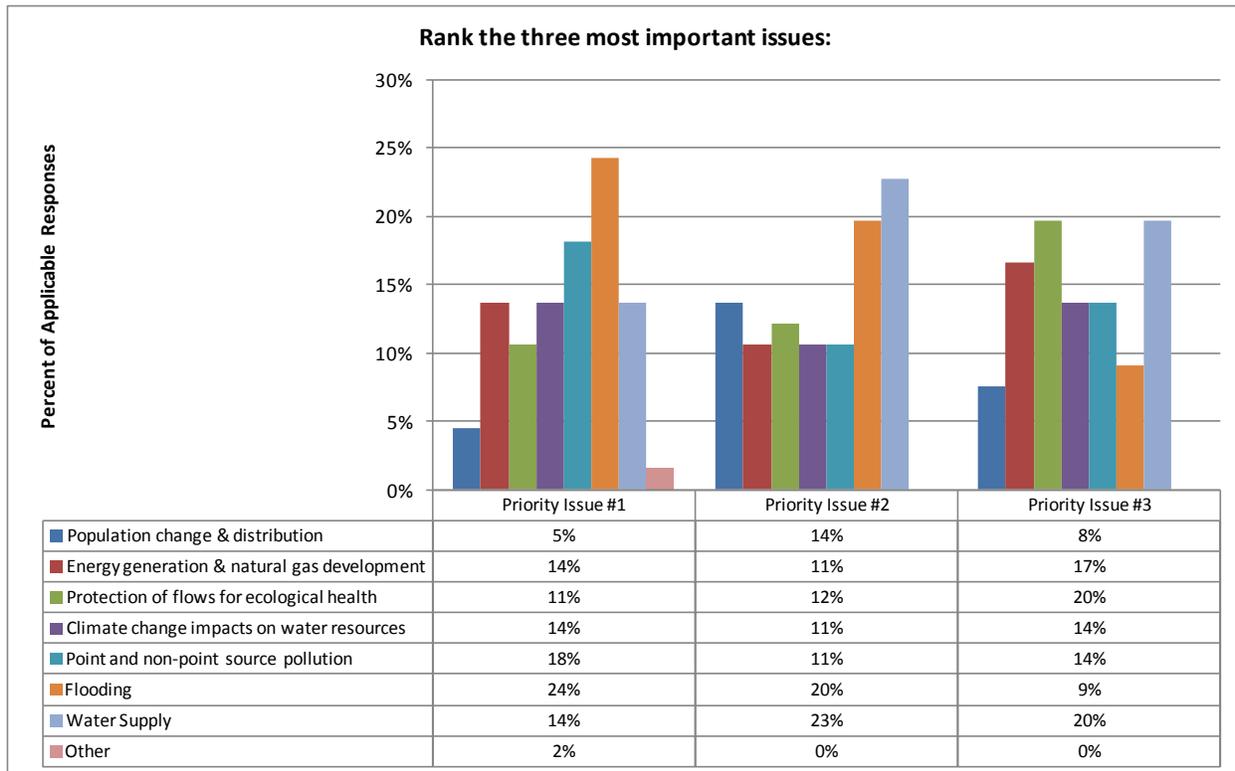
Figure 6-25. Responses to “Please indicate the importance of each of the following issues.”



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 68 survey responses. Those who skipped the question or never saw the question are not included here.

In accordance with their importance ratings, “Flooding” and “Water Supply” were the most likely priority issues to appear in respondents’ rankings of top three issues in the Delaware River basin, see Figure 6-26.

Figure 6-26. Responses to “Looking at the issues as a group, please rank the three most important issues that you think are facing the Delaware River Basin.”

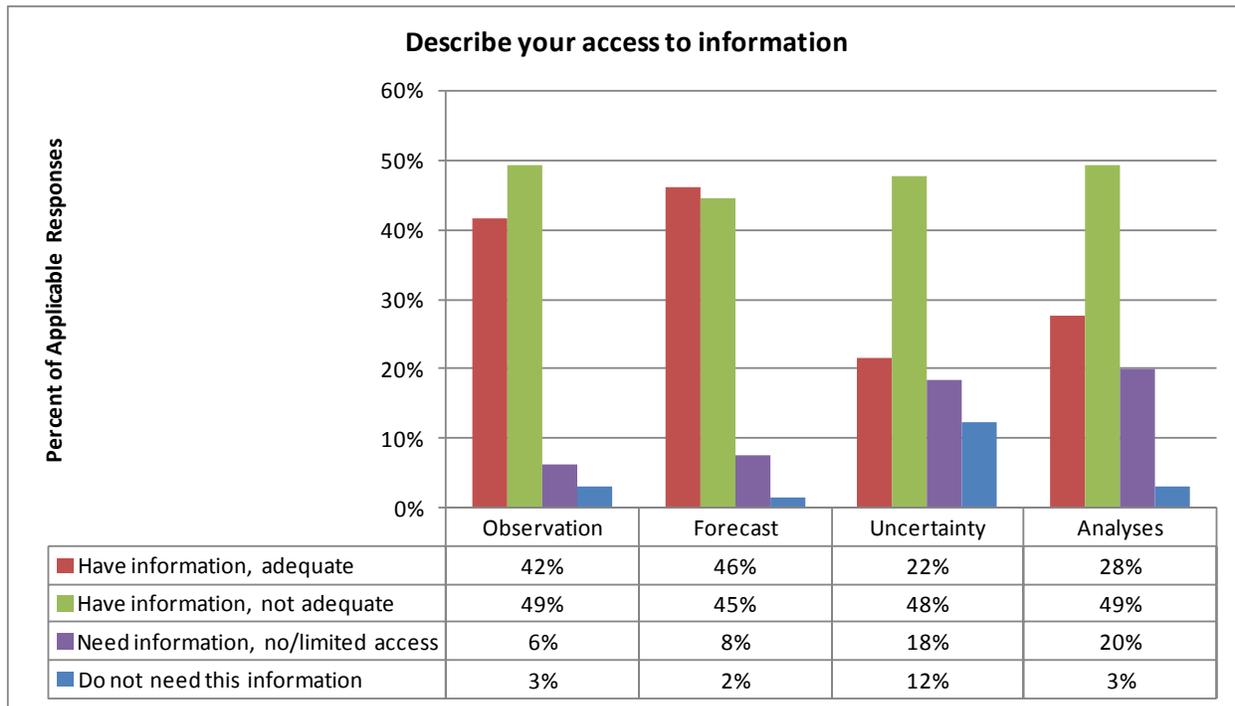


Note: There were 66 responses to this question.

Information Access and Use

Respondents described their access to observations, forecasts, uncertainty, and analyses information needed for informing decisions, see Figure 6-27. For observation and forecast information, respondents were evenly split between having adequate information to meet their needs and having inadequate information. Just under half of respondents indicated having inadequate uncertainty and analyses information, with another fifth having limited or no access to those types of information.

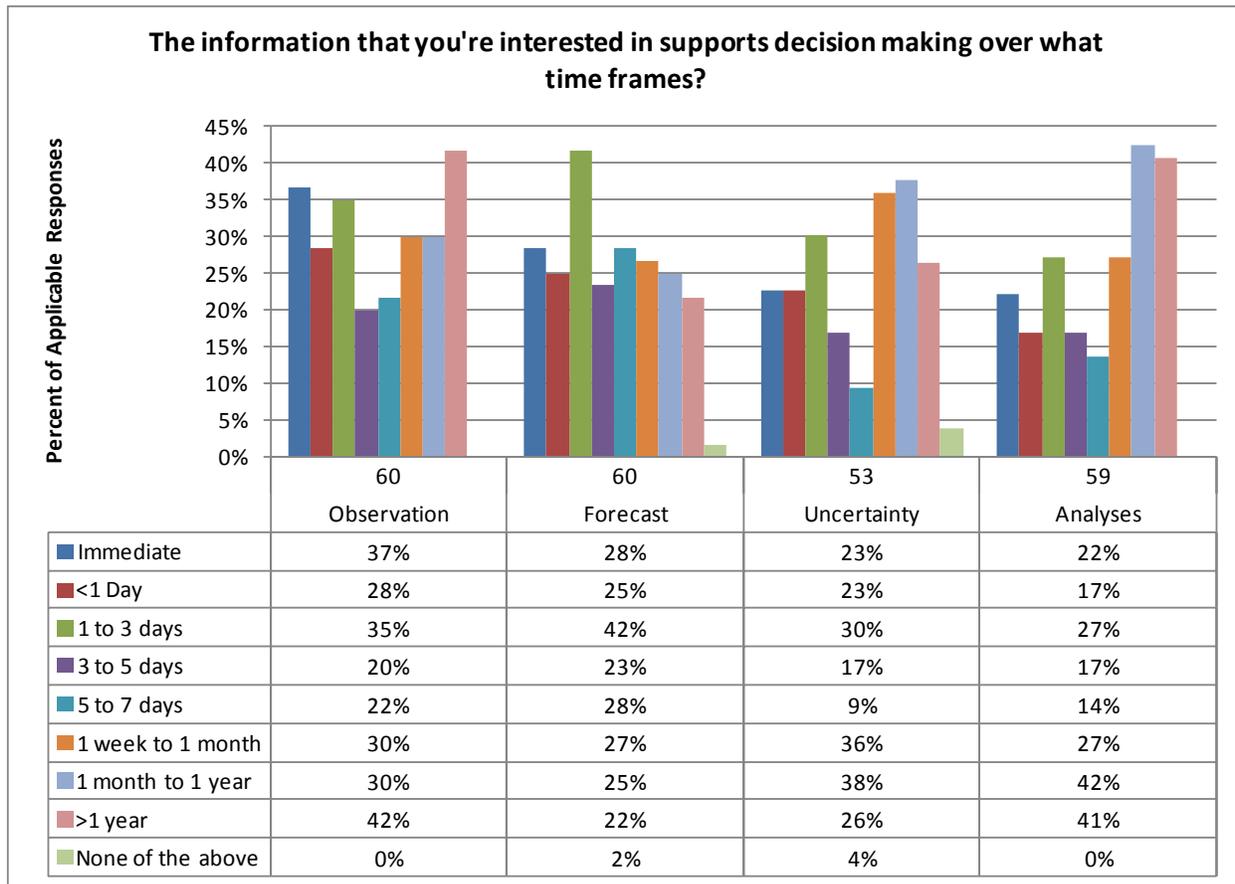
Figure 6-27. Responses to “For your highest priority issue, describe your access to the following types of information needed for informing decisions.”



Note: There were 65 responses to this question.

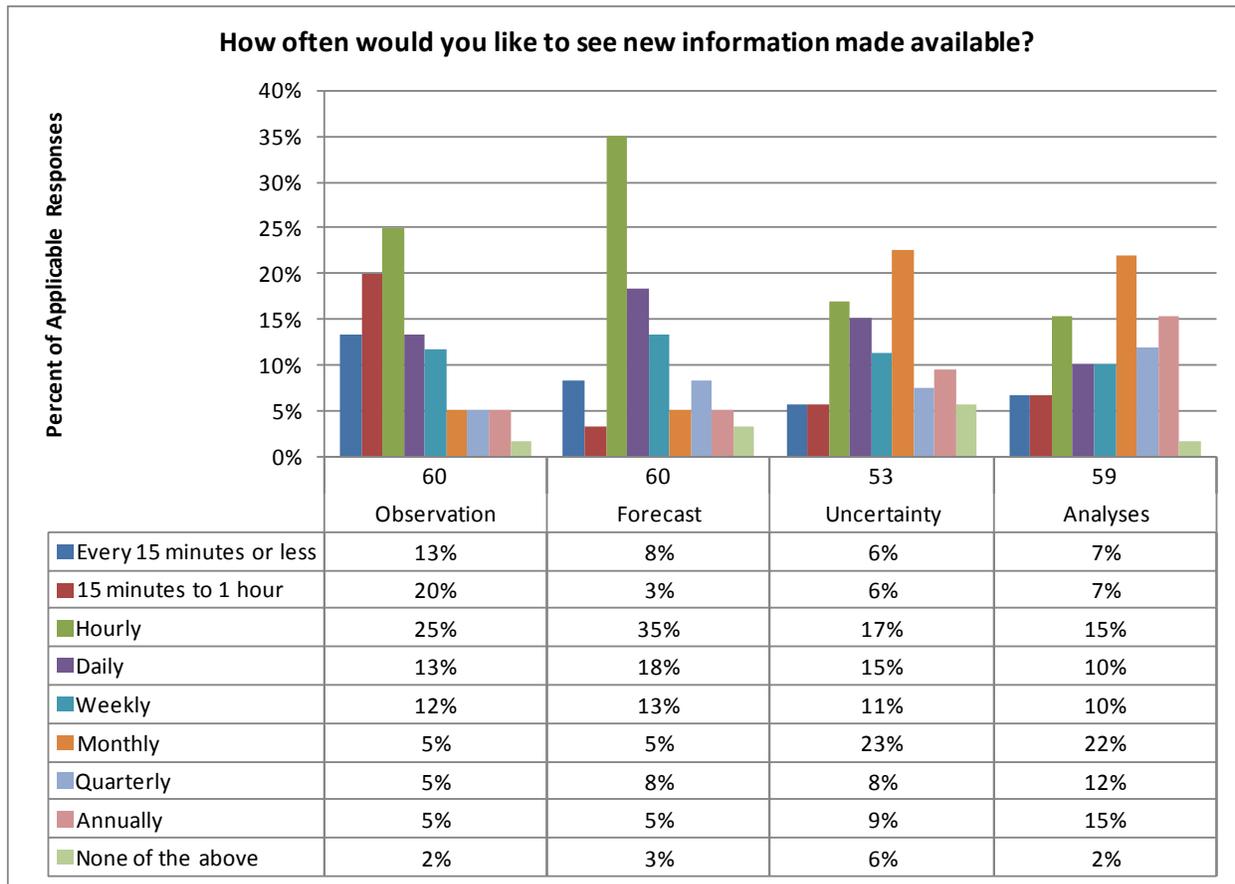
Respondents were also asked to indicate the decision-making time frames that would be supported by the information in which they were interested, see Figure 6-28, and how often they would like to see new information made available for use, see Figure 6-29. Regarding timeframes, 40 percent of respondents are using observations and analyses information for decisions over a 1 year timeframe, while forecast information is being used over a 1 to 3 day timeframe, and uncertainty over 1 week to 1 year. Respondents would like to see new observation and forecast information made available hourly (25 and 35 percent, respectively) and new uncertainty and analyses information monthly (23 and 22 percent, respectively).

Figure 6-28. Summary of the time frame for using observations, forecasts, uncertainty, and analyses for decision making.



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 68 survey responses. Those who never saw the question (i.e., incomplete or not applicable) are not included here.

Figure 6-29. Summary of respondent preferences for new observation, forecast, uncertainty, and analyses to be made available.



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 68 survey responses. Those who never saw the question (i.e., incomplete or not applicable) are not included here.

Respondents were asked to identify barriers to use for subsets of the four information categories (observations, forecasts, uncertainty and analyses).

For observations, forecasts, and uncertainties:

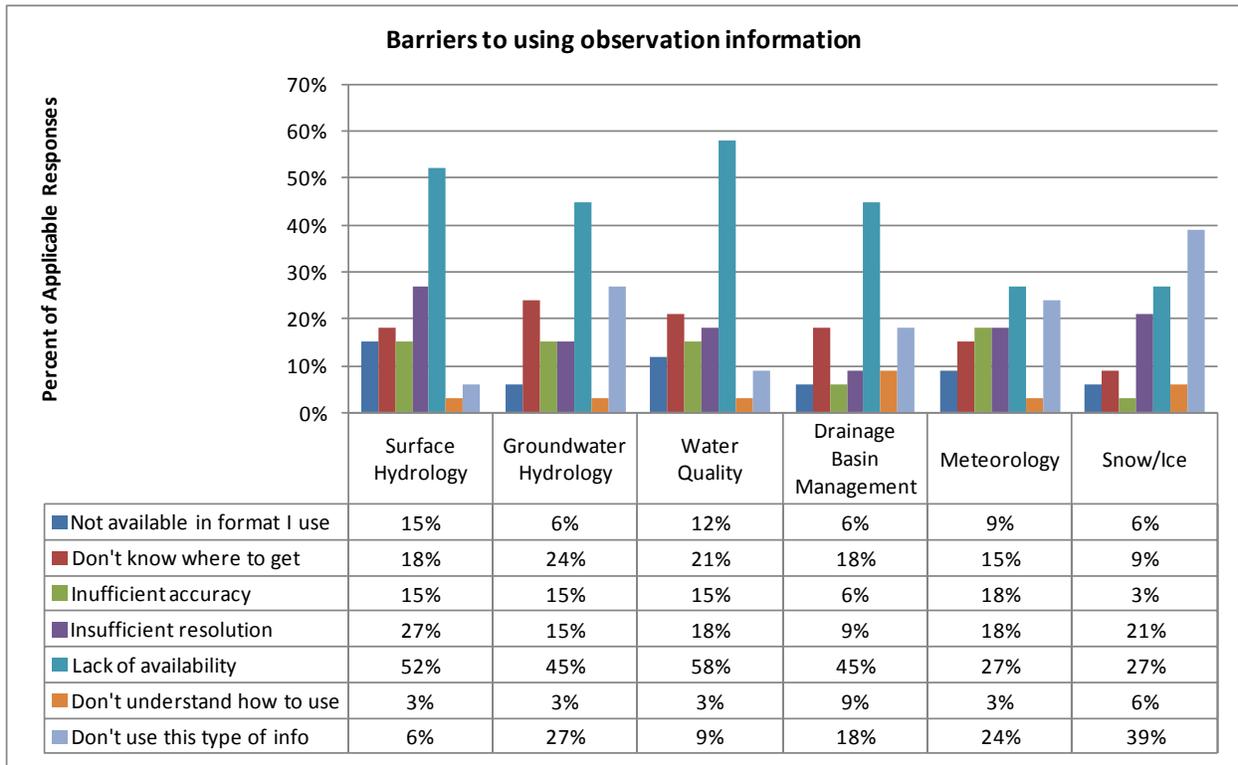
- Surface hydrology.
- Groundwater hydrology.
- Water quality.
- Drainage basin management.
- Meteorology.
- Snow/ice.

And for analyses:

- Public alerts.
- Meteorological analyses.
- Hydrologic analyses.
- Climatological analyses.
- Flood inundation mapping.
- Information integration.

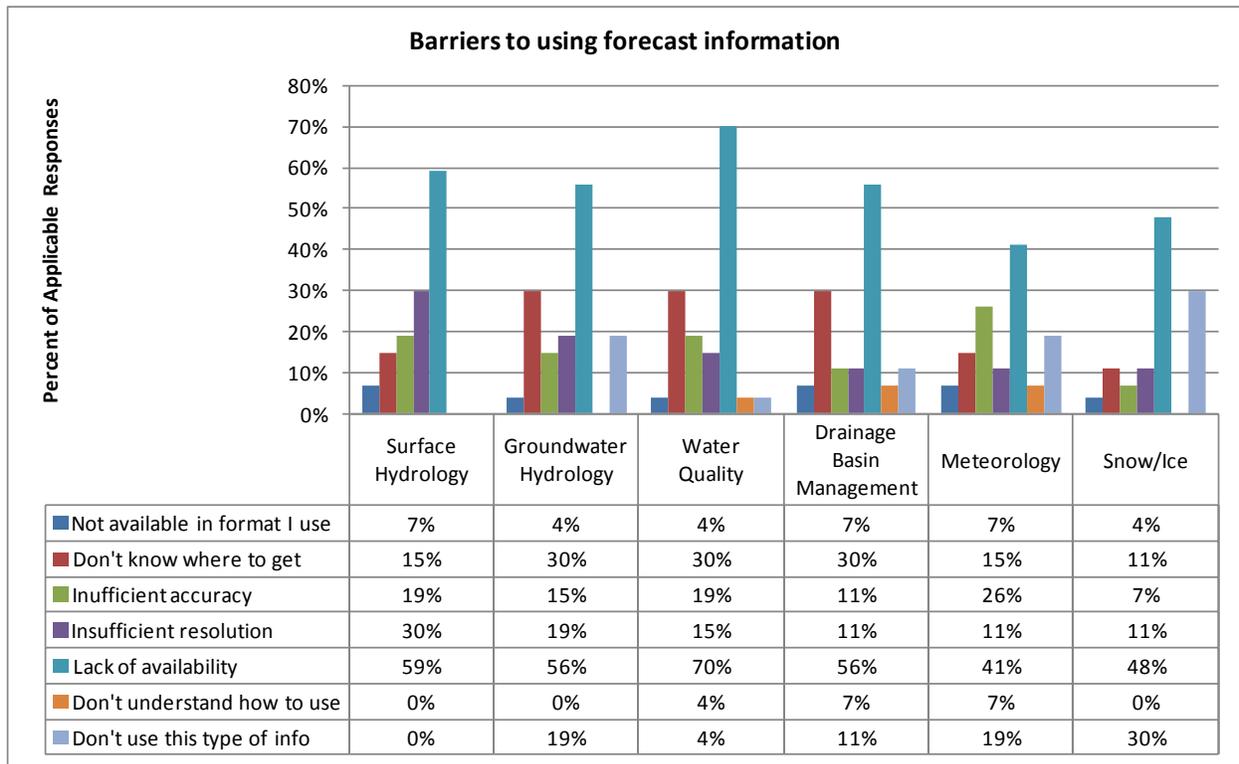
Across all information types, the most frequently identified barrier-to-use is the lack of availability, followed by insufficient accuracy or resolution. A number of respondents also indicated that they do not know where to get the information that they need. See Figure 6-30 to Figure 6-33.

Figure 6-30. “What are some of the barriers to using the following types of observation information?”



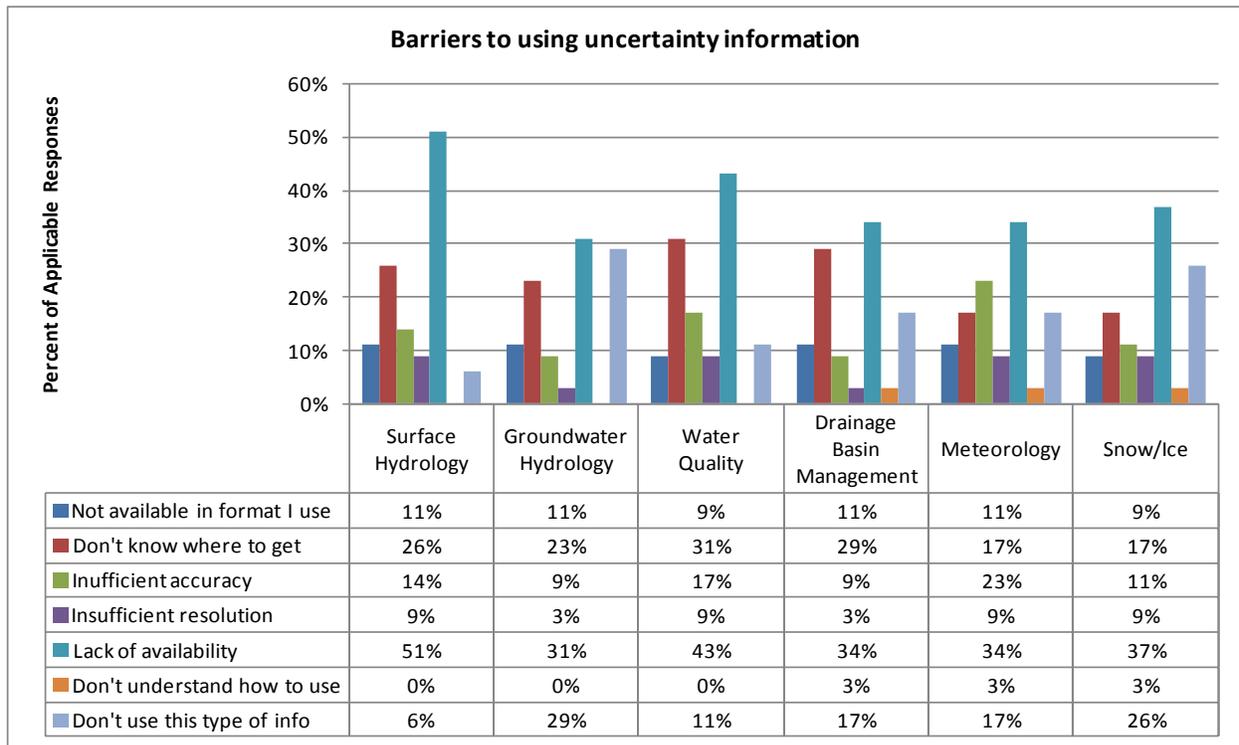
Note: There were 33 responses to this question.

Figure 6-31. “What are some of the barriers to using the following types of forecast information?”



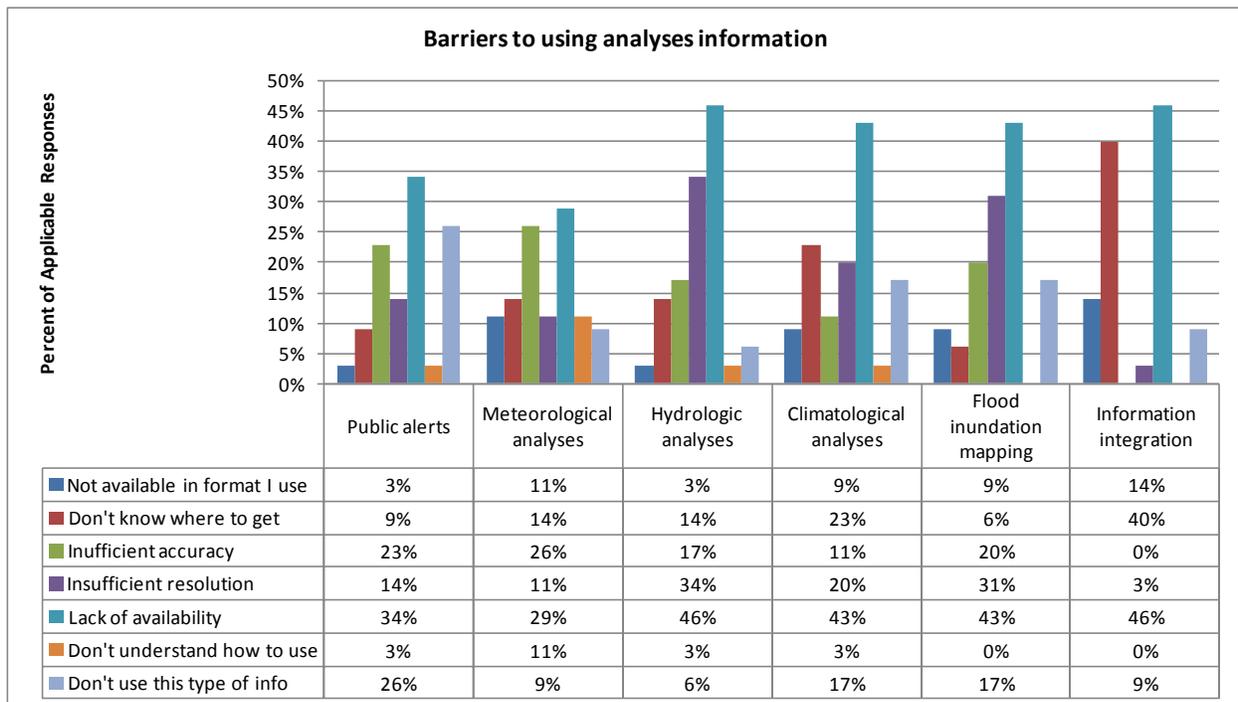
Note: There were 27 responses to this question.

Figure 6-32. “What are some of the barriers to using the following types of uncertainty information?”



Note: There were 35 responses to this question.

Figure 6-33. “What are some of the barriers to using the following types of analyses information?”

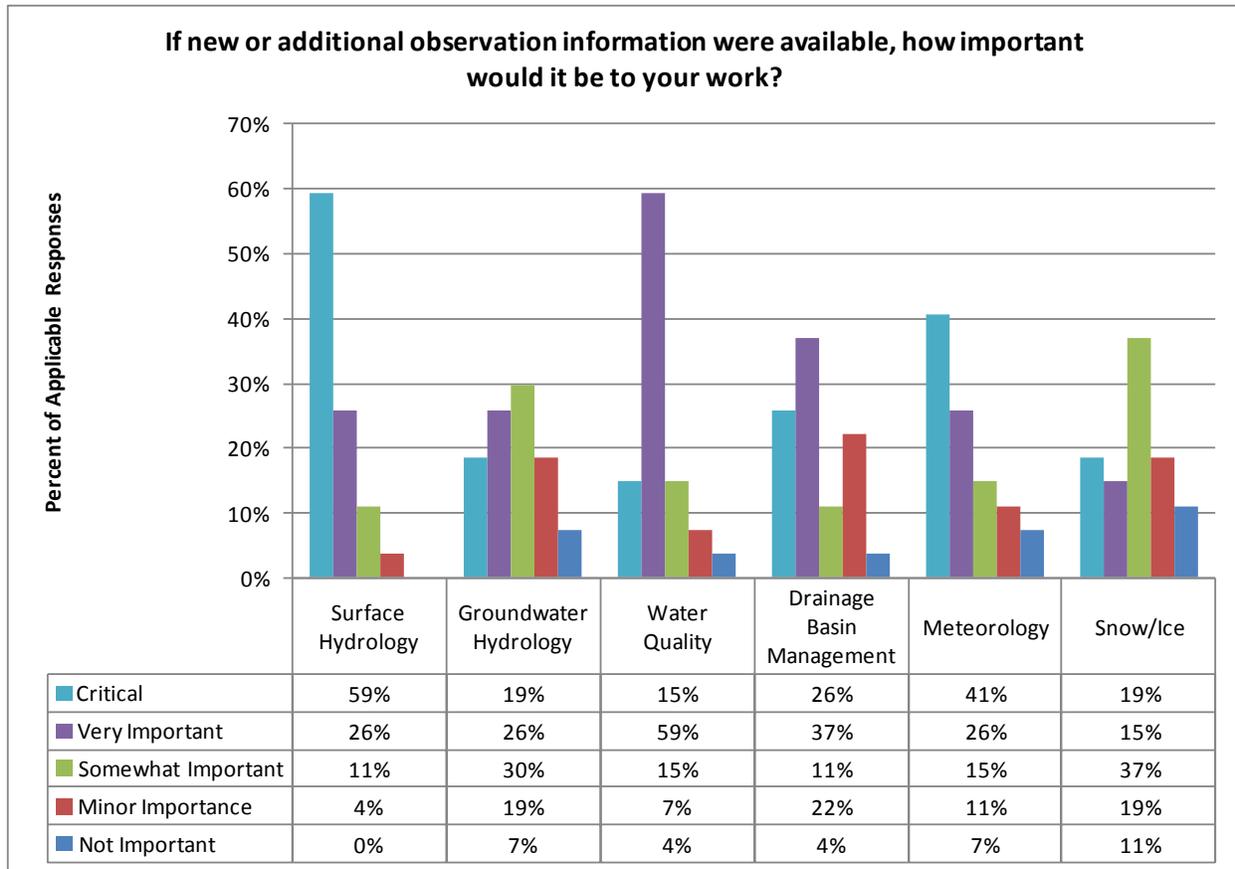


Note: There were 35 responses to this question.

Additional Information Needed

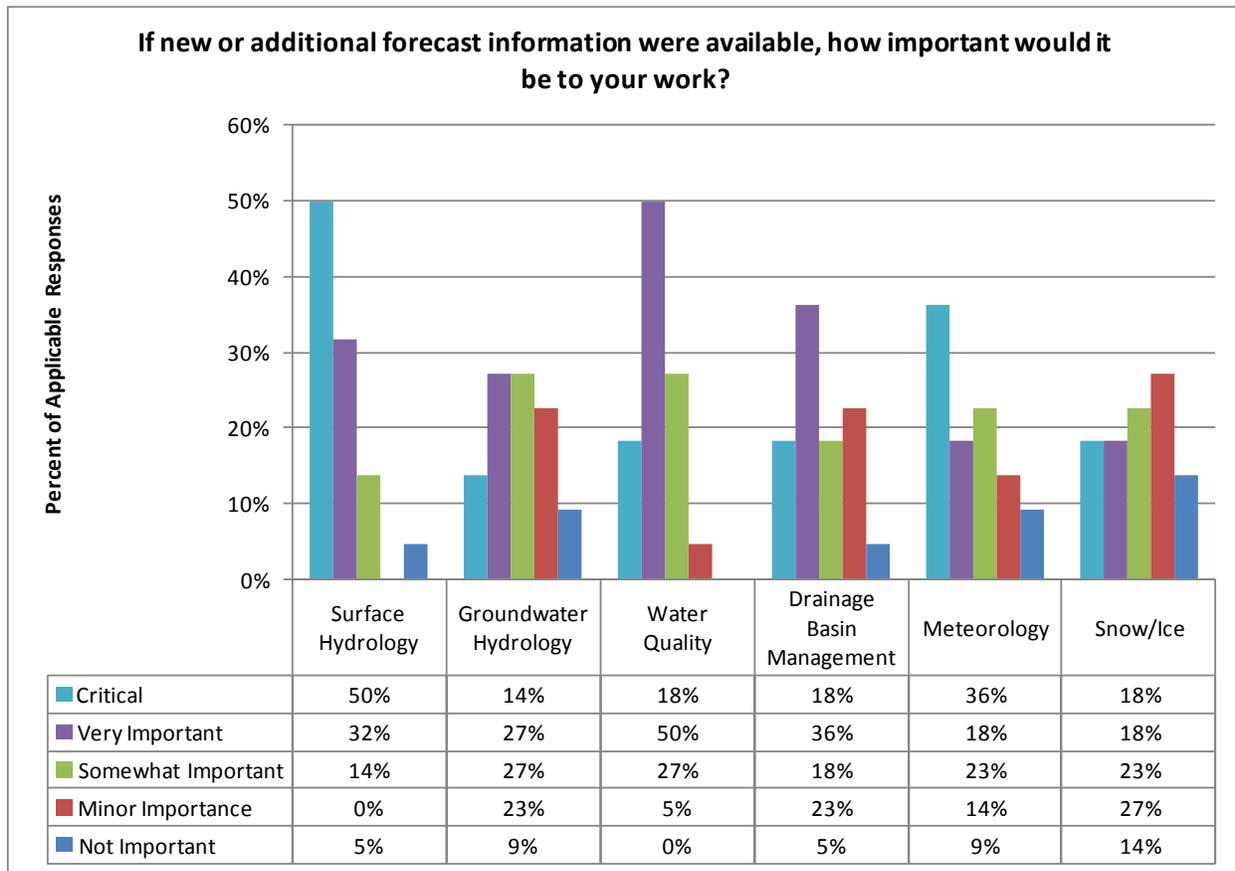
Respondents were asked if new or additional information were available, how important it would be to their decision making, see Figure 6-34 to Figure 6-37. For observations and forecasts, the subcategories of surface hydrology and water quality information were rated as the most important. For uncertainty, surface hydrology was rated as most important, followed equally by water quality, drainage basin management and meteorology. Under analyses, respondents rated hydrologic analyses and information integration as the most important. See Figure 6-34 to Figure 6-37.

