

**Scope of Work
Development of Draft Flow Ecology Building Blocks
for the Rivanna Watershed**

Preparation of Literature Reviews and Summary Report

Drs. Paul Angermeier (Virginia Polytechnic Institute and State University) and Mark Kopeny (the University of Virginia) will serve as the principal investigators for this project. In this role, Drs. Angermeier and Kopeny will foster regular communication among contributing scientists to ensure coordination of the tasks described below.

Drs. Angermeier and Kopeny will enlist the support of additional academic researchers as needed to create a team to compile the following information. The focus of this scientific investigation will be on the effect of various flow conditions on ecosystem components of the Rivanna River and the tributaries feeding into the Rivanna. Researchers will focus on riverine fishes and other significant faunal elements that may include sensitive or threatened taxa; floodplain ecosystems associated with the Rivanna river system; hydrology and geomorphology; and physical and chemical characteristics of the river and its tributaries.

1. Literature Review. Conduct a literature review of sources that appear useful in describing the ecological outcomes of various flow conditions in the Rivanna river and its tributaries. A particular emphasis should be placed on information regarding five segments of the Rivanna river and its tributaries: i) the Moormans river, ii) the Mechums river, iii) the North Fork of the Rivanna, iv) the South Fork from the base of the South Fork Rivanna Reservoir dam and the confluence of the North Fork and the South Fork of the Rivanna and v) the segment of the mainstem Rivanna from the confluence of the North and South Fork Rivanna and the confluence of the Rivanna with Moore's Creek. As used here, flow conditions shall refer to the four components of flow defined below in paragraph 1(b) and illustrated in Figure 1. This review will include, but is not limited to, informational sources that were identified during the orientation meeting held on February 25, 2005. The sources selected for review should be ones that inform our ability to define "flow-ecology building blocks." Flow-ecology building blocks depict the linkage between ecological conditions or processes and specific flow conditions (see Figure 2). To the extent possible, the literature review should identify sources that address each of the questions posed in Appendix A. A conference call will be convened at the start of the project to discuss the likelihood of finding published information relevant to these questions. Upon completion of the literature review, The Nature Conservancy and the Contractor shall again convene a conference call to discuss the extent of the data available, in order to identify the information which should be contained in the summary report, described below in paragraph 2.

- 1(a). Science Reviewers. Compile a list of potential science reviewers and review with The Nature Conservancy during the initial conference call. Contact each of these scientists and ask them to review a list of potential information sources

that can inform the ecological flow needs of the Rivanna river and its tributaries. Ask the scientists to prioritize the available information sources according to their relevance for informing ecological flow needs in the Rivanna and its tributaries. Also, ask scientists to identify representative indicator species for fishes and other aquatic organisms, and the riparian systems associated with the Rivanna river and its tributaries. These indicator species will be organisms that are known, or thought, to be dependent upon specific water conditions for one or more aspects of their life cycle needs.

- 1(b). Information Prioritization. Obtain and review all prioritized information sources. Summarize information provided in each priority information source. When summarizing pertinent information about species requirements and flow-dependent ecological processes, organize this information using the following components of flow: subsistence flows, base flows, high pulse flows, and overbank flows¹ (see Figure 1).
2. Summary Report. As a team, develop an integrated summary report of information available to construct flow-ecology building blocks. This summary report should, at a minimum, address each of the questions posed in Appendix A or discussed in a conference call convened after completion of the literature review. In addition to text descriptions of flow-ecology linkages, the summary report will include: (a) key findings about linkages between specific ecological flow components and biotic tolerances or dependencies; (b) pictorial models or box-and-arrow diagrams illustrating connections between flow components, life cycles of representative indicator species, and key ecological processes. Contractor and The Nature Conservancy will work together to determine the format requirements of this document.
 - 2(a). Peer Review. Solicit peer review of summary report by all scientists listed in 1(a) above, and incorporate summary comments in an interim report.

Workshop to Develop Draft Flow-Ecology Building Blocks

1. Distribute the final drafts of the literature review and summary report to all workshop participants at least three weeks prior to workshop and ask them to review these materials prior to the workshop.
2. Participate in a 3-day workshop to discuss the findings of the literature review and summary report. During the workshop, help facilitate interactions among scientists in small group discussions to refine or create new flow-ecology building blocks. These

¹ As used here, a high pulse flow or overbank flow would be generated by a rainfall event (see Figure 1). A high flow pulse remains within the banks of the channel, whereas an overbank flow spills into floodplain areas. All remaining (non-runoff) river flow periods would be characterized as being either a base flow or a subsistence (extremely low) flow; the threshold for the latter should be defined for each river, but might be defined as being the lowest 10th percentile of low flows.

flow-ecology building blocks will include quantified values for subsistence, base, high pulse, and overbank flows; and include (as necessary) different values for dry, average, and wet years.

