One Basin, One Future

Potomac River Basin

Comprehensive Water Resources Plan

Prepared by the Interstate Commission on the Potomac River Basin

- 2018 -

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Chester River
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Louisa
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VISION

This plan provides a roadmap to achieving our shared vision that the Potomac River basin will serve as a national model for water resources management that fulfills human and ecological needs for current and future generations. The plan will focus on sustainable water resources management that provides the water quantity and quality needed for the protection and enhancement of public health, the environment, all sectors of the economy, and quality of life in the basin. The plan will be based on the best available science and data. The ICPRB will serve as the catalyst for the plan's implementation through an adaptive process in collaboration with partner agencies, institutions, organizations, and the public.

Dedication

This plan is dedicated to Herbert M. Sachs, an ICPRB Maryland Commissioner and Executive Director. He also served for decades with the Maryland Department of Natural Resources and the Department of the Environment. He passed away in 2017.

During his nearly 30-year tenure of service to ICPRB, Sachs led the agency's efforts in supporting the regional Chesapeake Bay Program; reallocation of water supplies, cooperative law enforcement, and water quality efforts at Jennings Randolph Reservoir; and establishment of the North Brach Potomac Task Force, a group of stakeholders and officials facilitated by ICPRB that gives stakeholders a voice in management decisions. He also was at the helm when ICPRB embarked on its successful effort to restore American shad to the Potomac River.

Throughout his tenure, Sachs pushed for keeping a long-term view of managing the river's health, and consistently pushed the agency to consider comprehensive planning that would help ensure the many uses of the river for future generations.

Commissioner Statement

In 2014, ICPRB Commissioners authorized the development of a comprehensive water resources plan for the Potomac River basin, in conjunction with a wide range of stakeholders and in consultation with appropriate technical experts. This report is the culmination of that effort and represents what we believe to be a broad, informed consensus on a shared vision and a way forward. In authorizing its publication we affirm our commitment to protecting water supplies, drinking water sources, water quality and aquatic life in the basin. Specific details may not in all instances reflect the official views or policies of ICPRB signatories. Implementation is voluntary and is subject to applicable laws and regulations.

Authors' Note

The authors are proud to have been a part of this collaborative process. It has been a pleasure and an honor. Completion of this document, however, is only a first step toward achieving our shared vision. Through ongoing implementation and adaptation, the vision can become a reality.

Heidi Moltz, Associate Director for Water Resources
Jim Palmer, Senior Hydrogeologist
Claire Buchanan, Director of Program Operations
Carlton Haywood, Executive Director

Acknowledgements

Development of this plan was a collaborative process that depended on the thoughtful contributions of many organizations and individuals. The authors wish to acknowledge the leadership and vision of the ICPRB Commissioners. In addition, ICPRB gratefully acknowledges the dedication of the advisory committee members that volunteered their time and attention for this purpose and Kristin Rowles and Mark Masters of Policy Works LLC, who facilitated the advisory committee process. Policy Works LLC also authored **Section 1.8.1** of the plan. The Commissioners and advisory committee members are listed below.

A number of experts participated in advisory committee meetings during the development of this plan including Nicholas DiPasquale (Chesapeake Bay Program Office), Anna Compton (USACE), Zachary Clement (USDOE), Ed Ambrogio (USEPA), and Susan Gray (MD DNR). This plan was made better by the feedback received during a graduate student seminar at George Mason University (GMU).

The authors appreciate the contributions of Curtis Dalpra and Renee Bourassa, ICPRB staff who provided the historical context of planning in the basin (**Section 1.1**), created the document format and layout, and offered thoughtful suggestions for improvements throughout the process. Karin Bencala, ICPRB staff, prepared the annotated bibliography in Appendix B. Preliminary geospatial contributions to this work by Michael Glassman, former ICPRB intern, are greatly appreciated.

Planning Assistance to States funding from the U.S. Army Corps of Engineers (USACE) was utilized, in part, to develop Section 1.8.3 and Appendix D of this plan. Other sections of this plan were developed with ICPRB funds originating from the U.S. Environmental Protection Agency (USEPA) and ICPRB member jurisdictions.

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Advisory committee members that participated in all or part of the plan's development are listed below along with their organizational affiliation at the time of participation.

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Virginia: David K. Paylor, Paul A. Holland, and Delegate Jackson H. Miller; Alternates: Scott W. Kudlas and Delegate J. Randall Minchew

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Abbreviations

AWRA	American Water Resources Association
BCG	Biological Conditions Gradient
BIBI	Benthic Index of Biotic Integrity
CBP	Chesapeake Bay Program
CWA	United States Clean Water Act
CO-OP	Section for Cooperative Water Supply Operations on the Potomac
DOEE	District Department of Energy and Environment
DWMAPS	Drinking Water Mapping Application to Protect Source Waters
DWSPP	Potomac Drinking Water Source Protection Partnership
FEMA	Federal Emergency Management Agency
GMU	George Mason University
HUC-8	8-Digit Hydrologic Unit Code
IBI	Index of Biotic Integrity
ICPRB	Interstate Commission on the Potomac River Basin
IWRM	Integrated Water Resources Management
LFAA	Low Flow Allocation Agreement
MDE	Maryland Department of the Environment
MD DNR	Maryland Department of Natural Resources
MGS	Maryland Geological Survey
MPRWA	Middle Potomac River Watershed Assessment
MWCOG	Metropolitan Washington Council of Governments
NGDA	National Geospatial Data Asset
NGO	Non-Governmental Organization
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PA DEP	Pennsylvania Department of Environmental Protection
PRFC	Potomac River Fisheries Commission
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
U.S.	United States
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USDOE	United States Department of Energy
USEPA	United States Environmental Protection Agency
USFS	United States Forestry Service
USGS	United States Geological Survey
VA DEQ	Virginia Department of Environmental Quality
WIP	Watershed Implementation Plan
WMA	Washington, D.C., Metropolitan Area
WRDA	Water Resources Development Act
WSSC	Washington Suburban Sanitary Commission
WV DEP	West Virginia Department of Environmental Protection

Executive Summary

The Potomac River of several decades ago witnessed raw sewage discharges, large algal blooms, fish kills, and stormwater pollution that brought trash, nutrients, and sediment to large stretches of the river. During the Water Emergency Conference in 1965, President Lyndon B. Johnson said the state of the Potomac River was "disgraceful", adding "We have got to do something about it." Since that time, great strides have been made in cleaning up the Potomac and its tributaries, restoring fisheries, and removing and preventing trash from entering the waters. As these problems are being addressed, however, the basin's aquatic habitats and water resources face new challenges.

The challenges facing the basin will continue to grow and change and will not necessarily adhere to political boundaries. As such, planning that holistically considers the entire hydrologic system is key for responsible and sustainable management of this precious resource. Proactive, adaptive, and comprehensive water resources planning for the future of the basin's water and land resources is essential.

The Interstate Commission on the Potomac River Basin is charged by its Compact to conduct studies on pollution and other water problems; to cooperate with and assist other agencies in the formulation of plans and activities; and to disseminate to the public information about those problems and recommended actions.

This Potomac Basin Comprehensive Water Resources Plan seeks to identify surface water and groundwater resources issues of interstate and/or basin-wide significance and develop associated management recommendations (**Section 1**) to provide an interstate perspective for decision-making. It builds on existing state and local planning efforts and on an understanding of the basin's characteristics (**Section 2**), to facilitate ensuring sustainable and reliable drinking water supplies, protecting and improving water quality, managing land use sustainably as it relates to water resources, and protecting ecological health.

Within these four challenge areas (**Section 3**) are 14 recommended actions that ICPRB, in concert with other agencies, should take. One overarching recommendation relates to all challenge areas:

- Develop an inventory of roles, responsibilities, and areas of authority and discuss how effectively current programs and activities are being carried out

To ensure sustainable water uses and supplies, implementation recommendations focus primarily on further evaluating basin-wide conditions.

- Report on basin-wide water uses, projected demands, and consumptive demands
- Conduct additional studies on water uses that fall below state water reporting thresholds
- Pursue actions that would contribute to a more sustainable and resilient water supply, including an evaluation of the potential impact of climate change and reviews of existing interstate water management agreements

To protect and improve water quality, recommendations focus on promoting information sharing and education as well as fully assessing current activities and roles.

- Promote water quality information sharing
- Educate citizens and professionals about water quality in the Potomac basin
- Pursue actions that would contribute to protecting and improving water quality, such as identification of common water quality goals and recommending roles and actions for other agencies

To manage human land use for sustainability, this plan's recommended actions focus on research and dissemination of information to complement these activities.

- Research timely land use related information for decision-making
- Effectively disseminate scientific data and information compiled by ongoing research
- Pursue actions that would contribute to managing human land to protect water quality, water use, and aquatic health, for example, applying a watershed approach for mitigation and restoration and tracking, promoting and increasing riparian buffer protection

To protect ecological health, this plan's recommended actions focus on promoting coordination and information sharing as well as fully assessing current activities and roles.

- Share across jurisdictions the data, analysis results, and other information from successful restoration approaches
- Coordinate across jurisdictions plans and programs that protect ecological value
- Support and coordinate programs that identify, protect, conserve, restore, enhance, and connect natural areas, especially along waterways, for example, considering ecologically valuable waters in all land and water use planning and improving coordination between multiple, diverse restoration efforts
- Pursue complementary actions that would contribute to protecting ecological health, including actions involving identification of stressors and protection of refugia

Some problems impact more than one challenge area, including floods and droughts, source water protection, climate change, and the water-energy nexus. Implementation activities under the plan's four main challenge areas are expected to help address these cross-cutting issues.

There is a role for everyone in sustainably using and managing the basin's water resources. **Section 4** proposes roles and responsibilities for different levels of government, non-governmental organizations, academic institutions, drinking water utilities, commercial entities, and individuals. ICPRB's role in the plan's implementation is to act primarily as a catalyst and partner in carrying out the plan's recommendations. To that end, ICPRB commits to actively engaging the states, federal government, and basin stakeholders in implementation of this plan. This is a living process that involves the ongoing, adaptive updating and recalibration of the basin-wide plan. Successful implementation will require funding, which is a challenge for ICPRB and partner agencies and organizations. In addition to implementation of recommended future activities, an ongoing commitment to fully execute existing sustainable water resources initiatives at all levels is critical.

Milestones and activities over the next 15 years for each of the four challenge areas are identified in **Section 5**. This section necessarily is focused on ICPRB activities because we cannot make commitments for others. Many of these milestones and activities, however, involve collaboration between ICPRB and other agencies and organizations. This list will be a guide for successive ICPRB annual workplans and periodic strategic plans that will produce measurable progress towards a sustainable future.

A wide and varied array of stakeholders contributed to this plan (**Section 1**); they come from all parts of the basin representing diverse perspectives from governmental agencies to environmental advocacy groups and concerned citizens. As a first step, they concurred on a vision statement:

> *This plan provides a roadmap to achieving our shared vision that the Potomac River basin will serve as a national model for water resources management that fulfills human and ecological needs for current and future generations. The plan will focus on sustainable water resources management that provides the water quantity and quality needed for the protection and enhancement of public health, the environment, all sectors of the economy, and quality of life in the basin. The plan will be based on the best available science and data. The ICPRB will serve as the catalyst for the plan's implementation through an adaptive process in collaboration with partner agencies, institutions, organizations, and the public.*

RECOMMENDATIONS BY

Challenge Areas

ALL AREAS	• Develop an inventory of roles, responsibilities, and areas of authority and discuss how effectively current programs and activities are being carried out
ENSURE SUSTAINABLE WATER USES AND SUPPLIES	• Report on basin-wide water uses, projected demands, and consumptive demands • Conduct additional studies on water uses that fall below state water reporting thresholds • Pursue actions that would contribute to a more sustainable and resilient water supply, including an evaluation of the potential impact of climate change and reviews of existing interstate water management agreements
PROTECT AND IMPROVE WATER QUALITY	• Promote water quality information sharing • Educate citizens and professionals about water quality in the Potomac basin • Pursue actions that would contribute to protecting and improving water quality, such as identification of common water quality goals and recommending roles and actions for other agencies
MANAGE LAND USE FOR SUSTAINABILITY	• Research timely land use related information for decision-making • Effectively disseminate scientific data and information compiled by ongoing research • Pursue actions that would contribute to managing human land to protect water quality, water use, and aquatic health, for example, applying a watershed approach for mitigation and restoration and tracking, promoting and increasing riparian buffer protection
PROTECT ECOLOGICAL HEALTH	• Share across jurisdictions the data, analysis results, and other information from successful restoration approaches • Coordinate across jurisdictions plans and programs that protect ecological value • Support and coordinate programs that identify, protect, conserve, restore, enhance, and connect natural areas, especially along waterways, for example, considering ecologically valuable waters in all land and water use planning and improving coordination between multiple, diverse restoration efforts • Pursue complementary actions that would contribute to protecting ecological health, including actions involving identification of stressors and protection of refugia

1 Introduction

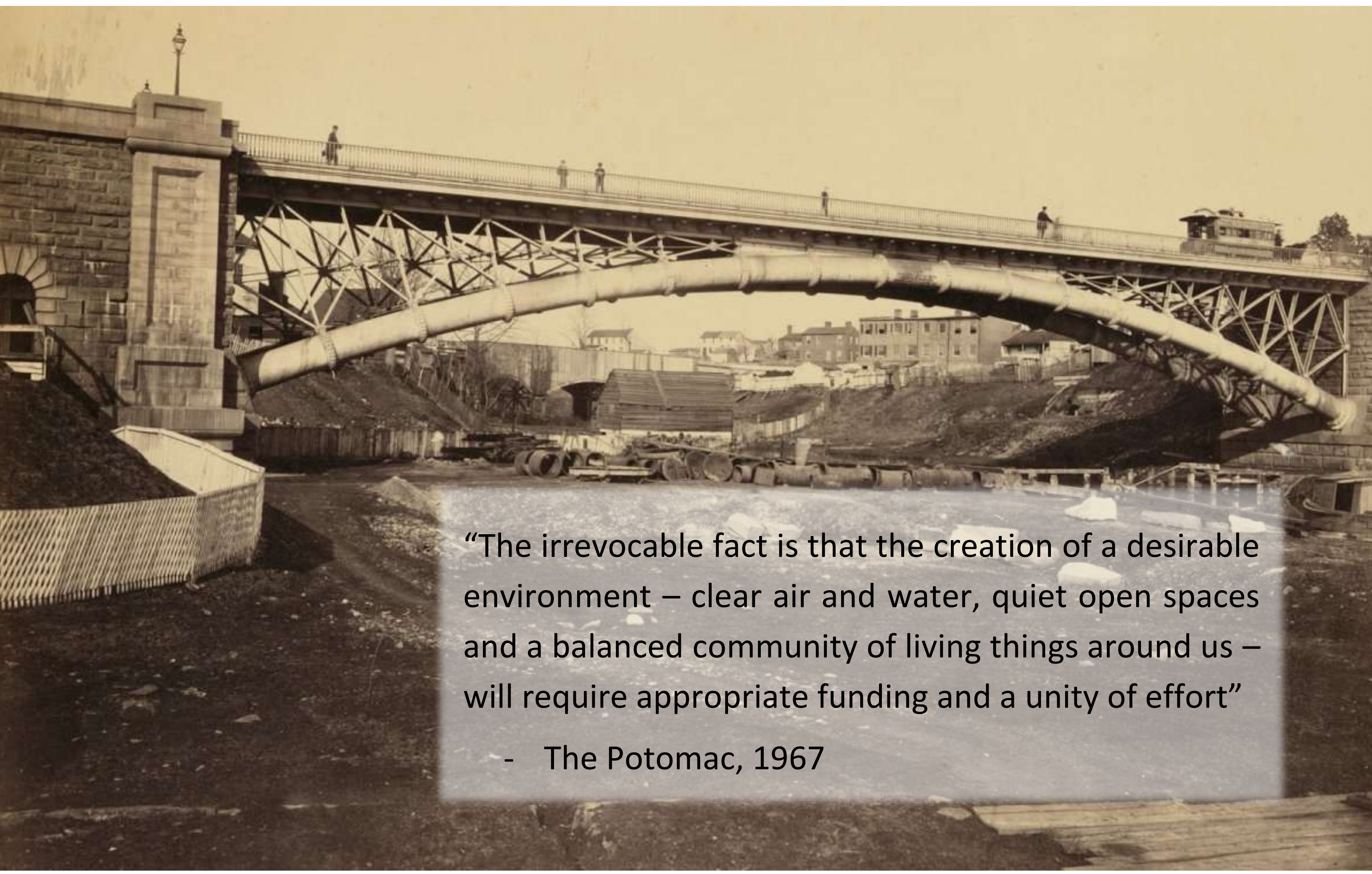
The Potomac River, its tributaries, and the associated groundwater resources are vital to the region. The river itself flows from the forested headwaters, through the agricultural valleys, and past the nation's capital on its way to the Chesapeake Bay. Steeped in human history, people have been dependent on the river for centuries for their livelihood, recreation, transportation, and drinking water. In addition to the people, the basin's diverse ecosystems are integrally linked to both surface water and groundwater. Because these systems do not align with political boundaries, proactive, comprehensive planning for the future of the basin's water and associated land resources is essential for responsible, sustainable management of this precious resource.

To date, comprehensive water resources planning in the Potomac basin has primarily occurred within political boundaries (e.g. states, counties, municipalities). The ICPRB developed this interstate, basin-wide comprehensive water resources plan in close coordination with diverse basin stakeholders. Planning at the basin scale has the added benefit of holistically considering the entire hydrologic system. The plan is a roadmap for the voluntary, sustainable management of water resources at the interstate, basin-wide scale.

Section 1 lays the foundation for this plan and provides background information about the Potomac basin. **Section 2** contains a description of the Potomac basin. **Section 3** describes the water resources challenges and recommendations for action. **Section 4** and **Section 5** provide implementation details.

1.1 HISTORY OF PLANNING IN THE POTOMAC BASIN

Historically, the Potomac River has been awash in studies. Stresses from rapid population growth and the federal focus on the "Nation's River" has produced several bookshelves of reports on all aspects of the river. Some have been very helpful. Others have contributed to the intractable problem of dusty bookshelves. Some have been far-fetched, such as the 1960s idea that a seawall built down the middle of the river could use the tides to carry pollution from Washington down to the bay (Barbour 1965). Some studies took a "big picture" approach, such as "The Potomac," a 1967 report by Potomac Planning Task Force appointed by the American Institute of Architects under authorization of Interior Secretary Stewart Udall (Potomac Planning Task Force 1967). They assembled "A group of brilliant men [sic] widely known for their imaginative thinking, broad scholarship and dedication to the preservation and enhancement of the quality of the American environment." The report was comprehensive, and recommended that the riverside be reserved and developed for water-oriented recreation, with urban development concentrated at carefully selected locations; that a comprehensive ecological inventory be conducted; and that a development foundation be developed. This foundation would be capitalized with $50 million per year in federal dollars for the first five years, and also be able to accept private funds and hold land. These funds would be spent on features of the comprehensive plan.



Some aspects of the 1967 comprehensive plan were carried out, although the overarching federal management of the river environs never occurred. The plan never attained the “buy-in” it needed from the public and economic sectors.

This Potomac Basin Comprehensive Water Resources Plan has avoided some of these pitfalls. The plan was developed not by an expert panel but through a long process of engaging stakeholders at every level. The diverse advisory committee of about 20 people included federal, state, and local government representatives, utilities, agricultural and industry representatives, developers, academic institutions, and fisheries/wildlife professionals. A larger group of nearly 200 interested individuals was engaged via email.

Collaboratively developing the plan with basin stakeholders will help it to be accepted and used as a way for the region’s many communities and agencies that produce water resources plans, especially smaller organizations with few resources. See **Section 1.8** for a complete description of the stakeholder involvement process.

1.2 INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN (ICPRB)

The ICPRB mission is to "protect and enhance the waters and related resources of the Potomac River basin through science, regional cooperation, and education." Established by an Act of Congress in 1940 as a non-regulatory entity, ICPRB is one of the oldest river basin commissions in the country. The Commission includes appointed Commissioners from each basin jurisdiction (Maryland, Pennsylvania, Virginia, West Virginia, the District of Columbia, and the federal government).

ICPRB staff have strong scientific and stakeholder engagement skills with focus areas in water quantity, water quality, aquatic life, communication, and education. Being an interstate, multidisciplinary organization with a geographic responsibility spanning the entire Potomac basin, ICPRB is well-situated to coordinate this planning effort, but active participation by basin stakeholders is essential to the success of the basin-wide planning process.

1.3 PARTNERS

The myriad partners of this planning process were essential for the successful development of this plan. Successful ongoing implementation and future adaptation of this plan will be achieved through continued partner participation. The stakeholder involvement process is discussed in detail in **Section 1.8**. Roles and responsibilities of various partners in the plan's implementation are provided in **Section 4.1**.

1.4 PURPOSE

The purpose of this plan is to identify and develop management recommendations for water resources issues of interstate and/or basin-wide significance. The plan recognizes and builds on existing state and local regulations and planning efforts. It provides basin-wide perspectives to decision-makers on activities upstream of their jurisdiction and anticipated effects of jurisdictional activities downstream. It aims to facilitate achievement of common goals, including protection of water supplies, drinking water sources, water quality, and aquatic life (see **Section 1.6** for additional details on the benefits of the proposed plan).

Considerable water resources planning efforts are underway in each basin jurisdiction. The rationales for the planning efforts are described in each state's unique legislation. Existing state legislation requires water resources planning: Maryland House Bill 1141, West Virginia Senate Bill No. 641, Pennsylvania Act 220, and Virginia's Title 9 Local and Regional Water Supply Planning Regulation. The state laws typically require both state and local level efforts. To provide context, a brief description of these activities follows.

Maryland House Bill 1141 of 2006 requires the state to develop a general water resources program and local governments (all counties and municipalities that exercise planning and zoning authority) to develop Water Resources Elements within comprehensive plans. Maryland's Wolman Report provides additional explanation on the state's need for comprehensive planning and sustainable water resources management (Wolman 2008).

Since 2005, Virginia's Local and Regional Water Supply Planning Regulation, with statutory authority from §62.1-44.15 and §62.1-44.38:1, has required development of local or regional water plans to "ensure that adequate and safe drinking water is available, encourage and protect all beneficial uses, encourage and promote alternative water sources, and promote conservation." The Virginia State Water Resources Plan was completed in 2015 to "ensure the availability of adequate and safe drinking water to all citizens in the Commonwealth" as well as to "encourage, promote, and protect all other beneficial uses of the Commonwealth's water resources" (VA DEQ 2015).

In Pennsylvania, Act 220 of 2002 resulted in a State Water Plan and Water Atlas that included an evaluation of regional water-related issues (PA DEP 2009). The Statewide Water Resources Committee designated three Critical Water Planning Areas in January 2011, one of which (the combined Marsh and Rock creek watershed) forms the headwaters to the Monocacy River in the Potomac basin. The associated Critical Area Resource Plan for the Marsh and Rock creek watersheds was submitted to the Pennsylvania Department of Environmental Protection (PA DEP) by ICPRB in 2012 (Moltz and Palmer 2012).

Article 26 of Senate Bill No. 641, the Water Resources Protection and Management Act of West Virginia, resulted in the West Virginia Water Resources Management Plan, an associated mapping tool, and a closer look at water resources in West Virginia watersheds (WV DEP 2013). An expected outcome of the basin-wide plan is to contribute to these state planning efforts by providing a hydrologically-based geographic context.

The comprehensive plan is a roadmap for the sustainable management of water resources at the interstate, basin-wide scale.

PURPOSE

The purpose of this plan is to identify and develop management recommendations for water resources issues of interstate and/or basin-wide significance. It aims to facilitate achievement of common goals, including protection of water supplies, drinking water sources, water quality, and aquatic life.

1.5 APPROACH

The Potomac basin planning process utilized an Integrated Water Resources Management (IWRM) approach. The Global Water Partnership defines IWRM as "a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP 2000). The American Water Resources Association (AWRA) further describes it as "the coordinated planning, development, protection, and management of water, land, and related resources in a manner that fosters sustainable economic activity, improves or sustains environmental quality, ensures public health and safety, and provides for the sustainability of communities and ecosystems" (AWRA 2011).

Basin plan as one piece of the puzzle

Collaboration and participation ensure that the resulting plan fully embraces the basin stakeholders' many diverse perspectives and strengthens the communication among basin organizations. Rigorous scientific investigations are essential to understanding the current and anticipated future state of the basin. Adaptive management is required for optimal implementation of the plan, creating a living process rather than development of a one-time strategy. As new scientific information is obtained or stakeholder perspectives change, the implementation approach should be modified as necessary.

1.6 BENEFITS

Because of its holistic, participatory approach to water resources management, many agencies and organizations have embraced the IWRM method (USACE 2014). There are a number of ways the IWRM method can specifically assist Potomac River basin stakeholders. These include:

1. Helping states plan for anticipated impacts from upstream activities and prevent unintended downstream consequences (e.g. upstream water uses, consumptive uses, source water threats, etc.).
2. Making it easier for each jurisdiction to see its water use in the context of neighboring jurisdictions.
3. Fostering plans and actions with a watershed perspective rather than the perspective of a political boundary to encourage the evaluation of potential interstate impacts. Existing management approaches for the Potomac basin are most often developed for politically defined areas. However, as everyone is affected by those upstream and affects those downstream, water resources management that looks beyond the political boundaries will benefit all.
4. Encouraging interstate collaboration and communication among basin stakeholders.
5. Facilitating the integration of existing data and research for basin-wide and interstate analyses. Extensive research has been conducted within the Potomac basin at different spatial scales and focusing on various issues. A basin-wide comprehensive plan can integrate existing knowledge to evaluate interstate issues and form the basis of decision-making.
6. Enhancing efficiency by sharing data, coordinating plans, and partnering to achieve common goals, especially by coordinating with the requirements and schedules of each participating entities' management plans.

1.7 PLANNING PROCESS

The planning process included five broad phases.

Phase 1 - Scoping

Phase 2 – Water Resources Issues

Phase 3 – Recommendations

Phase 4 – Document

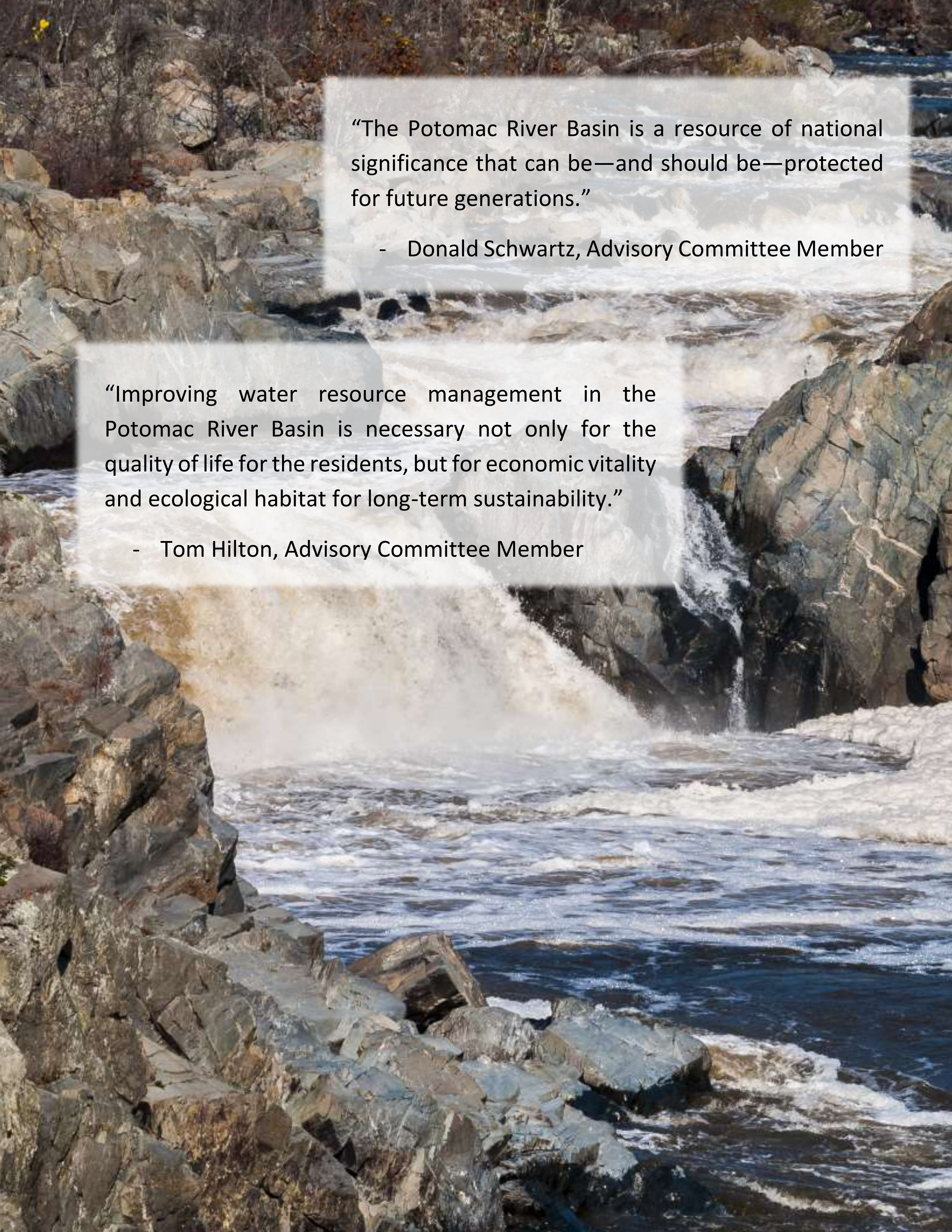
Phase 5 – Adaptive Management

Section 1 contributes to Phase 1 of the planning process (detailed in **Section 1.7**).

Text boxes appear in each major section to illustrate which phase of the planning process is addressed in that section.

- The first phase, scoping, included generating a concept paper (Moltz et al. 2011), developing an anticipated timeline, identifying possible funding sources, developing an outline of known water resources issues, discussing with state agencies how best to integrate the basin-wide plan with ongoing state planning efforts, and requesting feedback from stakeholders towards developing a shared vision for the plan.
- Phase 2 included identification of water resources challenges of interstate and/or basin-wide significance.
- Phase 3 resulted in recommendations to address identified issues by building on the results of the previous assessments and concurrent studies by ICPRB and other organizations.
- Phase 4 included preparation of this document.
- The final phase, Phase 5, of the planning process resulted in the development of a strategy for adaptive review and implementation.

Stakeholder participation was included throughout this process (details provided in **Section 1.8**).



"The Potomac River Basin is a resource of national significance that can be—and should be—protected for future generations."

- Donald Schwartz, Advisory Committee Member

"Improving water resource management in the Potomac River Basin is necessary not only for the quality of life for the residents, but for economic vitality and ecological habitat for long-term sustainability."

- Tom Hilton, Advisory Committee Member

1.8 STAKEHOLDER INVOLVEMENT

Stakeholder participation in the development of this plan included ongoing participation by an advisory committee, broad public participation, and contact with federal agencies about their goals and strategies for water resources management in the basin. These stakeholder involvement efforts are discussed in turn in the sections below.

1.8.1 ADVISORY COMMITTEE

To support the development of an implementable comprehensive plan, ICPRB created a participatory process to inform plan development. Stakeholder engagement offers multiple benefits to water resources planning. Input from stakeholders provides a source of guidance in plan development toward shared priorities and workable strategies. Stakeholder discussions are a valuable opportunity to mitigate potential conflicts during plan development instead of during plan implementation. Stakeholder involvement helps to create a broad sense of ownership in a plan and to build commitments that will be needed for plan implementation and future plan revisions and adaptation.