Figure 6-34. Importance of new or additional observation information.



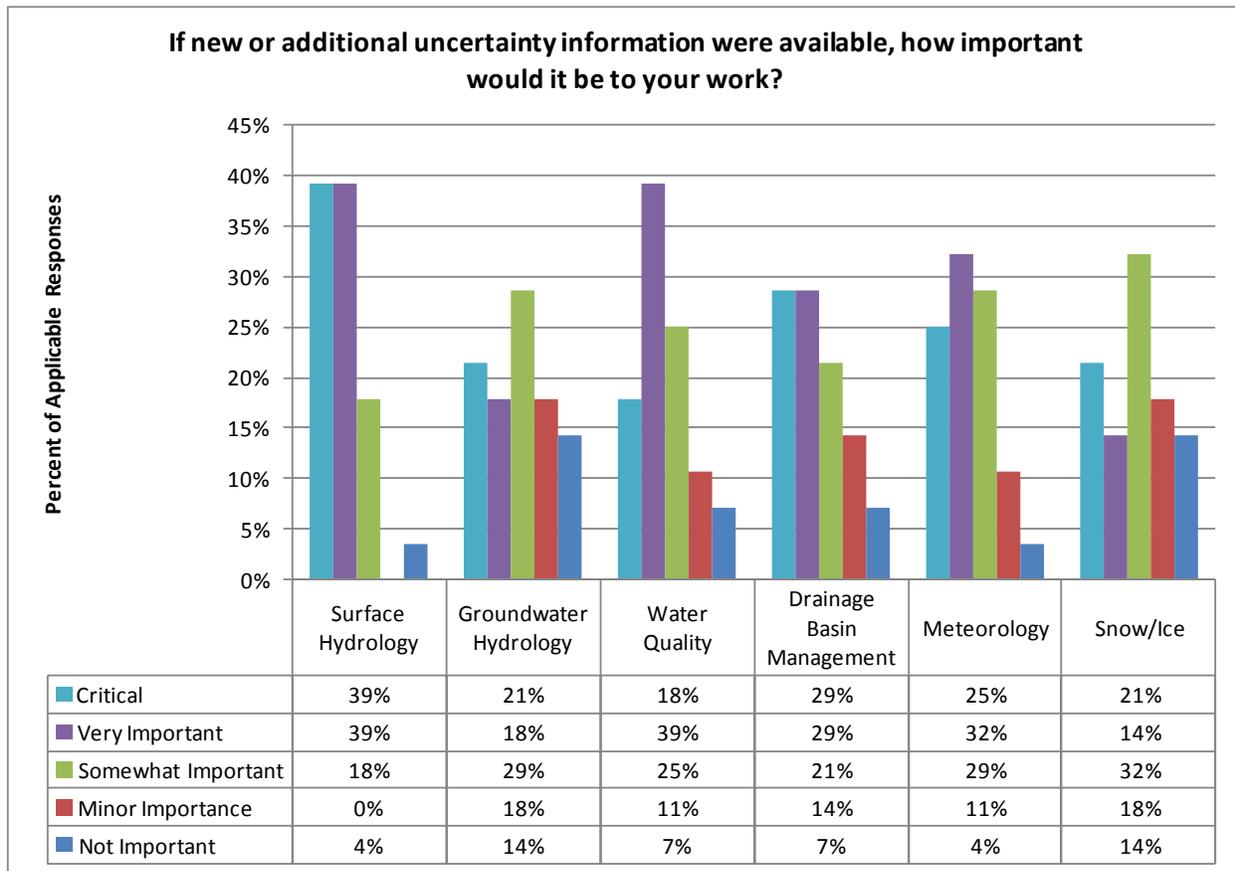
Note: There were 27 applicable responses to this question.

Figure 6-35. Importance of new or additional forecast information.



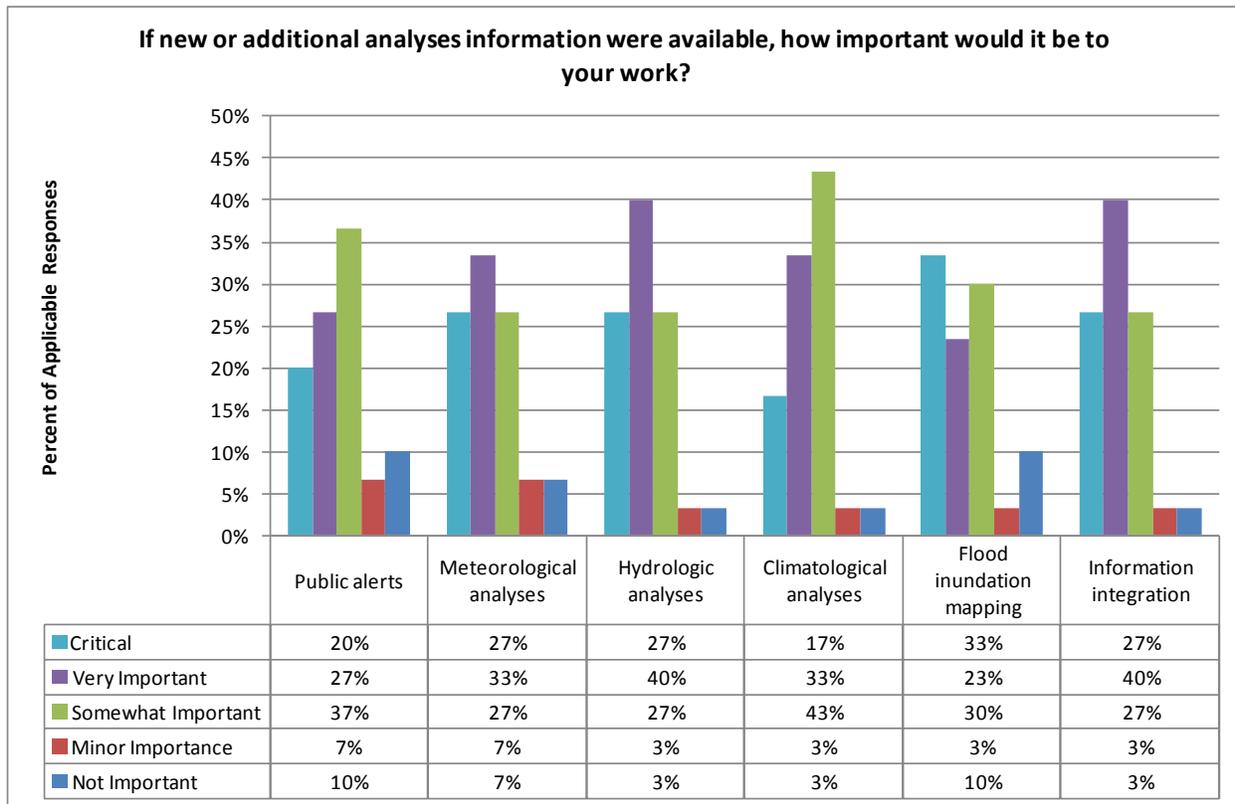
Note: There were 22 applicable responses to this question.

Figure 6-36. Importance of new or additional uncertainty information.



Note: There were 28 applicable responses to this question.

Figure 6-37. Importance of new or additional analyses information.



Note: There were 30 applicable responses to this question.

Summary of Open Comments

After respondents rated the importance of new or additional information types for their decision making, they were asked to describe the additional or new information for those types identified as very important or critical. This section summarizes the written comments in response to that question by category of information — observations, forecasts, uncertainty, and analyses.

For observations, forecasts and uncertainties the most important category of information is surface hydrology, followed by water quality; for analyses, the most important categories are hydrologic analyses and information integration. See Table 9 for a summary of responses by category.

Table 9. Number of respondents indicating that new or additional information is “Very important” or “Critical” to their decision making.

	Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/ice	Public alerts	Meteorological analyses	Hydrologic analyses	Climatological analyses	Flood inundation mapping	Information integration	Provided Description
Observations	23	12	20	17	18	9	--	--	--	--	--	--	22
Forecasts	18	9	15	12	12	8	--	--	--	--	--	--	21
Uncertainty	22	11	16	16	16	10	--	--	--	--	--	--	17
Analyses	--	--	--	--	--	--	14	18	20	15	17	20	19

Based on a review of the written comments from respondents the following new or additional information would be useful:

- **Observations:** more observations data through additional monitoring stations, integration of currently available data for the basin in one location, and information that supports targeted conservation activities or management of development.
- **Forecasts:** streamflow forecasts in smaller tributaries or estuarine zones to support planning water uses and response to high or low flow, forecasts of impacts (such as climate change and pollutants) at the basin level with comparisons to other levels (state, regional, coastal, national).
- **Uncertainty:** These comments are difficult to summarize because many repeat data needs stated in response to earlier questions or explain how the data would be used or why it is important. Specific data types needed include: flood forecasts, groundwater, surface temperature, reservoir elevations, and precipitation.
- **Analyses:** These comments are also difficult to summarize, but that is because each comment describes a specific topic; one trend that appears a few times is a need for a single “portal” or “clearinghouse” for the information.

The remainder of this section provides a summary of the written comments by information category (observations, forecasts, uncertainty, analyses) and a table presenting raw written comments by number and type of information types rated as “very important” or “critical.”

Observations

Twenty-two respondents provided written comments in response to the question “For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making.” There are three themes that appear in this set of comments, respondents need: more observations data through additional monitoring stations, integration of currently available data for the basin in one location, and information that supports targeted conservation activities or management of development. The most common theme is the desire for additional observations through monitoring stations, especially stream flow gages, to provide more detailed data at improved resolution. The following table summarizes the written responses by the information types marked as “very important” or “critical” to decision making (indicated with a check mark). The responses have been lightly edited for misspelled words and grammatical errors, non-substantive comments have been removed, and comments are ordered from most to least check marks. See Table 10.

Table 10. Summary of written responses to “For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making,” by information type.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making.
✓	✓	✓	✓	✓	✓	Additional stream flow gages, monitoring wells and water quality monitoring stations are needed throughout the Delaware basin.
✓	✓	✓	✓	✓	✓	All of the selected topics are connected and information on all topics is critical in making informed decisions in the basin.
✓	✓	✓	✓	✓	✓	Additional stream gages, additional surface water and ground-monitoring stations, air quality monitoring stations, precipitation monitoring.
✓	✓	✓	✓		✓	Integrating databases from various sources.
✓	✓	✓	✓	✓		Water availability forecast. Water Quality, eg TDS, TSS, Pathogen, etc. Temperature and PET forecast. Rainfall and Soil moisture forecast, etc.
✓	✓	✓	✓			Global, hemispheric, national, coastal, state, and local comparisons. How do we rate against other regional? What threats can change this?
✓	✓	✓	✓			I need a one-stop website where these data can be accessed, extracted, and sorted as necessary. Ground water hydrology needs to be defined on a smaller scale along with directional movement trends.
✓	✓	✓	✓			SW - Small stream hydrology data. GW - more observations to relate to SW Interaction.
✓	✓		✓	✓		Basin data is not integrated: USGS gages, rivermaster reports, NYC reservoir operations, weather data & forecasts are all isolated files.
✓		✓	✓	✓		It's not that the information is not being collected, the real improvement could be in how all that information is made available, data formats, and user interfaces.
✓		✓	✓	✓		New stream gages. More accurate short-duration rainfall data.
✓		✓	✓	✓		Surface hydrology - lessen lag time for gage reporting e.g. Lordville gage on web is 4 hours behind real time. Water quality - some continuous monitors should be placed in main stem and major tributaries in preparation for gas development to measure TDS, conductivity. Meteorology - archive of 1 and 2 days in advance weather forecasts should be maintained. Would assist with water temperature modeling.
✓			✓	✓	✓	Better rainfall runoff models with the updated climate change impacts included.
✓	✓	✓				Additional monitoring sites for SW, GW, and SW-water temperature.
✓	✓	✓				Information that would help us to work with developers in a way that would protect the resource while enabling development.
✓		✓		✓		In general, the observation information is good, additional observations in greater spatial resolution would be beneficial.
✓		✓		✓		Additional stream gages. Additional continuous water quality monitors with telemetry Improved meteorological forecasts.
✓		✓		✓		Daily flow statistics for ecoflow. Extreme Weather Events in future: flow and water quality.
✓			✓	✓		These three areas provide us with a focal point of where resources and support for life safety may be more important.
✓				✓	✓	Ice movement and ice jams observations. Additional streamgages. Additional precip, temperature and present weather gages.
		✓		✓		Main Stem and Tributary Water Quality, Dissolved Oxygen Data, Total Iron, Nutrients, UBOD, CBOD5.
		✓				Types of water quality impacts from urban/built environments and how it impacts fish and wildlife species. This will be information that can be used to target conservation activities.

Forecasts

Twenty-one respondents provided written comments in response to this question. Similar to the responses to the need for observation information, respondents are very interested in streamflow forecasts, especially along smaller tributaries or estuarine zones, for planning water uses and response to high or low flow. Several comments also highlight the usefulness of forecasts of impacts, including climate change and pollutants, at the basin level (and comparisons to global, national, coastal, regional, and state levels). See Table 11.

Table 11. Summary of written responses to “For the information types you rated as very important or critical, please describe the additional or new forecast information that you need for your decision making,” by information type.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new forecast information that you need for your decision making.
✓	✓	✓	✓	✓	✓	Forecast data is very important in planning seasonal water uses and possibly avoiding significant damages during storm events.
✓	✓	✓	✓	✓	✓	Additional monitoring stations (ground water and surface water), air quality stations, precipitation monitoring.
✓	✓	✓	✓	✓		Temperature, rainfall and streamflow forecast over a week.
✓	✓	✓	✓		✓	Integrating databases from different sources.
✓		✓	✓	✓	✓	We get this information but any improvement to accuracy would improve operations.
✓	✓	✓	✓			Global, National, Coastal, region and state comparisons. What threat currently impact and new threats and that impact they can have.
✓		✓	✓	✓		Both data sets are critical for improved flood hazard mapping and stormwater management.
✓			✓	✓	✓	The basin has older methods for forecasting. New methods that include climate change would be very helpful. Also, modeling for max and min foreseeable flows in the Delaware with new climate models.
✓	✓	✓				Forecast information related to impacts in the larger watershed area will help us to better forecast in our own area.
✓	✓	✓				Ability to compute flows on ungaged tributaries and assess impacts of changing water use or land use on flow or ecology.
	✓	✓	✓			Increased forecast knowledge of groundwater movements, water quality trends, and basin mgt trends are needed.
✓		✓		✓		Additional stream gages. Additional continuous water quality monitors. Better meteorological.
✓				✓	✓	Hourly surface hydrology forecasts for the length of the river, not at just points. Including the estuaries/tidal reaches. More accurate weather forecasts of rain, snow, snowmelt out 1-3 days. Forecasts of ice movement and ice jams.
✓				✓	✓	Climate change impacts to flow regime and ultimately, water supply needs.
✓				✓		Increased predictions at AHPS points with better accuracy further out in time. Better long-term low flow/drought forecasts.
✓				✓		Provide data support towards life safety initiatives.
✓			✓			Forecasts of precipitation, riverflows and reservoir releases as they pertain to potential drought declarations.
		✓				Are there specific water quality lags in the Delaware that correspond with specific events/time periods? Can we forecast them so we can manage the water to ensure

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new forecast information that you need for your decision making.
						limited impact on affected species, etc.
		✓				Hydrological and Water Quality Modeling on the fate and effects of pollutants.

Uncertainty

Seventeen respondents provided written comments on this question; the comments are somewhat difficult to interpret because only a few of them focus on describing what the information would look like. Many of the comments repeat data needs that were stated in response to earlier questions or explain how the information would be used and why it is important. The comments that do address uncertainty information directly describe specific data for which they need uncertainty information, such as: flood forecasts, groundwater, surface water temperature, reservoir elevations, and precipitation. See Table 12.

Table 12. Summary of written responses to “For the information types you rated as very important or critical, please describe the additional or new uncertainty information that you need for your decision making,” by information type.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new uncertainty information that you need for your decision making.
✓	✓	✓	✓	✓	✓	Global, National, Regional, and State comparisons? Threats and impacts current and foreseeable?
✓	✓	✓	✓	✓	✓	Understanding the uncertainty in data, forecasts and modeling work improves our overall understanding of the issues we are dealing with. It should also help us explain to the public the risks associated with taking actions that are based on the forecasts and modeling work we do.
✓	✓	✓	✓	✓	✓	Online, real-time reporting of stream water quality.
✓	✓	✓	✓	✓	✓	In all categories there is a certain amount of unknowns or uncertainty and all decisions would benefit if there was more information available to close such uncertainty gaps.
✓	✓	✓	✓	✓	✓	Better surface water, ground water, and or watershed models.
✓	✓	✓	✓	✓		Assurance of water availability with good quality for the growing season.
✓	✓	✓	✓		✓	Integrating databases from different sources.
✓	✓		✓	✓	✓	Critical to have NYC that empty into Delaware River with 20 percent year around voids! 06 Flood 6ft was attributed to overflow of NYC Reservoirs and can be proven by Roger Ruggles leading hydrologist, Leigh University. Reservoirs NYC were 1005 filled before June 06 rain event.
✓		✓	✓	✓		Surface Hydrology: So many of our structural BMPs are based on historical surface hydrology trends. With climate change we need a better understanding of potential increases in design storm frequency/duration/etc. Same comment for Water Quality and Drainage Basin Management. Climate change uncertainty makes it difficult to plan well for the future and anticipate the magnitude of potential change.
✓		✓	✓	✓		Stream flows, reservoir elevations, rainfall totals and forecasts, Total Nitrogen and TSS concentrations.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/ice	For the information types you rated as very important or critical, please describe the additional or new uncertainty information that you need for your decision making.
✓		✓	✓	✓		More precise streamflow and precipitation for modeling, mapping, and emergency management.
✓		✓	✓	✓		We have in-house modeling and are working with NWS to improve our forecasting ability. But modeling can always be improved.
✓			✓	✓	✓	Knowing the uncertainty of climate models and how they affect forecasting is very important.
✓		✓		✓		Better % chance forecasting of events.
✓	✓	✓				Would help in discussion about planning for the future needs of the community.
		✓	✓	✓		Water quality - daily and seasonal baseline trends have not been established in many locales which would be a benefit when natural gas development begins. better definition and reduction in uncertainty in meteorology would be important to me in predicting water temperature trends. Reservoir levels that are reported more frequently than one per week would allow better assessment of precipitation and use impacts. Snow/ice information - not sure how to obtain and what form it is in
✓				✓	✓	Uncertainty info needs to be in a form that is understandable by the public. Use social science.
✓	✓					Better 3-6 months forecasting of SW and GW would enable better decision making during wet or dry period. Currently, the CPC forecast is usually EC or maybe 40%-30%-30%. These forecasts are not very helpful. (Or maybe they're just not telling me what I want to hear...).
✓		✓				Uncertainty around hydrologic and water quality modeling.
✓						How confident are [you] that predictions will be close to reality?
✓						Uncertainty of flood forecasts such as confidence limits on a forecasted flood peak for a river.

Analyses

Nineteen respondents provided written comments in response to this question. While it is difficult to summarize the comments because many focus on the importance of analyses or describe very specific topics, one trend that appears in the responses is the need for a single “portal” or “clearinghouse” for the information. See Table 13.

Table 13. Summary of written responses to “For the information types you rated as very important or critical, please describe the additional or new analyses that you need for your decision making,” by analysis type.

Public alerts	Meteorological analyses	Hydrologic analyses	Climatological analyses	Flood inundation mapping	Information integration	For the information types you rated as very important or critical, please describe the additional or new analyses that you need for your decision making.
✓	✓	✓	✓	✓	✓	Information integration would significantly assist. Pulling together the information from different sources is time consuming. Much of the information (hydrologic, climatologic, etc.) is used for flood prediction, Ag BMP design, watershed analysis, nutrient management planning, etc. VERY valuable!

Public alerts	Meteorological analyses	Hydrologic analyses	Climatological analyses	Flood inundation mapping	Information integration	For the information types you rated as very important or critical, please describe the additional or new analyses that you need for your decision making.
✓	✓	✓	✓	✓	✓	Having credible information in all these areas will help with projections and planning.
✓	✓	✓	✓	✓	✓	Better information integration and modeling is important for all of these.
✓	✓	✓	✓	✓	✓	Improved hydrologic and topographic analyses for floodplain mapping and stormwater management.
✓	✓	✓	✓	✓	✓	High resolution, information that tells me what action I need to take to protect my life & property. Full flood threat graphics that include river flood, flash flood, storm surge, coastal flooding...all flood threats on to one easily understandable graphic.
✓	✓	✓	✓	✓	✓	Any improvement to our ability to analyze data and model results has to benefit overall watershed management objectives.
✓	✓	✓	✓	✓	✓	Need you to use above alerts and analyses to lower NYC Reservoirs and inform the public when reservoirs are full so they can start packing when heavy event is on its way!
✓	✓	✓	✓	✓	✓	Improved surface water, ground water, stormwater, air quality, and transportation models.
✓	✓	✓	✓		✓	All hydrologic info, forecast and analyses in one portal is very important.
	✓	✓	✓	✓	✓	Integrating databases from different sources.
✓	✓	✓		✓		Provide information that would be usable in planning procedures and public notification.
✓			✓	✓	✓	Text or email alerts for gage heights, streamflows, reservoir elevations, and digital flood inundation mapping linked to real-time stream flows and predicted flood flows. A single information portal - including spatial data would be extremely helpful.
	✓	✓	✓		✓	A single source for multi agency analysis would be helpful.
✓				✓	✓	One example would be to integrate inundation mapping with HAZUS. Develop integrated storm surge and riverine model that includes graphics and 3D visualization tools.
	✓	✓	✓			Analyses are what tie all the information together. This is often the piece that is very expensive and rarely regularly updated.
	✓	✓			✓	Public alerts - alerts of impending high or low flows at designated trigger points would make decision makers more aware of impending conditions. Meteorological analyses such as observed and trends of expected variation within each month would help manage reservoir releases, downstream flows and temperatures. Climatologic analyses such as temperature trends and incidence of storms and droughts (high and low flows) over time would assist with water use planning and reservoir management. Information integration would be important as a one stop location for important data.
	✓	✓				Trends in rainfall, average streamflows, and climatologic trends important for managing aquatic species into the future.
		✓			✓	Trending in analysis information will help focus planning for the future.
		✓			✓	Integrated information and analysis is always critical that is way you collect the data.
				✓	✓	To make the decision of where the most critical floodplain habitats to restore to store the most amount of water during high flows--it would be great to know which floodplains are the most inundated and how much water they can store if restored. In addition--having easy access to a "clearinghouse" of water quality and management information and analyses would be very useful for decision making. The MOST important thing would be to make sure it is in a format and translated

Public alerts	Meteorological analyses	Hydrologic analyses	Climatological analyses	Flood inundation mapping	Information integration	For the information types you rated as very important or critical, please describe the additional or new analyses that you need for your decision making.
						enough for decision making.
	✓					More frequent and readily available flood forecasts.
				✓		In general, I see flood inundation mapping as a key tool for making decisions that could directly lead to reduction in economic losses. Broader availability is key.
					✓	At this time, I am not even sure about what information is available to me for my purposes.

Other

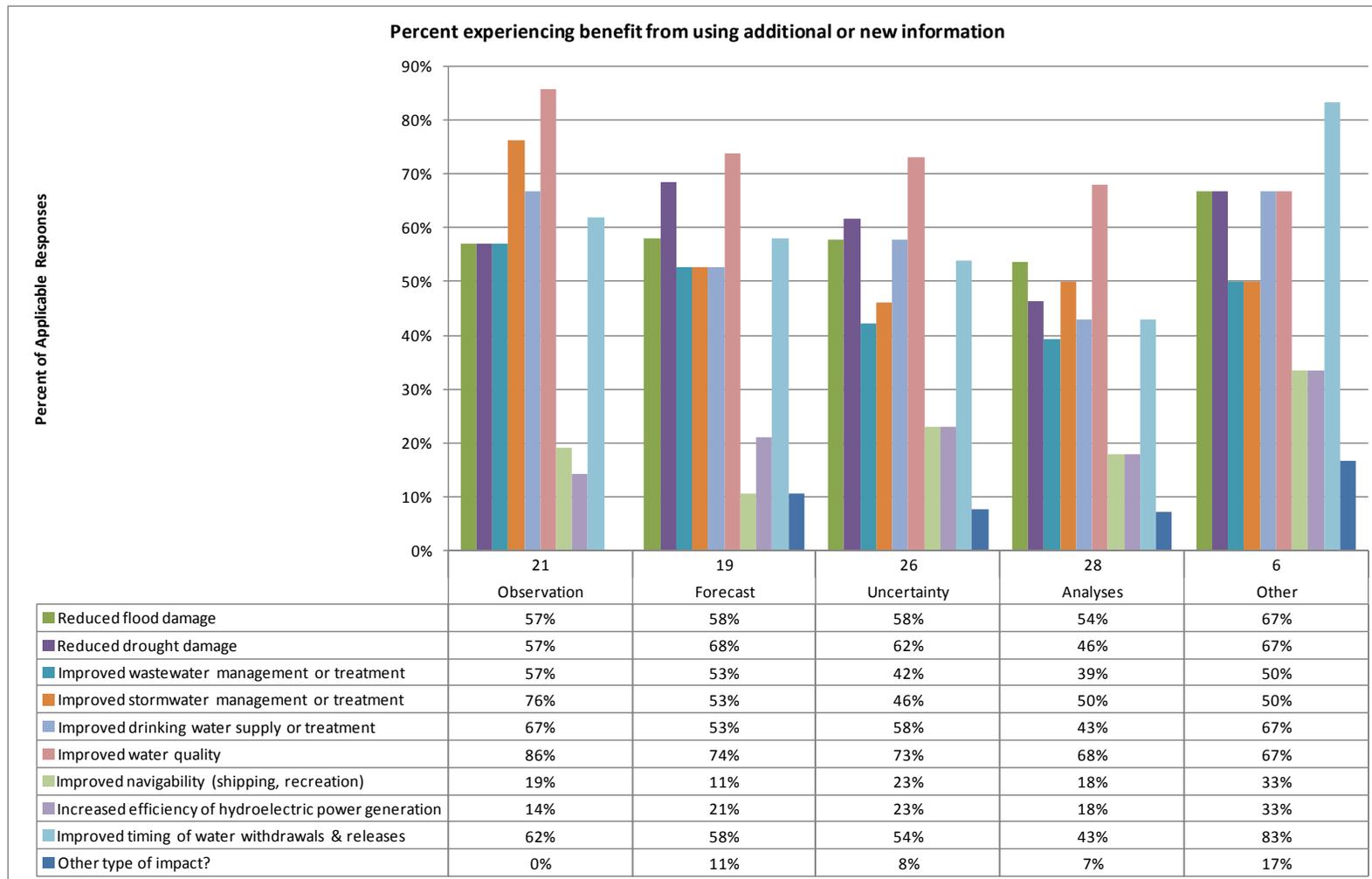
Seven respondents indicated that they would rank “other” types of information as needing improvement and critical for informing decisions on their top priority issue. They provided the following written comments to describe the other types of information that they need for their decision-making:

- Education and public information on the subjects as they apply to the basin. There are many misconceptions about climate change. Some are more informed than others. I think it would help people to know what the climate change means for them and how documented the evidence is for what they are being told.
- Information handling and dissemination. Standardizing ways in which data are available, such as USGS gage information, could greatly assist and information users. Availability of National Weather Service meteorology predictions would assist modelers.
- Long range history and projections can help determine if there are just normal trends or direct effects from development on water resources.
- More streamgaging and monitoring stations are needed.
- Non-bias, non industry driven to paid for studies showing the facts. Water was here and now it's here. Multiple years showing effects on watersheds, water quality, air quality, and light or noise pollution studies.
- Standardize and integrate state databases of NPDES discharge data (e.g. minimum standards for N and P monitoring, one access portal).
- When you sit around the table at your meetings...see what you can do to put 20% year around voids in the NYC Delaware Reservoirs.

Economic Impacts or Benefits

Respondents were asked if they would experience any of a set of impacts or benefits from using additional or new information from IWRSS partner agencies, see Figure 6-38. The most commonly anticipated benefits of new observation information are reduced flood damage and improved stormwater management or treatment. For forecasts and uncertainty, improved water quality and reduced drought damaged are cited by most respondents. And for new or additional analyses, respondents expect improved water quality and reduced flood damage.

Figure 6-38. Response to “would you experience any of the following impacts of benefits from using additional or new information from IWRSS partner agencies?”



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 68 survey responses. Those who never saw the question (i.e., incomplete or not applicable) are not included here. These totals do include those who saw but skipped the question.

Summary of Open Comments

Respondents who indicated that they would experience any of a set of impacts or benefits from using additional or new information from IWRSS partner agencies were then asked to describe the benefit and estimate the cost avoided or benefit gained per year or per event.

Observations

By providing new or additional observation information for the Delaware River Basin nine types of benefits would be realized: reduced flood damage, reduced drought damage, improved wastewater management/treatment, improved stormwater management/treatment, improved drinking water supply/treatment, improved water quality, improved navigability, increased efficiency of hydroelectric power generation, improved timing of water withdrawals/releases. Specifically:

- **Reduced flood damage:** Through improved flood hazard mapping, better definition of flood risk and management in reservoir release plans, better construction of floodgates and levees, better guidance for emergency managers to provide early warning for residents resulting in lower costs of emergency services and avoided loss of life, reduced risk, increased resilience, and protection of property.
- **Reduced drought damage:** New/additional observation information would reduce drought damage because data could be used to inform reservoir releases to protect aquatic ecology at \$100,000 per event. Also it would lead to more accurate predictions of deficiencies in water supplies and aquatic life would benefit from reduced frequency and duration of low flows.
- **Improved wastewater management/treatment:** New/additional observation information could inform fisheries managers on the correlations between fish population trends and wastewater management practices, saving over \$100,000 per year.
- **Improved stormwater management/treatment:** New/additional observation information could inform fisheries managers on correlations between fish population trends and stormwater management practices saving over \$100,000 per year. Additionally, it would provide additional monitoring information for the watershed, improve water quality and aquifer recharge, support the tourism industry, improve use of best management practices, improve planning and design of SCMs, and reduce sediment load and stabilize banks and substrate through less flashy flows.
- **Improved drinking water supply/treatment:** Through integration of models and hydrology to reduce salinity impact to drinking water intakes, early warning of a turbidity pulse could reduce water treatment costs, improvement of source water protection, provision of additional monitoring information, protection of public health, and improve reliability of supply and ease competing uses during droughts.
- **Improved water quality:** New/additional observation information would help protect \$1 billion worth of ecosystem services provided by natural capital, and inform fisheries managers on correlations between fish population trends and water quality parameters would result in \$250,000 savings per event. Also, respondents expect significant positive eco-service impacts, improved source water protection, improved recreational opportunities, reduced treatment costs, support of the tourism industry, and improved aquatic community health.
- **Improved navigability:** Increased access to ports. One respondent commented about the usefulness of PORTS — an observation system.
- **Increased efficiency of hydroelectric power generation:** Through minimized need for generation, and reduced impact on flows and by extension, aquatic life.

- **Improved timing of water withdrawals/releases:** New/additional information would help protect \$1 billion in ecosystem services provided by natural capital, and could be valuable to protect aquatic ecology at critical life stages and during droughts and result in \$250,000 in avoided costs per event.

Forecasts

By providing new or additional forecast information for the Delaware River Basin nine types of benefits would be realized: reduced flood damage, reduced drought damage, improved wastewater management/treatment, improved stormwater management/treatment, improved drinking water supply/treatment, improved water quality, improved navigability, increased efficiency of hydroelectric power generation, and improved timing of water withdrawals/releases. Specifically:

- **Reduced flood damage:** Through better flood hazard modeling and reduced damage to pumphouses on the river.
- **Reduced drought damage:** Through improved instream flows, reduced operation costs, and improved planning for future water supply.
- **Improved wastewater management/treatment:** New/additional forecast information could inform fisheries managers on correlations between fish population trends and wastewater management practices saving over \$100,000 per year. Also, through improved water quality for humans and ecological communities; discussion of use of fewer or smaller, decentralized plants; and identifying where to replace septic systems.
- **Improved stormwater management/treatment:** New/additional forecast information could inform fisheries managers on correlations between fish population trends and stormwater management practices saving over \$100,000 per year. Also, through increased discussion of use of BMPs and better control of nonpoint pollution and nuisance flooding.
- **Improved drinking water supply/treatment:** Through reduced treatment costs, improvement and maintenance of high quality water resources, and leading to improved human health through removal of organic and other components.
- **Improved water quality:** New/additional forecast information would lead to improved water quality by helping protect \$1 billion worth of ecosystem services provided by natural capital, and could inform fisheries managers on correlations between fish population trends and water quality leading to savings of over \$100,000 per year. Also, through improvement and maintenance of high quality water resources, improved ecological health, and more recreational opportunities.
- **Improved navigability:** Leading to increased access to ports and economic development.
- **Increased efficiency of hydroelectric power generation:** Through reduced frequency of operation which reduces ongoing cost, and improved flows due to less use of water per kilowatt produced.
- **Improved timing of water withdrawals/releases:** New/additional forecast information will help protect \$1 billion worth of ecosystem services provided by natural capital and could inform fisheries managers on correlations between fish population trends and wastewater management practices saving over \$250,000 per year. Also, improved efficiency resulting from optimized withdrawals/releases, improved flows for ecological health and recreation, and reduced energy and treatment costs.

