Alternative Environmental Flow Management Schemes

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Overview

Outline:

- Brief review of the larger research project on environmental flows
- What are environmental flows (i.e., eflows)?
- Types of eflow methods
- Good practices when choosing and applying eflow methods

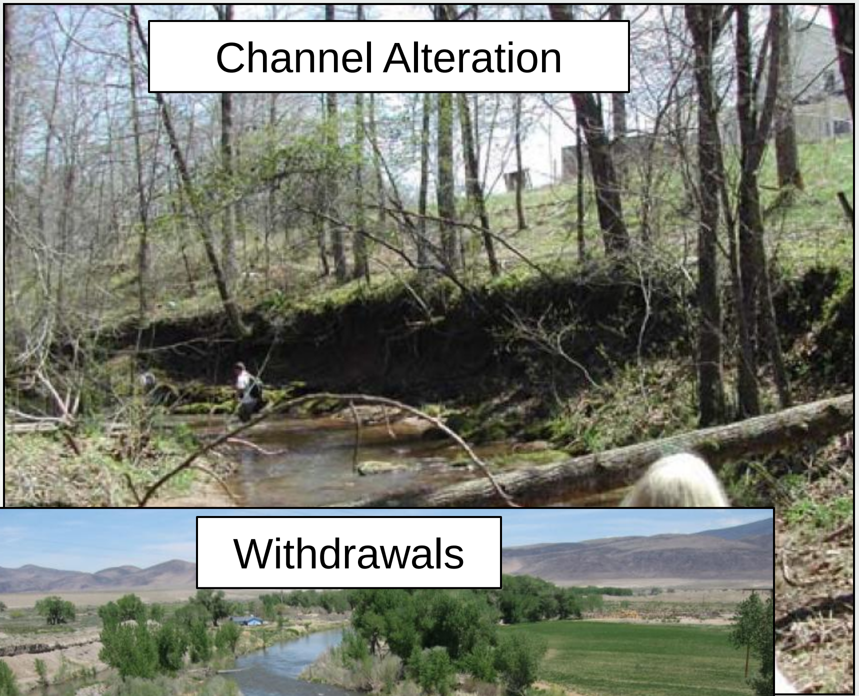
Acknowledgements

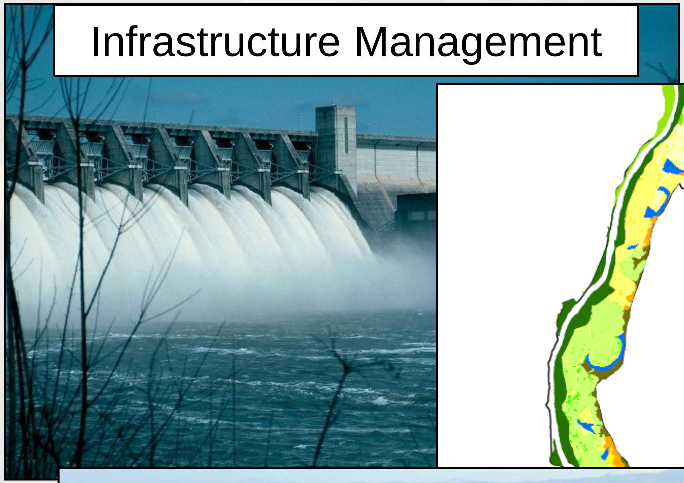
- Generously funded by: USACE Ecosystem Management and Restoration Research Program
- Guiding discussion: Jock Conyngham, Jack Killgore, Craig Fischenich
- Grounding in reality: Larry Oliver, Andrew Roach, Elizabeth Anderson, Andrew Warner, Eloise Kendy
- Tolerating my quirky working habits: Bruce Pruitt and Todd Rasmussen
- Good advice: Mary Freeman, Alan Covich, Rhett Jackson, and John Schramski

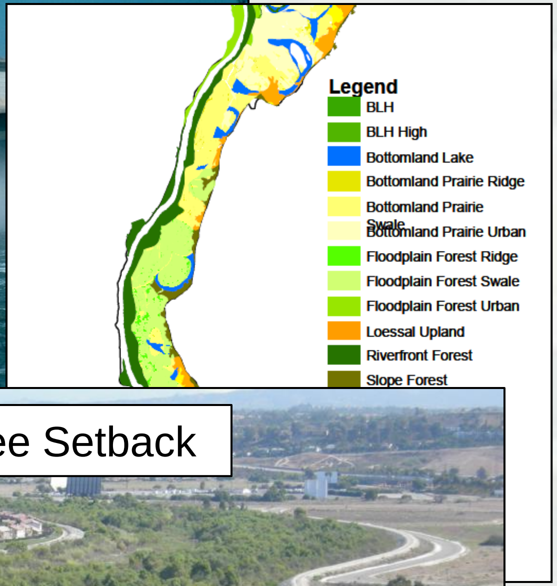
Trade-offs in Freshwater Management

Figure: J. Strom Thurmond Reservoir (USACE Savannah, TNC)