To ensure meaningful stakeholder engagement in plan development, ICPRB established an advisory committee for the planning process. A brief description of the advisory committee process is provided in this section. Full details are provided in **Appendix A**.

The advisory committee provided for in-depth engagement by stakeholders in plan development and review. The advisory committee membership was recruited by ICPRB with input from ICPRB Commissioners. Members were selected to represent a broad range of perspectives in the Potomac River basin, including water resource management, water and wastewater utilities, local government, agriculture, environmental organizations, recreational and commercial fisheries, and academic research. The members were also selected to represent the full geographic range of the basin from the headwaters to the river's mouth at the Chesapeake Bay and across the jurisdictions of the river's watershed, including Pennsylvania, West Virginia, Virginia, Maryland, and the District of Columbia. A complete list of the advisory committee members is provided in the **Acknowledgements** section of the plan.

Shared Vision Statement Developed by the Advisory Committee

This plan provides a roadmap to achieving our shared vision that the Potomac River basin will serve as a national model for water resource management that fulfills human and ecological needs for current and future generations. The plan will be based on the best available science and data and focus on sustainable water resources management that provides the water quantity and quality needed for the protection and enhancement of public health, the environment, all sectors of the economy, and quality of life in the basin. The ICPRB will serve as the catalyst for the plan's implementation through an adaptive process in collaboration with partner agencies, institutions, organizations, and the public.

The advisory committee was coordinated by an independent team of facilitators from Policy Works LLC, which was engaged by ICPRB. The facilitation team brought specific experience in water resources planning and designed a process for the advisory committee to provide guidance on the following aspects of plan development:

- Shared vision statement
- Identification and prioritization of current and future water issues
- Technical review of water issues
- Identification of strategies to address water issues

- Review of the draft plan

The facilitators sought to create a process of meetings and activities between meetings. The process was designed to provide the following benefits:

- Participation by all members through pathways that accommodate their individual styles of interaction
- Shared understanding by members of complex technical materials
- Productive meetings that make the best use of members' time
- Conflict management to support constructive resolution and identification of common ground
- Creation of a forum for open dialogue in an atmosphere of trust
- Accomplishment of project tasks within the time and budget available

The advisory committee process was structured around a series of seven meetings between September 2016 and March 2018 (**Appendix A**). Five of the meetings were held in person at the ICPRB office in Rockville, and two were conducted as conference calls. At the meetings, the advisory committee heard technical presentations, interacted with expert panels, reviewed plan components, worked in small groups, and discussed important issues as a full group. The meeting activities were structured using facilitation techniques including nominal group technique and single text negotiation, and polling tools were used as needed to assess group responses. Between meetings, the facilitation team conducted one-on-one telephone interviews with advisory committee members at multiple points in the process to gather stakeholder input and to inform development of constructive meeting agendas. Outside of meetings, the advisory committee members were asked to review technical materials and drafts of plan sections and to respond to follow-up questions to gather more input on important questions that were discussed in meetings.

The work of the advisory committee had several outputs that were used by ICPRB in developing the comprehensive plan. These outputs included:

- A shared vision statement (see text box at the beginning of this section)
- A list of water resource challenge areas to address in the comprehensive plan
- Prioritized strategies to address the challenge areas
- Recommendations for format and presentation of the comprehensive plan
- Review comments on the draft comprehensive plan

Through its work, the advisory committee provided a foundation for the development of this plan, and the input of the members was used from initial scoping to final edits of the plan. The recommended strategies in the plan reflect the input and priorities of the advisory committee members. The advisory committee provided detailed and extensive input on the plan content, but several over-arching themes in the committee's discussions have influenced the plan at the broad level:

- Make the plan accessible and useful to a broad audience
- Prioritize implementability in selecting strategies for the plan and consider how to facilitate plan implementation
- Address the whole Potomac basin and increase efforts to address the concerns of upstream communities and small utilities in the basin
- Engage federal agencies and academic institutions as partners in planning and implementation
- Ensure that education and public awareness are priorities
- Keep the plan meaningful and realistic
- Develop an adaptive process for the plan that updates it based on new information, goals, priorities, and activities over time
- Share information across jurisdictions (state, regional, local) in the basin to support improved management and coordination
- Build public awareness of the plan to promote buy-in and support for implementation

Stakeholder involvement in plan development provided a grounding in real world conditions and workable solutions.

While the advisory committee was the primary instrument to stakeholder engagement in development of the comprehensive plan, it was not the only way by which ICPRB sought stakeholder input. The following methods extended the opportunities for stakeholder involvement in the development of the comprehensive plan (discussed in more detail in **Section 1.8.2**):

- Communication via an electronic mailing list of approximately 200 stakeholders including updates on the planning process and requests for specific input and document reviews
- Public review of the draft comprehensive plan
- Workshop with George Mason University graduate students to discuss the comprehensive plan
- Regular opportunities for public comment at advisory committee meetings
- Regular updates through public communication outlets such as the comprehensive plan website and the ICPRB Facebook and Twitter accounts

Through meaningful engagement with stakeholders via multiple methods, ICPRB provided a foundation for an effective and implementable comprehensive water resources plan. Stakeholder involvement in plan development was extensive and provided a grounding in real world conditions and workable solutions. The advisory committee members committed substantial personal and organizational resources to this outcome, and their efforts will have an impact through improved understanding and management of water resources in the Potomac River basin.

Water Resource Challenge Areas Identified by the Advisory Committee

- **Ensure Sustainable Water Uses and Supplies:**
  The diverse users of the basin's water resources have clean, reliable, and resilient water resources for current and future generations.
- **Protect and Improve Water Quality**:
  The waters of the basin achieve or exceed water quality standards established by the states in accordance with the Clean Water Act. New and emerging threats are proactively addressed.
- **Protect Ecological Health:**
  The propagation and growth of balanced, desirable populations of aquatic life is ensured.
- **Manage Human Land Use for Sustainability:**
  Human land use in the basin supports sustainable water resource management.
- **Support Plan Implementation:**
  The basin-wide comprehensive plan is supported by a strong foundation for integrated, comprehensive, and coordinated approaches for sustainable water resources management.

1.8.2 BROAD PUBLIC PARTICIPATION

A broad stakeholder base was engaged in the development of the comprehensive plan through an email distribution list, workshops and presentations, and via online and social media outlets.

The email distribution list was developed as an initial step in the plan's development. The list consists of approximately 200 individuals representing a wide range of interests. Emails to disseminate information and request feedback were distributed to the list at key points during the plan's development.

In addition, ICPRB staff presented on the comprehensive plan to various groups to disseminate information and receive feedback. For example, staff participated in a graduate seminar at GMU in early 2017 to encourage involvement in the comprehensive planning process. Approximately 30 graduate students attended. The seminar included ICPRB staff presentations on the plan and a technical overview of the basin. The graduate students then brainstormed potential recommendations for each of the plan's challenge areas.

Information on the planning process and ways to get engaged were made available to interested parties and the general public via the ICPRB comprehensive plan website and the complementary advisory committee website. Regular updates were also disseminated through the ICPRB Facebook and Twitter accounts.

1.8.3 FEDERAL AGENCIES

Multiple federal agencies have responsibilities that relate to the management and use of water resources in the Potomac basin. In collaboration with ICPRB, the U.S. Army Corps of Engineers (USACE) has written a report on the restoration and protection actions in the Potomac basin of certain federal agencies. The report is included as **Appendix D**.

ACTION ITEMS

Simple Actions We Can Do To Make a Difference

EVERYONE

- Pick up after your pet
- Leave no trace
- Properly dispose of pharmaceuticals
- Minimize use of deicing salts

KIDS

- Take care to close faucets tightly after each use
- Tell a teacher or parent if you see a water leak or pollution entering a waterway
- Volunteer with an adult to plant trees, monitor water quality, or pick up trash
- Get involved in your community

HOMEOWNERS

- Regularly pump your septic tank
- Properly dispose of household chemicals
- Conserve water by fixing leaks and replacing old toilets, dishwashers, and washing machines
- Use native, drought-tolerant species when landscaping

NON-PROFIT/BUSINESS

- Participate in local land-use planning
- Obtain a green business certification
- Promote environmentally sound decision-making by clients and customers

AGRICULTURE

- Keep cows out of streams
- Install and/or protect vegetated buffers
- Talk to your state about financial incentives for new equipment, planting trees, and other conservation techniques
- Plant a cover crop

GOVERNMENT

- Promote rain gardens, green infrastructure, and low impact development
- Encourage environmentally friendly landscaping
- Promote community wastewater treatment rather than individual septic systems
- Conduct contingency planning to respond to emergencies

1.9 REGULATORY FRAMEWORK

This comprehensive plan builds on existing federal laws and regulations that encourage or enforce clean water, safe drinking water, and sustainable water resources. The Clean Water Act of 1972 and its subsequent amendments, implemented by the states and administered by the USEPA, is focused primarily on reducing pollutants in surface waters. The law's objective is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. The Safe Drinking Water Act of 1974 requires USEPA to set drinking water standards and oversee implementation of those standards by states, localities, and water suppliers. Its objective is to protect public drinking water supplies. Other federal laws govern the disposal of harmful materials that contaminate ground and surface waters, and provide assistance in remediating highly polluted sites. These include the Resource Conservation and Recovery Act of 1976, Surface Mining Control and Reclamation Act of 1977, and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980, also known as the Superfund Act.

Despite the consistency these federal laws offer interstate watersheds like the Potomac, state and local governments can decide and administer diverging policies on water quality assessments, water withdrawals, land use planning and development, agricultural practices, and other factors that eventually affect water resources. Not surprisingly, these policies are sometimes at odds with each other. This is especially the case when different users with conflicting priorities need to share a resource. Water resources planning efforts are underway now in each of the Potomac River basin jurisdictions (see **Section 1.4**). This comprehensive plan, while voluntary, works to bridge the federal, state and local perspectives for a holistic approach to water resources management. Achieving the shared vision for the basin requires unwavering commitment to environmental principles and science-based decision-making, and sufficient resources to plan and implement effective water and land programs at all levels.

2 Potomac Basin Description

Due to its sheer size, the Potomac basin is quite diverse – geographically, ecologically, hydrologically, economically, culturally, and socially. The 383-mile long Potomac River has a 14,670 square mile (sq. mi.) drainage area that includes portions of Virginia (5,723 sq. mi.), Maryland (3,818 sq. mi.), West Virginia (3,490 sq. mi.), and Pennsylvania (1,570 sq. mi.), and all of the District of Columbia (69 sq. mi.). Types of surface waters found in the basin include wetlands, streams, rivers, reservoirs, lakes, and the Potomac estuary. According to data from the Chesapeake Bay Program (CBP), approximately ten percent of the total basin area is federal land and managed separately from the states and District of Columbia. This section includes detailed information on the basin's physiography, hydrology, population, land use, water use, water quality, and aquatic life.

2.1 PHYSIOGRAPHY

The terrain of the Potomac basin is highly varied, ranging from mountainous areas, to rolling hills, to low-lying plains. Elevation in the basin ranges from sea level to 4,862 feet (1,482 meters) (**Figure 1**). The highest point in the basin is Spruce Knob in Pendleton County, West Virginia.

Figure 1. **Elevation in the Potomac basin. Data source: 30-meter resolution 1999 USGS Digital Elevation Model.**

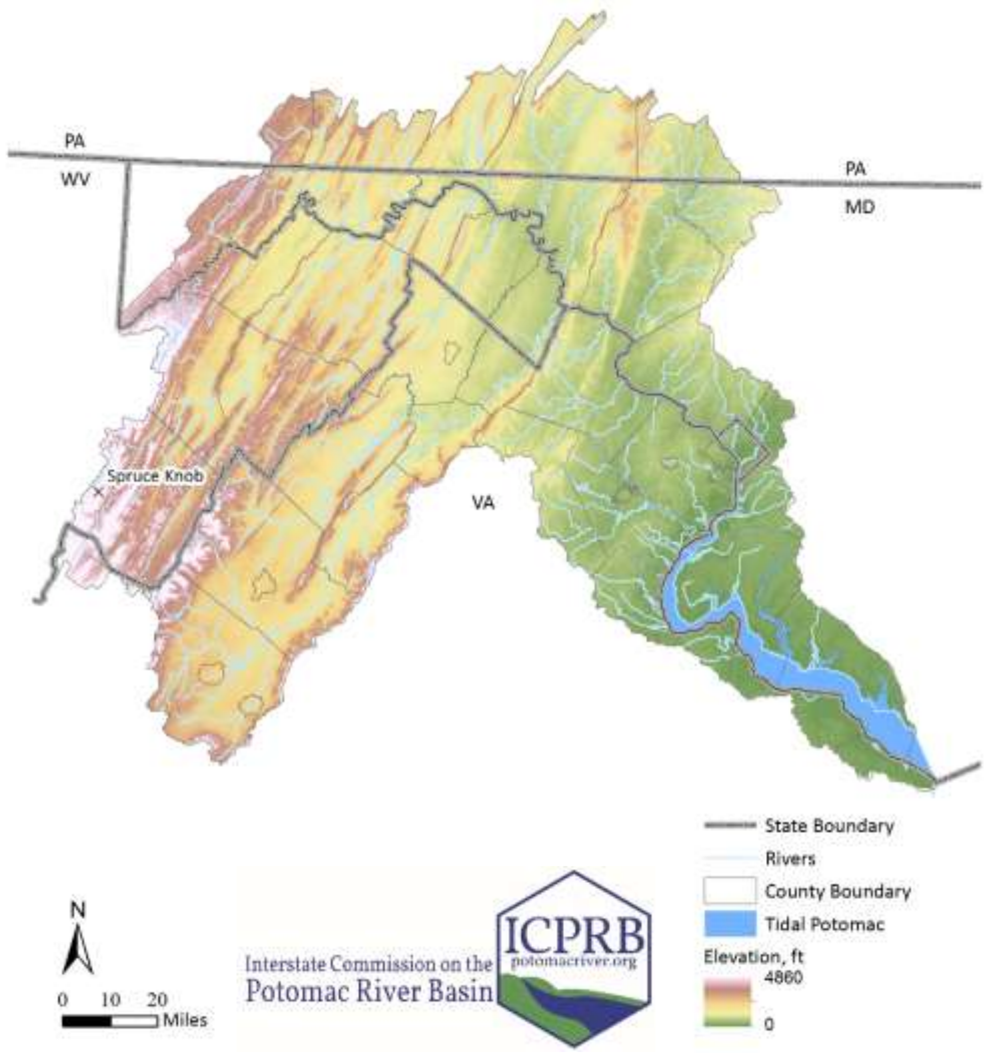
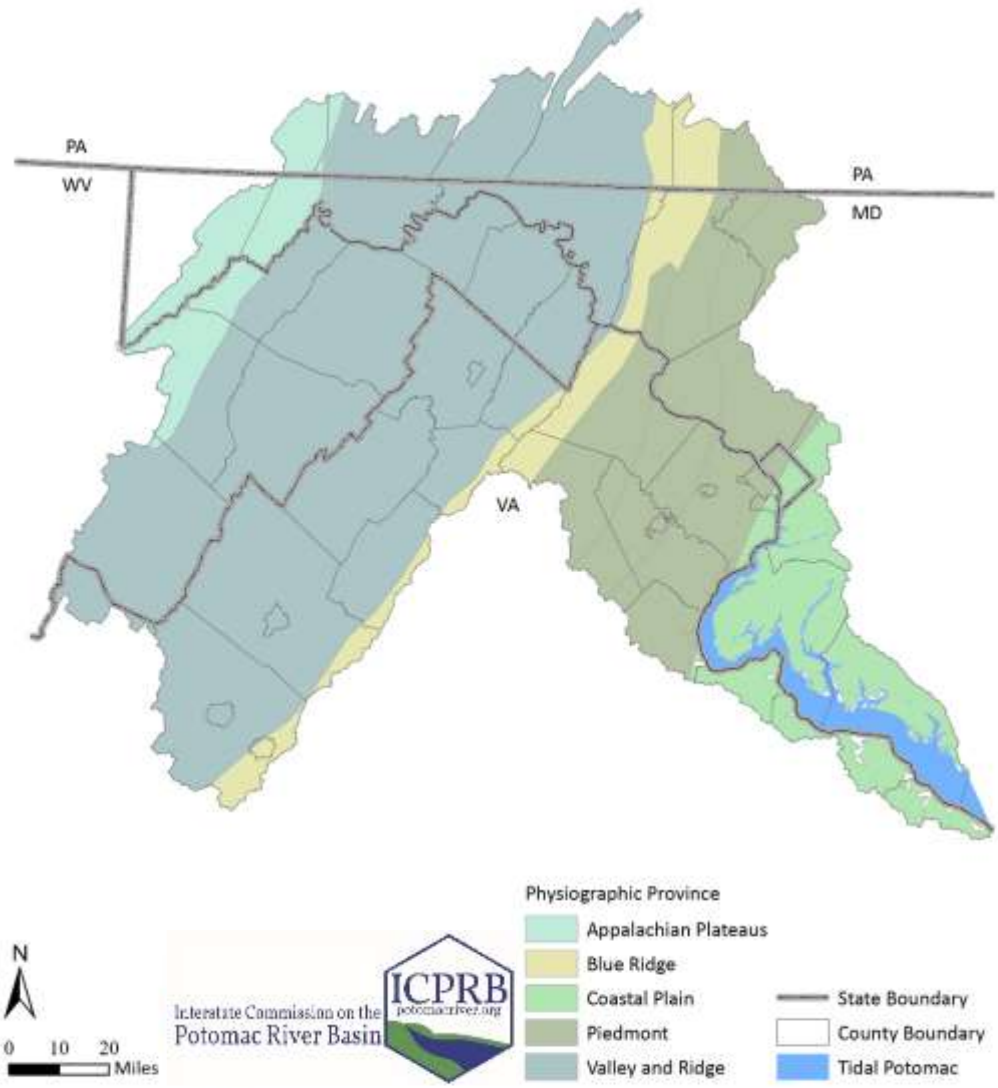


Figure 2. **Physiographic provinces in the Potomac basin. Data source: Fenneman et al. 1946.**



The Potomac basin intersects five major physiographic provinces including, from northwest to southeast, the Appalachian Plateau, Valley and Ridge, Blue Ridge, Piedmont, and the Coastal Plain (Fenneman et al. 1946) (**Figure 2**).

The Appalachian Plateau Province occupies the far northwestern part of the Potomac basin, consisting of both folded mountains and a westward tilting plateau, underlain by layered sedimentary and carbonate rocks. Due to the steep slopes, soil characteristics, and relatively cooler temperatures, this province is primarily forested with little agriculture (Wood et al. 1999). Relatively small amounts of groundwater exist in this province except under ideal hydrological and meteorological conditions (McCoy et al. 2015; MGS 2015).

To the east of the Appalachian Plateau lies the Valley and Ridge Province characterized by ridges of resistant layered sedimentary rocks and valleys of less resistant layers of limestone, dolomite, and shale (MGS 2015). The carbonate bedrock valleys are characterized by highly productive aquifers and the occurrence of karst terrain (VA DEQ 2014). As a result of the underlying geology, springs and caves can be common in this province (Wood et al. 1999). The largest and widest of the valleys, Great Appalachian Valley, bisects the entire Potomac River basin.

Coastal Plain aquifer system consists of six regional aquifers composed of alternating layers of sand, gravel, silt, and clay and extends from New Jersey to the North Carolina-South Carolina border (Trapp and Horn 1997). Groundwater is a primary source of water supply in the Coastal Plain and comes from several aquifers, a shallow unconfined system and a more productive, deeper, confined system. These deeper, confined aquifers are comprised of a series of aquifers and confining units which are recharged via infiltration from overlying aquifers and confining units and via outcroppings of the deeper aquifers near the Fall Line (Masterson et al. 2015; MGS 2015). These aquifers are truly regional in extent, shared to varying degrees between the states from New Jersey to North Carolina, including Maryland and Virginia in the Potomac basin.

The Potomac basin intersects five major physiographic provinces including the Appalachian Plateau, Valley and Ridge, Blue Ridge, Piedmont, and the Coastal Plain.

The Blue Ridge Province is a narrow mountain belt separating the Valley and Ridge Province from the Piedmont Province. Characterized by mostly forested slopes, high-gradient streams, and rugged terrain, the crystalline and sedimentary rocks of the province are covered by a thin layer of soil and weathered rock (Wood et al. 1999). The steep slopes and thin soils are responsible for high amounts of surface runoff and very little groundwater recharge (MGS 2015).

The Piedmont Province extends from the Blue Ridge on the west to the Fall Line on the east. A drive through the Piedmont reveals a landscape of rolling hills and open valleys. Aquifers in the Piedmont Province are composed of fractured metamorphic rock overlain by soil and weathered rock. Groundwater moves through the unconfined or partially confined system of fractures, faults, and joints in the surrounding impermeable crystalline rock. Recharge to groundwater is generally through the local infiltration of precipitation. The boundary between the Piedmont and the Coastal Plain is referred to as the Fall Line (MGS 2015).

The Coastal Plain Province is the final province that the Potomac River flows through before reaching the Chesapeake Bay. This low-lying area is characterized by low-gradient, sandy-bottomed streams (Wood et al. 1999). The Northern Atlantic

2.2 HYDROLOGY

The surface and ground water hydrology of the Potomac basin is spatially and temporally highly variable due to the climate, landscape, geology, and the relatively free-flowing (unimpounded) nature of the surface waters. Surface and ground water resources are described in **Section 2.2.1** and **Section 2.2.2**, respectively.

2.2.1 SURFACE WATERS

The Potomac River starts at the Fairfax Stone in West Virginia as the North Branch Potomac River. It forms the boundary between Grant, Mineral, and Hampshire counties in West Virginia, and Garrett and Allegany counties in Maryland, for 104 miles before it joins the South Branch Potomac River just downstream from Green Spring, West Virginia. The first 19 miles of the South Branch Potomac River are located in Highland County, Virginia, flowing the remainder of its 139 miles in West Virginia. After the confluence of the North and South branches, the Potomac River continues for 274 miles as the border between West Virginia and Virginia to the south and Maryland to the north. Ultimately, the Potomac River flows into the Chesapeake Bay at Point Lookout, Maryland. Major tributaries of the Potomac River are, in order downriver: Cacapon River, Conococheague Creek, Antietam Creek, Shenandoah River, Catoctin Creeks (one each in both Maryland and Virginia), Monocacy River, Seneca Creek, Rock Creek, Anacostia River, Occoquan River, and Wicomico River (**Figure 3**). The river is an estuary for its last 113 miles. The estuary formed after the last ice age as sea level rose and drowned the river's channel on the Coastal Plain. The estuary broadens to roughly five miles at its mouth and has depths over 60 feet in some reaches. The total volume is estimated to be around 1.87 trillion gallons but varies in response to the estuary's one to three-foot tides. It is freshwater for approximately 30 miles below head-of-tide, and partially stratified along its remaining length, ultimately reaching salinities as high as 15 parts per thousand at its mouth.

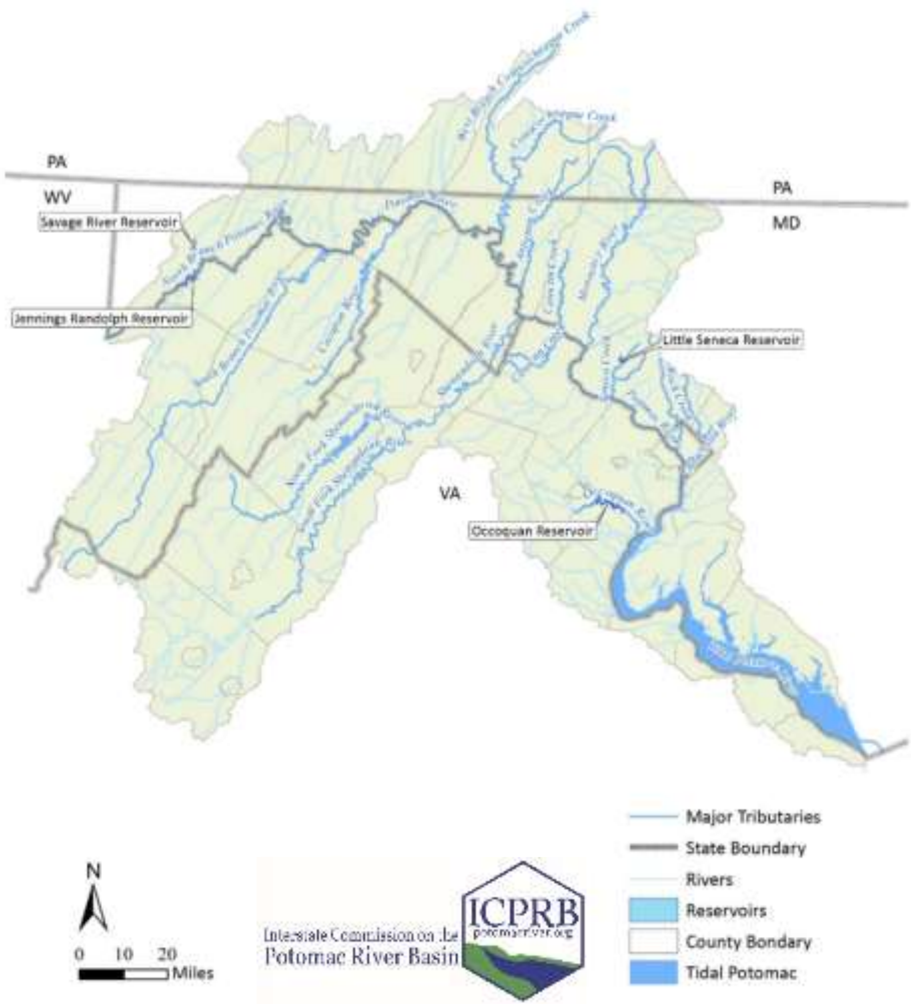
There are approximately 16,450 miles of perennial streams in the Potomac basin[1]. They range from fast moving mountain streams with frequent cascades, riffles, and pools to slow moving coastal streams that may have been ditched to channel water. Connected directly or by groundwater to the streams and rivers are 184,944 acres of freshwater and coastal wetlands. Freshwater wetlands occur in river floodplains and on low lands, near groundwater level. Saltwater wetlands fringe shores of the Potomac estuary where the ground is waterlogged[2].

[1] NHDPlus Version 1 Medium Resolution

[2] NLCD 2011 Land Cover (2011 Edition, amended 2014) - National Geospatial Data Asset (NGDA) Land Use Land Cover

The Potomac River and its tributaries are relatively unregulated compared to other major rivers in the Eastern U.S. In total, there are 481 impoundments in the non-tidal Potomac basin according to the 2007 National Inventory of Dams; however, only a dozen of these dams have storage capacities that are greater than ten percent of the mean annual flow volume, making them potentially significant sources of hydrologic alteration (USACE et al. 2014). The largest reservoirs in the basin are Jennings Randolph, Occoquan, and Savage River (**Figure 3**). Jennings Randolph, Savage River, and Little Seneca reservoirs are part of the cooperative management of Potomac drinking water supplies and instream flows during times of drought, releasing water for the Washington, D.C., Metropolitan Area (WMA) drinking water utilities and ensuring that the 100 million gallons per day (mgd) flow-by at Little Falls is to maintain. These water supply releases augment natural flows in the Potomac River for about 200 miles before reaching the CO-OP water supply system in the WMA.

Figure 3. **Major rivers of the Potomac basin. Select reservoirs are also displayed on the map. Data source: National Hydrography Dataset.**



The Potomac basin is fortunate to have a network of 236 USGS stream gages (**Figure 4**). The Point of Rocks gage (01638500), located on the mainstem Potomac River at Point of Rocks in Frederick County, Maryland, has one of the longest periods of record in the nation. Continuous daily data collection began at Point of Rocks in February 1895.

Average annual flows for the Potomac River and select major tributaries are provided in **Table 2**. The largest tributaries downstream of the confluence of the North and South branches, in terms of discharge, are the interstate Shenandoah and Monocacy rivers. On average, discharge per unit area from the major tributaries is fairly consistent with a range of 0.74 to 1.23 cubic feet per second per square mile (cfs/sq. mi.). Flows, however, are highly variable (**Table 2**). For example, the maximum observed flow at Point of Rocks on the Potomac River is almost three orders of magnitude larger than the minimum observed flow. The difference between maximum observed flow and minimum observed flow is at least four orders of magnitude for the Occoquan River and the Catoctin Creek gages. Of the 14 gages listed in **Table 2**, all but one have their high average flow month in March. The low average flow month varies more, seven are in August, four in September, two in July and the remaining one is in October.

Figure 4. **USGS stream gages in the Potomac basin by active status and length of record. Data source: USGS.**

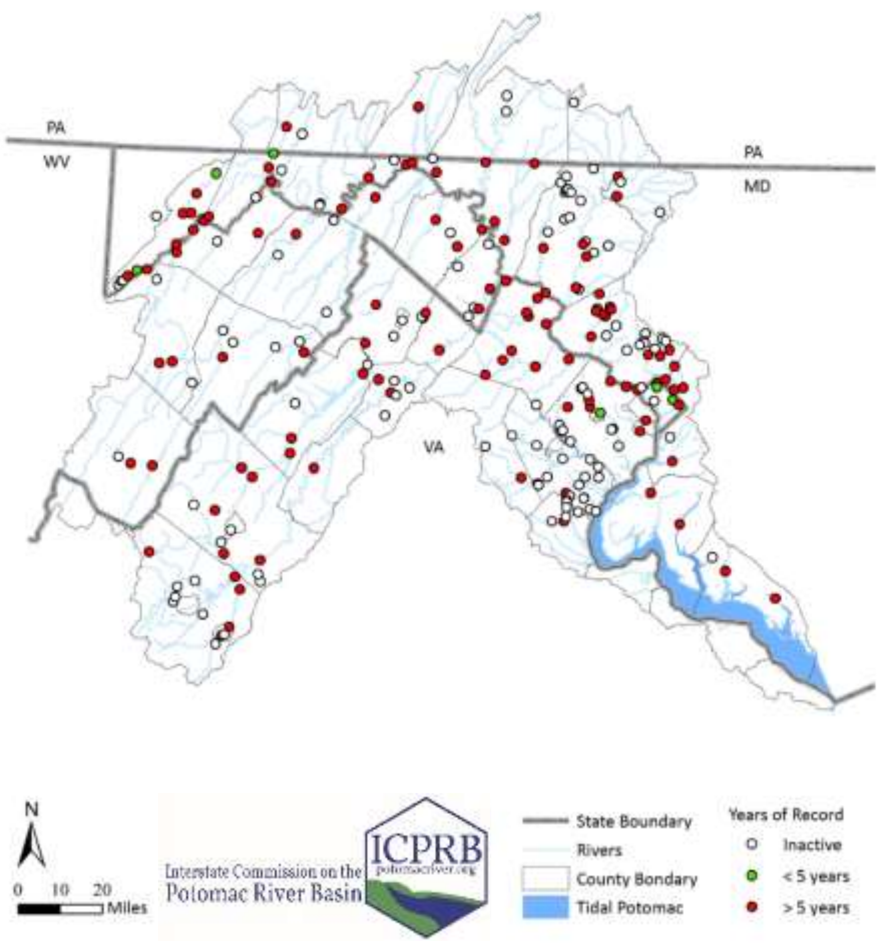


Table 2. **Average, minimum, and maximum daily flow for select USGS gages' period of record in cubic feet per second (cfs)*. Gages are arranged from upstream to downstream. No data = nd.**

USGS Gage Name	Period of Record	Area (sq. mi.)	Avg Daily Discharge (cfs)	Min Daily Discharge (cfs)	Max Daily Discharge (cfs)
Cacapon River near Great Cacapon, WV	1922 to 2018	675	587	26	67,900
Conococheague Creek at Fairview, MD	1928 to 2018	494	606	25	26,700
Antietam Creek near Sharpsburg, MD	1897 to 2018	281	291	37	8,970
Shenandoah River at Millville, WV	1895 to 2018	3,041	2,744	194	192,000
Catoctin Creek near Middletown, MD	1947 to 2018	67	78	0.0	4,880
Catoctin Creek at Taylorstown, VA	1970 to 2018	90	100	0.1	9,530
Potomac River at Point of Rocks, MD	1895 to 2018	9,651	9,498	540	434,000
Monocacy River at Jug Bridge near Frederick, MD	1929 to 2018	817	960	19	74,000
Seneca Creek at Dawsonville, MD	1930 to 2018	101	117	1.8	9,900
Potomac River (Adjusted) near Washington, DC†	1930 to 2018	11,560	11,821	601	426,000
Rock Creek at Q Street, Washington, DC	1892 to 1933	76	56	1.2	2,710
Northeast Branch Anacostia River at Riverdale, MD	1938 to 2018	73	88	1.4	6,830
Occoquan River near Occoquan, VA	1913 to 1956	570	484	1.0	27,700
Freshwater tributaries to Wicomico River	1983 to 2018	248	80**	nd	nd

* Compiled Apr 29, 2015

** Extrapolated from Zekiah Swamp Run gage near Newtown, MD

† Adjusted records include diversions for DC metro water supply

The variability of streamflows in the Potomac basin is primarily a function of temperature, precipitation, evapotranspiration, and the relatively free-flowing (unimpounded) nature of the surface waters, each of which are discussed below.