Uncertainty

By providing new or additional uncertainty information for the Delaware River Basin nine types of benefits would be realized: reduced flood damage, reduced drought damage, improved wastewater management/treatment, improved stormwater management/treatment, improved drinking water supply/treatment, improved water quality, improved navigability, increased efficiency of hydroelectric power generation, and improved timing of water withdrawals/releases. Specifically:

- **Reduced flood damage:** Reduced uncertainty about flood impacts will provide emergency services with a way to target response in advance of a flood event, increasing public safety and reducing loss of life and property. Also, understanding uncertainty improves our knowledge of the limitations of data, models, and forecasts (this point cuts across all benefit categories).
- **Reduced drought damage:** Through improved reservoir management and improved system reliability. Also, reduces the number of new wells to be drilled or redeveloped.
- **Improved wastewater management/treatment:** Through improved discussion about planning for the future, fewer facilities to be built, less poor water quality excursions.
- **Improved stormwater management/treatment:** Through support of discussions about using BMPs in new/reworked development, and use of information about nonpoint pollutant loads to target placement of costly BMPs. Also improved aquifer recharge and water quality, and reduced storm peaks.
- **Improved drinking water supply/treatment:** Flooding contributes huge sediment and nutrient loading spikes to the NYC water supply to 9 million+ users. Uncertainty information would lead to more reliable supplies, improve health impacts, and help to plan for protection of future water resources.
- **Improved water quality:** The Delaware portion of the NYC water supply relies on information for agricultural BMP design, flood mitigation, and stream restoration decisions. This information would improve support of existing and recovering aquatic life in systems like the Little Schuylkill River. Also, increased recreational opportunities, improved planning for protection of future water resources, and less money spent on unnecessary treatments.
- **Improved navigability:** Leading to increased access to ports.
- **Increased efficiency of hydroelectric power generation:** Through more predictable generation schedules and resulting flows, leading to reduced need to build new generating capacity and reductions in water use.
- **Improved timing of water withdrawals/releases:** Information about uncertainty about major storm precipitation amounts both real-time at fine resolution and forecasts would facilitate reservoir operations and dam safety precautions before and during major events. Also, better use of reservoir storage and support of various species and life stages affected by poor timing or management.

Analyses

By providing new or additional analyses information for the Delaware River Basin nine types of benefits would be realized: reduced flood damage, reduced drought damage, improved wastewater management/treatment, improved stormwater management/treatment, improved drinking water

supply/treatment, improved water quality, improved navigability, increased efficiency of hydroelectric power generation, and improved timing of water withdrawals/releases. Specifically:

- **Reduced flood damage:** Analysis of frequency, impacts and integrated reservoir management would help identify possible improvements in integrated water resource planning; and reduce the number of floodgates or levees to be built or repaired.
- **Reduced drought damage:** Through more effective water storage, use, and support of conservation releases; improved ability to plan for future water supply.
- **Improved wastewater management/treatment:** New/additional analyses could inform fisheries managers on correlations between fish population trends and wastewater management practices saving over \$100,000 per year. Also, analyses of treatment technologies, effectiveness and feasibility will improve overall water quality.
- **Improved stormwater management/treatment:** New/additional analyses could inform fisheries managers on correlations between fish population trends and stormwater management practices saving over \$100,000 per year. Analyses of existing stormwater management impoundments could direct retrofits that improve management and groundwater infiltration, increase aquifer recharge and water availability, and help focus planning on future needs.
- **Improved drinking water supply/treatment:** Analyses that integrate multiple systems along a river could increase system reliability and reduce waste, focus planning on future needs, and improve health impacts.
- **Improved water quality:** New/additional analyses would help to protect \$1 billion worth of ecosystem services, and data could inform fisheries managers on correlations between fish population trends and water quality trends saving over \$250,000 per year. Also, increase recreational opportunities and improve lake, stream, and river water quality; and help focus planning on future needs.
- **Improved navigability:** Leading to increased access to ports.
- **Increased efficiency of hydroelectric power generation:** Analyses of demand patterns could improve system reliability.
- **Improved timing of water withdrawals/releases:** New/additional analyses would help to protect \$1 billion worth of ecosystem services, and data could inform fisheries managers on correlations between fish population trends and water release/withdrawals saving over \$250,000 per year. Also, analyses of downstream flow patterns resulting from withdrawals and releases can lead to proposals for better release management.

Other

By providing new or additional information for the Delaware River Basin six types of benefits would be realized: reduced flood damage, reduced drought damage, improved wastewater management/treatment, improved stormwater management/treatment, improved navigability, and improved timing of water withdrawals/releases. Specifically:

- **Reduced flood damage:** Through the ability to predict and plan for floods.
- **Reduced drought damage:** Through better monitoring of aquifers and flow.
- **Improved wastewater management/treatment:** Through identification of where sewers are needed.

- ***Improved stormwater management/treatment:*** Leading to increased aquifer recharge.
- ***Improved navigability:*** Leading to increased access to ports.
- ***Improved timing of water withdrawals/releases:*** Archived weather information and multiple information sources available in similar formats would assist data users with analyses, predictions, and modeling.

APPENDIX D: Susquehanna River Basin Detailed Survey Results

Susquehanna River Basin

Responses

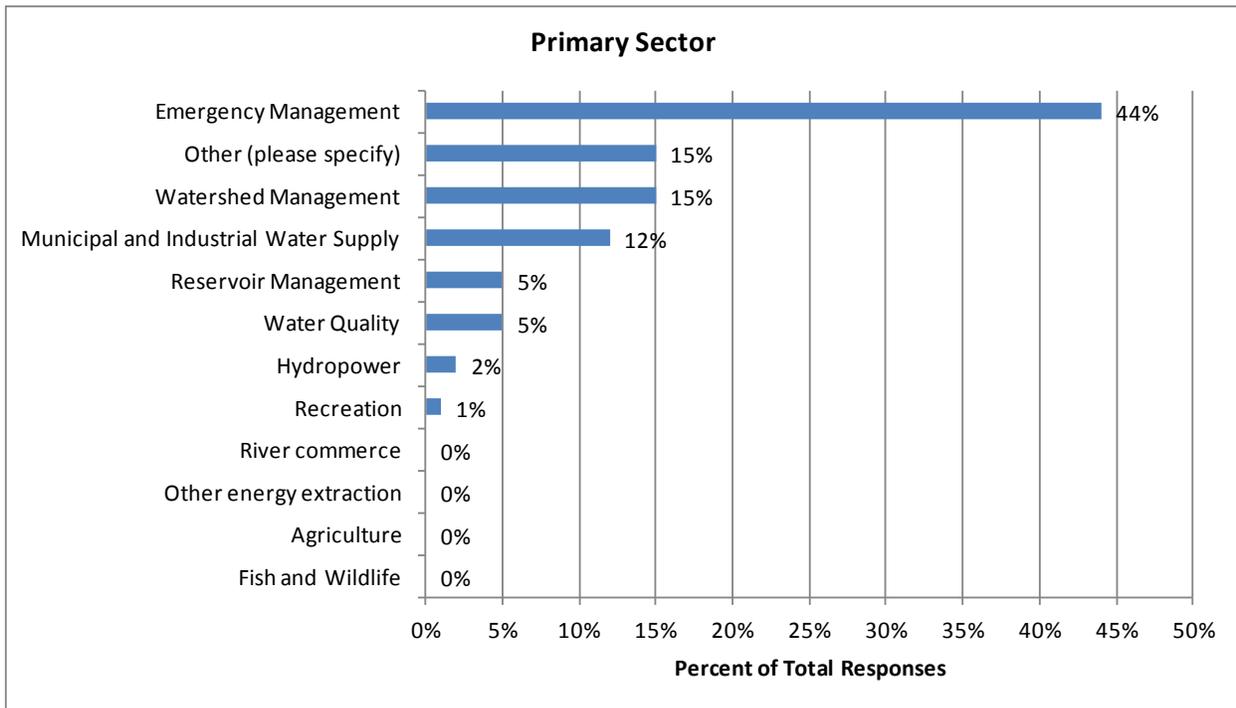
Personalized survey invitation emails were sent to 224 people. ERG received 81 total responses, including 55 complete surveys (i.e., respondent reached the end of the survey and hit submit) and 26 incomplete surveys (i.e., respondent closed out of the survey before completing). Of these 81 responses, 73 were from individuals on the mailing list or colleagues to whom those emails were forwarded; the other 8 responses came from “untracked” participants (i.e., those who arrived at the survey via a link on the RBC website). To the maximum extent possible, the incomplete surveys are included in the results presented below.

Respondent Demographics

Respondents were asked to select the primary sector in which their work or interest is focused in the Susquehanna River basin, see Figure 6-39. A large number of respondents (44 percent) indicated that their work or interest in the Susquehanna River basin is primarily focused on emergency management. Other common areas of focus are watershed management (15 percent) and municipal and industrial water supply (12 percent). An additional 15 percent of respondents specified an “other” sector (other than a categorized response option). Their verbatim responses were:

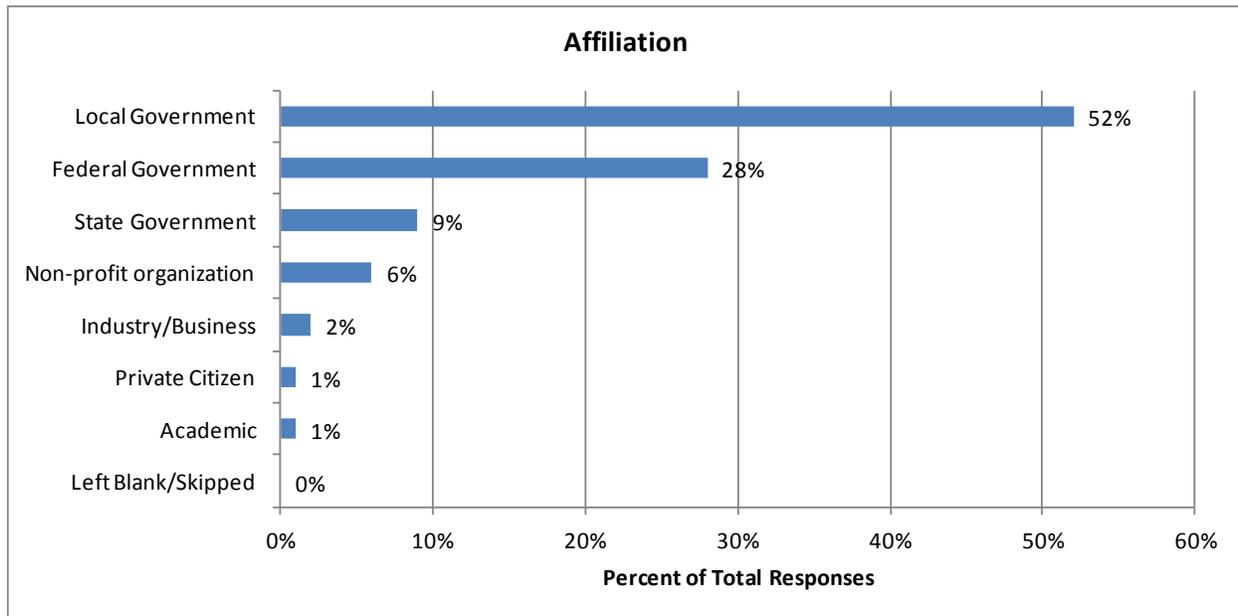
- 911
- Climate office
- DCNR Forestry
- Floodplain management
- Flow monitoring
- Monitoring, floods, and droughts
- Municipal gov.
- Planning
- River flow
- Scientific investigations and data collection
- US Geological Survey-federal govt
- Water data provider

Figure 6-39. Responses to “Please select the primary sector in which your work or interest is focused in the Susquehanna River Basin.”



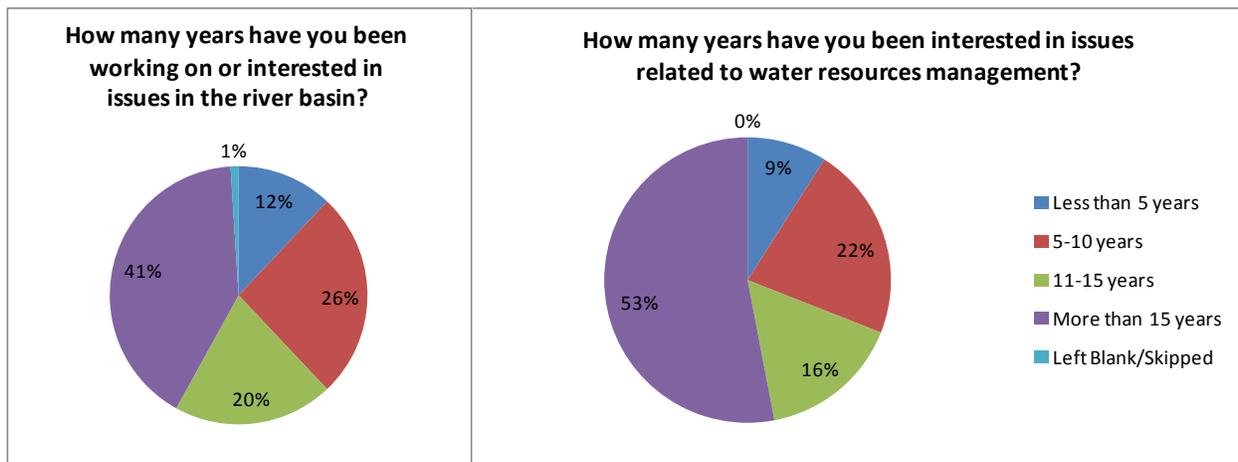
Respondents were asked to indicate the affiliation that best describes their work or interest in the Susquehanna River basin, see Figure 6-40. More than half (52 percent) of respondents are affiliated with a local government agency and 28 percent are affiliated with a federal government agency.

Figure 6-40. Responses to “Please select the affiliation that best describes your work or interest in the Potomac River Basin.”



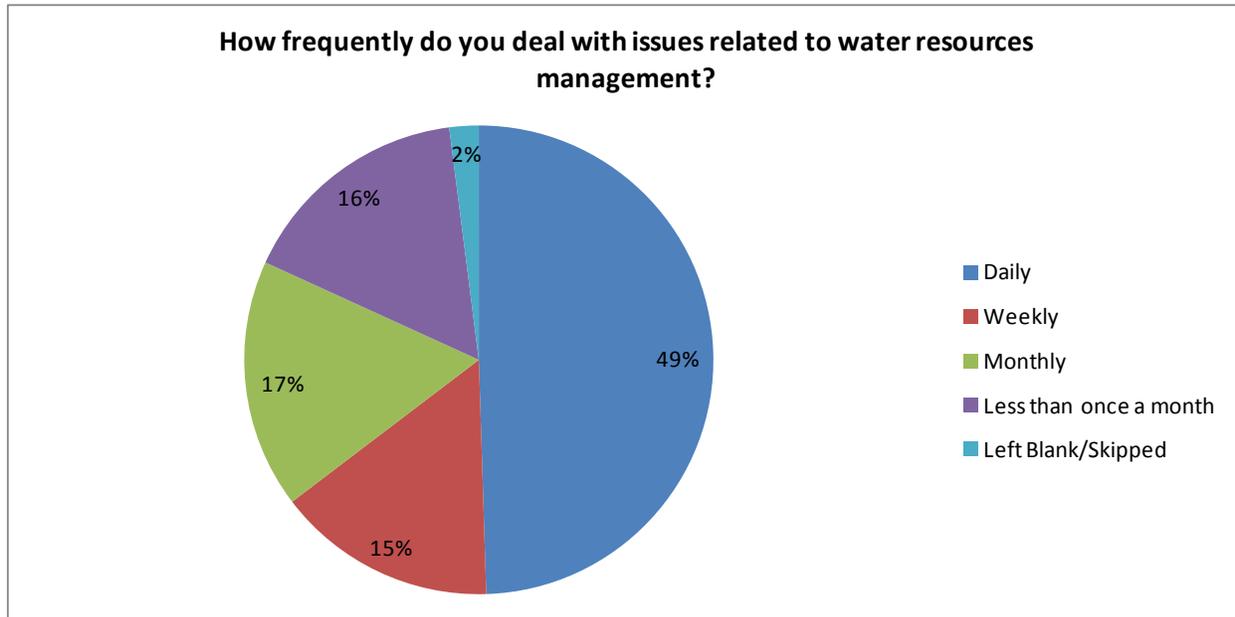
Respondents were asked to indicate how many years they have been working on or interested in issues in the Susquehanna River basin and how many years they have been interested in issues related to water resources management, see Figure 6-41. Nearly half of respondents (46 percent) have been working on or interested in the Susquehanna River basin for 5 to 15 years. Another 41 percent have been working on or interested in these issues in the Susquehanna River basin for more than 15 years. More than half of respondents (53 percent) have been working on or interested in issues related to water resources management for more than 15 years.

Figure 6-41. Number of years respondent has been working on or interested in issues in the river basin and water resources management.



The survey asked how frequently respondents deal with issues related to water resources management, see Figure 6-42. Dealing with issues related to water resources management is a daily issue for just under half (49 percent) of respondents.

Figure 6-42. Frequency of dealing with water resources management issues.



Most respondents (83 percent) have job responsibilities that include providing input to strategic planning; program, facility, operations or financial management; or project planning decisions on water resources information.

Priority Issues

Prior to the survey, priority issues facing the Susquehanna River basin were identified as follows:

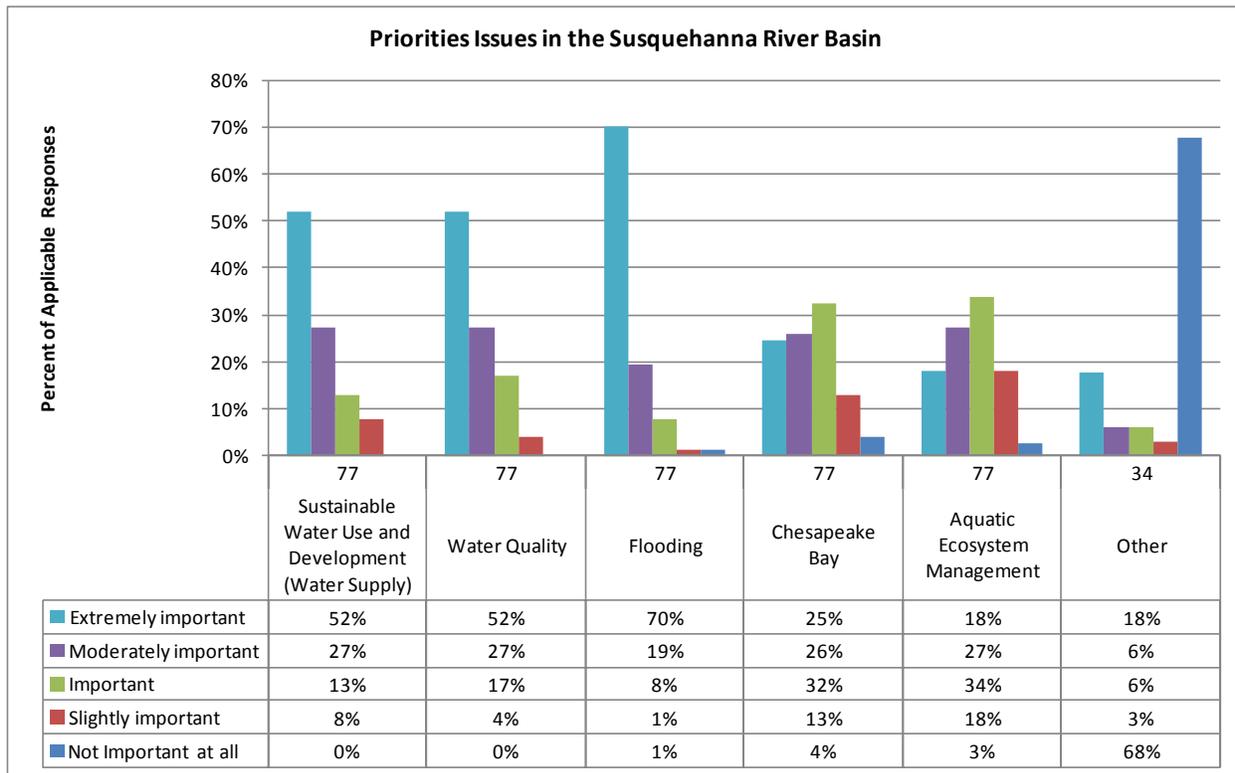
- **Sustainable Water Use and Development (Water Supply):** Ensure water supplies meet immediate and future needs: (1) ensure reliable and adequate water supplies including during drought (2) minimize impacts to in-stream needs (3) maintain appropriate flows to the Chesapeake Bay (4) recognize potential natural water supply shortages, and (5) mitigate long-term flow reductions due to consumptive water use, loss of groundwater recharge and increased surface runoff.
- **Water Quality:** Support the designated uses of all water bodies by achieving water quality that meets or exceeds standards. Key issues may include monitoring, mine drainage, stormwater management, point- and nonpoint pollution, mine drainage, and emerging contaminants.
- **Flooding:** Ensure sustainable stream gage monitoring network and emergency management and response; consider climate change impacts; conduct inundation mapping; ensure alternatives for high-risk communities and reduction of future damages from floods through an integrated system of structural and nonstructural flood damage reduction measures.

- **Chesapeake Bay:** Manage the water resources of the Susquehanna River Basin to assist in restoring and maintaining the Chesapeake Bay so it meets or exceeds applicable water quality standards and supports healthy populations of living resources.
- **Aquatic Ecosystem Management:** Achieve healthy ecosystems that provide groundwater and surface water of sufficient quality and in adequate supply to support abundant and diverse populations of aquatic, riparian, and terrestrial organisms, as well as human use.

Respondents were asked to indicate the importance of these issues and to rank the top three issues that they think are the most important, see Figure 6-43. In identifying the importance of water resource issues in the Susquehanna River basin, “Flooding” was identified as extremely important by 70 percent of respondents. Exactly 79 percent of respondents also identified “Sustainable Water Use and Development (Water Supply)” and “Water Quality” as extremely or moderately important. In comparison, less than half of respondents identified “Chesapeake Bay” and “Aquatic Ecosystem Management” as issues of moderate or extreme importance. Verbatim responses for other priority issues were:

- Drought Management and Response.
- Falls under water supply for use of drinking water by municipalities in the county.
- Headwater water withdrawal for gas drillers.
- Hydrofracking.
- Infrastructure assessment and asset management.
- Invasive species introductions (e.g. Zebra, Quagga mussels).
- Storm water.
- The above issues are all part of the “big picture.” The big picture must be seen and understood for effective integrated management.

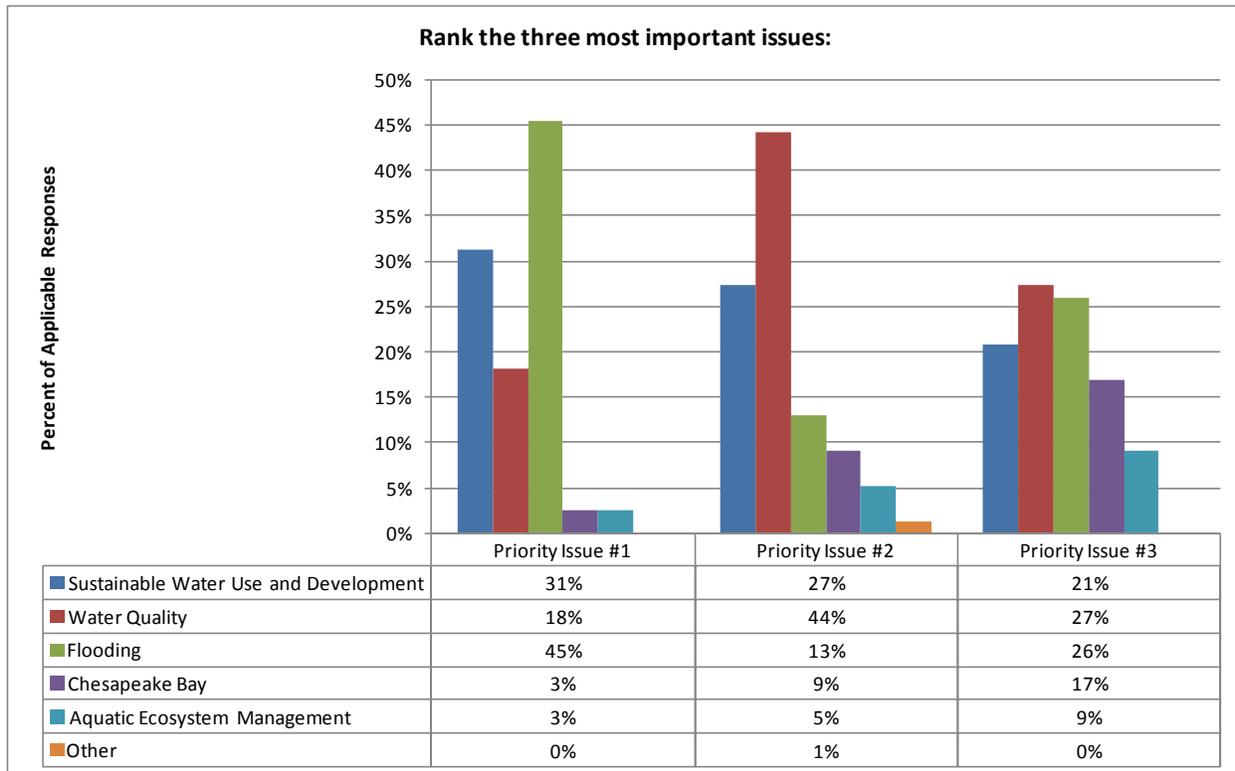
Figure 6-43. Responses to “Please indicate the importance of each of the following issues.”



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 81 survey responses. Those who skipped the question or never saw the question are not included here.

In accordance with the importance ratings, 45 percent of respondents identified “flooding” as the most important issue facing the Susquehanna River basin, see Figure 6-44. A similar number of respondents identified “Water Quality” as second most important and the third most highly ranked priority issue is “Sustainable Water Use and Development (Water Supply).”

Figure 6-44. Responses to “Looking at the issues as a group, please rank the three most important issues that you think are facing the Susquehanna River Basin.”

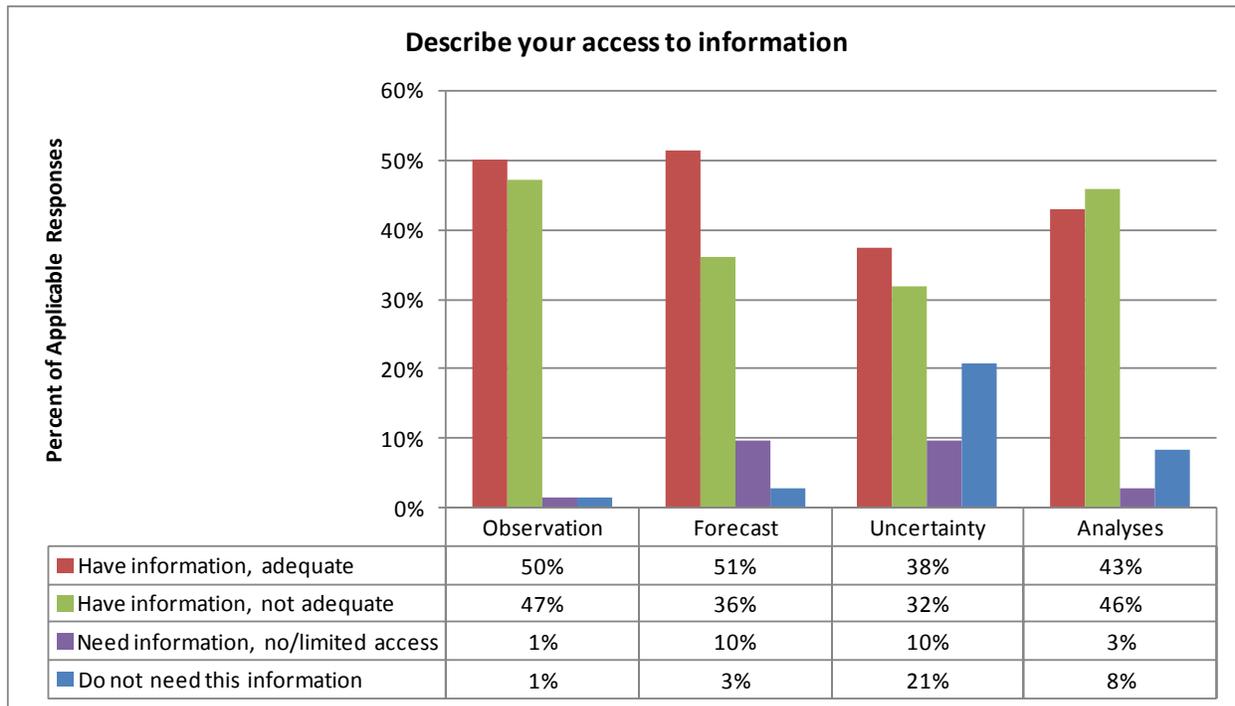


Note: There were 77 responses to this question.

Information Access and Use

Respondents described their access to observations, forecasts, uncertainty, and analyses information needed for informing decisions, see Figure 6-45. In general, across all information types (observation, forecast, uncertainty, analyses), respondents were fairly evenly divided between having the information to meet their needs and having inadequate or limited information. More respondents indicated needing access to forecast and uncertainty information than observation or analyses information. About 1/5th of respondents do not need uncertainty information.

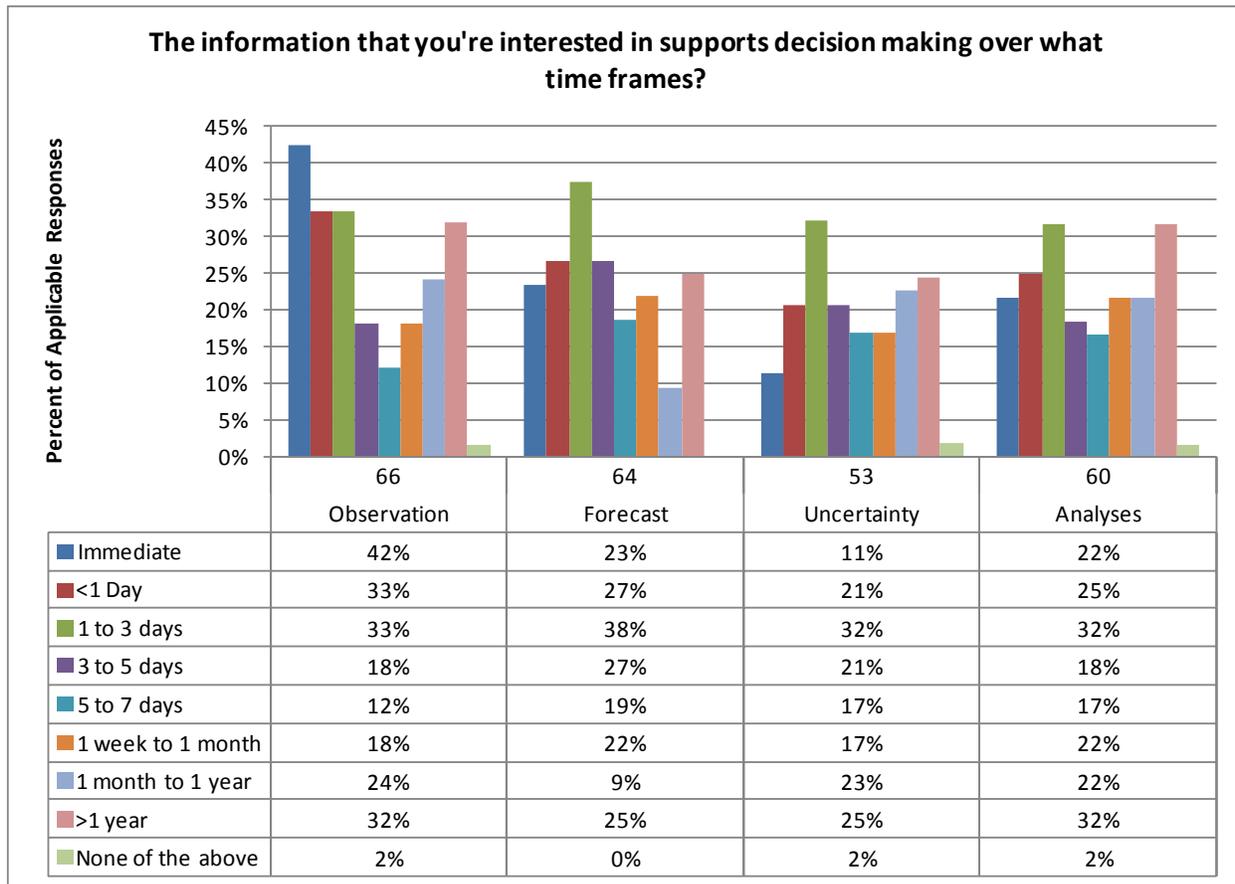
Figure 6-45. Responses to “For your highest priority issue, describe you access to the following types of information needed for informing decisions.”



Note: There were 72 responses to this question.

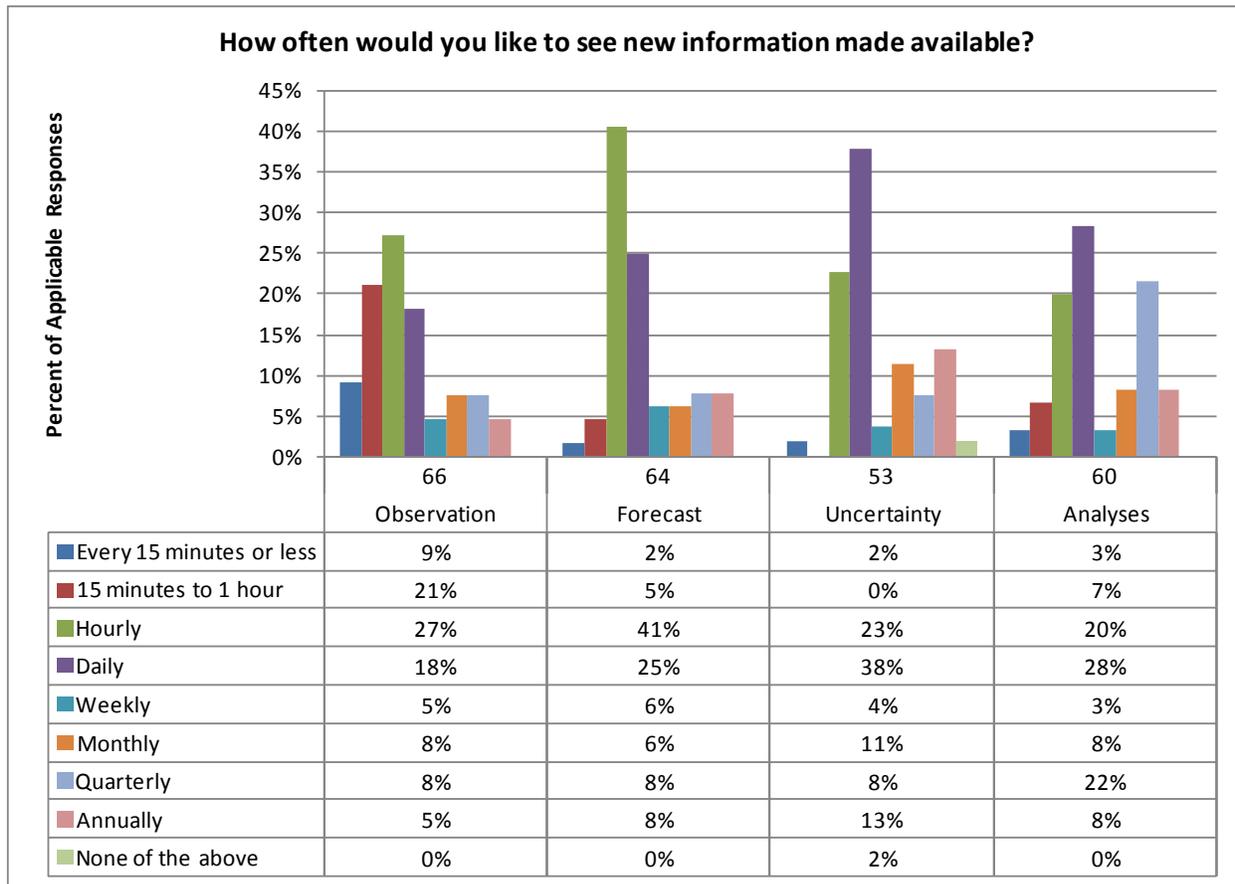
Respondents were also asked to indicate the decision-making time frames that would be supported by the information in which they were interested, see Figure 6-46, and how often they would like to see new information made available for use, see Figure 6-47. Around 30 percent would use information to support decision making over 1 to 3 days or less. For observation and forecast information respondents would like to see new information hourly, for uncertainty and analyses they would like to see information daily.

