Environmental Flows: Maintaining Hydrologic Integrity of Streams

U.S Geological Survey

Oklahoma Water Science Center

Presentation by Trevor Grout, Hydrologist

Slides courtesy Rachel Esralew and Environmental Flow Specialists

USGS
science for a changing world

Streamflow Alteration

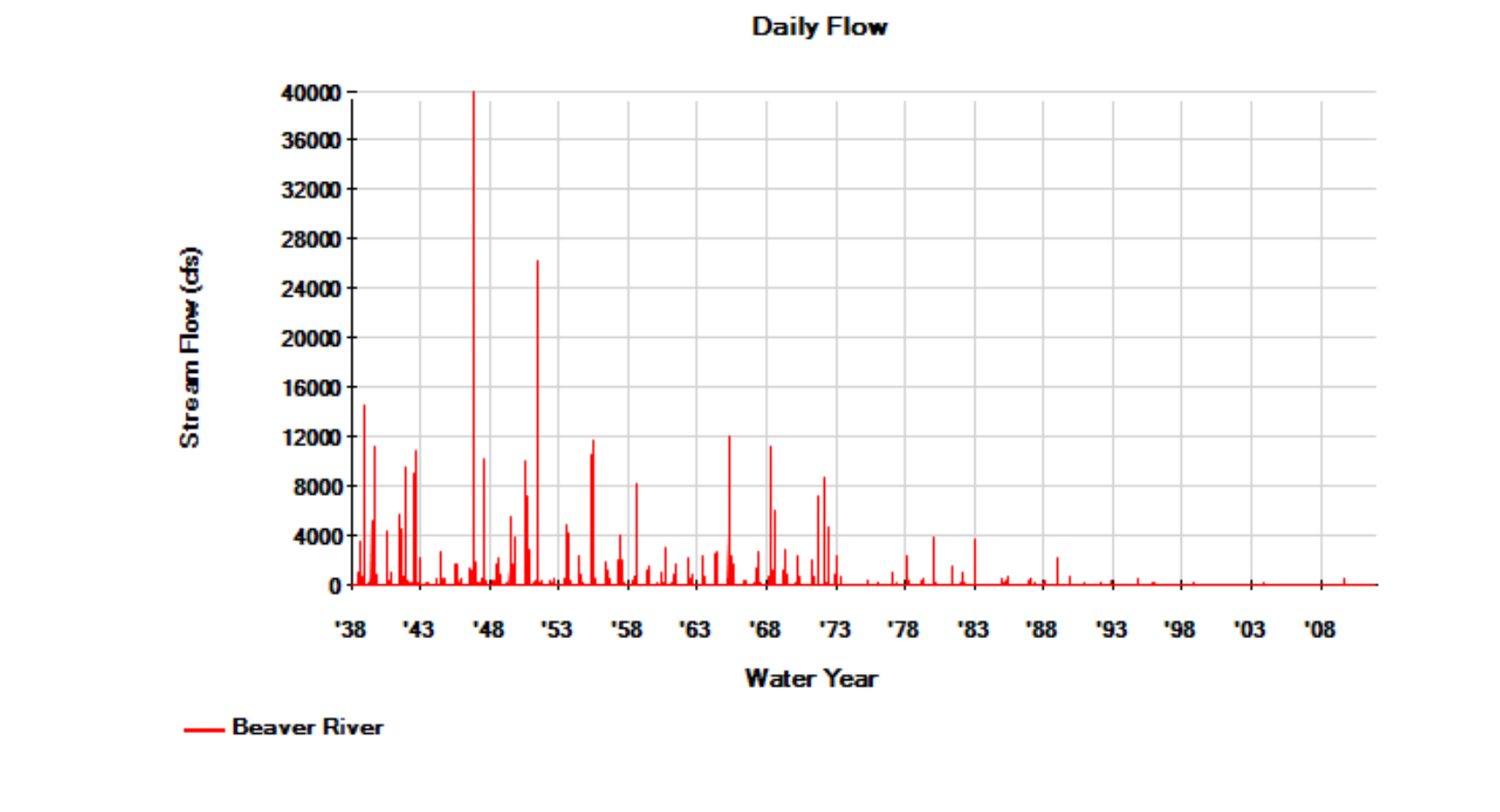
- “Alteration of flow regimes is often claimed to be the most serious and continuing threat to ecological sustainability of rivers and their associated wetlands” (Bunn and Arthington, 2002).

- Oklahoma contains many altered streams with more than 4,600 dams in the state.

- Alteration is done by dams, pumping/irrigation, wastewater discharge, stream diversions, others?

Examples of Alteration

Beaver River Near Beaver, OK (07234000)



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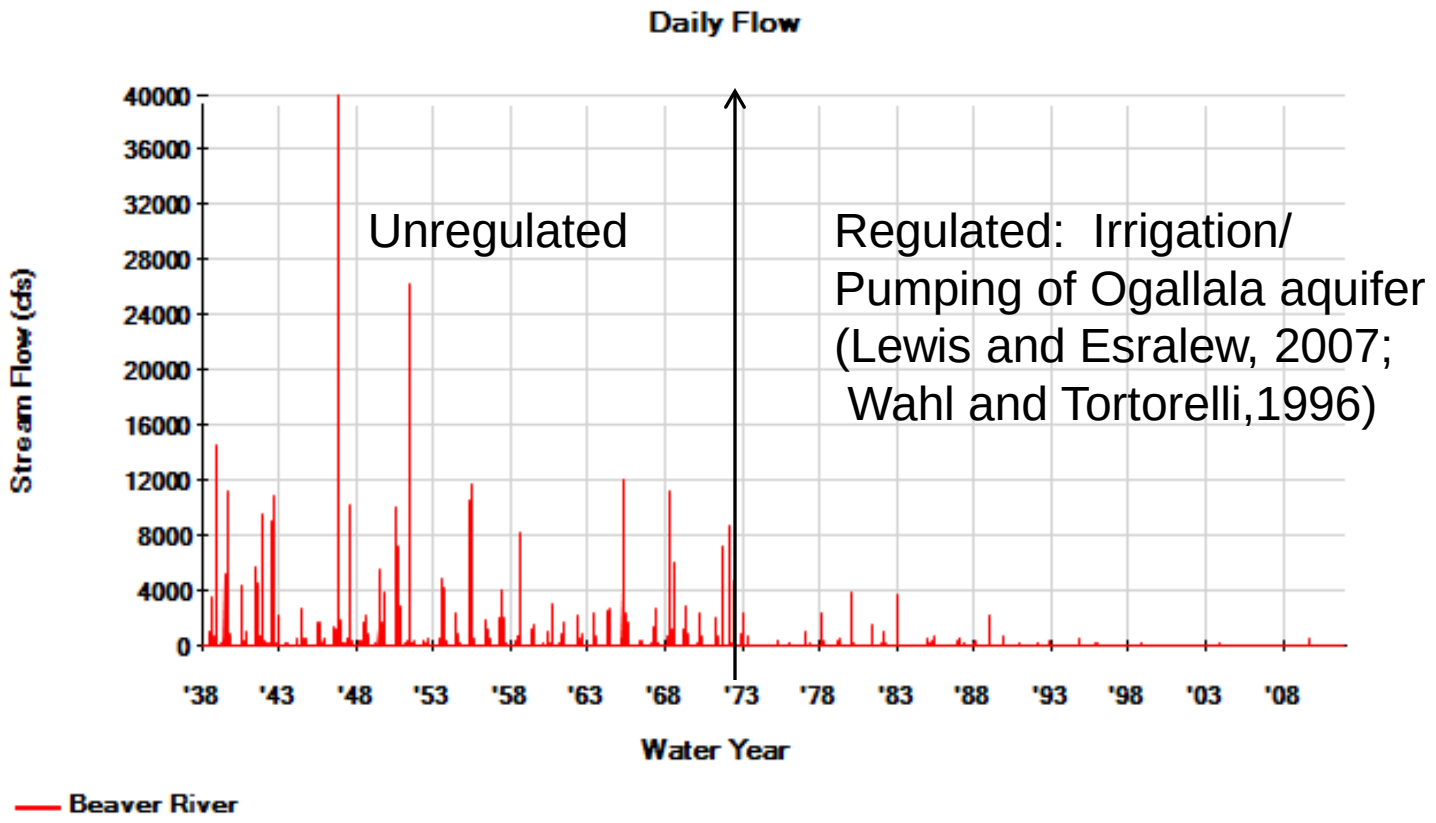

