Scientific Principles for Definition of Environmental Flows

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Background

The purpose of this memorandum is to describe some scientific principles for the establishment of environmental flow requirements in Texas streams, rivers, bays and estuaries. Since 1977, the State has performed bay and estuary studies to identify "beneficial inflows" that are associated with "a salinity, nutrient, and sediment loading regime adequate to maintain an ecologically sound environment in the receiving bay and estuary system that is necessary for the maintenance of productivity of economically important and ecologically characteristic sport or commercial fish and shellfish species and estuarine life upon which such fish and shellfish are dependent" (Texas Water Code §11.1491; §16.058). In 1985, the 69th Texas Legislature enacted legislation that directed the State's regulatory agency to consider the effects of issuing water rights permits on the environment, including freshwater inflows to bays and estuaries, water quality, and flows to protect existing instream uses for rivers and streams (Texas Water Code §11.147, §11.150, §11.152).

Prior to and since that time, instream flow studies on rivers and streams have been performed largely in response to individual water rights applications, or other regulatory proceedings, with varying levels of participation by State and Federal agencies and local entities. However, an instream flow data collection and evaluation program for rivers and streams was not authorized until the 77th Texas Legislature passed Senate Bill 2 in 2001. This bill mandated that "The Parks and Wildlife Department, the commission [TCEQ], and the board [TWDB], in cooperation with other appropriate governmental agencies, shall jointly establish and continuously maintain an instream flow data collection and evaluation program and shall conduct studies and analyses to determine appropriate methodologies for determining flow conditions in the State's rivers and streams necessary to support a sound ecological environment" (Texas Water Code §16.059). The three agencies maintain a website that documents the studies and reports produced to date: http://www.twdb.state.tx.us/InstreamFlows/

The three State agencies charged with implementing Senate Bill 2 prepared a Programmatic Work Plan and a Technical Overview to guide the instream flow program (TPWD, TCEQ, and TWDB, 2002, 2003). These documents were reviewed by a committee of the National Academy of Sciences, whose findings were published by the National Academy Press (National Research Council Committee, 2005). In the 2003 Texas Legislature, Senate Bill 1639 established a Study

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Commission on Water for Environmental Flows, and a Science Advisory Committee to provide advice and assessment of Texas current environmental flow procedures (Texas Water Code §36.116). The report of the Science Advisory Committee is available (Science Advisory Committee, 2004). These panels, on which the authors of this memorandum have served — the Study Commission on Water for Environmental Flows (Sansom), the Science Advisory Committee (Montagna, Ward), and the National Academy Committee (Maidment, Winemiller) — have carried out an extensive study of methods for establishing environmental flows. Based on these studies, we suggest the following principles to guide the scientific development of environmental flow requirements in Texas.

General Principles

1. **The soundness of ecological integrity is ensured by sustainability of natural resources.** For all aquatic ecosystems, sustainability is ensured when the habitats and critical flow regime characteristics that support ecosystem components and processes are maintained. Aquatic ecosystems are subject to periodic, sometimes extreme, variations of biotic and abiotic resources — these variations are not only natural, but are also important contributors to ecological sustainability in the long run. The extent to which ecosystem components and processes are maintained in the face of perturbations or variations in resources indicates the resilience of the system.
2. **Field measurements are the keystone to assessing and understanding ecosystem components and processes.** An aquatic ecosystem is characterized by its hydrology, aquatic chemistry, geomorphology, hydroclimatology, and a suite of biological parameters, all of which are subject to variation in space and time. Our desire to understand the effects of variability in abiotic and biotic factors in shaping aquatic ecosystems, and to detect trends in these systems over time, necessitates an organized, sustained program of data collection at established sites throughout Texas. These measurements should be summarized in numerical forms that permit comparisons of the soundness of the ecological environment at sites across Texas and through time.
3. **Scientific inference should be used to establish the relationship between the ecological integrity of an aquatic ecosystem and its associated environmental flows.** This involves the collection and compilation of observations and measurements, their quantitative characterization, and analysis of causal relations among the variables. It also entails the recognition and assessment of uncertainty in the analyses, arising from limitations in available data, variation in observed parameters, imprecision of measurement, and the presumptive nature of the underlying concepts or models.
4. **Adaptation of assessment procedures.** At any point in time, scientific understanding is circumscribed by the available data and the analyses those data permit. Environmental flow assessment procedures should be modified as additional observations, analyses, and new knowledge become available.

Environmental Flows for Streams and Rivers

1. **A unified approach to ecological assessment.** Texas is in the fortunate position, not shared by many States, of having its regulatory processes for both water quantity and water quality vested in a single agency, the Texas Commission for Environmental Quality (TCEQ). A

unified approach to ecological assessment in relation to both water quantity and quality can be created. If this is not done, two approaches for ecological assessment may emerge, one in relation to water quantity and the other in relation to water quality, which may be difficult to reconcile in future regulatory decisions.

2. **Aquatic Life Uses.** Texas has an extensive set of water quality standards for aquatic life use. These standards define acceptable categories of aquatic life use for all the major streams and rivers in the State and are contained in the Texas Administrative Code (§§307.1 – 307.10). Related TCEQ documents describe Texas' procedures for implementing these standards in the various programs required by the Federal Clean Water Act. Four tiers of aquatic life use have been defined: Exceptional, High, Intermediate and Limited. Aquatic life use designations are based on six ecological attributes: Habitat Characteristics, Species Assemblage, Sensitive Species, Diversity, Species Richness, and Trophic Structure. Aquatic life use subcategories, and the associated narrative description of the attributes are shown in Table 1.