Figure 6-46. Summary of the time frame for using observations, forecasts, uncertainty, and analyses for decision making.



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 81 survey responses. Those who never saw the question (i.e., incomplete or not applicable) are not included here.

Figure 6-47. Summary of respondent preferences for new observations, forecasts, uncertainty, and analyses to be available.



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 81 survey responses. Those who never saw the question (i.e., incomplete or not applicable) are not included here.

Respondents were asked to identify barriers to use for subsets of the four information categories (observations, forecasts, uncertainty and analyses).

For observations, forecasts, and uncertainties:

- Surface hydrology.
- Groundwater hydrology.
- Water quality.
- Drainage basin management.
- Meteorology.
- Snow/ice.

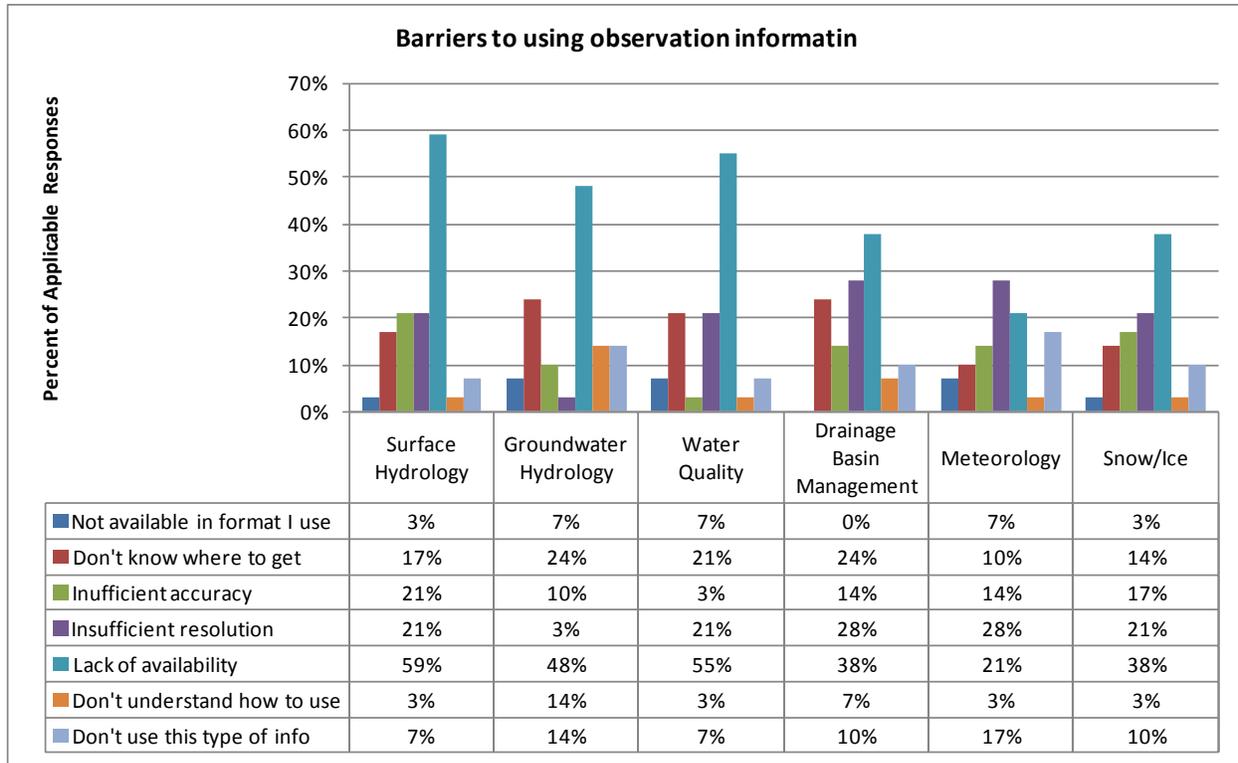
And for analyses:

- Public alerts.
- Meteorological analyses.
- Hydrologic analyses.
- Climatological analyses.
- Flood inundation mapping.
- Information integration.

Barriers to use are also fairly consistent across information types. For example, the most respondents identify the lack of availability of information as the most common barrier to use. Insufficient resolution and accuracy are the next most common barriers for observational information. Finally, 27-32 percent of

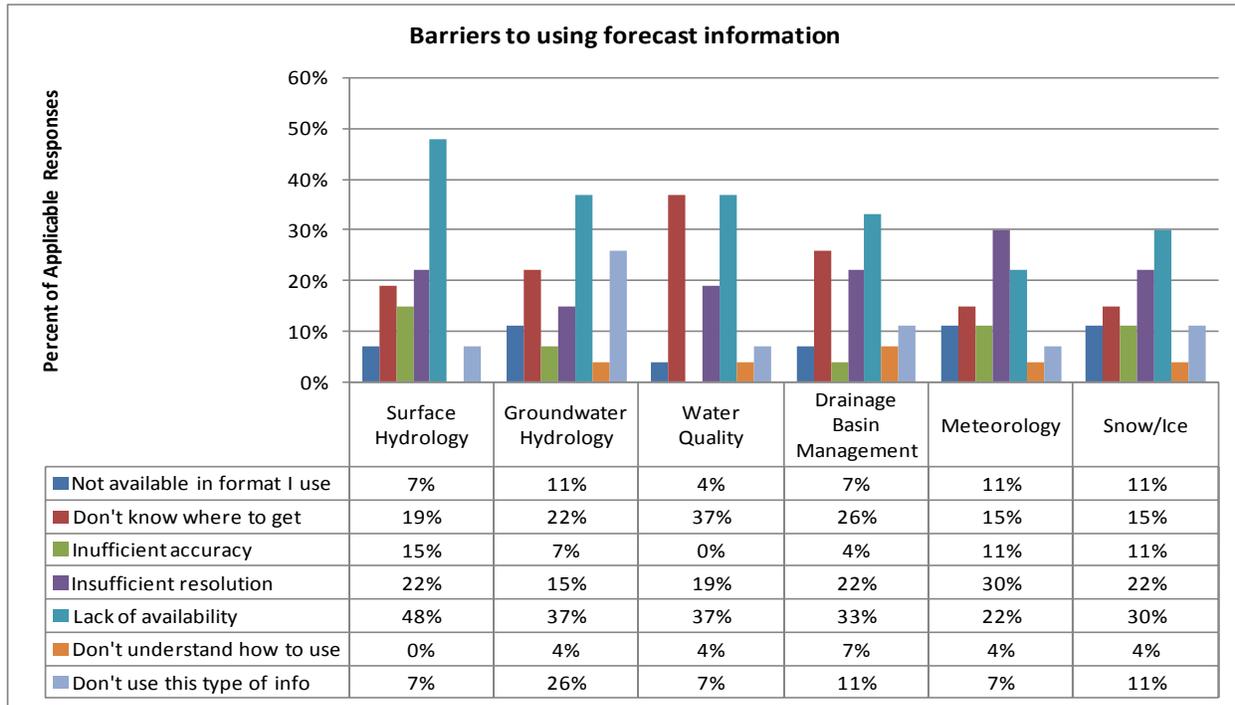
respondents do not use meteorology information and 41 to 49 percent of respondents do not use snow/ice information. See Figure 6-48 to Figure 6-51.

Figure 6-48. “What are some of the barriers to using the following types of observation information?”



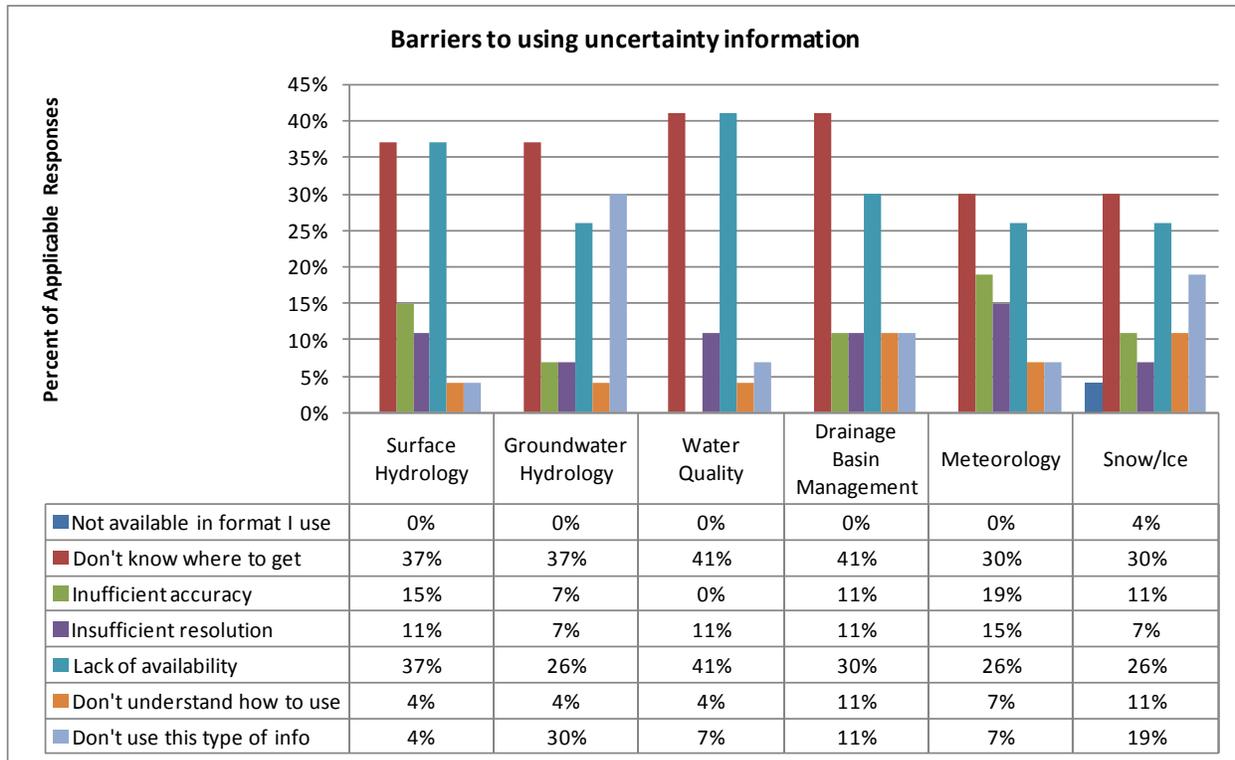
Note: There were 29 responses to this question.

Figure 6-49. “What are some of the barriers to using the following types of forecast information?”



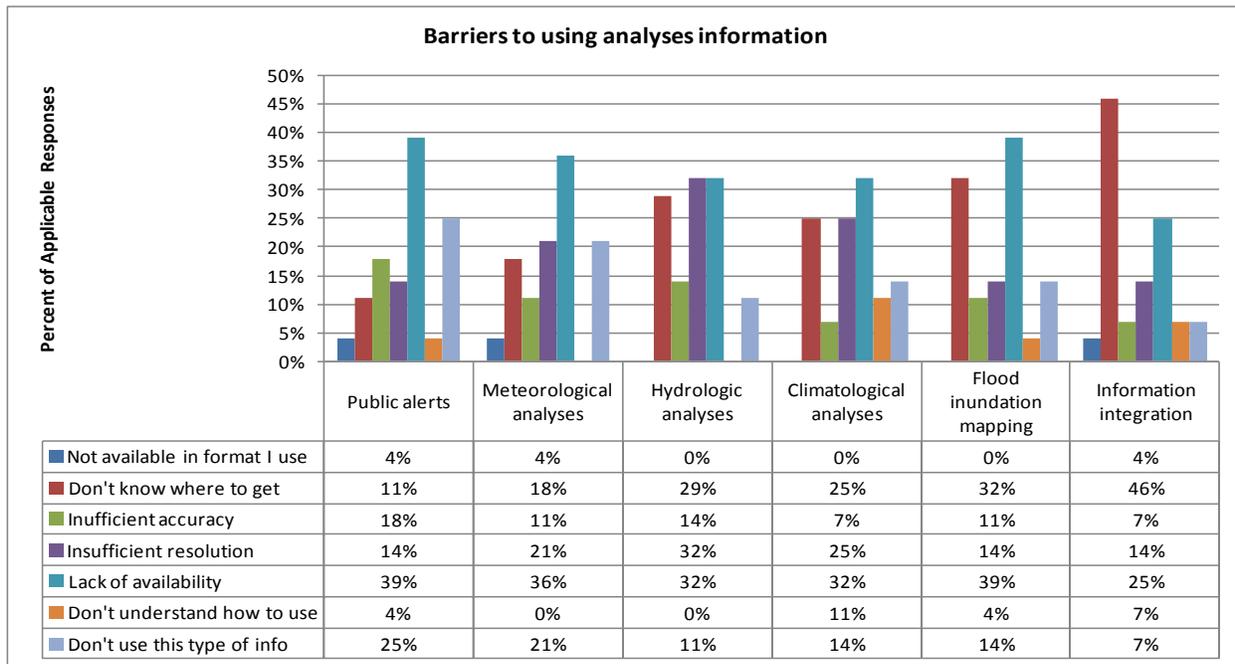
Note: There were 27 responses to this question.

Figure 6-50. “What are some of the barriers to using the following types of uncertainty information?”



Note: There were 27 responses to this question.

Figure 6-51. “What are some of the barriers to using the following types of analyses information?”

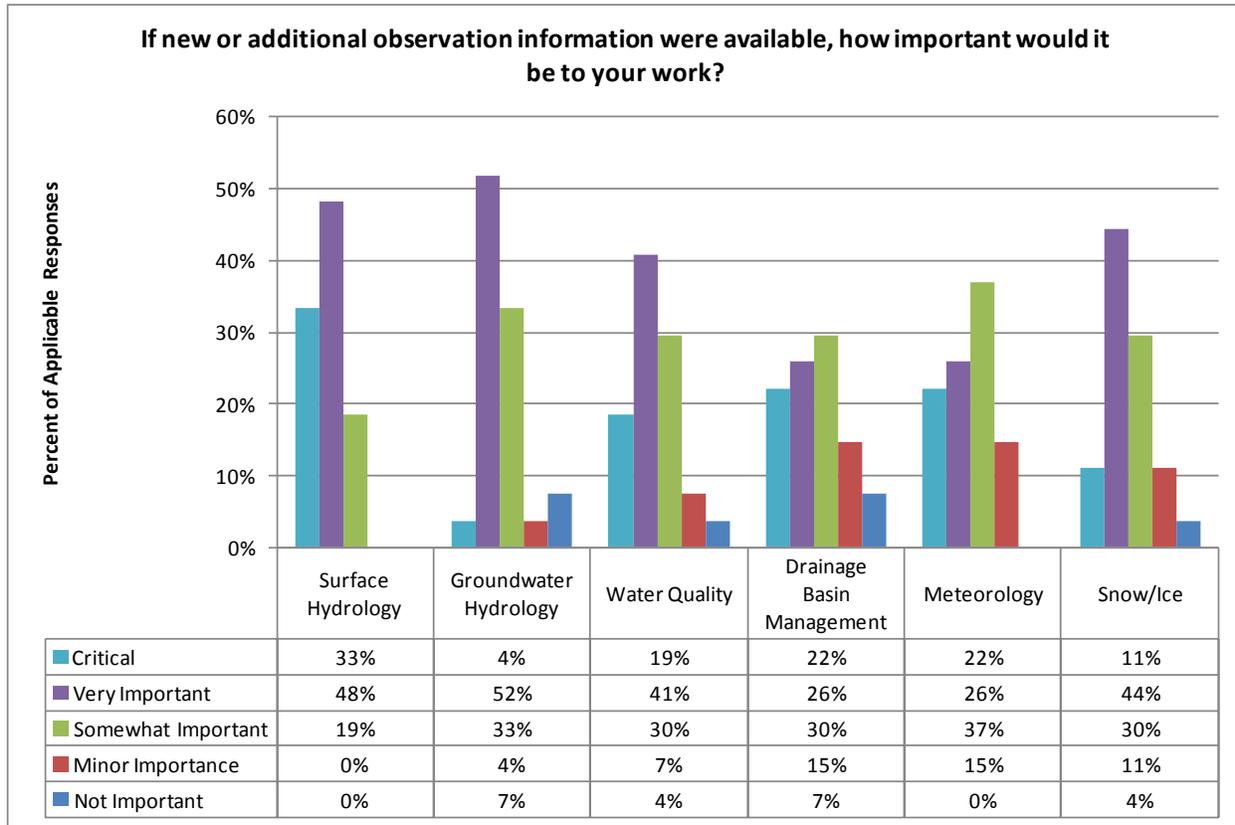


Note: There were 28 responses to this question.

Additional Information Needed

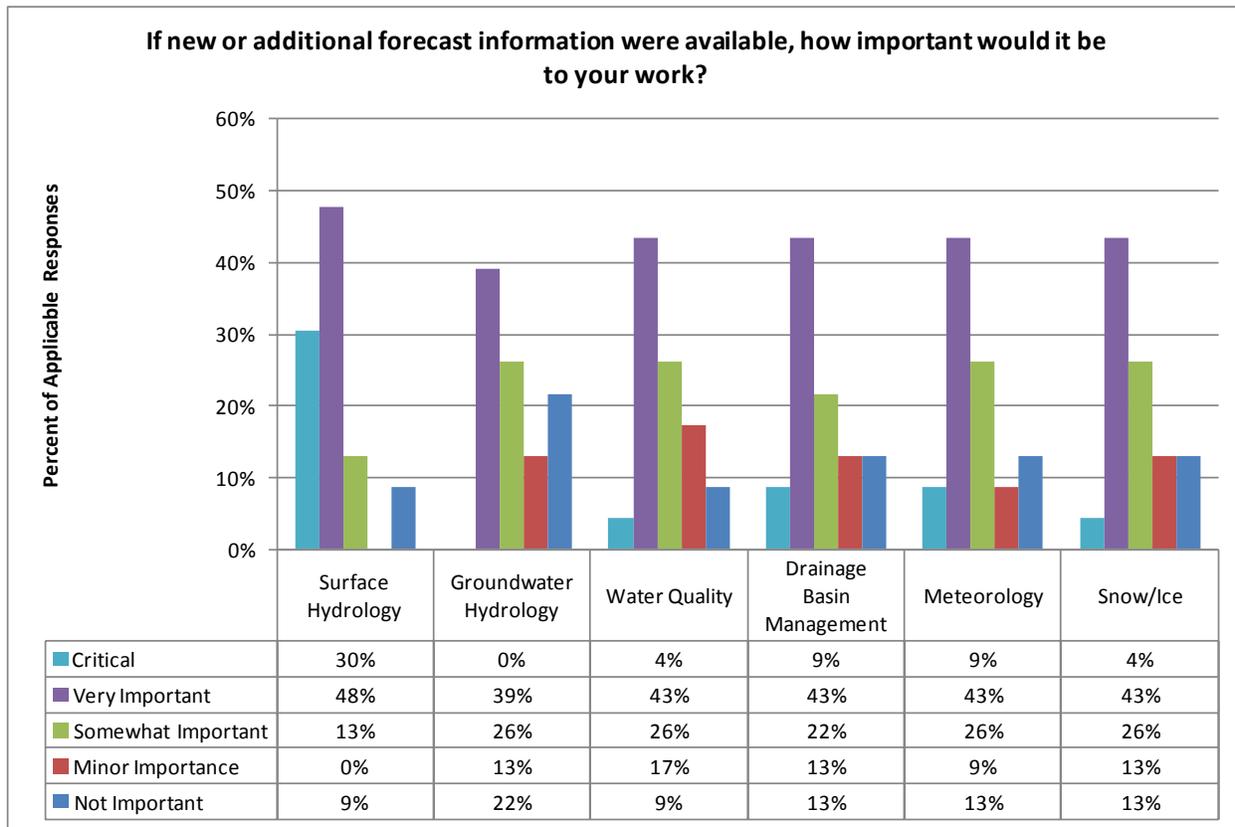
Respondents were asked if new or additional information were available, how important it would be to their decision making. The subcategory of surface hydrology was rated as most important for new or additional observational, forecast and uncertainty information. Under analyses, more respondents rated flood inundation mapping as critical than any other category, although hydrologic analyses appears more important overall when considering both the critically and very important ratings. See Figure 6-52 to Figure 6-55.

Figure 6-52. Importance of new or additional observation information.



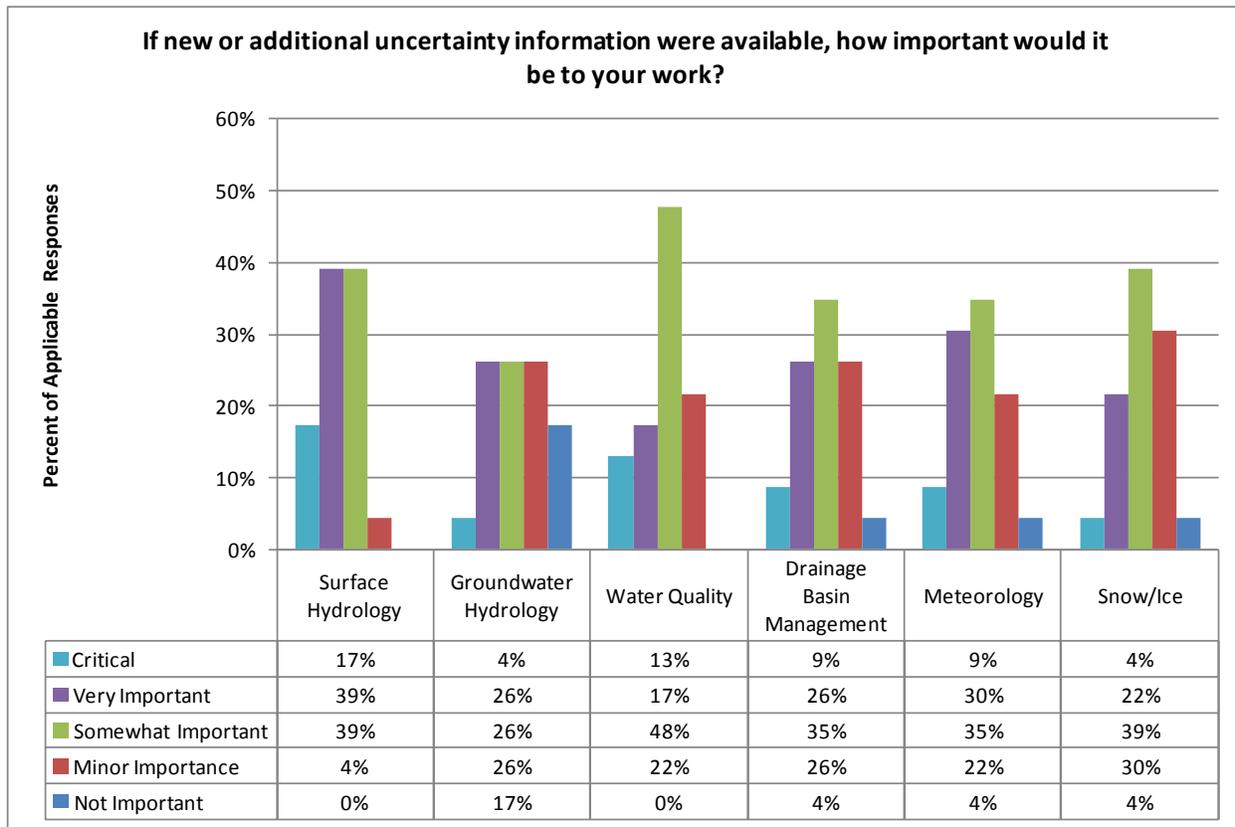
Note: There were 27 applicable responses to this question.

Figure 6-53. Importance of new or additional forecast information.



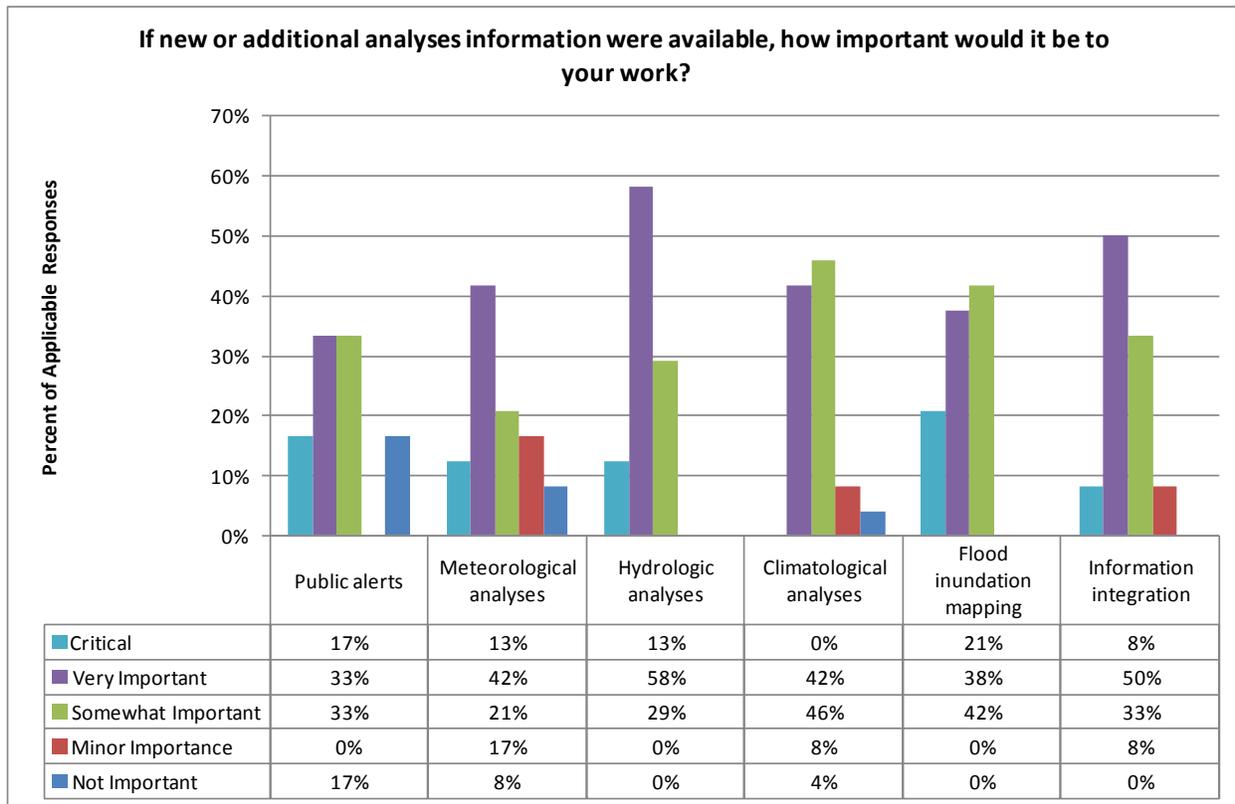
Note: There were 23 applicable responses to this question.

Figure 6-54. Importance of new or additional uncertainty information.



Note: There were 23 applicable responses to this question.

Figure 6-55. Importance of new or additional analyses information.



Note: There were 24 applicable responses to this question.

Summary of Open Comments

After respondents rated the importance of new or additional information types for their decision making they were asked “For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making.” This section summarizes the written comments in response to that question by category of information — observations, forecasts, uncertainty, and analyses. See Table 14.

Table 14. Number of respondents indicating that new or additional information is “Very important” or “Critical” to their decision making.

	Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/ice	Public alerts	Meteorological analyses	Hydrologic analyses	Climatological analyses	Flood inundation	Information integration	Provided Description
Observations	22	15	16	13	13	15	--	--	--	--	--	--	25
Forecasts	18	9	11	12	12	11	--	--	--	--	--	--	14
Uncertainty	13	7	7	8	9	6	--	--	--	--	--	--	16
Analyses	--	--	--	--	--	--	12	13	17	10	14	14	20

For observations, forecasts and uncertainties the most important category of information is surface hydrology; the second most important categories are water quality observations, drainage management and meteorological forecasts, and meteorological uncertainty. For analyses, the most important category is hydrologic analyses, followed by flood inundation mapping and information integration.

Based on a review of the written comments from respondents the following new or additional information would be useful:

- **Observations:** increased spatial resolution at the sub-watershed level; more observations of surface water, water quality, and groundwater; flood inundation observations; and impacts of development on water quality and aquatic species.
- **Forecasts:** increases spatial resolution of forecasts; and, more frequent or more easily available forecasts of water quality, streamflow, and flooding.
- **Uncertainty:** Comments on this information type are difficult to summarize, but one trend that emerges is a need for better communication around uncertainty. For example, “a clear statement of all the limiting conditions/assumptions set up in the model,” and “improved method of conveying uncertainty that is understandable by non-scientists.”
- **Analyses:** Flood inundation mapping to update old maps and increase the resolution in mapped areas, integrated information that is readily available and easy to communicate to the public.

The remainder of this section provides a summary of the written comments by information category (observations, forecasts, uncertainty, analyses) and a table presenting raw written comments by number and type of information types rated as “very important” or “critical.”

Observations

Twenty-five respondents provided written comments in response to the question “For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making.” Respondents expressed an interest in increased spatial resolution (i.e., more observations at the sub-watershed level); more observations of surface water, water quality, and groundwater; flood inundation observations; and impacts of development on water quality and aquatic species. The following table, Table 15, summarizes the written responses by the information types marked as “very important” or “critical” to decision making (indicated with a check mark). The responses have been lightly edited for misspelled words and grammatical errors, non-substantive comments have been removed, and comments are ordered from most to least check marks.

Table 15. Summary of written responses to “For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making,” by information type.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making.
✓	✓	✓	✓	✓	✓	Water Quality - More information on a daily basis being available
✓	✓	✓	✓	✓	✓	Real time and accurate information to do projections and warnings for the public that are in the highest percentages to occur.
✓	✓	✓	✓	✓	✓	Groundwater data, both quantity and quality, very limited data but critical data.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making.
✓	✓	✓	✓	✓	✓	In an area that is as vulnerable as the Chemung Basin understanding what the surface hydrology is doing touches everyone’s lives, businesses and the economy of the entire area. Drainage basin management and the impact meteorology has are intertwined. They drive the surface and at a slower pace the groundwater hydrology. A community that is not flooded unexpectedly; has a robust, clean viable water supply; and is a pleasant place to live and work becomes an economic engine that drives the economy, both locally and nationally.
✓	✓	✓	✓	✓	✓	Rain Gage and River Gages need to be maintained and kept up to good working conditions, improved technology would be beneficial as well. Information about Dam releases is extremely important. One dam in another county, can cause my county to have a 72 year flood, dam owners need to keep their plans maintained and follow the plans and State government, needs to keep the county informed.
✓	✓	✓	✓	✓		Need more real-time data from more sampling points for subwatersheds and tributaries, i.e., NEED MORE DATA. Also need monitoring equipment with more capabilities for water quality measurements, especially if real-time and portable.
✓	✓	✓	✓			Having accurate flood elevation data across the whole county would be very useful. We currently have many areas with no actual information. Know the water quality factors can also help us with grant justification.
✓	✓	✓	✓			Watershed modeling at different scales to locate natural infrastructure projects (wetlands, floodplain enhancement) that could help reduce flooding, groundwater infiltration area mapping, WQ info on 10 digit HUA outlets for N and P and sediment.
✓			✓	✓	✓	Need more advanced notice.
✓	✓	✓			✓	More input to a common data base in our local area that can be easily accessed.
✓	✓	✓				Land Use.
✓	✓	✓				More gages at critical places.
✓	✓	✓				As the Water Resources Coordinator at a County Planning Dept., stormwater runoff data, pollutant loads (especially nutrient/sediment loads) aquifer recharge/water water availability. Land use alterations on natural hydrology. Although I am not as interested in meteorological/precipitation data...the Hazard Mitigation Planners in my department would be.
✓	✓	✓				I must point out that I am a project manager and don't directly use data or conduct technical analyses. My responses in this survey should be viewed in this light.
✓	✓		✓			More gages on more streams, more well observations, detailed basin management areas used.
✓				✓	✓	More gages.
✓				✓	✓	Flood inundation maps. Ice jam observations. Accurate high resolution precip-type (snow vs. rain) forecasts.
✓				✓	✓	Easy access to current and historical data.
✓				✓	✓	More Reporting Locations.
	✓	✓	✓			We are concerned with fish population decreases, and the spread of invasive species. Additionally, mine drainage impacts and energy-related uses and extraction are key concerns.
✓			✓			Data at know high water areas.
		✓			✓	More Marcellus Shale region streams need to have water quality information. Methods need to be available to determine what impact if any bubbling methane into our streams may or may not have. Are evaluations done that have determined whether or not any other substances are accompanying this bubbling methane in our streams? The snow/ice melt information is very helpful to determine the impact of

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making.
						acid rain to our watersheds. Our watershed associations need training/information on this impact and how to evaluate and sample for it.
				✓	✓	Rainfall and stream gauges are essential (especially all weather/all season units).
		✓			✓	Current flows, river gauge readings, flooding potential, crest information, precipitation per hour and effect, precipitation amounts, etc.
✓						Stream Gages.