Managing Hydrologic Alteration

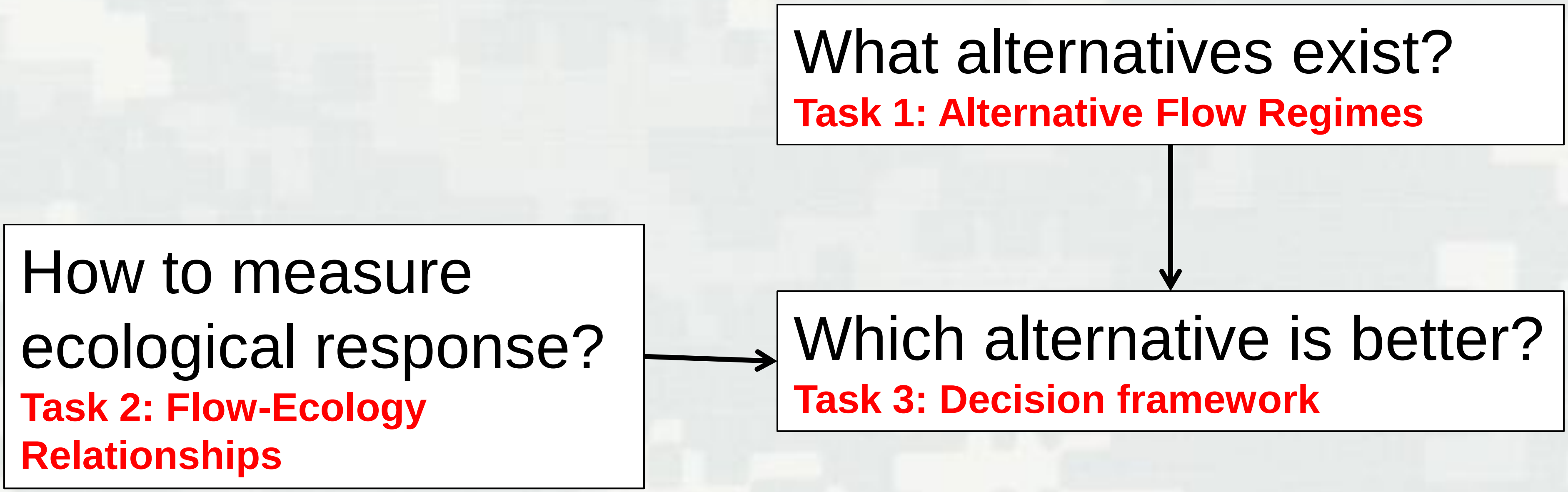






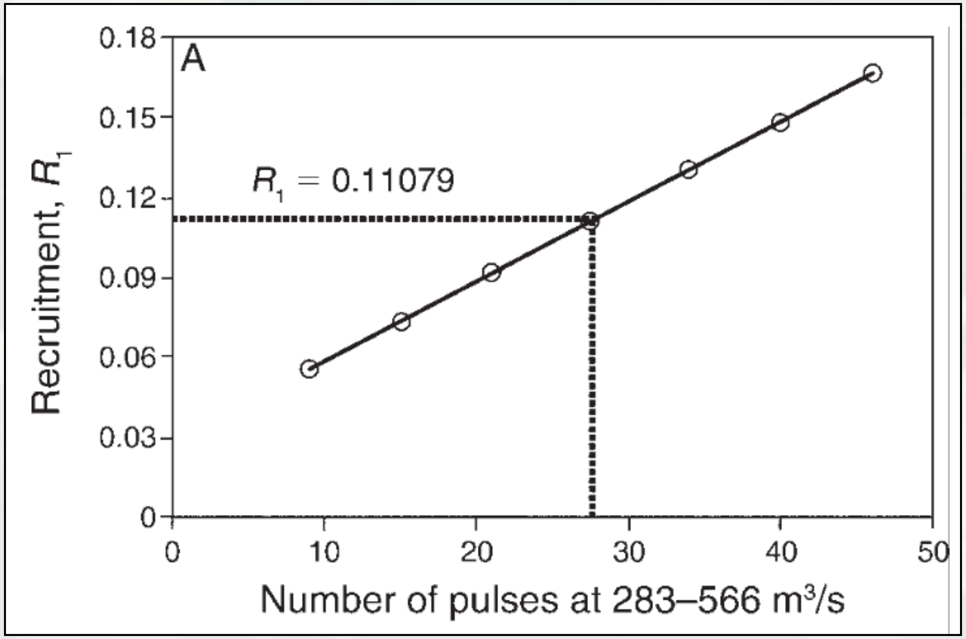
Figures: Little River (USACE Mobile 2009), USACE Savannah, Upper Mississippi (USACE Rock Island 2011), Truckee River, Sanata Clara River (Mark Stone)

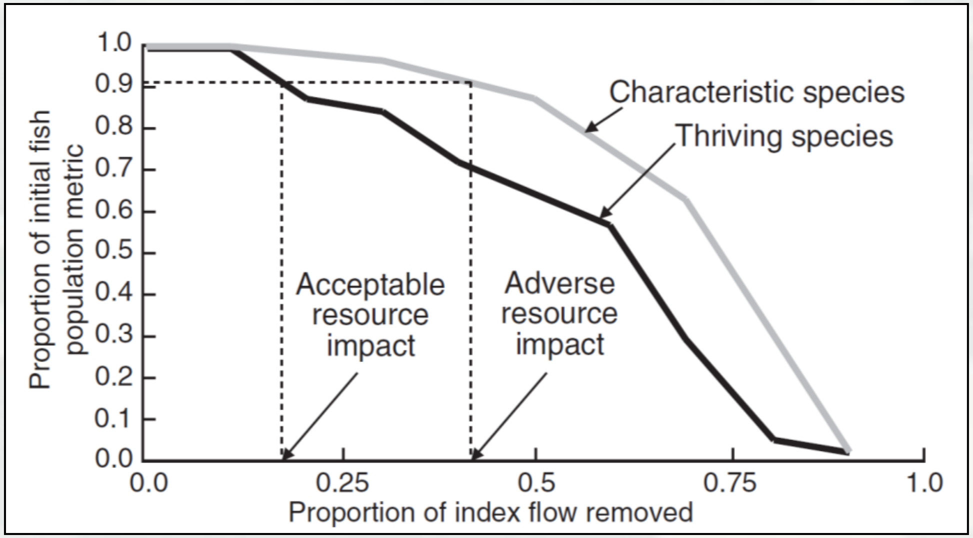
A Framework for Considering Ecological Effects of Hydrologic Processes



2. Flow-Ecology Relationships

- Crux of environmental flow recommendations, but remains challenging
- What element of ecology is of interest?
  - Physical Processes
  - Habitat Provision
  - Ecosystem Processes
  - Population Demographics
  - Behavioral Cues





Figures: Sakaris and Irwin (2010), Poff et al. (2010)

2. Flow-Ecology Relationships

- Two research goals:
  - ▸ Improve state-of-the-practice habitat modeling by including stochasticity
  - ▸ Extend state-of-the-science by examining novel application of the effective discharge concept from geomorphology
    - Sensitivity Analysis
    - Novel flow regime elements