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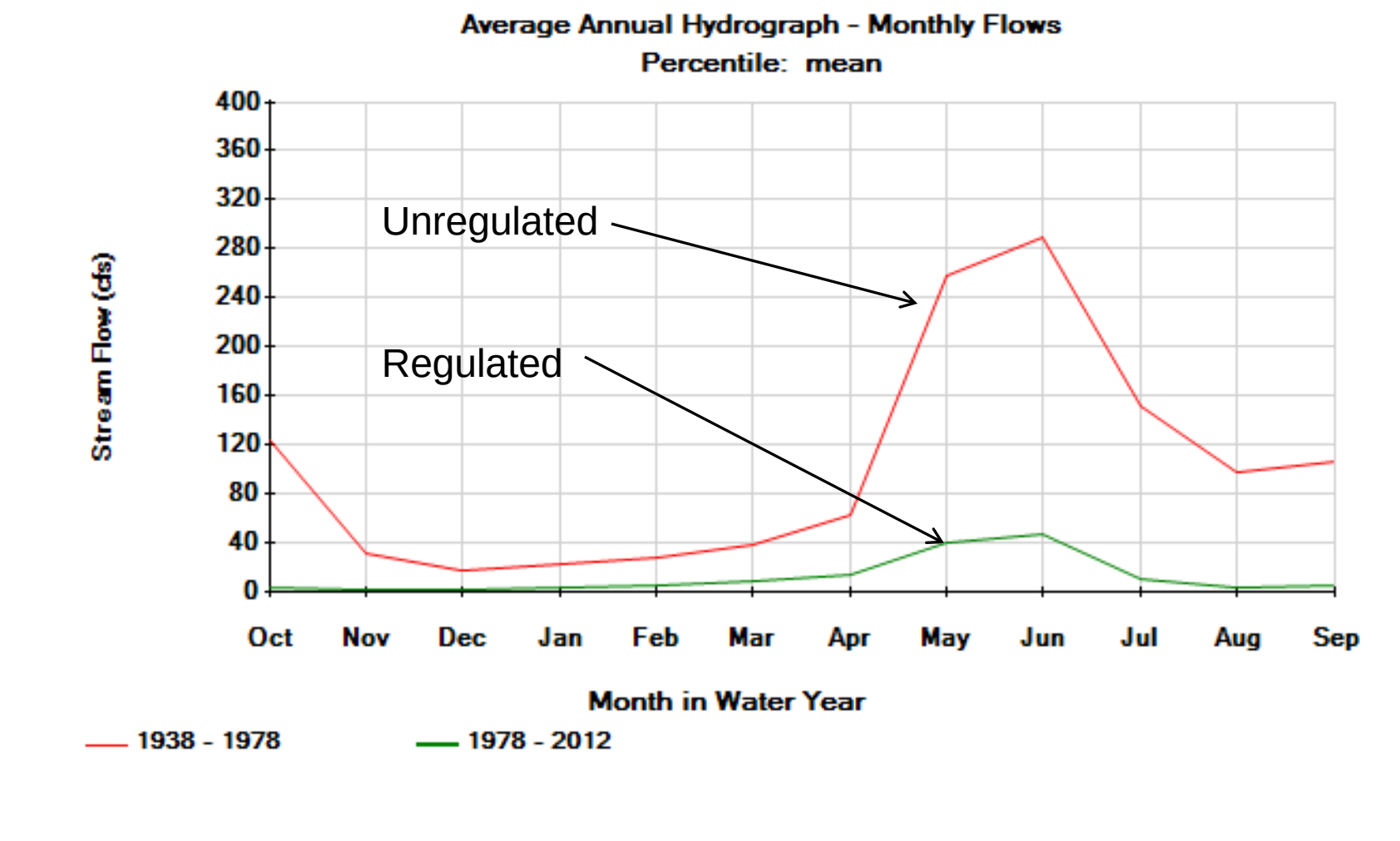
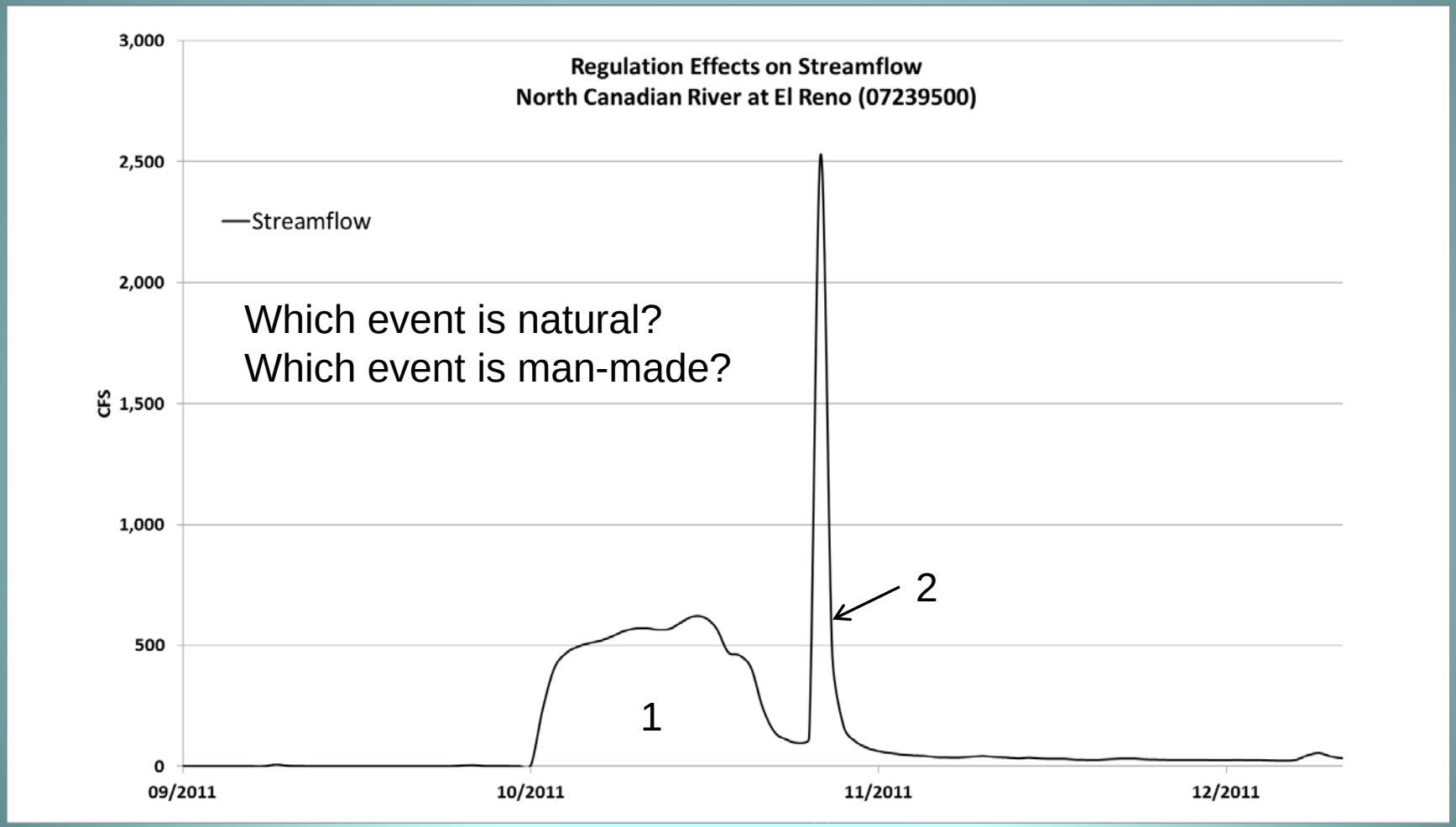