Residents and visitors alike enjoy the four distinct seasons in the Potomac basin including fall colors, spring flowers, and winter and summer recreational activities. Due to its location in the north temperate zone, extreme temperatures are possible. Winters can be cold, with record daily lows reaching -30 °F (-34 °C) in the mountains. Summers can be hot with record daily highs reaching 105 °F (41 °C) in the coastal areas of the basin. On a monthly basis, average temperatures in the basin range from 29 °F (-2 °C) in February to 73 °F (23 °C) in July (**Figure 5**).

Figure 5. **Monthly distribution of temperature for the Potomac basin. Calculated as the average of the means, minimums, and maximums for each month; 1971-2000. Data source: 122 National Weather Service (NWS) temperature stations.**

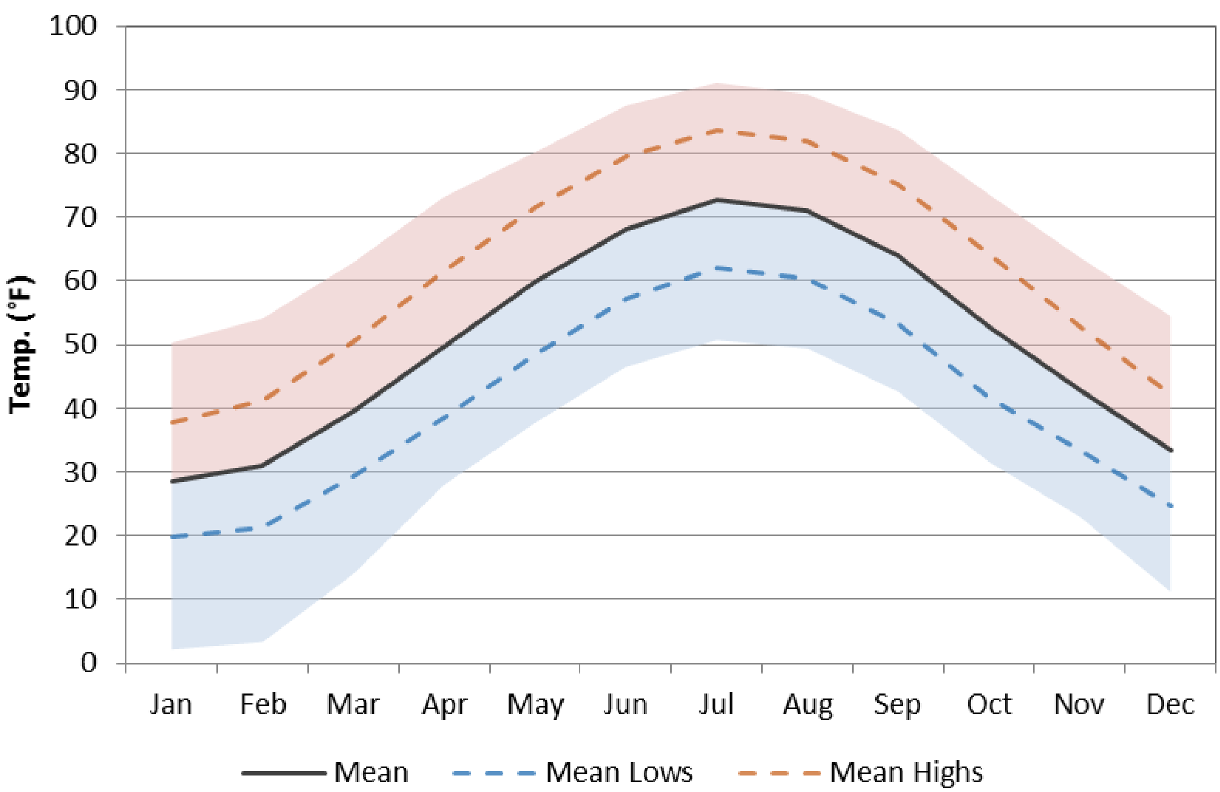
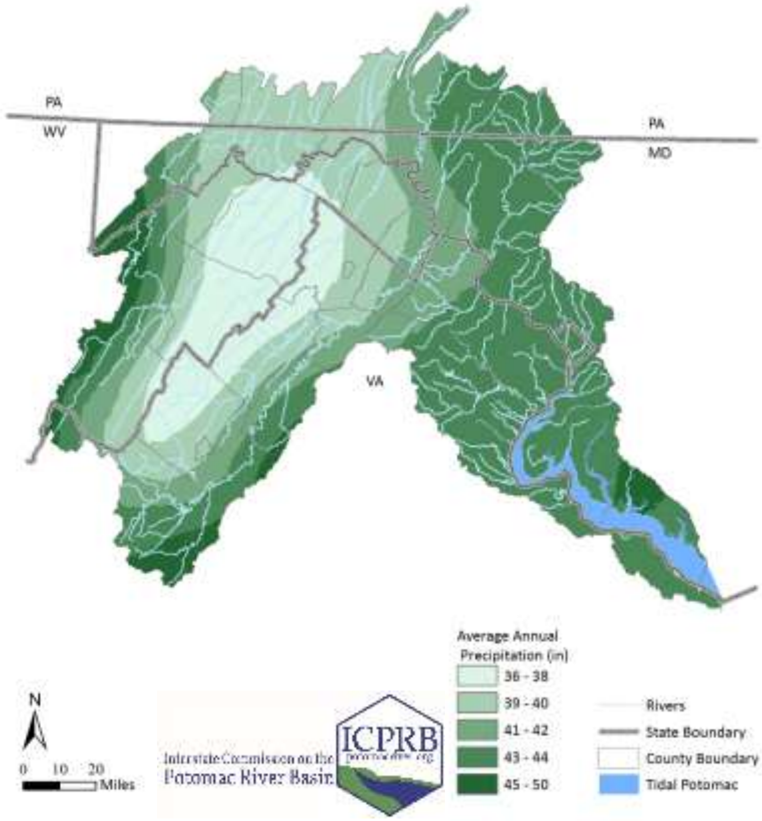


Figure 6. **Average annual precipitation in the Potomac basin; 1971-2000. Data source: NWS Middle Atlantic River Forecast Center precipitation data from 214 stations.**

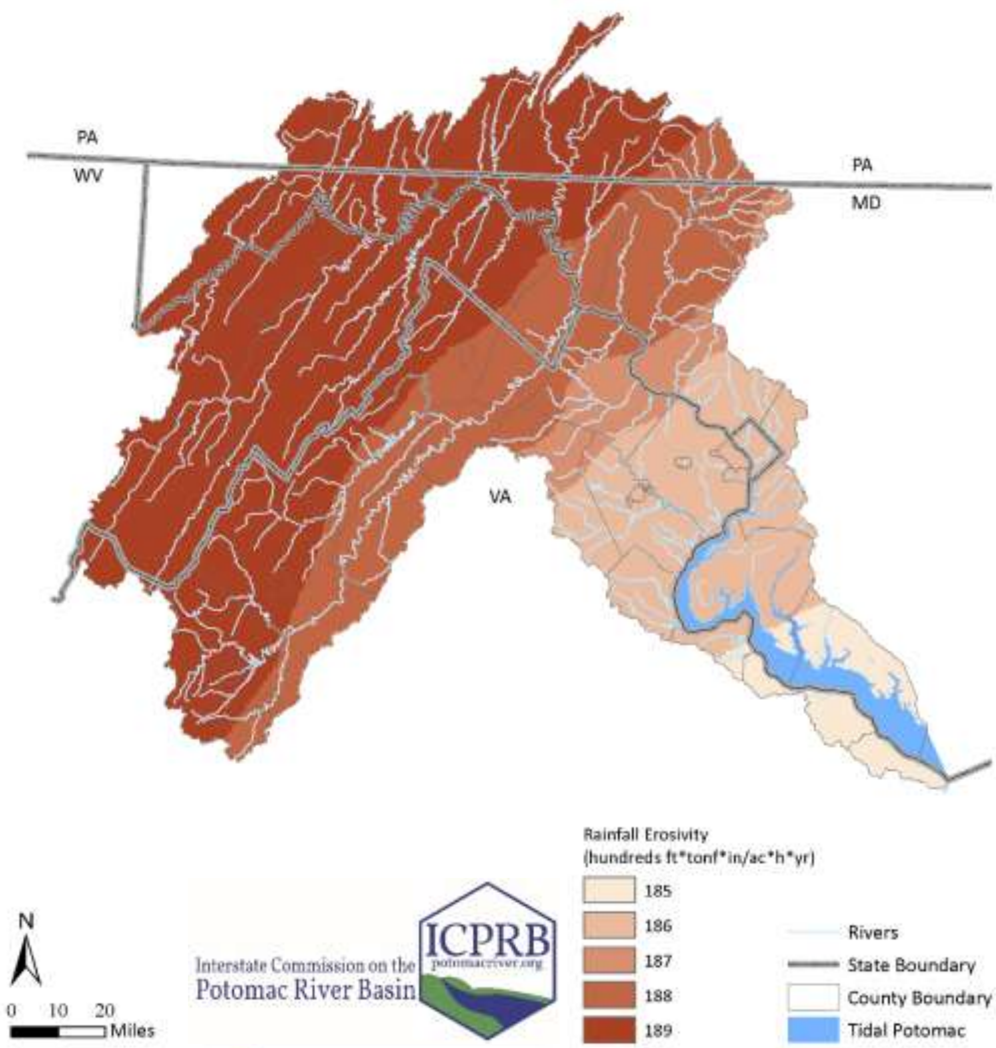


According to historic data from 84 National Weather Service (NWS) precipitation stations in and around the Potomac basin, rainfall averages approximately 42 inches per year. Spatial variability in precipitation across the basin is primarily driven by a large rain shadow, or dry area, on the eastern side of the Appalachian mountain system (**Figure 6**).

There is also variability in the intensity and duration of rainfall events across the basin (**Figure 7**). Rainfall erosivity is a metric based on rainfall intensity and duration that is calculated using many years of observed data. Specifically, rainfall erosivity is the average annual sum of individual storm erosion index values, EI_{30}, where E is the total storm kinetic energy per unit area and I_{30} is the maximum 30-minute rainfall intensity. In the Potomac basin, rainfall erosivity is highest upstream of the Appalachian Mountains and gradually decreases moving downstream on the mainstem Potomac River. Compared to other areas of the country, differences in the Potomac basin may be subtle (Renard et al. 1997); however, these characteristics influence components of the hydrologic cycle such as rainfall runoff amounts and the potential for erosion.

The Potomac basin receives approximately 42 inches of rain per year.

Figure 7. **Rainfall erosivity in the Potomac basin. Data source: Renard et al. 1997.**



Precipitation amounts in the Potomac basin are fairly consistent on a monthly basis; however, streamflows can decrease dramatically in the growing season due to high evapotranspiration (USACE et al. 2014) (**Figure 8**). Summer evapotranspiration causes flows during that period to be dependent on recent rainfall. On an average annual basis, more than half of the total available water is lost to evapotranspiration (**Figure 9**).

Figure 8. **Monthly mean precipitation, potential evapotranspiration, and flow at Potomac River gage at Little Falls Pump Station. Data sources: NWS, USGS, and Farnsworth and Thompson (1982).**

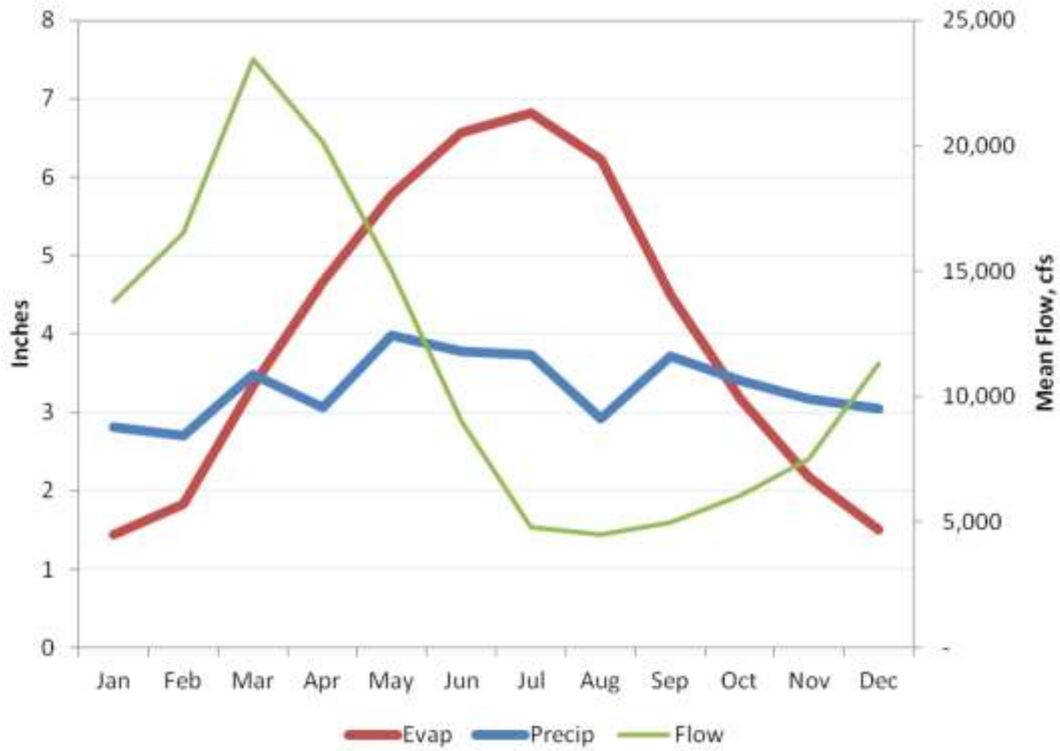
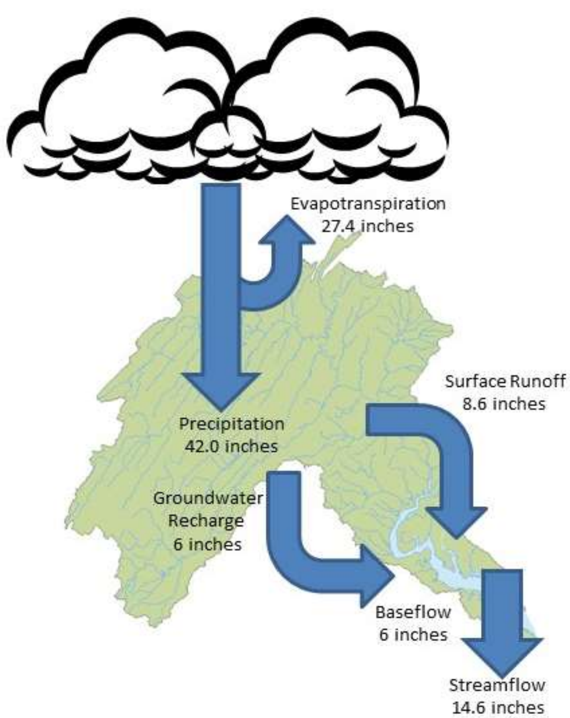


Figure 9. **Average annual water budget for the Potomac basin. Data sources: PRISM Climate Group 2004, Wolock 2003, and USGS. Baseflow is defined [here](#).**

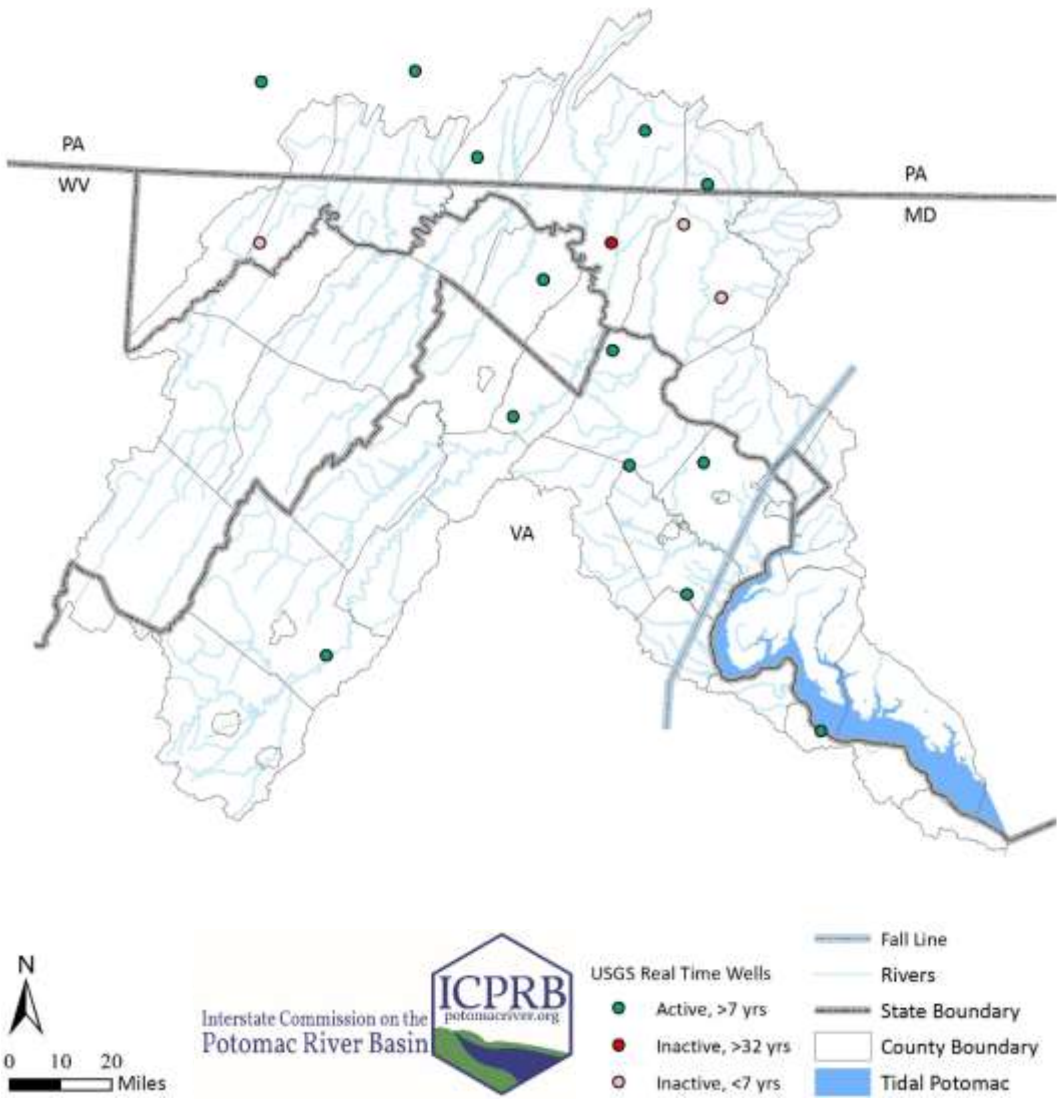


2.2.2 GROUNDWATER

There are distinct physical characteristics of the groundwater resources and the associated recharge features above and below the Fall Line. In the Coastal Plain Province, groundwater is contained in a confined aquifer system. Recharge of these aquifers primarily occurs by infiltration from overlying aquifers and through outcroppings near the Fall Line. Above the Fall Line, groundwater aquifers consist of fractured bedrock. Fractured bedrock aquifers consist of a thin layer of unconsolidated soil and weathered rock overlying the bedrock. These unconsolidated materials are far more porous than the bedrock and contain the largest volume of groundwater in the fractured rock aquifer. Groundwater is transmitted to wells and streams through the fracture system within the bedrock but there is relatively little storage in the fractures. The vastly different physical properties of the groundwater systems above and below the Fall Line result in unique characteristics like recharge rates.

USGS monitors 17 wells in or near the Potomac basin in real time (15 minute increments) to provide measurement data on the groundwater level (**Figure 10**). Thirteen of these wells are currently active with USGS receiving near-continuous water level data from instrumentation installed in the wells. The other four wells are no longer actively recording and transmitting real-time data. There are over 100 additional USGS groundwater wells in the Potomac basin that are not real time (i.e. measurements are collected at time intervals greater than every 15 minutes).

Figure 10. **Current and historic USGS real-time wells in or near the Potomac basin. Real-time wells record and transmit data every 15 minutes. Well locations are color coded by the number of years of available data. Data source: USGS.**



Groundwater recharge in the basin varies based on precipitation, geology, soil type, and land use. Average annual recharge estimates are provided in **Table 3** for each sub-basin based on reported values from Wolock (2003). On average, recharge ranges from 5.1 inches per year to 8.8 inches per year.

Table 3. **Mean annual average groundwater recharge estimate by sub-basin (based on data from Wolock 2003).**

Sub-basin Name	Minimum (inches)	Maximum (inches)	Average (inches)
South Branch Potomac	4.8	10.0	6.8
North Branch Potomac	4.9	12.0	8.8
Cacapon-Town	4.2	6.8	5.2
Conococheague-Opequon	4.5	9.6	6.7
South Fork Shenandoah	5.1	8.5	6.3
North Fork Shenandoah	4.4	6.0	5.2
Shenandoah	5.0	7.8	5.7
Middle Potomac-Catoctin	3.5	8.7	6.4
Monocacy	5.7	9.9	7.5
Middle Potomac-Anacostia-Occoquan	3.4	8.5	5.1
Lower Potomac	3.9	8.1	6.1

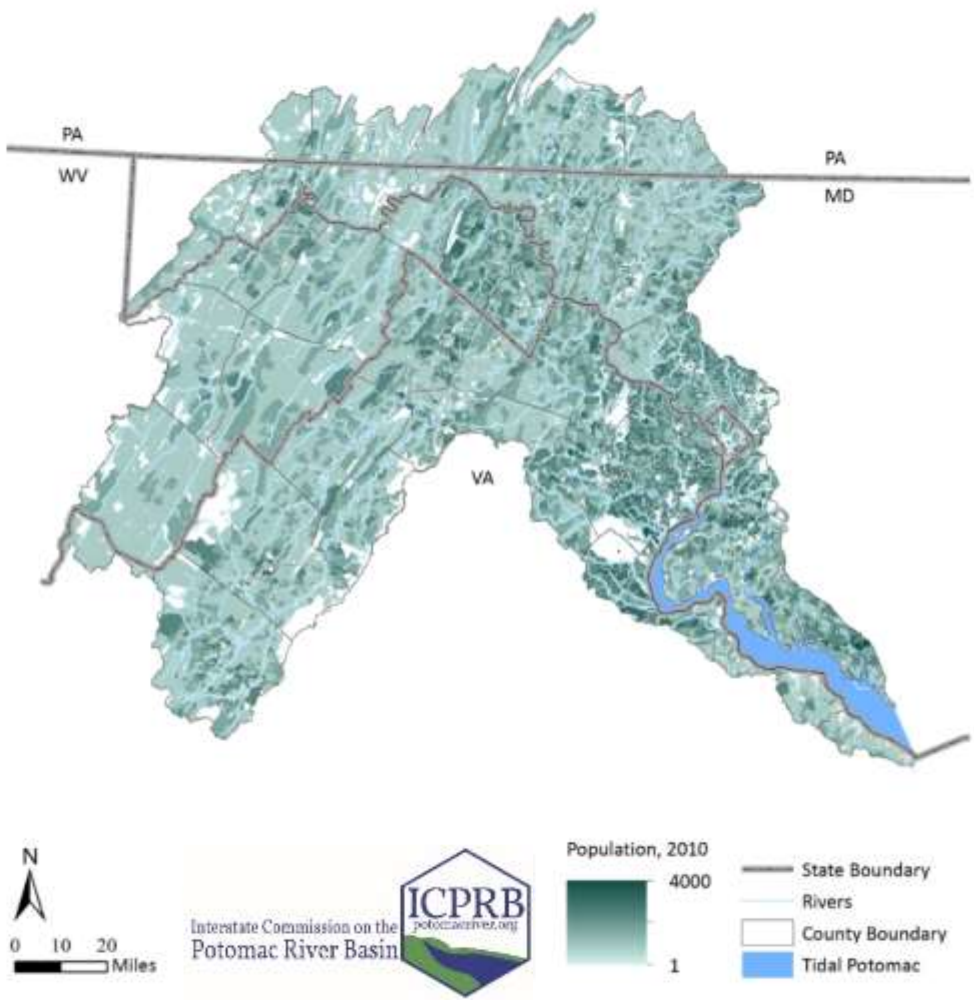
2.2.3 SUMMARY

Due to the hydrologic and climactic conditions in the basin, water management requires careful preparation for summers and autumns with low water supply (i.e. low flow) and/or high demand. Balanced, well-functioning ecosystems are able to handle fluctuations in streamflow and groundwater availability and depend on natural hydrologic variability for survival. Anthropogenic impacts to natural hydrologic variability can have negative impacts on these systems. For example, increases in impervious cover result in higher flood stages and longer dry periods, which can stress aquatic organisms.

2.3 POPULATION

According to the 2010 U.S. Census, the Potomac basin is home to 6.17 million people (**Figure 11**). Eighty percent of the basin's population lives in urban areas, with the vast majority of the urban dwellers (5.36 million people) living in the WMA. The remainder of the urban population live in cities scattered throughout the basin.

Figure 11. **Population by census block in the Potomac basin. White census blocks indicate a population of zero. Data source: U.S. 2010 Census.**

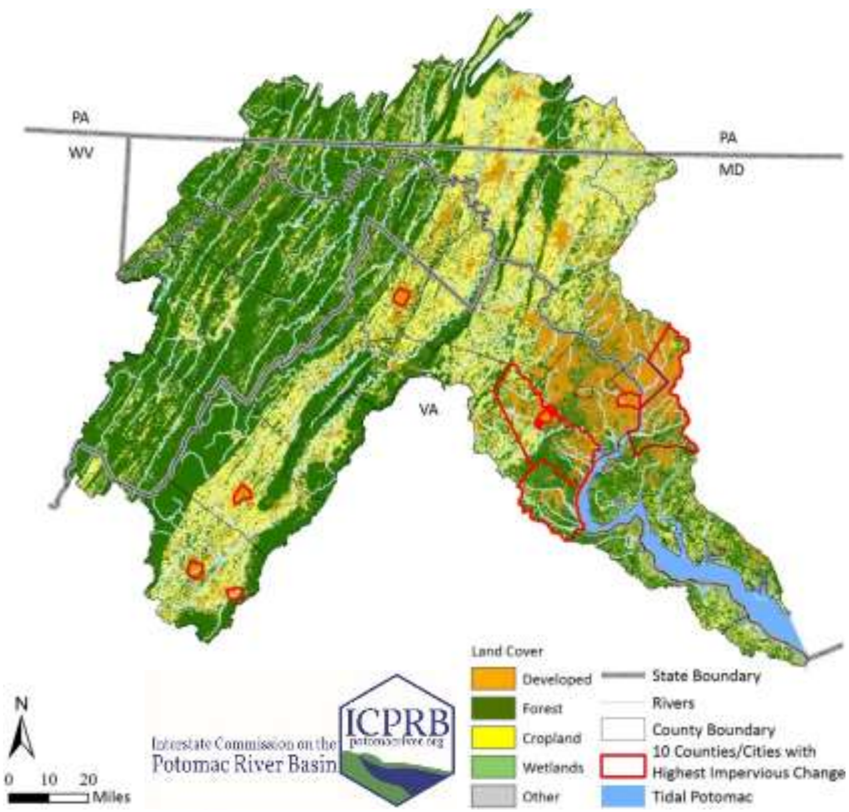


2.4 LAND USE

The Potomac basin is heavily forested, with approximately 53 percent forest cover (shown in green in **Figure 12**). Agriculture is also a major land use, particularly in the Great Valley and Piedmont regions (Section 2.1), and covers 26 percent of the basin (shown in yellow in **Figure 12**). Fourteen percent of the basin is developed (shown in orange in **Figure 12**) and some regions of the basin, especially those surrounding the WMA, are experiencing rapid urbanization.

According to the U.S. Census, the ten Potomac basin counties and equivalents with the largest increase in impervious cover between 2006 and 2011 are (from highest to lowest): Harrisonburg, Virginia; Manassas Park, Virginia; Winchester, Virginia; Manassas, Virginia; Prince William County, Virginia; Waynesboro, Virginia; Staunton, Virginia; City of Alexandria, Virginia; Prince George's County, Maryland; and Stafford County, Virginia. The change in imperviousness in this group over the five-year period ranged from 4 percent to less than 1.4 percent (USGS 2014).

Figure 12. **Land use in the Potomac basin. Data source: 2011 NLCD data[3].**



[3]The National Land Cover Dataset (NLCD) land use categories were aggregated for simplification. The following land use classes were included in each category. Forest: Deciduous Forest, Evergreen Forest, Mixed Forest, Shrub/scrub, and Herbaceous. Crops: Hay/Pasture and Crops. Developed: Developed Open Space, Developed Low Intensity, Developed Medium Intensity, Developed High Intensity, and Barren Land. Wetlands: Woody Wetlands and Emergent Herbaceous Wetlands.