3. Prepare report describing flow-ecology building blocks and obtain review and approval from all workshop participants.

Appendix A

Questions to be Addressed in Summary Report

Hydrology

1. Do stream gauges exist along the river and its tributaries, and if so, where are they located, who maintains them, and how long have they been in operation?
2. What are/were the typical seasonal patterns of natural river flow, e.g., when do higher flows tend to occur, when do the lowest flows occur?
3. To what extent have the base, high pulse, and overbank flows in the river changed over time in response to human influences? Have extreme low flows (i.e., subsistence flows) become more frequent or extreme?
4. What is the sensitivity of the flow regime to land use influences as compared to water system management?
5. What is the sensitivity of the flow regime to anthropogenic groundwater withdrawals?

Suggested approaches:

- Prepare a schematic drawing of the drainage network, noting the mean annual flow and drainage basin area at all available stream gauge stations.
- Provide a tabular summary of water uses and water structures, at the finest level of detail available.
- Prepare “typical” hydrographs (both annual and decadal hydrographs) for undeveloped and developed conditions at all river monitoring stations.
- Categorize the natural hydrologic regime into ecological flow components: subsistence flows, base flows, high pulse flows, overbank flows. Using the Indicators of Hydrologic Alteration (IHA) software, estimate quantitative values for each of these components under natural, historic, present, and future conditions (if hydrologic simulation data are available). Assess changes in the magnitude, duration, timing, and frequency of each flow component.
- Prepare flow duration curves for undeveloped and developed conditions at all stream gauges.
- Characterize typical groundwater-surface water interactions using monitoring well data or other sources of information.

Hydraulics

1. Has any hydraulic modeling been performed for the river? Has any flood hazard mapping been undertaken?
2. How well are relationships between river flow and the distribution of velocities and depths in the river channel understood?
3. Is there longitudinal (upstream to downstream) connectivity in flow or are there major discontinuities (i.e., diversion dams), and if so where?

4. Has the lateral connectivity between the river and its floodplain been altered in any way?

Suggested approaches:

- Develop river stage-discharge relationships (e.g., at flow monitoring stations or from hydraulics models).
- Plot the relationship between flow and estimated percent floodplain inundated at representative river transects (e.g., at stream gauges or from aerial photos).
- Develop flow depth and velocity estimates across river transects (e.g., at stream gauges or using hydraulics models)

Geomorphology

1. Have any topographical surveys been conducted of the river channel or its associated floodplain? (including any surveying for bridges, roads, floodplain mapping, etc)
2. Is the channel and floodplain system in dynamic equilibrium or disequilibrium? Is the sediment input to each segment in equilibrium with the capacity of the channel to transport it through the segment? Are there detectable trends in the elevation of the river bed, indicating degradation or aggradation? Has the river's longitudinal profile changed over time?
3. Is the South Fork Rivanna reservoir filling with sediment and organic matter, and if so, how rapidly?
4. Has the channel or floodplain width changed over time?
5. Has the channel's planform changed over time, such as between meandering and braided forms?
6. Has the size distribution of streambed sediments changed over time?
7. Has the availability of instream physical habitats changed over time? (e.g., changes in availability of pools or riffles)
8. Are lateral channel migration or bar formation important ecologically? (e.g., to support riparian plant communities). Is sediment deposition in the lake important to recruitment or survival of plants?
9. Has human activity and land use significantly altered the stream channel and floodplain morphology and processes?

Suggested approaches:

- Plot the river's present-day longitudinal profile from topographic maps or field survey information
- Characterize historical changes in longitudinal river slope, if adequate data are available (e.g., at multiple river flow monitoring station locations).
- Characterize changes in South Fork Rivanna river bathymetry, if adequate data are available.
- Review historical aerial photographs to assess changes in river plan form and floodplain over time

- Assess changes in channel cross-sectional shape, if data are available (e.g., at stream gauges)
- Develop sediment budget estimates for appropriate representative time periods, such as historic, pre-dam agricultural, and post-dam periods.
- Estimate flows necessary to entrain river sediments (to maintain desired streambed composition or move sediment downstream).
- Estimate channel forming flows necessary to maintain desired channel geometry.
- Estimate channel migration flows needed to sustain floodplain development and riparian ecosystem.

Water Quality

1. Has water quality data been collected for the river and its tributaries, and if so, by whom, where, for how long, and of what type?
2. How do water quality conditions vary spatially in the river and its tributaries?
3. What is known about water quality problems in the rivers and its tributaries? Are any of the designated uses for the river or its tributaries impaired? If so, has a TMDL study been done, and what are its results?
4. Where are the wastewater discharge permit locations on the segment? What are their permitted flows? What proportion of the summer low flows in the river arises from upstream wastewater discharges? What affect, if any, do upstream water withdrawals have on wastewater discharge?
5. What is known about daily, seasonal, annual fluctuations in key parameters such as dissolved oxygen or temperature in the river and its tributaries?
6. How do human activities, including the operation of any upstream reservoirs, affect water chemistry, temperature, or dissolved oxygen?
7. What water quality components are of greatest concern to the target organisms, life stages, or riverine processes (e.g., dissolved oxygen, suspended sediment, temperature, chemical elements, nutrients)? Are species distributions or abundances thought to be affected by water pollution?

Suggested approaches:

- Characterize natural and post-development patterns of water temperature, including seasonal and diurnal fluctuations.
- Characterize natural and post-development patterns of dissolved oxygen in the water, including seasonal and diurnal fluctuations.
- Identify known relationships between reservoir releases and discharge of contaminants present in the reservoirs.

