Potomac Basin Large River Environmental Flow Needs

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Front cover: the Potomac River from South Mountain, downstream of Harpers Ferry. Photo by Jim Palmer, ICPRB.

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EXECUTIVE SUMMARY

The purpose of the Potomac Large River Environmental Flow Needs assessment is to identify the hydrologic needs of flow-dependent species and communities in four segments of the mainstem Potomac and two selected large tributaries using a modification of the *Ecologically Sustainable Water Management* approach described in Richter et al. (2006). This analysis was undertaken to advance a collaborative, multi-jurisdictional dialogue among Federal, state, regional and local water, natural resource, and land managers on developing flow recommendations that are protective of the river's ecological health. Information developed for this report, plus additional information to be acquired from other studies (including additional studies proposed in Chapter 4), is intended to assist state and local jurisdictions in making policy and management decisions that are protective of key flow characteristics. The U.S. National Park Service provided funding for this project.

This report is part of a broader effort to identify, protect, and, where necessary, restore the Potomac watershed's environmental flows. That effort includes the Middle Potomac River Watershed Assessment, which is a U.S. Army Corps of Engineers (USACE) project in partnership with The Nature Conservancy (TNC) and the Interstate Commission on the Potomac River Basin (ICPRB). In that project, ICPRB is defining quantitative flow alteration-ecological response relationships for smaller (than the six segments addressed here) tributary streams across the Middle Potomac River basin (**Figure 1**). Together, the two projects can support the development of water resource advisory tools that will enable resource managers to consider the ecological implications of land and water use decisions across non-Coastal Plain portions of the Potomac watershed.

Environmental flow is defined as the seasonally and inter-annually variable flow of water that sustains healthy river ecosystems and the goods and services that people derive from them. A river's flow regime – the magnitude, frequency, duration, timing, and rate of change of water in the river – is regarded by river scientists to be a "master variable" that influences all other aspects of riverine ecosystems, from water quality to habitat availability to energy supply to biotic interactions. Aquatic species and natural communities have evolved in concert with naturally variable flows, and so the ecological health of a river system impacted by human uses depends on restoring and/or maintaining, to the extent possible, that natural flow regime.

Because the Potomac has few large dams and is hydrologically relatively intact compared to other large Eastern U.S. river systems, this assessment focused on defining and characterizing how existing flows serve to maintain species diversity, ecological function and ecosystem health. **The primary recommendation advanced in this assessment is to maintain inter- and intra-annual variability of current flow conditions, as measured by a variety of key flow statistics over a set period of record.** This recommendation is a precautionary measure to maintain the current suite of biotic communities, based on the assumption that current flow conditions are largely intact and will help maintain them. Current hydrological conditions and the ecological functions that depend upon them are documented in this report as a baseline for additional research to quantify the ecologically protective ranges around current conditions and for future reference, as land and water use decisions and changes are contemplated in the basin.

This Potomac Large River Flow Needs assessment was developed by a research team from the Interstate Commission on the Potomac River Basin (ICPRB), the Nature Conservancy (TNC), Leetown Science Center Aquatic Ecology Branch of the U.S. Geological Survey (USGS), and the Potomac Environmental Research and Education Center of George Mason University (GMU). It includes a comprehensive literature review, development of flow hypotheses, assessment of large river ecological flow needs, statistics proposed to track those flow needs, and recommendations for additional research, monitoring, and analysis to improve understanding of flow needs. As part of the literature review, more than 480 sources of information were collected, reviewed, and organized into a searchable on-line database (see Appendix G).

This report benefited from a workshop, held September 22-23, 2010, at the National Conservation Training Center in Shepherdstown, WV, (hereinafter referred to as the September 2010 Workshop) at which 60 hydrologists, biologists, engineers, water resource managers, and regional and national experts on flow and river ecology discussed draft findings (see Appendix H). At the September 2010 Workshop, participants concluded that despite the detailed review and analysis of currently available literature, more research and monitoring is needed in order to better understand ecologically protective flow thresholds, and that a new technical working group be convened to plan for additional hydroecological research and monitoring that will support the development of more quantitative flow recommendations.

The Potomac is the fourth largest river along the U.S. Atlantic coast and the second greatest source of freshwater flow to the Chesapeake Bay. The river travels 383 miles through a 14,670 square mile watershed of six million people, most of whom live in the Washington D.C. metropolitan region. The Potomac provides more than 500 million gallons of freshwater daily to those living in its watershed, as well as other critical environmental services such as wastewater assimilation, irrigation, and power plant cooling water.