2.5 WATER USE

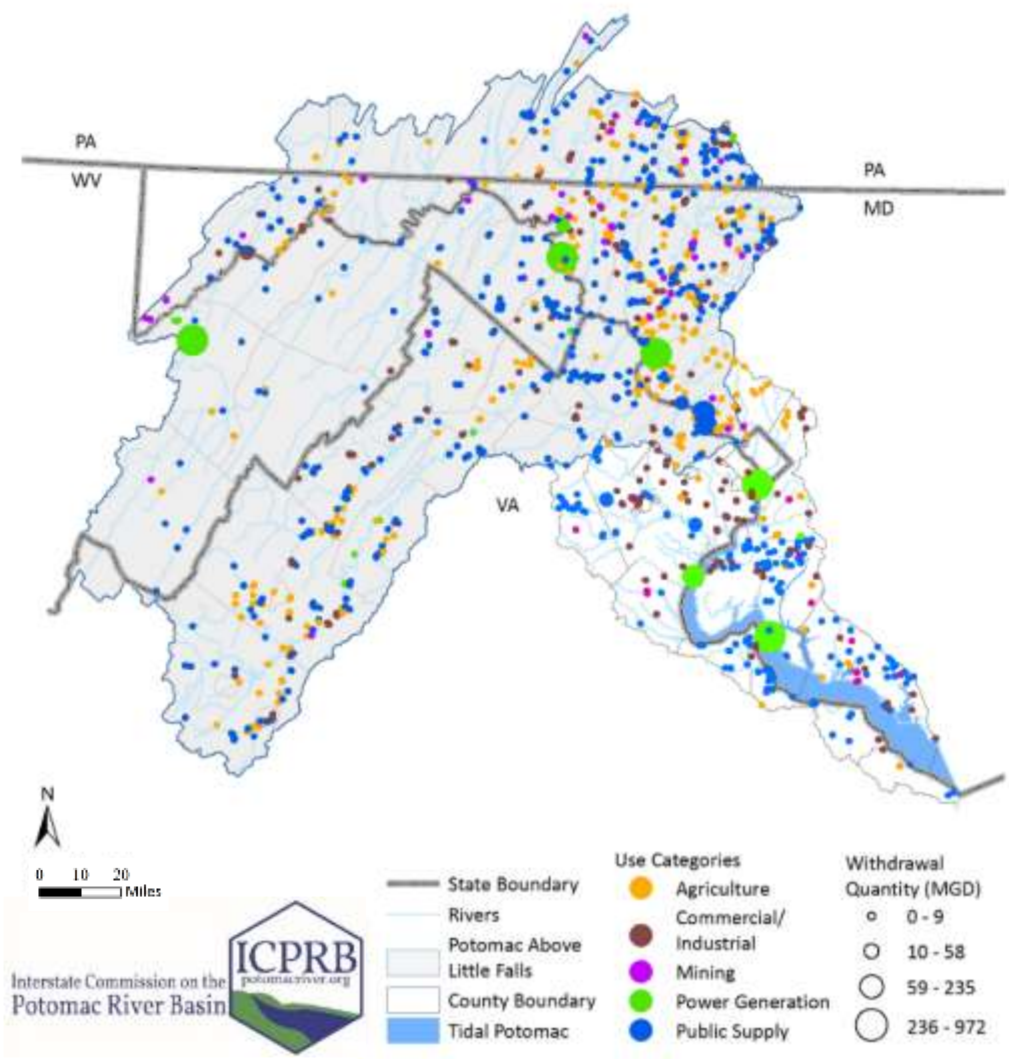
Given the distinct hydrologic and hydrogeologic characteristics (as described in **Section 2.2.2**), the ratio of surface and ground water uses differ above and below the Fall Line. Specifically, water uses above the Fall Line are typically from surface water sources given the relatively small amount of storage available in the groundwater systems. Conversely, the water uses below the Fall Line are typically from groundwater. Water uses in each of these regions are discussed in this section.

Water use data for the basin has been compiled as part of two recent ICPRB projects. The Middle Potomac River Watershed Assessment (MPRWA) (USACE et al. 2014) included a compilation of state reported surface and ground water withdrawals for the Potomac basin for the year 2005. Development of the ICPRB consumptive use tool (Ducnuigeen et al. 2015) brought together state reported withdrawals for the Potomac basin above Little Falls. The common period of record between state data in the consumptive use tool was 2005 through 2008.

In total, 1,134 registered withdrawals occurred in the Potomac basin upstream of Little Falls during the 2005 – 2008 time period (**Figure 13**). Approximately 1,800 mgd were withdrawn on an average annual basis during that time period. Thermoelectric power facilities accounted for 85 percent of withdrawals (by volume), followed by public water supply and industrial uses at eight and four percent, respectively (Ahmed et al. 2015). Ninety-six percent of the withdrawals above Little Falls were from surface water sources.

Based on the MPRWA withdrawal database, there were 328 registered withdrawals in the basin below Little Falls in 2005 with an average daily withdrawal of 1,500 mgd (**Figure 13**). The power sector used 93 percent of the reported water followed by public water supply with six percent. The other use types (agriculture, commercial/industrial, and mining) make up the remaining one percent of withdrawals. Eighty percent of the withdrawals were from groundwater, the rest from surface water. Recent studies have demonstrated the vulnerability of current water supplies to drought and other types of shortages (like spills), given the relatively small amount of water storage and alternative water sources (Ahmed et al. 2015). A water supply alternatives study was conducted in 2017 by the ICPRB Section for Cooperative Water Supply (CO-OP) to evaluate structural and non-structural options for dealing with potential future shortages in the cooperative system due to severe drought (Schultz et al. 2017). Another study which addressed potential shortfalls due to emergency events such as a contaminant spill in the Potomac River was the Metropolitan Washington Council of Governments (MWCOG) Redundancy Study (Black and Veatch 2016). Both of these studies were designed to address the vulnerabilities of the D.C. metro region. To date, there has been no systematic, comprehensive evaluation of the vulnerabilities of the basin as a whole.

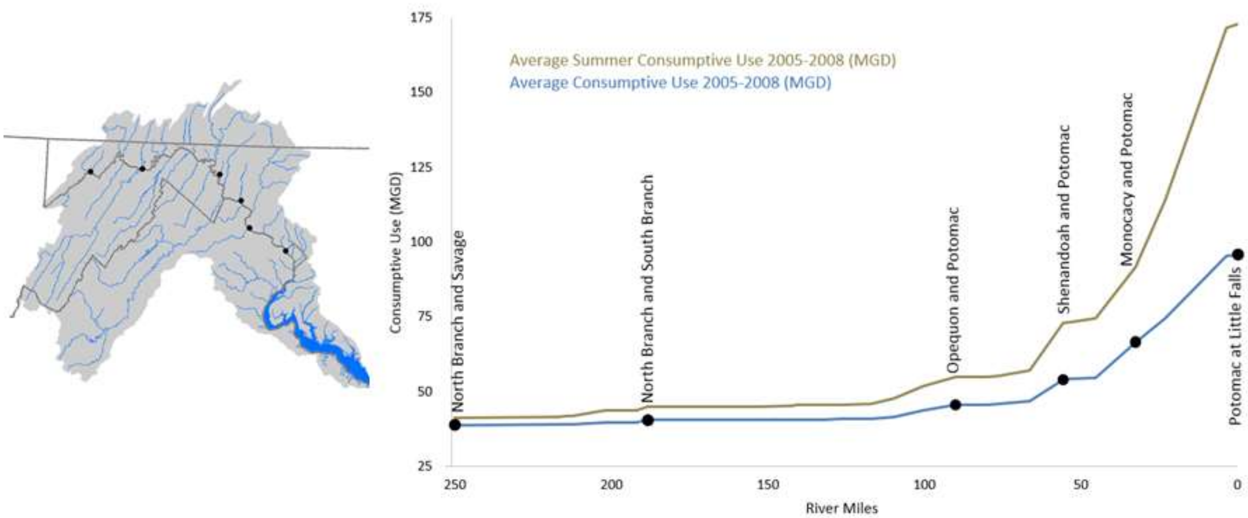
Figure 13. **State-reported withdrawals. Reported withdrawals include both consumptive and non-consumptive uses. Color indicates water use type and size indicates the magnitude of the withdrawal. The largest withdrawals in the Potomac basin are for power generation. Data sources: ICPRB CO-OP consumptive use database above Little Falls and the MPRWA 2005 withdrawal database below Little Falls.**



Consumptive use is the portion of water that is withdrawn from a resource and not returned to the same resource for subsequent use. A couple of examples include evaporated irrigation and cooling water, bottled drinking water, and water consumed by people or livestock. Estimates of consumptive use are important because they indicate how much water is being used and is subsequently not available for downstream use. Maryland and Virginia both regulate consumptive use during low-flow periods (Maryland Chapter 26.17.07 and Virginia §62.1-44.15:5.02).

Figure 14 shows cumulative upstream consumptive use at select locations on the mainstem Potomac River from Savage River to Little Falls for both average annual and average summer conditions. Under average annual conditions, cumulative consumptive use ranges from an estimated 40 mgd at the confluence of the North Branch and Savage River to 100 mgd at Little Falls on the Potomac River. Under average summer (June, July, and August) conditions, the value at Little Falls increases to approximately 170 mgd. Summer consumptive uses are primarily higher due to outdoor water uses like irrigation and lawn watering. When compared with estimates of water availability, geographic areas where demand approaches or exceeds supply can be identified.

Figure 14. **Cumulative upstream consumptive use, Savage River to Little Falls based on state-reported withdrawals. The black dots on the map correspond to the black dots on the graph.**



2.6 WATER QUALITY

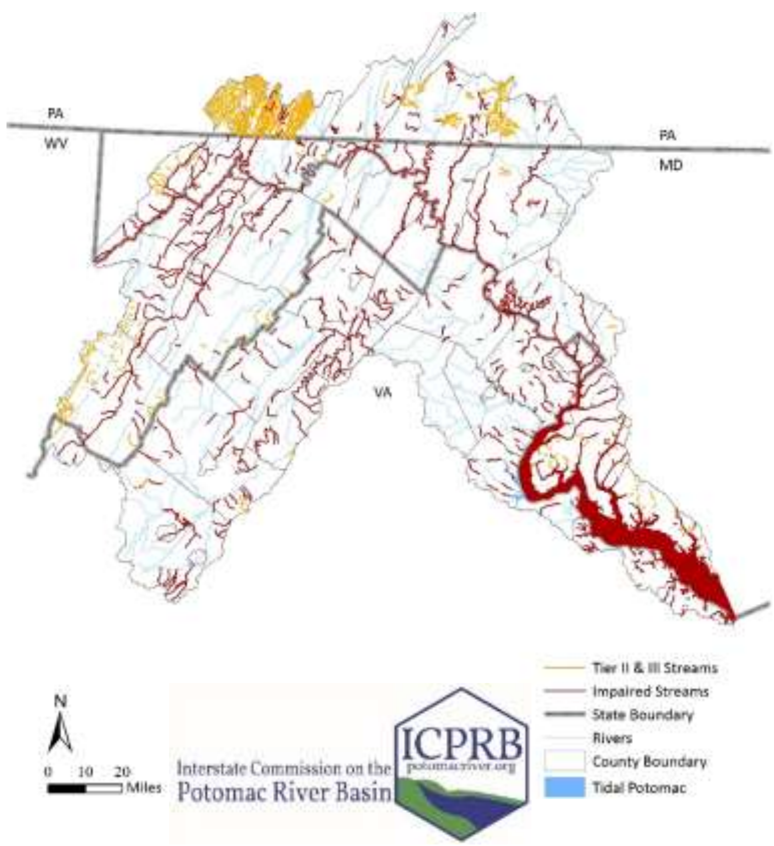
Sufficient quantities of clean water are essential to sustaining the many human and ecosystem water uses. The Potomac basin is home to high quality waters and, conversely, to waters that do not meet established water quality standards.

Tier II and Tier III designations are made under the anti-degradation policy of the states, according to requirements of the U.S. Clean Water Act (CWA). In addition to the basic antidegradation protections afforded to all waters under Tier I, Tier II and III waters under the CWA are expected to meet or exceed water quality standards for their designated uses and are considered pristine, high quality waters, and/or support a high quality aquatic community or wild native fish populations such as wild trout fisheries, or possesses unique local, regional, or national ecological or recreational significance. These streams are designated based on criteria and definitions established in each state. A total of 1,266 miles of high quality, Tier II and Tier III, waters are present in the basin (**Figure 15**).

The freshwater mainstem Potomac River is designated by MDE for water contact recreation, protection of aquatic life, and public water supply. The tidal Potomac is designated for support of estuarine and marine aquatic life and shellfish harvesting by MDE. Uses for tributaries vary throughout the basin depending on local activities and conditions.

The Chesapeake Bay watershed is well known for ongoing water quality problems and the substantial efforts underway to try to improve the water quality of the bay. The Potomac basin, being within the Chesapeake Bay watershed, is subject to the Chesapeake Bay Total Maximum Daily Load (TMDL),

Figure 15. **Tier II and Tier III streams and impaired streams. Impaired waters, associated with different designated uses and pollutants, occur throughout the basin. Note that not all waters have been assessed to determine impairment status. Data source: USEPA compilation of state impairment data (USEPA 2015).**



established by the USEPA in 2010. The TMDL identifies the pollution reductions for nitrogen, phosphorus, and sediment and sets pollution limits necessary for the Chesapeake Bay to meet established water quality standards. State implementation plans were developed to specifically identify how the pollution allocations would be met in each jurisdiction.

Basin states also submit an Integrated Report on water quality to the USEPA every two years, fulfilling the state's 303(d) and 305(b) requirements under the CWA. Impaired streams are those waterways that do not meet the water quality standards established for the designated or existing use under the CWA. Pollutants evaluated and subsequently managed as part of the CWA process vary from state to state but can include metals, nutrients, total dissolved solids, chlorides, dissolved oxygen, temperature, organics (like PCBs), among others. These pollutants can come from a wide range of natural and human activities and are subsequently transported to waterways either through direct discharges (like pipes) or by getting transported to the water by rainfall, snowmelt, or blowing wind.

Spatially, impaired streams occur throughout the basin, shown in red in Figure **15**. Of the total impaired streams in the basin, 32 percent are impaired for nutrients, 37 percent are impaired for pathogens, 26 percent are impaired for sediment, and 4 percent are impaired for metals (USEPA 2014). The entire Potomac estuary is impaired except for the tidal embayments of Virginia's Aquia Creek and Potomac Creek (MDE 2017 and VA DEQ 2016). While the impaired segments fail to meet water quality standards for at least one pollutant or protected use, they vary in their attainment of water quality standards for other pollutants or uses. Impairments are classified into categories: 4a, impaired but have a TMDL developed that establishes pollutant loading limits designed to bring the water-body back in to compliance; 4b, impaired but for which a technological remedy should correct the impairment; 4c impaired but not for a conventional pollutant (includes pollution caused by habitat alteration or flow limitations); and 5, impaired water bodies that may require a TMDL. Category 5 has historically been known as the 303(d) List.

Balanced, desirable populations of aquatic life are the definitive sign of healthy, well-functioning ecosystems and sustainable water resources management.

2.7 AQUATIC LIFE

In the context of this plan, aquatic life is the animal, plant, and microscopic organisms that live in water for part or all their life cycle. Balanced, desirable populations of aquatic life are the definitive sign of healthy, well-functioning ecosystems and sustainable water resources management. People derive valuable goods and services from Potomac waters when aquatic populations are vigorous, resilient, and effectively performing their ecological roles.

Aquatic life is a designated use in the water quality standards of the District of Columbia and the four states in the Potomac River basin. These jurisdictions recognize the importance of clean water in achieving and sustaining their aquatic life designated uses. Water quality standards are directly linked to desirable or ecologically important biological communities[4], and allowable limits (criteria) for dissolved oxygen, pH, and other parameters are set according to ranges tolerated by those communities. Water quality conditions have improved in the basin overall since a nadir in the mid- to late-20th century; however, most of the estuary and significant numbers of Potomac non-tidal streams and rivers are still listed as impaired by the jurisdictions (**Figure 15**).

> ***Aquatic Life***
>
> The term "aquatic life" rather than "living resources" is used in this plan. The latter implies the living parts of an ecosystem can be exploited independently of each other, as if they are inanimate quantities. Exploitation of aquatic populations—and especially animal populations—outside of the context of their ecological roles and needs has irrevocably damaged many natural systems and the goods and services they provide to people. Examples include single-species management approaches and non-native species introductions.
>
> This comprehensive plan attempts to consider aquatic life in the context of Potomac's natural ecosystems.

To thrive, aquatic communities require sufficient physical habitat—living spaces with environmental conditions that stay within the inhabitants' preferred bounds—and the option to move freely between habitats. For example, resident species move in and out of underwater grass beds or small tributaries to find food, or avoid predators or seasonally stressful conditions. Anadromous fish species migrate from the Atlantic Ocean to the Potomac River and its tidal freshwater tributaries to spawn. Dams built across Potomac waterways impede natural movements of aquatic populations. Hardened shorelines, in-filling, channel alteration, and other efforts to confine or redirect paths of natural flow can break important aquatic life connections to floodplain, wetland, and riparian buffer habitats. Historic loads of top soil and sediment from earlier forest clear-cutting and agricultural practices have permanently changed the estuary's bathymetry, filling in embayments, eliminating some deep water refugia, and shortening residence times in important nursery areas (e.g. Cummins et al. 2011).

Changes in physical stream habitat, coupled with increasing water withdrawals and impervious cover related to development in the watershed, have altered flow patterns to some extent in most Potomac streams and rivers. Flows have become generally flashier and more likely to flood or dry out (USACE et al. 2014). Flow alteration disrupts and overwhelms aquatic communities (Poff et al. 2010). Its influence on Potomac non-tidal stream macroinvertebrates seems to compound the impacts of poor water quality (Buchanan et al. 2013).

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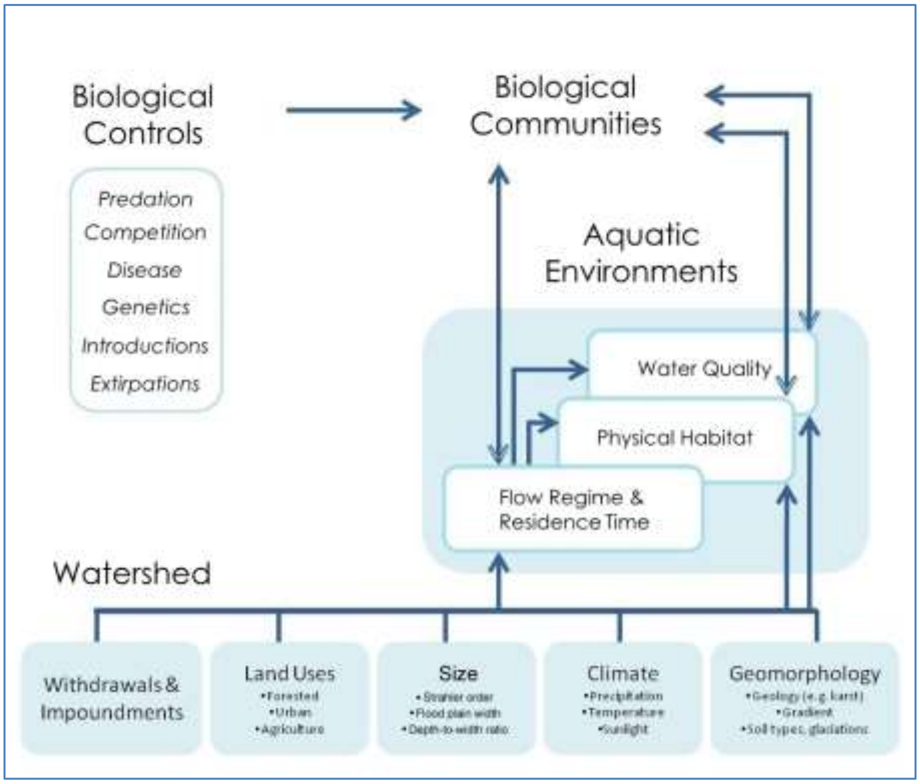
[4] Excerpts from water quality standards confirm this connection between water quality and aquatic life. Pennsylvania assesses its rivers and lakes to determine if they are "clean and pure enough to support fish and other aquatic life." West Virginia has "reasonable standards of purity and quality of the water [that are] consistent with … (2) the propagation and protection of animal, bird, fish, and other aquatic and plant life." Maryland seeks to "…provide water quality for the designated uses of …(c) propagation of fish, other aquatic life, and wildlife." Virginia designates all waters for "…the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g. fish and shellfish." Some District of Columbia waters are classified for the "…protection and propagation of fish, shellfish, and wildlife; [and] protection of human health related to consumption of fish and shellfish."

Biological forces also control aquatic populations, including predation pressure (e.g. fishing), competition for space and food, disease, genetics, extirpations, and introductions of non-native species (**Figure 16**). The relative importance of these controls rises when biological communities are already disturbed and weakened by other factors.

Figure 16. **Conceptual diagram of environmental factors that directly and indirectly affect biological community health in aquatic environments (adapted from USACE et al. 2014).**



2.8 SUMMARY

Human and natural systems are dependent on the water and associated land resources in the Potomac basin. **Section 2** provides a description of the Potomac basin's physiography, hydrology, population, land use, water use, water quality, and aquatic life. The characteristics of the five physiographic provinces vary dramatically. Further, the characteristics of these regions influence human land and water uses (as one example - the locations of agricultural activities). Population growth and land use change, particularly increases in impervious cover, can fundamentally alter these natural systems. In terms of hydrology, communities are dependent on surface waters for the majority of water use in the basin, including drinking water supply; however, streamflows are highly variable and can decrease dramatically in the summer and fall which coincides with peak demands for this resource. Summer and fall also correspond to the greatest probability of hurricanes or tropical storms which can quickly and substantially increase river flow. Flooding from these and other events can threaten lives and damage property. Groundwater supplies are also essential to human and ecosystem needs; however, the aquifer characteristics are fundamentally different above and below the Fall Line.

Section 3 describes challenges to the sustainable management of water resources in the basin, many of which are driven by the basin characteristics discussed in this section.

3 Water Resources Challenges and Recommendations

The goal of the second phase of the comprehensive planning process is to identify challenges to water resources sustainability in the basin. **Section 3.1** and **Section 3.2** describe approaches used to develop the list of challenges and recommendations. The challenges and recommendations are presented and discussed by category in **Section 3.2.1** through **Section 3.6**. **Section 3.7** brings together the four challenge areas by discussing cross-cutting topics including floods and droughts, source water protection, climate change, and the water-energy nexus.

Phase 1 – Scoping

Phase 2 – Water Resources Issues
Phase 3 – Recommendations

Phase 4 – Document

Phase 5 – Adaptive Management

3.1 IDENTIFYING THE CHALLENGES

An initial list of challenges to sustainable water resources management in the Potomac basin was identified utilizing a four-pronged approach. First, local, regional, and statewide plans across the basin were reviewed since they presumably document the existing priorities of basin jurisdictions. Understanding that these plans may be outdated, a web-based survey was conducted to gain additional information from participating agencies where possible. A geospatial review was also conducted to determine the geographic distribution of challenges and ensure identification of interstate and/or basin-wide challenges.

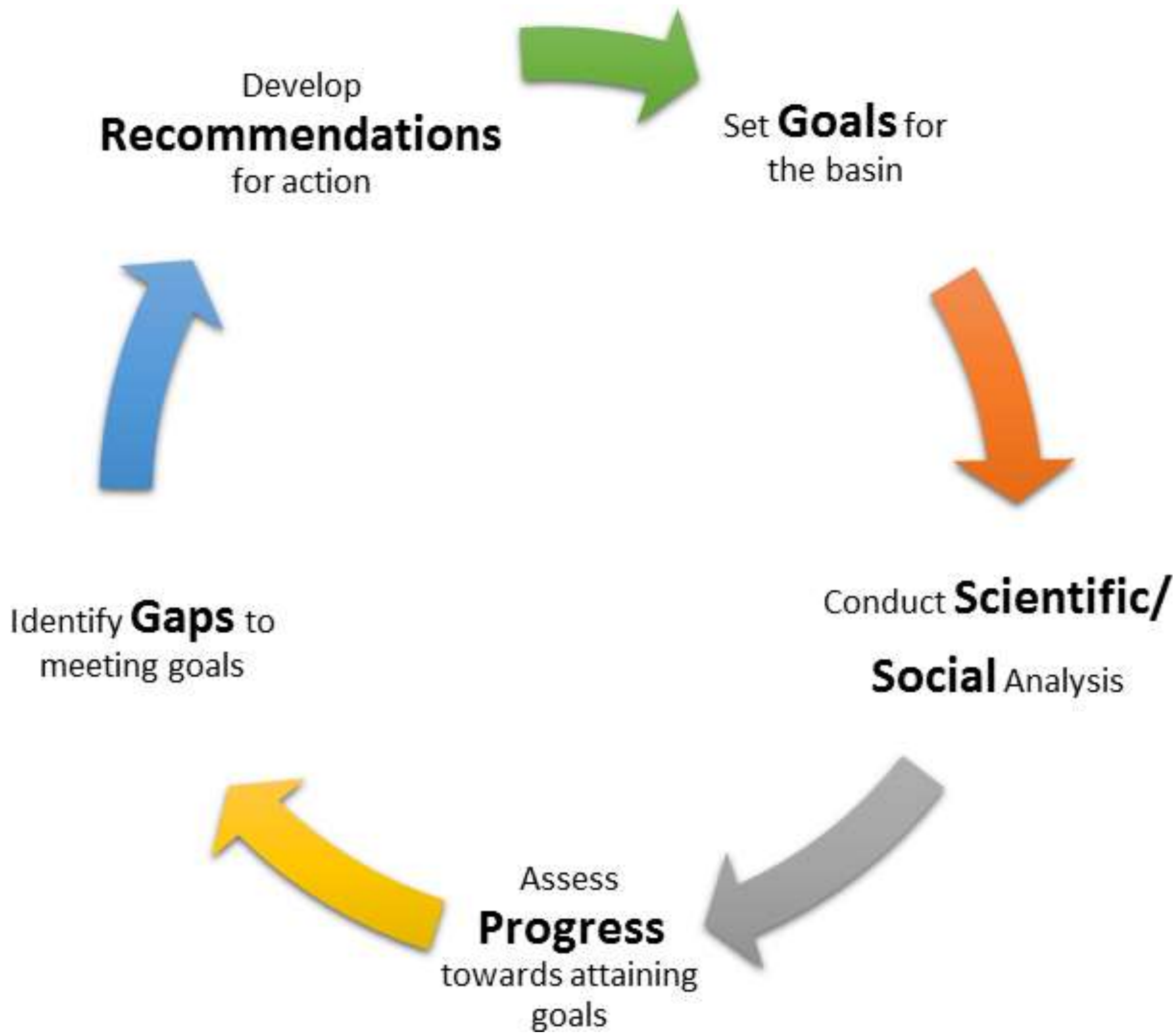
The initial list of challenges was reviewed by the advisory committee, the ICPRB Commissioners, and the email distribution list (see **Section 1.8** for a description of the stakeholder involvement process), resulting in the four broad challenge areas; namely, ensure sustainable water use and supplies, protect and improve water quality, manage human land use for sustainability, and protect ecological health.

3.2 DEVELOPING THE RECOMMENDATIONS

The process to develop and evaluate planning recommendations is provided in **Figure 17**. First, the goals were identified. Analyses were subsequently conducted to evaluate progress to date in achieving the goals. Then, areas requiring additional work were identified and formed the basis for the recommendations. The loop was closed with the adaptive management approach to plan implementation, re-evaluation, and update.

Goal statements for each challenge area were agreed to at the December 2016 advisory committee meeting. Stakeholder discussions were held with various groups regarding each topic area including advisory committee members, an information request to the email distribution list, and at a George Mason University graduate student seminar. At subsequent advisory committee meetings, members discussed the recommendation process for each topic area, brainstormed additional recommendations, and prioritized recommendations.

Figure 17. **Process for developing recommendations.**



3.2.1 OVERARCHING RECOMMENDATION

The process described in **Section 3.2** resulted in unique recommendations for each challenge area and one recommendation that is common to all challenge areas. The recommendation that is common to all challenge areas is described below.

A. DEVELOP AN INVENTORY OF ROLES, RESPONSIBILITIES, AND AREAS OF AUTHORITY AND DISCUSS HOW EFFECTIVELY CURRENT PROGRAMS AND ACTIVITIES ARE BEING CARRIED OUT

There are many organizations and individuals acting in support of the comprehensive plan's overall vision, either explicitly or implicitly. There are likely so many ongoing programs and activities that it is difficult to keep track of who is doing what (see **Appendix B** to get a sense of the myriad organizations at work with respect to each challenge area). To this end, this recommendation includes the following three parts: 1) develop an inventory of roles, responsibilities, and authorities; 2) define specific water criteria for which to compare progress related to current programs and activities; and 3) define subsequent planning efforts to evaluate progress and gaps in activities (**Figure 17**).

3.3 ENSURE SUSTAINABLE WATER USES AND SUPPLIES

3.3.1 DESCRIPTION OF CHALLENGES

The availability and use of clean, reliable, and resilient water resources are essential to the human, social, and economic health of the basin. As described in detail in the basin description section of the plan (**Section 2**), water availability and use in the Potomac basin are fairly well understood, but some data gaps exist. A preliminary annotated bibliography of research and studies conducted to evaluate water use and supplies in the basin is provided in **Appendix B**. Uncertainties arise, however, in areas of complex physical conditions (e.g. karst geology), when attempting to project current conditions to the future (e.g. climate change), and in estimating data where observed information is sparse or not available. Clarifying these uncertainties and developing an integrated understanding of water use and supplies in the basin are essential first steps to ensuring clean, reliable, and resilient water resources.

Desired Outcome:

The diverse users of the basin's water resources have clean, reliable, and resilient water resources for current and future generations.

"The North Branch Advisory Committee is an outstanding example of collaborative resource management. Evolving from a Task Force that formed in the early 1990's, the group includes diverse stakeholders such as federal and state regulatory bodies, dam operation engineers, independent corporations, anglers, and non-regulatory intermediaries such as ICPRB. By gathering this level of stakeholder diversity in one room we have become extremely efficient at identifying and resolving stakeholder conflicts, ultimately ensuring that the North Branch Potomac River as a water resource is shared fairly and managed sustainably."

- Mike Selckmann, Aquatic Biologist

Principles of this challenge area:

- Surface and ground water are linked as are water quantity and quality.
- Managing water resources requires balancing diverse, sometimes competing interests.
- Ensuring sustainable water resources has associated costs and benefits.
- High quality, long-term continuous measurements (e.g. streamflow, groundwater levels, and precipitation) are critical for effective management.
- Protecting source waters is desirable to ensure adequate, economical drinking water supplies.

3.3.2 RECOMMENDATIONS

Additional work is needed to fully evaluate progress thus far towards attaining the goal for this challenge area. Therefore, the four implementation recommendations under this challenge area primarily focus on further evaluating basin-wide conditions. Three recommendations specific to this challenge area are discussed below. The overarching recommendation discussed in **Section 3.2.1** also relates to this challenge area.

A. REPORT ON BASIN-WIDE WATER USES, PROJECTED DEMANDS, AND CONSUMPTIVE DEMANDS

Effective water use planning requires consideration of upstream uses, regardless of political boundaries, to achieve multiple interstate objectives including maintaining adequate surface and ground water supplies for diverse users during times of drought and meeting flow-by requirements throughout the basin including the Potomac flow-by at Little Falls dam. To this end, a first step in planning for sustainable water uses in the basin is to develop a clear understanding of the current and anticipated future locations, amounts, and uses of surface and ground water. The ICPRB developed a basin-wide database of withdrawals and consumptive use (Ducnuigeen et al. 2015). The database was used to estimate current and future withdrawals and consumptive use for the basin above Little Falls as part of the *2015 Washington Metropolitan Area Water Supply Study: Demand and resource availability forecast for the year 2040* (Ahmed et al. 2015). With modification, the database can be expanded and used as a resource for understanding surface and ground water use, including consumptive use, in a more spatially explicit way in the basin, including the Coastal Plain, as part of a basin-wide assessment.

WATER USE AND AVAILABILITY FACTS

- The Potomac River is the second largest source of fresh water to the Chesapeake Bay. The Susquehanna River is the number one source of fresh water.
- Over 90% of the water use above the Fall Line is from surface water, while only 20% of water use below the Fall Line is from surface water. Approximately 80% of the basin's area is above the Fall Line.
- For the 2008-2011 time period, average annual estimated consumptive use upstream of the metro Washington area is approximately 100 mgd (Ducnuigeen et al. 2015). Average annual flow at Little Falls during that same period was 5,811 mgd.
- Flows in the Potomac basin are highly variable. Maximum and minimum observed flows on the Potomac River differ by almost three orders of magnitude.
- The USGS Point of Rocks gage has one of the longest periods of record in the nation, beginning in 1895.
- Surface waters in the Potomac basin are the source of drinking water for approximately 77% of the basin population (based on 2010 U.S. Census and USGS data).