Examples of Alteration

North Canadian River at El Reno, Okla. (#07239500)



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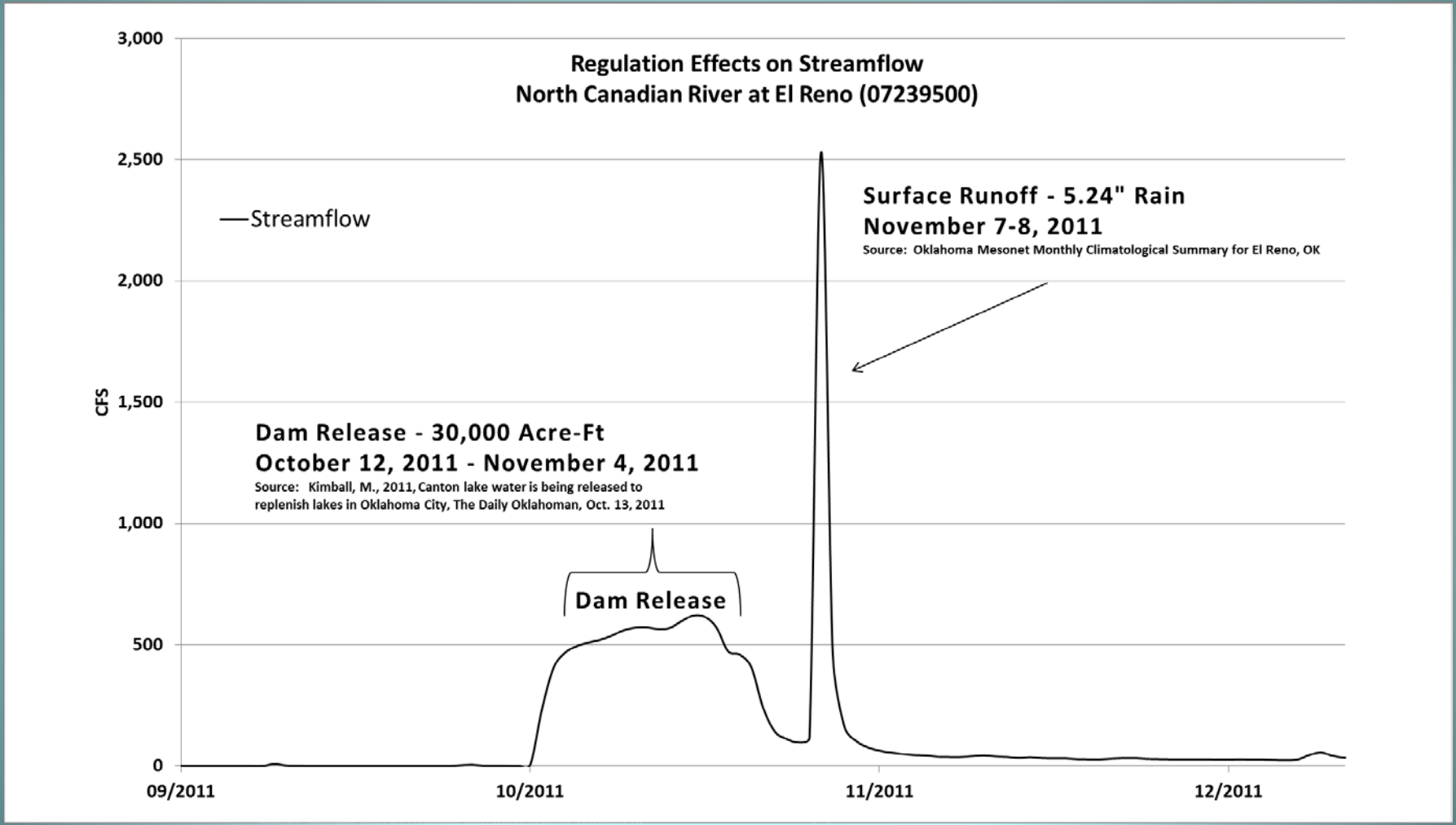
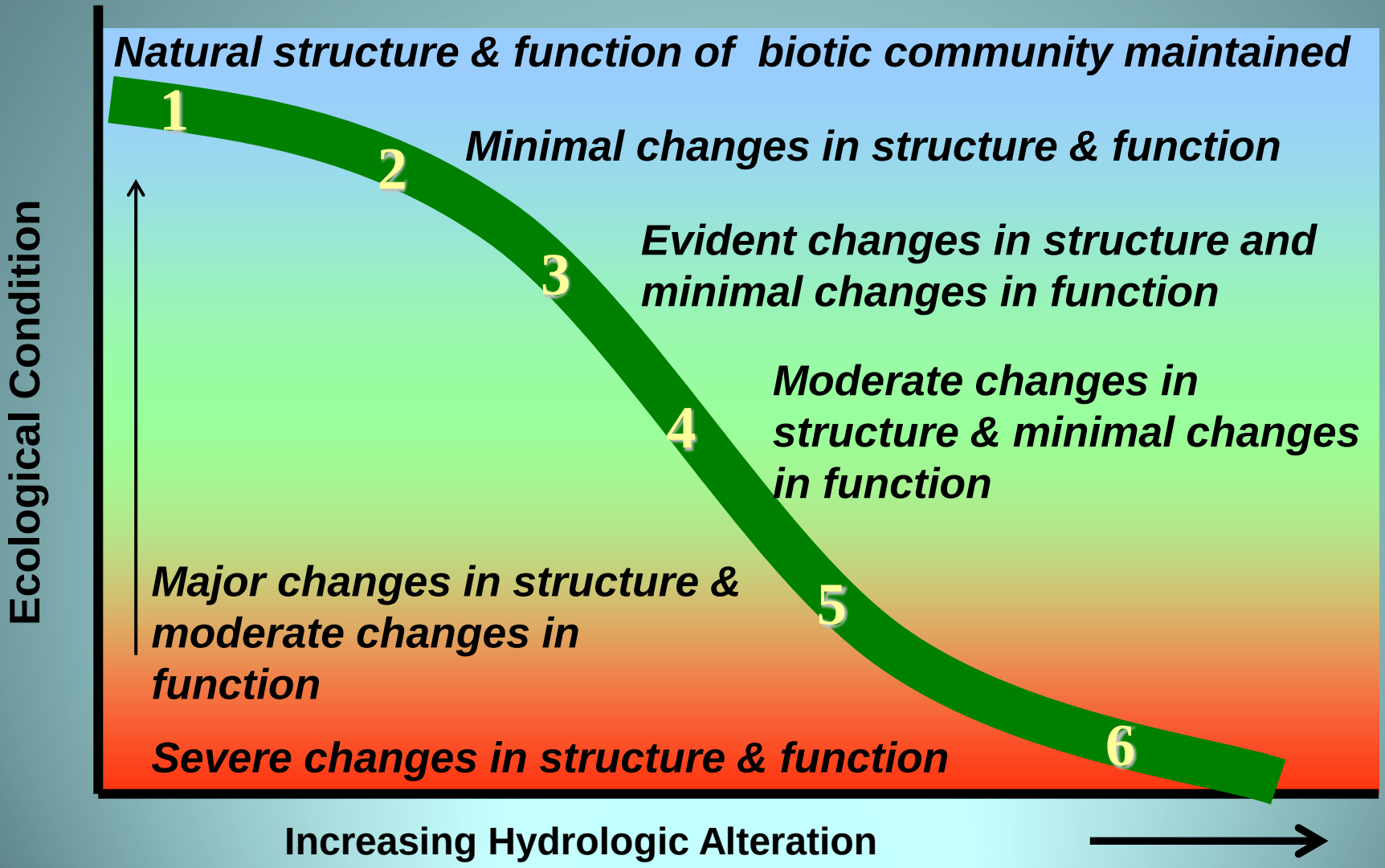


