Science Advisory Board begins task of selecting approach for ecological flow determination

On November 8, the N.C. Division of Water Resources (DWR) convened the first meeting of a Science Advisory Board (SAB) tasked by the North Carolina legislature with selecting an approach to identifying "ecological flows"—that is, flows needed to maintain ecological integrity in the state's streams and rivers. The mandate for a SAB was part of House Bill 1743 (SL 2010-143) "An act to direct the Department of Environment and Natural Resources to develop basinwide hydrologic models" passed by the 2010 General Assembly.

Addressing the first meeting of the 15-member SAB, DWR Director Tom Reeder emphasized that, while the board's work could take several years, it is only part of a much broader stakeholder process.

"The task of this expert panel is to advise the Department of Environment and Natural Resources on an approach to characterizing the ecology of river basins and a method to determine flows," said Reeder. "The SAB is not a final decision maker and will not advise on specific flow numbers. Nor will this board's recommendations replace site-specific studies that would be needed for Environmental Impact Statements and other such purposes."

Although the charge to the Ecological Flows SAB is limited and strictly scientific, the board's recommendations could be far-reaching. Some expect that the SAB recommendations will eventually become a basis for deciding how much water needs to be left in streams as part of a statewide water allocation system.

Although HB 1743 says nothing about water allocation or permitting of withdrawals, the scientific and technical capabilities that the law mandates will form the necessary groundwork for water allocation. It requires DWR to develop river basin models that include surface and groundwater resources, interbasin transfers, withdrawals and returns, data from local water supply plans, and ecological and instream flow requirements. The river basin models are required to be able to predict when yield will be inadequate to meet all needs and essential uses and when ecological flows will be adversely affected. Ecological flow as defined by HB 1743, is the stream flow necessary to support "ecological integrity"—that is, "to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat."

The current regulatory landscape

While the terms "ecological flow" and "ecological integrity" are new to North Carolina's regulatory lexicon, the concept of ecological integrity is not. North Carolina Administrative Code 15A 02B .0202 defines biological integrity as "the ability of an aquatic ecosystem to support and maintain a balanced and indigenous community of organisms having species composition, diversity, population densities and functional organization similar to that of reference conditions." The North Carolina Administrative Code also provides that

- the general standard for the best use of all waters is for "aquatic life propagation and maintenance of *biological integrity* (including fishing, and fish), wildlife, secondary recreation, agriculture, and any other usage except for primary recreation or as a source of water supply for drinking, culinary or food processing purposes," (italics added) and
- that "any water pollution sources that preclude any of the above-described uses are considered to be violating a state water quality standard."

Therefore, reducing flows so that existing pollution concentrations increase and undermine biological integrity would seem to be an indirect violation of water quality standards that could be remedied by restrictions on withdrawals. (Howett and Rogers 2005)

However, because North Carolina has no water withdrawal permitting program, there is no regulatory mechanism to prevent new withdrawals that would reduce flows below the needed volume. Streamflows are primarily regulated under the direct authority of federal laws such as Sections 404/401 of the Clean Water Act, the Endangered Species Act, the National Environmental Policy Act, and the Federal Power Act, and under authority of the N.C. Dam Safety Act and State Environmental Policy Act. Often, these laws require only the maintenance of minimum flows in rivers and streams. According to Jim Mead, DWR's aquatic ecologist, minimum flows are often set very low (usually 7Q10, a drought level) and provide only enough water for survival of aquatic life during occasional, short-term events. In areas with high population growth and increasing water withdrawals, streams are experiencing more frequent and longer periods when only the minimum flow is left, and aquatic life is suffering.

Current instream flow science

Under current scientific thinking, a regulatory focus on water quality standards alone cannot adequately protect ecological integrity. Decades of study have shown that stream flows provide much more than simple pollutant dilution:

- Flow determines physical habitat, which in turn determines biotic composition.
- Aquatic species have evolved life strategies in response to natural flow regimes.

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- The viability of many riverine species depends upon maintenance of natural patterns of longitudinal and lateral connectivity.
- Alteration of flow regimes facilitates the success of exotic and introduced species in rivers. (Bunn and Arthington 2002)

Based on these insights, the field of instream flow science has grown rapidly (Petts 2008), and many states have adopted or are in the process of adopting instream flow standards that move beyond the single minimum value required to meet a legal standard. According to the National Research Council (2005), the current trend is towards comprehensive river science that includes a hydrologic regime with seasonal and inter-annual variation, the biological aspects of aquatic and riparian ecosystems, in-channel and out-of-channel riverine physical processes, and water quality considerations including temperature, dissolved oxygen, nutrient loading, and toxics.

