Predicting the Consequences of Restoration Activities in Rivers and Estuaries

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Center for Ecohydraulics Research
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Delta Science Program
August 31, 2011

University of Idaho
College of Engineering

CENTER FOR ECOHYDRAULICS RESEARCH

Outline

1. Background
2. Data Challenges
3. The Role of Appropriate Analyses
4. Operations Flexibility Studies
5. Conclusions

Experimental Program to Stimulate Competitive Research

EPSCoR is not about playing ‘catch-up’ –
but about forging niche areas

EPSCoR is about building ‘community’.

- research community
- integrating research and education
- face of the US workforce reflects the face of America

EPSCoR is about transformative research - exploring high-risk concepts and establishing test-beds

Current Idaho theme: Water Resources in a Changing Climate

National Science Foundation WHERE DISCOVERIES BEGIN | Boise State University | Idaho State University | University of Idaho

Louisiana Coastal Area Science Board

Dr. G. Ronnie Best
Greater Everglades Science Program
US Geological Survey

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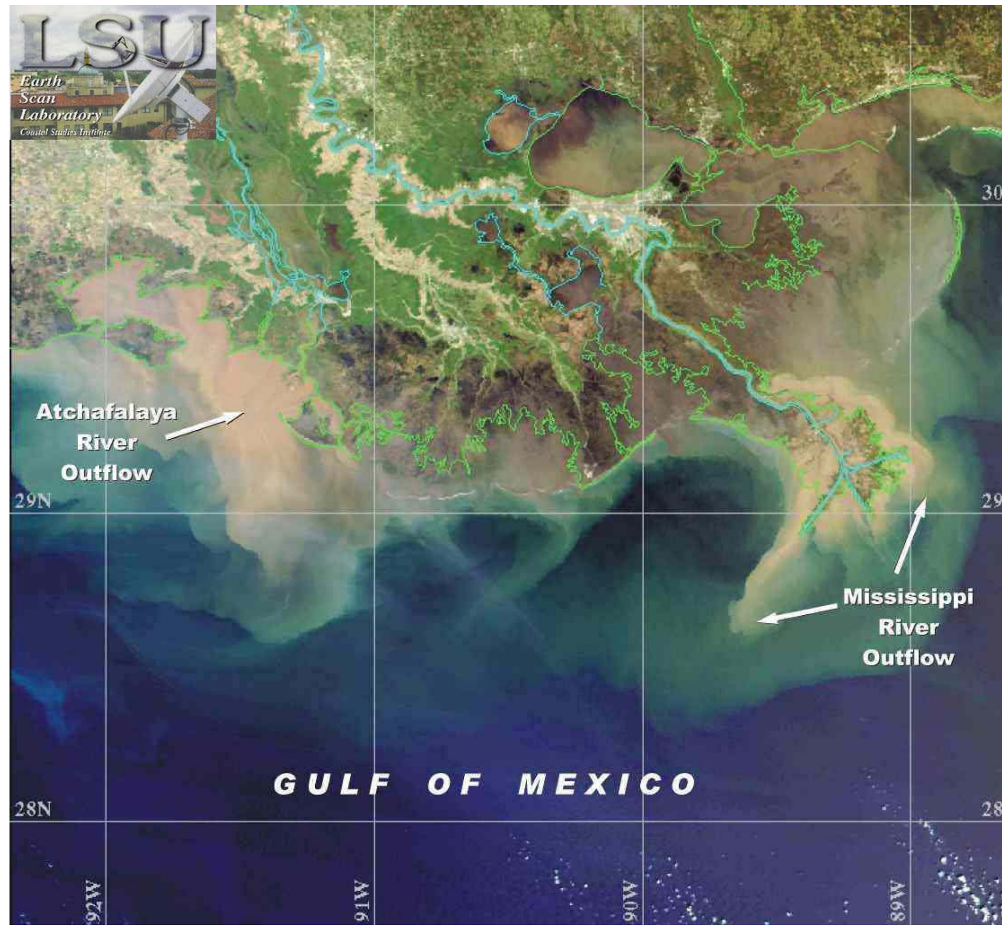

