ELOHA and the National Water Census: Characterizing Uncertainty to Support Management and Sustainability of Water Resources

Instream Flow Council
FLOW 2015
Portland, OR

Jonathan Kennen
Ecological Water Lead,
National Water Census

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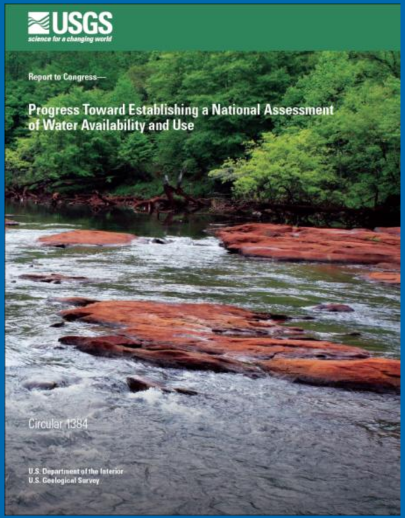
Presentation Overview

- Short Intro to the National Water Census (WC)
- What is the ELOHA framework and how is it woven into the WC?
- Predicting hydrologic time series at ungaged locations, models, methods and more….
- What is uncertainty and how do we estimate it?
- How the WC is addressing uncertainty in streamflow estimation and ecological assessment
- Final thoughts – end game and goals of the Water Census Regarding Uncertainty.

Our objective for the Water Census

To place technical information and tools in the hands of stakeholders, allowing them to answer two primary questions about water availability…



- Does the US have an enough freshwater to meet both human and ecological needs?
- Will this water be present to meet future needs?

SECURE Water Act (2009)
Public Law 111-11, § 9507 and 9508

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Water Availability Analysis

The process of determining the quantity and timing-characteristics of water, which is of sufficient quality, to meet both human and ecological needs.

Types of Information

Technical
Socio-economic
Legal
Regulatory
Political

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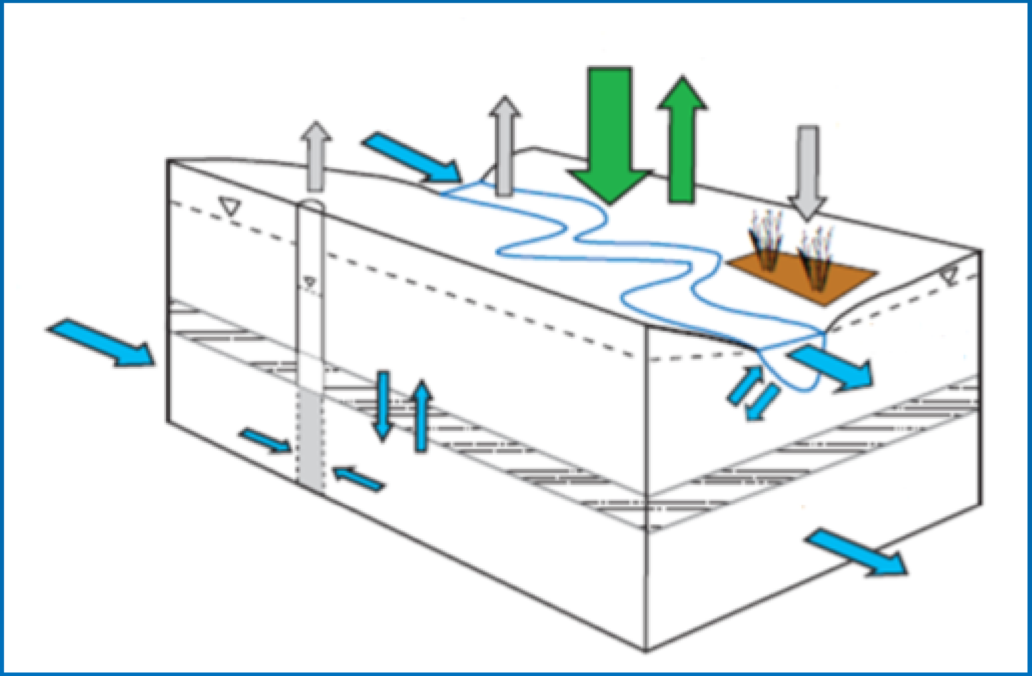
Account for water with a “budget”



Precipitation
+
Flow in
=
Evapotranspiration
+
Storage Change
+
Flow out

Green arrows = exchanges with atmosphere: P, ET
Blue arrows = water movement between streams & aquifers
Gray arrows = human withdrawals and return flows

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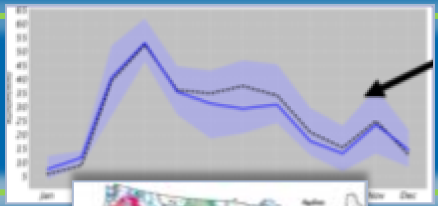
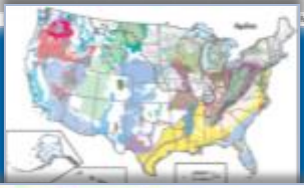
Six Areas of Nationwide Topical Work

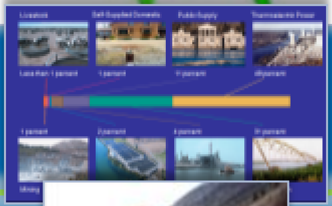


Estimation of Flow at Ungaged Locations

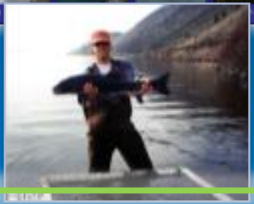


Groundwater Information

Estimation of Evapotranspiration



Water Use



Ecological Water Science

Water Requirements for UOG Development

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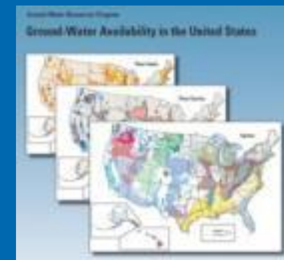
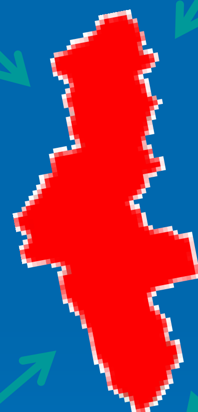
Focused Water Availability Assessments

Water Quality



Groundwater Resources

Water Use



Surface Water Trends, Precipitation, etc

Eco Water

Global Change

State, Local, Regional Stakeholder Involvement

Defined Technical Questions to be Answered

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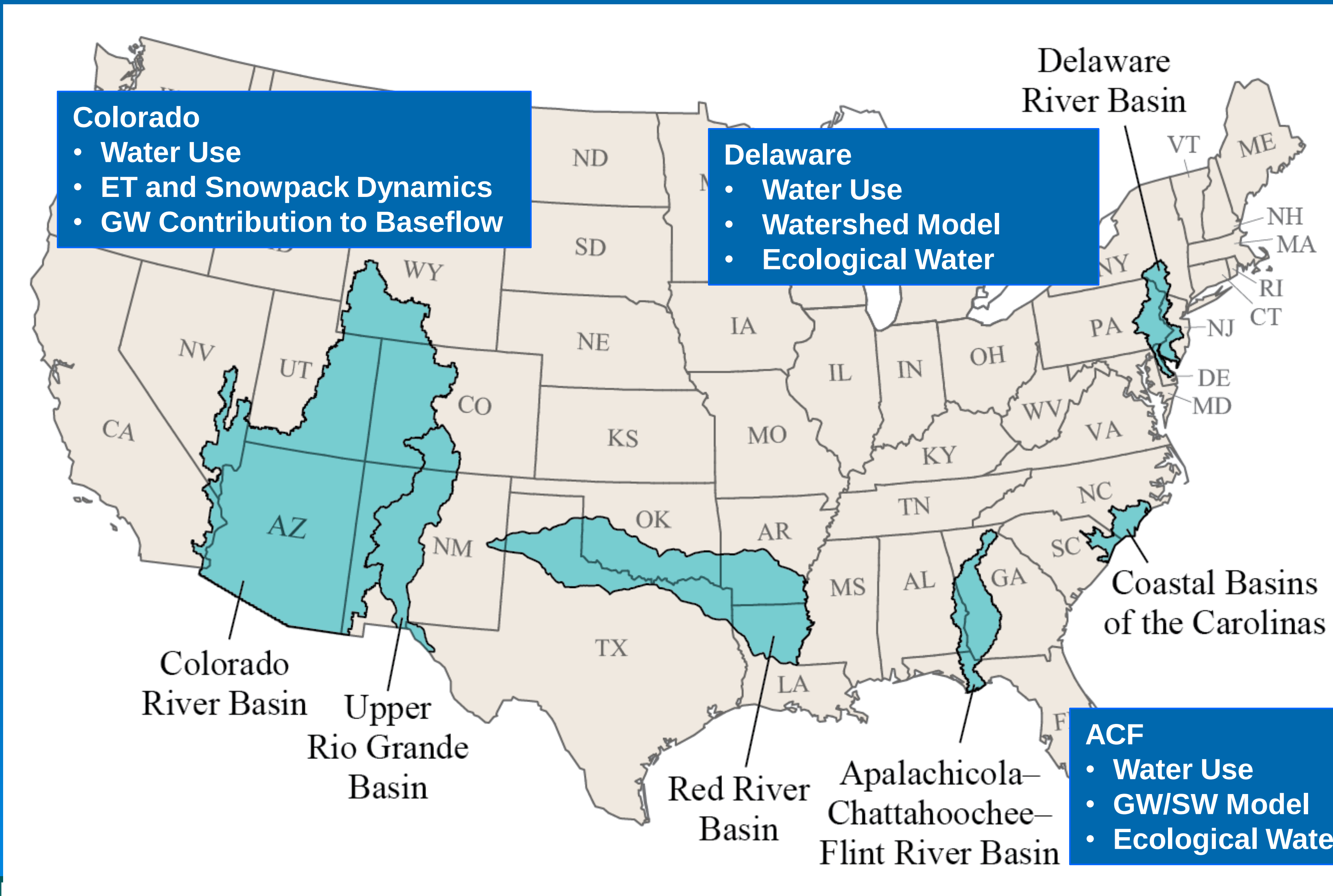
Areas of Geographically Focused Work