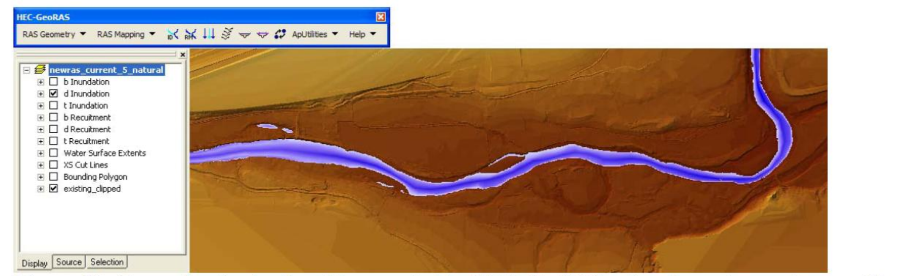
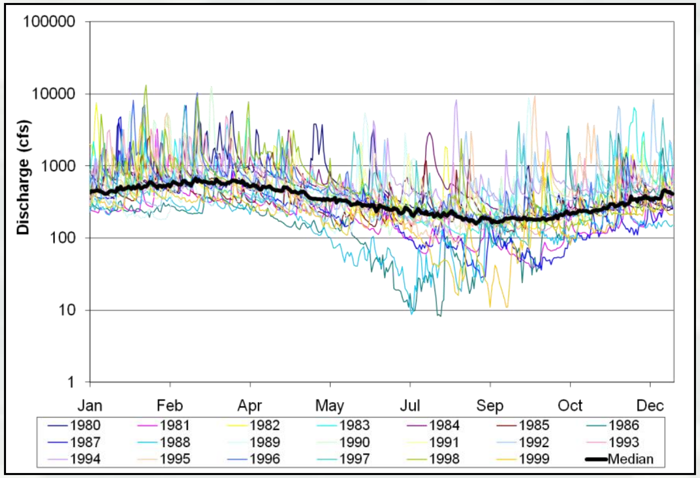
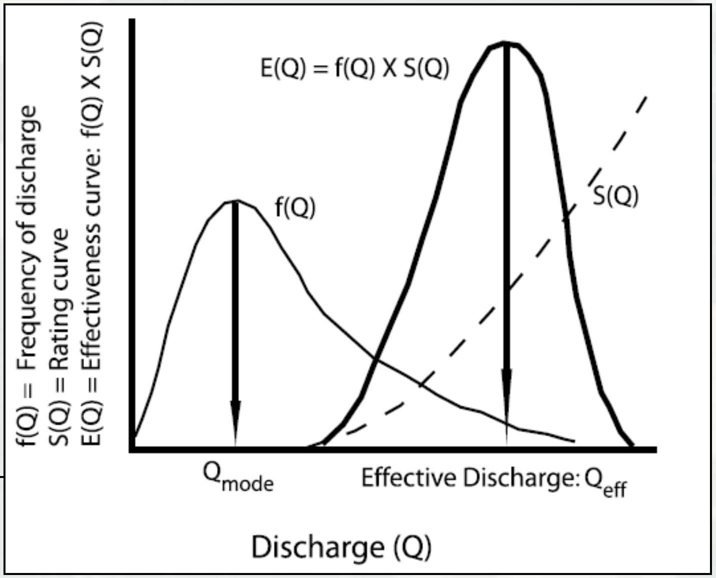


Figure 39. Example of a depth grid computed in HEC-GeoRAS using the water surface profile simulated by HEC-RAS for the statistical results of Riparian tree inundation from HEC-EFM.

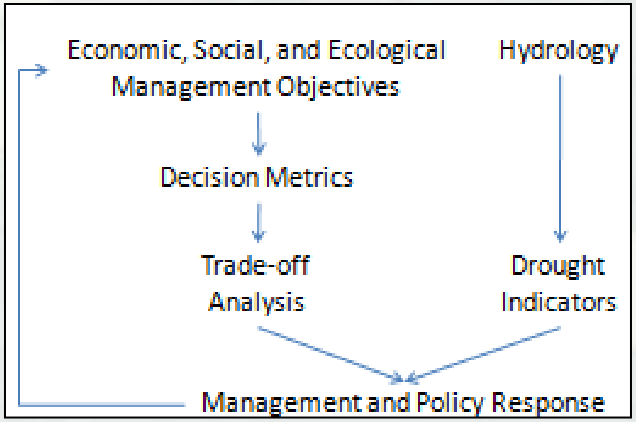


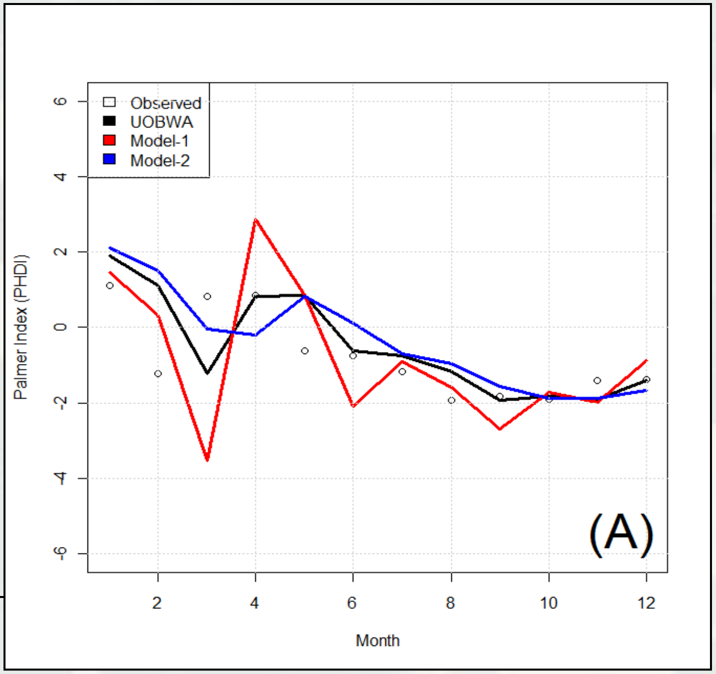


Figures: Hickey and Fields (2009), Katz and McKay (2011), Doyle et al. (2005)

3. Developing a Decision Framework for Environmental Flows

- What techniques are appropriate for assessing trade-offs between environmental and economic objectives in flow problems?
- Combining “lines of evidence” into a flow management decision
- Balancing flow management objectives
- Responding to ambient conditions (e.g., drought)





What are environmental flows (aka. instream flows)?

How much water does a river need?

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The Natural Flow Regime

A paradigm for river conservation and restoration

N. LeRoy Poff, J. David Allan, Mark B. Bain, James R. Karr, Karen L. Prestegaard, Brian D. Richter, Richard E. Sparks, and Julie C. Stromberg

River flows and water wars: emerging science for environmental decision making

N LeRoy Poff[1], J David Allan[2], Margaret A Palmer[3], David D Hart[4], Brian D Richter[5], Angela H Arthington[6], Kevin H Rogers[7], Judy L Meyer[8], and Jack A Stanford[9]

The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards

N. LEROY POFF*, BRIAN D. RICHTER†, ANGELA H. ARTHINGTON‡, STUART E. BUNN‡, ROBERT J. NAIMAN§, ELOISE KENDY¶, MIKE ACREMAN**, COLIN APSE††, BRIAN P. BLEDSOE‡‡, MARY C. FREEMAN§§, JAMES HENRIKSEN¶¶, ROBERT B. JACOBSON***, JONATHAN G. KENNEN†††, DAVID M. MERRITT‡‡‡, JAY H. O'KEEFFE§§§, JULIAN D. OLDEN¶¶¶, KEVIN ROGERS****, REBECCA E. THARME†††† AND ANDREW WARNER‡‡‡