B. CONDUCT ADDITIONAL STUDIES ON WATER USES THAT FALL BELOW STATE WATER REPORTING THRESHOLDS

Each of the basin jurisdictions require water use reporting for withdrawals that meet specific criteria (Palmer and Moltz 2013); however, there is a lack of understanding about water use that falls below state reporting thresholds. This volume of water can represent a significant portion of total water use in some of the basin's interstate watersheds and impacts calculations of consumptive use in the basin. For example, it is estimated that 46 percent of the water use in the Marsh and Rock creek watersheds of Adams County, Pennsylvania – headwaters of the interstate Monocacy watershed – is unreported (Moltz and Palmer 2012). Additional evaluation of unreported withdrawals will supplement planning efforts for ensuring sustainable water use and supplies in watersheds throughout the basin. For a summary of water use reporting requirements for each state, see the section on state data in Palmer and Moltz (2013).

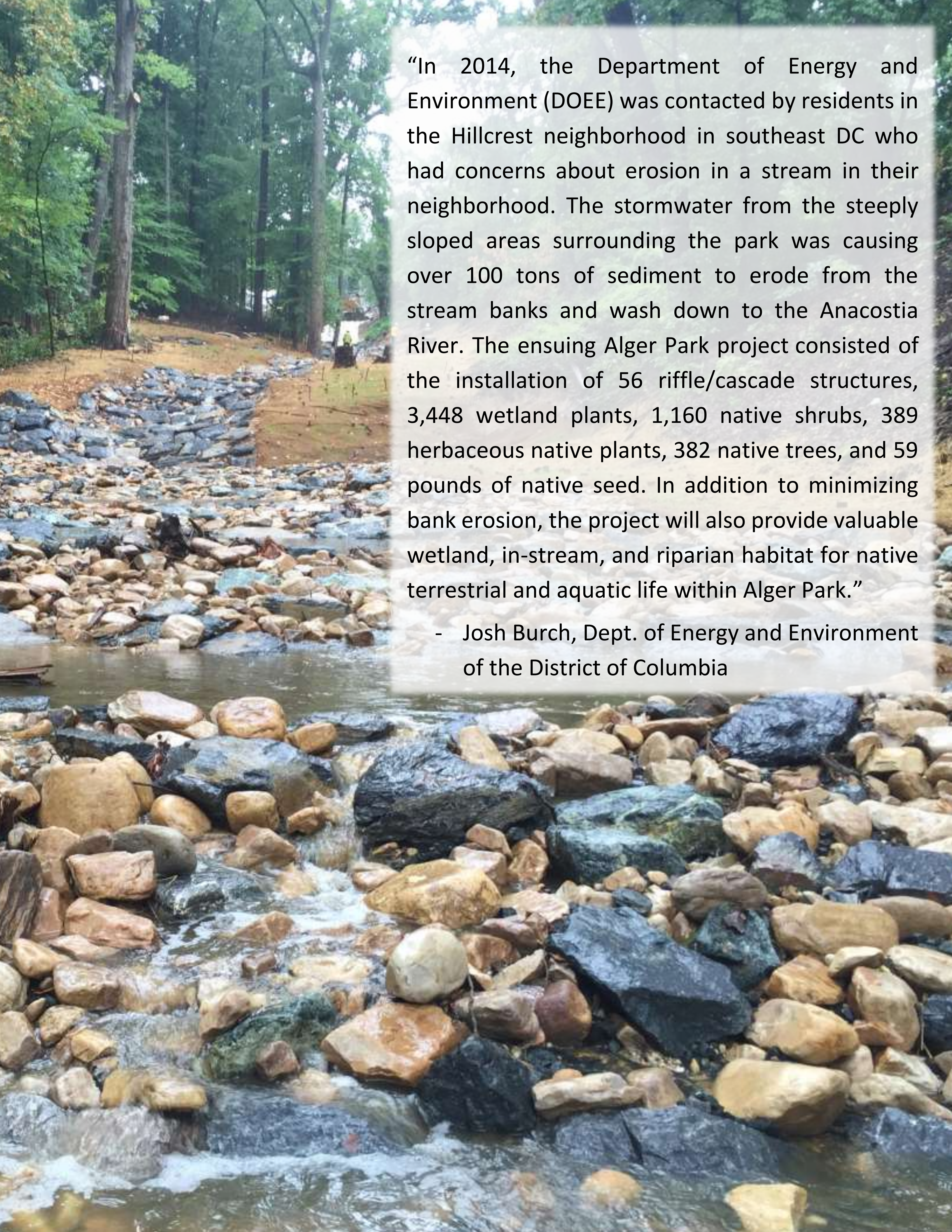
C. PURSUE A RANGE OF COMPLEMENTARY ACTIONS THAT WOULD CONTRIBUTE TO A MORE SUSTAINABLE AND RESILIENT WATER SUPPLY

There are a number of activities that could contribute to a more sustainable and resilient water supply including an evaluation of the potential impact of climate change, an examination of the efficacy of existing agreements (e.g. the Low Flow Allocation Agreement and the Water Supply Coordination Agreement), examination of water supply options, particularly in communities lacking reservoirs and other water supply storage, and protection of groundwater from contamination and overuse. Several of these activities are already underway through the ICPRB CO-OP section. Where possible, ICPRB and/or basin stakeholders should encourage the completion of these and other complementary tasks. A complete list of complementary actions discussed during the planning process is available in **Appendix A**, **Table 3**.

DEFINITIONS

Potomac flow-by: The environmental flow-by for the Potomac River at Little Falls dam is 100 mgd (155 cfs) as defined in a 1981 Maryland Department of Natural Resources (MD DNR) study and subsequently incorporated into the Low Flow Allocation Agreement. This is the river flow designated for maintaining environmental conditions.

Consumptive use: The amount of water associated with a withdrawal for water supplies (domestic, industrial, and agricultural uses) from a given resource that is not returned to the same resource and is thus unavailable to other users or aquatic communities.



"In 2014, the Department of Energy and Environment (DOEE) was contacted by residents in the Hillcrest neighborhood in southeast DC who had concerns about erosion in a stream in their neighborhood. The stormwater from the steeply sloped areas surrounding the park was causing over 100 tons of sediment to erode from the stream banks and wash down to the Anacostia River. The ensuing Alger Park project consisted of the installation of 56 riffle/cascade structures, 3,448 wetland plants, 1,160 native shrubs, 389 herbaceous native plants, 382 native trees, and 59 pounds of native seed. In addition to minimizing bank erosion, the project will also provide valuable wetland, in-stream, and riparian habitat for native terrestrial and aquatic life within Alger Park."

- Josh Burch, Dept. of Energy and Environment of the District of Columbia

3.4 PROTECT AND IMPROVE WATER QUALITY

3.4.1 DESCRIPTION OF CHALLENGES

Desired Outcome:

The waters of the basin achieve or exceed water quality standards established by the states in accordance with the Clean Water Act. New and emerging threats are proactively addressed.

The Potomac River is the second largest contributor of freshwater to the Chesapeake Bay. The health and restoration of the Chesapeake Bay is a problem of national significance as the bay is a "national treasure." For this reason, basin-wide water quality is an important part of bay restoration. The bay, however, is a long way from home for many basin residents. Local water quality problems throughout the basin can also have interstate impacts. As described in detail in the basin description section of the plan (**Section 2**), water quality issues are pervasive in the Potomac basin and in the larger Chesapeake Bay watershed. Although water quality conditions have improved from those documented in the past, continued efforts are essential to achieving the goals set forth in the CWA. These issues do not stop at political boundaries and, therefore, can be most effectively addressed through coordinated interstate planning and collaboration. Further, the basin is facing a number of new and emerging threats including, but not limited to, disinfection by-product precursors, toxic and non-toxic algae, hormones, pharmaceuticals, and personal care products. Proactively addressing these, and other, emerging issues is an important step to protecting human and ecosystem health and ensuring sufficient quantities of high quality water for the basin's many users.

A preliminary annotated bibliography of research and studies conducted to evaluate water quality in the basin is provided in **Appendix B**.

Principles of this challenge area:

- Water quality directly impacts the amount of water available for human and ecosystem uses.
- Instream water quality is affected by instream and upland processes, conditions, and activities.
- Water quality is evaluated and managed within the existing multi-level regulatory framework.
- High quality, long-term water quality measurements are critical for effective management.
- Protecting source waters is essential to ensure adequate, economical drinking water supplies.

3.4.2 RECOMMENDATIONS

As water quality management efforts fall within the national, state, and local regulatory framework, these organizations have an obligation to implement the water quality management activities within their purview. Building upon those existing efforts, the recommended actions in this plan focus on promoting information sharing and education as well as fully assessing current activities and roles. Three recommendations specific to this challenge area are discussed below. The overarching recommendation discussed in **Section 3.2.1** also relates to this challenge area.

A. PROMOTE WATER QUALITY INFORMATION SHARING

A myriad of individuals and organizations collect and/or analyze water quality data in the basin. Given the robust foundation of available data, making that data available to managers and others for decision-making is a critical component of promoting sound actions. A number of tools are available including the USEPA Region 3 long-term trends data viewer (Smith and Buchanan 2017), the ICPRB water quality data inventory (Moltz et al. 2014), and the USEPA Recovery Potential Screening Tool to name a few. Promoting information sharing through tools such as these assists decision-makers in accessing data without being limited to local jurisdictional boundaries. In addition to water quality monitoring data, information sharing such as BMP success stories, water quality improvements over time, and resources for available information is recommended to assist basin-wide and interstate efforts to protect and improve water quality.

B. EDUCATE CITIZENS AND PROFESSIONALS ABOUT WATER QUALITY IN THE POTOMAC BASIN

Education is an essential part of changing behavior and affecting changes in water quality. Water quality education may take numerous forms including: 1) assisting basin stakeholders with obtaining and interpreting water quality data; 2) convening water quality experts in a workshop forum to share data, assess completeness and gaps, and provide recommendations and priorities; and 3) developing web page(s) as a source of available information.

WATER QUALITY FACTS

- 1,266 miles of high quality, Tier II, and Tier III waters are present in the basin, 7.7% of all perennial streams in the basin (USEPA 2015).
- 3,270 miles of designated impaired waters are present in the basin (out of 16,450 stream miles in the basin). 37% are impaired for pathogens, 32% are impaired for nutrients, 26% are impaired for sediment, and 4% are impaired for metals (USEPA 2015).

C. PURSUE A RANGE OF COMPLEMENTARY ACTIONS THAT WOULD CONTRIBUTE TO PROTECTING AND IMPROVING WATER QUALITY

There are a number of activities that could enhance protection and improvement of water quality including identifying common water quality goals for the Potomac River mainstem, establishing potential roles and actions by entity that would best work toward those goals, commenting on proposed major infrastructure projects with potential basin-wide impacts, addressing areas of uncertainty to assist states in resource management, and monitoring and providing data on interstate waters. Where possible, ICPRB and/or basin stakeholders should encourage the completion of these and other complementary tasks. A complete list of complementary actions discussed during the planning process is available in **Appendix A**, **Table 4**.

"At Fox Haven Organic Farm, we have established 198-acres of riparian buffers. It is very rewarding now for me to look back over the past twenty-one years and realize that the acreages that we have established in new trees and riparian buffers will hold many positive benefits for people and wildlife for many years to come."

- Dick Bittner, Farm Manager, Fox Haven Organic Farm

3.5 MANAGE HUMAN LAND USE FOR SUSTAINABILITY

Land use is primarily managed at the local level in the Potomac basin, so implementation of land use related recommendations are likely to be most effective at the local level. The focus of this section of the plan will be on issues of interstate and/or basin-wide significance.

Desired Outcome:

Human land use in the basin supports sustainable water resource management.

3.5.1 DESCRIPTION OF CHALLENGES

Human land uses can have profound local impacts on water quality, water quantity, and ecological health (Hughes et al. 2014a). Numerous studies and activities in the basin related to the impacts of human land use activities on water resources are documented in **Appendix B**.

Land uses that "harden" the land surface (e.g. impervious surfaces like roads, parking lots, and buildings) decrease the amount of precipitation that infiltrates the soil. As a result, the amount of water that runs off over the land's surface is increased. Decreasing infiltration reduces the amount of groundwater available to plants, streams, and water wells for human use. Increasing surface runoff exacerbates erosion and associated instream sediment and nutrient problems. The MPRWA (USACE et al. 2014) found that significant streamflow alteration can be associated with very low amounts of impervious cover, less than two percent. However, all impervious cover may not be equal in its ability to alter stream flows. The ICPRB conducted a study that supported the MPRWA findings of hydrologic impacts to streamflows at low levels and identified watershed traits (e.g. high slopes, small drainage areas) that exacerbated the effects of impervious cover on stream flows (Moltz et al. 2018).

Agricultural land uses in the basin also have the potential to impact water resources sustainability. The Potomac basin has a rich agricultural history. As of 2011, 26 percent of the basin is comprised of agricultural land uses (**Section 2.4**). Agricultural activities provide many economic, aesthetic, wildlife, and social/cultural benefits. There can, however, be negative environmental impacts from agriculture including water quality degradation from sediments, nutrients, and pesticides (CBP 2018). Development in agricultural areas alters the flow regime, reduces open spaces, and potentially threatens local heritage. Some areas of the basin have taken measurable steps to preserve agricultural areas. For example, Montgomery and Carroll counties in Maryland have 93,000 acre and 60,000 acre agricultural reserves, respectively. Similar programs are underway in areas around the basin.

Principles of this challenge area:

- Human land uses can promote economic development, support thriving communities, and enhance social and cultural values.
- Human land use activities in the basin can impact water quality, quantity, and ecological health.
- Land use decision-making has human health implications, both positive and negative.
- Land use decision-making primarily occurs at the local level in the Potomac basin.

From a basin-wide perspective, the cumulative impacts of human land use activities are significant. Strategically planned human land uses that maintain hydrologic and forest connectivity, promote holistic rehabilitation and mitigation with a watershed view of upland processes, and include comprehensive monitoring can reduce negative impacts (Hughes et al. 2014a and 2014b, Harman et al. 2012). Collaboration is essential to ensuring that upstream and downstream community and ecosystem needs are met.

3.5.2 RECOMMENDATIONS

As land use decision-making is primarily a local activity, sustainable water resources management depends on the focused efforts of localities throughout the basin. Recommended actions in this plan focus on research and dissemination of information to complement these activities. Three recommendations specific to this challenge area are discussed below. The overarching recommendations discussed in **Section 3.2.1** also relates to this challenge area.

A. RESEARCH TIMELY LAND USE RELATED INFORMATION FOR DECISION-MAKING

A major challenge in managing land uses with sustainable water resources management in mind is pulling together timely information from various sources and filling in gaps where needed. As a first step in this process, the following activities are recommended:

- Compile scientific data and information on the complex relationships associated with human land use (natural resources, development, impervious cover, stormwater management, etc.).
- Identify creative, effective use of local, regulatory, programmatic, and financial tools to achieve goals.
- Develop guidance on getting “bang for your buck” out of preservation/conservation areas; improved ecosystem services in protected areas.

B. EFFECTIVELY DISSEMINATE SCIENTIFIC DATA AND INFORMATION COMPILED BY ONGOING RESEARCH

Informed decision-making at the local level requires effective dissemination of scientific data to decision-makers. Dissemination of data and information may take different forms in different areas of the basin. For example, in the D.C. metropolitan area, MWCOG may serve as an excellent resource to help disseminate information to local governments. In more rural regions, contacts with local conservation districts and planning departments may be developed to disseminate information like compiled lists of best practices to local decision-makers.

C. PURSUE A RANGE OF COMPLEMENTARY ACTIONS THAT WOULD CONTRIBUTE TO MANAGING HUMAN LAND USE FOR SUSTAINABILITY

There are a number of activities that could assist in effectively managing human land use for sustainability including application of a watershed approach for mitigation and restoration; tracking, promoting, and increasing riparian buffer protection in the basin. Where possible, ICPRB and/or basin stakeholders should encourage the completion of these and other complementary tasks. A complete list of complementary actions discussed during the planning process is available in **Appendix A**, **Table 5**.

"The American shad is an important fish, both ecologically and economically for the Potomac River. Decades of pollution, over-harvest and loss of habitat led to population decline. The ICPRB and its partners, particularly the U.S. Fish and Wildlife Service, a family of northern Virginia watermen, and thousands of local school children and teachers, worked hard to restore the American shad to the Potomac River. Thankfully, shad populations are once again strong and growing. The recovery has a ripple effect on other species, from rockfish, bald eagles and crabs in the estuary to cod and bottlenose dolphins in the ocean, creating stronger, more resilient ecosystems for the river, the bay and the eastern seaboard."

- Jim Cummins, Retired Aquatic Biologist

3.6 PROTECT ECOLOGICAL HEALTH

Ecological health is expected to improve as strategies that address challenges in the water quantity, water quality, and human land use sections are implemented. Water resources challenges of interstate or basin-wide significance that are related to ecological health but not covered in other sections are discussed in this section of the plan.

Desired Outcome:

The propagation and growth of balanced, desirable populations of aquatic life are ensured.

3.6.1 DESCRIPTION OF CHALLENGES

"Ecological" refers to the network of relationships of living organisms to one another and to their physical environment. Healthy ecological systems, or ecosystems, are resilient, relatively stable, and able to adapt and self-manage when environmental conditions change. Pennsylvania, West Virginia, Maryland, Virginia, and the District of Columbia recognize aquatic life as the definitive indicator of the ecological health of their waters. They list aquatic life as a designated use in their water quality standards, and use indicators and biocriteria to identify and report impairment of that use. For these reasons, the ecological health of aquatic ecosystems is an important challenge area in managing water resources.

Several distinct aquatic ecosystems with different assemblages of animals and plants are found in the Potomac River basin. These include the estuary (from the river's confluence with Chesapeake Bay at Point Lookout to head-of-tide just above D.C.), large rivers (including the North Branch Potomac, South Branch Potomac, Shenandoah, and Monocacy), smaller rivers, streams, reservoirs, and wetlands.

The complex network of relationships in aquatic ecosystems is disrupted by strong anthropogenic pressures, which include eutrophication, chemical contaminants, overexploitation of species, non-native species introductions, and loss of habitat and habitat connectivity. Climate change and the related rise in sea level also disrupt aquatic ecosystems. These pressures in turn exacerbate a biological community's susceptibility to other natural stressors such as disease and parasitism. As aquatic conditions degrade, undesirable shifts in species abundance occur, signs of physiological stress appear, ecosystem functions become less complex and less resilient, and amounts of unused nutrients and materials build up. The Potomac River basin experienced degrading trends in ecological health during the 20th century (e.g. Mason and Flynn [ed.] 1976, Flynn and Mason [ed.] 1978, Lippson et al. 1979, Buchanan [ed.] 1999, Jaworski et al. 2007). These degrading trends have leveled off and begun to reverse in some areas of the Potomac basin (e.g. Baldizar and Rybicki 2007, Cummins 2016, de Mutsert et al. 2017).

A preliminary annotated bibliography of research and studies conducted to evaluate aquatic life in the basin is provided in **Appendix B**.

Principles of this challenge area:

- A well-functioning ecosystem is an adaptable, self-managing network of relationships of living organisms to one another and to their physical environment.
- In-stream and watershed processes, conditions, and activities affect aquatic ecological health. The health of aquatic ecosystems, in turn, significantly impacts human quality of life, health, economics, and aesthetics.

- Long-term monitoring and interdisciplinary, holistic approaches are critical for effective management of aquatic ecosystems.
- Management actions should maintain or improve existing aquatic ecosystems (anti-degradation).
- Well-managed ecosystems should provide a range of goods and services to current and future generations (sustainable).
- Improved ecological health is expected to be an outcome of the strategies that address the challenges in other categories.

3.6.2 RECOMMENDATIONS

Management of aquatic life falls within the purview of national, state, and local regulatory agencies. Actions recommended in this plan focus on promoting coordination and information sharing as well as fully assessing current activities and roles. Three relatively broad recommendations on ecological health were selected as high priorities and are discussed individually in the sections below. Activities that complement or facilitate implementation of these three recommendations were introduced and discussed by the advisory committee and stakeholders (see **Section 3.2.1**). They are underlined below.

A. SHARE ACROSS JURISDICTIONS DATA, ANALYSIS RESULTS, AND INFORMATION ON SUCCESSFUL RESTORATION APPROACHES

This recommendation aims to increase the usefulness of existing and future monitoring data through data exchanges. Using comparable sampling and analytical methods will further enhances these data's worth and should be encouraged. Ongoing efforts to compile biological monitoring data into regional databases need support. High quality, readily accessible regional databases ultimately help resource managers coordinate and evaluate restoration and protection efforts across jurisdictional boundaries. An example is stream macroinvertebrate data collected by state and county governments in the Chesapeake watershed for water quality assessments. When raw data were combined in a common database, it enabled development of an index of biotic integrity that addresses CBP regional information needs (Buchanan et al. 2011, Smith et al. 2017). The index has facilitated large-scale studies of how stream communities respond to flow alteration (Buchanan et al. 2013, USACE 2014) and different land uses (Maloney et al. In press).

B. COORDINATE ACROSS JURISDICTIONS PLANS AND PROGRAMS THAT PROTECT ECOLOGICAL VALUE

This recommendation is intended to foster consistency in the ways aquatic communities are evaluated. Aquatic communities are oblivious to jurisdictional boundaries, yet they are managed by separate state and local entities that can, at times, work at cross purposes. Building a regional consensus on what constitutes high ecological

ECOLOGICAL HEALTH FACTS

- Nitrogen and phosphorus levels are still not low enough to prevent nuisance summer algal blooms.
- Only a little more than half of streams in the Potomac watershed have "Chessie BIBI" scores for bottom-dwelling macroinverte-brates that rank Fair, Good, or Excellent.
- A fish passageway at the Potomac Little Falls dam and long-term stocking efforts have restored American shad to healthy, sustainable levels.
- Overall, submerged aquatic vegetationin the Potomac estuary has recovered to about ¼ of its historic area.

value is an important step in coordinating jurisdictional plans and programs that protect ecological value. Aquatic communities in least-disturbed "reference" environments are viewed as healthy, and managers typically use these communities to build specific metrics and tools to assess ecological health at other locations. Common tools are Indices of Biotic Integrity (IBI) and Biological Condition Gradients (BCG) (e.g. Herlihy et al. 2008, Martínez-Crego et al. 2010, Hawkins et al. 2010, Davies and Jackson 2006, USEPA 2016, Cicchetti et al. 2017). Regional IBIs applicable to Potomac waters exist for tidal phytoplankton (Lacouture et al. 2006) and non-tidal stream macroinvertebrates (Smith et al. 2017). BCGs are descriptive models of ecosystem response to stress and have been developed for parts of the Potomac basin. They are the basis for establishing tiers of aquatic life use used in water quality assessments (e.g. PA DEP 2012). Reference environments can also be used to establish the water quality and quantity levels that improve and maintain ecological health.

C. SUPPORT AND COORDINATE PROGRAMS THAT IDENTIFY, PROTECT, CONSERVE, RESTORE, ENHANCE, AND CONNECT NATURAL AREAS, ESPECIALLY ALONG WATERWAYS

This recommendation is intended to promote ecosystem resiliency. The outcomes are primarily water quality conditions and natural flow regimes that sustain biological diversity and health. The recommendation encompasses riparian corridors and floodplains as well as surface waters. There are several major components. One involves the consideration of ecologically valuable waters in all land and water use planning. All four states in the Potomac watershed have identified habitats and waters with high ecological value. However, the protected status of these waters and their associated anti-degradation policies are not always reflected at the local planning level. Local jurisdictions need to update master plans and government regulations to manage the environmental impacts of development, ensure ecological protections, and meet state guidelines. Critical to this effort will be inventories of natural resources on proposed development sites and specific protections for key resources such as forest stands, steep slopes, streams, wetlands, and environmental buffers. A second component involves improving coordination between multiple, diverse restoration efforts to maximize and sustain recovery of aquatic habitats and biological communities. These efforts directly involve actions taken to meet TMDLs; construct stormwater retention systems; manage invasive species; set aside and protect forest, wetlands, and stream buffer lands; and allocate water resources to meet aquatic life needs. Coordinated restoration efforts avoid duplicative or cross-purpose actions. A third component involves long-term planning to anticipate and prepare for the impacts of climate change and sea level rise. The goal is to sustain, as the environment changes, the ecosystem resiliency that has been recovered.

Other activities that can reinforce ecosystem resiliency were suggested. They include:

- support and coordinate programs that promote native aquatic species;
- restore and protect functioning wetlands for the purpose of improving ecological health, and not to substitute for wetland areas removed for development;
- restore and protect oyster reefs for the purpose of improving ecological health of tidal waters; and
- maintain thriving recreational fisheries as a way of encouraging outdoor experiences and fostering environmental stewardship.

D. PURSUE A RANGE OF COMPLEMENTARY ACTIONS THAT WOULD CONTRIBUTE TO PROTECTING ECOLOGICAL HEALTH

Actions involving stressor identification and refugia protection were also suggested by the Advisory Committee or stakeholders, and they complement the recommendations above. Stressor identification is an important prerequisite to developing TMDLs for biologically impaired waters. Identifying the factors causing harmful algae blooms and excess filamentous algae and the factors negatively impacting macroinvertebrate and fish communities guides the development of a TMDL. Further identifying factors harming fish health and leading to intersex fish and fish kills may eventually change land use practices and how pesticides, herbicides, and pharmaceutical products are used. The protection of refugia, or areas where the biological communities are minimally disturbed, is the focus of multiple private and state conservation programs. Some programs prioritize, acquire, and protect lands with high ecological value. Others identify rivers with outstanding natural, cultural, and recreational values and lobby to protect river segments as critical fish habitat. A complete list of complementary actions discussed during the planning process is available in **Appendix A**, see the section on ecological health.

3.7 CROSS-CUTTING CHALLENGES

This plan's four challenge areas (ensuring sustainable water uses and supplies, protecting and improving water quality, managing human land use for sustainability, and protecting ecological health) are linked in many ways. Improving any one area provides benefits for other areas. For example, if all other areas are managed proactively, improved ecological health is an expected outcome. Similarly, if land use is managed sustainably, water quality and ecological health may be improved. This section discusses cross-cutting themes that transcend any one challenge area; namely, floods and droughts, source water protection, climate change, and the water-energy nexus.

In addition to the cross-cutting challenges discussed in the following sub-sections, there are a number of issues for which there is a great deal of debate about real or potential water resources impacts like oil and gas pipelines, coal ash, mining impacts, and hydraulic fracturing (fracking). The ICPRB will continue to track and make information available to the public about these issues. It is recommended that other basin stakeholders do similarly in an effort to promote continued dialogue on these and other emerging, cross-cutting issues.

3.7.1 FLOODS AND DROUGHTS

Due to its geography, the Potomac basin can experience floods throughout the year (as they are not dependent on snowmelt) and droughts typically occur in the summer and fall with high evapotranspiration and low precipitation (USACE et al. 2014) (**Figure 8**). Climate change has the potential

to make these events more frequent and more severe in the region (Ahmed et al. 2013).

Floods and droughts are issues of interstate concern. Damaging floodwaters can travel downstream, impacting communities and ecosystems. Flooding can threaten lives and cause significant damage to buildings and other infrastructure. Droughts require careful consideration and management of cumulative water needs. Several efforts are underway to plan for the potential effects of floods and droughts, described below.

The three major WMA water suppliers (Washington Aqueduct Division of USACE, Washington Suburban Sanitary Commission - WSSC, and Fairfax Water) rely on the cooperative management of Potomac River supplies during times of drought. The ICPRB CO-OP was formed in 1979 to coordinate this effort in response to record low flows in the 1960s and '70s. The guiding principles behind the cooperative agreement were established as part of the Low Flow Allocation Agreement of 1978 and the Water Supply Coordination Agreement of 1982.

A series of hazard management plans have been developed in the basin to minimize the negative effects of flooding, droughts, and other natural hazards. One such example is the *Metropolitan Washington Water Supply and Drought Awareness Response Plan* (MWCOG 2000).

Previous studies have identified geographic areas of flooding concern. For example, USACE (2004) identified Martinsburg, West Virginia; Frederick, Maryland; and Alexandria, Virginia, as areas of particular interest. Flood risk management activities recommended in the 2004 study included environmental flow protection, flood protection and management, hydrologic and floodplain function restoration, and water supply and sustainable watershed management.

As a threat to life and property, planning and mitigation are needed in some areas to reduce flood risk. For this reason, Maryland, the District of Columbia, and Virginia coordinate and collaborate through Silver Jacket Interagency Teams. An example interagency project is flood inundation mapping for the Potomac River in the District of Columbia area.

The North Atlantic Coast Comprehensive Study (USACE 2015b) is another recent effort to manage flood risk in the region. Specifically, the study aimed to "1) reduce flood risk to vulnerable coastal populations, and 2) promote coastal resilient communities to ensure a sustainable and robust coastal landscape system, considering future sea level rise and climate change scenarios." The study concluded that the District of Columbia is a high-risk area that warrants additional analysis to address coastal flood risk.

3.7.2 SOURCE WATER PROTECTION

The availability of clean drinking water is a concern that unites all basin stakeholders. With millions of people dependent on the Potomac River and its tributaries for drinking water (and the rest dependent on the associated groundwater resources), protection of surface and ground source waters is essential. Threats to drinking water supplies include cross-cutting issues described under the other challenge areas like sustainable water use, water quality impairments, and altered hydrologic conditions resulting from urbanization in addition to vandalism, inadvertent contamination (e.g. spills), and potential terrorism. Interstate coordination of source water protection activities is ongoing through the Potomac River Basin Drinking Water Source Water Protection Partnership (DWSPP), coordinated by ICPRB. DWSPP is a basin-wide partnership of water suppliers and government agencies working to ensure safe drinking water.

Efforts have been made to prioritize source water protection areas across the basin (Weidner 2009); identify source area issues for suppliers across the basin; and conduct source water assessments, including one for the District of Columbia whose assessment area covers 11,500 sq. mi. of the Potomac Basin (Vann et al. 2004). In partnership with the WMA water utilities, the MWCOG, USEPA Region 3, and various state agencies, efforts are underway to update the region's source water assessments to ensure that accurate information is available to inform source water protection activities to protect regional water supplies. The update will include specific activities like mapping federal and state data of potential sources of contamination, assessing risk, and prioritizing concerns. Tools available to support these and other source water protection efforts include USEPA's Drinking Water Mapping Application to Protect Source Waters (DWMAPS) and a Potomac-specific version of the WaterSuite application. MWCOG has been a critical proponent of tailoring WaterSuite to the Potomac suppliers' needs.

A number of recent spills in and around the Potomac basin including the 2014 Elk River chemical spill in Charleston, West Virginia (outside the basin), and the 2015 North Branch Potomac latex spill in Westernport, Maryland, have underscored the need for effective spill response and prevention efforts in the basin. Although there are ongoing activities in the basin (e.g. regional exercises, after action meetings, and interstate notification procedures), lessons learned from recent events have highlighted ways in which current coordination can be enhanced. Examples of future action items include improved information sharing capabilities, sources of chemical information, and emergency response monitoring needs. Lessons learned from the Elk River spill (outside the basin) are available online.

A pervasive threat to source waters is diffuse pollution that is spread across the landscape by human activities. These pollutants can include sediments, nutrients, toxics, pathogens, trash, and emerging contaminants to name a few. When rain falls or snow melts, the pollution is transported to local waterways, impacting the quality of downstream drinking water supplies.

Source water protection is linked with each of the other challenge areas discussed in this plan because the practices for protecting source waters achieve multiple watershed benefits. In addition, clean water supplies for drinking water are also supported by regulations and policies affecting land use and pollution.