Forecasts

Fourteen respondents provided written comments in response to this question; a key issue for respondents seems to be the need for increased spatial resolution of forecasts. Several responses also express an interest in more frequent or more available forecasts on water quality, streamflow, and flooding. See Table 16.

Table 16. Summary of written responses to “For the information types you rated as very important or critical, please describe the additional or new forecast information that you need for your decision making,” by information type.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new forecast information that you need for your decision making.
✓	✓	✓	✓	✓	✓	More frequent updates on water quality.
✓	✓	✓	✓	✓	✓	Our forecasting is based on 3 forecasting locations. This leaves roughly 60 percent of our watershed above the area forecast. The headwaters are difficult to forecast but needs to be considered.
✓	✓		✓	✓	✓	Information needs to be current, needs to be updated more timely and the technology needs to be there to provide this information.
✓		✓	✓	✓	✓	Ensemble climatology and streamflow forecasts.
✓		✓	✓	✓		Drainage basin management- release schedules, dam elevations.
✓	✓	✓	✓			Any further information that is more current for flood levels and forecasting would be helpful.
✓	✓	✓			✓	Internet available monitor stations for creek levels, stream and river flow, precip per hour flooding issues, forecast predictions, historical crest info, evacuation areas, etc.
✓	✓	✓				More gages.
✓	✓		✓			Water supply forecast information.
✓		✓		✓		Timely info on Conowingo Dam flood gate status and forecasting of flooding at least three days in advance.
✓		✓	✓			More reporting locations.
✓				✓	✓	Flood forecasts using flood inundation maps. Forecasts along the entire reach of the river (including tidal/estuary portions), not at just selected points. Hourly river forecasts. More accurate, higher resolution, meteorological forecasts of temperature, precipitation type (rain vs snow), snow water equivalent forecasts, ice jam forecasts.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new forecast information that you need for your decision making.
			✓	✓	✓	Advanced notice.
✓					✓	It would be nice to get automatic updates on surface hydrology and snow/ice by email.

Uncertainty

Sixteen respondents provided written comments on this question. Interestingly, one trend that emerges from these written comments is a need for better communication around uncertainty: for example, “a clear statement of all the limiting conditions/assumptions set up in the model,” “improved method of conveying uncertainty that is understandable by non-scientists,” and simply “where to find it.” See Table 17.

Table 17. Summary of written responses to “For the information types you rated as very important or critical, please describe the additional or new uncertainty information that you need for your decision making,” by information type.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new uncertainty information that you need for your decision making.
✓	✓	✓	✓	✓	✓	Ensemble forecasts representing uncertainty.
✓	✓	✓	✓	✓		Need two things: A clear statement of all of the limiting conditions/assumptions set up in every model, and the margins of error for all data produced by forecasting.
✓	✓	✓		✓	✓	Where to find it.
✓	✓		✓	✓	✓	More gages, more well observations, better resolution of data and more consistent data.
		✓	✓	✓	✓	Quantitative results.
✓		✓	✓	✓		Better drought forecasting. Understanding of how basin management impacts available water resources.
✓	✓		✓			Uncertainty information associated with observed and forecast streamflow and groundwater levels.
✓	✓			✓		Dam control data.
✓		✓	✓			More reporting locations.
✓				✓	✓	Improved method of conveying uncertainty that is understandable by non-scientists. Social science research needed.
✓	✓					Would be important for flooding information, etc.
✓			✓			More information at known flooding areas.
				✓	✓	Better forecasts.
✓						Frequency-based flows.
		✓				Information seems to be reactive not proactive. The easiest way to clean water, don't get it messed up in the first place.
✓						Need information of the combined uncertainty that relates to a value observed or

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new uncertainty information that you need for your decision making.
						forecasted i.e. the uncertainty of all measurements and computations combined.

Analyses

Twenty respondents provided written comments in response to this question. Although it is difficult to summarize the responses due the uniqueness of the analyses described, there are two themes that can be drawn from the comments. There is a need for flood inundation mapping to update old maps and increase the resolution mapped areas. Also, several comments touch on a need for integrated information that is readily available and easy to communicate to the public. See Table 18.

Table 18. Summary of written responses to “For the information types you rated as very important or critical, please describe the additional or new analyses that you need for your decision making,” by analysis type.

Public alerts	Meteorological analyses	Hydrologic analyses	Climatological analyses	Flood inundation mapping	Information integration	For the information types you rated as very important or critical, please describe the additional or new analyses that you need for your decision making.
✓	✓	✓	✓	✓	✓	Integrating federal water information would improve the efficiency of analyzing the data.
✓	✓	✓	✓	✓	✓	Where to find it.
✓	✓	✓	✓	✓	✓	Probabilistic simulations of system operations to inform optimization of basin management.
✓	✓	✓	✓	✓	✓	Accurate flood inundation mapping is critical to good public alerts. The state of flood mapping within the Chemung Basin is 40 years old and not usable by the public. It is barely usable by emergency management and therefore not a routine part of flood operations. All of the forecasting and better, timely information cannot be used effectively without good inundation mapping.
✓	✓	✓	✓	✓	✓	Improved, tested, effective methods of delivering actionable messages to the public all on as few graphics as possible. Total water message needs to be conveyed.
✓	✓	✓	✓	✓	✓	More reporting locations.
✓	✓	✓	✓	✓	✓	Alerts enable timely planning and evacuation of flood prone facilities. Inundation mapping is critical for future infrastructure planning.
	✓	✓	✓	✓	✓	Better forecasting would improve pre-event planning and impacts to the water withdraw schedule.
✓	✓	✓	✓	✓		My responsibility is to prepare and protect the citizens, if information is not accurate or not received in timely matter, lives can be lost. Alerts, meteorological and flood mapping are extremely important.
	✓	✓	✓	✓		Better forecasts.
✓	✓	✓			✓	In our watershed Public Alerts are very important and can be critical. People have more than once been caught unaware of potential flooding that had caused them to be evacuated under difficult situations or not evacuated at all because they could not be easily reached. Minimum flow data is important in the Marcellus Shale region where our headwaters are being impacted by multiple, closely located in

Public alerts	Meteorological analyses	Hydrologic analyses	Climatological analyses	Flood inundation mapping	Information integration	For the information types you rated as very important or critical, please describe the additional or new analyses that you need for your decision making.
						some cases, and smaller stream locations by gas industry water withdrawals. There are threatened and endangered mussels for example in some of these areas, has there been any evaluation on the effect of these increased withdrawal locations in areas of their known habitats? Integrated one stop shopping for such information creates a more transparent divulging of information to the public. It is also easier to find all relevant information in one location.
✓	✓		✓	✓		Public Alerts....I like the system as it is now. It is fine. Continue to subsidize NWS Weather Radio and get it into the new nationwide alert system. Meteorological....continue doing what is happening now. I use all of the information provided, do not stop the USGS Gauge System from continuing to function. Climatologic.....once again don't stop these important functions due to funds. We have a tough job to do and to take away key information providers to us would be criminal. Flood Inundation Mapping...this is a wonderful item but it isn't done. We need funding made available to complete this on all of our watersheds along with the Susquehanna River. Also, how to get the information is sometimes difficult to locate.
✓	✓				✓	Sudden increase or decrease in flow, contaminants entering the river. Drought conditions. Having all the issues together on one site would speed up the flow of information.
		✓		✓	✓	IWRSS efforts should be able to relate to the NFIP products currently in use within all communities.
✓	✓					Public alerts relating to water quality degradation, spills, fish advisories, etc. An understanding of how gas drilling, and other consumptive industries are impacting flow regimes.
	✓		✓			Hydrological analyses that would provide specific site location information for implementing natural infrastructure projects.
	✓		✓			Hydrologic analyses — more long-term monitoring data to allow reduced error in statistical analyses. Flood inundation mapping - additional calibrated hydraulic and digital elevation models to allow the creation of more inundation mapped areas.
		✓			✓	There has been an increased push across PA for much more collaboration among community water suppliers, so information integration is key with these efforts. Hydrologic analyses are just another key part of this effort.
	✓				✓	Need more complete picture of overall water quality and quantity expectations over the long view to assist with watershed management planning for the future through legislative and regulatory actions.
					✓	Historical trends over time would be helpful for determining the impacts of Best Management Practices put in place to improve water quality.

Other

Four respondents indicated that they would rank “other” types of information as needing improvement and critical for informing decisions on their top priority issue. They provided the following written comments to describe the other types of information that they need for their decision-making:

- Educational outreach (beyond alerts) are needed to help two types of populations...residents need more basic education about water resources tailored to their living styles, and political

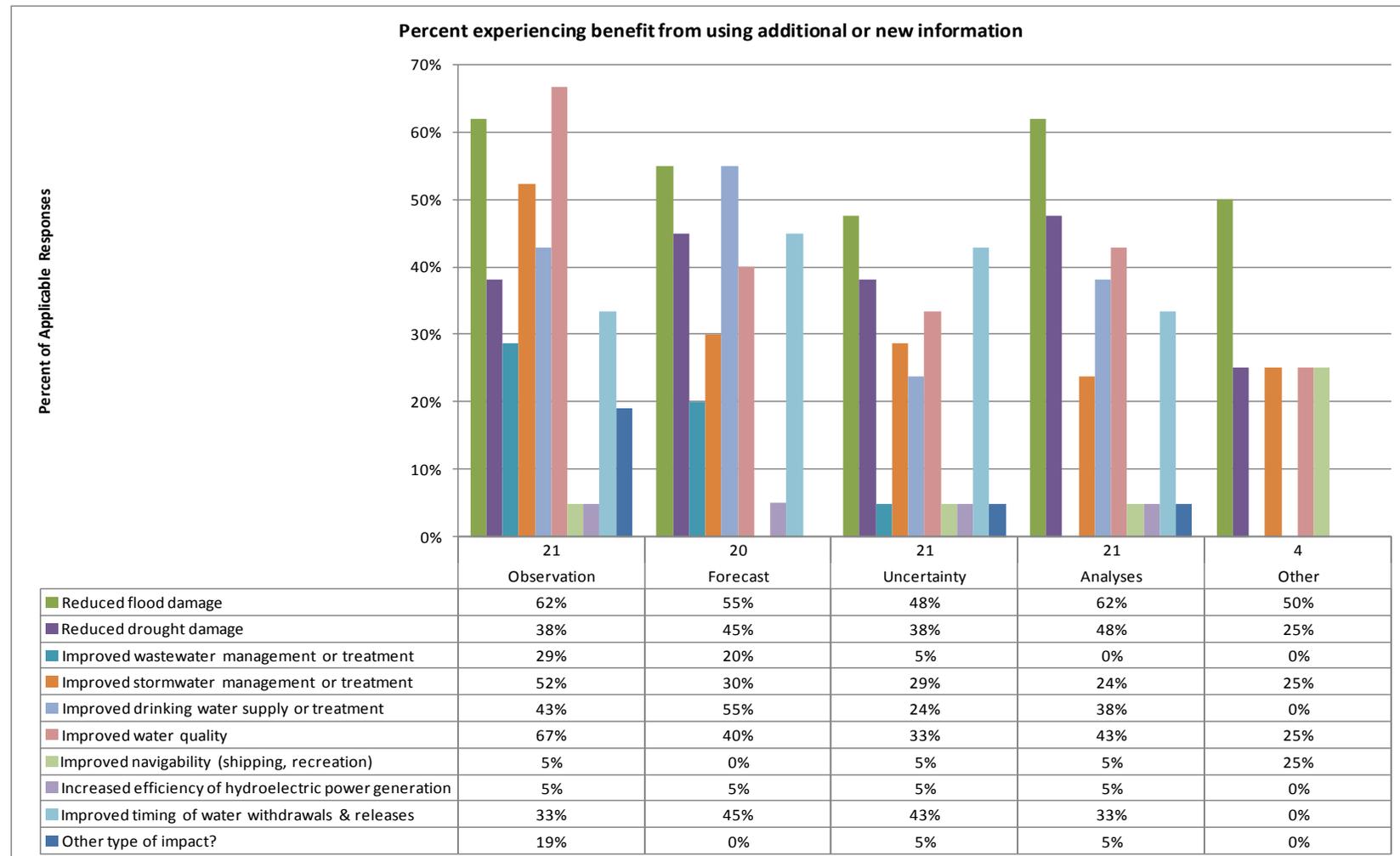
leaders need the same type of information tailored to their duties as administrators or policy makers.

- Media clips, photos, and 'web-ready' articles that could be used to further SRBC's protection strategies.
- The continuation of funding of the USGS Stream Gauges in the Susquehanna River Basin is paramount to our success in protection of our residence from flooding. We cannot allow this system to be gutted by the Federal government!
- We do not have a single unified mapping database to which all information can be connected and upon which decisions can be justified; garbage in, garbage out.

Economic Impacts or Benefits

Respondents were asked if they would experience any of a set of impacts or benefits from using additional or new information from IWRSS partner agencies, see Figure 6-56. The most commonly anticipated benefits of new observation information are reduced flood damage, improved water quality, and improved stormwater management or treatment. For forecasts, reduced flood damage and improved drinking water supply and treatment are cited by most respondents. For uncertainty, the two most common benefits are improved water quality and improved timing of water withdrawals and releases. And for new or additional analyses, respondents expect improved reduced flood damage and improved water quality.

Figure 6-56. Responses to “would you experience any of the following impacts of benefits from using additional or new information from IWRSS partner agencies?”



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 81 survey responses. Those who never saw the question (i.e., incomplete or not applicable) are not included here. These totals DO include those who saw but skipped the question.

Summary of Open Comments

Respondents who indicated that they would experience any of a set of impacts or benefits from using additional or new information from IWRSS partner agencies were then asked to describe the benefit and estimate the cost avoided or benefit gained per year or per event.

Observations

By providing new or additional observation information for the Susquehanna River Basin seven types of benefits would be realized: reduced flood damage, reduced drought damage, improved stormwater management/treatment, improved drinking water supply/treatment, improved water quality, improved timing of water withdrawals/releases, and other impacts. Specifically:

- **Reduced flood damage:** New/additional observation information will lead to \$4 saved for every \$1 spent in mitigating losses. Also through preventing further building in floodplains, improved accuracy in directing people and property away from risk, reduced cost of flood repairs and emergency response, and better resolution of where flood damage did or will occur and insurance cost efficiency.
- **Reduced drought damage:** New/additional observation information on water quality would help measure progress in cleaning up the Chesapeake Bay and also aid in determining the most effective measure to improve water quality in the amount of tens of millions county wide. Also, through reduced crop damage and financial impact to agriculture, and in drought planning.
- **Improved stormwater management/treatment:** Leading to reduced cost of stormwater infrastructure if the analysis has better spatial resolution and determines localized needs in design, lower system operation costs if fewer solids are carried, and higher return from recreation if fish habitat improved. Also, reduced flooding in non-riverine areas, better information on BMPs needed, and preparedness planning and information.
- **Improved drinking water supply/treatment:** Leading to reduced costs of treatment chemicals (coagulant, disinfectant) and improved compliance with MCLs at surface and groundwater treatment plants, and improve cost effectiveness of identifying new water supply areas.
- **Improved water quality:** New/additional observation data might reduce the implementation levels required to meet CBP TMDL standard, currently spending \$250 million for water quality non point source improvements. Also through better information for decision making, lower health care costs, lower treatment costs, and improvement of recreation opportunities for tourism.
- **Improved timing of water withdrawals/releases:** New/additional observation information would lead to reduced storage requirements, 50 to 86 million. Also through improved preparedness for flood and drought, and improved ecological conditions.
- **Other impacts:** Land development, economic development/growth, hazard mitigation planning, are all very much dependent on all aspects of water quantity/quality. Constant tracking of water quality and quantity is necessary to ensure/understand cause and affect relationships.

Forecasts

By providing new or additional forecast information for the Susquehanna River Basin seven types of benefits would be realized: reduced flood damage, reduced drought damage, improved wastewater

management/treatment, improved stormwater management/treatment, improved drinking water supply/treatment, improved water quality, and improved timing of water withdrawals/releases. Specifically:

- **Reduced flood damage:** Through improved predictions of flood events, lead time on evacuations, mobilization of personnel, and operation of flood control reservoirs.
- **Reduced drought damage:** Through improved ability to prepare for drought, improved timing of withdrawals and releases, reduced chemical costs for treatment, increased water conservation practices ahead of drought, and better long term planning for additional water sources.
- **Improved wastewater management/treatment:** Through improved preparation for increased flow through the treatment plant.
- **Improved stormwater management/treatment:** Leading to reduced impact on drinking water sources affected by stormwater runoff.
- **Improved drinking water supply/treatment:** Reduced treatment costs by maintaining supplies of better quality water and avoiding treatment when water is high in solids, improved preparation by storage in water in finished water towers, and help with locations of water supplies.
- **Improved water quality:** Through earlier monitoring to assess conditions and take steps to mitigate treatment costs, and water quality management decision support.
- **Improved timing of water withdrawals/releases:** Improved timing of the withdrawal schedule to reduce treatment costs by balancing water quality and availability.

Uncertainty

By providing new or additional uncertainty information for the Susquehanna River Basin seven types of benefits would be realized: reduced flood damage, reduced drought damage, improved wastewater management/treatment, improved stormwater management/treatment, improved drinking water supply/treatment, improved water quality, and improved timing of water withdrawals/releases. Specifically:

- **Reduced flood damage:** Through avoided flooding in sensitive areas, better model performance (with greater spatial resolution in mapping), improved planning of exit routes, more viable decisions and improved response.
- **Reduced drought damage:** Through improved timing of withdrawals, better understanding of timing of drought conditions, and more viable decisions.
- **Improved wastewater management/treatment:** Through improved operations.
- **Improved stormwater management/treatment:** Through forecast of overflows, reduced water pollution through mandatory requirements instead of suggestions.
- **Improved drinking water supply/treatment:** Reduced treatment costs through pre-event planning, improved quality, and more viable decisions and improved response.
- **Improved water quality:** Through earlier withdrawals to maintain storage in primary water supply.
- **Improved timing of water withdrawals/releases:** Through improved understanding of when allowed water withdrawals would be reduced by drought trigger flows, improved and fewer

approval for water withdrawal sites for gas drillers, use of data to gage management techniques on in-house water use models.

Analyses

By providing new or additional analyses information for the Susquehanna River Basin seven types of benefits would be realized: reduced flood damage, reduced drought damage, improved stormwater management/treatment, improved drinking water supply/treatment, improved water quality, improved timing of water withdrawals/releases, and other impacts. Specifically:

- **Reduced flood damage:** Improved credibility of and response to alerts, forecasts, and maps released through media; decreased annual disbursements to cover flood losses through the NFIP.
- **Reduced drought damage:** New/additional analyses would lower the cost of water withdrawals from the Conowingo pool (expensive due to pumping costs, water withdraw rates) allowing for more accurate timing of withdraws — current cost is \$90,000 per month to operate a single pump. Also, through better decision making and reduced chemical costs for community water suppliers.
- **Improved stormwater management/treatment:** Would help community water suppliers produce higher quality water.
- **Improved drinking water supply/treatment:** Through improved planning for changing water quality, reduced treatment costs by storage of higher quality waters in the system for mixing with lower quality water (coming from Conowingo pool), and help drinking water providers target time, energy and financial resources to produce the most benefit to quality.
- **Improved water quality:** New/additional analyses would reduce the need for \$250 million worth of nonpoint source practices to meet water quality TMDL (n, p, sediment). Also, any additional information would be beneficial for community water suppliers.
- **Improved timing of water withdrawals/releases:** Related to drought impacts.
- **Other impacts:** Planning for management of rural industries and communities would be helped significantly.

Other Information

Respondents that indicated potential economic benefits of other information did not provide additional verbatim comments to explain the benefits.

APPENDIX E: Hudson River Basin Detailed Survey Results

Hudson River Basin

Responses

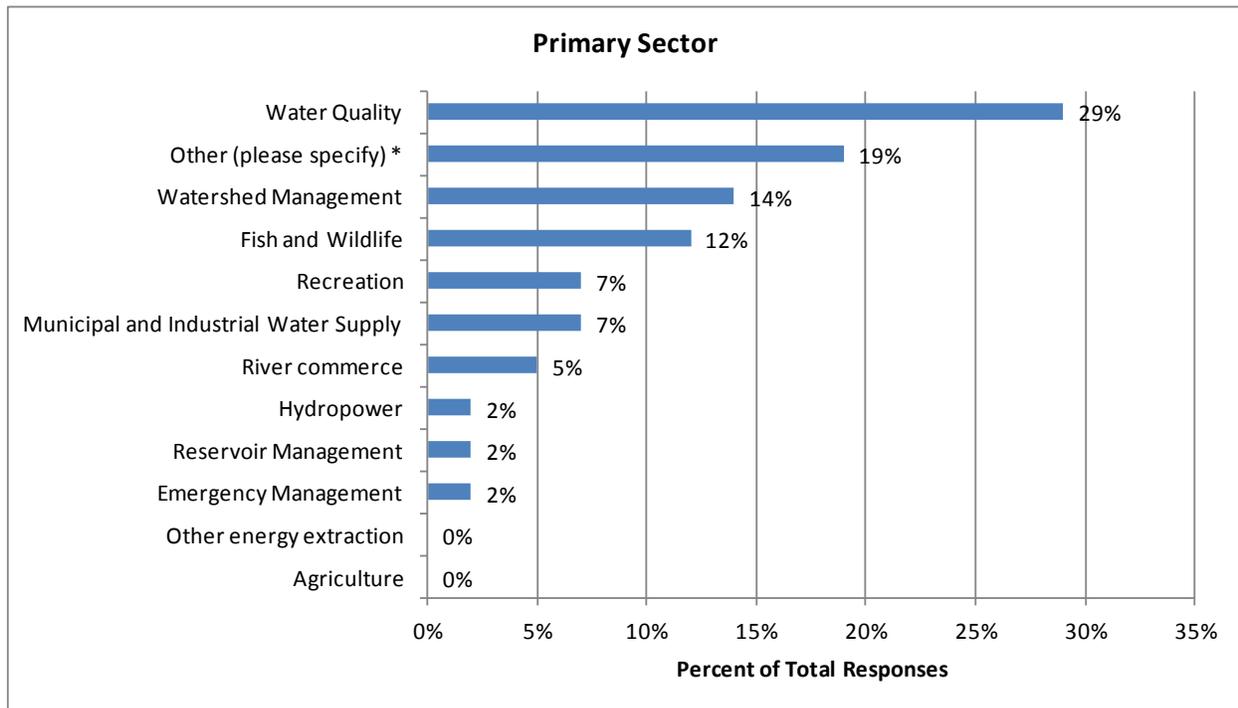
Personalized survey invitation emails were sent to 93 people. ERG received 42 total responses, including 30 complete surveys (i.e., respondent reached the end of the survey and hit submit) and 12 incomplete surveys (i.e., respondent closed out of the survey before completing). Of these 42 total responses, 39 were from individuals on the mailing list or colleagues to whom those emails were forwarded; the other 3 responses came from “untracked” participants (i.e., those who arrived at the survey via a link on the RBC website). To the maximum extent possible, the incomplete surveys were included in the results presented below.

Respondent Demographics

Respondents were asked to select the primary sector in which their work or interest is focused in the Hudson River basin, see Figure 6-57. Just under half of respondents indicated that their work or interest was primarily focused on water quality (29 percent) and watershed management (14 percent). Nineteen percent, however, specified an “other” sector (other than a categorized response option). Their verbatim responses were:

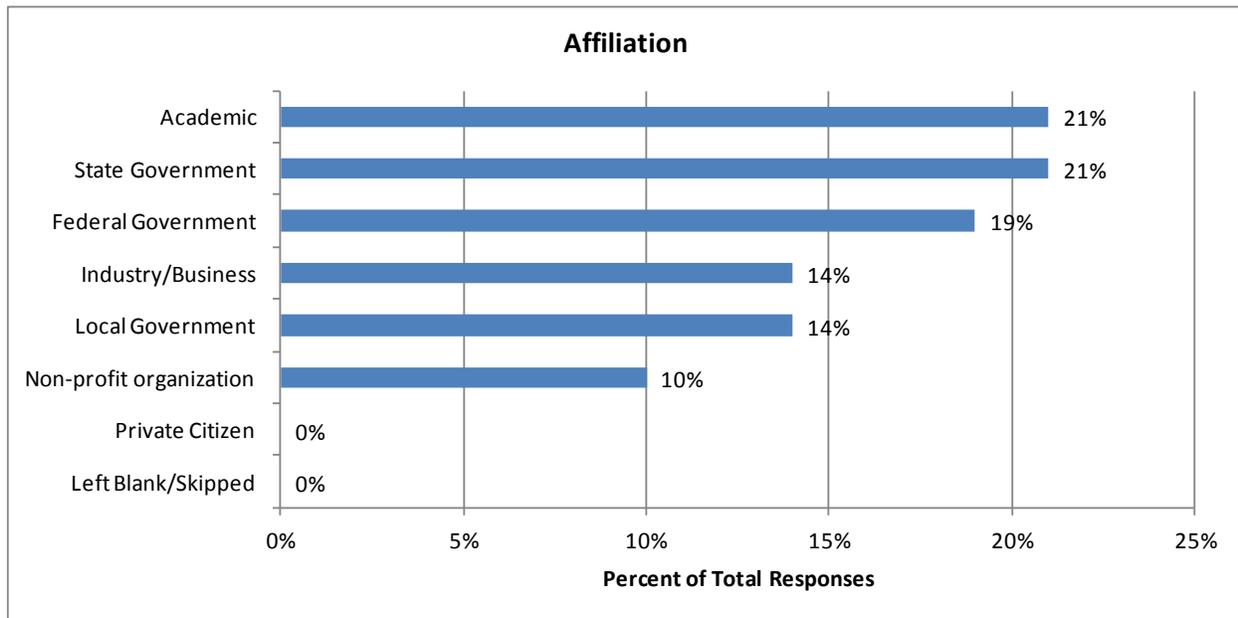
- Coastal Resources & waterfront planning
- Education
- Flooding
- Floodplain Management
- Navigation
- NOAA interests in drought and flooding
- Research
- Urban resiliency
- Wastewater Treatment

Figure 6-57. Responses to "Please select the primary sector in which your work or interest is focused in the Hudson River Basin."



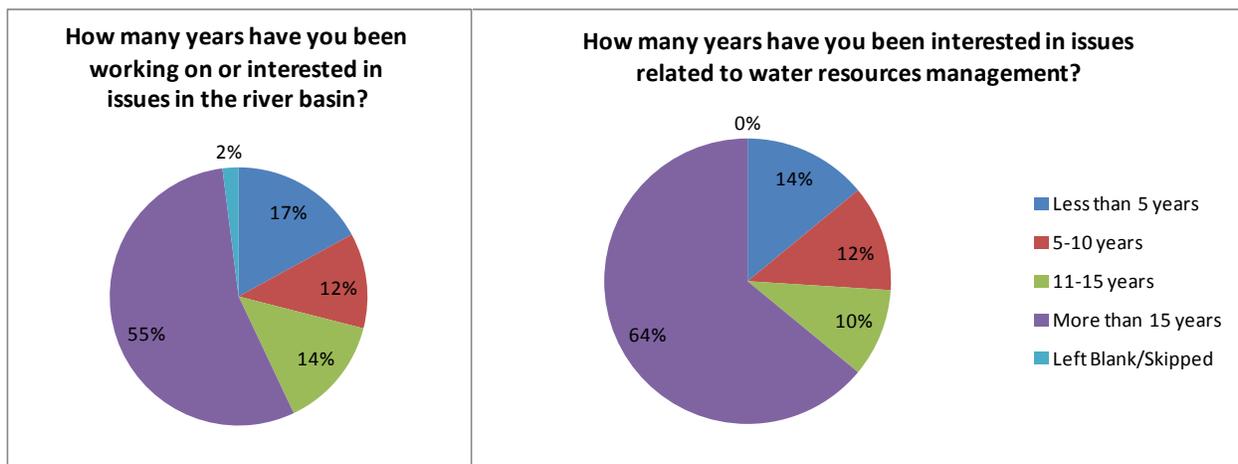
Respondents were asked to indicate the affiliation that best describes their work or interest in the Hudson River basin, see Figure 6-58. Over half of respondents (54 percent) are affiliated with a government agency (federal, 19 percent; state, 21 percent; local, 14 percent). In addition, one-fifth of respondents (21 percent) are affiliated with academia.

Figure 6-58: Responses to "Please select the affiliation that best describes your work or interest in the Hudson River Basin."



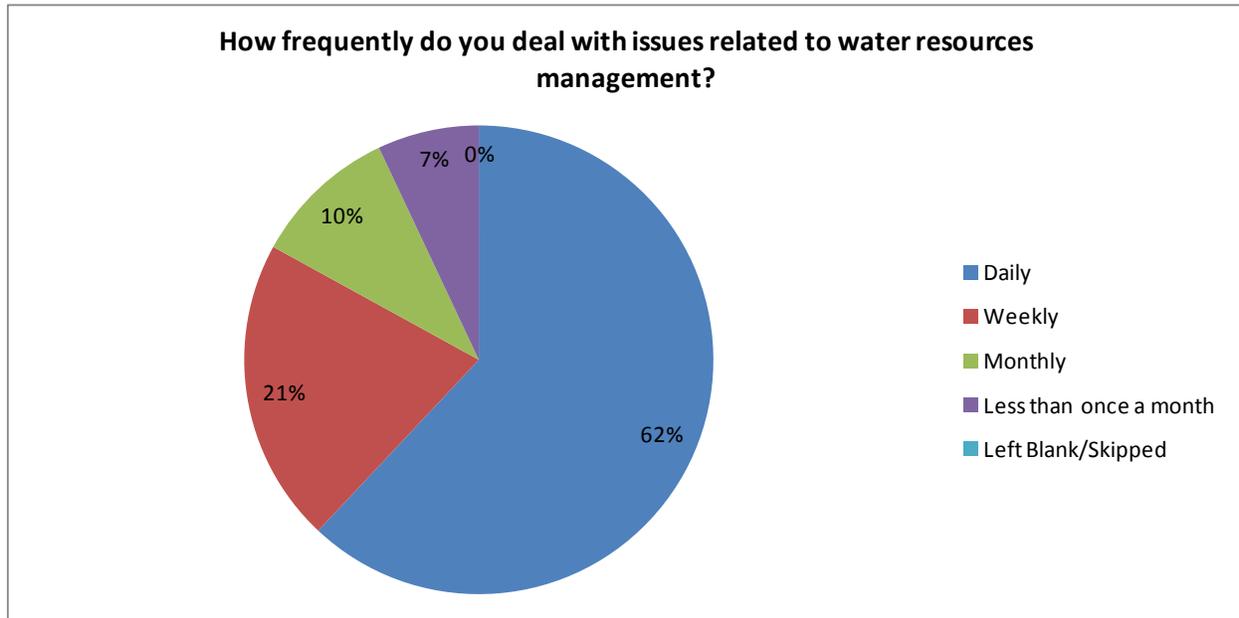
Respondents were asked to indicate how many years they have been working on or interested in issues in the Hudson River basin and how many years they have been interested in issues related to water resources management, see Figure 6-59. Over half of respondents (55 percent) have been working on or interested in issues in the Hudson River basin for more than 15 years. Accordingly, over half (64 percent) have also been working on or interested in issues related to water resources management for more than 15 years.

Figure 6-59: Number of years respondent has been working on or interested in issues in the river basin and water resources management.



The survey asked how frequently respondents deal with issues related to water resources management, see Figure 6-60. The majority of respondents (83 percent) deal with such issues on a daily or weekly basis.

Figure 6-60: Frequency of dealing with water resources management issues.



The majority of respondents (83 percent) have job responsibilities that include providing input to strategic planning; program, facility, operations or financial management; or project planning decisions on water resources information.

Priority Issues

Prior to the survey, priority issues facing the Hudson River basin were identified as follows:

- **Flooding:** Flooding issues include: ice jams in the upper watershed during spring thaw; damage from extreme precipitation events (including recent hurricanes/tropical storms such as Irene and Sandy); and storm surge in the lower basin. Growing concerns include the combined effects of riverine peak flooding and coastal storm surge, and management of reservoir impoundments to mitigate flooding and prevent catastrophic releases.
- **Water Supply:** Reservoirs in the Croton and Catskill sub-watersheds provide a portion of drinking water to 8 million residents and visitors of New York City. Issues focus on source protection to ensure these watersheds continue to deliver high quality and adequate flows to the reservoirs. New York City may be required to build a filtration plant for the Catskill/Delaware system if it cannot ensure continued protection the source (costs estimated at \$8-12 billion for construction with operating costs \$350 million/year). Thus, land protection in these watersheds is critical for cost-effective, long-term sustainable supplies.