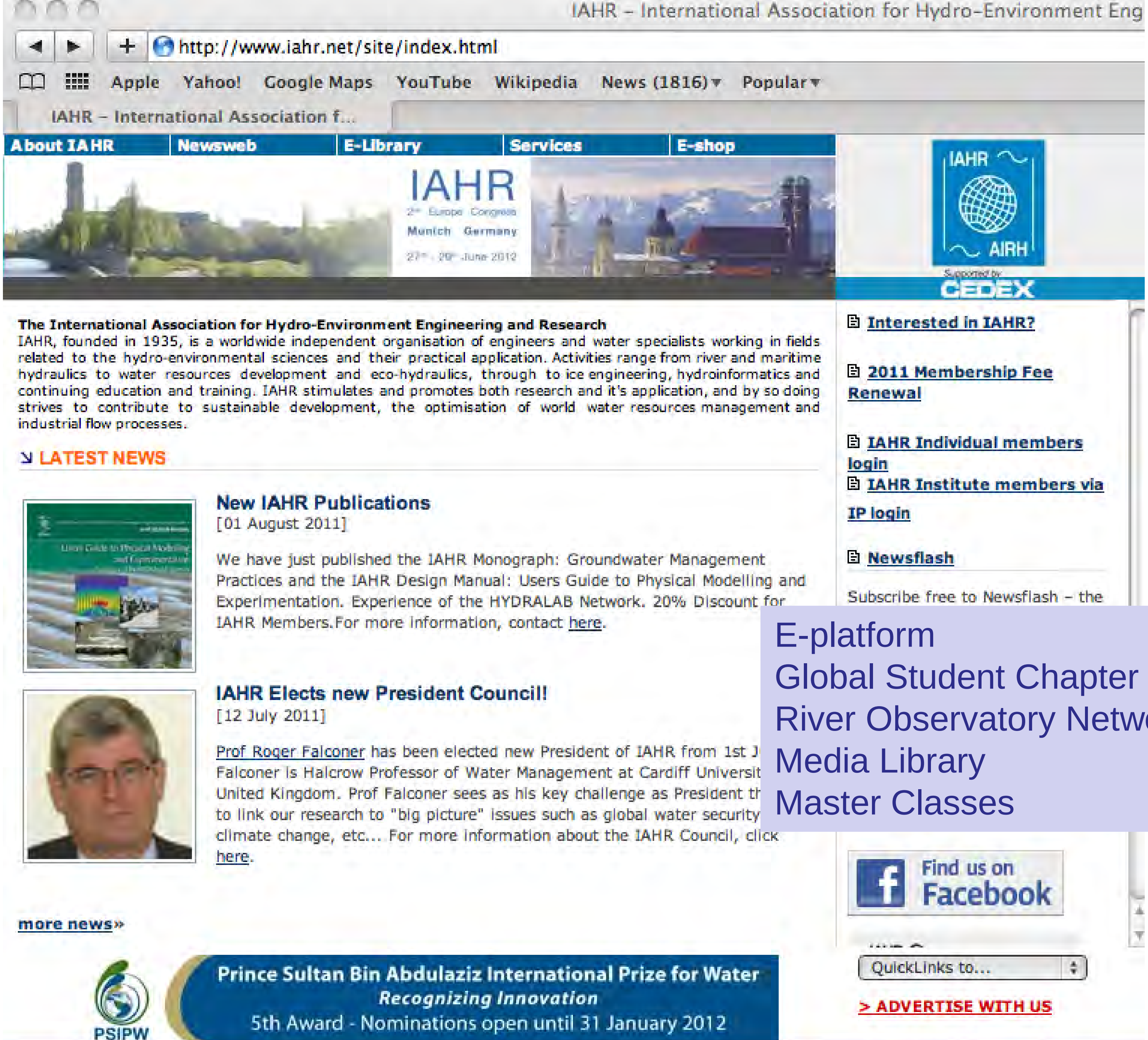

IAHR – International Association for Hydro-Environment Eng

http://www.iahr.net/site/index.html

Apple Yahoo! Google Maps YouTube Wikipedia News (1816) Popular

IAHR – International Association f...

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IAHR 2nd Europe Congress Munich Germany 27th - 29th June 2012

IAHR AIRH Supported by CEDEX

The International Association for Hydro-Environment Engineering and Research
IAHR, founded in 1935, is a worldwide independent organisation of engineers and water specialists working in fields related to the hydro-environmental sciences and their practical application. Activities range from river and maritime hydraulics to water resources development and eco-hydraulics, through to ice engineering, hydroinformatics and continuing education and training. IAHR stimulates and promotes both research and it's application, and by so doing strives to contribute to sustainable development, the optimisation of world water resources management and industrial flow processes.