The Challenges of Deicing Salts

Deicing salts are increasingly applied during winter storm events for the important purposes of maintaining public safety and economic activity. Once in the environment, however, these salts can have major impacts on the natural environment as well as property and infrastructure, including drinking water systems. It has been demonstrated that reducing salt applications while maintaining needed benefits is possible. For further information, see **Appendix B**.

3.7.3 CLIMATE CHANGE

Climate change is a transboundary issue that has the potential to affect all jurisdictions in the Potomac basin. In Maryland alone, temperature is expected to rise 2.7 to 5 °C in the summer months and 2.2 to 3.9 °C in the winter months over the next century. In general, precipitation is increasing as temperatures rise; however, specific projections for the region are mixed. Climate change may also lead to increased frequency and intensity of extreme events (i.e. floods and droughts) (Ahmed et al. 2013). In fact, the Mid-Atlantic region is already experiencing the effects with 12-20 percent increases in the number of major weather events relative to the previous century (Williamson et al. 2008). By working together and leveraging resources, basin resilience can be strengthened.

Adaptive management will be a key to managing water resources in a changing climate. Since forecasting climate change includes a large component of uncertainty, adaptive planning efforts will be required. That is, as climate change science and associated prediction tools improve and the community's tolerance to risk changes, the plan for managing water resources under the expected conditions will likely require revision.

ICPRB CO-OP conducted assessments on behalf of the CO-OP water utilities to understand the potential impacts of climate change on water availability and use. Specifically, ICPRB CO-OP prepared a climate change module as part of the 2010 demand study that evaluated the resiliency of the water supply system under multiple climate change scenarios (Ahmed et al. 2013). The 2015 ICPRB CO-OP demand study (Ahmed et al. 2015) built on the previous efforts by including a sensitivity analysis of a range of precipitation and temperature changes in the basin based on values obtained in the previous study. Implementing the recommendations from these studies may provide an integral resource for understanding expected future land and water uses, population growth, and the effects of potential climate change scenarios on water resources availability and use. In addition, the water supply alternatives study evaluated the ability of ten alternatives to help the WMA water supply system meet the challenges of population growth and climate change (Schultz et al. 2017).

By working together and leveraging resources, basin resilience to climate change can be strengthened.

3.7.4 WATER-ENERGY NEXUS

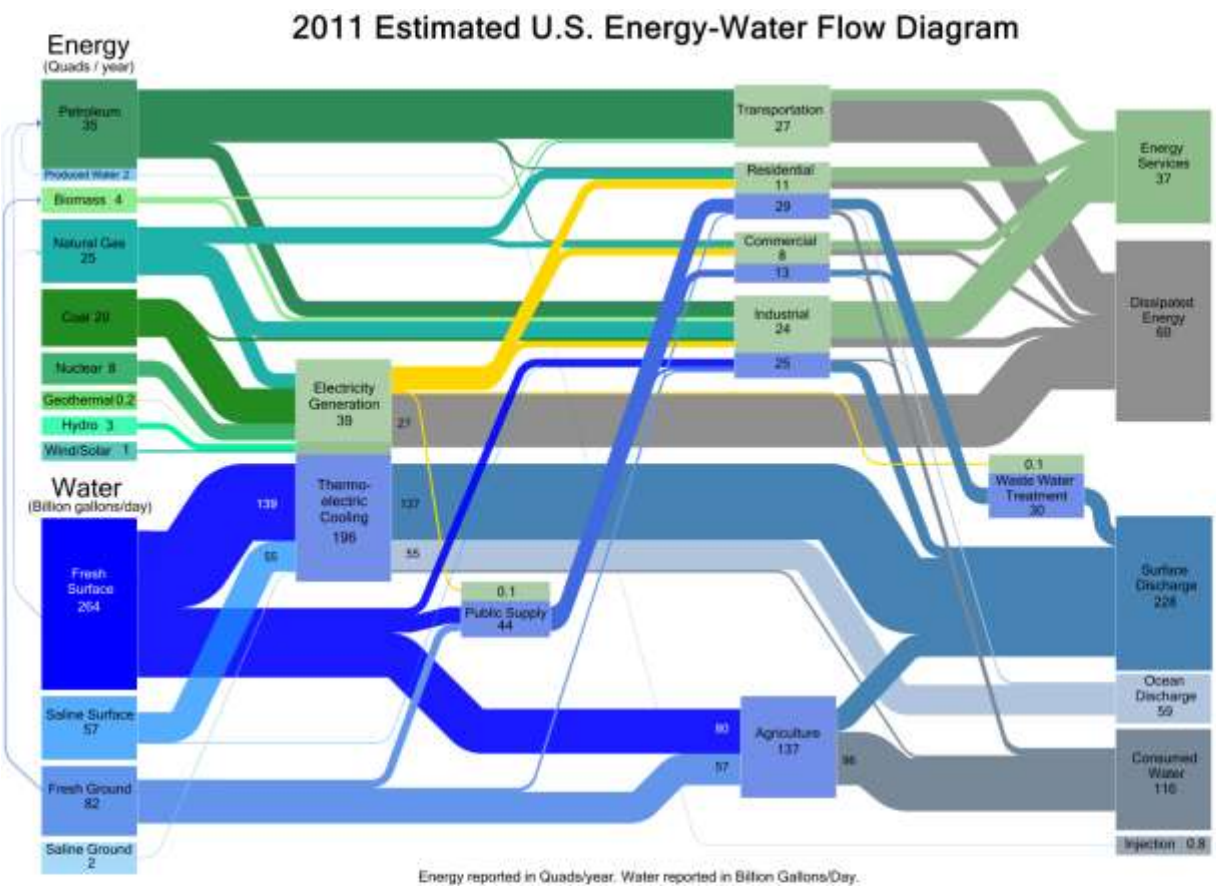
Water and energy systems are interdependent. Energy extraction and production and electrical generation require water, sometimes large quantities of water. The usability of water resources can be negatively impacted during these processes. Energy is required again in the treatment and final release of the wastewater generated during the energy production process. Production of drinking water, on the other hand, requires energy for multiple purposes including withdrawing the water from its source, treating it, distributing it to the consumer, and treating and discharging the wastewater. The development of energy and water resources have traditionally considered the other only as a necessary ingredient. Improving the efficiency of each has typically been accomplished with little consideration of the impact on the other. In recent years, however, the critical interconnections have been investigated (**Appendix B**).

One such study developed recommendations within the United States Department of Energy (USDOE) for maximizing efficiencies at the water-energy nexus (Bauer et al. 2014). The report identified six strategic pillars, quoted below, to serve as their guiding principles. These pillars are examples of the types of actions being taken by other organizations to promote sustainability at the nexus of energy and water.

- *Optimize the freshwater efficiency of energy production, electricity generation, and end use systems*
- *Optimize the energy efficiency of water management, treatment, distribution, and end use systems*
- *Enhance the reliability and resilience of energy and water systems*
- *Increase safe and productive use of nontraditional water sources*
- *Promote responsible energy operations with respect to water quality, ecosystem, and seismic impacts*
- *Exploit productive synergies among water and energy systems.*

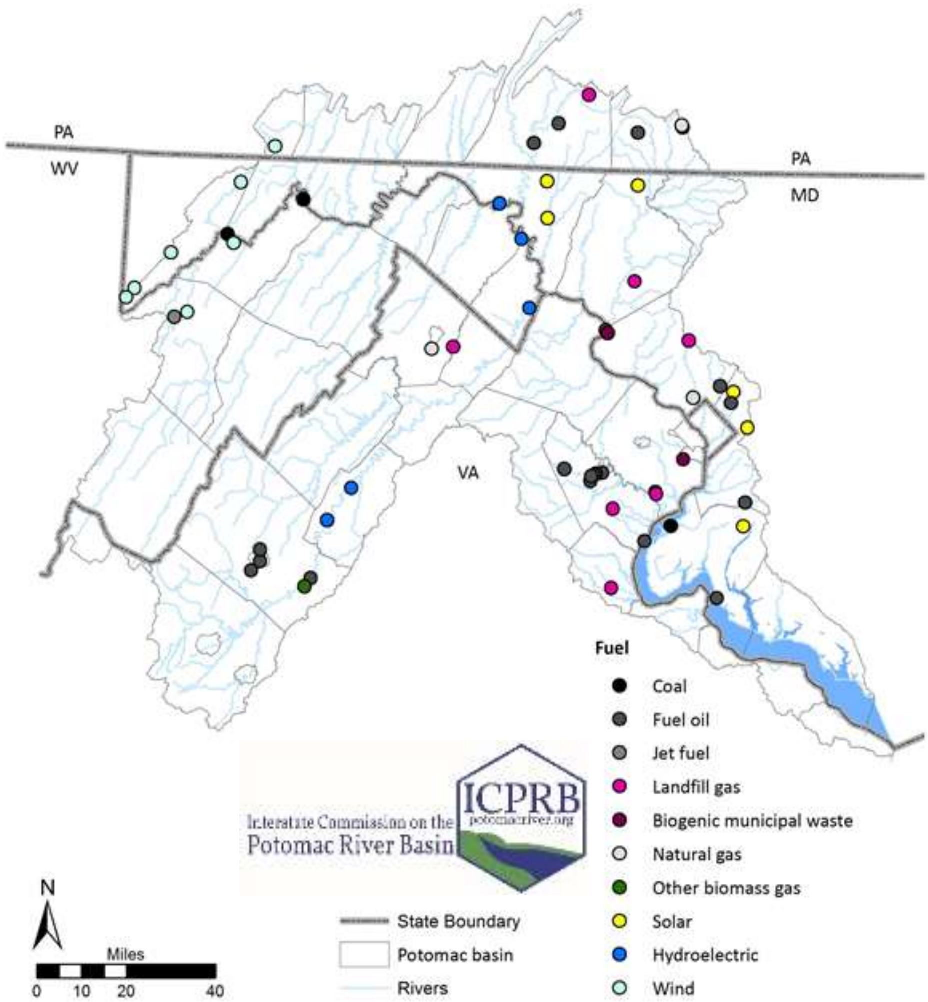
To illustrate the interconnectedness of water and energy, USDOE produced a Sankey diagram (**Figure 18**) showing the magnitude of the water and energy flow in the United States from sources to sinks (Bauer et al. 2014). This diagram attempts to show the relative magnitude of sources, sinks (or discharges), and general uses of water and energy, plus the interaction between water and energy. Units used are quadrillion BTUs (Quads) for energy and billion gallons per day for water. USDOE is currently working on similar Sankey diagrams for each state and possibly one for the Potomac basin (personal communication, USDOE, 2017).

Figure 18. **Sankey diagram of energy-water flows in the U.S. (reprinted from Bauer et al. 2014). Quads are quadrillion BTUs. It can be seen, for example, that thermoelectric cooling uses 139 billion gallons per day of fresh surface water nationwide, substantially more than agriculture (80 billion gallons per day).**



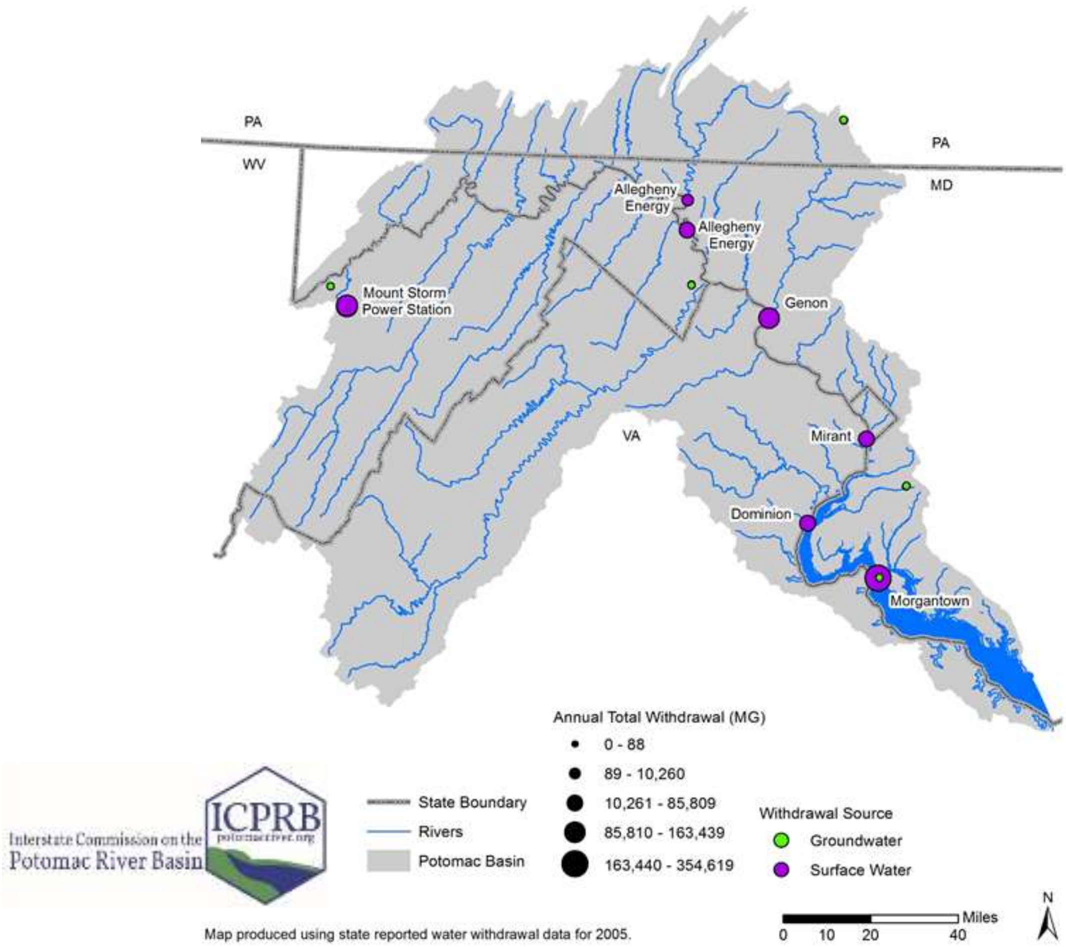
Power plants by fuel type in the Potomac basin are shown in **Figure 19**. The relationship between these power generation facilities and water resources varies significantly. Not all power generation processes have water impacts (e.g. solar, wind, and landfill gas energy generating facilities) while others like thermoelectric generation may have significant water impacts for cooling. Many thermoelectric power plants have closed-loop systems in the Potomac basin. Those thermoelectric plants that are not already closed-loop systems are expected to make the conversion from once-through systems. Closed-loop systems require smaller water withdrawals but, overall, may have higher consumptive use depending on the specific design (see consumptive use discussion in **Section 2.5**). Power plants can also have numerous water quality impacts including those associated with coal mining, acid mine drainage, and coal ash ponds.

Figure 19. **Power generation facilities by fuel type. Data source: EIA-923 Report 2015.**



State-reported water withdrawals for power generation in the Potomac basin as of 2005 are shown in **Figure 20**. Power plants withdraw more water than any other use type (at 68 percent of the basin total), but have only the second largest consumptive use (at 12 percent of the basin total) (2005 data, Kenny et al. 2009).

Figure 20. **State-reported water withdrawals for power for the year 2005.**



An example of a regional water-energy challenge is the increase in data centers, especially in northern Virginia. These facilities are large users of both energy and water. A recent study by USDOE found that on-site water consumption is estimated at 1.8 liters (0.46 gallons) per kilowatt hour of total data center site energy use. Nationally, data centers that have 15 megawatts of capacity consume between 80 and 130 million gallons annually (Shehabi et al. 2016). Many facilities use reclaimed, treated effluent which has implications on overall consumptive use and sustainability as water once returned to the basin is diverted and no longer available for downstream use.

Transporting energy resources like oil and gas via pipelines also poses a potential risk to water resources. There are five natural gas interstate transmission pipelines and two petroleum product interstate transmission pipelines in the basin. These are pipeline networks with main transmission lines and numerous local connections. An additional interstate natural gas transmission pipeline has been proposed for the western portion of the basin and is under review. There are no crude oil pipelines in the basin. This data was obtained from the National Pipeline Mapping System under the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration.

Promoting sustainable water resources management in the Potomac basin requires consideration of the interconnections between water and energy. This is an evolving field and should be incorporated as appropriate in future iterations of the comprehensive plan (see **Section 5.3** for a discussion of the adaptive review process).

4 IMPLEMENTATION

4.1 ROLES AND RESPONSIBILITIES

All governmental agencies, water resources related sectors, private and non-profit organizations, and individuals have a role to play in the plan's implementation. A general description of each is provided in the sections below.

4.1.1 ICPRB

Section 1.2 provides an introduction to the ICPRB organization. The ICPRB Strategic Plan, revised in 2015, describes ICPRB's role in the basin as complementing:

> *…the ongoing work of the states and Federal government in the Potomac River Basin, in areas where the Commission has the mandate, expertise, comparative advantage and financial resources. The Compact specifically gives the ICPRB powers with regard to water and associated land resources in several areas, including:*
>
> - *collecting, analyzing and distributing technical and other data; and conducting studies and sponsoring research;*
> - *cooperating with state, Federal, local governmental and nongovernmental agencies to promote uniform laws, rules or regulations;*
> - *disseminating information and recommendations to the public;*
> - *cooperating with, assisting and providing liaison among public and nonpublic agencies and organizations in formulating and coordinating plans, programs and cooperative action;*
> - *reviewing and commenting on the plans and programs of public or private agencies and organizations; and*
> - *revising and recommending reasonable minimum standards for treatment of sewage and other wastes and for water quality in streams.*

The ICPRB role in the plan's implementation is focused on these areas with the primary goals of acting as a catalyst and as an implementer of the plan's recommendations.

4.1.2 FEDERAL GOVERNMENT

Multiple federal agencies have responsibilities that relate to the management and use of water resources in the Potomac basin. Responsibilities vary depending on the federal laws that each agency carries out. Federal agencies, variously, enforce laws, collect and provide to the public important data, conduct research, and provide technical and financial assistance to states, local governments, and private parties. The USACE report in **Appendix D** documents the breadth of federal authorities, expertise, and resources that federal agencies bring to water management efforts in the Potomac basin. That report concludes with three recommendations for ICPRB (and this plan):

1. Continue to follow and be engaged in the Chesapeake Bay Program Phase 3 Watershed Implementation Plan (WIP) process. The restoration of the Bay is the largest water quality and ecological restoration effort in the U.S. Mid-Atlantic. The Potomac basin accounts for about 25% of the Bay watershed and so the federal and state programs intended to restore the Bay will benefit the Potomac and, similarly, Potomac restoration efforts will benefit the Bay.
2. Continue to follow and request assistance from USACE to clip out the Potomac watershed from the larger Chesapeake Bay Comprehensive Plan, currently in development by the USACE (USACE 2015a). The databases that USACE is developing for their Plan will include useful data for the Potomac.
3. Consider adopting goals, objectives, timeframes, indicators, monitoring plans/methods, data repositories, and tracking efforts into the ICPRB comprehensive plan to dovetail with other large scale federal and state programs. The authorities, expertise, and resources that the federal agencies have make them important, and oftentimes essential, partners in restoration and protection of the basin.

The existing regulatory framework, and the agency responsibilities that stem from it, play an integral role in water resources management. A continued, strong commitment to these efforts is needed to sustain the benefits.

4.1.3 STATE GOVERNMENT

State agencies are empowered and delegated in a variety of ways to manage water and other natural resources within their jurisdiction. State agencies with responsibility and authority for water resources may work to support plan implementation by:

- Continuing and, where possible, intensifying ongoing efforts to address water quality and quantity issues in the context of the CWA and other relevant legislation
- Supplying data and information to improve water resources management
- Supporting education and outreach efforts to improve water resources stewardship
- Funding cooperative efforts when possible to address the identified challenge areas
- Coordinating efforts among state agencies responsible for water resources related programs, regulations, and oversight
- Coordinating across state lines to promote and implement comprehensive watershed management

4.1.4 REGIONAL GOVERNMENT

There are a variety of regional organizations related to water and land resources. Each organization has a unique function and may find ways to support common goals and activities. Two examples are the Potomac River Fisheries Commission (PRFC) which regulates the fisheries of the mainstem of the tidal Potomac River, and MWCOG which currently is focused on regional infrastructure, economic competitiveness, and transportation in the WMA. Actions that regional entities may be involved in include:

- Coordinating with states and other regional entities
- Collecting, analyzing, and supplying information and data to improve water resources management at the basin, regional, and sub-watershed scales
- Leading and supporting watershed-based water resources planning and management at the local and regional level
- Enhancing communication and cooperation within and between related organizations

4.1.5 MUNICIPAL GOVERNMENT

Many of the challenges defined in this plan not only affect basin-wide or interstate resources, but also impact municipalities in the basin. In addition, a number of these issues fall within the authority of municipal government (e.g. land use planning and zoning). Municipalities are encouraged to play a role in this plan's implementation by taking action when possible on affecting change and addressing local impacts related to these issues. Further, the plan may serve as a supporting resource when seeking implementation funding.

4.1.6 NON-GOVERNMENTAL ORGANIZATIONS

Non-Governmental Organizations (NGOs) play an essential role in protecting the basin's resources through research, community engagement, communication, education, implementation of conservation and mitigation projects, and policy and partnership development. NGOs can participate in the plan's development within the framework of their existing activities by promoting partnerships and working with partners towards achieving the common vision for the basin. Examples of NGOs in the basin include the Potomac Conservancy, The Nature Conservancy, the Isaak Walton League, Trout Unlimited, and the Montgomery Countryside Alliance.

4.1.7 ACADEMIC INSTITUTIONS

Numerous universities in the Potomac basin and around the region promote development of new, highly qualified water resources professionals. Some examples include George Mason University's Department of Environmental Science and Policy; the University of the District of Columbia's College of Agriculture, Urban Sustainability, and Environmental Sciences; the Department of Civil and Environmental Engineering at the University of Maryland; and West Virginia University's College of Agriculture, Natural Resources, and Design. Professional and volunteer mentors foster stewardship in the basin's youth through classroom and field experiences. In addition, these institutions provide valuable scientific and policy related research. A basin-wide emphasis on science and education will serve to underscore the importance of these efforts for all.

4.1.8 DRINKING WATER SUPPLIERS

Drinking water suppliers are responsible for providing safe and reliable potable water to residents, businesses, institutions, and governmental agencies within their service areas. This task is essential for human health and hygiene, fire protection, commerce, economic development, and operation of government. The success of the drinking water utilities depends on long-range proactive planning and management, system resilience, and emergency response preparation and activation activities. DWSPP is one mechanism that some suppliers in the basin use to engage in source water protection activities. In addition, they are dependent on the decisions and actions of the myriad stakeholders throughout the basin, especially those upstream.

4.1.9 OTHER COMMERCIAL ENTITIES

Many businesses require water to cultivate food or produce materials. In the Potomac River basin, these include agriculture, fishing (and recently aquaculture), forestry, mining, and manufacturing. Agriculture is an important economic and cultural component of the basin's past, present, and future. Environmental stewardship on behalf of the agricultural community is one part of sustainable water resources management. Potomac seafood harvests were the envy of the East Coast historically, and commercial and recreational fisheries are still important economic drivers in the region. The deleterious economic and ecological impacts of overfishing were one reason the Chesapeake Bay Program was established in 1984. Sustainable fisheries have consistently been a major programmatic goal of the bay restoration since then. Over half of the basin is covered in forests. Those forests play a significant role in maintaining healthy ecosystems, protecting water quality, and enhancing public health to name a few. Forest management plays a critical role in the implementation of this plan. Mines, and more recently fracking, have yielded abundant fossil fuels and ore, but mining practices severely damaged streams and rivers in the western part of the basin. Similarly, outfalls from manufacturing and power generating plants—many of which rely on clean water—have negatively impacted local downstream water resources. These commercial entities are encouraged to participate in the implementation of this plan and to proactively engage in the protection and maintenance of the basin's water resources by:

- Taking advantage of management practices expertise and/or implementation funding when possible
- Serving as a role model for their community in conserving and protecting natural resources and applying sustainable management practices
- Engaging and educating basin stakeholders, when possible, on the importance of environmental sustainability and the goods and services derived from healthy ecosystems
- Promoting public awareness and access to forest and agricultural reserves

4.1.10 INDIVIDUALS

Each person of the basin has many opportunities to make positive impacts on the resources. Individuals are encouraged to participate in the plan's implementation through:

- Considering the water resources consequences of actions and choices
- Applying sustainable practices at home when possible
- Supporting no or low-impact development and maintaining "green spaces"
- Participating in local decision-making and volunteering in local efforts
- Learning about water resources, sharing that knowledge with others, and leading by example

4.2 POTENTIAL FUNDING SOURCES

The scale of water resources issues in the Potomac basin is larger than any one organization. As such, addressing the issues requires working collaboratively in partnership with numerous organizations. As each organization has issues and geographic areas of particular interest, matching mutual interests on specific issues to leverage funding resources will be key. Funding opportunities for implementation activities are available at various levels of government, the private sector, and through non-profit organizations. Each of these are discussed in more detail in this section. Piecing together applicable funding sources for any particular effort will require case-by-case evaluation. As such, this is not an exhaustive list and does not indicate a commitment of funding by any organization discussed.

Federal funding options are available through numerous water-related agencies and include, but are not limited to, the U.S. Department of Agriculture's (e.g. the Conservation Reserve Program, the Conservation Reserve Enhancement Program, and the Environmental Quality Incentives Program), the USACE (e.g. Planning Assistance to States), the USEPA (e.g. Section 319 Funds and Clean Water State Revolving Fund), and through the Water Resources Development Act, administered by USACE.

Additional regional funding programs that promote Chesapeake Bay cleanup efforts are documented by the Chesapeake Bay Program and include the Chesapeake Bay Stewardship Fund, the National Oceanic and Atmospheric Administration's (NOAA) Chesapeake Bay Watershed Education and Training grants, and the Chesapeake Bay Trust among others.

Funding from state programs may assist in state-specific implementation activities. Each jurisdiction has a unique set of funding opportunities. In Virginia, for example, funding programs are available for forest and agricultural activities through the Virginia Conservation Assistance Program and Virginia Forest Stewardship Program just to name two. West Virginia Department of Environmental Protection has watershed planning funding to help carry out their USEPA-approved water quality management planning activities.

Federal Funding Sources (by topic)

- Source water protection
- Disaster funding opportunities for water and wastewater utilities
- Watershed protection
- Water Finance Clearinghouse
- Funding in the Chesapeake Bay watershed

State Funding Sources (by topic)

- West Virginia water and wastewater funding sources
- Funding sources for West Virginia watershed groups
- Maryland watershed restoration assistance directory
- DOEE grants and other funding
- PA DEP grant and loan programs
- VA DEQ clean water financing

Local-level implementation of this plan's recommendations as well as complementary activities is encouraged. Local funding opportunities are numerous and should be identified based on the locations and needs of specific projects. Conservation districts are one option.

Private sector funding has made significant contributions to water resources sustainability and may be a viable option for projects in the basin. As examples, water is a priority area for the Coca-Cola Foundation as is sustainability for the Walmart Foundation. Water utility companies sometimes offer grants like the water supply stakeholder outreach grant program of Fairfax Water as do power companies such as the Dominion Energy Charitable Foundation.

Non-profit organizations such as The Nature Conservancy, the National Fish and Wildlife Foundation, and the Virginia Environmental Endowment are a potential source of implementation funding. In other watersheds, non-profits have contributed substantial resources to promote water resources sustainability including the William Penn Foundation's commitment of $17 million to protect clean water in the Delaware Watershed, the Joyce Foundation's commitment in the Great Lakes region, and the Schuylkill Action Network's River Restoration Fund.

4.3 INTEGRATION WITH OTHER PLANS

This basin-wide water resources plan builds on and provides support for state, regional, and local water resources plans in the basin by drawing attention to the pervasive issues in the basin, providing opportunities to leverage funding, and offering a broad, hydrologically based perspective.

Fifty-five state, regional, county, and local plans were reviewed as part of the development of this plan (**Appendix C**). As such, this plan is aligned with priority issues that have been identified at various levels of government and are interstate and/or basin-wide in nature.

This effort also complements plans that extend beyond the borders of the Potomac basin such as the Chesapeake Bay Comprehensive Water Resources and Protection Plan (USACE 2015a) and the North Atlantic Coast Comprehensive Study (USACE 2015b).

Watershed-based plans like TMDL Implementation Plans are also working towards common goals (e.g. the Chesapeake Bay Watershed Implementation Plans). By planning for the implementation of on-the-ground measures to improve water quality, numerous synergistic benefits can be achieved. Further, implementation progress to date has been tracked by various outlets like the Potomac Conservancy's Potomac Report Card.

5 Strategy for Adaptive Implementation

This basin-wide plan is a 15-year plan that will be will be reviewed every five years to evaluate implementation progress and identify actions over the next five-year period. As part of that review, ICPRB will evaluate progress in collaboration with other stakeholders utilizing the milestones and measures of success described in the plan. The first update will take place in 2023. The first complete review of the comprehensive plan will occur in 2033.

Phase 1 – Scoping

Phase 2 – Water Resources Issues

Phase 3 – Recommendations

Phase 4 – Document

Phase 5 – Adaptive Management

5.1 MILESTONES

The purpose of this section is to identify measurable milestones to determine whether recommendations are being implemented as planned. The milestones discussed in this section focus primarily on ICPRB activities; however, achievement of the goals set forth in this plan requires collaboration and partnership with numerous organizations.

Short- and long-range milestones for each challenge area are described. Milestones for implementation of the overarching recommendation are also described by challenge area. Short-term milestones are activities that will be accomplished within two years of adopting this plan. Within three to five years, the long-term milestones will be achieved. All milestones are expected to be achieved over the five-year period (2019-2023). Upon successful implementation of these milestones, the planning process should be re-initiated to identify the most appropriate follow-up actions. An asterisk (*) at the beginning of the milestone indicates that once initiated, the activity will continue for the duration of implementation.

5.1.1 ENSURE SUSTAINABLE WATER USE AND SUPPLIES

Short-Term (Years 1 and 2) Milestones, 2019-2020

- ☐ Working with the federal government (e.g. USGS), state agencies responsible for water use reporting, and drinking water utilities, ICPRB will develop a scope of work for a report on basin-wide water uses, projected demands, and consumptive demands. The scope of work will include a detailed timeline to ensure timely completion of the report in accordance with this plan. The time period of the water use analysis will depend on the time periods for which consistent data is available throughout the basin. (Recommendation 3.3.2 A)

- ☐ ICPRB will collect readily available data sets (e.g. land use, census urban areas, water utility service areas, etc.) to estimate basin-wide unreported water uses. (Recommendation 3.3.2 B)
- ☐ ICPRB will convene a workshop of basin stakeholders with responsibilities related to water use and supplies to develop a spreadsheet inventory of roles, responsibilities, and areas of authority. (Recommendation 3.2.1 A)

The Challenge of Funding

One major hurdle towards successful implementation of this plan's recommendations is funding. Funding is a common issue not only for ICPRB, but for partner agencies such as the basin states and the federal government.