Compared to other large eastern U.S. river systems, the Potomac River is relatively intact, with few large dams regulating its flows. For this reason, the Potomac presents a rare opportunity to be proactive in defining a hydrological baseline of the flows required to sustain its natural diversity and ecosystem functions while meeting the needs of a growing regional human population. The opportunity is timely considering the watershed jurisdictions' development of state water management plans and policies, increased demand for consumptive use of river water, and the potential for increased incidence of droughts or catastrophic floods with global climate change. Continued population growth in the watershed is expected to convert forest and farmland into developed and hardened landscapes, increasing demand for water and electricity and increasing levels of runoff and pollution to the river and the Chesapeake Bay.

Based on a hydrologic alteration risk assessment, two large tributary streams and four mainstem segments were selected for this study due to the high count and severity of risk factors that can lead to altered hydrology (see Appendix B). These were:

1) Potomac mainstem from the confluence of the Shenandoah River to Point of Rocks
2) Potomac mainstem from Point of Rocks to Great Falls
3) Potomac mainstem from Great Falls to Chain Bridge (Potomac Gorge or Fall Zone)
4) The tidal fresh Potomac estuary from Chain Bridge to Occoquan Bay
5) Monocacy River mainstem
6) Opequon Creek mainstem

The Potomac River Gorge is of special concern because of its relatively unique and rare biological communities. One charge to the study's research team was to re-examine the 100 million gallon per day (mgd) (155 cfs) minimum flow-by requirement established for the Gorge by the Potomac River Environmental Flow-by Study (MD DNR 1981) and implemented through the 1978 Potomac River Low-Flow Allocation Agreement.

Four plant communities, twelve fish species, and sixteen native mussel species were selected and used as indicators to represent the diversity of species, the flow ecology relationships, and the flow needs of communities found in the large, free flowing rivers of the basin. Sufficient research and empirical data to define thresholds of ecologically acceptable hydrologic change applicable to the large rivers of the Middle Potomac River study area were not found. The research team used the available literature and professional judgment to develop five general flow-ecology hypotheses that apply to a broad range of species/communities and 18 specific flow-ecology hypotheses tailored to selected indicator taxa in the non-tidal Potomac large river segments and selected large tributaries.

Phytoplankton, aquatic grasses, zooplankton, and benthic invertebrate communities, and four fish species were used to represent key aspects of tidal freshwater ecology and its responses to low freshwater flows in the tidal fresh estuary. In general, the ecological impacts of flow into the Potomac tidal fresh estuary are to deliver nutrients and pollutants and to determine the location of the salinity gradient which governs structure and function of biological communities along the entire length of the estuary. Low flow effects on estuarine biota are for the most part indirect and realized as a change in salinity, or the volume proportions of fresh and salt water. Flow alteration as a factor affecting the Potomac tidal fresh biological communities is presently far outweighed by the effects of poor water quality and other stressors. Although of lesser importance than water quality impacts, Chapter 3 includes seven general flow-ecology hypotheses for the tidal fresh estuary.

Key Considerations that Shaped the Study Team's Findings Regarding Large River Flow Needs include:

1) The Potomac River has only minimal flow regulation, and that occurs only at very low flows. There are no dams regulating flow on Opequon Creek or Monocacy River. Thus, high and mid range flow magnitude, and frequency and duration of events, while not subject to operational management, are more influenced by land use management.
2) Except for low flows from Great Falls to Little Falls, and potentially in the Monocacy, the observed distribution of flows appears to be the result of weather, climate, and land use factors.
3) Evidence suggests that there have been changes in flow distributions over the past 100 years, but additional analyses are required to determine the roles of climate, land use, or other factors, in those changes.
4) Intra- and inter-annual variability in flows is high for these stream reaches.
5) For aquatic species, very few studies in the literature provided directly applicable quantitative measures of flow needs (beyond velocity requirements at the individual organism scale). These requirements could not be translated to stream discharge values. The literature and expert judgment did provide qualitative descriptions of flow needs.
6) No documented evidence of species impairment due to current levels of flow management was found in Potomac large rivers.
7) Low flows in the Great Falls to Little Falls reach are lower than they would otherwise be due to drinking water withdrawals at, and above, Great Falls. A 100 million gallons per day (mgd), equivalent to 155 cubic feet per second (cfs) minimum flow-by at Little Falls and 300 mgd (464 cfs) from Great Falls to Little Falls recommendation has been observed since the early 1980s. During that time flows have rarely been that low. In 2002, when flows were approaching these levels, field observations in areas that were surveyed did not identify any stressed communities, and there did not seem to be a significant loss of habitat in these reaches.
8) The flow "needs" of most freshwater species in the tidal fresh river segment are typically a reflection of their salinity preferences and tolerances. High river flows can benefit taxa and life stages that prefer freshwater while low flows can benefit taxa and life stages that prefer salt water.
9) Eutrophication and sedimentation of the tidal Potomac River have significantly changed many estuarine flow-ecology relationships. The flow needs identified for tidal freshwater biota do not consider the very significant confounding influence of the tidal freshwater Potomac River's poor water quality. Nor do they consider the flow needs of higher salinity taxa such as oysters, young-of-year menhaden, and older, resident striped bass.
10) Future impacts on flow from climate change are uncertain, but studies have suggested that impacts in the middle Atlantic region of the U.S. will be lower in magnitude than elsewhere and

may result in both greater precipitation and higher temperatures (which could increase demand for electricity and consumptive water use).

