Environmental Flow: Linking Water Use and Flow-Ecology Response Relations

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Presentation Overview

- Introduction — Environmental Flows
- Hydroecological Integrity Assessment Process (HIP)
- Example — Why Incorporating Water Use information is essential
- Future directions
Human Water Use and Environmental Flows (eFlows) are Intimately Connected

- Brisbane Declaration recognized this…
  eFlows = the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihood and well-being that depend on these ecosystems.

- Growing societal interest in eflows

Global eFlow Efforts

- **NGO’s** -- The Nature Conservancy, World Wildlife Fund

- **Government’s** -- EU Water Framework Directive, Australia, South Africa, Tanzania, Vietnam, China, Colombia

Implementation Challenge

- Regulatory authority over water *quantity* issues as they relate to Clean Water Act authority
- Need supporting science
  - We know:
    - Flow variability influences ecological process and pattern
      - Flow-ecology relations
    - Flow alteration induces ecological change
      - Quantitative relations

- We also know …
• Multiple Stressors influence ecological condition
• "Noisy" flow alteration – ecological response relations are the norm
• Need creative approaches
• **Challenge: How to develop "simple" models that account for human WU and supports regulatory implementation?**

Dudgeon et al., 2006
Flow variability and the vitality of rivers

Flow variability shapes the physical, chemical and biological attributes and functioning of riverine systems
- Channel form and habitat complexity
- Life-history patterns
- Lateral and longitudinal connectivity
- Resistance to species invasions

At the same time, human societies modify natural flow regimes to provide dependable ecological services and to seek protection from floods and droughts.
Major hurdles to linking ecological responses to riverine hydrology

- Devising testable hypotheses from general principles
- Informing decision support tools
- Generating simple models that are realistic, mechanistic and defendable
- Accounting for human water use
Hydroecological Integrity Assessment Process (HIP)

- USGS WRD / BRD-developed HIP as a method to determine the minimum streamflow needed to adequately protect aquatic biota
- Developed in NJ and is currently being applied in several other states, e.g., MO, MA, TX, .

http://www.fort.usgs.gov/HIP/

Hydroecological Integrity Assessment Process (HIP)

Process relies on three primary software tools:

- HIT – Hydrologic Index Tool
- SCT – Stream Classification Tool
- NJHAT – New Jersey Hydrologic Assessment Tool
NJHAT Analysis Tools

**Trend Analysis**

**Exceedence plot for pre and post time periods profiles**

**Minimum flows for three time periods**

**Pre and post baseline comparison**
Cooper River

Alternative Hydrologic Index Range Comparisons

Lower Bound = 25th percentile  Upper Bound = 75th percentile

1) ↑ WU
2) Regionalized WWT
Cooper River

Alternative Hydrologic Index Range Comparisons

Lower Bound = 25th percentile  Upper Bound = 75th percentile
NJ Pinelands -- Evaluating natural and human-induced changes in stream flow regime on fish and aquatic invertebrate assemblages in the New Jersey Pinelands.

Primary Question -- Can we evaluate ecosystem response to hydrologic stress based on water use scenarios and develop simple statistical models that can be used in a management context?
Kirkwood-Cohansey Project
A hydroecological investigation in the New Jersey Pinelands

New Jersey Pinelands Commission
U.S. Geological Survey
Rutgers University
U.S. Fish and Wildlife Service
NJ Department of Environmental Protection
Problem

- Human demand for water from the aquifer system is increasing as planned growth occurs within & around the Pinelands area.
- The effects of changes in ground water use on the ecology of the Pinelands are poorly understood.
P.L. 2001, ch. 165 directs named partners to:

“assess and prepare a report on the key hydrologic and ecological information necessary to determine how the current and future water supply needs within the Pinelands area may be met while protecting the Kirkwood-Cohansey aquifer system and while avoiding any adverse ecological impact on the Pinelands area.”
Hydrologic Assessment / Infrastructure

Depth of water

Water Budget

P

WU

ET

GW

SW

Water-level maps

Stream Gaging

Wetland/aquifer interactions
Pumping lowers the water table in the surrounding area, including wetlands.

Drawdown magnitude and extent are concerns.

Pumping for human use will also divert discharge or induce changes in flow.
Simulate Changes in Depth to Water Table

Depth to water without pumping

Depth to water with pumping

Example: McDonalds Branch

Hypothetical pumping well

Simulated Drawdown, cm

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<tr>
<th>VALUE</th>
<th>SYMBOL</th>
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<tr>
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</tr>
<tr>
<td>&gt; 0.2 - 0.4</td>
<td>&gt; 1.5 - 2</td>
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<td>&gt; 0.4 - 0.6</td>
<td>&gt; 2.0 - 3</td>
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<td>&gt; 0.6 - 0.8</td>
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<tr>
<td>&gt; 0.8 - 1</td>
<td>&gt; 5.0 - 10</td>
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<tr>
<td>&gt; 10.0 - 21</td>
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</table>

EXPLANATION

- McDonalds Branch study area
- McDonalds Branch drainage basin

Depth to water table, in meters, as shown in Table 3.
Comprehensive aquatic invertebrate sampling – mod. MACS Protocol
- Electrofished & seined 100 m sampling reaches.
  - High & low flow periods
  - Identified to species, TL, Wt.
- Water Quality and Staff measurements
- Habitat assessment (stream and riparian)
Generalized Application

HYPOTHETICAL RESULTS

Change in Ecological Metric (% of initial)

Acceptable Change Threshold

Stressor Factor (e.g., Withdrawal Rate)

PC Decision on Acceptable Change
Possible Maximum Allowable Stress

McDonalds Branch
Albertson Brook
Morses Mill Stream
Flow-ecology Response Relations

![Graphs showing ecological response relations with R² values for different indicators.](image)

Invertebrates
General Flow Chart of hydrologic analysis

(A) MODFLOW Sim vs Obs for Alberson’s Brook

(B) 3 GW withdrawal scenarios at -5, -10, & -15 CFS

(C) Predict potential change in flow at “Index Gage”

(D) MOVE 1 at Sites X, Y, Z...

(E) Predict potential change in flow at other gaging locations w/in index basin, e.g., Batsto Basin
Flow-Alteration Ecological Response Relations

Invertebrates
Other Directions

- TMDL’s?
- Linkages with SW & GW flow models?
- Climate Change?
- National Water Census—CR, DR & ACF
Water Availability for Human and Ecological Needs

- It’s not necessarily a question of how much water a river needs, but how much can flow regimes be altered before having an appreciable affect on ecosystem integrity.

- Ultimately, a balance needs to be established between water supply intended to meet human needs and conservation of biological integrity.
KIRKWOOD-COHANSEY AQUIFER SYSTEM WITHDRAWALS, 2005

EXPLANATION

(MGY)
- 0 - 10
- 10 - 50
- 50 - 100
- 100 - 300
- 300 - 700

- PINELANDS AREA
- K-C AQUIFER SYSTEM

McDonalds Branch
Morses Mill Stream
Albertson Brook