Defining environmental river flow requirements – a review

Mike Acreman and Michael J Dunbar

RE-THINKING ENVIRONMENTAL FLOWS: FROM ALLOCATIONS AND RESERVES TO SUSTAINABILITY BOUNDARIES

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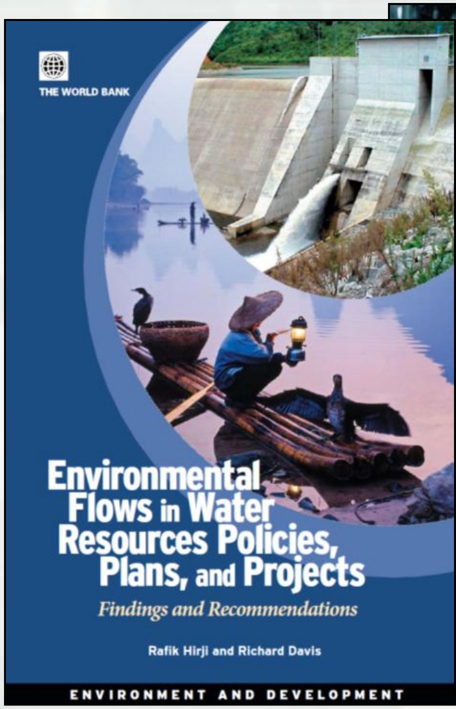
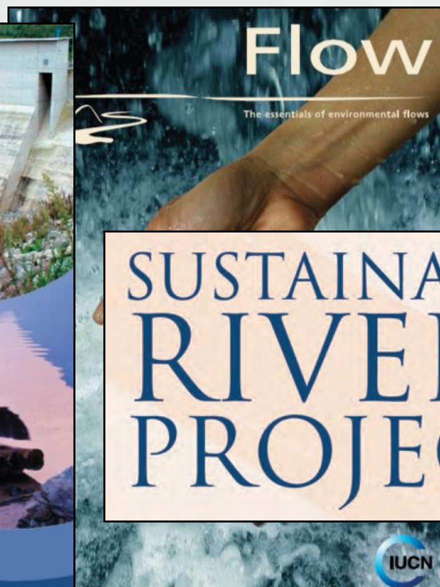




SUSTAINABLE RIVERS PROJECT

Indicators of Hydrologic Alteration

Version 7.1

User's Manual

Developing Instream Flow Criteria to Support Ecologically Sustainable Water Resource Planning and Management

Final Report to the Pennsylvania Instream Flow Technical Advisory Committee
Project funded by a Growing Greener Environmental Stewardship and Watershed Protection Grant

The Nature Conservancy
Protecting nature. Preserving life.

Ecosystem Flow Recommendations for the Susquehanna River Basin

Report to the Susquehanna River Basin Commission and U.S. Army Corps of Engineers

Environmental flows describe the ***quantity, timing, and quality*** *of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems.*

Brisbane Declaration (2007)

Natural Flow Regime (Poff et al. 1997)

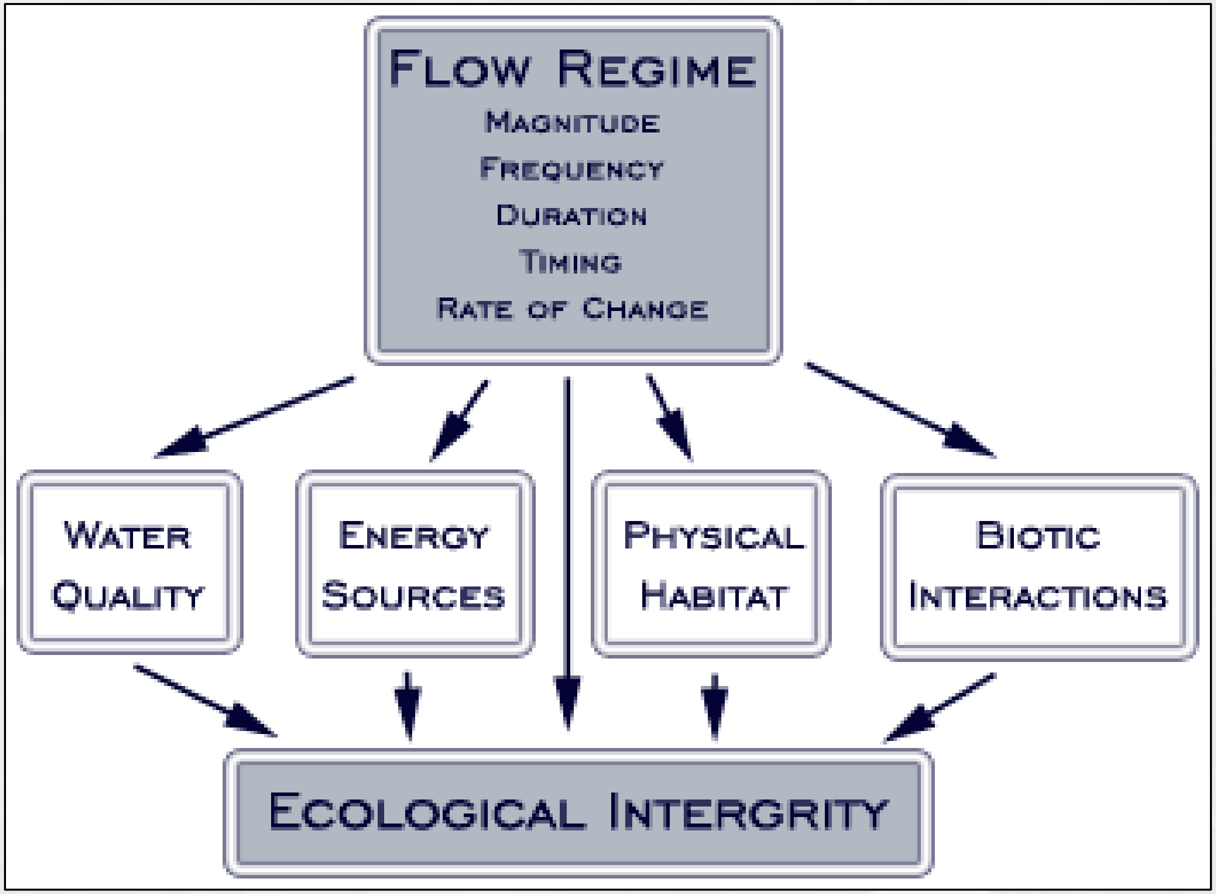


Figure: Poff et al. (1997)