Colorado
- Water Use
- ET and Snowpack Dynamics
- GW Contribution to Baseflow

Delaware
- Water Use
- Watershed Model
- Ecological Water

ACF
- Water Use
- GW/SW Model
- Ecological Water

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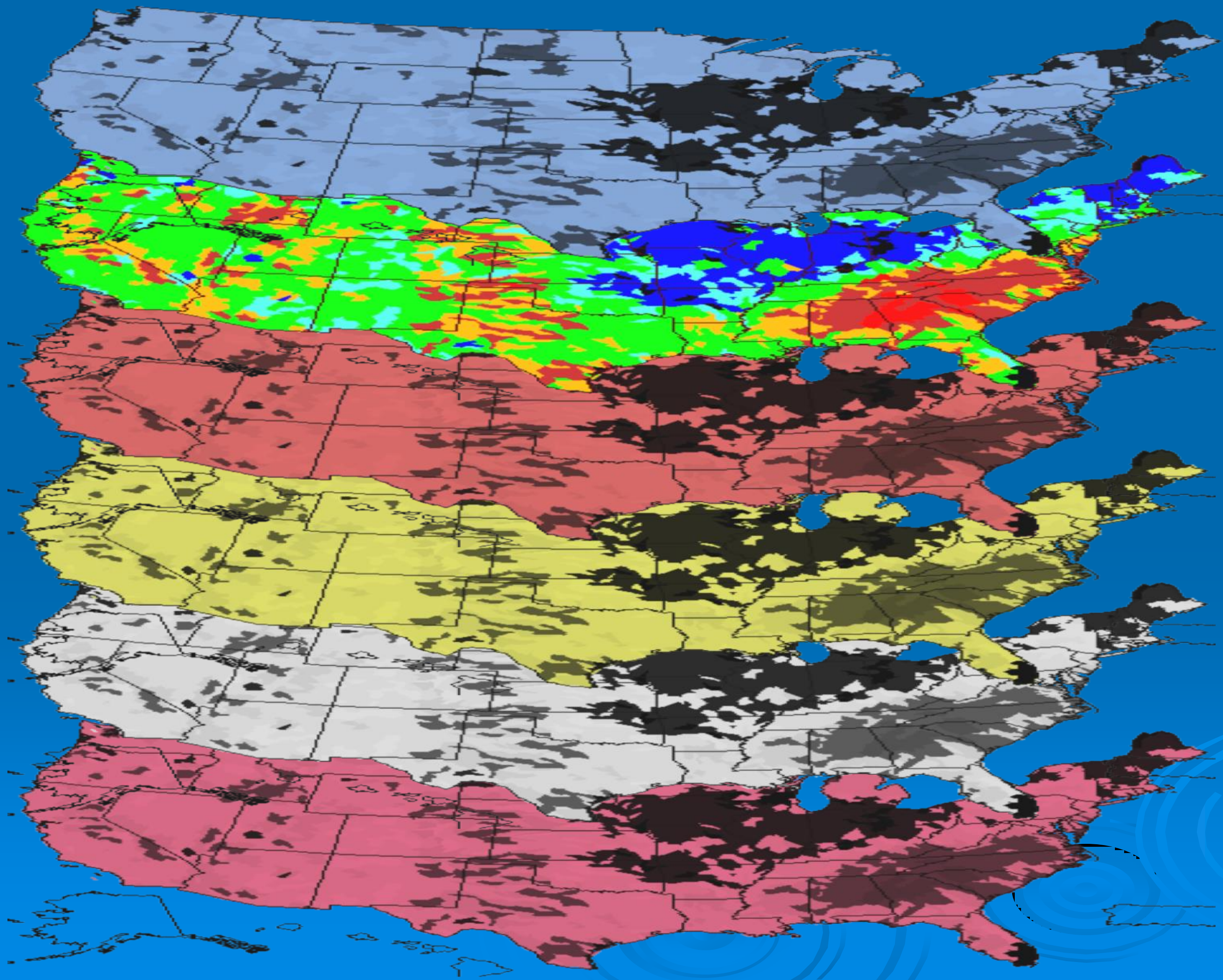
A US-wide System to deliver water accounting information



Precipitation

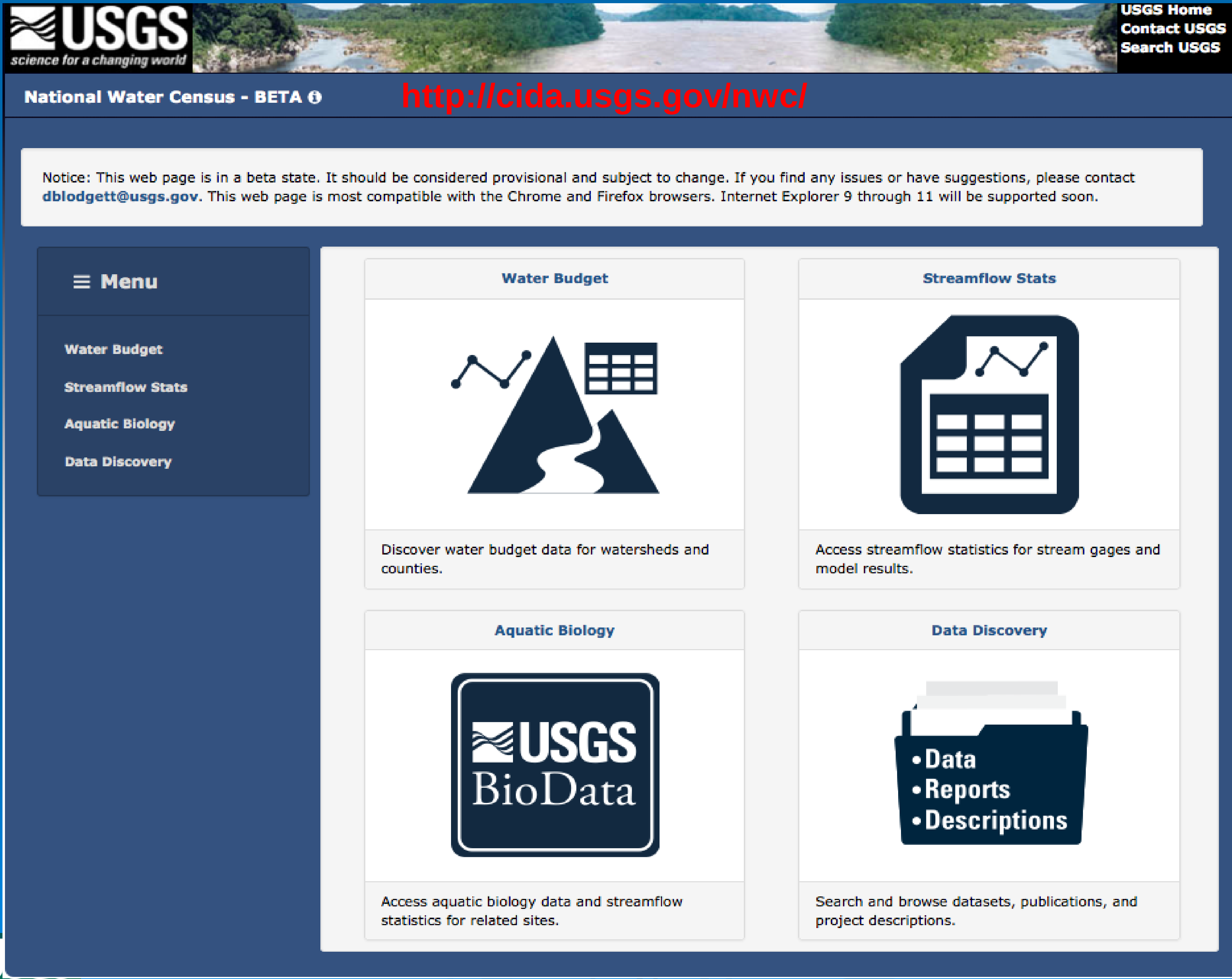
Runoff

Baseflow

ET

Recharge

Surface Storage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Aquatic Biology
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Access streamflow statistics for stream gages and model results.
Aquatic Biology
USGS BioData
Access aquatic biology data and streamflow statistics for related sites.
Data Discovery
•Data
•Reports
•Descriptions
Search and browse datasets, publications, and project descriptions.

The Ecological Limits of Hydrologic Alteration (ELOHA):

a flexible framework for developing regional environmental flow standards

Cost Effective, Pragmatic and Scientifically Defensible Framework

Freshwater Biology (2009) doi:10.1111/j.1365-2427.2009.02204.x

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[‡‡‡‡]

[*]*Department of Biology & Graduate Degree Program in Ecology, Colorado State University, Fort Collins, CO, U.S.A.*
[†]*The Nature Conservancy, Charlottesville, VI, U.S.A.*
[‡]*Australian Rivers Institute and eWater Cooperative Research Centre, Griffith University, Brisbane, Qld, Australia*
[§]*School of Aquatic & Fishery Sciences, University of Washington, Seattle, WA, U.S.A.*
[¶]*The Nature Conservancy, Helena, MT, U.S.A.*
[**]*Centre for Ecology and Hydrology, Wallingford, U.K.*
[††]*The Nature Conservancy, Brunswick, ME, U.S.A.*
[‡‡]*Department of Civil and Environmental Engineering, Colorado State University, Fort Collins, CO, U.S.A.*
[§§]*Patuxent Wildlife Research Center, U.S. Geological Survey, Athens, GA, U.S.A.*
[¶¶]*U.S. Geological Survey, Fort Collins, CO, U.S.A.*
[***]*Columbia Environmental Research Center, U.S. Geological Survey, Columbia, MO, U.S.A.*
[†††]*U.S. Geological Survey, West Trenton, NJ, U.S.A.*
[‡‡‡]*USDA Forest Service, Watershed, Fish, and Wildlife, Fort Collins, CO, U.S.A.*
[§§§]*Department of Environmental Resources, UNESCO-IHE Institute for Water Education, Delft, The Netherlands*
[¶¶¶]*School of Aquatic & Fishery Sciences, University of Washington, Seattle, WA, U.S.A.*
[****]*University of the Witwatersrand, Johannesburg, South Africa*
[††††]*International Water Management Institute, Colombo, Sri Lanka*
[‡‡‡‡]*The Nature Conservancy, University Park, Pennsylvania, PA, U.S.A.*

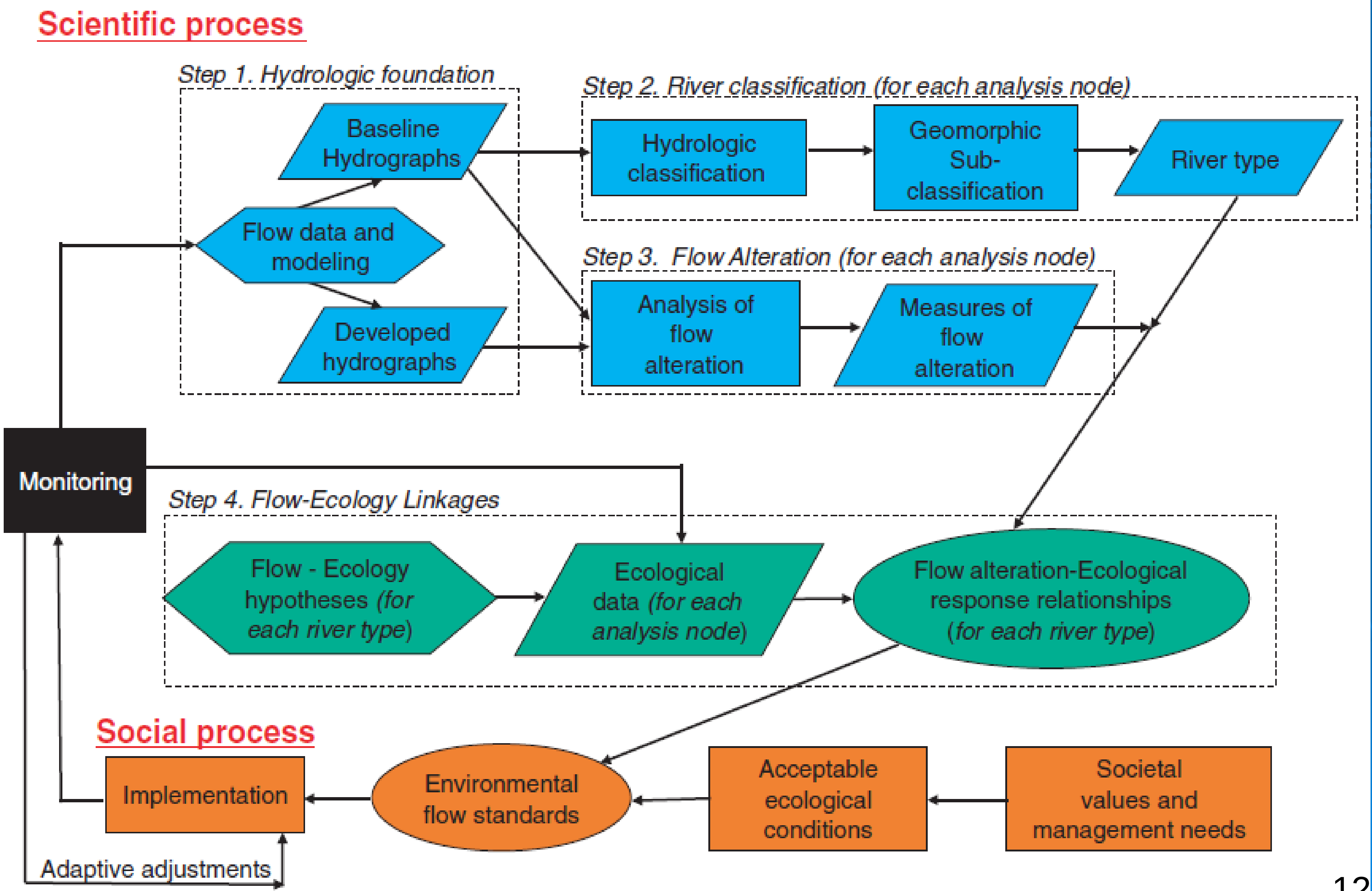
SUMMARY

1. The flow regime is a primary determinant of the structure and function of aquatic and riparian ecosystems for streams and rivers. Hydrologic alteration has impaired riverine ecosystems on a global scale, and the pace and intensity of human development greatly exceeds the ability of scientists to assess the effects on a river-by-river basis. Current scientific understanding of hydrologic controls on riverine ecosystems and experience gained from individual river studies support development of environmental flow standards at the regional scale.