Freshwater Ecology

1. What type of biological data has been collected for the river and its tributaries? Who collected these data, over what time frame, and how often?
2. Has the abundance or distribution of certain species changed over time? Are these changes thought to be linked to changes in river flows? Are data available to document these trends?
3. What species (fish, birds, mammals, invertebrates, aquatic plants or riparian vegetation) are of greatest concern from either ecological or socioeconomic, or recreational standpoints?
4. What is known about the linkages between flow variations and life histories of aquatic species? What times of year are most critical for indicator species, life stages, or species assemblages?
5. Can the flow needs of certain indicator species be used to represent the flow needs of assemblages of organisms (e.g., fish communities, riparian vegetation)?
6. If the river flow regime has been altered by human influences, are necessary flow conditions still properly sequenced to enable successful life cycle completion for indicator species?
7. Which habitats are most limiting, and what is the importance of drought, flooding and intermediate flow conditions for developing and maintaining these habitats?
8. Are aquatic floodplain habitats critical for maintaining fish populations in rivers?
9. Is the aquatic ecosystem dependent upon energy subsidies (e.g., detrital matter) that are brought into the river from the floodplain during floods?
10. Do certain species require particular flow levels to facilitate movements in the river?
11. If reservoir releases are proposed in order to provide recommended flows, could there be the effects on the ecosystem function and fisheries of the stream system?
12. Is large woody debris an important component of the aquatic ecosystem?
13. Are any invasive plant species an issue of concern?

Suggested approaches:

- Define life history stages for a diverse cross-section of species, such as aquatic plants, invertebrates, and resident and anadromous fishes, along with any known relationships to flow components and their seasonality. Specific life history aspects to consider include adult foraging, survival, and gonadal development; spawning migration and activity; egg, larva, and juvenile development; juvenile growth and survival.
- Define relationships between flow components and maintenance or access to critical habitats for completion of life history stages for key species.
- Describe ways in which flow components will influence primary productivity, decomposition processes, and nutrient dynamics.

Riparian Ecology

1. Have the riparian plant communities or distributions of riparian plant or animal species been surveyed or characterized? Have they changed over time?
2. What is known about relationships between river flows, alluvial water table levels, floodplain inundation patterns, and the influence of these hydrologic conditions on riparian plants or animals?
3. Do certain riparian plants or animals depend upon physical habitat conditions that are shaped by river flows? Is lateral channel migration or bar formation important in forming these physical habitats?

Suggested approaches:

- Define life history stages for a diverse cross-section of riparian obligate flora and fauna species, along with known relationships to flow components and the seasons in which they occur.
- Define relationships between flow components and maintenance or access to riparian habitat conditions.
- Describe relationships between flow components and vulnerability to disturbances such as fire or introduced species invasions.
- Describe ways in which flow components will influence primary productivity, decomposition processes, and nutrient dynamics.

Appendix B

Project Schedule

Conference call to discuss project objectives	01 June 2005
Complete review of priority information sources	30 June 2005
Conference call to define scope of summary report	01 July 2005
Complete summary report	31 August 2005
Obtain reviews from selected reviewers	15 September 2005
Conference call to discuss workshop	29 September 2005
Revise and re-distribute literature review and summary report	30 September 2005
Participate in workshop	To be scheduled in October 2005
Final workshop report	31 October 2005

Figure 1. Example depiction of four different flow conditions to be used in organizing the literature review and summary report.

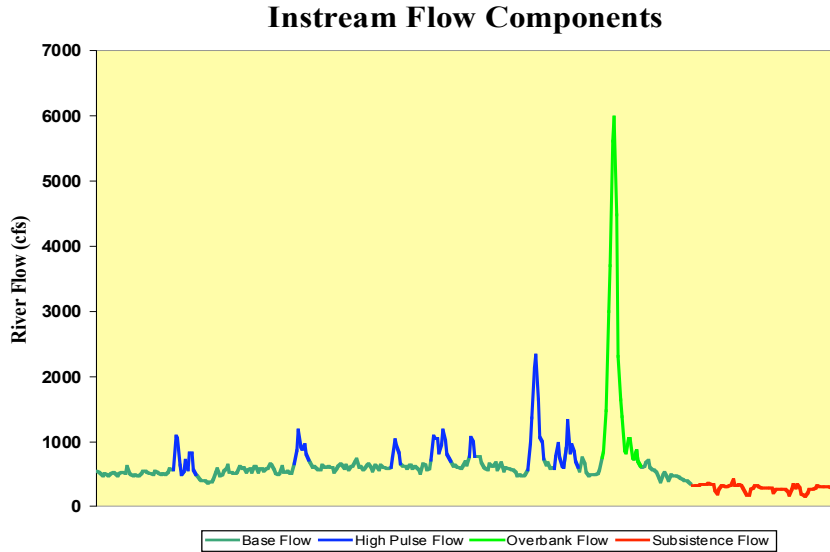


Figure 2. Example of flow-ecology building blocks developed for the Savannah River.