Aquatic Biodiversity and Natural Flow Regimes

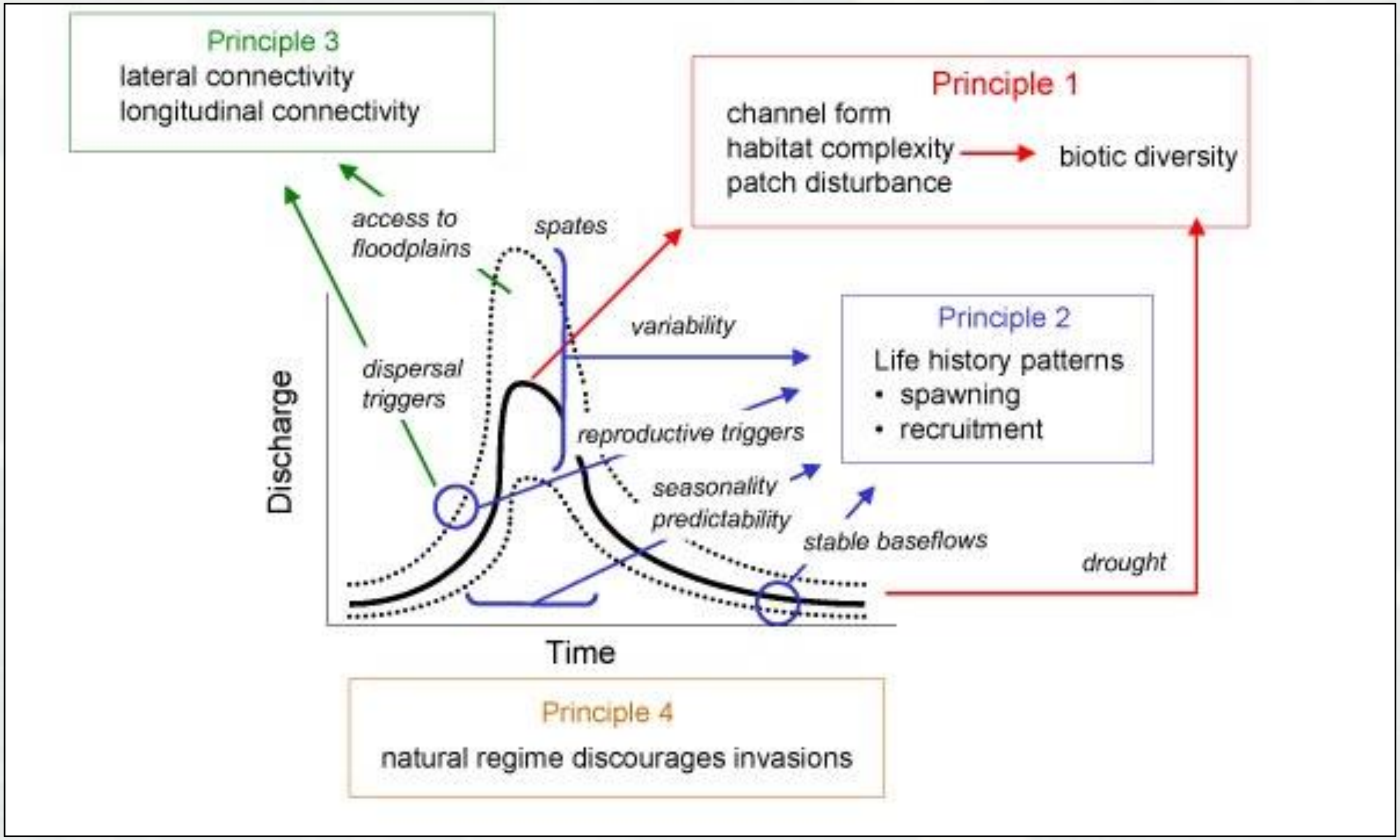


Figure: Bunn and Arthington (2002)

Environmental Flow Components (Matthews and Richter 2007)