Altering Flows

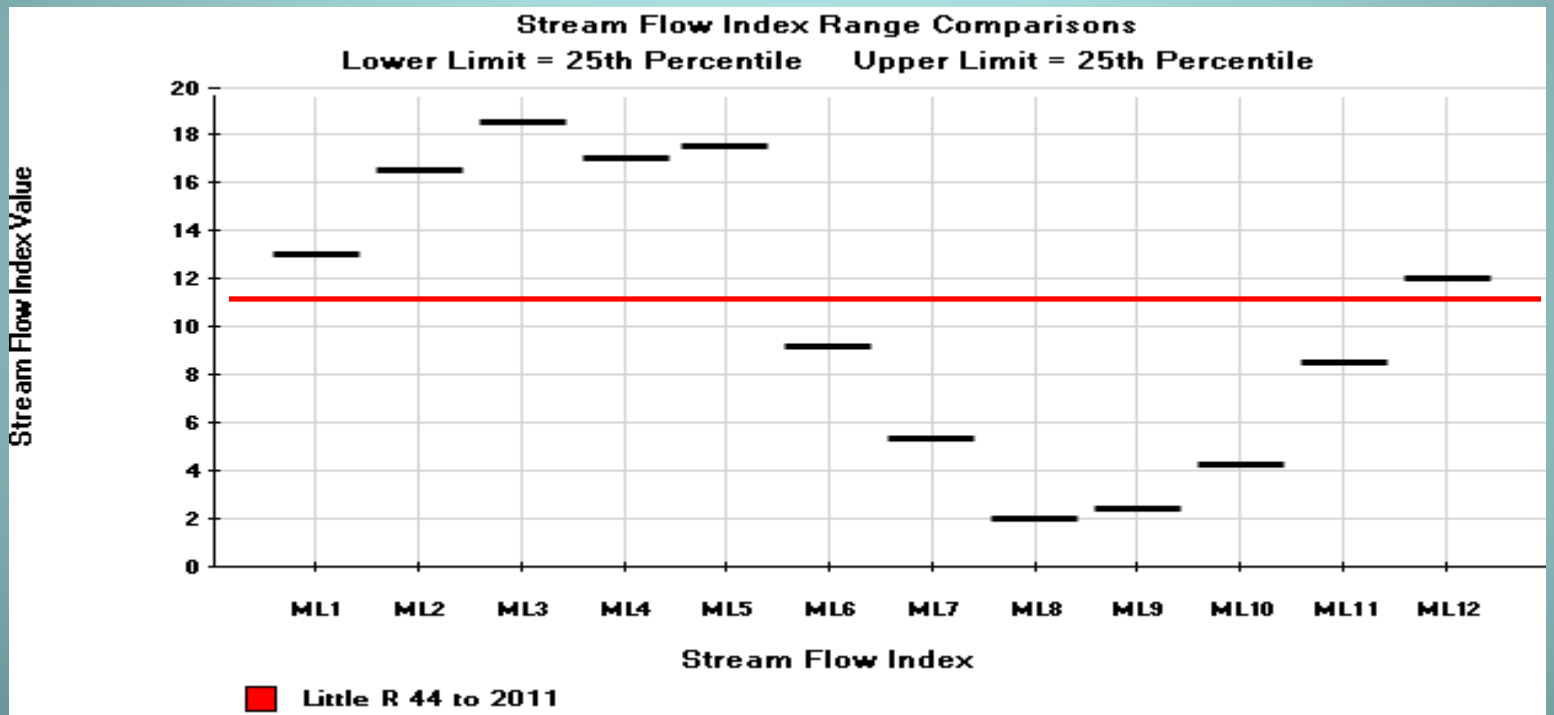


Environmental Flows

- After WWII, infrastructure development dramatically altered many of our rivers and typically reduced streamflow.
- The adverse effects of human-altered rivers concerned many people by the 1970's.
- Congress passed the Clean Water Act (1972) and Endangered Species Act (1973).
- People recognized that rivers and their ecosystems needed water and environmental-flow standards were initiated.

Environmental Flows

- When alterations first were made to streams, the question was “What minimum amount of water do the fish require?”
- Resulted in a single flow value which was maintained year round (known as “Flat-lining”)



Environmental Flows

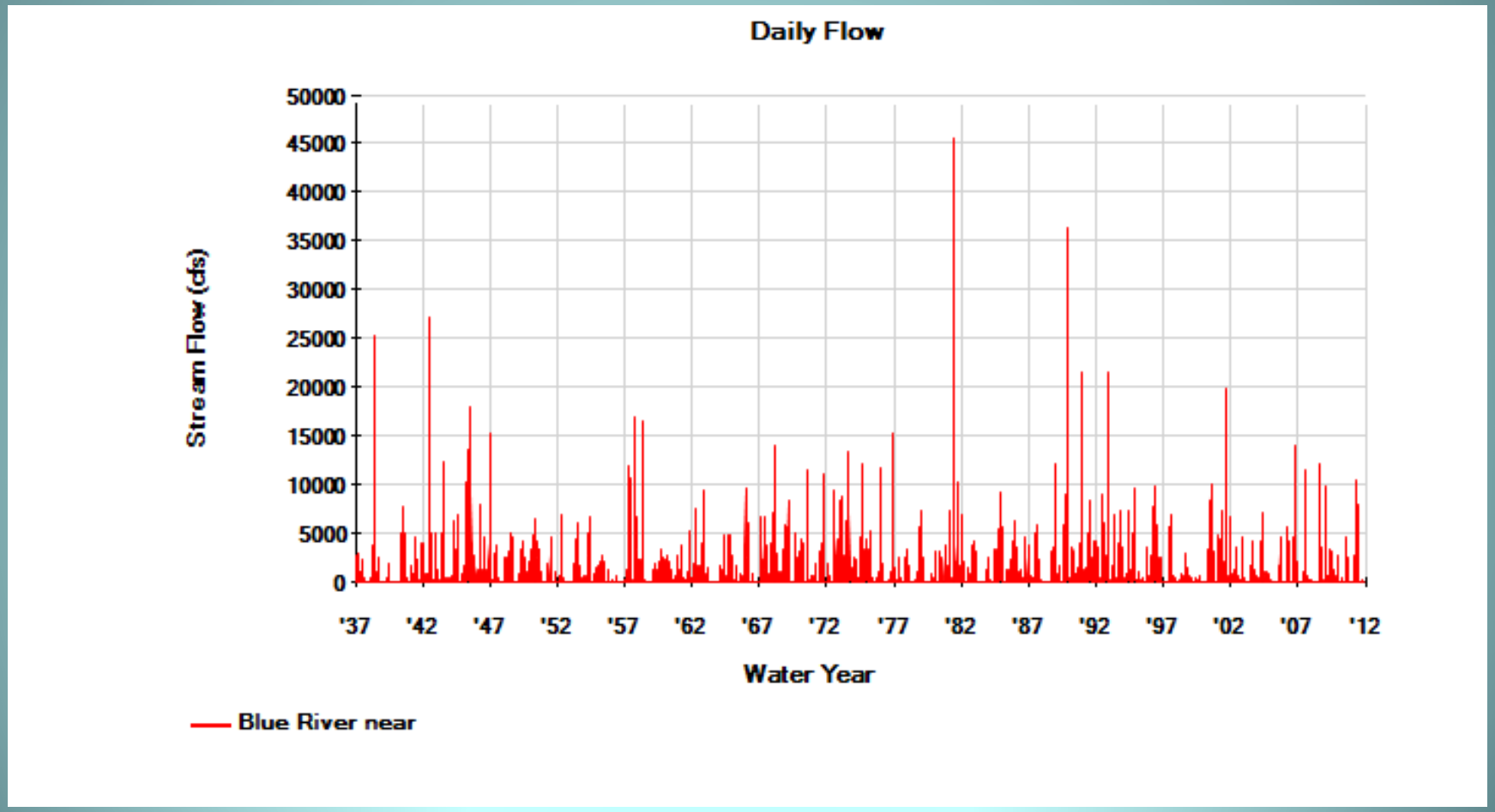
- Flat-lining proved to be inadequate to maintain ecosystem function.
- Various flow levels are beneficial.
- Flat-lining neglects the need for the riverine ecosystem to have different flow requirements throughout the year.
- Flat-lining does not replicate the natural flow variability of river systems.