LATEST NEWS

New IAHR Publications
[01 August 2011]

We have just published the IAHR Monograph: Groundwater Management Practices and the IAHR Design Manual: Users Guide to Physical Modelling and Experimentation. Experience of the HYDRALAB Network. 20% Discount for IAHR Members.For more information, contact here.

IAHR Elects new President Council!
[12 July 2011]

Prof Roger Falconer has been elected new President of IAHR from 1st J... Falconer is Halcrow Professor of Water Management at Cardiff Universit... United Kingdom. Prof Falconer sees as his key challenge as President th... to link our research to "big picture" issues such as global water security... climate change, etc... For more information about the IAHR Council, click here.

more news»

Prince Sultan Bin Abdulaziz International Prize for Water
Recognizing Innovation
5th Award - Nominations open until 31 January 2012

PSIPW

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2011 Membership Fee Renewal

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AHORA ¡NUNCA!
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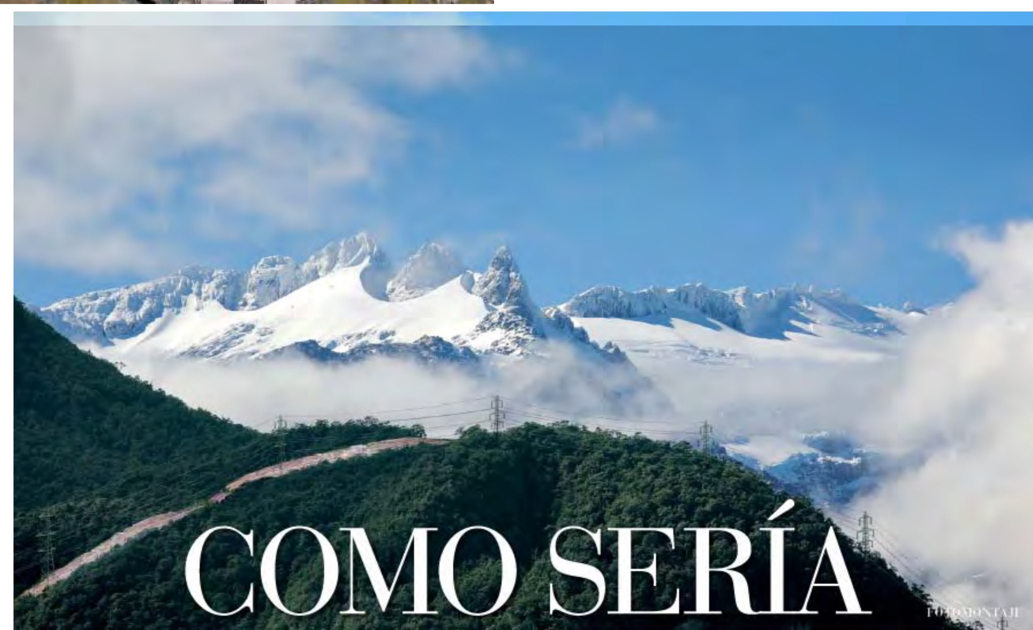
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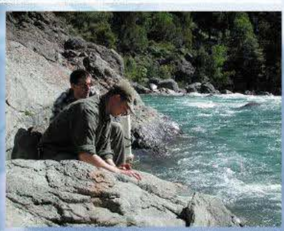

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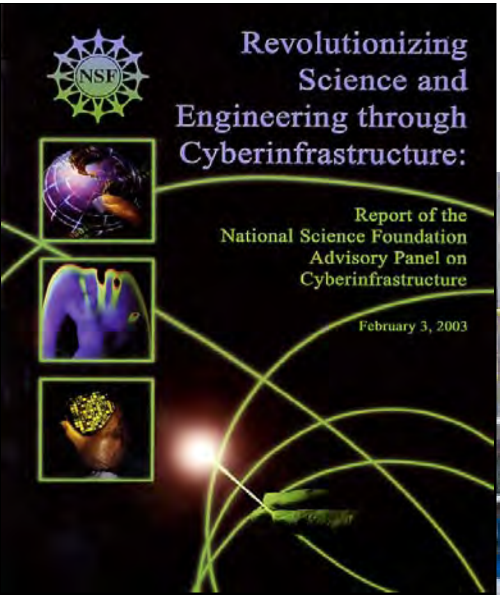
The Concept of Cyberinfrastructure (Atkins Report, 2003)