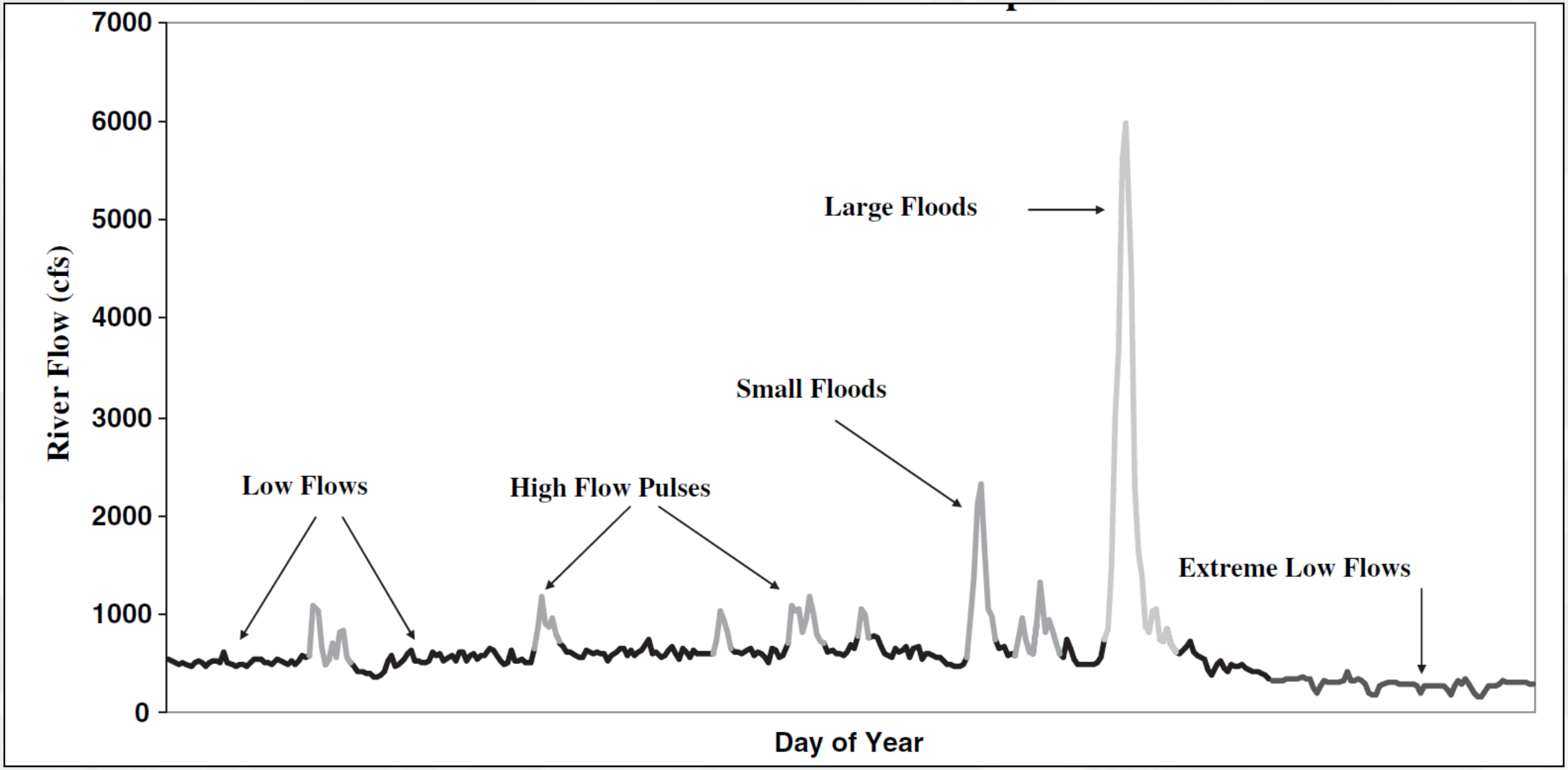


Figure: Matthews and Richter (2007)

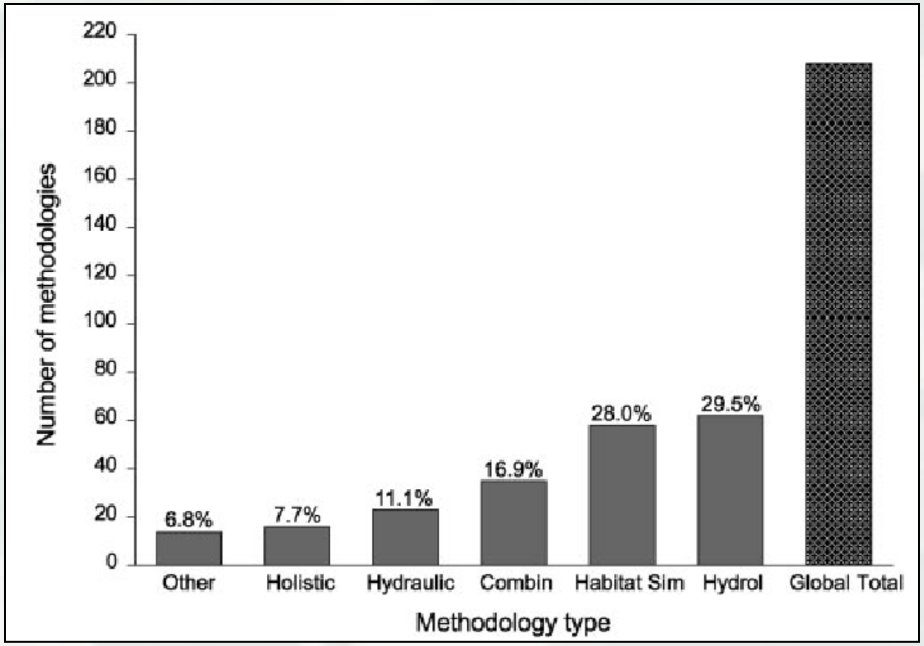
Types of eflow recommendations

How many methods are there?

- Over 200 environmental flow methods (Tharme 2003)
- Here, environmental flow alternatives (i.e., methods, schemes) are defined in the general sense of any scheme or rubric for managing water for environmental objectives

Six Types of Eflow Methods

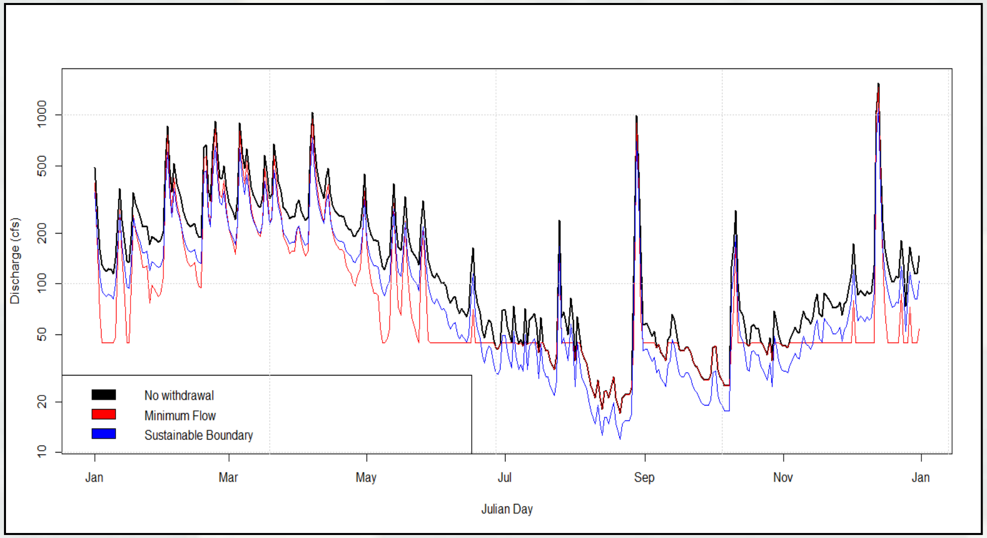
- Four broadly acknowledged:
  - Hydrologic methods
  - Hydraulic rating
  - Habitat analysis
  - Holistic methodologies
- Two emerging:
  - Optimization
  - Regionalization



Figures: Tharme (2003)

Hydrologic Methods

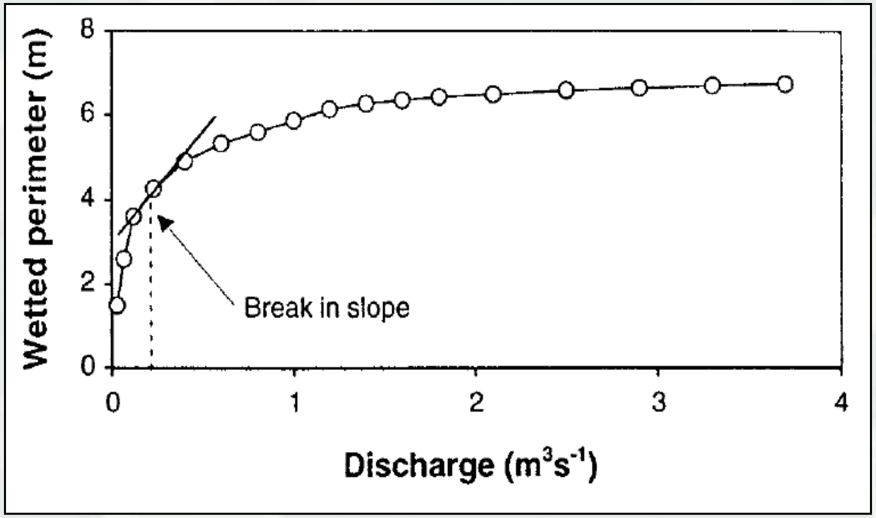
- Simple hydrologic "rules"
  - Minimum flows
  - Peak shaving
  - "Sustainability boundaries"
- Desktop application