- ☐ *ICPRB will collaborate with basin stakeholders and partners such as the Interstate Council on Water Policy to promote continued operation and maintenance of long-term USGS gages and other essential monitoring efforts. (Recommendation 3.3.2 C)
- ☐ The signatories to the Potomac River Low Flow Allocation Agreement will review the agreement and consider changes to bring it up to date. (Recommendation 3.3.2 C)
- ☐ The CO-OP Section of ICPRB, working with the CO-OP utilities, will begin implementation of operational alternatives five through eight of the water supply alternatives study (Schultz et al. 2017). (Recommendation 3.3.2 C)
- ☐ *ICPRB, working through its Task Force on Water Supply Alternatives and jointly with the WMA utilities, will move forward the planning and implementation of supplemental raw water storage that could be used to supplement supplies in case of severe drought or in case of a spill event in the Potomac River. (Recommendation 3.3.2 C)
- ☐ *The CO-OP Section of ICPRB, working with the CO-OP utilities, will seek to broaden the regional cooperative system which provides for cooperative drought planning and operations and shared funding of water supply storage. (Recommendation 3.3.2 C)
- ☐ ICPRB will assist basin stakeholders in information sharing during drought events in the upper portion of the basin to supplement and enhance drought management activities for the WMA. (Recommendation 3.3.2 C)

Long-Term (Years 3 through 5) Milestones, 2021-2023

- ☐ The CO-OP Section of ICPRB will conduct the demand study for the Washington Metropolitan Area in 2020 and every five years thereafter as required by the Water Supply Coordination Agreement. (Recommendation 3.3.2 A)
- ☐ Basin jurisdictions will provide historic and current reported water use data to ICPRB staff for assessment as part of developing a report on basin-wide water uses, projected demands, and consumptive demands. (Recommendation 3.3.2 A)
- ☐ Following the scope of work developed in partnership with the federal government, state agencies, and drinking water utilities, ICPRB staff will develop a report on basin-wide water uses, projected demands, and consumptive demands. The report will be distributed to basin jurisdictions and other stakeholders for review and comment. (Recommendation 3.3.2 A)

- ☐ ICPRB will estimate and prepare a report on basin-wide unreported water uses. The report will be distributed to basin jurisdictions and other stakeholders for review and comment. (Recommendation 3.3.2 B)
- ☐ The CO-OP Section of ICPRB, working with the CO-OP utilities, will continue implementation of operational alternatives five through eight of the water supply alternatives study (Schultz et al. 2017) as deemed appropriate during short-term implementation. (Recommendation 3.3.2 C)

5.1.2 PROTECT AND IMPROVE WATER QUALITY

Short-Term (Years 1 and 2) Milestones, 2019-2020

- ☐ ICPRB will develop a plan to merge the water quality data inventory and the long-term trends data for viewing and dissemination. (Recommendation 3.4.2 A)
- ☐ A workshop will be convened by ICPRB to share data, assess completeness, and identify gaps. (Recommendation 3.4.2 B)
- ☐ ICPRB will convene a workshop of basin stakeholders with responsibilities related to water quality (either in conjunction with or independent from previously described workshop of water quality experts) to develop a spreadsheet inventory of roles, responsibilities, areas of authority. (Recommendation 3.2.1 A)
- ☐ *ICPRB will develop and maintain a series of web pages, in close partnership with stakeholders, to serve as a resource for water quality decision-makers and the general public. (Recommendation 3.4.2 B)
- ☐ *ICPRB will collaborate with basin stakeholders and partners such as the Interstate Council on Water Quality to promote continued operation and maintenance of long-term USGS gages and other essential monitoring efforts. (Recommendation 3.4.2 C)

Long-Term (Years 3 through 5) Milestones, 2021-2023

- ☐ ICPRB will execute the plan to merge the water quality data inventory and the long-term trends data. (Recommendation 3.4.2 A)
- ☐ ICPRB will evaluate and implement, along with identified partners, additional next steps as deemed appropriate based on the results of the workshops described in the short-term milestones. (Recommendations 3.4.2 B and Recommendation 3.2.1 A)

5.1.3 MANAGE HUMAN LAND USE FOR SUSTAINABILITY

Short-Term (Years 1 and 2) Milestones, 2019-2020

- ☐ ICPRB will develop a method for compiling data and information associated with human land use. (Recommendation 3.5.2 A)
- ☐ ICPRB will document local regulatory and programmatic approaches to managing human land use currently underway in the basin. (Recommendation 3.5.2 A)
- ☐ ICPRB will conduct a literature review of creative, effective uses of land use management tools (regulatory, programmatic, and financial) to achieve goals. (Recommendation 3.5.2 A)
- ☐ ICPRB will develop relationships with organizations to effectively disseminate land use related information to stakeholders. (Recommendation 3.5.2 B)
- ☐ ICPRB will convene a workshop of basin stakeholders with responsibilities related to land use to develop a spreadsheet inventory of roles, responsibilities, and areas of authority. (Recommendation 3.2.1 A)

Long-Term (Years 3 through 5) Milestones, 2021-2023

- ☐ ICPRB will implement the method developed in the short-term for compiling data and information, described above. (Recommendation 3.5.2 A)
- ☐ ICPRB will utilize the documented existing approaches to managing human land use and the results of the literature review in order to propose potential creative, effective uses of local, regulatory, programmatic, and financial tools to achieve goals in the Potomac basin. (Recommendation 3.5.2 A)
- ☐ As it becomes available, ICPRB will disseminate land use related information to stakeholders in a timely manner. (Recommendation 3.5.2 B)

5.1.4 PROTECT ECOLOGICAL HEALTH

Short-Term (Years 1 and 2) Milestones, 2019-2020

- ☐ ICPRB will work with diverse stakeholders to perform Phase II of the Jennings Randolph Lake Water Control Plan Scoping Study, which seeks to develop protections for downstream ecological value and recreational fisheries through better, model-based coordination of the various human uses of the North Branch Potomac River. (Recommendation 3.6.2 C)
- ☐ ICPRB will work with state agency staff to identify water chemistry conditions that increase the likelihood streams will form nuisance filamentous algal blooms, and will complete a study of the negative impacts of filamentous algae blooms on aquatic life in the Potomac's Cacapon River. (Recommendation 3.6.2 D)
- ☐ A "2008 baseline" with which to measure change in stream macroinvertebrate health in the Chesapeake watershed, including the Potomac, will be developed with stakeholders and implemented at the CBP. (Recommendation 3.6.2 B)

Long-Term (Years 3 through 5) Milestones, 2021-2023

- ☐ ICPRB staff will continue to work with agency and volunteer monitoring programs and the Chesapeake Bay Program Data Center to compile biological monitoring data in basin-wide databases. (Recommendation 3.6.2 A)
- ☐ ICPRB staff will continue to work with stakeholders to develop computer programs to evaluate habitat, water quality, and biological data in consistent ways, and will encourage data and information exchanges. (Recommendation 3.6.2 A, B)
- ☐ ICPRB will continue to seek consensus on what is high ecological value, identify habitats and waters in the basin with high ecological value (references), and use reference-based approaches to develop metrics and tools for evaluating ecological health. (Recommendation 3.6.2 B)
- ☐ ICPRB will continue to coordinate the North Branch Potomac River Advisory Committee meetings. (Recommendation 3.6.2 C)
- ☐ As it becomes available, ICPRB will disseminate ecological health related information to stakeholders in a timely manner. (Recommendation 3.6.2 A)

5.2 MEASURES OF SUCCESS

The tangible products of implementing recommendations under each challenge area are provided in the sections below.

5.2.1 ENSURE SUSTAINABLE WATER USE AND SUPPLIES

- ICPRB report containing estimates of unreported water use by sub-watershed (e.g. HUC-8 or similar) and by sector in the basin.
- ICPRB report on water uses, projected demands, and consumptive demands in the basin.
- A spreadsheet inventory of roles, responsibilities, and areas of authority.
- A CO-OP demand study in 2020 and every five years after.

5.2.2 PROTECT AND IMPROVE WATER QUALITY

- Basin-wide, publicly available online repository of monitoring site locations and associated metadata as well as long-term trend information, where available.
- Publicly available ICPRB web pages to disseminate water quality resources.
- A spreadsheet inventory of roles, responsibilities, and areas of authority.
- A written assessment of activity completeness and gaps as well as recommendations and priorities for future activities.

5.2.3 MANAGE HUMAN LAND USE FOR SUSTAINABILITY

- ICPRB report of data and information associated with human land use in the basin.
- ICPRB report compiling potential creative, effective uses of local, regulatory, programmatic, and financial tools to achieve land use goals in the Potomac basin.

5.2.4 PROTECT ECOLOGICAL HEALTH

- ICPRB report on shared uses of the North Branch Potomac River.
- ICPRB report on water chemistry conditions that increase the likelihood of nuisance filamentous algal blooms.
- ICPRB report on the Chesapeake Bay Program “2008 Baseline” for evaluating and reporting stream health across the watershed.
- ICPRB journal article about the negative biological impacts of filamentous algal blooms in the Potomac’s Cacapon River.
- ICPRB journal article describing a method to forecast likely phytoplankton condition and algal bloom frequencies in Chesapeake Bay and its tidal tributaries.
- USGS and ICPRB journal article relating stream macroinvertebrate condition to land uses in the Chesapeake watershed.
- PA DEP and ICPRB journal article describing a multi-metric index to evaluate the biological condition of large rivers in the Mid-Atlantic region.
- Accessible biological databases and data documentation.
- User-friendly computer programs to calculate biological metrics and indices.
- Maps and information on ICPRB website about aquatic life in the Potomac River basin.

5.3 REVIEW PROCESS

This plan is a 15-year plan that will be will be reviewed every five years to evaluate implementation progress and identify actions over the next five-year period.

Every five years, ICPRB will evaluate implementation progress utilizing the milestones and measures of success sections of the plan (**Section 5.1** and **Section 5.2**, respectively). The product of this evaluation will be updated milestones and measures of success sections for implementation during the next five-year period. The first five-year update will take place in 2023 and will include an evaluation of regulatory tools, roles, responsibilities, and areas of authority based on the results of the workshops described in **Section 5.1**.

The full plan will be reviewed every 15 years. The review process will engage ICPRB staff and Commissioners, the advisory committee, and a broad stakeholder base. All major sections of the plan will be reviewed and revised as needed. The result of this process will be the release of a new version of the comprehensive plan. The first complete review of the comprehensive plan will occur in 2033 and may include identification of metrics/indicators to be used to evaluate implementation success during subsequent plan reviews.

5.4 COMMUNICATION PLAN

This section describes efforts to reach people with the information contained in this plan and efforts to promote ongoing support for these efforts as the plan evolves. The strategies to successfully reach and engage people are:

- Public release of the plan in June 2018: Posting this report on ICPRB website and promoting the plan through existing ICPRB web-based publications and social media. This process will be continued as milestones in the effort are reached or as additional opportunities are presented.
- Targeted presentations: Comprehensive plan advisory committee and ICPRB staff will provide input to determine where presentations should be given. Includes MWCOG committees, state and federal planning groups, and universities. ICPRB staff should identify federal and state agencies with resources

planning responsibilities and set up meetings or presentations. This can help those agencies spread the word with county and local planning agencies with which they share responsibilities.

- Technical staff: Submit articles about the plan to professional and/or academic journals.
- Reach out directly to AWRA, Chesapeake Bay Program, water suppliers, Potomac Conservancy, DWSPP, etc., to enlist their support and participation in the plan.
- Use national social media campaigns to promote the plan, such as the AWWA Drinking Water Week.
- Send press release to area papers, radio, and television.
- Reach out personally to journalists, bloggers, and podcasters with which we have relationships to encourage coverage.
- Create video(s) based on plan action items for use on the web and social media.
- Meet outreach goal of at least four presentations during the first six months of outreach.
- Explore creation of an e-book for easier reading on Kindles, tablets, and smart phones. The e-book would be available on the ICPRB website and possibly on popular online stores such as Amazon.
- Provide an annual update on the plan to other agencies and the public through methods described above.

REFERENCES

Ahmed, S.A., K.R. Bencala, and C.L. Schultz. 2013. 2010 Washington Metropolitan Area water supply reliability study, part 2: Potential impacts of climate change. ICPRB Report No. 13-07. http://www.potomacriver.org/wp-content/uploads/2014/12/ICPRB13-071.pdf, accessed 5/20/2015.

Ahmed, S.N., K.R. Bencala, and C.L. Schultz. 2015. 2015 Washington Metropolitan Area Water Supply Study: Demand and resource availability forecast for the year 2040.

AWRA. 2011. AWRA policy statement on Integrated Water Resources Management in the U.S. http://www.awra.org/policy/policy-statements-IWRM.html, accessed 4/27/2015.

Baldizar, J. and N. B. Rybicki. 2007. Restoration Potential of Submerged Aquatic Vegetation in the Tidal Pocomoke River (Chesapeake Bay, USA). Ecological Restoration 25(2):138-139.

Barbour, H.O. 1965. The Potomac, a river that can and will clean itself. 1v. Nov 5 1965. A783484.

Bauer D., M. Philbrick, and B. Vallario. 2014. The Water-Energy Nexus: Challenges and Opportunities. USDOE. https://energy.gov/sites/prod/files/2014/07/f17/Water%20Energy%20Nexus%20Full%20Report%20July%202014.pdf, accessed 12/20/2017.

Black and Veatch. 2016. National Capital Region (NCR) Water Supply and Distribution System Redundancy Study, Final Report. B&V Project No. 188286 prepared for Metropolitan Washington Council of Governments.

Buchanan, C. [ed.]. 1999. Tidal Potomac Integrative Analysis Project: A Series of Reports on the Water Quality and Living Resources Responses to Management Actions to Reduce Nutrients in the Potomac River Estuary. ICPRB. 378 p. www.potomacriver.org, accessed 1/24/2018.

Buchanan, C., H. L. N. Moltz, H. C. Haywood, J. B. Palmer, and A. N. Griggs. 2013. A test of the Ecological Limits of Hydrologic Alteration (ELOHA) method for determining environmental flows in the Potomac River basin, USA. Freshwater Biology 58:2632-2647.

Buchanan, C., K. Foreman, J. Johnson, and A. Griggs. 2011. Development of a Basin-wide Benthic Index of Biotic Integrity for Non-tidal Streams and Wadeable Rivers in the Chesapeake Bay Watershed: Final Report to the Chesapeake Bay Program. ICPRB Report 11–1.

CBP. 2018. Agriculture. https://www.chesapeakebay.net/issues/agriculture, accessed 1/25/2018.

Cicchetti, G., M.C. Pelletier, K.J. Rocha, P. Bradley, D.L. Santavy, M.E. Pryor, S.K. Jackson, S.P. Davies, C.F. Deacutis, and E.J. Shumchenia. 2017. Implementing the Biological Condition Gradient Framework for Management of Estuaries and Coasts. U.S. Environmental Protection Agency, Office of Research and Development, Atlantic Ecology Division, Narragansett RI. EPA/600/R-15/287.

Cummins, J. 2016. The return of American Shad to the Potomac River: 20 years of restoration. Final report. ICPRB Report No. 16-5. https://www.potomacriver.org/focus-areas/aquatic-life/american-shad/, accessed 1/24/2018.

Cummins, J., C. Buchanan, C. Haywood, H. Moltz, A. Griggs, R.C. Jones, R. Kraus, N. Hitt, and R.V. Bumgardner. 2011. Potomac Basin Large River Environmental Flow Needs. Prepared for The Nature Conservancy. 108p.

Davies, S.P., and S.K. Jackson. 2006. The Biological Condition Gradient: A descriptive model for interpreting change in aquatic ecosystems. Ecological Applications 16:1251–1266.

deMutsert, K., A. Sills, C. J. C. Schlick, and R. C. Jones. 2017. Successes of restoration and its effect on the fish community in a freshwater tidal embayment of the Potomac River, USA. Water 9(6) 421. doi:10.3390/w9060421.

Ducnuigeen, J., S.N. Ahmed, K.R. Bencala, H.L.N. Moltz, A. Nagel, and C.L. Schultz. 2015. Geospatial analysis tool for estimating watershed-scale consumptive use: Potomac River basin case study. *Chapter In* Advances in Watershed Science and Assessment. Springer International Publishing Switzerland. T. Younos and T.E. Parece (eds.). 141-169.

Farnsworth, R.K. and E.S. Thompson. 1982. Mean monthly, seasonal, and annual pan evaporation for the United States. NOAA Technical Report NWS 34, Washington DC.

Fenneman, A., M. Nevin, and D.W. Johnson. 1946. Physiographic divisions of the U.S. USGS, Washington, DC.

Flynn, K. C. and W. T. Mason [ed.]. 1978. The Freshwater Potomac: aquatic communities and environmental stresses. ICPRB. 194p.

GWP. 2000. Integrated Water Resources Management. Global Water Partnership Technical Advisory Committee. TAC Background Papers No. 4. https://www.gwp.org/globalassets/global/toolbox/publications/background-papers/04-integrated-water-resources-management-2000-english.pdf, accessed 5/10/2018.

Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, and C. Miller. 2012. A function-based framework for stream assessment and restoration projects. USEPA, Office of Wetlands, Oceans, and Watersheds. Washington, DC. EPA 843-K-12-006.

Hawkins, C. P., J. R. Olson, and R. A. Hill. 2010. The reference condition: predicting benchmarks for ecological and water-quality assessments. J. N. Am. Benthol. Soc. 29(1):312–343.

Herlihy, A. T., S. G. Paulsen, J. van Sickle, J. L. Stoddard, C. P. Hawkins, and L. L. Yuan. 2008. Striving for consistency in a national assessment: the challenges of applying a reference-condition approach at a continental scale. J. N. Am. Benthol. Soc. 27(4):860–877.

Hughes, R.M., S. Dunman, K.G. Maas-Hebner, J.A. Yeakley, C. Schreck, M. Harte, N. Molina, C.C. Shock, V.W. Kaczynski, and J. Schaeffer. 2014a. A review of urban water body challenges and approaches: (1) Rehabilitation and remediation. Fisheries 39(1):18-29.

Hughes, R.M., S. Dunman, K.G. Maas-Hebner, J.A. Yeakley, M. Harte, N. Molina, C.C. Shock, and V.W. Kaczynski. 2014b. A review of urban water body challenges and approaches: (2) Mitigating effects of future urbanization. Fisheries 39(1):30-40.

Jaworski, N., et al. 2007. The Potomac River Basin and its Estuary: Landscape Loadings and Water Quality Trends, 1895 – 2005. Self-published. www.potomacriver.org, accessed 1/24/2018.

Kenny, J.F., N.L. Barber, S.S. Hutson, K.S. Linsey, J.K. Lovelace, and M.A. Maupin. 2009. Estimated Use of Water in the United States in 2005. Scientific Investigations Report. USGS. http://pubs.usgs.gov/circ/1344, accessed 2/1/2018.

Lacouture, R.V., J.M. Johnson, C. Buchanan, and H.G. Marshall. 2006. Phytoplankton Index of Biotic Integrity for Chesapeake Bay and its tidal tributaries. Estuaries 29(4):598–616.

Lippson, A. J., et al. 1979. Environmental Atlas of the Potomac Estuary. Johns Hopkins University Press. 280p.+ 9 maps.

Maloney, K., Z. M. Smith, C. Buchanan, A. Nagel, and J. A. Young. *(In Press)* Predicting stream biological conditions for small headwater streams in the Chesapeake Bay watershed.

Martínez-Crego, B., T. Alcoverro and J. Romero. 2010. Biotic indices for assessing the status of coastal waters: a review of strengths and weaknesses. Journal of Environmental Monitoring, 12, 1013–1028.

Mason, W. T. and K. C. Flynn [ed.]. 1976. The Potomac Estuary: biological resources trends and options. ICPRB. 140p.

Masterson, J.P., J.P. Pope, J. Monti, M.R. Nardi, J.S. Finkelstein, and K.J. McCoy. 2015. Hydrogeology and hydrologic conditions of the Northern Atlantic Coastal Plain aquifer system from Long Island, New York, to North Carolina (ver. 1.1, September 2015). USGS Scientific Investigations Report 2013–5133. 76p. http://dx.doi.org/10.3133/sir20135133, accessed 11/24/2015.

McCoy, K.J., R.M. Yager, D.L. Nelms, D.E. Ladd, J. Monti, and M.D. Kozar. 2015. Hydrologic budget and conditions of Permian, Pennsylvanian, and Mississippian aquifers in the Appalachian Plateaus Physiographic Province (ver. 1.1, October 2015). USGS Scientific Investigations Report 2015–5106. 77p. http://dx.doi.org/10.3133/sir20155106, accessed 11/24/2015.

MDE. 2017. Draft 2016 Integrated Report of Surface Water Quality. http://mde.maryland.gov/programs/Water/TMDL/Integrated303dReports/Pages/2016IR.aspx, accessed 1/18/2018.

MGS. 2015. Maryland geology. MD DNR. http://www.mgs.md.gov/geology/index.html, accessed 5/4/2015.

Moltz, H., J. Palmer, and Z. Smith. 2018. Streamflow Alteration from Impervious Cover: Are All Watersheds Created Equal? Journal of the American Water Resources Association. *(Under Review)*

Moltz, H. and J. Palmer. 2012. Critical Area Resource Plan for the Marsh and Rock creek watersheds of Adams County, Pennsylvania. Prepared by ICPRB for PA DEP. ICPRB-12-2. 295p. http://files.dep.state.pa.us/Water/Division%20of%20Planning%20and%20Conservation/StateWaterPlan/CARPS/CARP_MainReport_082812_DEP.pdf, accessed 5/8/2018.

Moltz, H., C. Haywood, and J. Hoffman. 2011. Integrated water resources management in the Potomac River basin. *In* Integrated water resources management: The emperor's new clothes or indispensable process? AWRA Summer Specialty Conference, June 27-29, Snowbird, UT.

Moltz, H., J. Palmer, and K. Bencala. 2014. Development of a Potomac basin water quality data inventory. ICPRB Report No. 14-2. 14p.

MWCOG. 2000. Metropolitan Washington Water Supply and Drought Awareness Response Plan: Potomac River System. https://www.mwcog.org/file.aspx?&A=fgF3XCNxqACwUc0tACfZXFeY2S3%2B2kcoPHFRUnGNQS0%3D, accessed 5/10/2018.

PA DEP. 2009. Commonwealth of Pennsylvania state water plan principles. 82p. http://www.pawaterplan.dep.state.pa.us/docs/Publications/3010-BK-DEP4222.pdf, accessed 5/20/2015.

PA DEP. 2012. A benthic macroinvertebrate index of biotic integrity for wadeable freestone riffle-run streams in Pennsylvania. Division of Water Quality Standards. http://files.dep.state.pa.us/Water/Drinking%20Water%20and%20Facility%20Regulation/WaterQualityPortalFiles/Technical%20Documentation/freestoneIBImarch2012.pdf, accessed 5/12/2018.

Palmer, J. and H.L.N. Moltz. 2013. Potomac basin water withdrawals: Evaluation of state water withdrawal data collection and recommendations for aligning efforts. ICPRB Report No. 13-8. 66p.

Poff, N.L., B.D. Richter, A.H. Arthington, S.E. Bunn, R.J. Naiman, E. Kendy, M. Acreman, C. Apse, B.P. Bledsoe, M.C. Freeman, J. Henriksen, R.B. Jacobson, J.G. Kennen, D.M. Merritt, J.H. O'Keeffe, J.D. Olden, K. Rogers, R.E. Tharme, and A. Warner. 2010. The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards. Freshwater Biology 55(1):147–170.

Potomac Planning Task Force. 1967. The Potomac: The Report of the Potomac Planning Task Force. A report on its imperiled future and a guide for its orderly development. Prepared for the Department of the Interior.

PRISM Climate Group. 2004. Oregon State University. http://prism.oregonstate.edu, accessed 7/7/2015.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). USDA, Agricultural Handbook No. 703. 404p.

Schultz, C.L., S.N. Ahmed, H.L.N. Moltz, and A. Seck. 2017. Washington Metropolitan Area Water Supply Alternatives: Meeting the Challenges of Growth and Climate Change. ICPRB Report No. 17-3. 114p.

Shehabi, A., S.J. Smith, N. Horner, I. Azevedo, R. Brown, J. Koomey, E. Masanet, D. Sartor, M. Herrlin, W. Lintner. 2016. United States Data Center Energy Usage Report. Lawrence Berkeley National Laboratory, Berkeley, California. LBNL-1005775. 56p.

Smith, Z., C. Buchanan, and A. Nagel. 2017. Refinement of the basin-wide Index of Biotic Integrity for non-tidal streams and wadeable rivers in the Chesapeake Bay watershed. ICPRB Report No. 17-2.

https://www.potomacriver.org/wp-content/uploads/2017/05/ChessieBIBI_Report_Final_5-25-2017.pdf, accessed 1/24/2018.

Smith, Z. and C. Buchanan. 2017. Long-term water quality trends data viewer. (in prep.)

Trapp, H. Jr. and M.A. Horn. 1997. Ground water atlas of the United States, Delaware, Maryland, New Jersey, North Carolina, Pennsylvania, Virginia, West Virginia HA 730-L. http://pubs.usgs.gov/ha/ha730/ch_l/L-text3.html, accessed 11/19/2015.

USACE, TNC, and ICPRB. 2014. Middle Potomac River watershed assessment: Potomac River sustainable flow and water resources analysis. Final Report. 140p and 10 appendices.

USACE. 2004. Middle Potomac watershed, Maryland, Pennsylvania, Virginia, West Virginia, District of Columbia - Section 905(b) (WRDA 86) analysis. 43p. Baltimore, MD.

USACE. 2014. Building strong collaborative relationships for a sustainable water resources future: Understanding integrated water resources management. http://www.building-collaboration-for-water.org/Documents/IWRMReportJAN2014.pdf, accessed 4/27/2015.

USACE. 2015a. Chesapeake Bay Comprehensive Water Resources and Restoration Plan, DC, DE. MD, NY, PA, VA, and WV. http://www.nab.usace.army.mil/Missions/Civil-Works/Chesapeake-Bay-Comprehensive-Plan/, accessed 12/06/2017.

USACE. 2015b. North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk. http://www.nad.usace.army.mil/compstudy, accessed 6/4/2015.

USEPA. 2014. Scoring spreadsheet for recovery potential screening. Version 12/20/2014. www.epa.gov/recoverypotential/, accessed 5/17/2015.

USEPA. 2015. National Geospatial Datasets, ATTAINS program data of 303(d) Listed Impaired Waters. http://www.epa.gov/waters/data/rad_303d_20150501_shp.zip, accessed 6/8/2015.

USEPA. 2016. A Practitioner's Guide to the Biological Condition Gradient: A Framework to Describe Incremental Change in Aquatic Ecosystems. EPA-842-R-16-001. U.S. Environmental Protection Agency, Washington, DC.

USGS. 2014. NLCD 2001-2006 percent developed imperviousness change pixels (2011 Edition). USGS, Sioux Falls, SD. http://www.mrlc.gov, accessed 5/6/2015.

VA DEQ. 2014. Physiographic provinces of Virginia. http://www.deq.virginia.gov/programs/water/watersupplywaterquantity/groundwaterprotectionsteeringcommittee/physiographicprovincesofvirginia.aspx, accessed 5/20/2015.

VA DEQ. 2015. Commonwealth of Virginia: State water resources plan. http://www.deq.virginia.gov/Programs/Water/WaterSupplyWaterQuantity/WaterSupplyPlanning/StateWaterPlan.aspx, accessed 5/21/2015.

VA DEQ. 2016. Virginia Water Quality Assessment 305(b)/303(d) Integrated Report 2014. http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityAssessments/2014305(b)303(d)IntegratedReport.aspx, accessed 1/18/2018.

Vann, D.T., R. Mandel, J.M. Miller, E. Hagen, A. Buda, and D. Cordalis. 2004. The DC source water assessment. ICPRB, Rockville, MD.

Weidner, E. 2009. Potomac watershed priority lands strategy: Conserving lands to benefit drinking water quality. Duke University. 44p. http://www.potomacdwspp.org/Meetings/Jul22-2009/Weidner_Report.pdf, accessed 5/20/2015.

Williamson, S., C. Horin, M. Ruth, R.F. Weston, K. Ross, and D. Irani. 2008. Climate change impacts on Maryland and the cost of inaction: A review and assessment by the Center for Integrated Environmental Research at the University of Maryland. 24p. Maryland Commission on Climate Change. http://www.cier.umd.edu/climateadaptation/Chapter3.pdf, accessed 5/20/2015.

Wolman, M.G. 2008. Water for Maryland's future: What we must do today. Final report of the Advisory Committee on the management and protection of the state's water resources. http://www.mde.state.md.us/assets/document/wolmanreport_vol1.pdf, accessed 9/20/2015.

Wolock, D.M. 2003. Estimated mean annual natural ground-water recharge in the conterminous U.S. USGS Open-File Report 03-311 USGS, Reston, VA.

Wood, A.J., J.M. Omernik, and D.D. Brown. 1999. Level III and IV ecoregions of Delaware, Maryland, Pennsylvania, Virginia, and West Virginia. http://www.epa.gov/wed/pages/ecoregions/reg3_eco.htm, accessed 5/4/15.

WV DEP. 2013. West Virginia water resources management plan. http://www.dep.wv.gov/WWE/wateruse/WVWaterPlan/Pages/default.aspx, accessed 1/24/2018.

Glossary

Aquatic life – Animal, plant, and microscopic organisms that live in water for part or all of their life cycles. Some species have economic value and support commercial and recreational fisheries.

Baseflow – Sustained flow of a stream in the absence of direct runoff. It includes natural and human-induced streamflows. Natural baseflow is sustained largely by groundwater discharges. Human-induced streamflows include direct discharges (e.g. wastewater treatment plants) (adapted from USGS).

Biocriteria – Narrative and numeric descriptions of the biological "qualities that must be present to support a desired condition in a waterbody and serve as the standard against which assessment results are compared" (USEPA website).

Climate Change & Sea Level Rise – Ongoing long-term changes in weather patterns and coastal topography. These changes will reshape the Potomac coastline and restructure Potomac aquatic communities. Well-functioning, resilient communities will be able to adapt and survive these threats if stream corridors and estuarine shorelines are adequately protected and allowed to change.

Contaminants – Chemicals that can pollute or poison when present in sufficient concentrations. Concentrations that affect wildlife also affect humans since wildlife and human health requirements for safe drinking water are often similar. These substances include herbicides, pesticides, mercury, and PCBs. Animals living in aquatic environments can "bioaccumulate" some of the toxic or cancer-forming pollutants, making them unsafe to eat.

Designated Uses – Specific goals and expectations codified in a jurisdiction's water quality standards for how a waterbody is used, e.g. the protection and propagation of fish, shellfish, and wildlife; recreation; public drinking water supply; and agricultural, industrial, navigational, and other purposes (USEPA website).

Diagnostic / Decision tools – Analytical, problem-solving, computer-based programs that support processes that lead to resource management based on scientific evidence. Examples applicable to the Potomac watershed include USEPA's CADDIS tool (identifies the major stressors degrading a stream or river), USEPA's Recovery Potential Screening tool (scores a watershed's potential to recover from degradation), and NOAA's Chesapeake Bay Oyster Decision Support tool (identifies where oyster restoration efforts in tidal waters would be most effective).

Disease & Parasitism – Structural or functional disorders in living organisms that often are caused by contaminants or pathogens, and are more likely to occur in organisms stressed by degraded or altered habitats.

Ecosystem Management – Interdisciplinary, holistic approaches to managing ecosystems that consider multiple uses, including aquatic life uses, and consequences.

Ecosystem Models – Numeric representations of ecological systems. Equations are used to describe the network of relationships of living organisms to one another and to their physical environment. Models can be scaled to an individual population or an entire ecosystem. They allow analysts to explore the potential outcomes of different management decisions.

Eutrophication – A process where excess amounts of nutrients from runoff, groundwater, and point-source discharges cause algae blooms. Algae blooms can result in very low oxygen levels (hypoxia) that harm or kill fish, shellfish, and aquatic invertebrates and plants. Algae blooms are frequently dominated by toxin-producing species that can inhibit growth in plants and other algae and damage or kill exposed animals and people. Eutrophication has long been a problem for aquatic life. It is increasingly a problem for drinking water and recreation uses.

Habitat – The natural living spaces of an animal, plant, or other organism where environmental conditions stay within normal or preferred bounds (e.g. temperature, light).