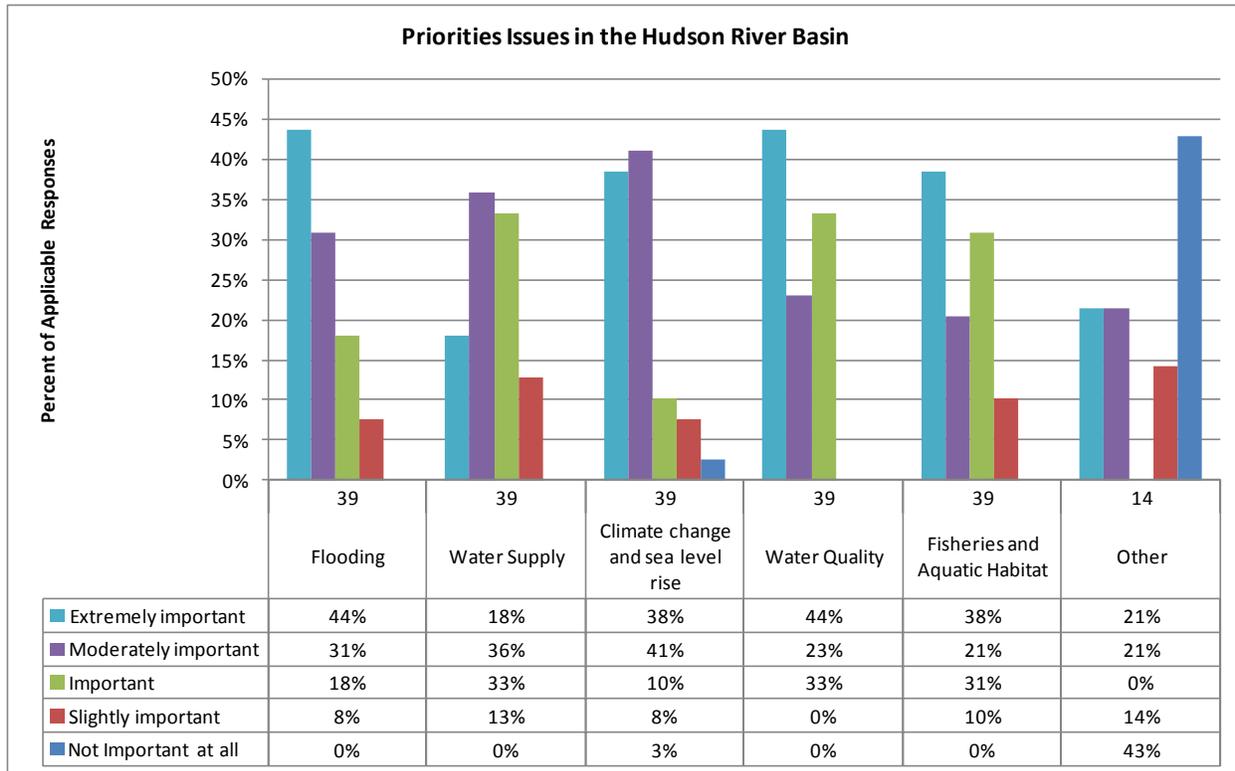
- **Climate change and sea level rise:** Climate change issues include increased drought, increased frequency and intensity of flooding associated with sea level rise, and stronger storms. Understanding the scope of these issues and adapting to them is gaining increasing attention including: building community resilience (including infrastructure); conducting species vulnerability assessments; and developing adaptation guidance for local communities.
- **Water quality:** Water quality issues include stormwater runoff, sewage discharges, saltwater intrusion, contaminated sediment and concerns about the impacts associated with hydraulic fracking⁶ impacts. Upstream migration of the salt front is an issue for communities like Poughkeepsie that draw drinking water from Hudson River. Nutrients and bacteria from wastewater discharges are also an issue, and wastewater system infrastructure upgrades will be necessary in the near future. Contaminated sediment is also an issue affecting water quality and aquatic life. Contaminants of concern include PCBs, pharmaceuticals, endocrine disruptors and heavy metals such as mercury.
- **Fisheries and aquatic habitat:** There are several stressed fish populations in the Hudson. Issues include: flood waters from storms flushing fish downriver and causing severe scouring and sedimentation; contaminants including pharmaceuticals and endocrine disruptors; atmospheric deposition of mercury (causing consumption advisories); impacts from development (polluted runoff, changes in natural hydrology); and entrainment by cooling water intakes. Species of concern include: American shad, river herring, and Atlantic sturgeon (federally endangered). Issues related to aquatic habitat include: oyster bed restoration and difficulty establishing and maintaining them due to freshwater inundation from precipitation events; and the spread of invasive species which threatens indigenous populations and biodiversity.

Respondents were asked to indicate the importance of these issues and to rank the top three issues that they think are the most important, see Figure 6-61. Just under half of respondents rated “flooding” (44 percent), as well as “water quality” (44 percent) as “extremely important.” A similar percentage of respondents (38 percent) also rated “climate change and sea level rise” and “fisheries and aquatic habitat” as “extremely important.” Between 54 and 79 percent indicated that the each issue identified was moderately or extremely important. Respondents were also invited to describe any additional concerns that they would rank as one of their top three most important issues. Many of the “other” priority issues identified in verbatim responses probably could be included under the pre-determined priority issues. These verbatim responses were:

- Dam removals and fish passage; tributaries health.
- Forecasting Rain and Reservoir Management.
- Infrastructure design specifications; Commerce & Navigation; Sediment loading.
- Invasive species and Canadian Geese related to water quality.
- Sediment quality.

⁶ A fracking moratorium, which has been in place in NY State since 2008, will expire in May 2015 pending completion of an Environmental Impact Statement and subsequent rule-making.

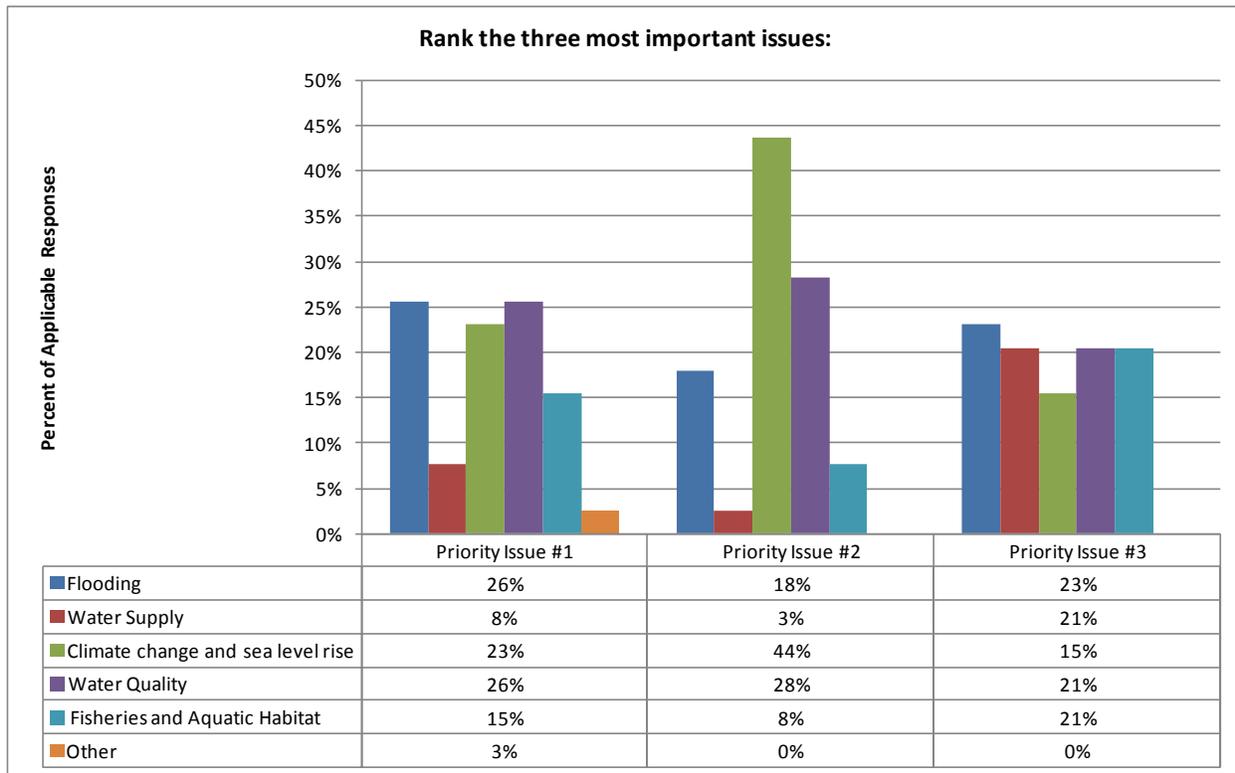
Figure 6-61: Responses to "Please indicate the importance of each of the following issues."



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 42 survey responses. Those who skipped the question or never saw the question are not included here.

When ranking the most important issues facing the Hudson River basin, respondents were divided on the issues they feel are most important. About one-quarter of respondents each identified “flooding” and “water quality” and “climate change and sea level rise” as most important. See Figure 6-62.

Figure 6-62: Responses to "Looking at the issues as a group, please rank the three most important issues that you think are facing the Hudson River Basin."

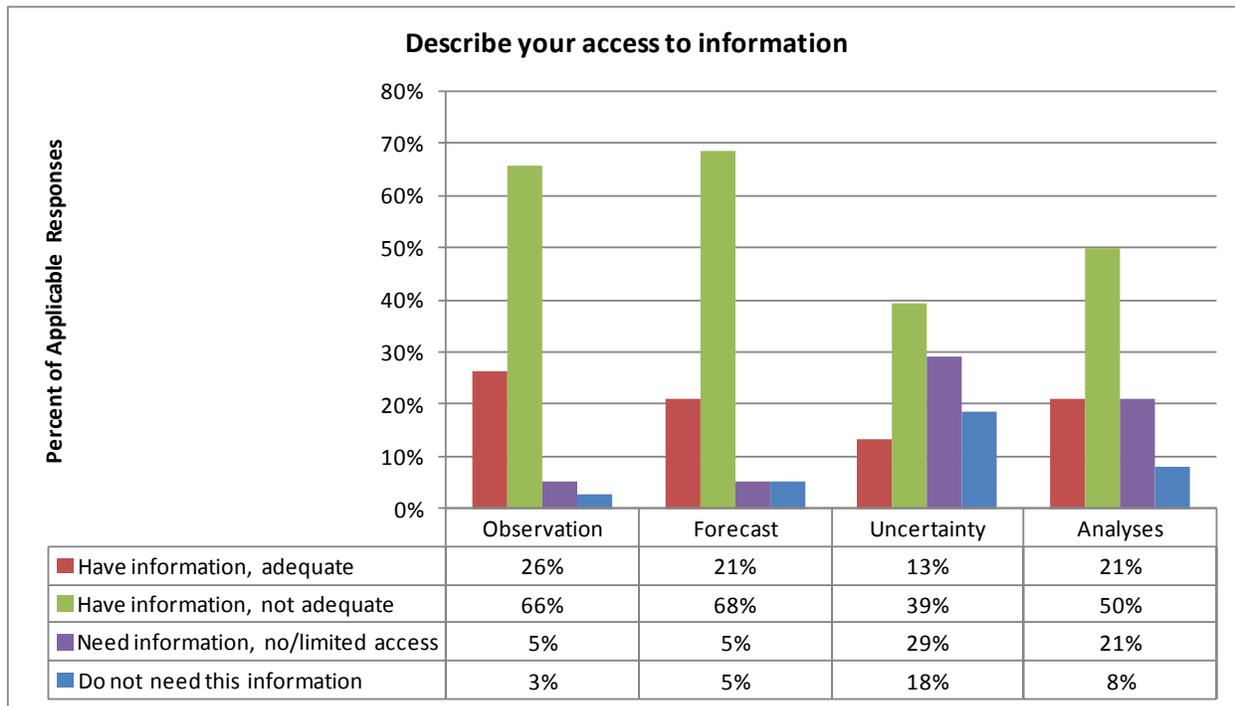


Note: There were 39 responses to this question.

Information Access and Use

Respondents described their access to observations, forecasts, uncertainty, and analyses information needed for informing decisions, see Figure 6-63. Across all types of information (observation, forecast, uncertainty, analyses), nearly three-quarters of respondents indicated that they have information but it is inadequate or that they lack access to the information they need. Relatively few respondents (3-8 percent) do not need the observation, forecast or analyses information; 18 percent do not need uncertainty information.

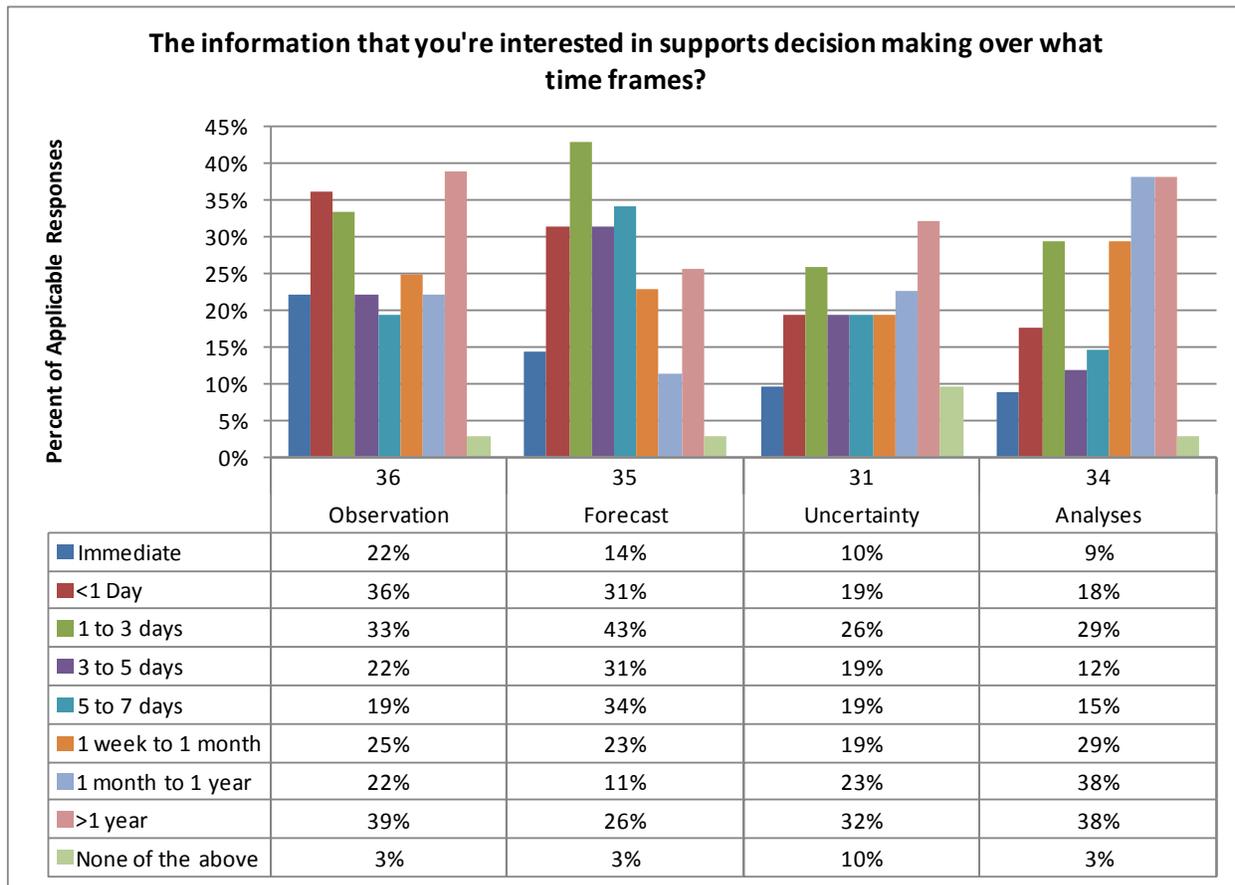
Figure 6-63. "Responses to "For your highest priority issue, describe your access to the following types of information needed for informing decisions."



Note: There were 38 responses to this question.

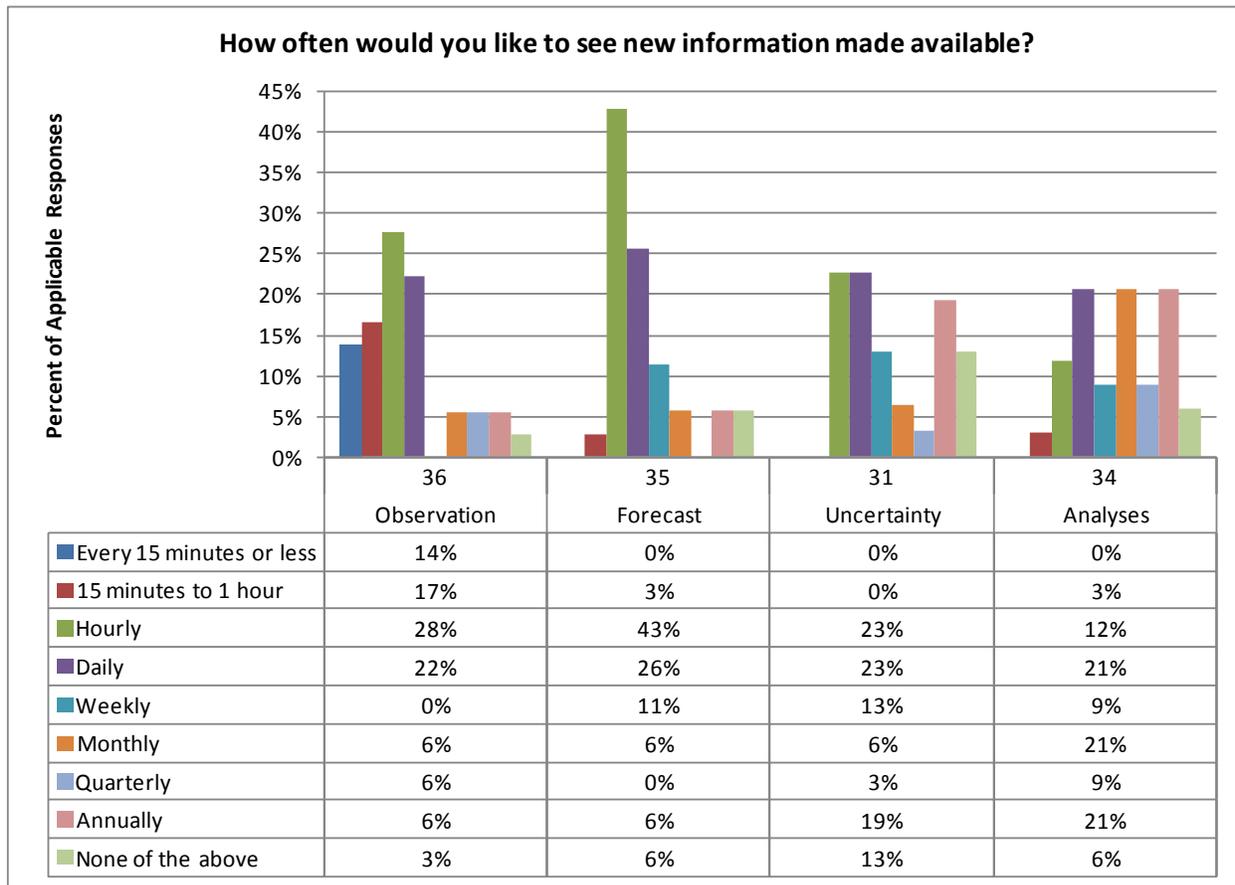
Respondents were also asked to indicate the decision-making time frames that would be supported by the information in which they were interested, see Figure 6-64, and how often they would like to see new information made available for use, Figure 6-65. Regarding timeframes, respondents were divided but most often selected greater than one year for observation, uncertainty and analyses information, 1-3 days for forecast information. Respondents would like to see new or additional observation information made available hourly or daily; forecast information available hourly, daily or annually; uncertainty information available hourly or daily; and analyses information available annually, monthly or daily.

Figure 6-64. Summary of the time frame for using information regarding observations, forecasts, uncertainty, and analyses for decision making.



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 42 survey responses. Those who never saw the question (i.e., incomplete or not applicable) are not included here.

Figure 6-65. Summary of respondent preferences for new observations, forecast, uncertainty, and analyses information to be available.



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 42 survey responses. Those who never saw the question (i.e., incomplete or not applicable) are not included here.

Respondents were asked to identify barriers to use for subsets of the four information categories (observations, forecasts, uncertainty and analyses).

For observations, forecasts, and uncertainties:

- Surface hydrology.
- Groundwater hydrology.
- Water quality.
- Drainage basin management.
- Meteorology.
- Snow/ice.

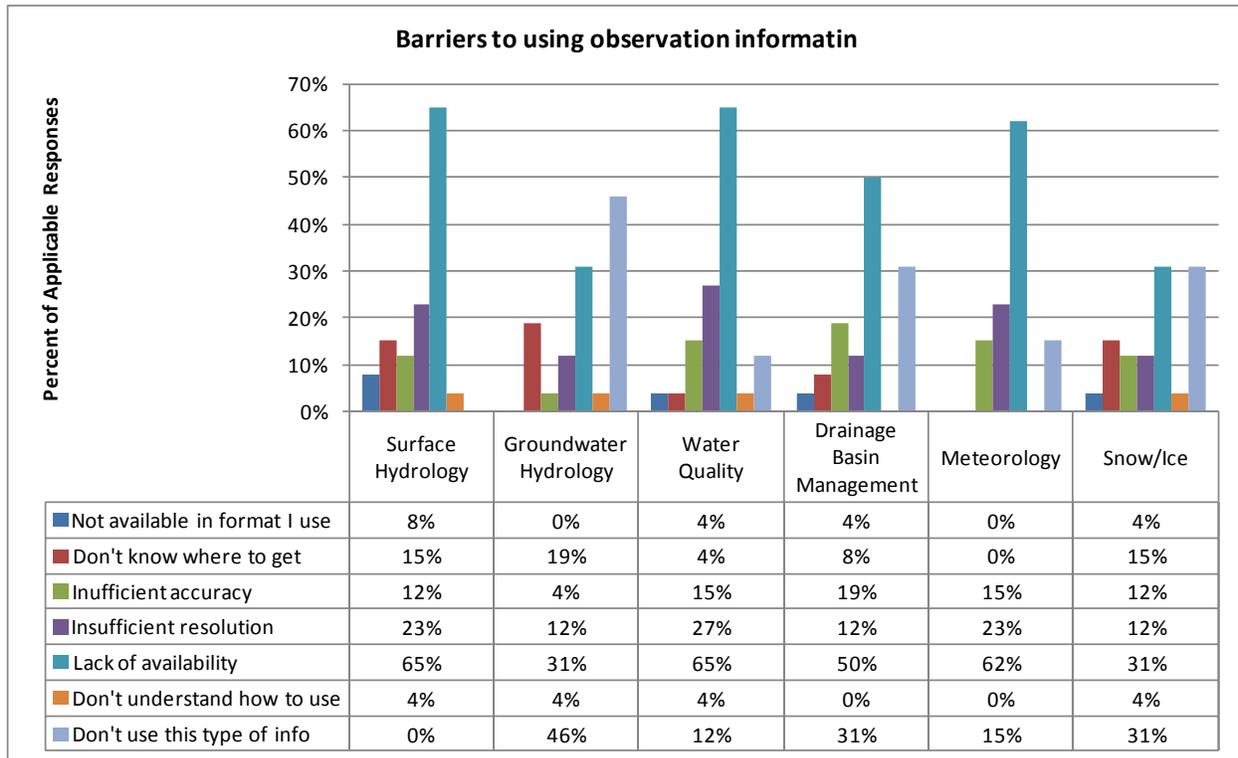
And for analyses:

- Public alerts.
- Meteorological analyses.
- Hydrologic analyses.
- Climatological analyses.
- Flood inundation mapping.
- Information integration.

Results show that barriers to use are fairly consistent across information types. For example, lack of availability is the most common barrier to use. Insufficient resolution and accuracy are also common barriers to use. For observation, forecast, and uncertainty information, 35-52 percent of respondents do

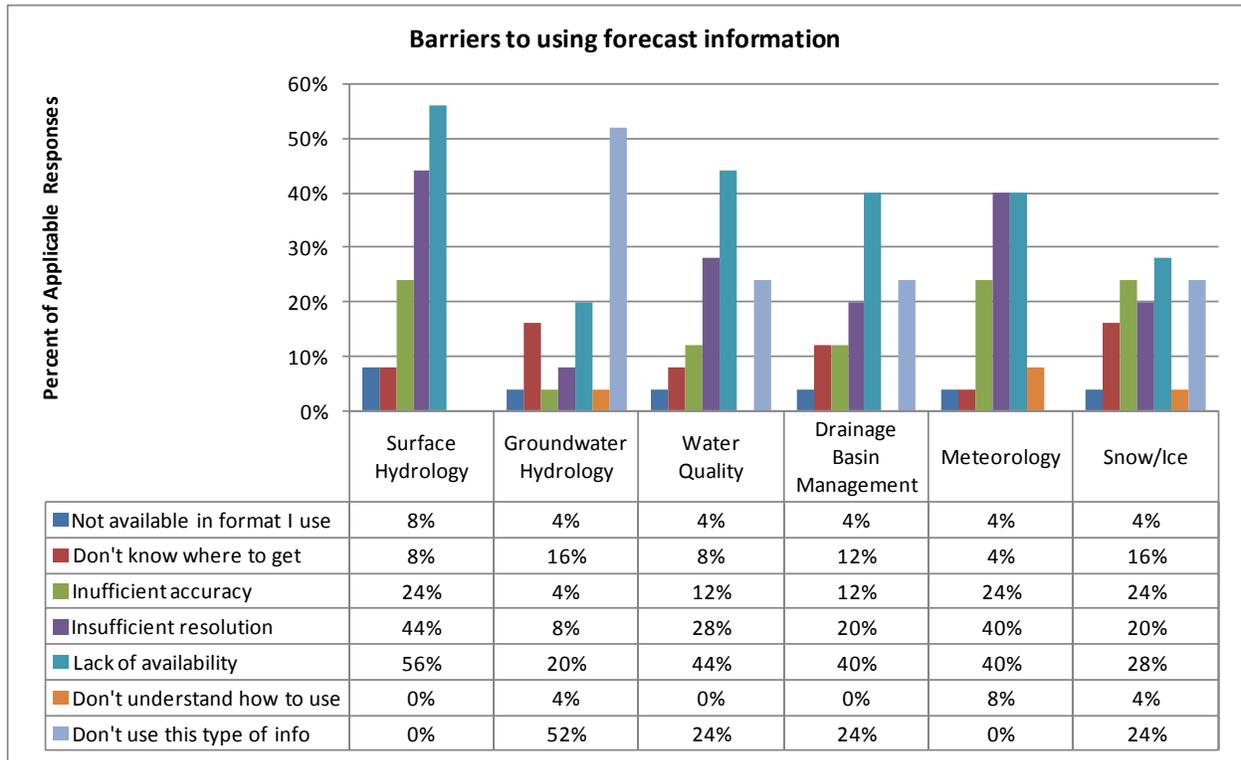
not use groundwater hydrology information. Nearly a quarter of respondents do not know where to get various types of uncertainty and analyses information. See Figure 6-66 through Figure 6-69.

Figure 6-66. Responses to "What are some of the barriers to using the following types of observation information?"



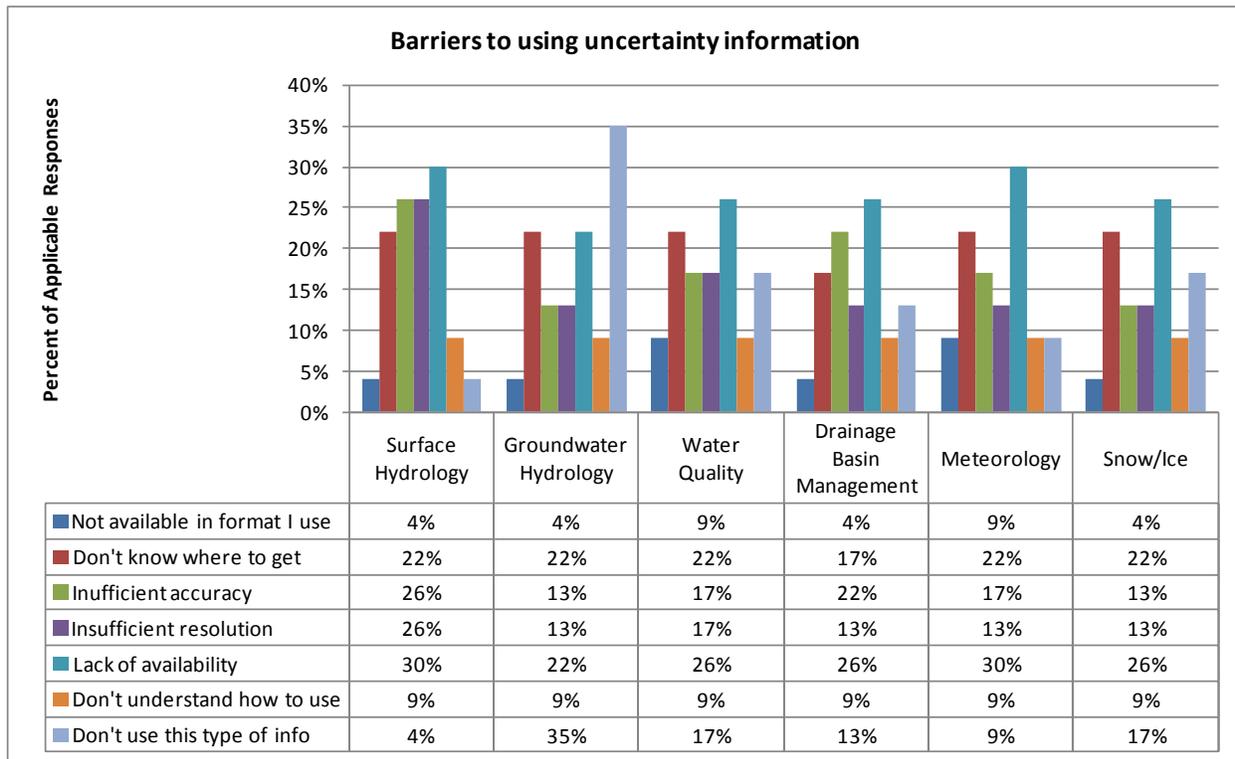
Note: There were 26 responses to this question.

Figure 6-67. Responses to "What are some of the barriers to using the following types of forecast information?"



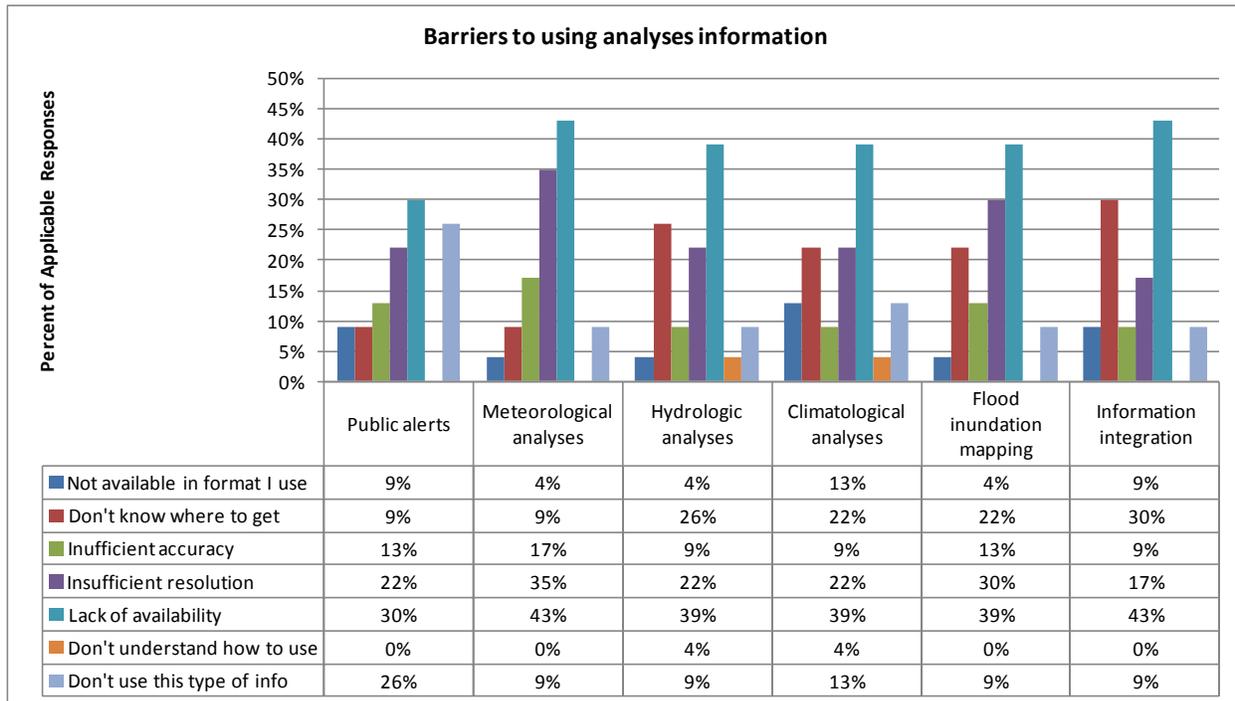
Note: There were 25 responses to this question.

Figure 6-68. Responses to "What are some of the barriers to using the following types of uncertainty information?"



Note: There were 23 responses to this question.

Figure 6-69. Responses to "What are some of the barriers to using the following types of analyses information?"

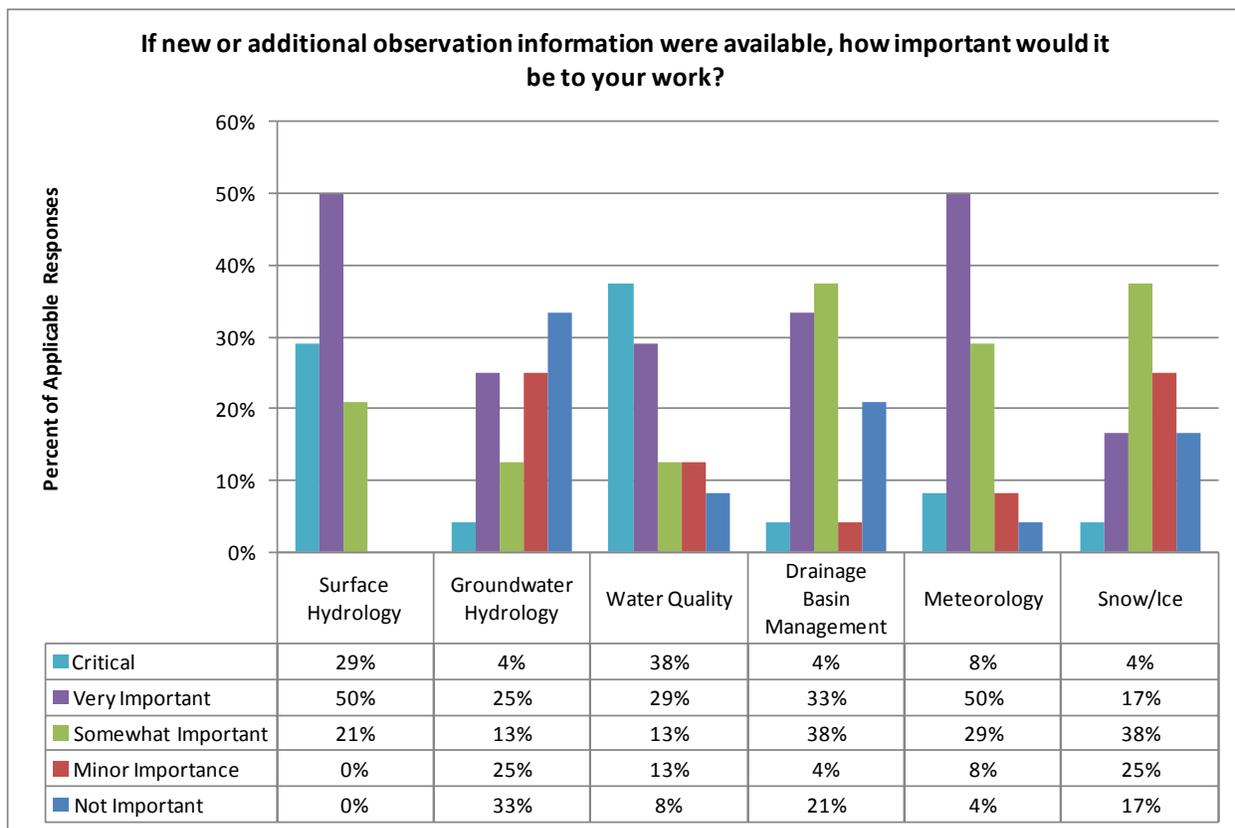


Note: There were 23 responses to this question.