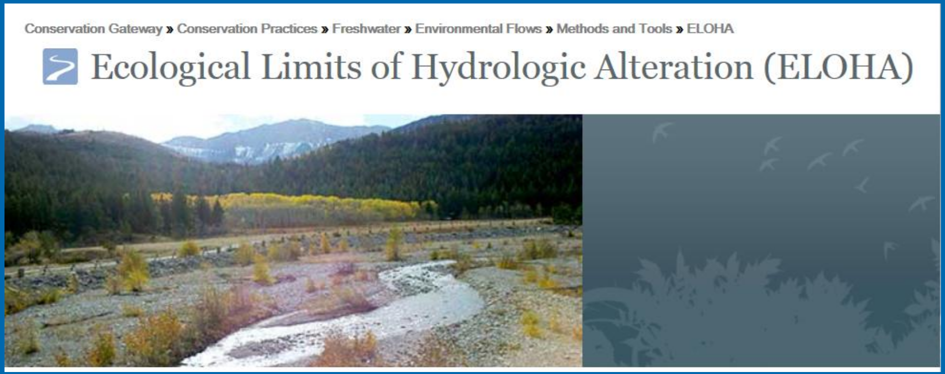
2. This paper presents a consensus view from a group of international scientists on a new framework for assessing environmental flow needs for many streams and rivers simultaneously to foster development and implementation of environmental flow standards at the regional scale. This framework, the ecological limits of hydrologic alteration (ELOHA), is a synthesis of a number of existing hydrologic techniques and environmental flow methods that are currently being used to various degrees and that can support comprehensive regional flow management. The flexible approach allows

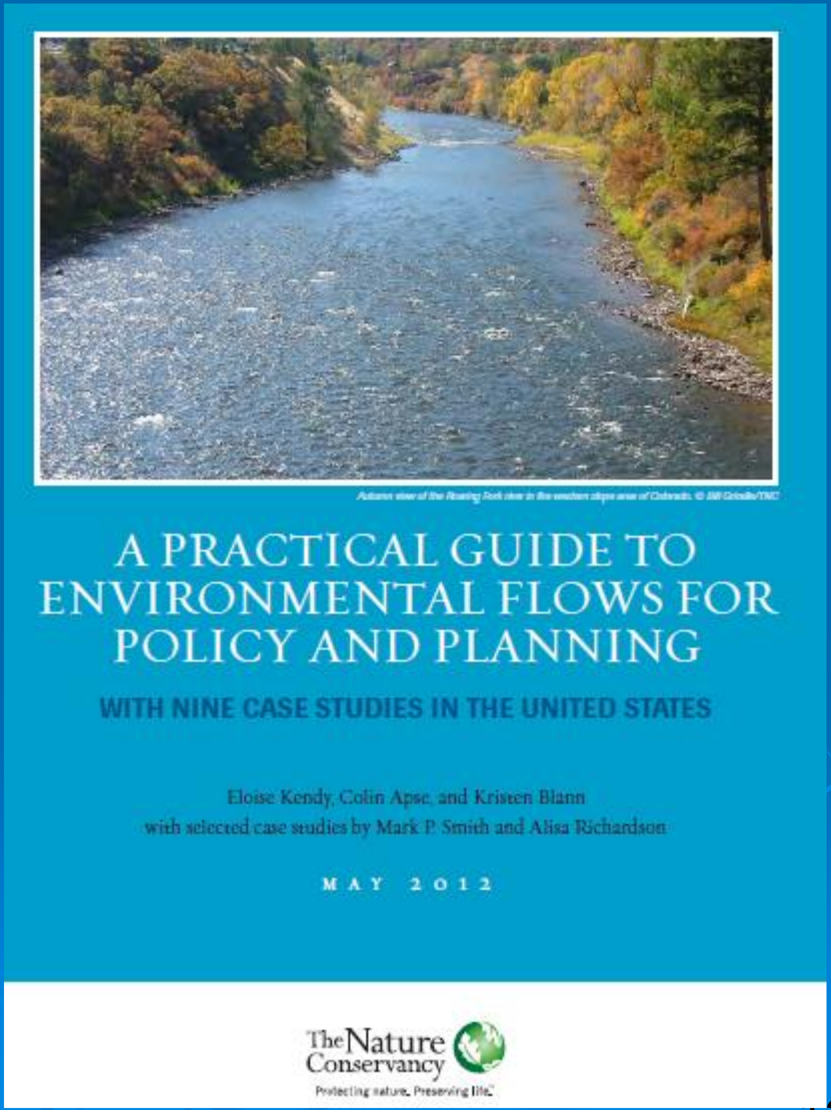
Correspondence: N. LeRoy Poff, Department of Biology, Colorado State University, Fort Collins, 80523 CO, U.S.A.
E-mail: poff@lamar.colostate.edu
Present address: James Henriksen, Environmental Flow Specialists, Inc. Fort Collins, CO 80526, U.S.A.

ELOHA – scientific and social elements



The ELOHA ToolBox





Hydrologic Foundation
River Types
Flow + Ecology
Policy Implementation
ELOHA Projects Proposals
Bibliography
Case Studies

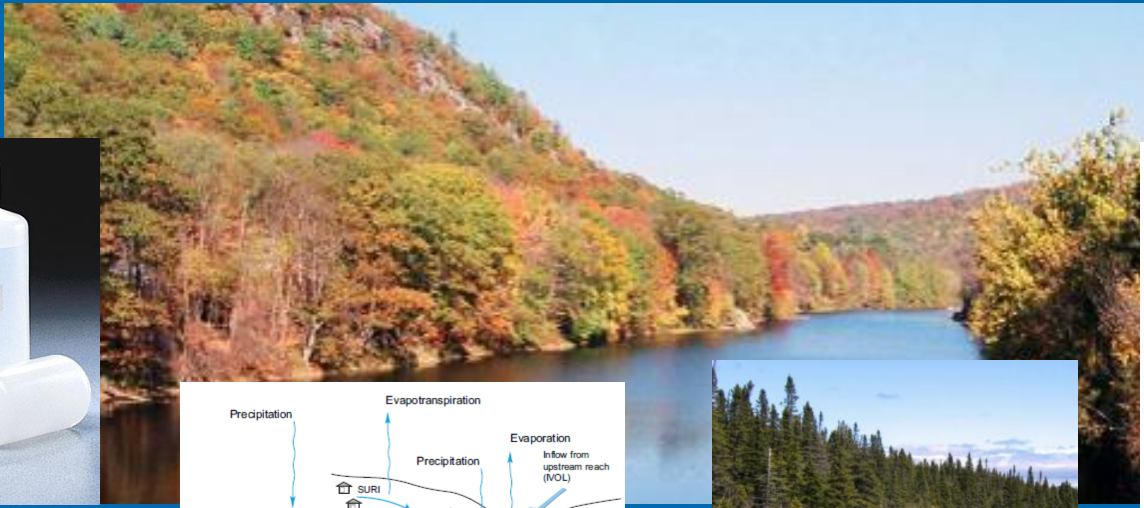
>576 citations

Water Census - Ecological Water Needs for Wildlife and Habitat

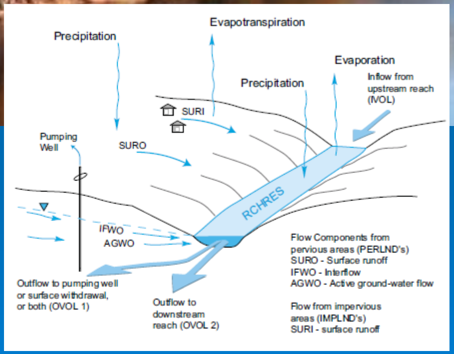
- Flow estimation in ungaged catchments
- Nationally classify streams - hydroecological type
- Create tools for systematically assessing hydrologic change
- Delivery of hydrologic and ecological information to stakeholders for supporting the development of water (flow) – ecology response relations