Strengths	Weaknesses
•Low resource requirements •Rapid application •Desktop approach •Broad spatial application is simple	•Often results in simplistic, inflexible, or low resolution outputs •Low ecological relevance •Not site-specific •Flow dynamism is seldom considered •Likely inappropriate for highly controversial decisions

Hydraulic Rating

- Hydraulic parameters such as wetted perimeter, cross-sectional area, hydraulic radius, velocity, depth, shear stress,…
- Application of thresholds or breakpoints
- Largely applied in conjunction with habitat methods



Strengths	Weaknesses
•Readily available tools and support •Rapid application	•Low ecological relevance •Proxy for habitat •Few recent developments

Figure: Gippel and Stewardson (1998)

Habitat Analysis

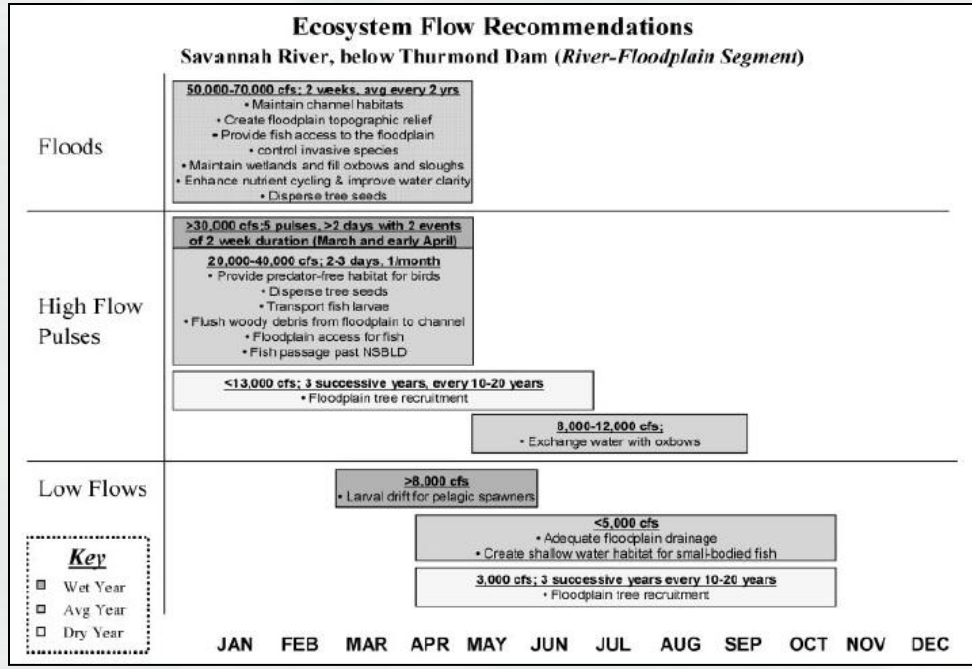
- Requirements of individual taxa or guilds
- Long history (e.g., IFIM)
- Many tools available: HEC-EFM, PHABSIM, RCHARC, MESOHABSIM, SEFA, etc.
- Increasing computational precision (e.g., 2D models)

Strengths	Weaknesses
•Repeatable •Predictive •Demonstrated legal precedent •Capacity to examine multiple focal taxa	•Habitat is not necessarily the endpoint of interest (populations are) •Focus on specific taxa rather than ecosystem health •(Often) Limited consideration of flow regime beyond flow magnitude •Significant uncertainty can be associated with suitability indices

Figure: Hickey and Fields (2009)

Holistic Methods

- Evolved to encompass multiple ecological endpoints
- Top-down v. bottom-up approaches
- Many formats used for communicating findings

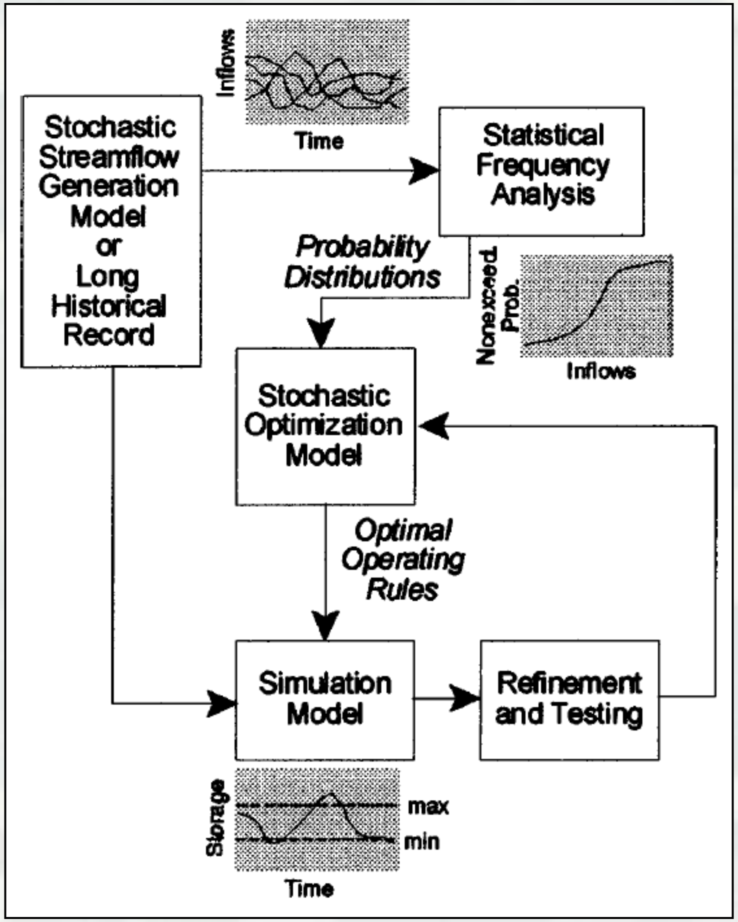


Strengths	Weaknesses
•Flexible and robust •Broad ecological basis and focus on the whole ecosystem •Multi-disciplinary input •Incorporates socio-economic endpoints •Scalable to data rich and data poor environments •Addresses multiple flow regime components	•(Often) Resource and time intensive •Reliant on expert judgment •Challenges in reconciling a vision for the river and conflicting judgments •High ecological data or knowledge requirements