   Aquatic life uses are designated in the Water Quality Standards for all of the 194 free flowing rivers and streams (i.e. not lakes, bays or tidally influenced rivers), that are designated water quality segments. All of the river segments proposed for study in the State's present Programmatic Work Plan for instream flow assessment have designated aquatic life uses. Methods for implementing these procedures are prescribed in TCEQ (2005), which includes methods for numerical assessment of fish, macroinvertebrate and habitat quality. The aquatic life assessment methods in this manual are targeted towards wadeable streams, but comparable methods for larger rivers could be developed.

Aquatic Life Use Subcategory	Habitat Characteristics	Species Assemblage	Sensitive Species	Diversity	Species Richness	Trophic Structure
Exceptional	Outstanding natural variability	Exceptional or unusual	Abundant	Exceptionally high	Exceptionally high	Balanced
High	Highly diverse	Usual association of regionally expected species	Present	High	High	Balanced to slightly imbalanced
Intermediate	Moderately diverse	Some expected species	Very low in abundance	Moderate	Moderate	Moderately imbalanced
Limited	Uniform	Most regionally expected species absent	Absent	Low	Low	Severely imbalanced

Table 1. Characteristics of Aquatic Life Use Subcategories (Source: Table 4, 30 TAC §307)

3. **Build on existing procedures.** There is significant merit in considering this existing system for aquatic life use assessment to help define the soundness of the ecological environment in relation to instream flow requirements, not least because the desired level of aquatic life use

has already been defined in the Texas Administrative Code for all the river segments being considered in the instream flow program. To adapt this system for instream flow assessment, it will be necessary to consider additional ecological characteristics that are flow-sensitive. The aquatic life use assessment procedures may also need to be revised to more faithfully reflect the regional differences of ecological characteristics necessary to maintain the natural diversity of stream and river environments that occur across Texas. For example, the State does not presently have a procedure for assessing the ecological integrity of riparian vegetation. However, the attributes presented in Table 1 could be used as a basis for developing such a procedure for riparian vegetation or any other environmental condition necessary to maintain a sound ecological environment.

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4. **Characterizing streamflow.** Determining environmental flows requires describing the distribution of streamflow through time at gauging sites by flow characteristics that are ecologically meaningful. Scientifically defensible relationships need to be developed between these streamflow characteristics and ecological characteristics. We consider that there are four types of relevant streamflow characteristics:
   a. a *subsistence flow* to maintain water quality criteria;
   b. a *base flow* to ensure adequate habitat;
   c. a frequency of within-bank *flow pulses* to maintain longitudinal connectivity of species in streams and rivers, and to scour sediment accumulation;
   d. a frequency of over-bank *flood flows* to maintain lateral connectivity between a river or stream and its adjacent riparian zone.

Environmental Flows for Bays and Estuaries

1. **Build upon existing inflow studies.** Texas already has an established program to monitor and model flows to bays and estuaries. The program must be extended to include flows from groundwater sources to the coastal zone, and to understand the relationship between the bays with direct inflow inputs and the lagoons or minor bays where flow inputs are indirect.
2. **Characterizing ecological integrity.** Habitats are critical to sustaining the desired commercial and recreational resources in the coastal zone. The sustainability of coastal productivity rests on the soundness of coastal habitats. New measures of coastal habitat integrity, threats to habitats, and responses to inflow regimes and tidal regimes are required.
3. **A multiple stressor approach is required.** The coast is undergoing dramatic change because of multiple stressors, including erosion, pollution, altered flows, development, extractive uses, and navigation projects. These stressors have interactive effects. By themselves, each stressor may not pose a problem, but when combined, they reduce sustainability.

References

National Research Council Committee (2005), "The Science of Instream Flows: A Review of the Texas Instream Flow Program", Committee on Review of Methods for Establishing Instream Flows for Texas Rivers, National Research Council, published by the National Academy Press, Washington, DC, 150pp. http://books.nap.edu/catalog/11197.html

Science Advisory Committee (2004), Report on Water for Environmental Flows, October 26, 2004, 158 pp. http://www.senate.state.tx.us/75r/senate/commit/c890/c890.htm

30 TAC Chapter 307: http://info.sos.state.tx.us/pls/pub/readtac$ext.ViewTAC?tac_view=4&ti=30&pt=1&ch=307&rl=Y

TPWD, TCEQ, and TWDB (Texas Parks and Wildlife Department, Texas Commission for Environmental Quality and Texas Water Development Board) (2002), "Texas Instream Flow Studies: Programmatic Work Plan", December 19, 2002, 19 pp. http://www.twdb.state.tx.us/InstreamFlows/pdfs/Programmatic_Work_Plan.pdf

TPWD, TCEQ, and TWDB (Texas Parks and Wildlife Department, Texas Commission for Environmental Quality and Texas Water Development Board) (2003), "Texas Instream Flow Studies: Technical Overview–Draft", August 8, 2003, 74 pp. http://www.twdb.state.tx.us/InstreamFlows/pdfs/TechnicalOverview-Draft080803.pdf

TCEQ (2005), Surface Water Quality Monitoring Procedures, Volume 2: Methods for Collecting and Analyzing Biological Community and Habitat Data, Report RG-416, 114p., Draft, August 2005, http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/mtr/swqm_procedures.html