Environmental Flows

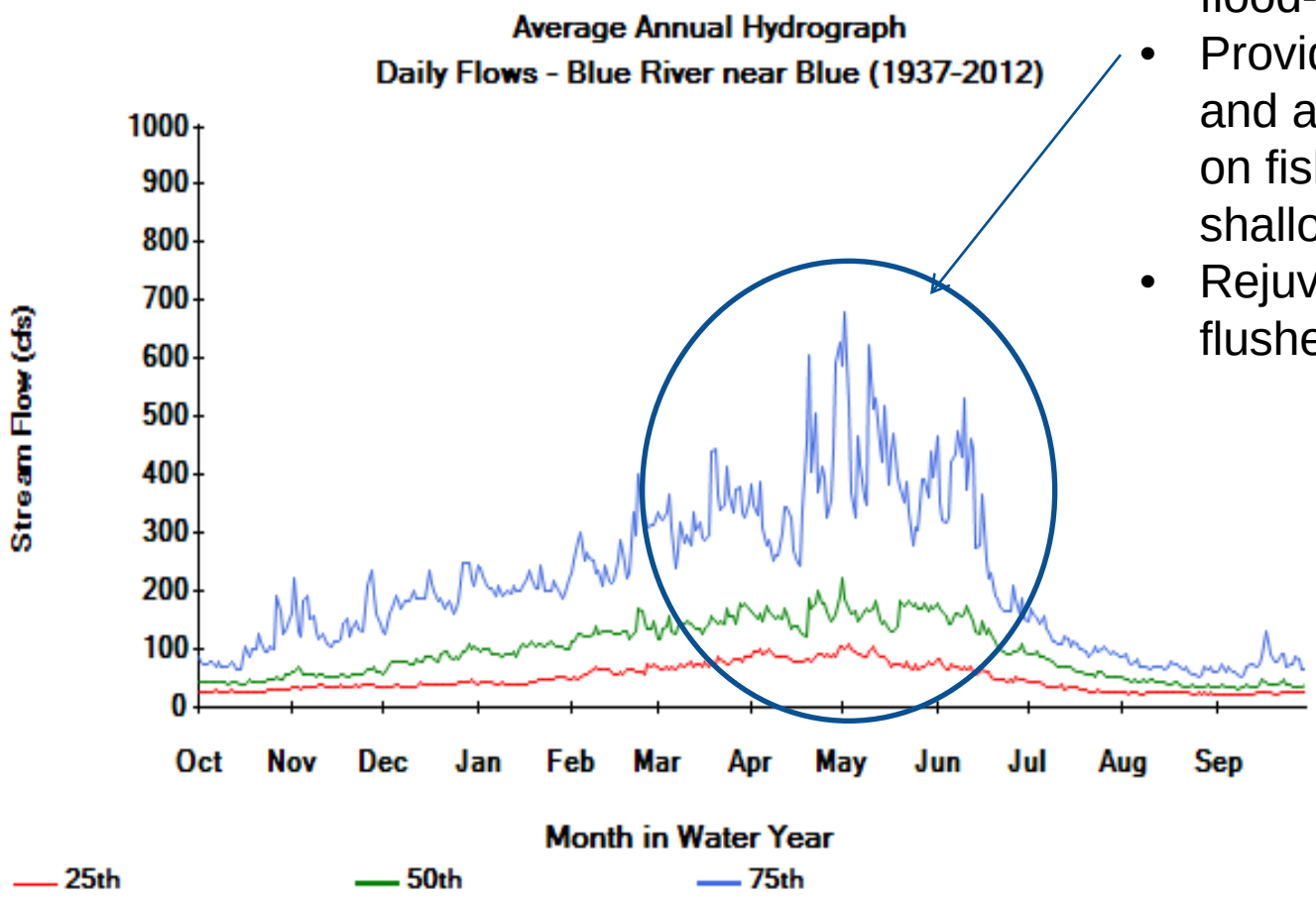
- A new model for developing environmental flow standards is replacing the flat-lining method.
- This approach is called the “Natural Flow Paradigm”.
- The Natural Flow Paradigm accounts for seasonal patterns in terms of magnitude, frequency, timing, and duration of natural streamflow.

Natural Streamflow

Blue River At Blue, Okla. (#07332500)