The need for streamflow time series

Streamflow time series are essential information for many types of analyses

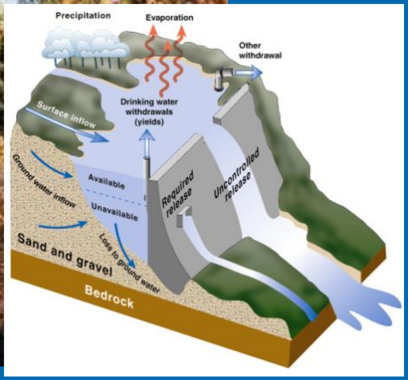


Water quality monitoring and modeling



Water quantity modeling

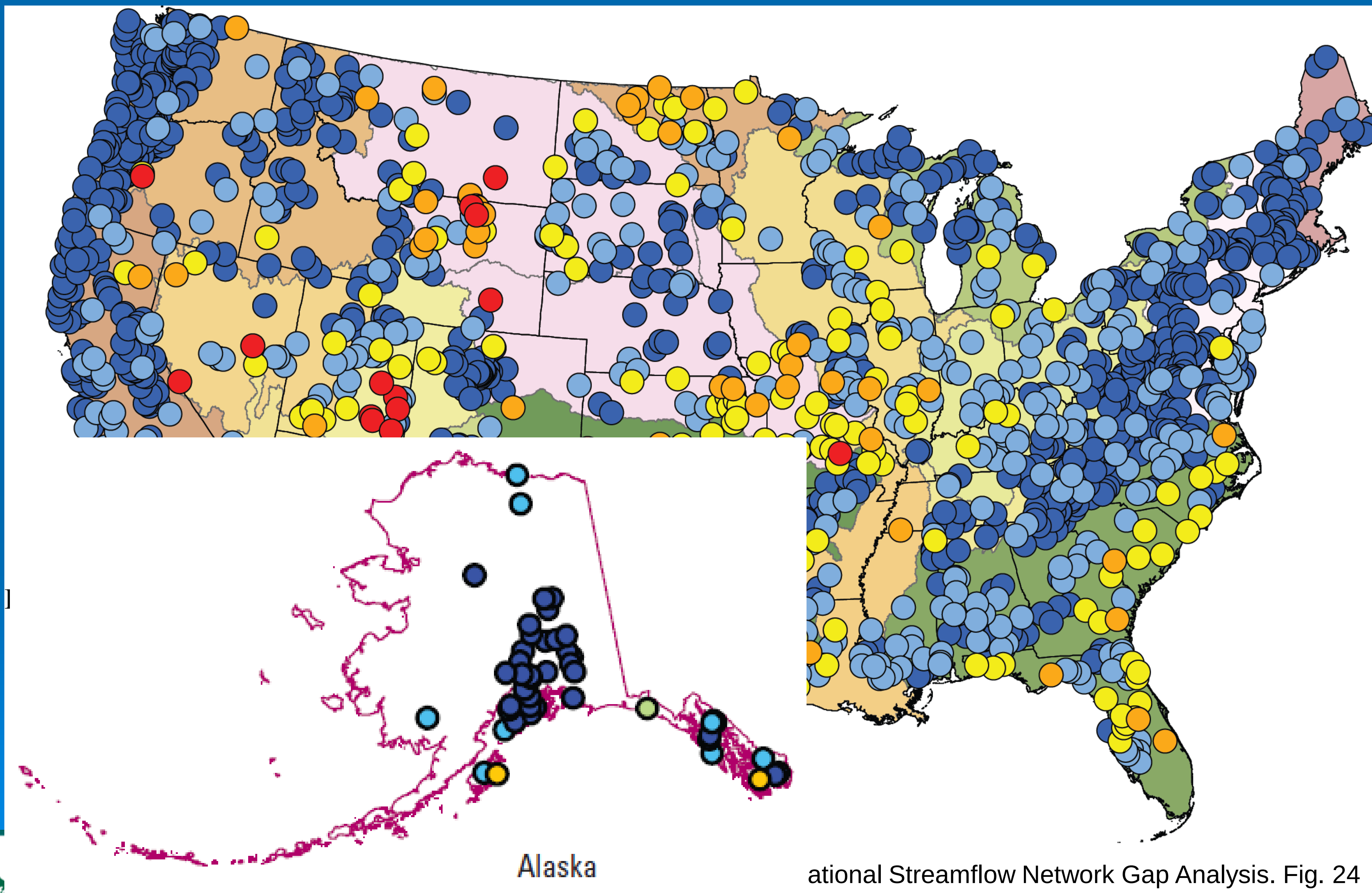
Ecological Water Assessment



Water management decisions

Photographs from: http://www.labsafety.com/Nalgene-Environmental-Sample-Bottles_24545938, Zarriello, P.J. and Reis, K.G., 2000, and Waldron and Archfield (2006).

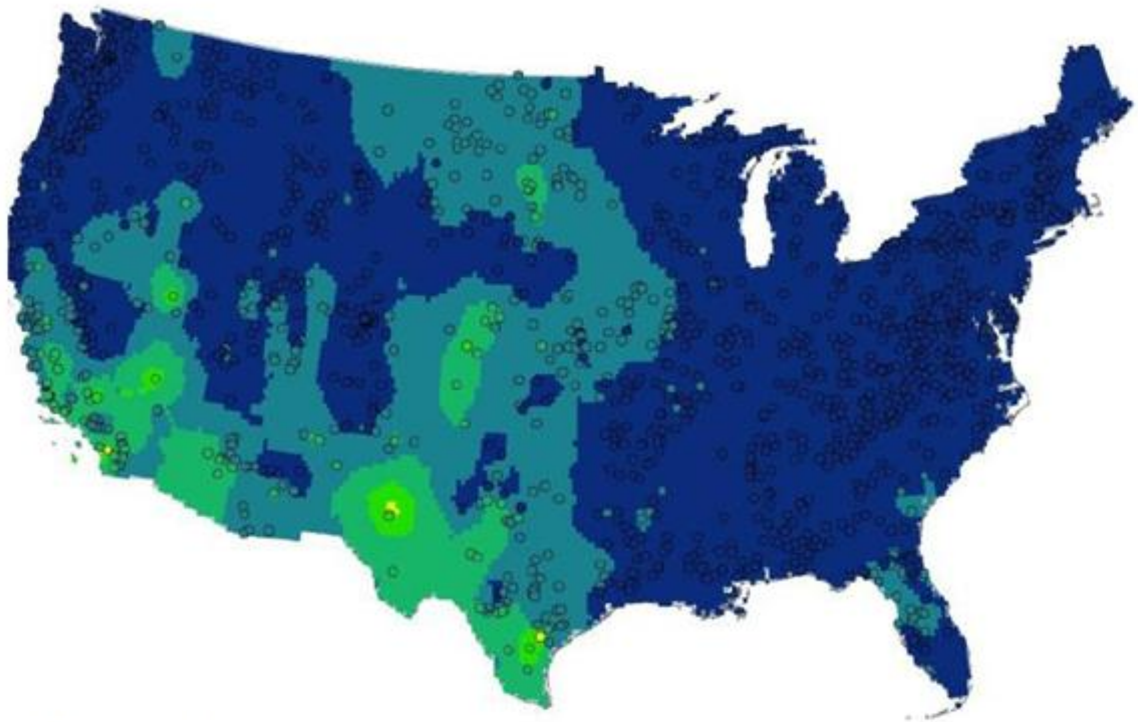
Correlation between streamgages across the United States



ational Streamflow Network Gap Analysis. Fig. 24

Uncertainty Map of US

Sample uncertainty map



Might be produced for different-sized basins, for different parts of the flow regime, etc.

What is Uncertainty?

- A state of having limited knowledge, where it is impossible to exactly describe the existing state.
- It is the probability of producing a different result.
- More simply put, it is the probability of not being certain.
- Uncertainty is a common attribute of any information (data or model).

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Types of Uncertainty

<u>Two types of uncertainty:</u>

1. Natural variability

2. Imperfect understanding of natural systems (errors)

Errors

Deviations between a data value and the true value

Model Uncertainty

Uncertainty is present in hydrologic models for many reasons, but ultimately because it is impossible to reproduce a natural hydrologic system in a model with complete accuracy.

Different models don't agree.

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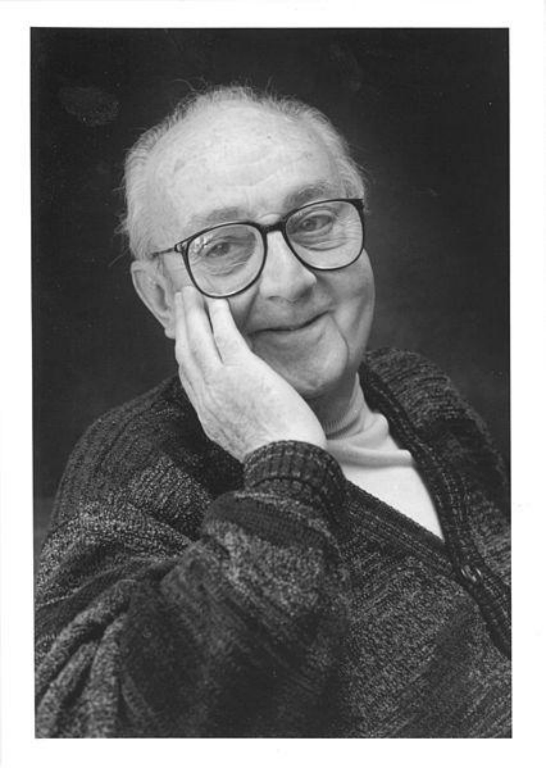
Model Uncertainty

"…essentially, all models are wrong, but some are useful…"

"…the practical question is how wrong do they have to be to not be useful?"



George E. P. Box
University of Wisconsin

Estimating Streamflow at Ungaged Locations

Drainage-area ratio

$$Qu_t = \frac{Au}{Ag} Qg_t$$

Scaling by the at-site mean and variance

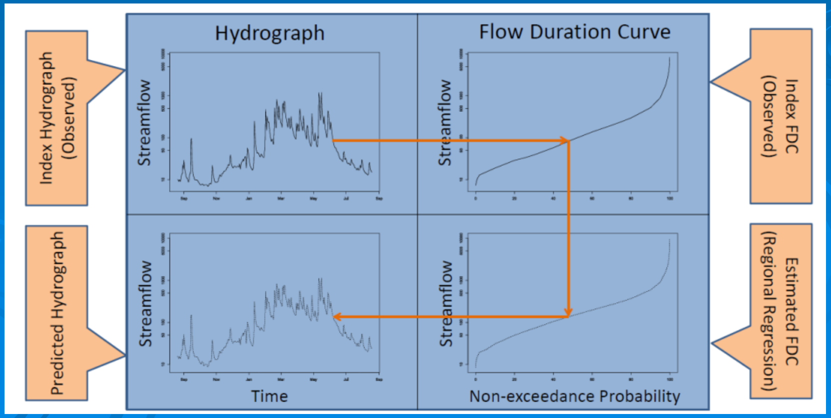
$$Qu_t = \hat{\mu}_u + \hat{\sigma}_u \left(\frac{Qg_t - \hat{\mu}_g}{\hat{\sigma}_g} \right)$$

Process Based Rainfall Runoff Models

PRMS, SWAT, GWLF, HSPF

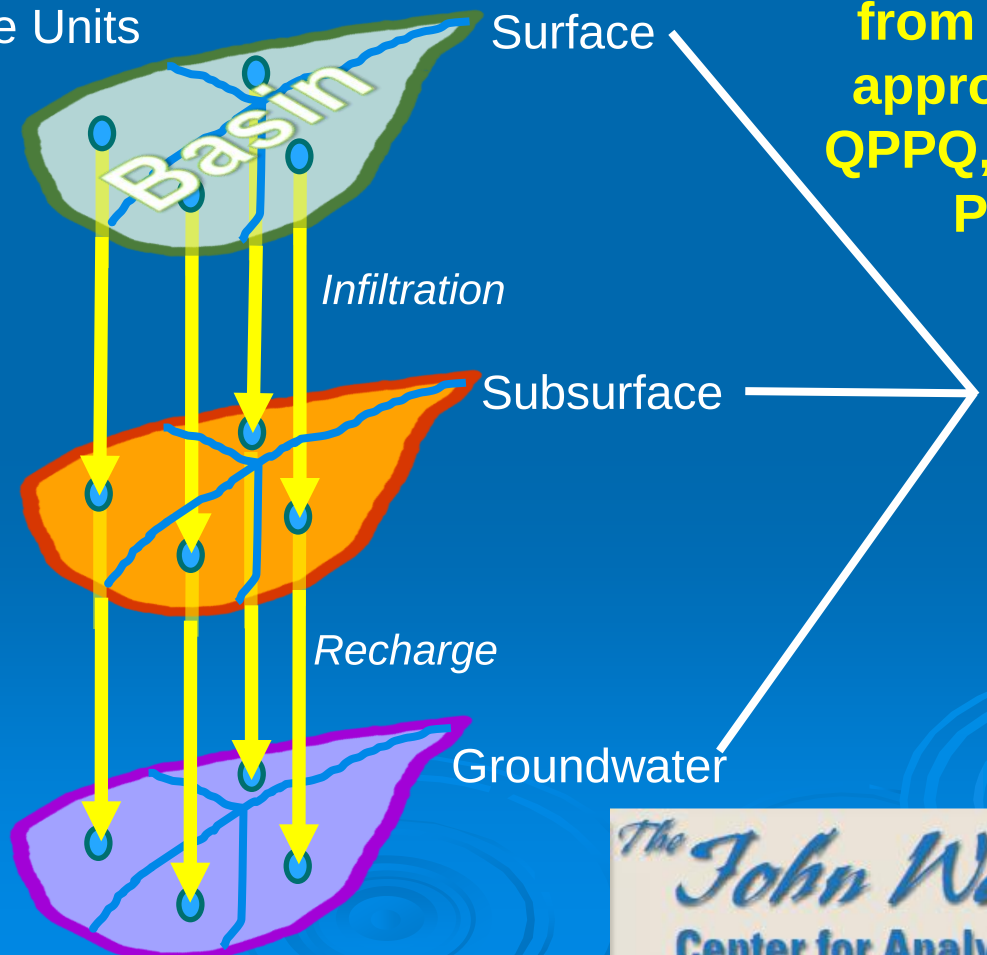
Non-linear spatial interpolation (QPPQ)

(Fennessey, 1994; Smakhtin, 1999; Smakhtin et al. 1997, Mohamoud, 2008; Archfield and others, 2010)



Collaboration via the John Wesley Powell Center for Analysis and Synthesis

Hydrologic Response Units (HRUs)