Additional Information Needed

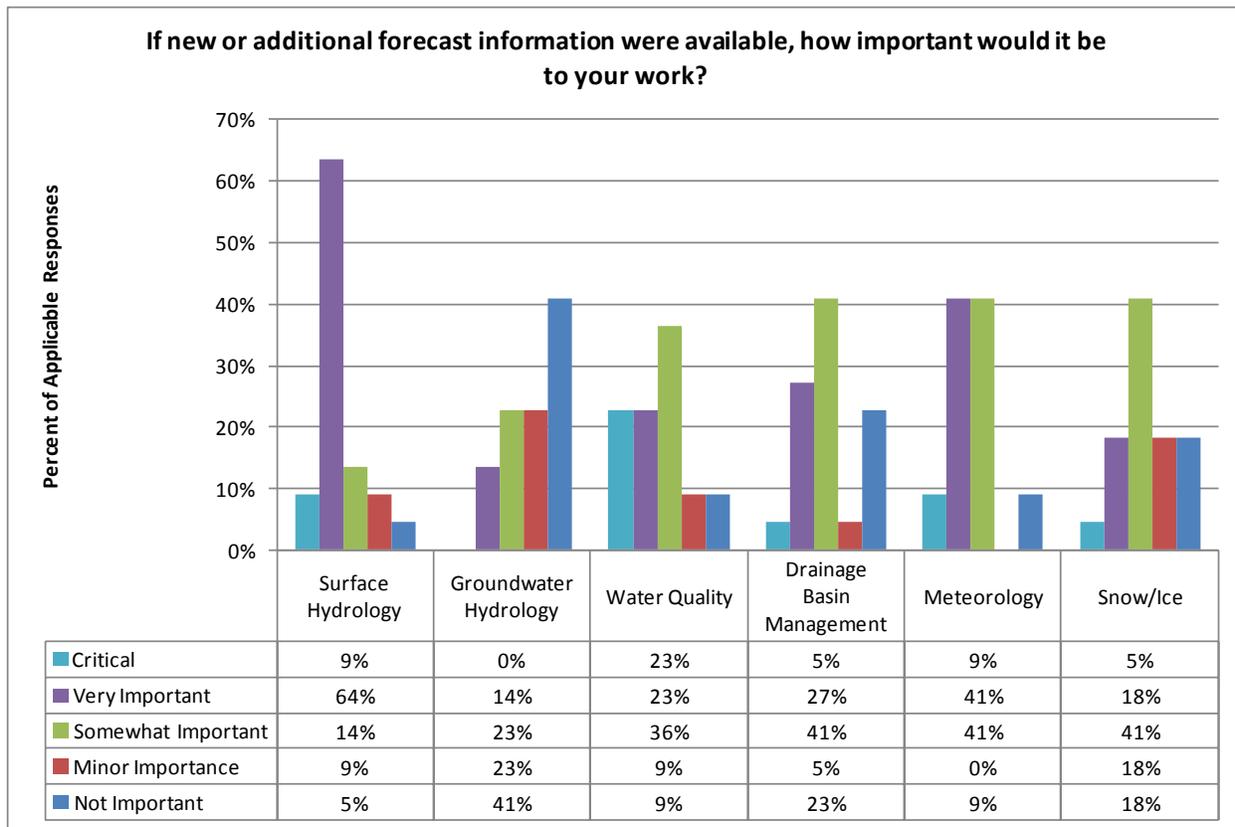
Respondents were asked if new or additional information were available, how important it would be to their decision making. For observation and uncertainty information, the subcategories of surface hydrology and water quality information were rated as the most important (when combining “critical” and “very important” responses). For forecast information, the categories of surface hydrology and meteorology were rated at the most important. Under analyses, respondents rated hydrologic analyses and flood inundation mapping as most critical, but overall rated the various information types (except public alerts) as almost equally important. See Figure 6-70 to Figure 6-73.

Figure 6-70. Importance of new or additional observation information.



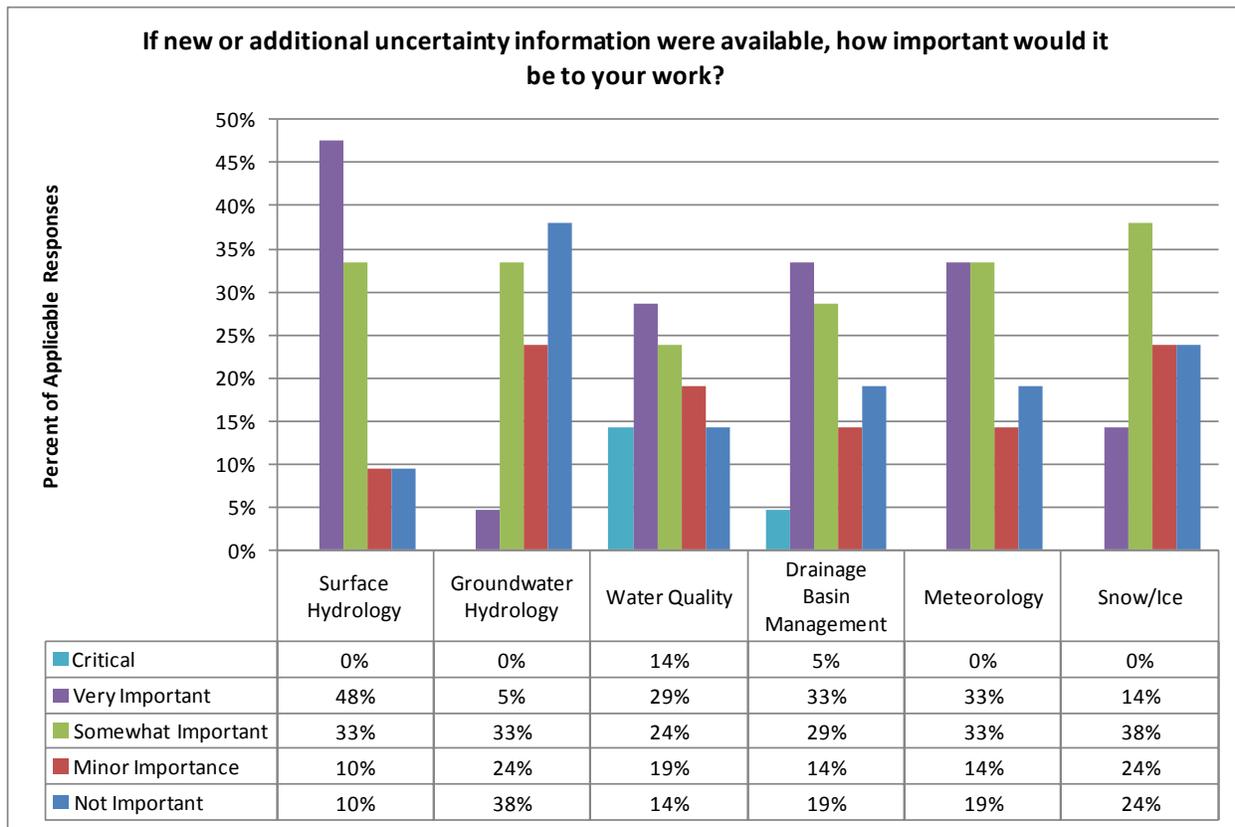
Note: There were 24 applicable responses to this question.

Figure 6-71. Importance of new or additional forecast information.



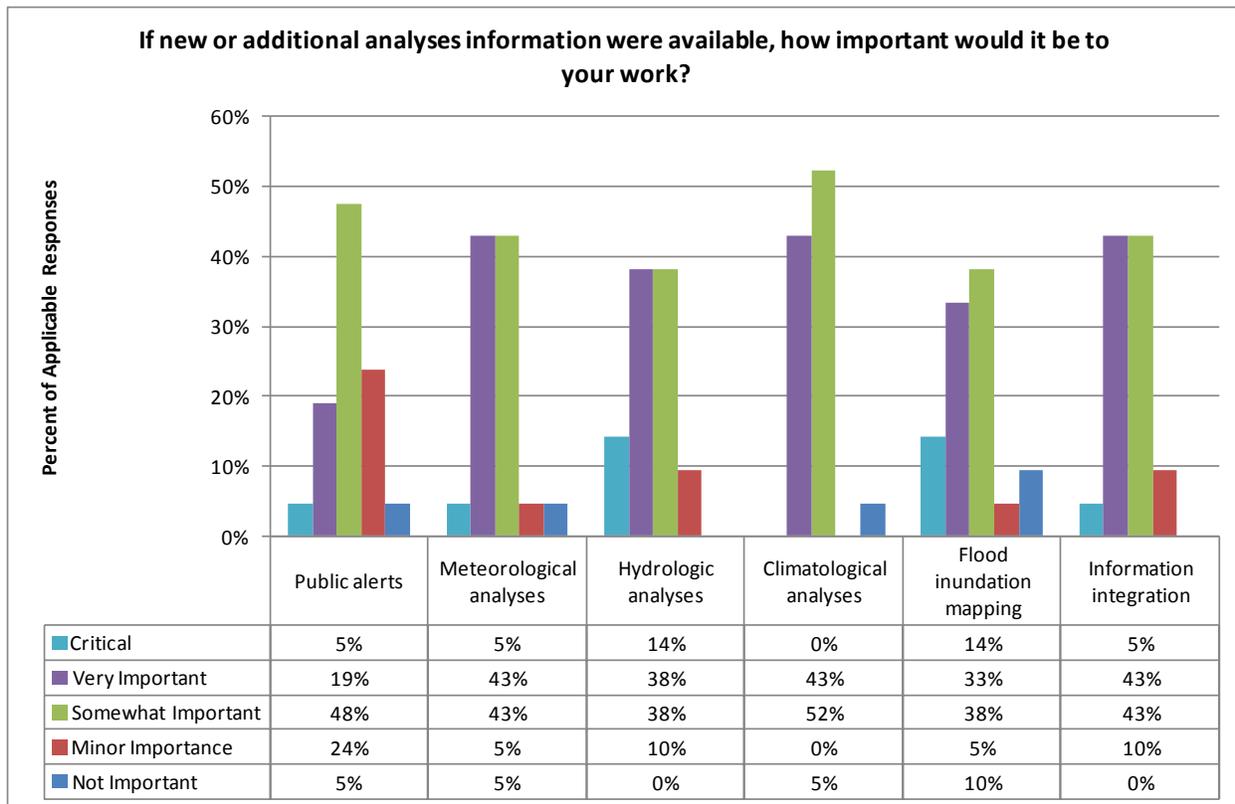
Note: There were 22 applicable responses to this question.

Figure 6-72. Importance of new or additional uncertainty information.



Note: There were 21 applicable responses to this question.

Figure 6-73. Importance of new or additional analyses information.



Note: There were 21 applicable responses to this question.

Summary of Open Comments

After respondents rated the importance of new or additional information types needed for decision making, they were asked to describe the additional or new information for those types identified as very important or critical. This section summarizes the written comments in response to that question by category of information — observations, forecasts, uncertainty, and analyses.

For observations and uncertainties the most important category of information is surface hydrology, followed by water quality; for forecasts it is surface hydrology followed by meteorology; for analyses, the most important category is hydrologic analyses. See Table 19 for a summary of responses by category.

Table 19. Number of respondents indicating that new or additional information is "Very important" or "Critical" to their decision making.

	Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	Public Alerts	Meteorological Analyses	Hydrologic Analyses	Climatological Analyses	Flood Inundation Mapping	Information Integration	Provided Description
Observations	19	7	16	9	14	5	--	--	--	--	--	--	20
Forecasts	16	3	10	7	11	5	--	--	--	--	--	--	17
Uncertainty	10	1	9	8	7	3	--	--	--	--	--	--	13
Analyses	--	--	--	--	--	--	5	10	11	9	10	10	16

Based on a review of the written comments from respondents the following new or additional information would be useful:

- **Observations:** expanded stream gage networks (including additional, smaller stream segments) with increased observations of surface water variables and water quality; and improved spatial and temporal resolution. Observations of salinity, dissolved oxygen, and bacterial contamination.
- **Forecasts:** improved spatial and temporal resolution of forecasts related to river flows, improved accuracy. Responses also discussed how the information could be used (improved planning, management, and communication).
- **Uncertainty:** specific needs such as uncertainties related to oxygen levels, stream flow, temperature, and salinity at specific locations as well as the overall benefits of uncertainty information for communication, decision making, and planning.
- **Analyses:** The comments fall into two categories: examples of specific analyses, and the format of the information. In terms of specific analyses, respondents mentioned long term trends analyses of water quality (especially the position of the salt front), statistical distributions of high and low parameters, water quality alerts for recreational users, and flood inundation mapping. In terms of information format, several respondents note that they need analyses that provide clear, straightforward results that can be communicated to and understood by the public.

The remainder of this section provides a summary of the written comments by information category (observations, forecasts, uncertainty, analyses) and a table presenting raw written comments by number and type of information types rated as "very important" or "critical."

Observations

Twenty respondents provided comments in response to this question, the comments focused on surface hydrology and water quality information. The primary theme in the responses relating to these two topics is a need for more observations at greater spatial and temporal resolution; respondents mention expanded stream gage networks that could provide more real-time monitoring of surface water and water quality as well as more local information from specific stream segments. Several respondents also offered specific comments on water quality information including a need for measurements of salinity

gradients, dissolved oxygen, and bacterial contamination as well as tools such as a smart phone app to advise recreational users of water quality.

The following table, Table 20, summarizes the written responses by the information types marked as “very important” or “critical” to decision making (indicated with a check mark). The responses have been lightly edited for misspelled words and grammatical errors, non-substantive comments have been removed, and comments are ordered from most to least check marks.

Table 20. Summary of written responses to "For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decision making," by information type.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decisionmaking.
✓	✓	✓	✓	✓	✓	Greater spatial coverage, improved reliability, more readily available
✓	✓	✓	✓	✓		New data to support increased understanding of the water and sediment delivery from the watershed to the river and NY Harbor. New data to support increased understanding of the transport and trapping of sediments in the River
✓	✓		✓	✓	✓	Surface Hydro percent range in forecast Ground water would be good for ground saturation figures Drainage Basin management would help with reservoir management Snow pack would be great for spring runoff calculations
✓		✓	✓	✓		More observation sites/gauges on streams and rivers
✓			✓	✓	✓	Better availability of real time/near real time river water levels and currents (speeds) in a water column at more locations between Kingston and Albany
✓	✓	✓				Continuous monitoring at additional locations
✓		✓		✓		For surface hydrology, there are not enough gauging stations in the important tributaries of the Hudson River. Also, the major gauging stations such as Green Island do not update the data frequently enough. The availability of water quality data is poor, particularly outside of New York City’s Harbor Survey region. Even there, the resolution of the data is typically not sufficient to analyze the impact of critical events like storms. The temporal resolution of meteorological records is very good at the official stations, but the spatial resolution is poor for the analysis of small-scale (<20 km) conditions. This is a problem when determining the potential impact of local rainfall on water quality parameters.
✓		✓		✓		I seek current and historic salinity gradient information, temperature, and dissolved oxygen concentrations measured throughout the water column at various locations along the Hudson river Estuary from Battery Park to the Troy Dam above Albany. USGS has recently abandoned several gaging stations along this reach of the river (e.g., Hastings and West Point). The best long term data set I am aware of comes from daily grab samples of water temperature taken from Poughkeepsie Water Works withdrawal at mile 76 (north of the Battery). If other water quality data such as turbidity or salinity (specific conductance) are available and could be added to the PWW data set extending back to the 1950's, this would be useful for short term climate change analysis and correlation with fish habitat and assemblage changes.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new observation information that you need for your decisionmaking.
✓		✓		✓		We are always looking to expand our environmental monitoring network, and these are the types of observational data that we provide. We don't necessarily use the data for decision making, but we provide it in hopes that it will be used as such.
✓		✓	✓			More gages.
✓				✓	✓	Additional locations for surface water discharge, point location for precipitation and location information for ice jams.
✓		✓				Greater resolution on Q in tributaries (more sampling locations in watershed) Greater frequency and resolution of temp., DO, turbidity.
✓		✓				It would be great to have a smart phone app so that recreational users can get this information when needed. Having it in an easy to use, none technical format would help the public know when it's safe to use the Hudson River and other bodies of water.
✓		✓				More current data on bacterial contamination in the Hudson and tribs. Restoration of Hudson River salt front monitoring (USGS).
✓				✓		Stream gaging Accurate stream flow/stage forecasting
		✓		✓		Regular inshore or near shore water quality testing
✓						Flood forecasting and modeling is not sufficient for local decision making.

Forecasts

Seventeen respondents provided written comments describing new or additional forecast information. The comments focused on surface hydrology and meteorology, respondents focused on improved spatial and temporal resolution of forecasts related to river flows. Several respondents also commented on the need for improved accuracy as well as how the information could be used (improved planning, management, and communication). See Table 21.

Table 21. Summary of written responses to "For the information types you rated as very important or critical, please describe the additional or new forecast information that you need for your decision making," by information type.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new forecast information that you need for your decisionmaking.
✓	✓	✓	✓	✓	✓	How to advise on new projects, how to plan for extreme events, improved communication
✓	✓	✓		✓		Increased resolution for Hudson River Estuary.
✓			✓	✓	✓	More frequent river forecasts than twice daily updates during high-flows. Computer model with a shorter time-step to allow smaller basins to be forecast.
✓		✓		✓		For surface hydrology, forecasts on the important tributaries as well as the

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new forecast information that you need for your decisionmaking.
						Hudson River would be valuable. The forecasts of water quality are critical to higher level products to advise water treatment, WWTF and recreational user of the river. Better resolution of meteorological data would permit high resolution sampling of events that are important to water quality, but usually unresolved by sampling programs.
✓	✓			✓		Surface better forecasts of River Flows. Better forecasts of ground absorption of Water. Better Forecasts of Rain. All of these lead to better reservoir management and smoother river flows and allow ramping of flows
✓				✓	✓	For surface hydrology, forecast discharges in the basin at more locations than currently available. For snow/ice easier to visualize snow depth and location of ice jams.
✓		✓		✓		Our monitoring program does not currently provide forecast information on water quality and hydrology; however we hope to do so in the future. The prevalence of this type of information would help us work towards providing it.
✓		✓				models of flooding from storm surge and runoff; salt front location in Hudson River
✓				✓		Presently, forecasts are very inaccurate. This needs to be resolved. Also, the timeliness of information is challenging since the current system does not respond to changing conditions appropriately.
✓						See previous comments...more sensors in the upper river giving water level and current data
		✓				Comprehensive and timely water quality data, including biological, from Hudson and tributaries.

Uncertainty

Thirteen respondents provided written comments in response to the question. Respondents focused on specific needs such as uncertainties related to oxygen levels, stream flow, temperature, and salinity at specific locations as well as the overall benefits of uncertainty information for communication, decision making, and planning. In terms of information types, the responses focus on surface hydrology and water quality. See Table 22.

Table 22. Summary of written responses to "For the information types you rated as very important or critical, please describe the additional or new uncertainty information that you need for your decision making," by information type.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new uncertainty information that you need for your decisionmaking.
✓	✓	✓	✓	✓	✓	in advising the public, scientific uncertainty must be reduced in order to have the public accept forecasts and information as being as being believable

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new uncertainty information that you need for your decisionmaking.
✓			✓	✓		Presently forecasting is very poor. The uncertainty does not provide sufficient time to made operation decisions since they are wrong more than they are right
		✓	✓	✓		For water quality, the uncertainties of critical features, such as oxygen levels, are needed. For Drainage Basin Management and Meteorology, the uncertainties regarding the potential extremes are critical because these drive most of the societal impacts.
✓		✓				I could use updated probability of flow or temperature or salinity data for specific locations along the estuary from the Battery to the Troy Dam. for example, if I observe a dissolved oxygen value of 4.5 mg/l at West Point near the river bottom, how does this value compare to the historical time series of DO readings at that specific location? Does 4.5 mg/l DO have a probability of occurrence of 50% or is it rare at 1%.
✓		✓				A better understanding of uncertainty in water quality sensor measurements.
✓						The uncertainty of an event forecast would help in defining our response.
✓						a measure of how accurate the observation or forecast will be is critical to determining ship voyage planning

Analyses

Sixteen respondents provided written comments on the types of new or additional analyses that they need for their decision making. The comments fall into two categories: examples of specific analyses, and the format of the information. In terms of specific analyses, respondents mentioned long term trends analyses of water quality (especially the position of the salt front), statistical distributions of high and low parameters, water quality alerts for recreational users, and flood inundation mapping. In terms of information format, several respondents note that they need analyses that provide clear, straightforward results that can be communicated to and understood by the public. See Table 23.

Table 23. Summary of written responses to "For the information types you rated as very important or critical, please describe the additional or new analyses that you need for your decision making," by information type.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new analyses that you need for your decisionmaking.
✓	✓	✓	✓	✓	✓	More and better analysis will help reduce uncertainty
✓	✓	✓	✓	✓	✓	Accurate information is critical. Presently analyses are fair at best
	✓	✓	✓			Updated long term analysis of trends in water quality information that could affect fish populations and fisheries habitat. For example, has the salt front position changed over time and is it predicted to change further.
	✓	✓		✓		The meteorological and hydrologic analyses, and flood inundation mapping would assist us in preparing to response to an event.

Surface Hydrology	Groundwater Hydrology	Water Quality	Drainage Basin Management	Meteorology	Snow/Ice	For the information types you rated as very important or critical, please describe the additional or new analyses that you need for your decisionmaking.
	✓		✓		✓	Providing a single, easy to access tool that puts the data into context for the public, educators and decision makers.
		✓	✓		✓	For the Hydrologic and Climatologic analyses, the statistical distribution of high and low parameters would be insightful. The integration of information would lead to much faster progress on forecasting abilities.
		✓	✓		✓	I'm chiefly involved in education; analyses that provide clear, straightforward explanations are desired
		✓		✓	✓	It comes down to having the information available when you need it and in a format that the public can understand. It would be nice if businesses could embed the information on their website so customers see it without having to go to another website.
✓	✓					need a much better water quality alert system for recreational use of the waterways, also better forecasting of likely
				✓	✓	We could use flood inundation mapping in our outreach.
				✓		Flood inundation mapping for tidal floodplain.
					✓	Our network does not currently have plans to provide such analyses, but having such information available would help us to improve our network.

Other

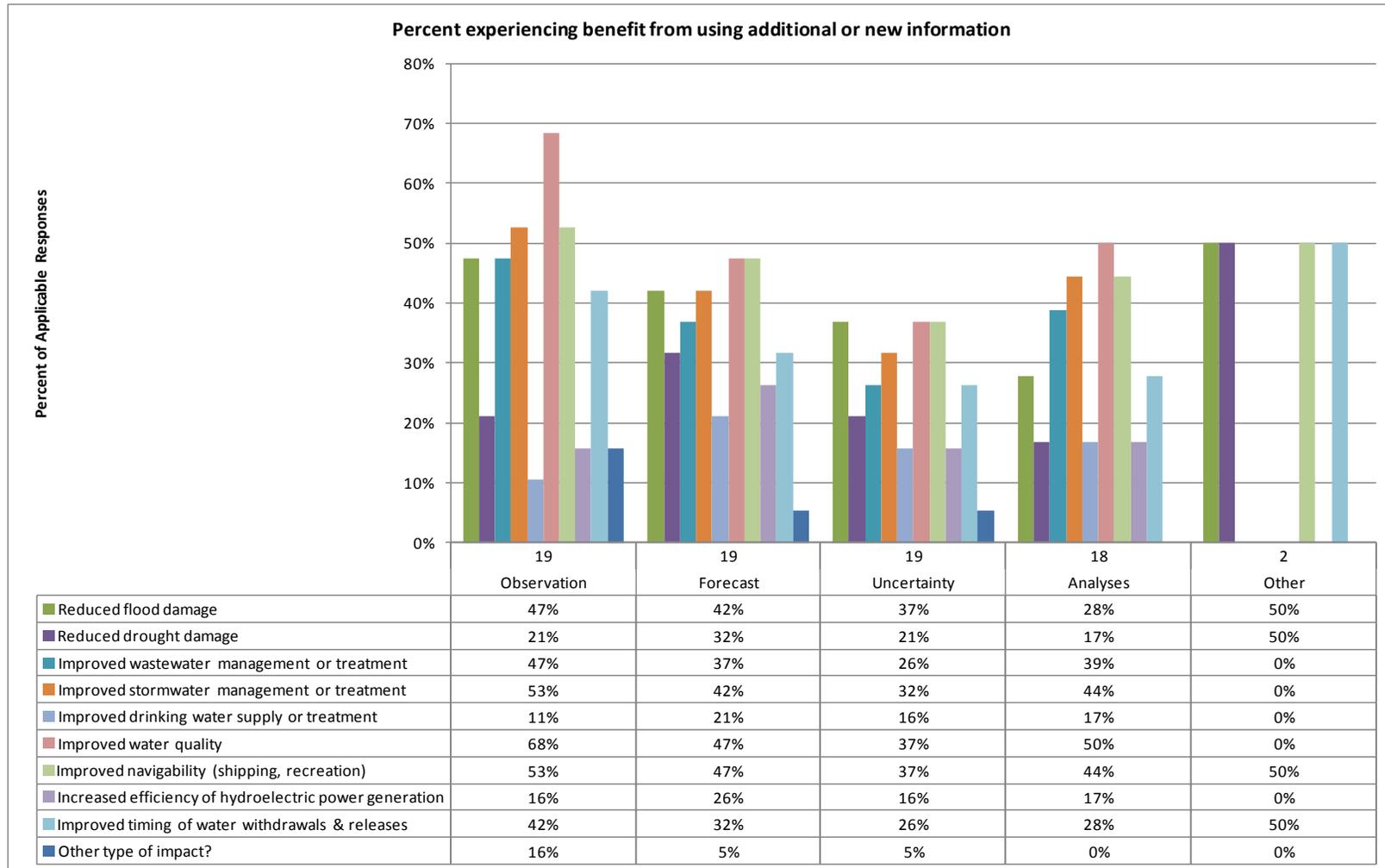
Two respondents indicated that they would rank “other” types of information as needing improvement and critical for informing decisions on their top priority issue. They provided the following written comments to describe the other types of information that they need for their decision-making:

- The next step would be for the optimization of such information to guide system operations to minimize damages while maximizing benefits.
- Web pages occasionally slower to load than desired.

Economic Impacts or Benefits

Respondents were asked if they would experience any of a set of impacts or benefits from using additional or new information from IWRSS partner agencies, see Figure 6-74. The most commonly anticipated benefits across all types of new information (observation, forecasts, uncertainty, and analyses) include improved water quality, improved navigability, and improved stormwater management or treatment, followed by reduced flood damage and improved wastewater management or treatment.

Figure 6-74. Responses to "Would you experience any of the following impacts or benefits from using additional or new information from IWRSS partner agencies?"



Note: The numbers in the horizontal axis labels represent the number of responses to the question out of a total of 42 survey responses. Those who never saw the question (i.e., incomplete or not applicable) are not included here. These totals DO include those who saw but skipped the question.

Summary of Open Comments

Respondents who indicated that they would experience any of a set of impacts or benefits from using additional or new information from IWRSS partner agencies were then asked to describe the benefit and estimate the cost avoided or benefit gained per year or per event.

Observations

By providing new or additional observation information for the Hudson River Basin eight types of benefits would be realized: reduced flood damage, reduced drought damage, improved wastewater management/treatment, improved stormwater management/treatment, improved drinking water supply/treatment, improved water quality, improved navigability, and improved timing of water withdrawals/releases. Specifically:

- **Reduced flood damage:** Through improved management of reservoirs to absorb flows during some instances and leading to reduced flood damage to infrastructure.
- **Reduced drought damage:** Minimized negative impacts on navigation during prolonged drought periods.
- **Improved wastewater management/treatment:** New/additional observation information could lead to tens of millions of dollars in avoided costs to the wastewater treatment plants as a result of improved understanding of rain and storm impacts on water quality and the development of better strategies to anticipate and deal with storm water. Also, it would improve the chance of swimmability and increase contact recreation.
- **Improved stormwater management/treatment:** New/additional observation information could lead to several million dollars per year in avoided costs of treating infections due to sewage overflow and improved water quality. Also it would reduce the impact on fisheries in terms of population abundance and species composition of various life stages.
- **Improved drinking water supply/treatment:** Better information and forecasting of the water quality parameters, such as suspended sediment and harmful algal blooms, would lead to more efficient operation of water supply plants and results in several millions of dollars of saving each year.
- **Improved water quality:** Improved fisheries and recreational use of the river, reduction of thermal pollution to tributaries and maintenance of appropriate temperature ranges in water classified for trout. These impacts have an effect on local economies totaling in the millions of dollars per year.
- **Improved navigability:** Safer navigation and cargo management and maintenance of stable water levels conducive to navigation.
- **Improved timing of water withdrawals/releases:** Through better utilization and optimization of reservoir storage and releases.

Forecasts

By providing new or additional forecast information for the Hudson River Basin nine types of benefits would be realized: reduced flood damage, reduced drought damage, improved wastewater management/treatment, improved stormwater management/treatment, improved drinking water

supply/treatment, improved water quality, improved navigability, improved timing of water withdrawals/releases, and other impacts. Specifically:

- **Reduced flood damage:** Through pre-emptive storage of water in reservoirs, and resulting in reduced repetitive damage of infrastructure.
- **Reduced drought damage:** Through pre-emptive reduction of flows to store water, and leading to reduced impacts on navigation during prolonged drought periods
- **Improved wastewater management/treatment:** New/additional forecast information would improve predictions of rain and storm impacts on water quality and could save tens of millions of dollars for the WWTP in the Hudson region.
- **Improved stormwater management/treatment:** Reduced risk of and treatment cost of infectious disease from contamination.
- **Improved drinking water supply/treatment:** New/additional forecast information for water quality parameters such as harmful algal blooms would lead to more efficient operation of water supply plants and results in several millions of dollars of savings each year
- **Improved water quality:** Reduced risk of and treatment cost of infectious disease from contamination.
- **Improved navigability:** Through more stable water levels conducive to safe navigation.
- **Improved timing of water withdrawals/releases:** Through improved utilization and optimization of reservoir storage and releases.
- **Other impacts:** Through cost-effective use of human resources for data collection.

Uncertainty

By providing new or additional uncertainty information for the Hudson River Basin six types of benefits would be realized: reduced flood damage, improved wastewater management/treatment, improved stormwater management/treatment, improved water quality, improved timing of water withdrawals/releases, and other impacts. Specifically:

- **Reduced flood damage:** Improvements in uncertainty would minimize flood damage by allowing decisions to be made based on more certain outcomes; this would eliminate millions of dollars in annual damage and streamline reservoir planning.
- **Improved wastewater management/treatment:** Reduced impacts on fisheries in terms of population abundance and species composition of various life stages.
- **Improved stormwater management/treatment:** Reduced impacts on fisheries in terms of population abundance and species composition of various life stages.
- **Improved water quality:** Reduced impacts on fisheries in terms of population abundance and species composition of various life stages.
- **Improved timing of water withdrawals/releases:** Improved efficiency of planning water releases.
- **Other impacts:** Cost-effective use of human resources by knowing the uncertainty of the forecast.

Analyses

By providing new or additional analyses information for the Hudson River Basin five types of benefits would be realized: improved wastewater management/treatment, improved stormwater management/treatment, improved drinking water supply/treatment, improved water quality, and improved timing of water withdrawals/releases. Specifically:

- **Improved wastewater management/treatment:** Improved analyses would improve how wastewater treatment plants operate and save tens of millions of dollars.
- **Improved stormwater management/treatment:** Better analyses regarding stormwater management would result in better ways to anticipate events and reduce impacts like infections resulting from sewage overflow and floatables in the river. This could result in savings of several millions of dollars per year for reduced medical costs and work loss, as well as reduced damage to water intakes by debris.
- **Improved drinking water supply/treatment:** Better analyses would lead to more efficient operation of water supply plants and results in several millions of dollars of saving each year.
- **Improved water quality:** Reduced impacts on fisheries in terms of population abundance and species composition of various life stages, and improved recreational uses which have an impact on local economies totaling in the millions of dollars per year.
- **Improved timing of water withdrawals/releases:** Reduced impacts on fisheries in terms of population abundance and species composition of various life stages.

Other

By providing new or additional information for the Hudson River Basin four types of benefits would be realized: reduced flood damage, reduced drought damage, improved navigability, and improved timing of water withdrawals/releases. Specifically:

- **Reduced flood damage:** Reduction in flood damages and protection of costly infrastructure.
- **Reduced drought damage:** Optimization would minimize drought impacts to the extent possible.
- **Improved navigability:** Minimize costly negative impacts on commercial shipping.
- **Improved timing of water withdrawals/releases:** Maximizing operational efficiencies.

**APPENDIX G: SUPPORTING MATERIALS FOR DEMONSTRATION PROJECT
IDENTIFICATION**

RBC INPUT ON IWRSS DEMONSTRATION PROJECT

Consensus on Priority Large-Scale Watershed Modeling and Mapping Capabilities

During the December 5, 2013, webinar with IWRSS and three of the RBCs, the staff affirmed the process used by IWRSS partners to identify, as the priority need, the development of a large-scale watershed modeling system with mapping capability (LWMM) as an IWRSS demonstration project. This conclusion was confirmed as the logical outcome based on findings from the stakeholder forums and survey. The RBCs identified priority subcomponents, or functionalities, of a LWMM that would be most valuable in meeting their needs, as shown in Table D-1.