Infrastructure that enables <u>distributed, real-time collaboration requiring large-scale, dynamic information</u>

Examples of components to be integrated:

- Unique experimental facilities
- Networks of real-time and offline data collection devices
- Major computational processing capabilities
- High-speed networks
- Tele-participation and tele-operation tools
- Data/metadata storage and curation
- Computational models and model components
- Data analysis and information extraction tools
- Digital assets management



"*Cyberinfrastructure Is Ever-Increasing*."

Dr. Bement, April 2006

Trends in Community Science

Environmental Observatories

LTER

CLEANER
Collaborative Large-scale Engineering Analysis Network for Environmental Research

CUAHSI
universities allied for water research

neon

ORION
ocean research interactive observatory networks

EU Initiatives such as TWINBAS and TWINLATIN

Waters Network

Common features

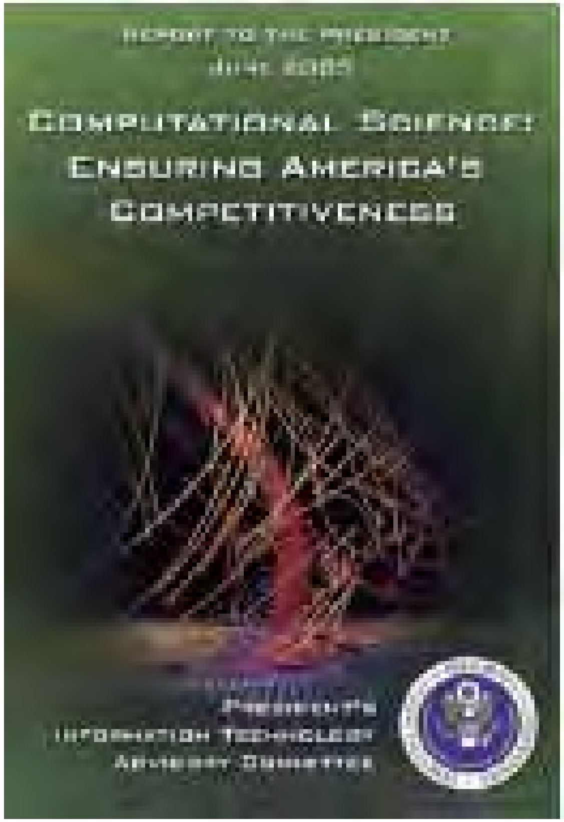
- Driven by scientific and engineering communities
- Cyber-infrastructure emphasis
- Grand Challenges
- Sensor and Sensor Networks
- Community databases
- Paradigm shift in simulation models
  Closure relations, data mining, data assimilation