Figure: Richter et al. (2006)

Optimization

- Rich tradition from economic and engineering applications
- Objective, constraint, and penalty functions
- Facilitates examination of multiple reservoirs in series

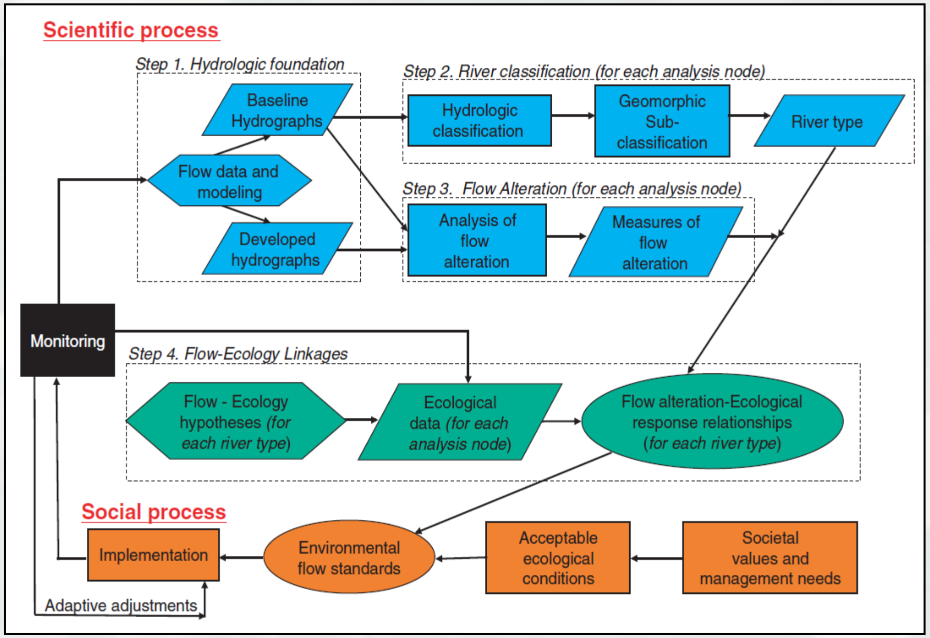


Strengths	Weaknesses
•Objective development of flow recommendations based on specification of objectives and constraints •Familiar to classical dam operation •Can be used in conjunction with holistic methods	•Numerical expertise required •Developing holistic, quantitative objectives (and a multi-objective combination algorithm) is challenging •"Optimality" may not exist due to incomplete specification of objectives

Figure: Labadie (2004)

Regionalization

- Couples holistic perspectives with rapid application
- Four key scientific steps
- Recent development with a BIG head of steam



Strengths	Weaknesses
•Generates flow prescriptions for many rivers and streams in a region which accelerates implementation •Holistic view of multiple components of the socio-ecological system •Broad spatial application to sites beyond those studied •Multi-disciplinary input •Emphasizes hypothesis-driven, adaptive management	•Regional development may be time and resource intensive •Requires significant expertise to facilitate the process (hydrologic foundation, classification, flow alteration, flow-ecology relationships) •Better suited to tributaries than to river mainstems •For any individual site, it’s not as robust as site-specific assessment

Figure: Poff et al. (2010)

A few good practices when choosing and applying eflow methods

Choosing an eflow method

- No method is appropriate in all situations
- Many methods are applied together (e.g., holistic with habitat, optimization, or regional)

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What are the project objectives?

- Clarifies need for a particular environmental flow component
- Provides a mechanism for measuring the success of a given flow recommendation
- Streamlines the analyses undertaken
- Habitat is not the only endpoint:
  - Population demographics (e.g., survival or recruitment)
  - Ecosystem energetics (e.g., food web stability)
  - Ecosystem process rates (e.g., sediment transport, leaf breakdown, nutrient uptake, or primary production)

What is the project scope?

- Spatial extent of the analysis
  - Necessary data resolution for decision-making
  - Detailed site-specific v. regional guidelines
- Constraints
  - Time and resources
  - Level of controversy associated with a decision
  - Availability of expertise
  - Accessibility of existing data
  - Physical limitations (e.g., capacity to adjust the shape of a bedrock channel, maximum discharge through a structure)
  - Operational limitations (e.g., non-negotiable water supply uses, public safety)

How does the team function?

- Who should be on the team?
- How are experts used in the process?
- Good practices for working with a panel (Cottingham et al. 2002, Arthington et al. 2003):
  - Identify the processes for selecting panel members, protocols for panel conduct, and the interaction between panelists
  - Develop a clear vision statement and management objectives
  - Develop data collection, quality, and management guidelines
  - Acknowledge uncertainty
  - Consider social and environmental implications of recommendations
  - Develop a standard for documentation of findings.
  - Identify additional information to improve future decision making

What are the nitty-gritty science-y issues that need to be addressed?

- Key sources of variability
- Is discharge (i.e., ‘flow) the master variable?
- What timescales are appropriate for each ecological process?
- What is the reference condition?
- Where is the project positioned in the watershed?

What is the institutional, legal, and cultural framework?

- Upfront understanding of the setting and constraints helps avoid conflicts within the team and with existing regulations
- Moving out quickly with incremental decision-making
  - Some environmental flow analyses may take significant amounts of time
  - Many authors propose a tiered approach with simpler analyses (e.g., hydrologic) preceding more complex forms (e.g., optimization)
  - "Sustainability boundary" provides a strong starting point.
- Thinking in terms of "environmental flow hypotheses" and adaptive management

Questions and Feedback

Take-away Points:

- Many techniques exist for environmental flow provision (minimum flows are not the only instream flow need).
- Eflow recommendations minimally should consider:
  - Characteristics of each flow regime component
  - Social and ecological trade-offs of alternatives
  - Key assumptions and uncertainties
  - How these uncertainties can be reduced over time

Additional Information

- USACE Ecosystem Management and Restoration Research Program
  http://el.erdc.usace.army.mil/emrrp/
- Technical Note is downloadable as EMPRR-**SR-XX**.
- Jock Conyngham, Jack Killgore, Larry Oliver, Andrew Roach, Elizabeth Anderson, Mary Freeman, Andrew Warner, and Eloise Kendy reviewed and improved this report!

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