Establishing ecological flows

Just how to incorporate all these considerations into ecological flow standards that can be administered across a jurisdiction with varying climate, geology, soils, topography and resulting biotic communities in a way acceptable to stakeholders is a task that many states have grappled with. While the negative impacts of flow alteration have been widely documented, no general rules to guide setting of instream flow standards have emerged. Poff and Zimmerman (2009) reviewed 165 studies done across the globe over the last four decades in an effort to determine if general relationships could be drawn from disparate case studies to help guide environmental flows science and management. They concluded:

Our analyses do not support the use of the existing global literature to develop general, transferable quantitative relationships between flow alteration and ecological response; however, they do support the inference that flow alteration is associated with ecological change and that the risk of ecological change increases with increasing magnitude of flow alteration.

Without "general, transferable quantitative relationships" it would seem that only site specific studies could support the establishment of ecological flow standards, but site specific studies are time consuming and expensive. In 2001, the Texas legislature directed several state agencies to "conduct studies and analyses to determine appropriate methodologies for determining flow conditions in the state rivers and streams necessary to support a sound ecological environment." Studies on priority basins and bays were launched. However, in 2007, the Texas legislature recognized the need for quicker action and passed legislation creating an accelerated process for developing instream flow recommendations based on existing information.

If general quantitative flow-response relationships cannot be established, and site-specific studies are too time consuming and expensive, how, then, are ecological flow standards to be set? Scientists have suggested a number of approaches. According to Petts (2008) approaches are of two types: hydrological and habitat.

Under the rationale that flows should mimic natural climate conditions, hydrological approaches rely on analysis of flow records. Flow is used as a simple proxy for parameters that have a key influence on aquatic, wetland and riparian habitats along the river corridor. Long records of stream flow are needed and, in highly modified systems, baseline conditions may be difficult to determine.

Habitat approaches are based on evidence that biological communities have evolved in response to flow variability, with a range of habitats available to different species at different locations (pools, riffles, runs for instance) and times. This approach assumes that habitat locations can be identified by observation of surface flow and verified by hydraulic measurements and that rating curves can be developed to describe changes in areas of suitable habitat in response to flow. Habitat approaches may also assume that if habitat for the most common species is preserved, the most important characteristics of the ecosystem and survival conditions for most of the aquatic community might also be preserved.

ELOHA: Combining a regional hydrological approach and ecological response relationships

Building on earlier work, a number of leading experts in instream flow science recently collaborated on a framework for assessing environmental flow needs. The collaborators say that it is now possible to classify rivers according to ecologically meaningful streamflow characteristics and to use hydrologic modeling to estimate necessary streamflows even where stream gauging records are lacking. In their framework—the ecological limits of hydrologic alternation (ELOHA), existing hydrologic and ecological data from rivers within a region are used to establish relationships between flow alteration and ecological responses. The relationships then become the basis for a stakeholder driven process of developing regional flow standards. (Poff 2009)

Hydrologic stream classification system for North Carolina

To support its ongoing river basin planning program, in 2009, DWR (with funding from the Environmental Defense Fund) contracted with Environmental

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Flow Specialists of Fort Collins, CO, to develop a hydrologic stream classification system specific to North Carolina. The project resulted in software that can be used to assign streams and rivers to one of seven perennial or intermittent classes with similar flow regime characteristics. A panel of experts convened by DWR then modified four of the seven classes by establishing two subclasses, and producing 11 classifications overall. Based on evidence that similar flow regimes result in similar biotic communities and community functioning, this classification system can be used with basinwide hydrologic models to identify flow regimes needed to maintain or restore ecological integrity in streams and rivers. DWR will test the viability of the classification system using the Neuse River Basin hydrologic model combined with existing high quality habitat modeling studies at two demonstration sites in the Eno River Basin.

Responsibilities of the SAB

Once the SAB has agreed upon an approach to characterizing the ecology of river basins—whether it be hydrologic, habitat, or a hybrid approach—and identifying flow regimes that will protect ecological integrity, then they must agree on an approach for expressing the flow needs in a management context.