Computational Science

Four centuries of constancy
Four decades with 10^{9-12} change

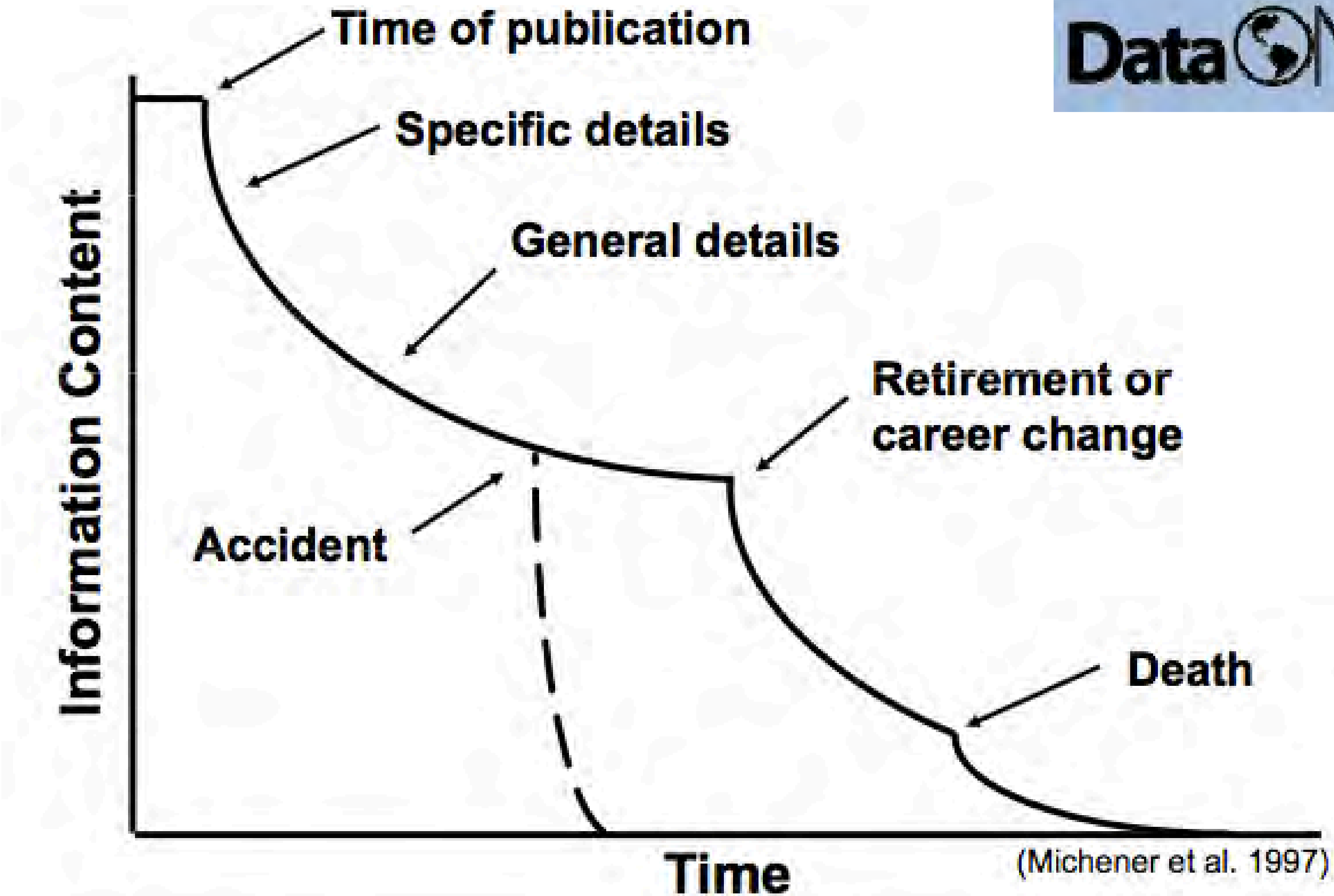
A. Blatecky, NSF. May 2011

✓ Science and scholarship are team sports
✓ The best team will marshal the best resources and capabilities - coalitions and virtual organizations
✓ More discoveries will arise from searches of new and legacy data from disparate sources