Habitat Connectivity – In stream corridors, the openness of routes where natural movements and migrations of aquatic organisms occur, between upstream and downstream segments and between riparian and instream habitats. A dam is an example of an impediment to connectivity. The Potomac is presently one of the least dam-regulated river systems in the eastern United States. Most of the 481 registered impoundments are small and run-of-river, comparable in function to beaver dams. Fish passages at some of the 153 “significant impoundments” are successfully used by migratory fish. Over 50,000 stream and river road crossings are also found in the basin. Most involve culverts which, as they age and erode, can block upstream passage for fish.

HUC-8 – Eight digit hydrologic units. The sub-basin scale. The Potomac basin includes 11 HUC-8 sub-basins, averaging 1,340 square miles.

Index, or Indices – Several indicators, or metrics, that have been scored on a common scale and then combined into an index score. Indices are calculated from monitoring data and are typically more sensitive and robust than individual indicators.

Indicators – Measurements collected by monitoring programs that tell us something about a biological population or its habitat. Examples of indicators used in Potomac management include the American shad young-of-year numbers (MD DNR), annual fish harvests (PRFC), chlorophyll *a* concentration, daily precipitation totals, and streamflow statistics.

Non-Native Species – A species that is not endemic (native) to the area. Non-native species can disrupt the structure and function of an existing biological community, especially if that community is experiencing other stressors. In some cases, the native and non-native species can adjust to each other and rebalance into a new biological community. The recent arrival of snakeheads seemed to threaten the ecological health of the Potomac River at first. Their populations have stabilized to some extent. Largemouth bass, the underwater grass Hydrilla, and the Asiatic clam Corbicula are all non-native species introduced decades ago that have assimilated into Potomac aquatic ecosystems. Their ongoing impacts on Potomac ecosystems are not certain.

Overexploitation – Occurs when a shared resource, such as fish or shellfish, is exploited by many individuals acting in their own self-interest and contrary to the resource’s ability to sustain itself. The resource eventually collapses. This is often referred to as the “tragedy of the commons.” Self-regulation by educated, responsible users is hard to achieve but is often the most successful approach for avoiding overexploitation.

Source Waters – Surface water (streams, rivers, and lakes) or groundwater (aquifers) can serve as sources of drinking water, referred to as source water. Source water provides water for public drinking water supplies and private water wells. Public utilities treat most water used for public drinking water supplies. Protecting source water from contamination can reduce treatment costs. Protecting source water also reduces risks to public health from exposures to contaminated water (USEPA website).

Stratification (in estuaries) – Occurs when saltier ocean water intruding along the bottom and freshwater flowing out across the surface remain separate. This prevents the water column from mixing, which can lead to hypoxia and anoxia in the bottom layer and nutrient depletion in the surface layer. Friction and diffusion at the interface of the two layers weakens their differences and breaks down the stratification.

Valley and Ridge Province (aka Ridge and Valley Province) – Located in the Appalachian Mountain region, the Valley and Ridge Province is a series of northeast-southwest trending valleys and ridges composed of Early Paleozoic sedimentary rocks. Limestones and shales are more susceptible to erosion and make up much of the valleys, whereas more resistant sandstones and conglomerates form the ridges. These folded rock layers are the result of the compression associated with the assembly of the supercontinent Pangea and the various mountain building events that produced the Appalachian Mountains (National Park Service website).

Water Quality Standards – Water quality standards are provisions of state, territorial, authorized tribal or federal law approved by USEPA that describe the desired condition of a waterbody or the level of protection or mandate how the desired condition will be expressed or established for such waters in the future. These standards form a legal basis for controlling pollution entering the waters of the U.S. from a variety of sources (e.g. industrial facilities, wastewater treatment plants, and storm sewers) (USEPA website).

Appendix A. Final Report of the Advisory Committee

The advisory committee final report, prepared by Kristin Rowles and Mark Masters of Policy Works LLC, is available on the ICPRB website.

Appendix B. Annotated Bibliography by Challenge Area

An annotated bibliography for literature related to water use and supplies, water quality, human land use, ecological health, the water-energy nexus, and deicing salts in the Potomac basin is available for download on the ICPRB website.

Appendix C. List of Reviewed Plans

Fifty-five plans were reviewed to develop the preliminary list of water resources challenges in the Potomac basin (**Table C-1**).

Table C-1. List of state, region, county, and local plans reviewed during the development of the basin-wide comprehensive water resources plan.

Coverage	Plan
State	Pennsylvania
	Virginia
	West Virginia
Region	Carroll County, Hampsted, Manchester, Mt. Airy, New Windsor, Sykesville, Union Bridge, and Westminster, MD
	SE Adams County, Germany and Union Townships, Littlestown Borough, PA
	NW Adams County, PA
	Mt. Pleasant Township and Bonneauville Borough, PA
	Fulton County, PA, 8 Townships, and 1 Borough
	Region 8 Planning and Development Council, WV
County	Allegany County MD
	Charles County, MD
	Frederick County, MD
	Garrett County, MD
	Montgomery County, MD
	Prince George’s County, MD
	St. Mary's County, MD
	Washington County, MD
	Somerset County, PA
	Franklin County, PA
	City of Winchester, VA
	Clarke County VA
	Frederick County, VA
	Loudoun County, VA
	Warren County VA
	Shenandoah County VA
	Prince William County, VA
	Arlington County, VA
	Fairfax County, VA

Coverage	Plan
	Fauquier County, VA
	King George County, VA
	Westmoreland County, VA
	Northumberland County, VA
	Page County, VA
	Stafford County, VA
	Rockingham County, VA
	Augusta County, VA
	Highland County, VA
	Berkeley County, WV
	Jefferson County, WV
	Morgan County, WV
	Hampshire County, WV
	Hardy County, WV
	Grant County, WV
	Pendleton County, WV
Local	Cumberland Township, PA
	Hamiltonban Township, PA
	City of Harrisonburg, VA
	City of Alexandria, VA
	City of Falls Church, VA
	City of Manassas, VA
	City of Manassas Park, VA
	City of Staunton, VA
	City of Fairfax, VA
	City of Waynesboro, VA
	Washington, DC

Appendix D. Federal Perspective and Input

This appendix was prepared by the USACE Baltimore District for this comprehensive plan. See Authority and Study Process sections below for further explanation.

PURPOSE AND BACKGROUND

The purpose of the comprehensive plan is to build on existing state and local planning efforts to identify surface water and groundwater resources issues of interstate and/or basin-wide significance and develop associated management recommendations. The basin-wide plan aids in statewide planning by providing additional information for decision-making (e.g. activities upstream of the jurisdiction and anticipated effects of jurisdictional activities downstream) and may facilitate achievement of common goals including protection of water supplies, drinking water sources, water quality, and ecological resources. In general, the plan is expected to include background information about the basin and the planning.

STUDY AREA

The Potomac River basin stretches across parts of four states (Maryland, Pennsylvania, Virginia and West Virginia) as well as the District of Columbia. The nearly 15,000 square mile watershed is the fourth largest river along the Atlantic Coast. The land of the Potomac basin varies across five geological provinces with diverse ecosystems that support more than six million residents. A basin-wide comprehensive plan is being pursued to focus on sustainable water resources management to protect and enhance public health, the environment, all sectors of the economy and quality of life.

AUTHORITY

This summary report was produced as part of Fiscal Year 2017 Planning Assistance to States (PAS) program of the U.S. Army Corps of Engineers (USACE), Baltimore District, Planning Division. PAS projects are authorized by Section 22 of the 1974 Water Resources Development Act for assistance in the preparation of comprehensive plans for the development, utilization, and conservation of water and related resources. The program can encompass many types of studies dealing with water resources issues including water supply/demand, water conservation, water quality, environmental/conservation, wetlands evaluation/restoration, dam safety, flood damage reduction, coastal zone protection and harbor planning. Efforts under this program are cost shared on a 50% federal – 50% non-federal basis. The sponsor has the option to contribute via kind or in-kind. In this case, the study sponsor provided 50% in-kind for its share of the study cost.

STUDY PROCESS

The ICPRB has a congressional mandate to consider water resources on a watershed basis, rather than along political boundaries. In support of this mandate, the ICPRB is developing a voluntary, basin-wide, Comprehensive Water Resources Plan. The Plan builds on existing planning efforts to identify water resources issues of interstate and/or basin-wide significance and develop associated management recommendations. The Plan's four topic areas are provided below along with their associated long-term goals.

A. Ensure sustainable water uses and supplies: The diverse users of the basin’s water resources have clean, reliable, and resilient water resources for current and future generations.

B. Protect and improve water quality: The waters of the basin achieve or exceed water quality standards established by the states in accordance with the Clean Water Act. New and emerging threats are proactively addressed.

C. Protect ecological health: The propagation and growth of balanced, desirable populations of aquatic life is ensured.

D. Manage human land use for sustainability: Human land use in the basin supports sustainable water resource management.

As the Federal chair on the ICPRB commission, and as part of this project, USACE is responsible for coordination and input from federal agencies to the Plan. USACE sent letters request water resources related information to the following agencies:

- Dept of Agriculture, U.S. Forest Service
- Dept of Agriculture, National Resources Conservation Service
- Dept of Commerce, NOAA
- Dept of Defense, U.S. Army Corps of Engineers
- Environmental Protection Agency – Headquarters and Region III
- Dept of Homeland Security, Federal Emergency Management Agency Region III
- Dept of Interior, Bureau of Land Management
- Dept of Interior, Fish and Wildlife Service
- Dept of Interior, National Park Service
- Dept of Interior, U.S. Geologic Survey

Based on the feedback received from the federal agencies, the following sections provide a summary of the restoration and protection actions implemented throughout the Potomac River basin. The input provided does not represent the full list of federal agencies working throughout the basin.

TABLE OF RESULTS

U.S. FOREST SERVICE

RESPONDENT'S CONTACT INFORMATION:	
Name:	Sally Claggett
Title:	Program Coordinator
Organization:	U.S. Forest Service
Department:	State and Private Forestry
Address:	410 Severn Ave, Ste 209
City, State, Zip:	Annapolis, MD 21403

A. Ensure sustainable water uses and supplies

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Forests to Faucets	Conduct analysis of relative importance of forests to drinking water and the risk to forests/drinking water	National	Original 2011 Update 2018

B. Protect and improve water quality

The Forest Service (USFS) works with state and local partners to reduce nonpoint source pollution by 1) promoting forest restoration and conservation, 2) promoting the consideration of trees in zoning and ordinances, and 3) improving habitat for fisheries.

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Chesapeake forestry initiatives	Promote riparian forest buffer conservation and restoration, forest conservation, and urban tree canopy expansion to improve water quality --Management Strategies for each of these initiatives	Chesapeake watershed	na
National Forests	Monongahela and George Washington National forests protect and manage forests for water quality	Potomac headwaters	na
Forest Legacy	USFS program to help states protect priority parcels	National	na
Urban and Community Forestry	Promote tree canopy expansion through partnerships	National	na

C. Protect ecological health

The USFS restores and protects priority forests, as well as promotes native species and reducing invasive species.

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Fisheries programs	Restore and protect aquatic habitat primarily on National Forests	National Forests	na

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Forest Health	On all forests, promote native forest species and initiate pest eradication campaigns	National	na
Chesapeake Bay initiatives	Promote riparian forest buffer conservation and restoration, forest conservation, and urban tree canopy expansion to improve water quality --Management Strategies for each of these initiatives	Chesapeake watershed	na
USFS Research Baltimore Field Station	Research branch of USFS works on some public health issues in the city that is applicable across the country	National	na
Landscape Scale Restoration Grants	Grant program to encourage restoration or conservation of forests for public good	Regional competitive grant program	na

D. Manage human land use for sustainability

The USFS works through the Chesapeake Forestry program, promoting planning, creation, and protection of riparian buffers, as well as other interconnected green infrastructure elements throughout the basin. The USFS also promotes best practices in forestry.

Projects–Programs	Description	Location (County, State)	Timeframe Year)
Chesapeake Bay initiative for Riparian Forest Buffers	Promote riparian forest buffer conservation and restoration --Management Strategies for RFB (USFS lead)	Chesapeake watershed	na
Forest Stewardship Program	Promotes best practices on private forest land, includes tree planting on ag land	National	na
Urban and Community Forestry Program	Promote urban tree canopy expansion and GI --Management Strategies for UTC (USFS lead)	National and Chesapeake watershed	na
Landscape Scale Restoration Grants	Grant program to encourage restoration or conservation of forests	Regional competitive grant program	na

NATIONAL PARK SERVICE

RESPONDENT'S CONTACT INFORMATION:	
Name:	Marian Norris
Title:	Aquatic Ecologist, National Capital and Northeast Regions
Organization:	National Park Service
Department:	Department of the Interior
Address:	4598 MacArthur Blvd., NW
City, State, Zip:	Washington, DC 20007

A. Ensure sustainable water uses and supplies

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
National Capital Region Network (NCRN) Water Quantity Monitoring	Monthly monitoring	Washington, MD Frederick, MD Prince George's, MD Washington, DC Jefferson, WV Loudoun, VA Arlington, VA Alexandria, VA Fairfax, VA Prince William, VA	ongoing
Appalachian Highland Network (APHN) Water Quantity Monitoring	Monthly monitoring	Various, VA	Ongoing
Mid-Atlantic Network (MIDN) Water Quantity Monitoring	Monthly monitoring	Adams County, PA; VA	Ongoing
NCRN Air & Climate Monitoring	Annual precipitation reporting	Allegany, Washington, Montgomery, Frederick, Prince George's Counties, MD; Loudoun, Fairfax, Arlington, Alexandria, Prince William, Stafford Counties, VA; Washington, DC; Jefferson County, WV	Ongoing
MIDN Weather & Climate Monitoring	Annual precipitation reporting	Adams, PA; Various, VA	Ongoing

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
APHN Weather & Climate Monitoring	Annual precipitation reporting	Various, VA	Ongoing
Water conservation	Monthly monitoring	Washington, Frederick, and Prince George's , MD; Washington, DC; Jefferson, WV; Alexandria, Arlington, Fairfax, and Prince William, VA	Ongoing
Groundwater-surface water interaction studies	Monthly monitoring	Allegany, MD Washington, MD Frederick, MD Jefferson, WV Loudoun, VA	Ongoing
Water infiltration BMPs	Monthly monitoring	Washington, Frederick, and Prince George's, MD; Washington, DC; Arlington, Alexandria, Fairfax, Prince William, and Westmoreland, VA	Ongoing
Park Planning Documents	State of the Parks Reports, Natural Resource Condition Assessments , and Resource Stewardship Strategies summarize the monitoring data and translate it into management plans for the parks in the watershed	Parks in watershed	Ongoing

B. Protect and improve water quality

The National Park Service (NPS) has many initiatives already ongoing in the Potomac River basin, which align with this topic area.

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
NCRN Water Quality Monitoring	Monthly monitoring	Washington, Frederick, and Prince George's, MD; Washington, DC; Jefferson, WV; Arlington, Alexandria, Fairfax, and Prince William, VA	Ongoing
Northeast Coastal & Barrier Network	Monthly monitoring	Westmoreland, VA	Ongoing

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
(NCBN) Estuarine Nutrient Monitoring			
MIDN Water Quality & Quantity Monitoring		Adams, PA; Various, VA	Ongoing
APHN Water Quality Monitoring	Monthly monitoring	Various, VA	Ongoing
Bridging the Watershed	Pertinent curriculum modules include Watershed Watchdogs, Don't Get Sedimental, and Talkin' Trash throughout the watershed; Battle to Save Water Quality at MONO; Mine over Matter at PRWI; Urban Pools at NAMA; Water Power at HAFE	Throughout watershed	Ongoing
Maintain native grasslands	Monthly monitoring	Washington, Frederick, and Prince George's, MD; Washington, DC; Arlington, Alexandria, Fairfax, Prince William, and Westmoreland, VA	Ongoing
Park Planning Documents	State of the Parks Reports, Natural Resource Condition Assessments , and Resource Stewardship Strategies summarize the monitoring data and translate it into management plans for the parks in the watershed	Throughout watershed	Ongoing

C. Protect ecological health

The NPS has many initiatives already ongoing in the Potomac River basin which align with this topic area.

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Chesapeake Large Landscape Conservation Partnership		Potomac Watershed wide	Ongoing
Aquatic Macroinvertebrates Monitoring	Annual	Various, VA	Ongoing

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Benthic Macroinvertebrates Monitoring	Annual monitoring	Adams, PA; VA	Ongoing
Fish Monitoring	Annual monitoring at SHEN	VA	Ongoing
Biological Stream Survey	Every 10 years	Allegany, Washington, Montgomery, Frederick, Prince George's Counties, MD; Loudoun, Fairfax, Arlington, Alexandria, Prince William, Stafford Counties, VA; Washington, DC; Jefferson County, WV	Ongoing
Salt Marsh Nekton & Vegetation Monitoring	Annually	Westmoreland, VA;	Ongoing
Forest Vegetation	Annually	Adams, PA; Westmoreland, VA; Charles County, MD	Ongoing
Forest Vegetation	Annually	Allegany, Washington, Montgomery, Frederick, Prince George's Counties, MD; Loudoun, Fairfax, Arlington, Alexandria, Prince William, Stafford Counties, VA; Washington, DC; Jefferson County, WV	Ongoing
Exploited Plants Monitoring	Annually	Various, VA	Ongoing
Coastal Geomorphology: Ocean Shoreline Position Monitoring	Every 10 years	Westmoreland, VA	Ongoing
Marsh birds Monitoring	Annually	Westmoreland, VA; Charles County, MD	Ongoing
Forest Birds Monitoring	Annually	Allegany, Washington, Montgomery, Frederick, Prince George's Counties, MD; Loudoun, Fairfax, Arlington, Alexandria, Prince	Ongoing

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
		William, Stafford Counties, VA; Washington, DC; Jefferson County, WV	
Grassland Birds Monitoring	Annually	Washington, Frederick Counties, MD; Prince William County, VA	Ongoing
Amphibians Monitoring	Annually	Allegany, Washington, Montgomery, Frederick, Prince George's Counties, MD; Loudoun, Fairfax, Arlington, Alexandria, Prince William, Stafford Counties, VA; Washington, DC; Jefferson County, WV	Ongoing
Park Planning Documents	State of the Parks Reports, Natural Resource Condition Assessments , and Resource Stewardship Strategies summarize the monitoring data and translate it into management plans for the parks in the watershed	Throughout watershed	Ongoing
Bridging the Watershed	Pertinent curriculum modules include Exotic invaders and Water Canaries throughout the watershed; Herring Highway at ROCR; Potomac Gorge at CHOH & GWMP; and Native Plant Restoration with Prince George's County Public Schools	Throughout watershed	Ongoing
Biodiversity Youth Ambassadors		Throughout watershed	Ongoing

D. Manage human land use for sustainability

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Remote Sensing & Landscape Pattern Monitoring	Every 10 years	Allegany, Washington, Montgomery, Frederick, and Prince George's Counties, MD; Loudoun, Fairfax, Arlington,	Ongoing

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
		Alexandria, Prince William, Stafford Counties, VA; Washington, DC; Jefferson County, WV	
Landscape Change Monitoring	Every 10 years	Westmoreland, VA; Charles County, MD	Ongoing
Landscape Change Monitoring	Every 10 years	Various, VA	Ongoing
Visitor Use Impacts Monitoring	Annually	Westmoreland, VA; Charles County, MD	Ongoing
Climate Friendly Parks Plans		Washington, Frederick, and Prince George's , MD; Washington, DC; Jefferson, WV; Alexandria, Arlington, Fairfax, and Prince William, VA	Ongoing
Bridging the Watershed	Pertinent curriculum modules include Native Plant Restoration	Prince George's County, MD	Ongoing
Park Planning Documents	State of the Parks Reports, Natural Resource Condition Assessments , and Resource Stewardship Strategies summarize the monitoring data and translate it into management plans for the parks in the watershed	Throughout watershed	Ongoing
Native Meadow Classroom	Development of an outdoor classroom within native meadow and shade gardens	Fairfax, VA	Ongoing
Youth Conservation Corps and Chesapeake Youth Corps Projects	Most recent projects including addressing restoring Anacostia River vegetation	Parks in the Watershed	As funded
Camping 101	Reach out to families and help them develop hiking and camping skills that build a deeper appreciation for the natural world	Shenandoah Park	Ongoing
Teacher-Ranger-Teacher Program	Across the watershed	Parks in the Watershed	Ongoing

U.S. ARMY CORPS OF ENGINEERS

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A. Ensure sustainable water uses and supplies

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Washington Aqueduct	Water supply for Washington Metropolitan Area (155 mgd from two treatment plants in the District of Columbia)	Washington D.C.	Ongoing
Jennings Randolph Lake	Own and operate for flood risk management, water quality, low flow augmentation, water supply, recreation	Garrett County, MD	Ongoing
Savage Rover Reservoir	Operate to maintain flow	Northwest MD	Ongoing
Emergency Management	Provide assistance, within authority, when natural disasters or other emergencies occur (flooding, hurricanes, drought, etc.)		Ongoing

B. Protect and improve water quality

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Technical Services	Providing technical assistance to states as needed, including in the area of environmental infrastructure and stormwater management	Across the watershed	As needed
Dyke Marsh	Marsh restoration within Potomac watershed and associated water quality improvements	Fairfax, VA	Contract award in 2017
Anacostia Watershed Restoration	Feasibility Study - Stream restoration in Anacostia and resulting downstream sediment reductions	Prince George's County, MD	Ongoing

C. Protect ecological health

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Chesapeake Bay Comprehensive Plan	Study to identify environmental restoration actions in the Bay watershed and to synchronize agency efforts	Bay watershed	Study end FY19
Dyke Marsh	Marsh restoration within Potomac watershed and associated water quality improvements	Fairfax, VA	Contract award in 2017
Anacostia Watershed Restoration	Feasibility Study - Aquatic ecosystem restoration (stream restoration) in Anacostia sub-watersheds	Prince George's County, MD	Study end FY18
Section 510	Design, build authority - ecosystem restoration, environmental infrastructure, stormwater management		As needed

D. Manage human land use for sustainability

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Technical Services	Providing technical assistance to states as needed, including floodplain management services, mapping, vulnerability studies, hydrologic and hydraulic modeling, data evaluation tools	Across the watershed	As needed
DC Coastal	Study to investigate flooding problems in the District of Columbia metro area (North Atlantic Coast Comprehensive Study area warranting further analysis)	Metro DC	Started this year
Silver Jackets	Interagency flood risk management team (recently completed flood inundation mapping for areas along the Potomac)	Maryland, Washington, D.C.	Ongoing

U.S. GEOLOGIC SURVEY

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A. Ensure sustainable water uses and supplies

USGS conducts water supply, quantity and use studies in areas throughout the Potomac Watershed. Projects are carried out by the USGS MD-DC, VA-WV, and PA Water Science Centers.

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Water Availability and Use Science	The goals of this program to look at water availability and use for human and ecosystem needs.	All states in watershed	Ongoing
Groundwater and Streamflow Information Program	This Program's goals are collection, analysis, and research of streamflow and groundwater, as well as the development of and application of integrating groundwater and surface-water models.	All states in watershed	Ongoing
Projects in MD-DC, VA-WV, and PA Water Science Centers.	Water supply, quantity and use studies.	All states in watershed	Ongoing

B. Protect and improve water quality

The USGS Chesapeake Science Theme 2: Characterize and explain changes in water quality and its effect on freshwater and estuarine ecosystems. Theme 2 has the following objectives:

- Characterize status and trends in nutrient, sediment, and streamflow
- Explain water-quality changes in response to human actions
- Collaborate to integrate hydrology and water quality with freshwater and estuarine ecosystem assessments

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
National Water Quality Program	The goals of the National Water Quality Program are met by monitoring and understanding the factors affecting nutrient and sediment transport in major environmental settings, forecasting potential change(s) in water-quality conditions within the Bay watershed, and application of regional SPARROW models.	Entire watershed	Ongoing
Groundwater and Streamflow Information Program	USGS Chesapeake Bay studies are further collaborating with the Federal Priority Streamgages effort by maintaining streamflow measurements at sites that are part of the Chesapeake Bay Program nontidal water-quality network.	Entire watershed	Ongoing

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Environments	The goals of this program are met by explain the factors affecting the conditions water quality—and using an adaptive management approach to inform decision-making for conservation and restoration.	Entire watershed	Ongoing

C. Protect ecological health

The USGS Chesapeake Science Theme 1: Provide science to support restoration and conservation of fish, wildlife, and critical habitats. Theme 1 has the following objectives:

- Enhance science to support the management of freshwater fisheries and aquatic habitats.
- Characterize sources and effects of environmental stresses toxic chemicals on fish and wildlife.
- Improve understanding of coastal ecosystem structure, function, and resiliency to manage water birds.

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Environments Program	The goals of this program are met by addressing the factors affecting the conditions of major aspects of the Chesapeake Bay ecosystem—fish, wildlife, habitats, and water quality—and using an adaptive management approach to inform decision-making for conservation and restoration.	PA, VA, WV, MD	Ongoing
Fisheries	The Program mission is met through freshwater species research, with a focus on cold-water fisheries (brook trout as a sentinel indicator species). During 2018, there will be a significant pivot towards the study of multiple fish species from the headwaters to the tidal freshwater zone, including analyses of occurrence and distribution, as well as the major factors, drivers, and stressors that affect fisheries, habitat, and their health.	PA, VA, WV, MD	Ongoing
Contaminants Biology	The goal of the program is being addressed through study of the sources and effects of endocrine-disrupting compounds (EDCs) on fish and wildlife in the Bay watershed	PA, VA, WV, MD	Ongoing
Toxic Substances Hydrology	The goal of the program is met through study of the occurrence and fate of emerging contaminants that are impacting fish and birds (in close collaboration with EDC project above).	PA, VA, WV, MD	Ongoing

D. Manage human land use for sustainability

The USGS Chesapeake Science Theme 3: Assess and forecast effects of climate and land change on ecosystem conditions. The Theme 3 has the following objectives:

- Improve the understanding of climate and land changes on streams and freshwater fisheries
- Assess the effects of climate change and development on wetlands, ecosystem conditions and their resiliency
- Characterize and forecast land change and provide implications for conservation

Projects–Programs	Description	Location (County, State)	Timeframe (Year)
Land Change Science	The program mission is met by research to understand and forecast the impact of human activities on the land surface, including the impact on water quality and habitat in the Bay watershed, and development and enhancement of land-change forecasting models and decision-support tools for resource managers.	Entire watershed	Ongoing

CONCLUSIONS

There is quite a bit of diversity among the federal agencies considered in this assessment. This stems from the variation in agency mission areas and agency cultures that grow up to support the mission. For example, the USFS and NPS are primarily resource management agencies charged with the management of large areas. USACE on the other hand, has significant water resources infrastructure development and operations missions. The Federal Management Agency (FEMA) is primarily a disaster preparedness and management agency. NOAA and the USGS are primarily science agencies. The USEPA and the Fish and Wildlife Service have significant environmental protection and regulatory missions. It is also important to recognize that a multitude of Congressional committees and subcommittees oversee the operations and budgets of the various agencies. As the tables above show, there are five House and three Senate committees that authorize agency programs, and three House and three Senate appropriations subcommittees that provide budget authority for the federal water agencies. (Source: federal agency assessment January 2010).

RECOMMENDATIONS FOR ICPRB

1. Continue to follow and be engaged in the Chesapeake Bay Program Phase 3 WIP process
2. Continue to follow and request assistance from USACE to clip out the Potomac watershed from the larger Chesapeake Bay Comprehensive Plan
3. Consider adopting goals, objectives, timeframes, indicators, monitoring plans/methods, data repositories, and tracking efforts into the ICPRB comprehensive plan to dovetail with other large scale federal and state programs. Promotes the sharing of information and collaboration

FEDERAL AGENCY MISSIONS

This section provides a description of federal stakeholders. Additional information, including summaries for federal funding directed toward the Chesapeake Bay restoration can be found at: http://www.chesapeakeprogress.com/funding

Under the U.S. Department of Agriculture, the Natural Resources Conservation Service funds conservation easement programs and provides technical and financial assistance to farmers and other private landowners to support the implementation of conservation practices on working lands. The U.S. Forest Service provides technical assistance and project funds to promote the establishment and retention of forests on non-Forest Service lands (through the Forest Stewardship Program), in urban areas (through the Urban and Community Forestry Program) and on conservation easements on forest land (through the Forest Legacy Program). It also provides for the management of National Forests. The Animal and Plant Health Inspection Service, Agricultural Research Service, Economic Research Service, Farm Service Agency, National Institute of Food and Agriculture and Office of the Chief Economist provide additional watershed support.

FEMA's mission is to support our citizens and first responders to ensure that as a nation we work together to build, sustain and improve our capability to prepare for, protect against, respond to, recover from and mitigate all hazards.

Under the U.S. Department of Commerce, the National Oceanic and Atmospheric Administration funds scientific research in the fields of tidal and coastal fisheries and aquatic habitats (including oyster reefs) and syntheses and analyses to predict and describe ecosystem processes. The agency also funds the development of environmental science education programs, the delivery of advice and technical assistance to decision-makers, the maintenance of the Chesapeake Bay Interpretive Buoy System (CBIBS) and the preparation of coastal communities in protecting natural and manmade infrastructure.

The U.S. Department of Defense funds regional operations and maintenance that support the prevention of stormwater runoff, upgrades to wastewater treatment plants, water quality monitoring, land conservation, natural resources planning and management, and environmental outreach and stewardship. Under the U.S. Department of Defense, the U.S. Army Corps of Engineers supports small- and large-scale studies and design and construction projects that benefit habitats and fisheries.

The Corps largest mission on the Potomac River began with construction of Jennings Randolph Lake (formerly Bloomington Reservoir) in 1971. This was the last major dam completed by the Baltimore District and provides flood protection, water supply, water quality control and recreational access. Additional flood control projects have been established in Lock Haven, the Wyoming Valley, and Scranton PA, Moorefield, WV, and Petersburg, WV. Source: A History of the Baltimore District

More than two-thirds of U.S. Environmental Protection Agency funds are directed toward state governments, local governments and other partners to help them meet the goals of the Chesapeake Bay Total Maximum Daily Load (TMDL) and the *Chesapeake Bay Watershed Agreement*. Additional funding from the agency supports the operation of the Chesapeake Bay Program office; the coordination of data collection and scientific research, monitoring and modeling; reporting on the quality of the Chesapeake Bay ecosystem; and outreach to enhance environmental stewardship.

While the Departments of Homeland Security and Transportation do support restoration in the watershed, their activities did not meet the definitional limits of this crosscut and were not reported. More information about federal funding to support restoration in the watershed can be found in the Chesapeake Bay Restoration Spending Crosscut.

Under the U.S. Department of the Interior, the U.S. Geological Survey funds the generation of scientific information about fish, wildlife and their relation to water quality, habitat and land conditions. The U.S. Fish and Wildlife Service funds strategic conservation to connect people with nature and create sustainable watershed capable of supporting fish, wildlife and plants. The National Park Service funds the protection of habitat, the creation of public access and the promotion of tourism.

The USACE Federal Agency Assessment Report (2010) focuses on how the federal governmental programs and resources can support states, tribes, non-governmental organization and other regional water resource entities with integrated water resources management. The report identified 117 water resources programs among 12 federal water agencies. Each of the programs provides water resources (e.g. planning, funding, technical assistance, engineering design and construction) toward the attainment of water resources objectives (e.g. assuring adequate water supplies, achieving water quality standards, managing flood hazards, balancing competing water demands, etc.). In addition, agencies develop and maintain a wide range of analytic methods, models, and databases to carry out their missions and execute their program responsibilities. (page 14 Federal Agency Assessment)

The *Federal Support Toolbox* for integrated water resources management serves as a hub of information about authorities, programs, policies, methods, best practices, lessons learned, collaborations, and data to support IWRM.

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