Use estimated streamflow resulting from other modeling approaches, such as QPPQ, to constrain the PRMS model

Streamflow

Reduce Uncertainty

The John Wesley Powell Center for Analysis and Synthesis

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Uncertainty in Flow Estimation Techniques

- How much can we trust our flow predictions?
  - Uncertainty in flow estimation can have significant impact on our understanding of water availability & EWater modeling.
  - Flow estimation techniques do not provide a explicit measure of prediction uncertainty
- Therefore, there is a strong need to build uncertainty estimates into flow time series

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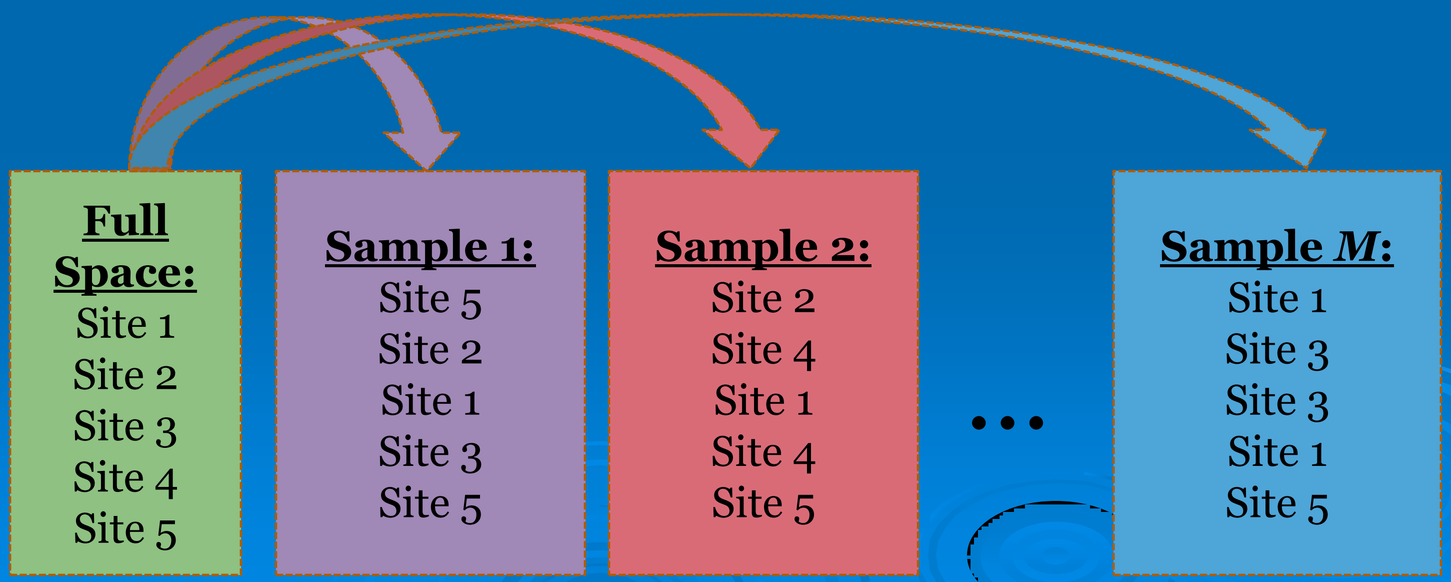
Resampling Streamgage Networks

- Develop a resampling technique (bootstrapping) to provide a an Interval of Uncertainty (a CI if you will) around a flow time series
  - The best predictions consider the entire observed network
  - Resampling this network can produce equally-plausible predictions

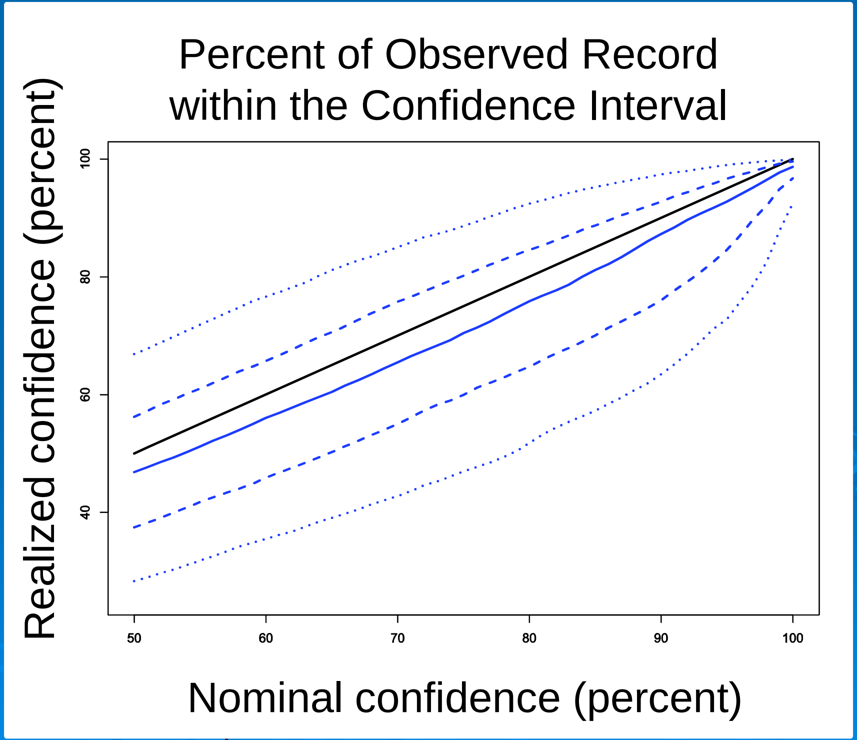


Finding the "Best" Confidence Intervals

- Comparing average behavior of CI's via re-centering…

Re-centering	Average Difference	Standard Deviation of Difference
None	-4.10%	1.30%
Differenced Median	-5.04%	1.67%
Differenced Mean	-3.96%	0.74%
Proportional Median	-3.67%	0.98%
Proportional Mean	-7.55%	2.68%

- Proportional, Median Re-Centering



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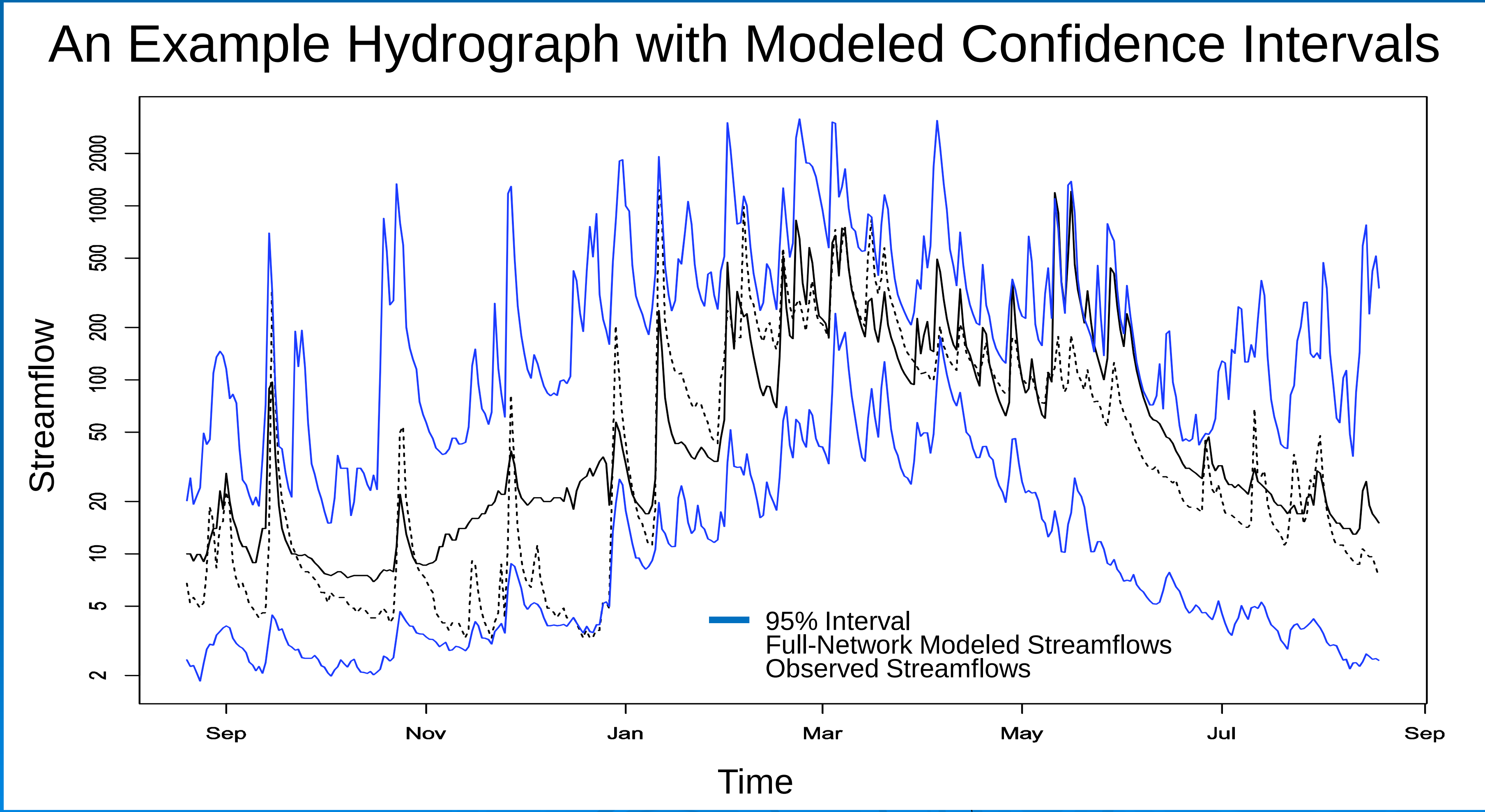
Re-sampled Confidence Intervals: A First Approximation