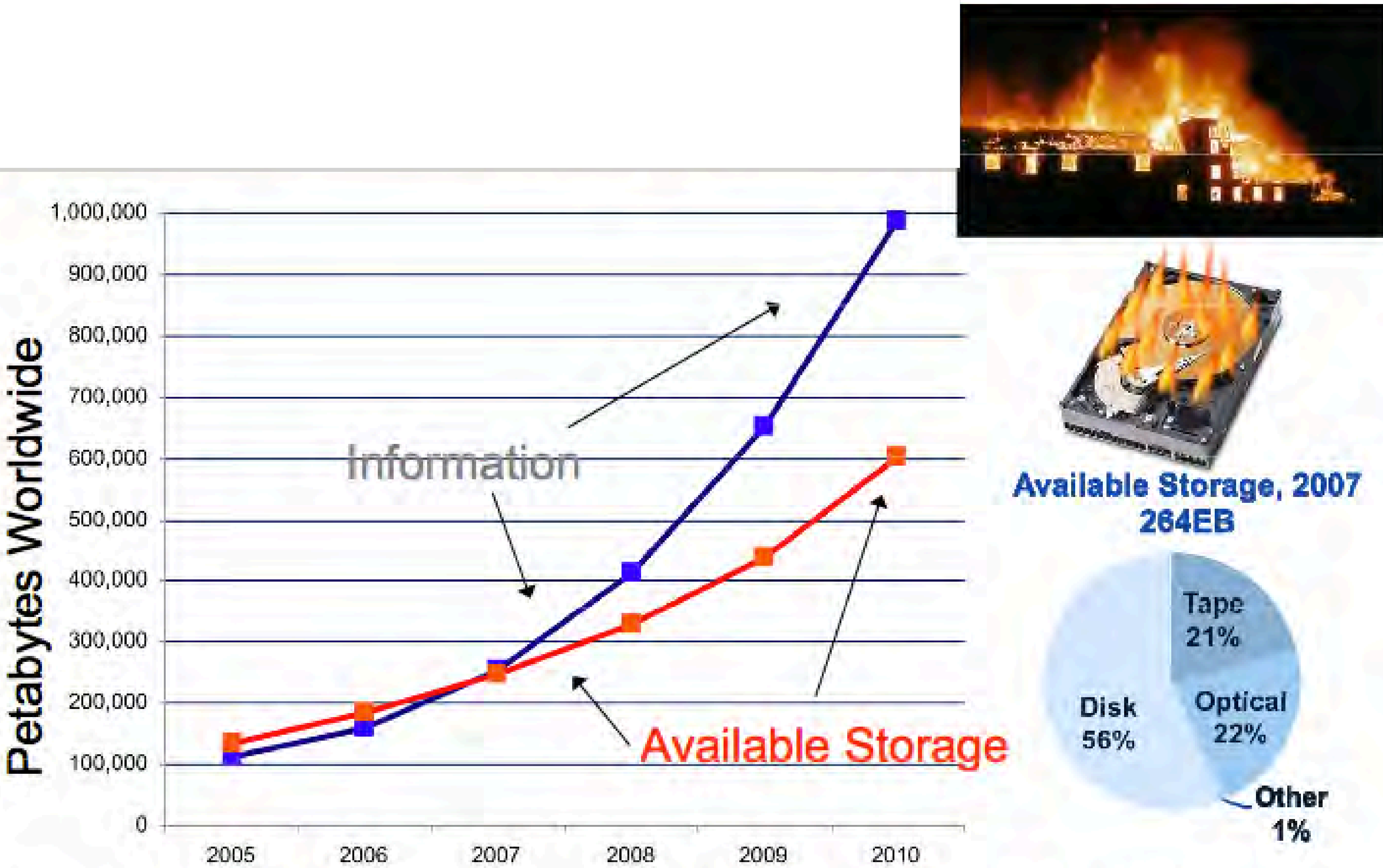


Universities [and agencies] must significantly change organizational structures: multidisciplinary & collaborative research are needed [for US] to remain competitive in global science

http://www.nsf.gov/od/oia/programs/epscor/pdpa_agenda.jsp



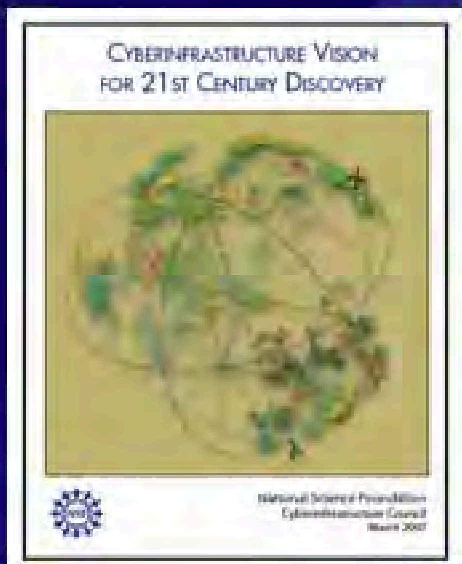
DataONE: A Virtual Data Center for the Biological , Ecological and Environmental Sciences. Michener, April 2010.
http://www.nevada.edu/epscor/nsf/tricyber2/tristate2010/tri-state-agenda.html



Source: John Gantz, IDC Corporation: The Expanding Digital Universe

What is Needed?

An ecosystem, not components...