Considering these points, the team's approach has been less a question of determining what flows are required to *restore* these river sections, and more a matter of *defining and characterizing how existing flows are functioning* to maintain ecological values. Tables 12-16 provide that characterization. Tables 12 and 13 relate the flow hypotheses listed at the end of Chapters 2 and 3 to flow needs, grouped into high, mid-range, and low flow categories and, within categories, addressing magnitude, frequency and duration of events. In Table 14, a set of flow metrics, or statistics, are proposed to "capture" the ecological needs identified in Tables 12-13. Table 15 provides a cross reference showing which flow statistics are relevant to the flow needs of each biotic community.

Table 16 shows values computed for each flow statistic for the five non-tidal large river reaches (the Opequon Creek mainstem, the Monocacy River mainstem, and three Potomac River mainstem segments between the Shenandoah River confluence and Little Falls) selected for this study. These values are what the project research team has deemed to be the current conditions. The flow statistics for each reach were calculated from daily mean flows recorded at U.S Geological Survey stream gages between 1984 and 2005, a period sufficiently long for reasonable estimates of flow statistics but not so long as to be unduly influenced by longer-term historic conditions. Freshwater inflow to the upper tidal estuary can be represented by either the Little Falls or Little Falls (adjusted) flow statistics. Most of the drinking water withdrawn above Little Falls is returned to the tidal fresh estuary at Blue Plains as treated wastewater. Since Little Falls (adjusted) flow equals Little Falls flow plus drinking water withdrawals, that flow is a better measure of total Potomac River contribution to the tidal fresh zone downstream of the Anacostia River. Little Falls flow is the better measure of Potomac River contribution to the portion of the tidal river above the Anacostia River. Table 16 includes first and third quartile values, in addition to medians, in order to indicate variability associated with these measures.

Potomac Large River Flow Needs Assessment Conclusions

1) **For the entire range of flows, the current flow characteristics, as defined in Table 16, should be maintained as a precautionary principle**. If additional monitoring and analysis provides more definitive indications of biological degradation due to flow, then other more protective flow recommendations might be needed.
2) **Extreme floods**: High flows and floods in the river segments in this study are not controlled by dams or other structural measures and so there are no operational mechanisms for controlling high flows. The impact on extreme high flows of impervious surface area and extent of vegetative cover in the watershed upstream of these river segments is not known presently but is being evaluated as part of the Middle Potomac Watershed Assessment.
3) **Small Floods**: No observed major problems, so current flow characteristics should be maintained.
4) **Low Flows at Potomac Harpers Ferry to Point of Rocks**: This section benefits from slightly augmented flows during low flow due to water quality and water supply releases from Jennings Randolph and Savage River reservoirs. There are no observed flow-related, ecological problems in this reach, therefore, recommend maintaining current flow characteristics.
5) **Low Flows at Potomac Point of Rocks to Great Falls**: Withdrawals should be managed so that Potomac River flows do not fall below those experienced in the 1999 and 2002 droughts. It is recommended also that a stream flow gage be installed to measure actual flow levels at the Great Falls weir.
6) **Low Flows at Potomac Great Falls to Little Falls**: a) prior (1981) recommendation for a 300 mgd minimum flow should be continued, but b) implement an ecological monitoring program to better understand if there are impacts and need to adapt our management, and c) as a

precautionary measure until this study is completed, develop reservoir operating procedures which give consideration to maintaining variability at extreme low flows.

7) **Low Flows at Potomac Little Falls to Chain Bridge (tidal river)**: a) maintain the existing 100 mgd minimum flow-by, but b) implement an ecological monitoring program to better understand if there are impacts and need to adapt our management, and c) as a precautionary measure until this study is completed, develop reservoir operating procedures which give consideration to maintaining variability at extreme low flows.
8) **Low Flows at Potomac Chain Bridge to Occoquan Bay**: Water quality is the major determinant of biological health, not freshwater flow. Current flow characteristics should be maintained.
9) **Low Flows at Monocacy River and Opequon Creek**: As a conservative measure, until additional investigations of potential low flow impairment can be conducted, current low flow statistics should be maintained and withdrawal volumes not be allowed to push flows below those observed in 1999 and 2002.