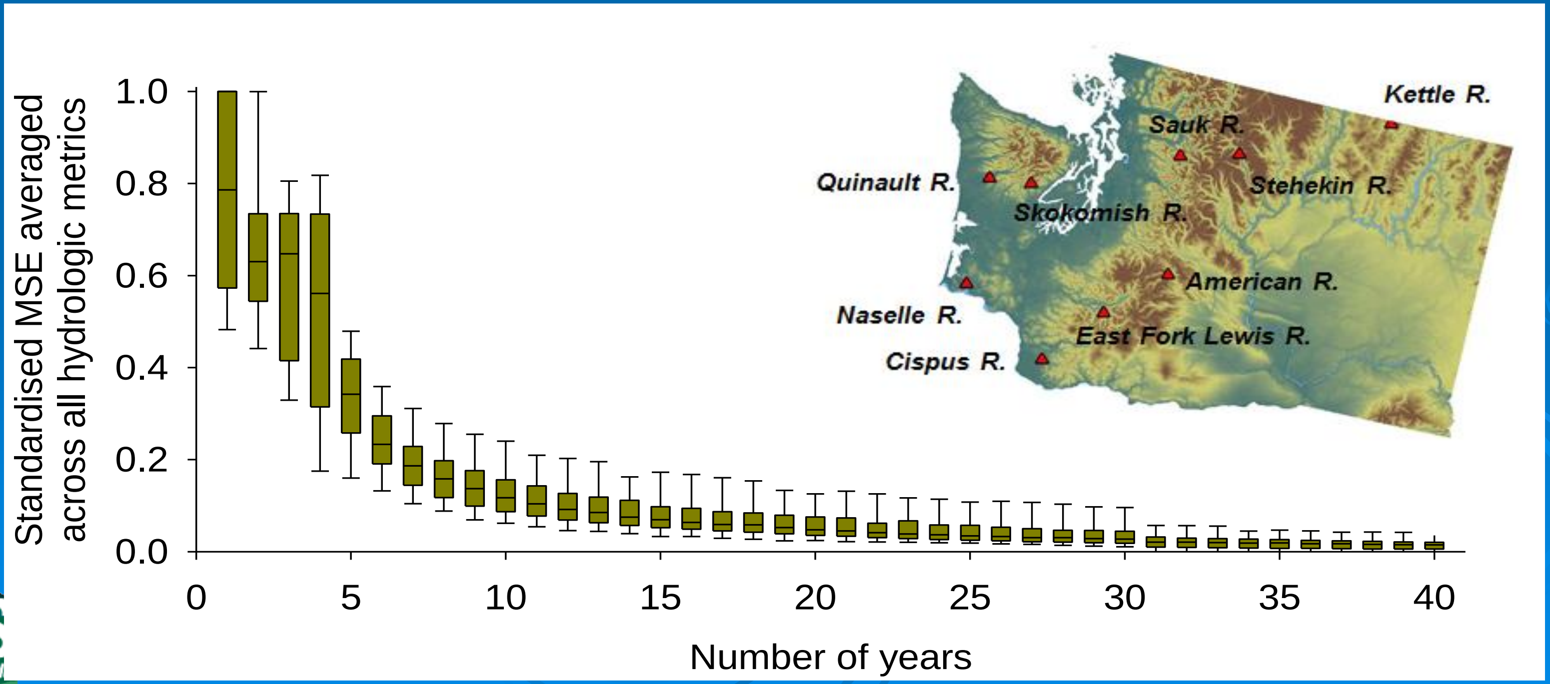


Site 2422500, Mulberry Creek at Jones, AL – 204 sq-mi

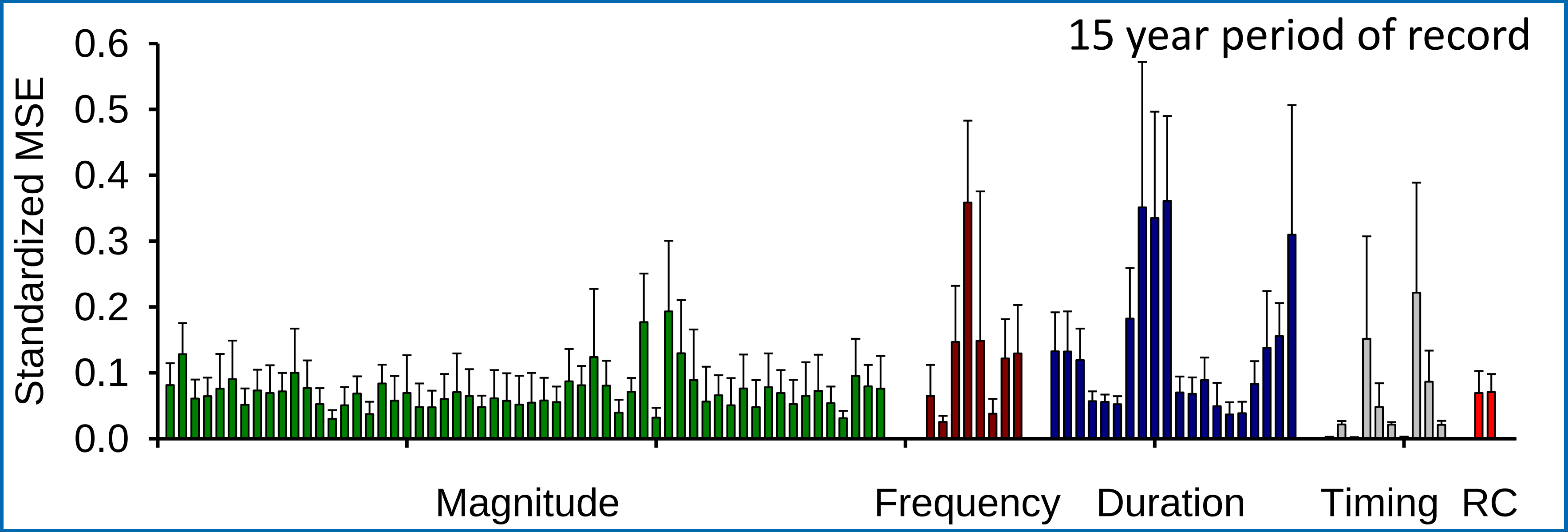
There is Uncertainty Associated with Flow Metric Estimation

Uncertainly in metric estimation is a function of:

- Length of flow record
- Period of flow record
- Number of years of overlap (temporal similarity)



Uncertainty in Flow Metric Estimation



General recommendations (from Kennard et al., 2010, River Res. Appl.)

- Metric estimation must be based on at least 15 years of discharge data
- Metric estimation should be based on overlapping discharge records contained within a discrete temporal window (ideally >50%)
- Metric uncertainty varies greatly and should be accounted for when developing flow-ecology relations.

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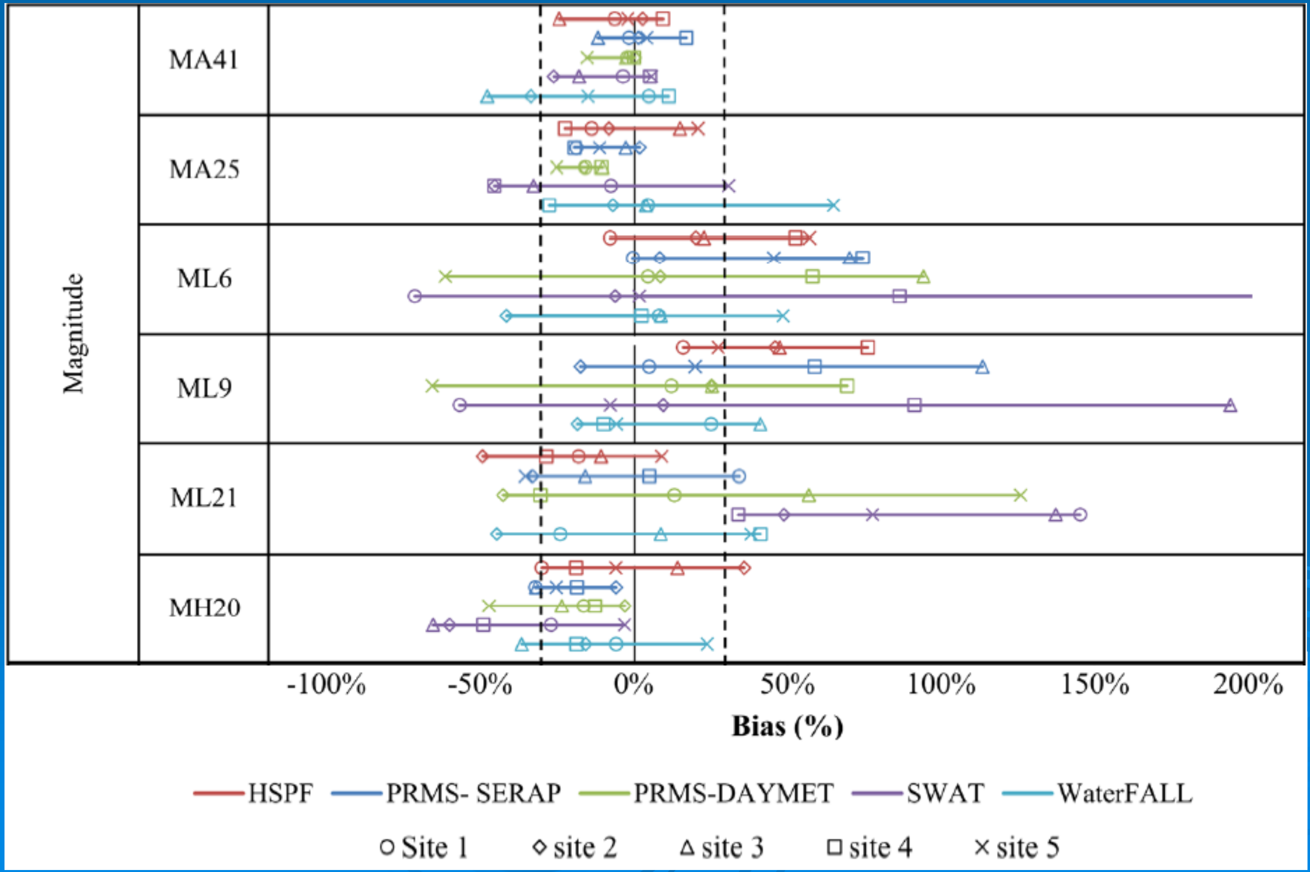
Uncertainty in EFlow Metric Estimation

- The WC, in collaboration with the SECSC, wanted to understand the uncertainty associated with hydrologic metric estimation so we compared the output from five process models at a subset of stream locations in the SE US.



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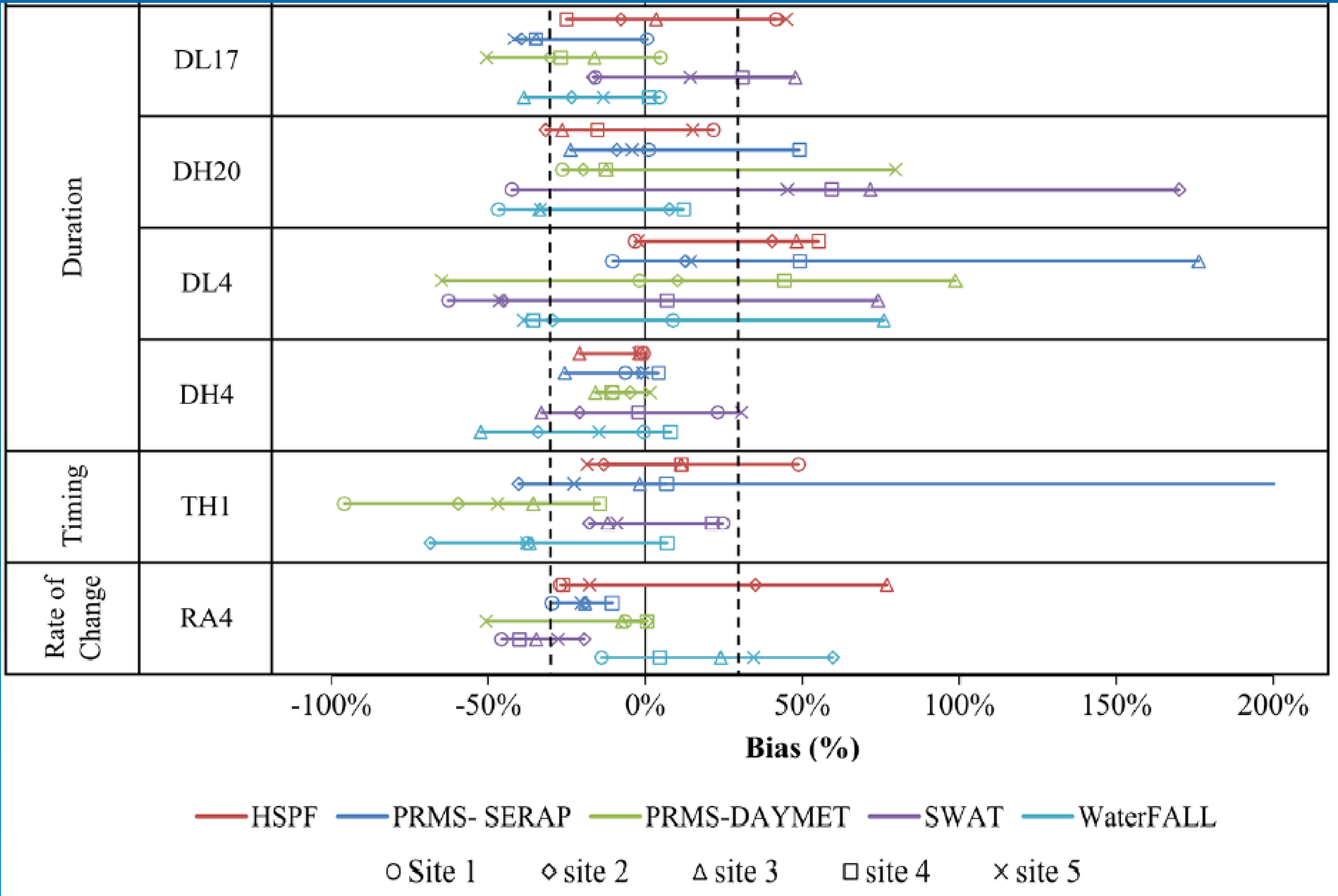
Uncertainty in EFlow Metric Estimation

- Model uncertainty (Bias) varied by model, but was consistently higher for high-and low-flow metrics



Summary – Uncertainty in EFlow Metrics

- Uncertainty in the prediction of the Eflow metrics among models varied by site and by flow.
- All models had at least one flow statistic falling outside the 30% range of hydrologic uncertainty at every site.
- Uncertainty was greater for many of the low flow statistics due to the low absolute magnitudes.
- Generally had lower uncertainty in the prediction of flow statistics representing mean flows.