NSF-wide CI Framework for 21st Century Science & Engineering

People, Sustainability, Innovation, Integration

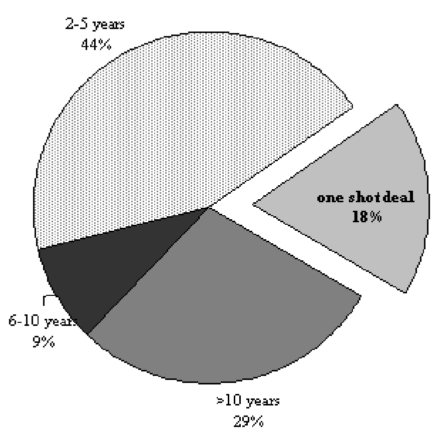
National River Restoration Science Synthesis

- Over 37,000 projects
- More than $1bn per year in 2004
- Fewer than 10% of restoration projects are monitored or have performance assessment
- 20% had no listed goals
- Opportunities to learn are being lost and cumulative benefits/impacts unclear
- Implications for adaptive management?

Further details at http://nrrss.nbii.gov/

NRRSS: Northwest Node

- Over 23,000 projects @ 35,000 locations
  [Steve Katz, NOAA]
- 70% reported successful
- 43% no quantitative success criteria
- 66% anticipate future maintenance
- 35% no maintenance funding

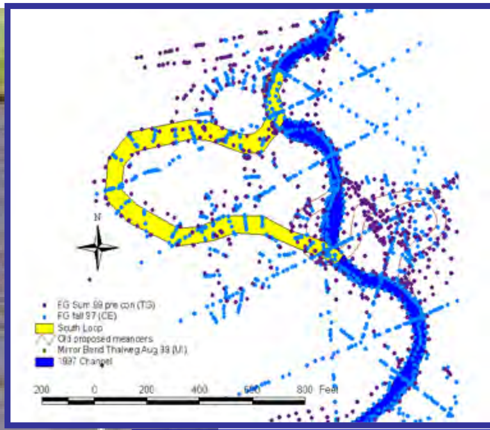


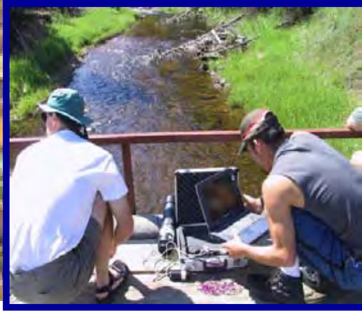
Jeanne Rumps [McFall]

Robin Jenkins

Challenges in Performance Assessment Monitoring

Identifying linkages between physical processes, habitat changes, and biological responses





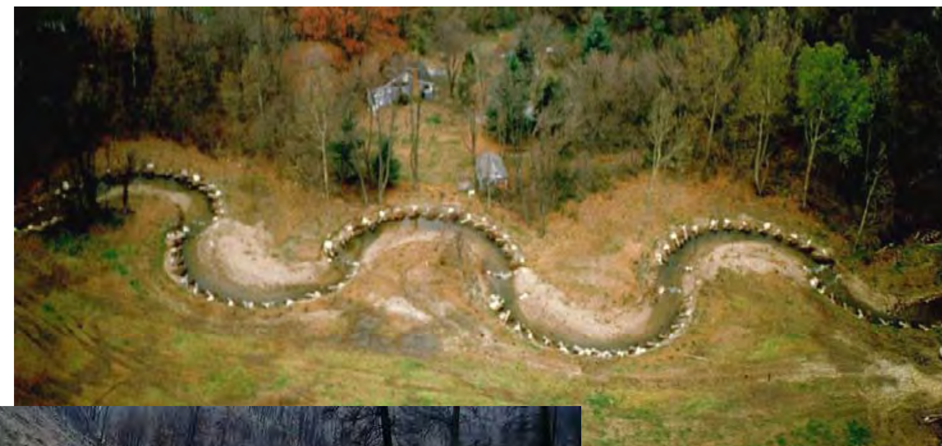
Challenges in Performance Assessment Monitoring

- Spatially-sparse, short-duration data sets
- Little or no pre-restoration data
- Detectable change from restoration is a small percentage of diurnal, seasonal, or inter-annual variability
- Effects occur at multiple spatial and temporal scales
- Individual restoration actions may have cumulative responses that are less predictable at the systems level
- Confounding effects of climate change

Restoration goal	Typical restoration activity	Individual physical responses			Cumulative responses	
		Shear stress	Particle size	Thermal gain	Physical	Biological
"Restore channel geometry"	Reduce w/d	+	+	-	?	?
"Restore channel slope and sinuosity"	Increase length	-	-	+		