Information Gaps, Research, and Monitoring Recommendations

For most of the species discussed in this report, existing information is adequate only for qualitative estimates of how normal variability in population and distribution is affected by alterations in flow conditions. Therefore, additional research, monitoring, or analysis could help to define ecologically acceptable levels of hydrologic change, or acceptable thresholds of hydrologic alteration from current conditions.

Although the September 2010 Large River Flow needs workshop was aimed at defining the full range of natural flow conditions for six river segments, the participants paid greatest attention to low flow conditions and ecological response in the Great Falls to Little Falls river segment. Some of the workshop participants' most significant suggestions, selected by the report authors, include:

1) Address monitoring and data analysis gaps identified in the past 2004 and 2005 Potomac low flow workshops, including studies to better understand "normal" variation of species populations and ranges, and studies to better understand the effects of extreme low flows on species and their habitat.
2) Monitor effects of high flows using floodplain plants and communities. Floodplains have many advantages for monitoring ecological impacts of high flows and their alteration. Long-term floodplain vegetation monitoring will allow for specifying critical thresholds in flow more accurately, and can serve as an observatory of changes in floodplain communities in response to changes in hydrologic regime (and other changes). The Potomac Gorge should be a priority site for monitoring the effects of high flows due to its great concentration of rare flood-dependent vegetation community types.
3) Monitor impacts of low flows using mussels. Mussels are a useful group to use for studying impacts of low flows because they are sessile and more likely to become stranded. The species recommended to be used to monitor instream environmental conditions are *Elliptio complanata, Pyganadon cataracta, Utterbackia imbecillis, Lampsilis sp,* and possibly *Strophitus undulatus and Alasmidonta undulata.*
4) Monitor fish to establish a better quantification of their flow needs, including fall young-of-year fish, alosid passage over the Little Falls weir, and in- and out-migration of fish. Also pursue research on fish species which live near drinking water intake pipes, focusing on short rather than long life span species.
5) Acknowledge opportunities and limitations for researching flow-ecology relationships in other species groups:
    a. Macroinvertebrates may be useful for flow-ecology research, but large river study protocols are not well developed. Crayfish may be an important group to study as they

are an important food source to other species, and to discern their life-cycle relationships to flow.
   b. Amphibians and reptiles are difficult to study because they are mobile, but could be of interest for tracking loss of habitat if flooding is reduced.
   c. Cormorants are important as fish predators, but they are mobile, part-time residents, and population changes may be due to factors other than river flow and fish (prey) abundance.
6) Track cumulative upstream consumptive use of water because of its potential role in reducing extreme low flows.
7) Investigate the use of remote-sensed imagery, such as Light Detection and Ranging (LIDAR) high-resolution topographic data, for determining the extent of loss of habitat at different flow levels.
8) Consider pursuing a modified Instream Flow Incremental Method (IFIM) study for evaluating the relationship between flow and habitat at flows below 1000 mgd in the stretch from Great Falls to Little Falls.

Workshop participants recognized that funding, staff time, and public attention or political will are constraining factors for developing a large river flow needs research and monitoring program. They concluded that a coordinated federal, interstate, and academic partnership would be needed to obtain resources and long term commitment to: (a) developing a baseline during mid-range flow conditions, and (b) enabling monitoring and additional research during the more extreme high and low flow conditions. The broader Middle Potomac River Watershed Assessment project (of which this large river flow needs assessment is a part) is analyzing *quantitative* flow alteration-ecological response relationships for classes of smaller streams and river systems, but it may yield some insights relevant to larger river flow needs. After that work is complete (expected 2011), it should be evaluated for any flow-ecology monitoring variables that could be applied and pursued in a larger river context.

Next Steps

The following "next steps" were proposed at the September 2010 Workshop to begin addressing the information gaps described above.

1) Convene a large river flow needs small technical workgroup to build on findings of this assessment and inputs provided in the September 2010 Workshop:
   a. Develop more quantitative flow recommendations for large river segments to define bounds around what are acceptable levels of variation from current conditions.
   b. Develop a large river hydroecological monitoring plan and priority research needs list.
   c. Re-evaluate historic 300/100 mgd flow recommendation and requirement with a research and monitoring plan that will provide the scientific basis for either maintaining or revising the low flow recommendations for Great Falls-Chain Bridge reach.
2) Take advantage of concurrent related work from the Middle Potomac Watershed Assessment project to:
   a. Examine quantitative analysis of flow alteration/ecological response relationships for classes of smaller streams and rivers in 2011 for patterns or relationships that could inform development of large river flow recommendations.
   b. Meet with watershed jurisdictions agencies to discuss the use of both large river and smaller stream flow-ecology work for informing state-level water (and land) management and decision-making processes that will impact ecological flows in these river segments.
   c. Investigate support for development of a Potomac basin-wide comprehensive plan, as a framework to support state-level water resource management needs in a coordinated manner across the basin, and potentially including applied tools like Decision Support Tools.