RBCs that participated in the follow-up December 2013 webinar included:

Interstate Commission on the Potomac River Basin (ICPRB),

Delaware River Basin Commission (DRBC)

Susquehanna River Basin Commission (SRBC)

Table D-1. Priority functional components preferred for LWMM

Component	ICPRB	DRBC	SRBC
Coupled freshwater coastal model		✓	
Model scenarios, including sea level rise, climate change, storm surge		✓	
Reservoir and flow management*	✓	✓	✓
Low flow decision support	✓	✓	✓
Graphics and visualization tools (including mapping)	✓	✓	✓
Water supply forecasting	✓		
Probabilistic scenarios	✓		
Modeling drought and flood intensity, duration, and frequency		✓	
Others?			WQ real-time monitoring network

*In follow-up discussions, the reservoir and flow management component was deemed an overlapping priority (as an outgrowth of low flow decision support). SRBC and ICPRB demonstration projects both specifically relate to reservoir flow management. SRBC didn't initially check this because they have the OASIS basin-wide hydrologic model for optimizing reservoir releases; however, additional information used by OASIS, especially with respect to low flow forecasting and decision support capability, would be value-added. DRBC also expressed a subsequent interest in selecting this component as a priority.

An IWRSS demonstration project with improved modeling of extreme high and low flows with a richer set of information (e.g., assessing impact, identifying time periods, communicating and understanding risks,) resonated with the RBCs. A project that improved the interoperability of a suite of existing models linked in a seamless, more robust way was also a theme that emerged. The RBCs preferred for IWRSS to

enhance existing models through improvement of a few sub-components rather than development of a new complex model that would take years to create.

After further group discussion, consensus was reached on a LWMM for drought and flood intensity with capability to:

- Better model low flow to address reservoir optimization, storage, releases and water resources allocation decision-making to prepare for severe drought and ensure adequate stream flow (low flow decision support tool) under climate change scenarios.
- Better predict the timing and magnitude of high flow (under various climate change scenarios). In particular, there was interest in including a coupled riverine/estuarine model to predict salt wedge movement under low flow conditions and the convergence of peak riverine flow with oceanic storm surge.
- Build on the models and tools that are already in place so this capability may take the form of filling specific gaps with information or modeling components that could be integrated into the existing suite of tools; or develop a modeling framework to enable interoperability of an existing system of models with some key gaps filled.
- Provide easy to understand and timely spatial visualization tools for better and time-sensitive communication of risks and results.

River Basin Demonstration Applications

IWRSS partners will need to justify the allocation of technical, financial, and staffing resources toward the development of new LWMM capabilities. Part of making that case is illustrating how each river basin could apply these capabilities to fill priority information and decision-making gaps. To this end, the RBCs were asked to help articulate how these new capabilities might be applied and the “return on investment” for expenditure of IWRSS resources.

During the meeting, the RBCs engaged in this consensus-based process by responding to the following questions:

1. **How will new LWMM capabilities be applied in your basin?** What problems would these capabilities help to solve? What type of project could demonstrate new LWMM capabilities? Try to be as specific as possible describing the location, scale, and range of your proposed project and what questions can be answered based on the new models/tools/applications.
2. **How will this capability build on what's already in place?** What models/information/applications already exist that application of new LWMM capabilities would fit into or build upon?
3. **Who will the stakeholders be (e.g., decision-makers, utilities)?** List specific agencies, resource users, or decision-makers who are the real beneficiaries of this project. How will the stakeholders you invited to the IWRSS forums use LWMM in your basin?
4. **What are your ideas for generating "the business case" for this project/capability?** What's the economic value of this application in your basin? Provide specific dollar estimates, if possible, for benefits AND avoided costs of your proposed application, including infrastructure, ecosystem, or health and safety related items.

5. *How do you see your role in helping to develop, raise awareness, and/or apply an IWRSS LWMM in your basin? What resources can you offer to help generate support for an IWRSS demonstration?*

Project Descriptions for Applying LWMM Capabilities

The following project descriptions were developed by each of the RBCs in response to a specific request to envision how a new LWMM capability could be applied in their basins. The project summaries were generated from one-on-one follow-up discussions with John Balay (SRBC), Carlton Haywood (ICPRB), and Bob Tudor (DRBC) subsequent to the December 2013 meeting.

Similarities among the three projects described include:

- Better modeling of low flow conditions for water supply allocation purposes;
- Heavy involvement of RBCs in implementation/testing of capabilities and in assistance with stakeholder engagement;
- Components that could be incorporated into existing basin models rather than creation of a new model;
- Better, real-time data that could be automatically updated and linked with operational triggers; and
- More effort on evaluating climate change scenarios.

SRBC: DEMONSTRATION PROJECT DESCRIPTION FOR APPLICATION OF LWMM

Point of contact: John Balay

Objective: Develop a basin-wide Low Flow Decision Support Tool to: (1) monitor existing hydrologic conditions; (2) track quantitative trigger thresholds; (3) integrate hydrometeorological forecast information; and (4) facilitate scenario analysis to inform low flow management decision-making.

1. How will LWMM capabilities be applied in the basin/what problems would they be used to solve?

The proposed demonstration project focuses on a low flow decision support capability to inform decisions related to sustainably managing water supply sources, specifically for the better planning of shared resources when water availability is low. SRBC has the regulatory authority to make tough decisions related to operation of the water supply storage, out-of-basin diversions, and withdrawal and consumptive use approvals during critical low flow events and/or drought emergencies. As such, updating SRBC's Drought Coordination Plan developed in the 1990s from a paper document into an electronic, living decision support tool is a priority. Recently, SRBC worked with study partners to submit a grant application for developing a basin-wide framework for drought forecasting and planning in the Chesapeake Bay Region under the NOAA-led Coping with Drought Initiative in support of the National Integrated Drought Information System (NIDIS); however, a real gap remains in SRBC's capabilities for leveraging existing and forecasted hydrologic information for driving low-flow management decision-making in the basin. To fill this need, the proposed project includes the following four components:

1. **Hydrologic Conditions Monitoring.** Develop a Web-based GIS portal that compiles available hydrologic data (precipitation, soil moisture, stream flow, reservoir level, groundwater, etc.) basin-wide into one consolidated location by hydrologic unit (HUC-8 or subbasin) for comprehensive and standardized evaluation of existing hydrologic conditions. PA Drought Monitor (<http://pa.water.usgs.gov/drought/>) and NY Hydrologic Conditions Mapper

(<http://ny.water.usgs.gov/projects/eom/>) serve as relevant examples for a starting point. Tool functionality will be optimally achieved through access to real- or near real-time hydrologic data inputs. This portal will be accessible by all basin stakeholders, not just SRBC.

2. **Trigger Threshold Tracking.** Create a master database application that compiles qualitative and quantitative attribute data for existing emergency, operational, regulatory, and other planning trigger thresholds associated with low flow management activities basin-wide. Specific examples include thresholds for drought emergency declarations, water supply storage releases, pass-by flow permit requirements, etc. The master trigger threshold dataset would link to the hydrologic conditions monitoring portal to automatically track and notify if/when specified thresholds are reached. Trigger occurrences would be documented in automated reports emailed directly to key water managers and stakeholders, and would also be visible within the conditions monitoring portal. Examples of key water managers include NWS, USACE, USGS, NYSDEC, PADEP, MDE, etc. Examples of key stakeholders include public water suppliers, electric utilities, commercial and industrial facilities, oil and gas operators, agricultural producers, etc.
3. **Hydrometeorological Forecast Integration.** With the hydrologic conditions monitoring portal compiling and conveying baseline data representing antecedent conditions, existing hydrometeorological forecast methods and products will also be leveraged to evaluate a range of potential future hydrologic conditions. Examples include NWS short-term forecasts; NWS RFC water resource outlooks and hydrologic forecast products; statistical analysis of historic hydrologic data; NWS CPC drought, precipitation, and temperature outlooks; and NIDIS products/tools. Forecast information will be integrated to synthesize short- and moderate-term hydrologic conditions, which could be looped back to the hydrologic conditions monitoring portal and trigger threshold tracking application.

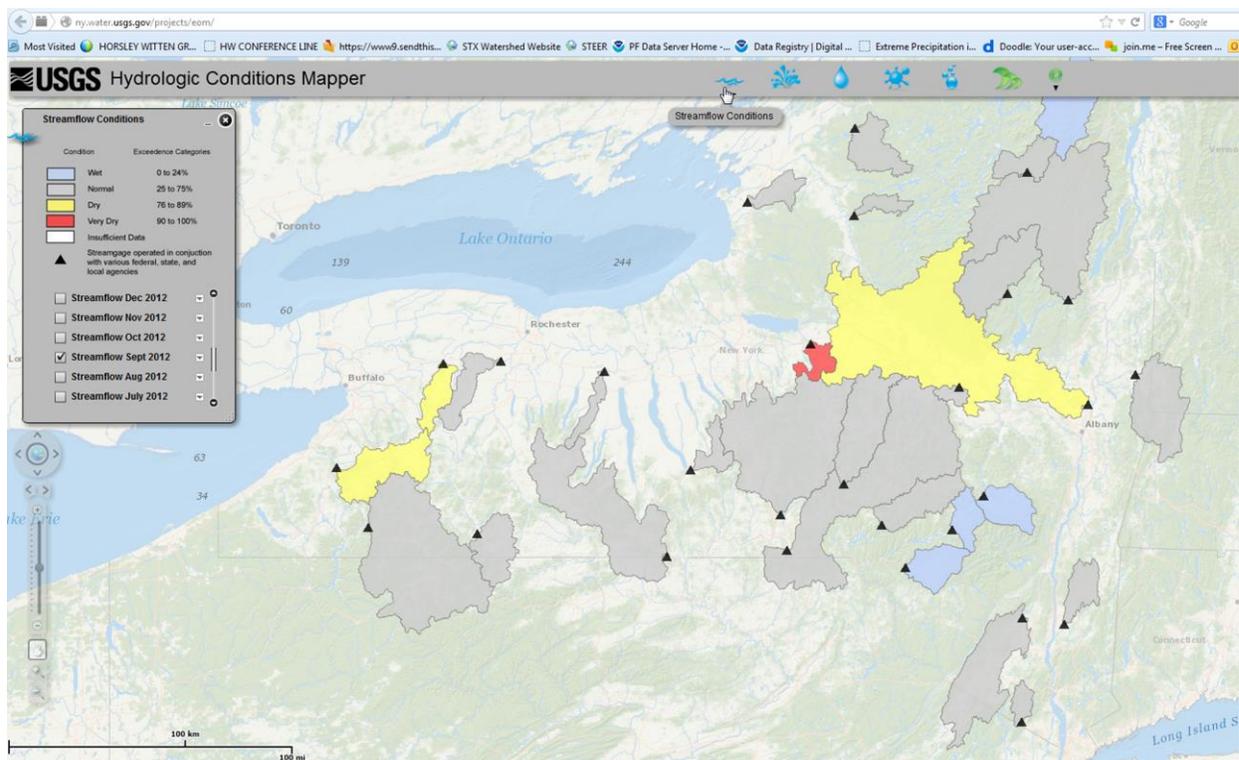


Figure D-1. USGS conditions mapper for NY is a visual example of what an interface component might look like of the Web-based GIS portal.

- 4. Low Flow Management Scenario Analysis.** Assimilating the hydrologic conditions monitoring portal, trigger threshold tracking application, and hydrometeorological forecast integration, a module will be developed to facilitate scenario analysis to drive informed low flow management decision-making. Specific examples include examination of existing and forecasted hydrologic conditions relative to (1) drought declaration triggers; (2) voluntary and/or mandatory water use restrictions; (3) reliance on conjunctive and/or back-up water supply sources; (4) pass-by flow, conservation release, and minimum flow requirements; (5) consumptive use mitigation and low flow augmentation releases; and (6) emergency operations, waivers, and certificates, etc. The module will provide insight to the evaluation of “what if” scenarios both in terms of existing and forecasted hydrologic conditions as well as baseline and modified management activities.

While specific to the Susquehanna River Basin, this capability is considered highly transferable to other basins.

2. How will this desired IWRSS capability build on what’s already in place?

SRBC has an existing Drought Coordination Plan and Coordinating Committee for which a need has been identified to update monitoring protocols and tools to improve low flow decision-making. SRBC also has an existing OASIS basin-wide hydrologic model that has been successfully implemented to inform hydropower, water supply, and reservoir release operations in the basin. Better integration of existing and forecasted hydrologic conditions into the modeling framework has been identified as an action item during past drought/low flow exercises.

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

The primary beneficiaries would be the member jurisdictions and partner agencies that work together with SRBC, including utilities and public water suppliers. SRBC has various committees comprised of both partner agencies as well as stakeholders from the regulated community, NGOs, and the general public that could serve as conduits for utilizing information and tools generated.

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

While specific money estimates have not been determined, significant cost-savings could be realized for efficiencies introduced to internal SRBC operations, power industry planning/scheduling, water supply industry planning and operations, etc.

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

In addition to providing the necessary support to IWRSS for moving the project forward, SRBC anticipates a role in technical development, statistical analysis, and in integrating basin-specific issues. SRBC will take the lead on disseminating data/results to stakeholders, as well as providing public information and outreach.

DRBC: DEMONSTRATION PROJECT DESCRIPTION FOR APPLICATION OF LWMM

Point of contact: Bob Tudor

Objective: Develop a coupled freshwater and coastal model for the freshwater/estuarine transition zone between Trenton, New Jersey, and Wilmington, Delaware, that can be integrated into an existing suite of basin models.

1. How will LWMM capabilities be applied in the basin/what problems would they be used to solve?

The Delaware River Basin is relatively small as basins go (~13, 500 sq. miles), but serves as a water supply to over 15 million people in New York City, central New Jersey, and the Philadelphia metropolitan areas, which is 5 % of the United States population (Kauffman, 2011). The lower section of the tidal system is the broad Delaware Bay, which has the longest contiguous wetland border of any estuary in the nation. The freshwater tidal portion of the river between Trenton, New Jersey, and Wilmington, Delaware, includes the largest freshwater port in the world; the major urban centers of Philadelphia, Camden, and Wilmington; and a significant portion of the basin's water supply area (Figure D-1). The Delaware River Basin has 15 reservoirs built for different purposes, including water supply, recreation, and flood control. DRBC is working on a 50-year water resource sustainability strategy with an emphasis on development of a sustainable water supply based on assessment of need (human and ecological), optimization of existing supply systems and instream flows, and non-structural and structural alternatives.

Over the next few decades, climate change predictions for the basin point to increased temperatures, more intense storms in winter and spring, and longer drought conditions in the summer. This trend could lead to increased flood intensity, increased stream flashiness, reduction in snowpack, extended summer droughts, increased water temperature, decreased dissolved oxygen saturation, and increased turbidity/sediment loads. The impacts on water supply and reservoir management are numerable (e.g., increased upper basin use, salt water intrusion, salt encroachment at the Philadelphia and NJ American intakes, decreased water quality, taste and odor problems, increased drought operations, and possibly increased allocations for instream needs. Reservoir capacity and operational procedures will have to be re-evaluated in order to meet more needs with equal or less water during dry periods. Flood mitigation must also be taken into account as more reservoir storage dedicated for flood control equates to less storage for water supply. Ensemble forecasting and nimble reservoir operations will be needed.

When predicting future drought and flood intensity frequency scenarios (2050-2060), two management questions DRBC would like to answer are: (1) In future low flow scenarios, are we more vulnerable to salt moving up river that would be beyond our capacity to control with the reservoir storage we have? and (2) What happens if a high flow event like tropical storm Sandy hit in the Delaware Bay? How far upstream would we anticipate flooding (e.g., at the Philadelphia airport) as the storm surge moves inland and meets stormwater runoff flowing downstream?

Fortunately, DRBC already has good riverine models, and a storm surge analysis for the shores of Delaware Bay is currently being conducted as part of the USACE's \$19 million North Atlantic Coastal Study (Figure D-2). An integration of existing models is needed that will require better information on, and representation of, the riverine to tidal transition zone between Trenton and Wilmington. Thus, the priority demonstration project for the Delaware River would include the following four elements:

1. Inventory of existing tools to assess what models we have for the basin, priority areas for "stitching" them together, and methods and benefits for using them.

2. Development of a coupled freshwater coastal model going from estuarine to freshwater to enhance existing DRBC basin models.
3. Evaluation of various climate change and sea level rise scenarios. If you have to pick a sea level rise problem along the east coast, the coastal plain of New Jersey is a good choice because of the added complication of land subsidence in addition to sea level rise.
4. Improvement in visualization tools to more effectively communicate modeling results with stakeholders.

While specific to the Delaware River Basin, this project could be an ideal demonstration of how to integrate the federal family of tools and how to make them applicable to specific place/time/issue.

2. How will this build on what's already in place?

DRBC anticipates integrating the capability within their current toolbox: PRMS by USGS, RESSim, and HEC-RAS models. Other efforts underway that could be specifically integrated include:

- USGS Water Census: The Delaware River Basin is one of three locations where USGS is developing the WATERS model, which is supposed to link the watershed with OASIS, the daily flow model, to predict water availability scenarios in future years.
- FEMA's flood impact analysis (HEC-FIA) to quantify structures at risk within a flood inundation zone.
- The USACE North Atlantic Coastal Study (www.nad.usace.army.mil/CompStudy.aspx), which provides risk reduction strategies for vulnerable coastal populations, property, ecosystems, and infrastructures and promotes more resilient communities considering future sea level rise and climate change scenarios.
- Cross-calibration of the USAC Philadelphia District's Corps CH3D-Z 3D hydrodynamic model with DRBC's 1D DYNHYD5 model. The 3D model is rectilinear and stops at the shoreline. Understanding how this model interacts with rising elevations and flooding of the surrounding landscape has implications for predicting salt line migration, property at risk, etc.
- Potential use of a "cloud"- based data storage system such as eRAMS.

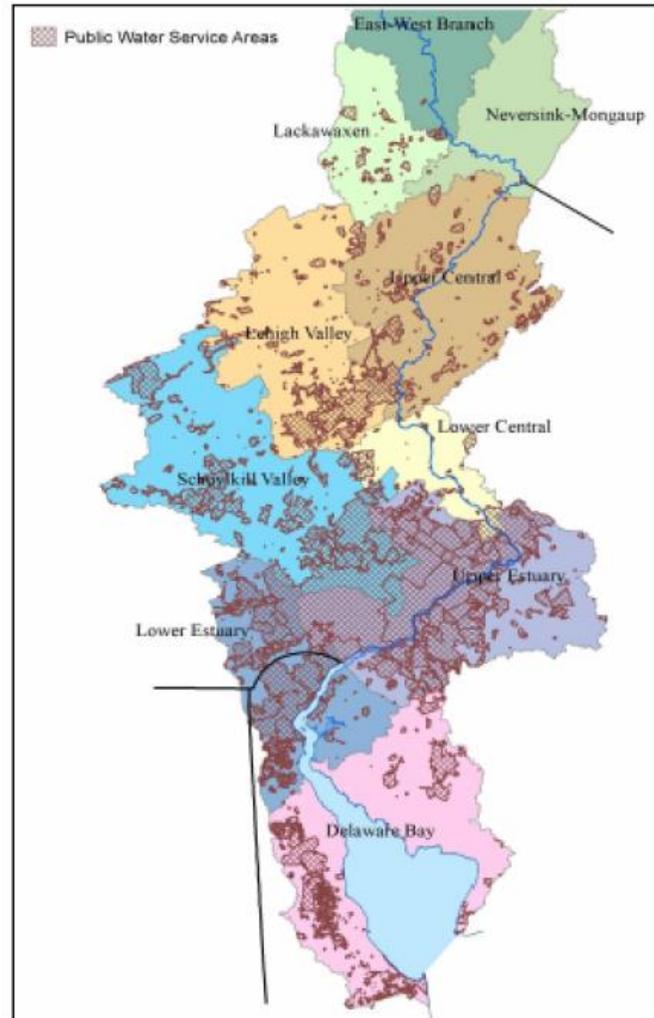


Figure D-2. Public water supply services areas in the Delaware River Basin (DRBC 2011).

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

Beneficiaries will include community managers concerned about infrastructure vulnerabilities, including flood-proofing energy production facilities and wastewater facilities. Obviously, water utilities such as the Philadelphia Water Department would be a major stakeholder. DRBC anticipates coordinating commissioner and stakeholder involvement during the project using the DRBC Water Management Advisory Committee and other existing outreach options. FEMA is working with state and county emergency response managers on community infrastructure risk assessments, so there is a significant customer base out there that would be interested in helping with community planning.

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

A 2011 socioeconomic study of the Delaware River Basin by Kauffman (2011) estimates that the Basin's water supplies, natural resources, and ecosystems:

- Contribute \$25 billion in annual market/non-market value to the regional economy (Figure D-3).
- Provide ecosystem goods and services (natural capital) of \$21 billion per year in 2010 dollars with net present value (NPV) of \$683 billion discounted over 100 years.
- Are directly/indirectly responsible for 600,000 jobs with \$10 billion in annual wages.

Filling this major gap in DRBC's ability to seamlessly model future drought and flood intensity/frequency scenarios would better inform water storage decisions, reduce flood risk to infrastructure and property, and lower insurance rates. Putting a dollar value on reliable water supplies is challenging. In fact, EPA's (2013) analysis of the value of water concedes that information on the economic importance of water as a commodity is "elusive" and that water's value is highly variable, complex, and undervalued. Empirical estimates of the value of water require information on a number of factors (e.g., amount, location, timing, reliability, and quality). Data on these factors are often limited, but could be better understood with tools being proposed here. That being said, Kauffman (2011) estimated the annual value of drinking water in Philadelphia exceeds \$3 billion (Kauffman, 2011).

Specific avoided costs and infrastructure damage assessments may be available through FEMA flood inundation studies or state hazard mitigation plans. In addition, Phase I of the USACE NACS scheduled for completion in early 2014 is to include a storm economic impact estimation tool and sea level rise vulnerability assessment maps that might be useful in estimating these costs for Delaware Bay.

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

DRBC would complete the inventory of existing models, work with IWRSS partners to draft a scope of work, and review/test interim products to ensure functionality meets anticipated needs. DRBC would also coordinate stakeholder involvement through the Water Management Advisory Committee, which is

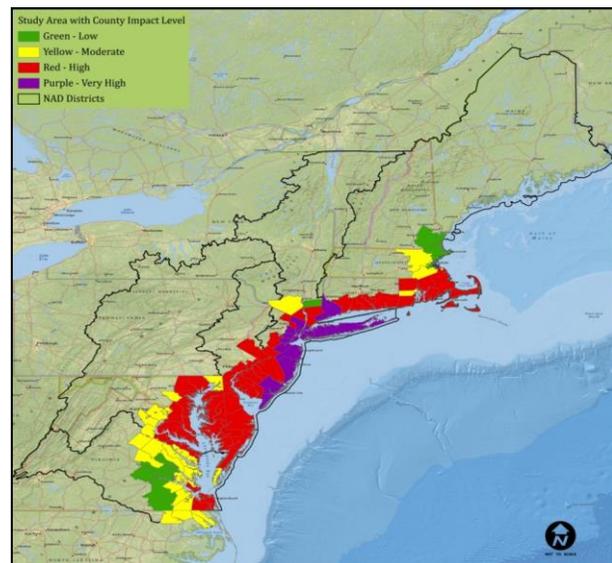


Figure D-3. Study area of the North Atlantic Coast Comprehensive Study (NACCS) (purple and red indicates very high to high impact counties).

a standing advisory committee that consists of federal agencies, states, local governments, and NGOs to work through any initiatives. This committee would be involved in discussions about demonstration project scope of work, responsibility sharing, stakeholder engagement, and communication about current models and what works and doesn't. In addition, DRBC can provide congressional outreach to garner budgetary support for IWRSS demonstration projects.

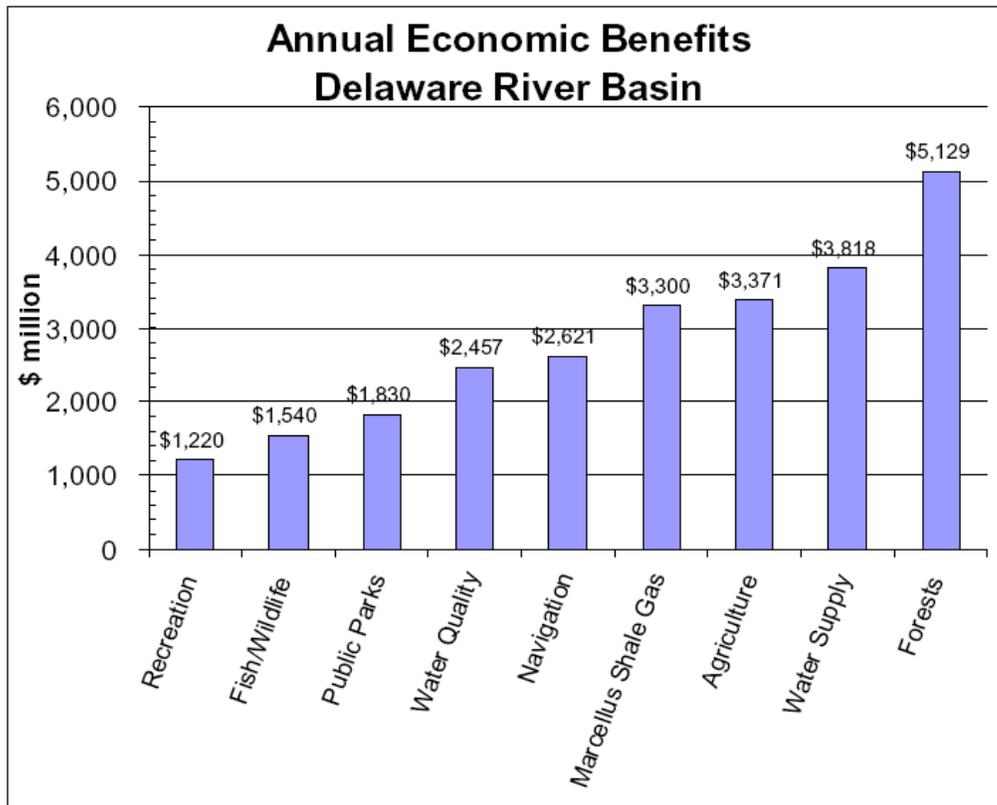


Figure D-4. Annual economic benefits of the Basin's natural resources (Kauffman, 2011).

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ICPRB: DEMONSTRATION PROJECT DESCRIPTION FOR APPLICATION OF LWMM

Point of contact: Carlton Haywood

Objective: Improve storage reservoir release decisions by enhancing existing basin models with real-time upstream withdrawals and discharge data and better predictions of in-stream flow losses (e.g., evaporation and groundwater interactions).

1. How will LWMM capabilities be applied in the basin/what problems would they be used to solve?

ICPRB's overall management concern is in providing drinking water for the metropolitan Washington, DC (District) area by coordinating allocations among three large water utilities operating in three different jurisdictions. The District is located at the bottom of the watershed, and there are increasing demands downstream and upstream as regional populations continue to grow. Spatially, the majority of the water users are in the metropolitan area; however, some of the water supply reservoirs are located over 200 miles away. When an upstream release is made, when is it going to arrive at given downstream location? What volume loss can be expected? A lot can happen during the nine-day travel time between the upper watershed and the District intakes (e.g., it could rain, thereby "wasting" a valuable flow release; surface flows can evaporate; or measureable volumes can infiltrate).

ICPRB has tools to estimate travel times and losses to groundwater and evapotranspiration, but more confidence in these predictions is needed to improve efficient use of our resources (e.g., natural flow in river plus storage in reservoirs). Because the margins of error are large, a large buffer is built into the decision process. Better tools means less risk of making a mistake (e.g., shortage of drinking water or risk of not meeting environmental flow-by requirements), and further postponement of the time new storage reservoirs will need to be built.

ICPRB is interested in modeling tools to make better decisions about timing and efficiency of water releases in order to create a more resilient reservoir system. In addition to these operational uses, ICPRB also sees a need for enhanced scenario testing capability that would improve planning for climate change and population growth impacts on low river flows.

The priority demonstration project for the Potomac River would involve integrating new IWRSS capability with existing tools to solve operational and planning issues related to timing of storage releases during droughts and for evaluating resource sustainability 30 to 40 years in future. Basin-wide model improvements might include the following additions:

1. Real-time data on upstream withdrawals and discharge flows at intake and release points. Our current information is not very good, is geographically spotty, is often made available after the fact, and is primarily based on looking at monthly averages for previous years.
2. Integration of reservoir operational procedures at as fine a time scale as possible into predictive model(s). USACE is operator of two supply reservoirs, for example, and they have operating rules for when water quality and water supply releases should be made. Currently, there is an exchange of phone calls and the manual entering of information into the model. Evolving to a system where operational information is transmitted automatically rather than typing up input files would improve efficiency (for example, in importing precipitation data into the watershed model on a daily basis).
3. Better representation of evapotranspiration effects on flow. ICPRB currently does not have a high level of confidence in current estimates and would look to replace the current model component with something better.

4. Improved model component that does a better job of handling surface and groundwater interactions. At low flow this can be a significant issue, and it is poorly understood. We would anticipate swapping an improved module into the current watershed model.
5. Utilization of mapping as one component of a visualization tool to communicate results and differences between scenarios (e.g., line graphs are not new or creative).

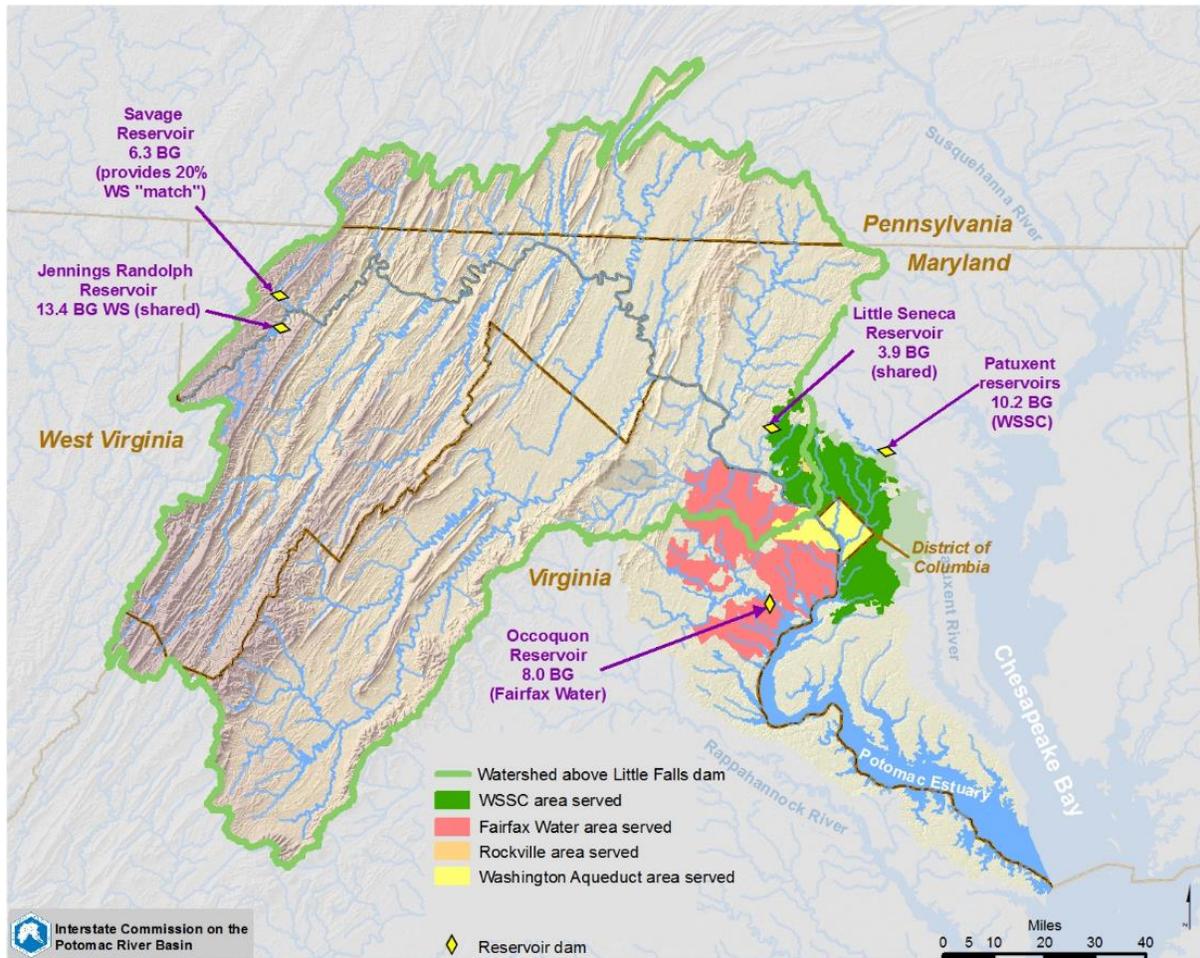


Figure D-5 Water supply service areas and reservoirs for the Potomac Basin.

2. How will this build on what's already in place?

ICPRB already has a Hydrologic Simulation Program Fortran (HSPF) watershed model that was designed for water quality, but has a hydrologic component. ICPRB is working to improve its model and anticipates this new project would provide components and data that could be added to generate better or more precise results.

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

ICPRB would be model operator (i.e., run models, interpret results, provide products) on behalf of local utilities, which include Washington Aqueduct (USACE is the utility operator for the District), Washington Suburban Sanitary Commission (WSSC); Fairfax Water, Loudon Water, and the city of Rockville.

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

The value of this project could be estimated based on deferred costs of capital expenditures. In the 1960s and 1970s, regional planners and the USACE planned to meet the projected water demand by building hundreds of millions of dollars worth of new reservoirs and associated infrastructure. In lieu of these capital expenditures, three key cooperative agreements were established to mitigate the need for new infrastructure: the 1978 Low Flow Allocation Agreement (LFAA), the 1979 Cooperative Water Supply Operations (COOP), and the Water Supply Coordination Agreement (WSCA). The LFAA is an agreement between the states and the District to protect the District's water supply from upstream withdrawals; the COOP established the ICPRB, and the WSCA is an agreement between the utilities and the ICPRB for establishing a mechanism for implementing the agreements and operational and planning needs. Every five years the adequacy of the regional supply is reviewed over a 20-year planning horizon. The 2010 report predicts that new measures will be required to maintain secure drinking water supply for the District by 2040. Development of this tool may help to defer those capital costs if additional efficiencies in water supply releases can be realized.

5. What is ICPRB's role in helping to develop, raise awareness, and/or apply an IWRSS LWMM in your basin?

In addition to working closely with the IWRSS partners in developing and employing these capabilities, ICPRB is willing to participate in cost-share components, taking the lead on keeping stakeholders informed and up-to-date about new IWRSS tools or products under development, and ensuring user community buy-in. IWRSS partner participation is anticipated in stakeholder engagement only on an as-needed basis.