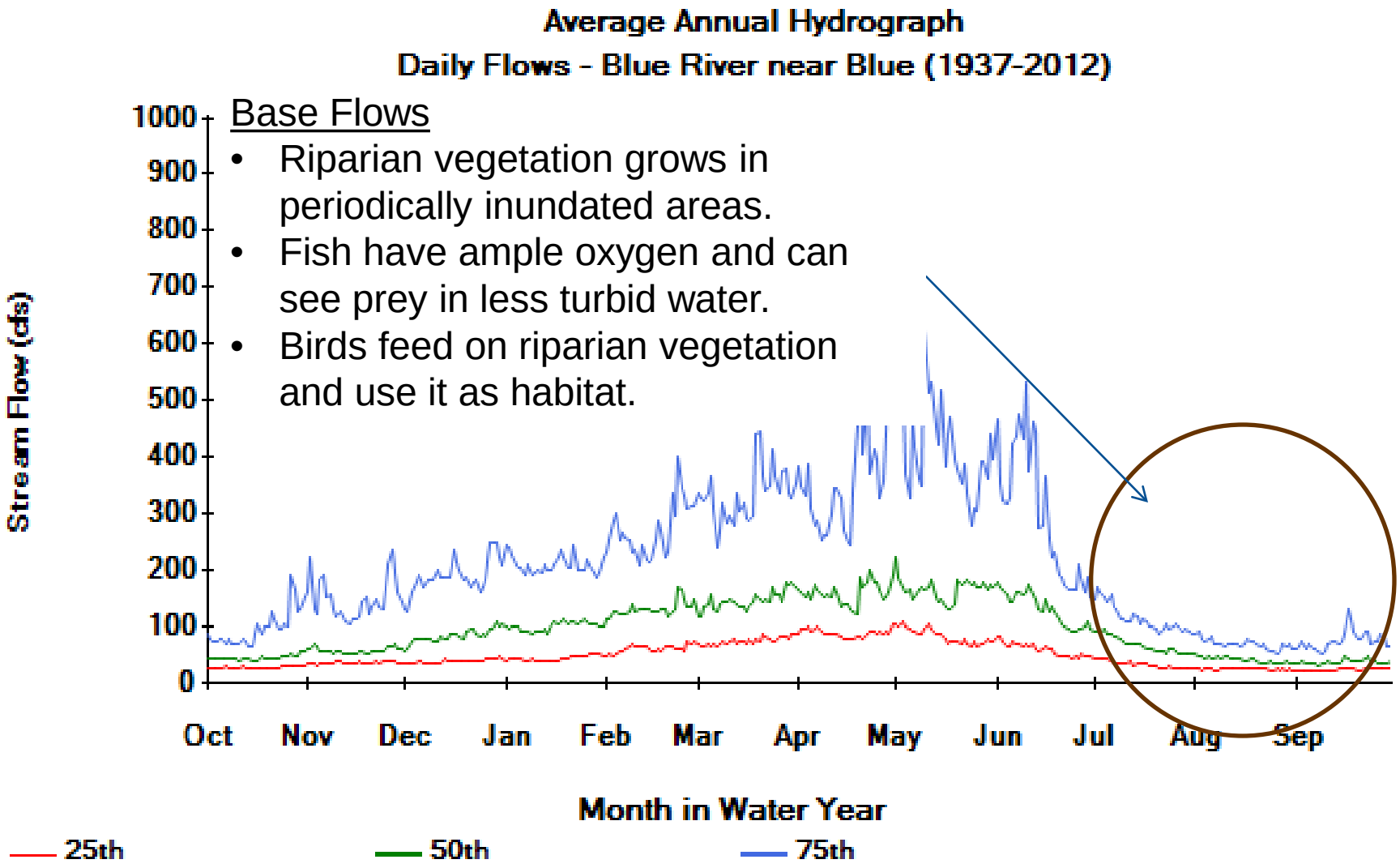
Natural Streamflow



<u>High Flows</u>

- Trigger spawning of fish
- Assist germination of riparian plant seeds on flood-deposited sediments
- Provide food to terrestrial and avian wildlife that feed on fish and plants in shallow flooded areas
- Rejuvenate streambed and flushes silt downstream

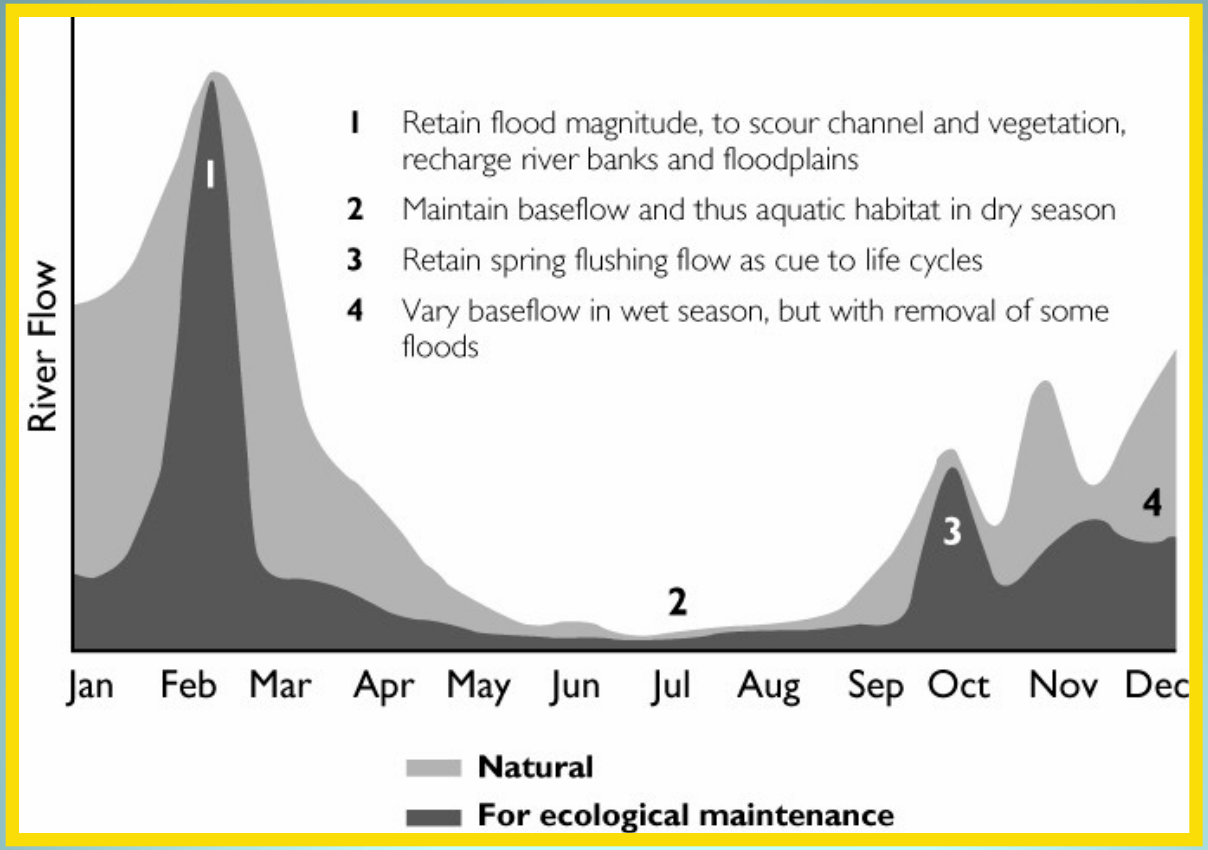
Natural Streamflow



Base Flows

- Riparian vegetation grows in periodically inundated areas.
- Fish have ample oxygen and can see prey in less turbid water.
- Birds feed on riparian vegetation and use it as habitat.

Natural Flow Paradigm



Courtesy: Environmental Flow Specialists and Postel and Richter, 2003

Natural Flow Paradigm

- Streamflow is strongly related to many ecologically sensitive physiochemical components of river systems:
  - channel geomorphology
  - dissolved oxygen, pH, and water temperature
- Alterations in the flow regime may:
  - Modify aquatic habitat of plants and animals
  - Increase disturbances that affect species diversity

Natural Flow Paradigm

- Ecological flows are not a matter of how much water a fluvial ecosystem needs, but how much alteration of regimes can be done before having an appreciable effect on ecosystem integrity.
- The minimum flat-line flow is not enough to maintain this integrity.
- A balance needs to be established between water-supply needs for human and conservation of fluvial ecosystems.