Understanding the Effects of Uncertainty in Ecological Response

- Recent studies have demonstrated that ecological responses to flow variation and alteration can be inferred based on the biological attributes of species (e.g., resource and habitat utilization, species richness, abundance, O/E, life history traits etc.)
- However, the approaches used to rectify taxonomic information across disparate data sources can increase the uncertainty and potentially obscure flow-ecology relations, especially for basin or regional assessments.

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Uncertainty in Ecological Response

Basin, Regional & National studies require aggregating data from a large number of sites dispersed over a large areas and often over a long time period.

Consequently, most regional studies will require combining data from multiple sources:

- States
- Provinces
- Federal agencies
- Non-governmental agencies
- Other

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The Ideal ☺

- Data collected by one agency.
- Data collected using consistent methods and crews.
- Data processed using consistent methods.
  - Consistent subsampling method
  - Consistent set of major groups identified
  - Common level of taxonomic resolution within major groups

The Reality ☹

- Data collected by multiple agencies.
- Samples collected using multiple methods.
- Samples processed using multiple methods.
- Major taxonomic groups collected differ among agencies.
- Level of taxonomic resolution varies by agency.
- Data from multiple agencies must be combined for analysis.

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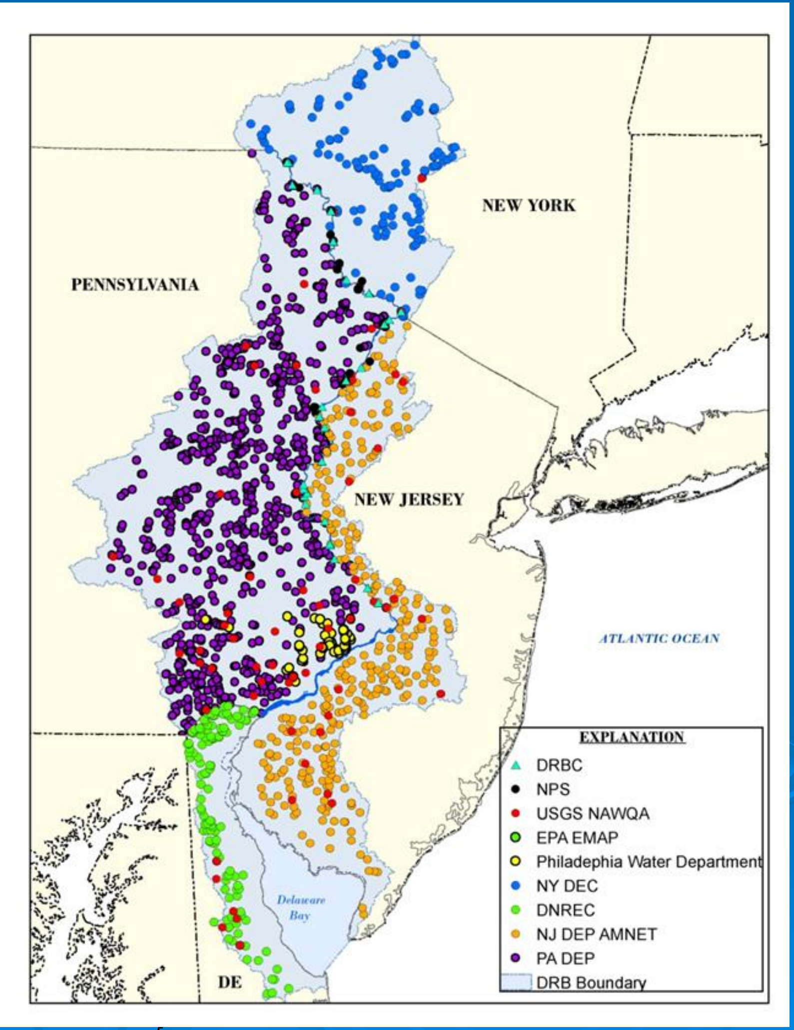
Prior Work

- Data from different sources require modification before they can be combined:
  - Harmonization of taxonomy
  - Comparability of subsample sizes
- Failure to modify data from different sources can lead to incomparable assemblages and misleading results, especially for metrics based on Richness.



Effect of Uncertainty on Ecological Response

- How Do Differences In Fixed Count and Taxa Subsamples affect the Interpretation of Invertebrate Responses to environmental gradients –gradients such as altered streamflow, urbanization, land use disturbance, physiography, and climate that are known to affect the distribution and abundance of aquatic organisms?

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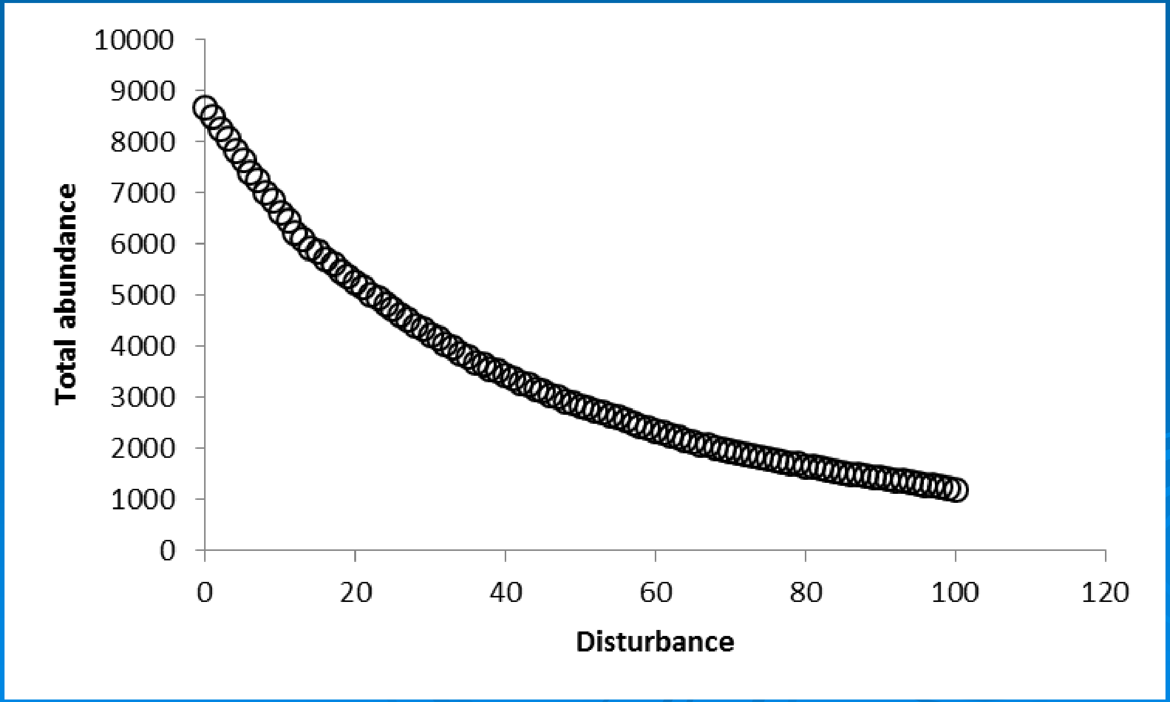
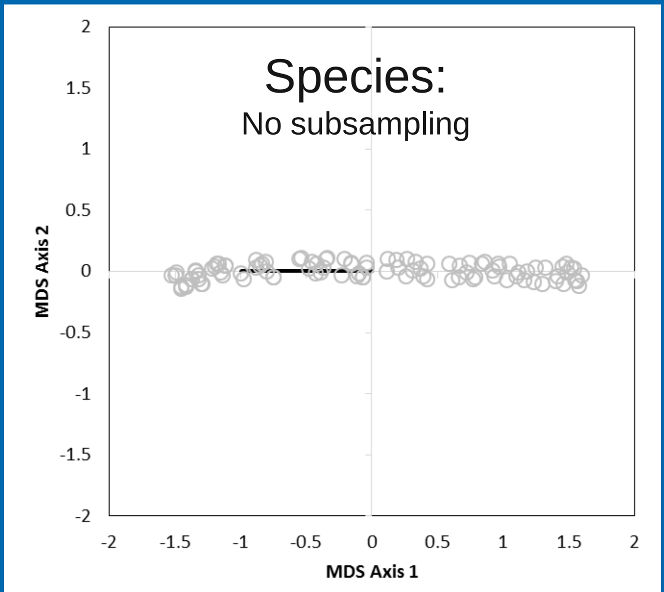
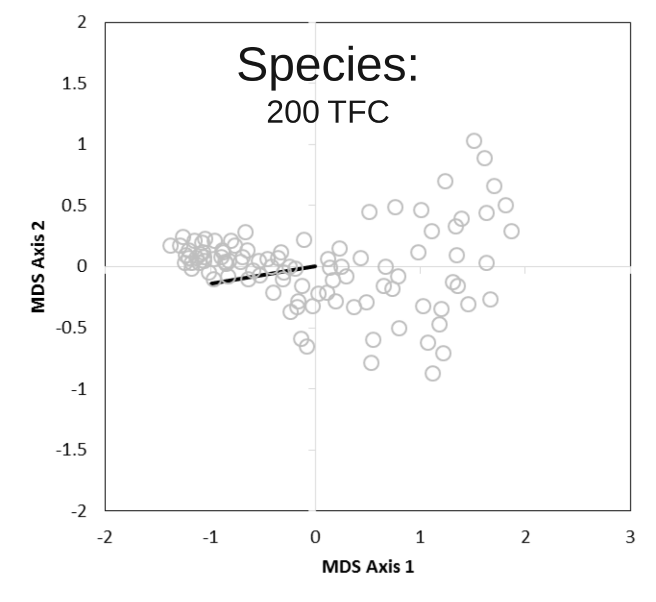
Developing a known response to disturbance

- Used Delaware River data to determine that these data respond to a disturbance.
- Want to see if we can reproduce this response curve using differing fixed count subsamples.