For example, Richter (2009) has suggested a hydrologic approach to quantifying desired environmental flows called the Sustainable Boundary Approach. This approach would link water management to maintaining a semblance of natural (baseline) conditions by setting the degree of allowable flow alteration. A precautionary approach, the Sustainable Boundary Approach, would set only the magnitude of flow rather than complex, multi-parameter, seasonally varying flow prescriptions. The advantage of this approach is that it is easier to implement.

A related approach developed and used widely in South Africa is called the Downstream Response to Imposed Flow Transformation (DRIFT). The basis of the DRIFT method is a classification system that describes different levels of ecological health and the associated degree of allowed flow alteration. This approach makes implications of management decisions explicit. (Postel and Richter 2003) A similar system has just been proposed for the state of Connecticut.

Other approaches cited by DWR include setting the threshold for allowable withdrawals as the amount that results in a change in the hydrologic stream classification, and setting a flow target that varies seasonally or monthly and allowing some variation within bounds above and below the target. Other approaches may emerge as the SAB reviews studies and deliberates.

Public input

It may take several years for the SAB to do its work and DWR to develop the first river basin model that incorporates ecological flow prediction. However, when models start rolling off the assembly line, the public will have opportunities to review the models and make comments. SL 2010-143 requires that the N.C. Environmental Management Commission review and approve all models and that public comment be part of the EMC review. By November 2011, DWR must report to the General Assembly on how long it will take to complete all models and incorporate ecological flows.

Meetings of the Ecological Flows SAB are open to the public and meeting times and places will be posted on the DWR website at: http://www.ncwater.org/Data_and_Modeling/eflows/index.php?tabid=1 Presentations made to the SAB, materials that the SAB reviews, summaries of meetings, and recordings of meetings will also be posted on the website. An announcement will be sent to the WRRI electronic listserv when new materials are posted. A listing of SAB members and materials and a recording from the November 8 meeting are currently available.

Resources

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Reckhow to help guide RTI International's global water strategy

After thirty years of teaching and research at Duke University─seven of which he also served as director of WRRI—Dr. Kenneth Reckhow has joined RTI International (Research Triangle Institute) where he will play a key role in the realization of RTI's global water strategy.

In developing a strategic direction for its water programs, RTI will benefit from Reckhow's unique combination of expertise in Bayesian statistics and application of Bayesian approaches to deal with uncertain information in making decisions about water quality and ecological problems. He has collaborated on the development of a Bayesian probability network to recommend a nitrogen TMDL for the Neuse River, a Bayesian model to predict benthic oxygen demand from organic matter loading in estuaries and costal zones, a Bayesian network model to assess drought indicators for lake management, and Bayesian analysis to model phosphorus trapping in Everglades wetlands, among other applications.

His recognized expertise in uncertainty analysis for ecological applications has led to his selection for numerous scientific panels and committees, including chair of the National Research Council Committee to Assess the Scientific Basis of the Total Maximum Daily Load Approach to Water Pollution Reduction and member of the Committee on Restoration of the Greater Everglades Ecosystem. He currently chairs the National Research Council's Committee on Evaluation of Chesapeake Bay Program Implementation for Nutrient Reduction to Improve Water Quality and has just been selected as a member of the EPA Science Advisory Board's Review Panel on Nutrient Criteria for Florida's Estuarine and Coastal Waters, and Southern Canals - Methods and Approaches for Deriving Numeric Approaches.

At RTI he will bring this expertise to collaborative projects involving modeling and decision analysis for environmental management and to his role as a thought leader and principal investigator.

Reckhow said the opportunity to work in an environment where there is ample support for investigators, the ability to collaborate on large projects, and the prospect of offering new directions in environmental research persuaded him to retire from teaching and focus on research.

He said that his long involvement in scientific panels evaluating efforts at ecosystem restoration has suggested to him an emerging question for environmental management efforts: Have we set water quality standards we can't meet without enormous lifestyle changes that people are unlikely to accept? He cited restoration efforts in the Chesapeake Bay and Lake Okeechobee where millions of dollars have been spent with only marginal improvement. He suggested that the same might be true of nearby Falls Lake .

Reckhow hinted at a possible direction for future research with the questions: Shouldn't sustainability analysis include an assessment of the relationship between our lifestyle expectations and our water quality expectations? How is water use and enjoyment affected if we fall short of our water quality standards?

He brings his ideas for future directions in ecosystem management to RTI as chief scientist for the Water and Ecosystem Management Program in the Global Climate Change and Environmental Sciences Unit. As Duke Professor Emeritus, he continues to advise his current doctoral students.

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