Determining Environmental Flows

- How?
- Detailed analysis of streamflow data which characterizes patterns of streamflow through streamflow indices

Determining Environmental Flows

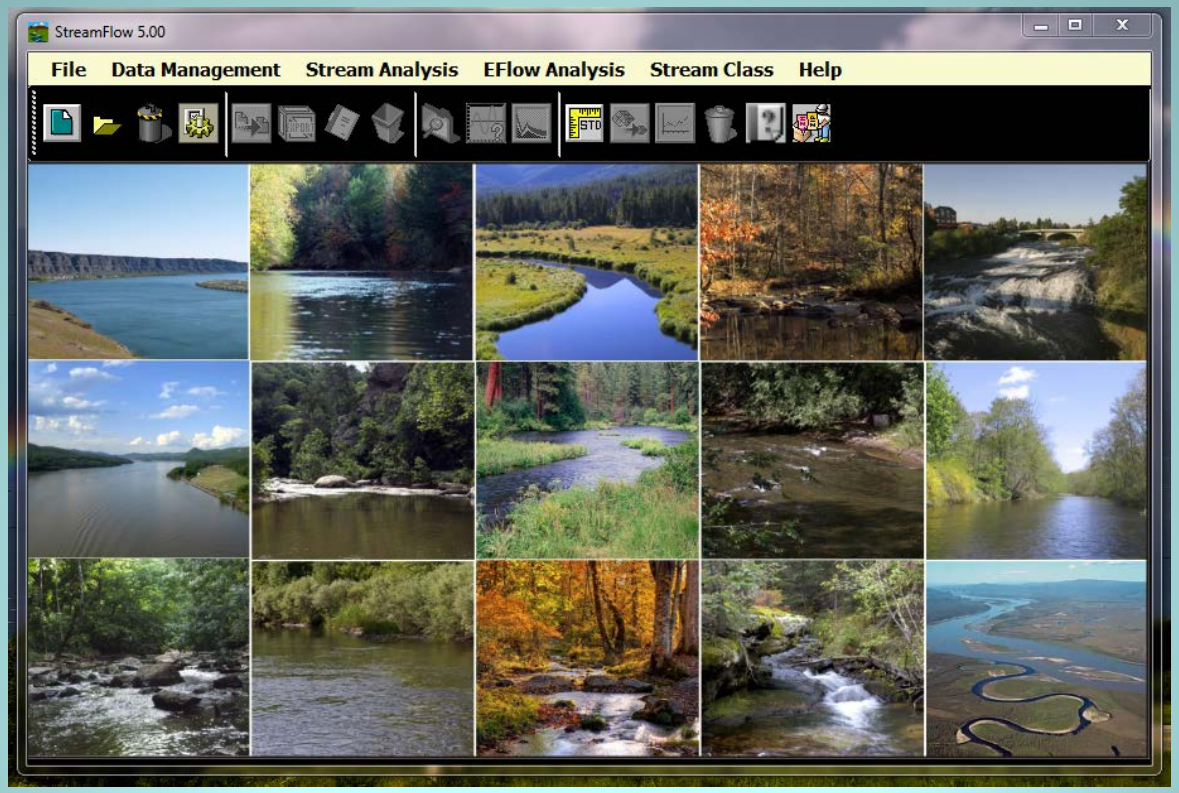
- Olden and Poff (2003) reviewed 171 biologically relevant hydrologic indices, such as those related to:
  - Variation of mean daily flow
  - Skewness of peak discharges
  - Seasonal distribution of monthly low flows
  - Annual frequencies of low flow
  - Frequency and duration of intermittent dry periods
- They recognized that there is challenge in selecting the “best” indices for ecological protection.

Determining Environmental Flows

- Which minimum set of hydrologic indices is needed to adequately describe the main aspects of a flow regime?
  - Timing (high and low)
  - Duration (high and low)
  - Frequency (high and low)
  - Rate of Change
  - Magnitude (average, low, and high)

StreamFlow®

- USGS personnel developed a streamflow classification software program (StreamFlow ®)that can be used to develop ecological flow standards

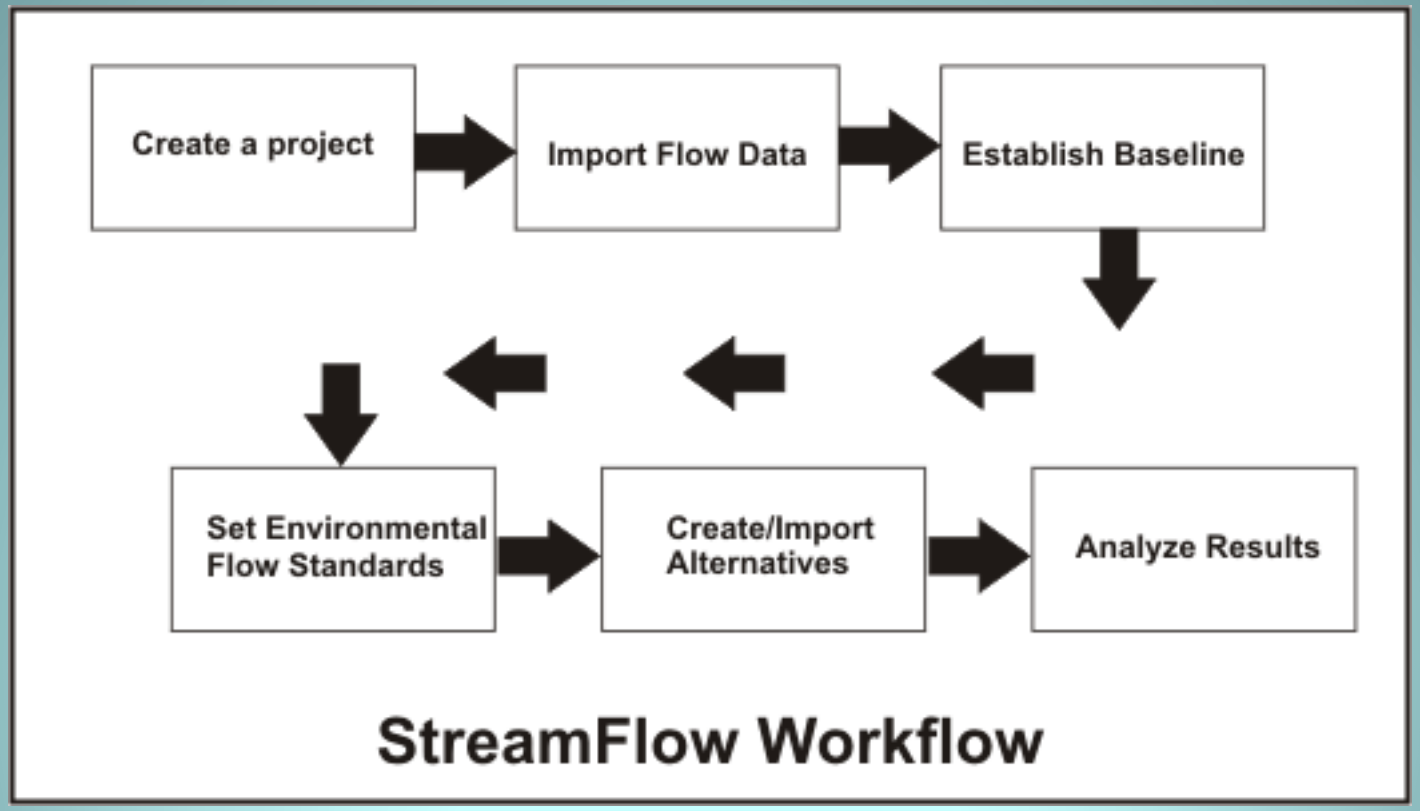


StreamFlow®

Objectives:

- Manage hydrologic data
- Calculate streamflow indices
- Provide tools for identifying baseline periods of record
- Provide tools for defining environmental-flow standards
- Provide tools for the analysis of alternative-flow regimes

StreamFlow® Workflow



Streamflow indices

89 indices are divided among 10 categories:

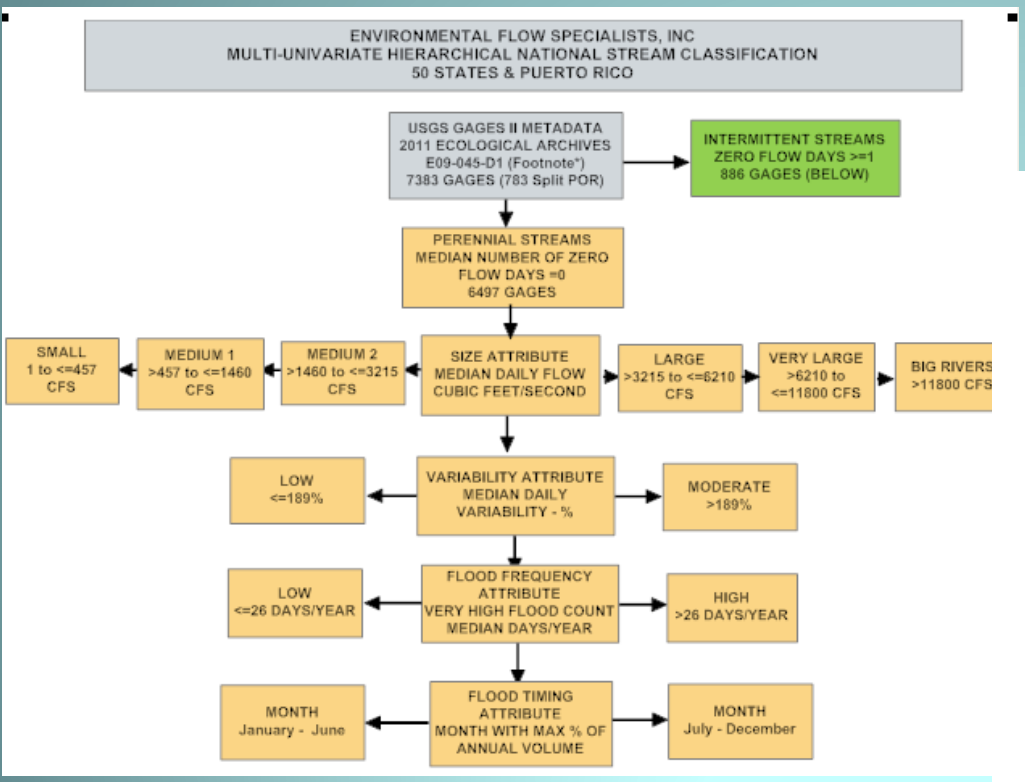
General Magnitude	**10 indices**
Low Magnitude	**12 indices**
Median Magnitude	**12 indices**
High Magnitude	**12 indices**
Frequency	**12 indices**
Duration	**6 indices**
Timing	**9 indices**
Rate of Change	**1 index**
Variability	**9 indices**
Eflow Signature	**6 indices**

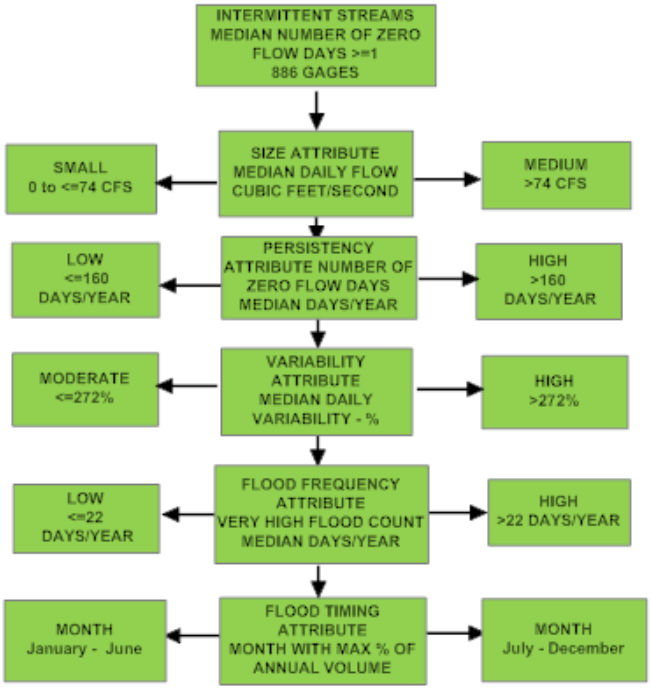
Stream Classification

Using the streamflow indices, we can classify hydrologically similar streams based on common themes such as:

- Size of watershed
- Permanence (perennial vs. intermittent)
- Variability
- Predictability
- Flood characteristics (frequency and flashiness)

Classification Flow Chart





* Authors: James A. Falcone, Daren M. Carlisle, David M. Wolock, and Michael R. Meador

Benefits of StreamFlow®

- Calculate critical streamflow indices which quantify how a stream behaves
- Provides insight into what indices are associated with desirable biological conditions
- Provides insight as to what variables are important to maintain streamflow
- Intuitive, customizable, and understandable classes
- Establish environmental-flow standards suitable for a specific stream or a specific class of streams

Benefits of StreamFlow®

<u>Analyze Alternative and Modeled Streamflow Data</u>

- Quantify how alteration may affect streamflow and perturb it from a desired baseline or target streamflow
- Import streamflow from a hydrologic model and analyze ungaged streams
- Evaluate the effects of climate change on streamflow using hydrologic model output

Summary

- Stream alteration poses a substantial threat to riverine ecosystems.
- Environmental flow standards were developed to minimize the adverse impacts on altered streams.
- The Natural Flow Paradigm is an emerging approach to establish environmental flow standards.
  - Accounts for natural variations in magnitude, timing, frequency, and duration of natural flow
- StreamFlow software is a powerful tool capable of analyzing streamflow and developing environmental standards.

References

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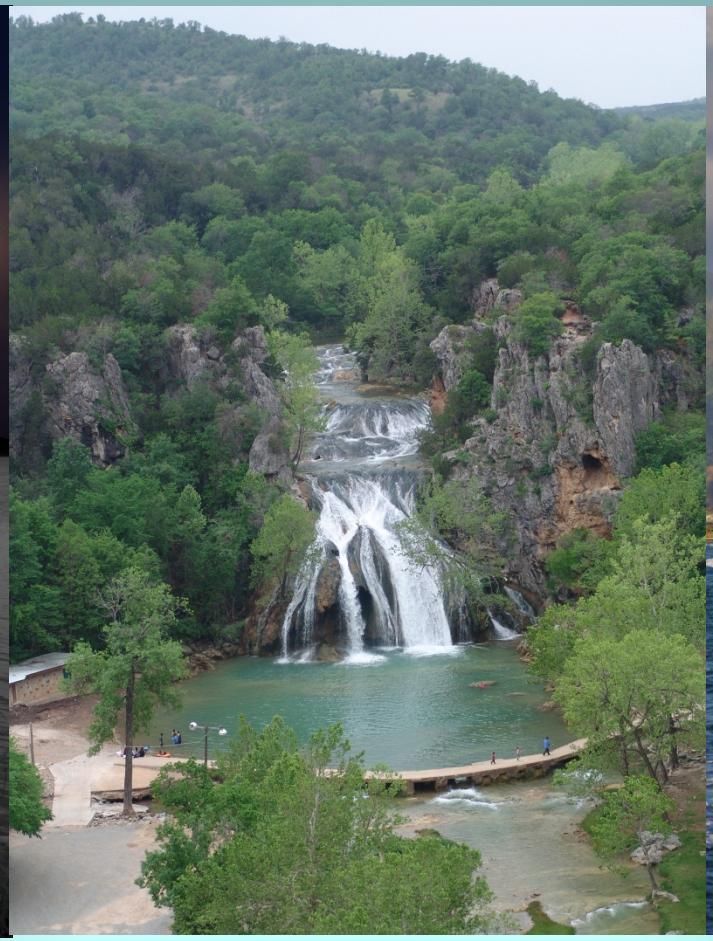
Questions?

Lake Thunderbird
Photo by T. Grout



Turner Falls,
Photo by S. Paxton

Hawaii,
Photo by T. Grout