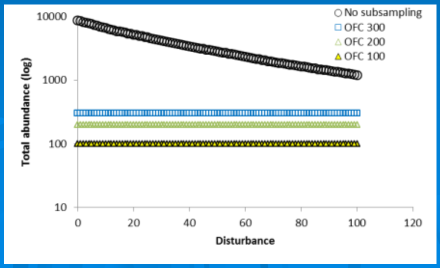


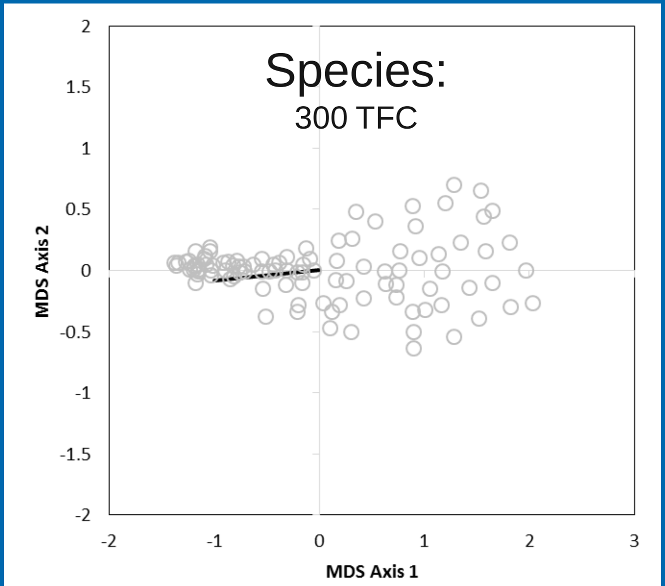
Affect of Fixed Count Subsampling: MDS

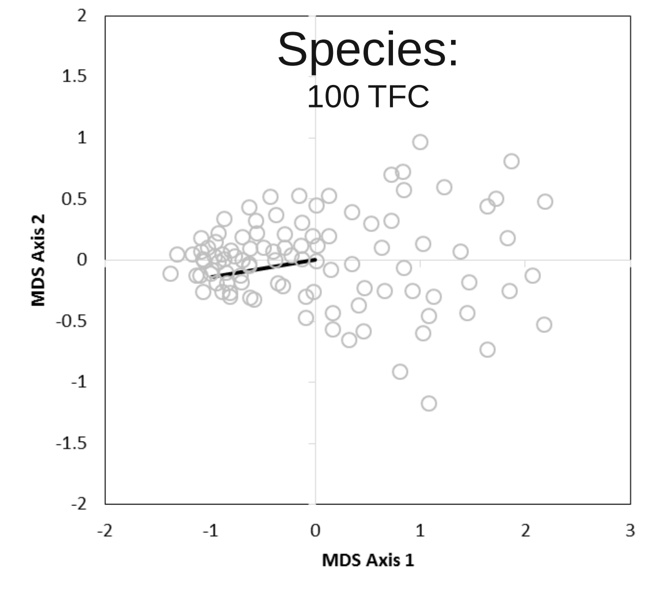




- No subsampling:
- 300 TFC
- 200 TFC
- 100 TFC
- Probability of misinterpretation increases as subsample size decreases.

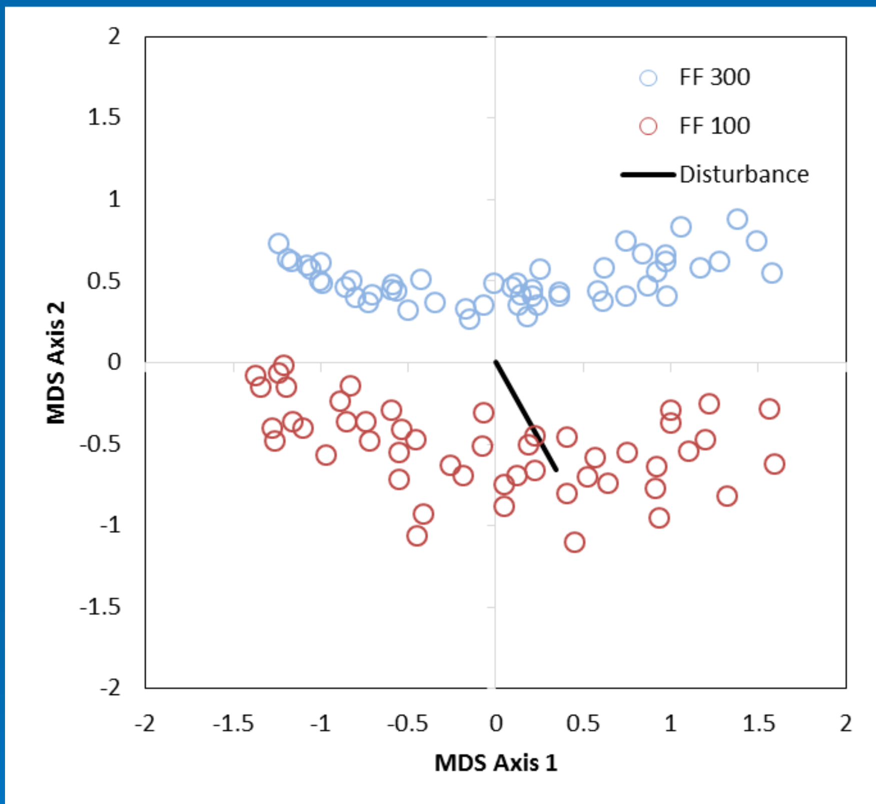




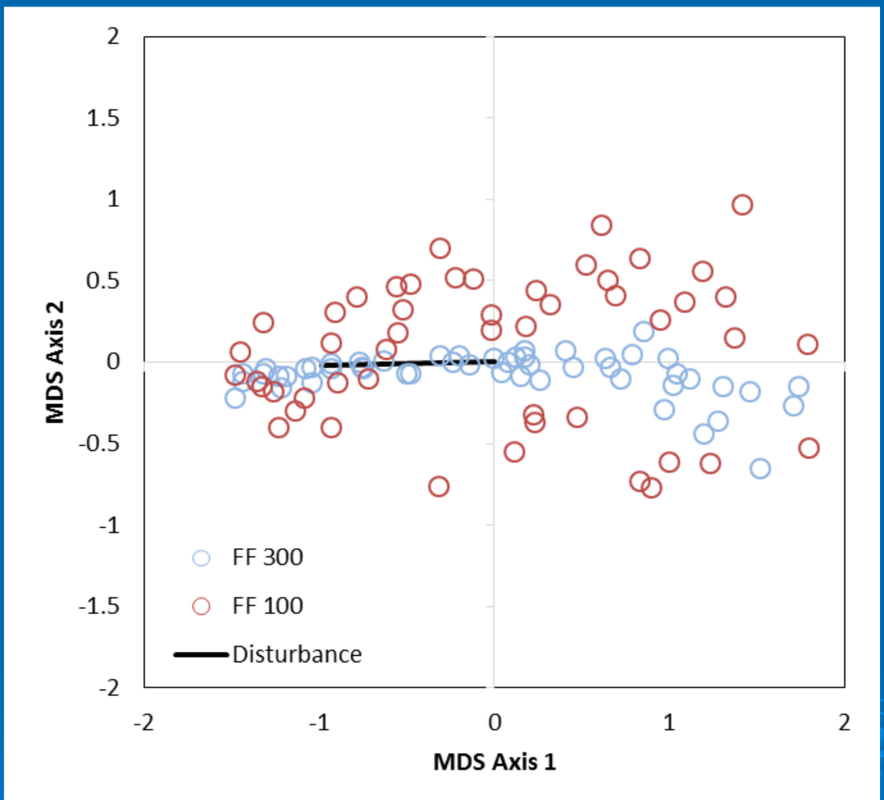


Mixed Fixed Count vs % Abundance

Abundance



% Abundance



- Mixed fixed count is not parallel to the axes (orthogonal)
- If you convert back to proportional abundance, you can still get a correct interpretation of the disturbance gradient.

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Preliminary Findings

- Minimizing Fixed Count subsamples can obscure responses (i.e., increase uncertainty).

- However, using percent abundance can reduce uncertainty and reduce our inability to detect a response along a disturbance gradient.

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The WC End Game Regarding Hydrologic Uncertainty? The so What.

- To quantify or estimate the uncertainty associated with Water Census information products.
- To address uncertainty in water data by improving spatial and temporal coverage for key hydrologic variables.
- To improve estimation techniques through advanced incorporation of key data layers into statistical and physical models.
- To provide quantitative / qualitative guidance about hydrologic and ecological data and model uncertainties to better support information-product user needs.

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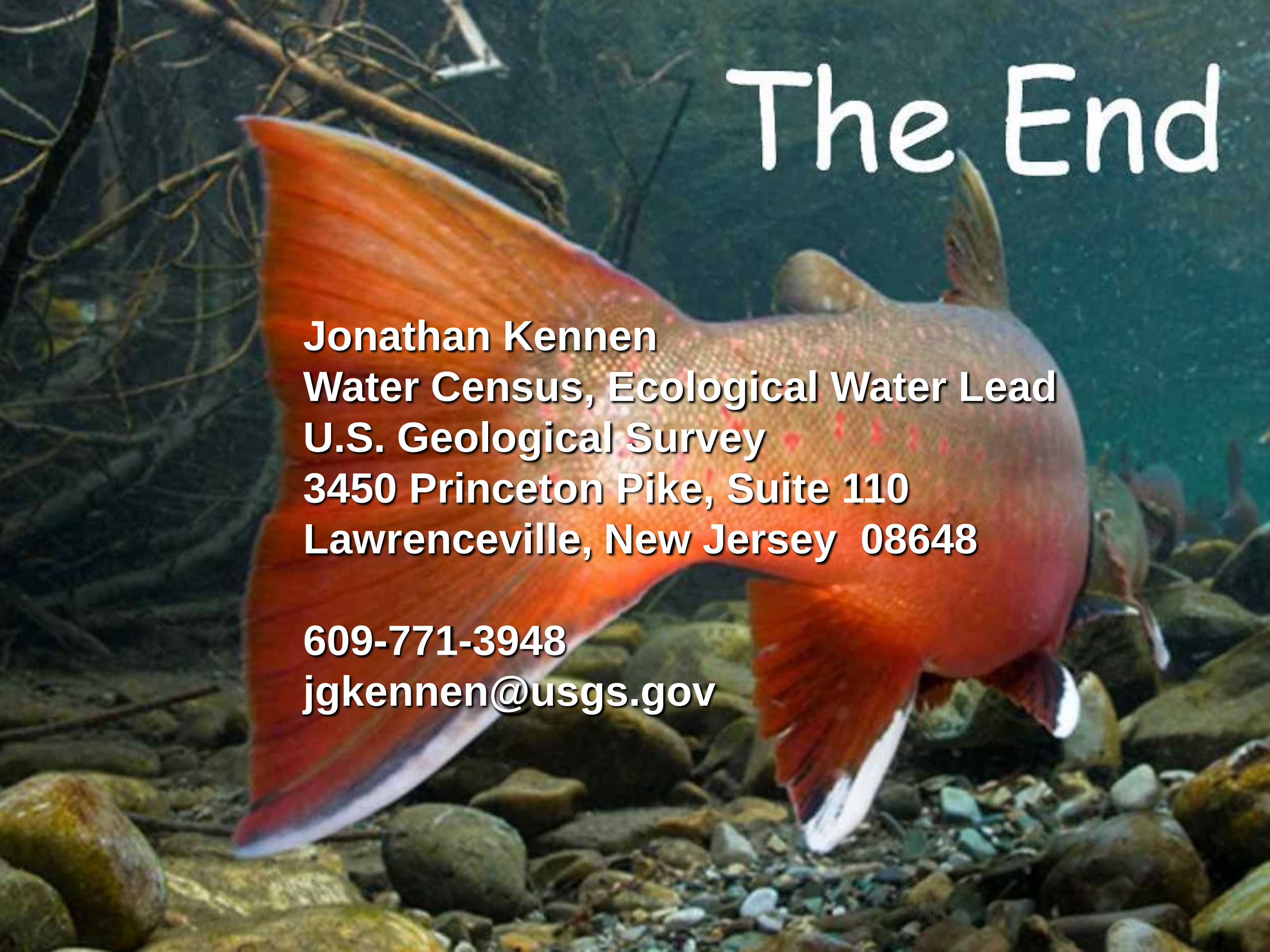

The End

Jonathan Kennen
Water Census, Ecological Water Lead
U.S. Geological Survey
3450 Princeton Pike, Suite 110
Lawrenceville, New Jersey 08648

609-771-3948
jgkennen@usgs.gov