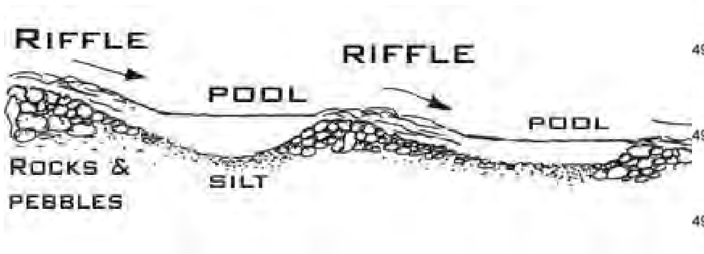
Fundamental Question

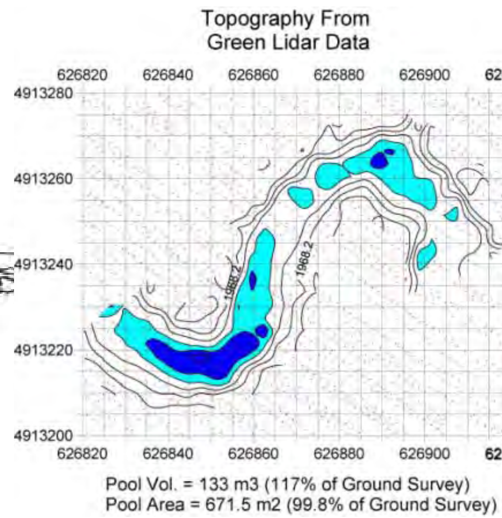
Why do the pools in some systems persist despite major perturbations, while in other rivers a relatively small change in watershed characteristics result in the permanent loss of pool-riffle habitat?



A Possible Mechanism for Pool Sustainability

- Keller (1971) proposed the velocity reversal hypothesis as the mechanism responsible for pool-riffle sustainability

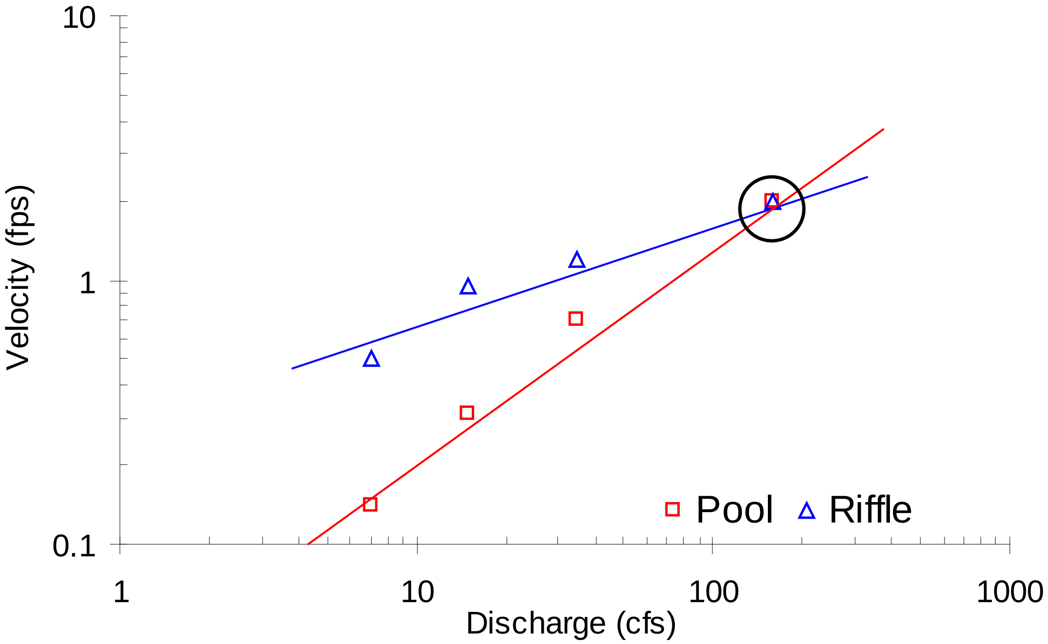




- Caamaño et al. (2009) used analytical methods to build on the velocity reversal hypothesis:
  - A simple 1-dimensional criteria to predict the occurrence of velocity reversal
  - 3-dimensional analysis of 1-d criteria

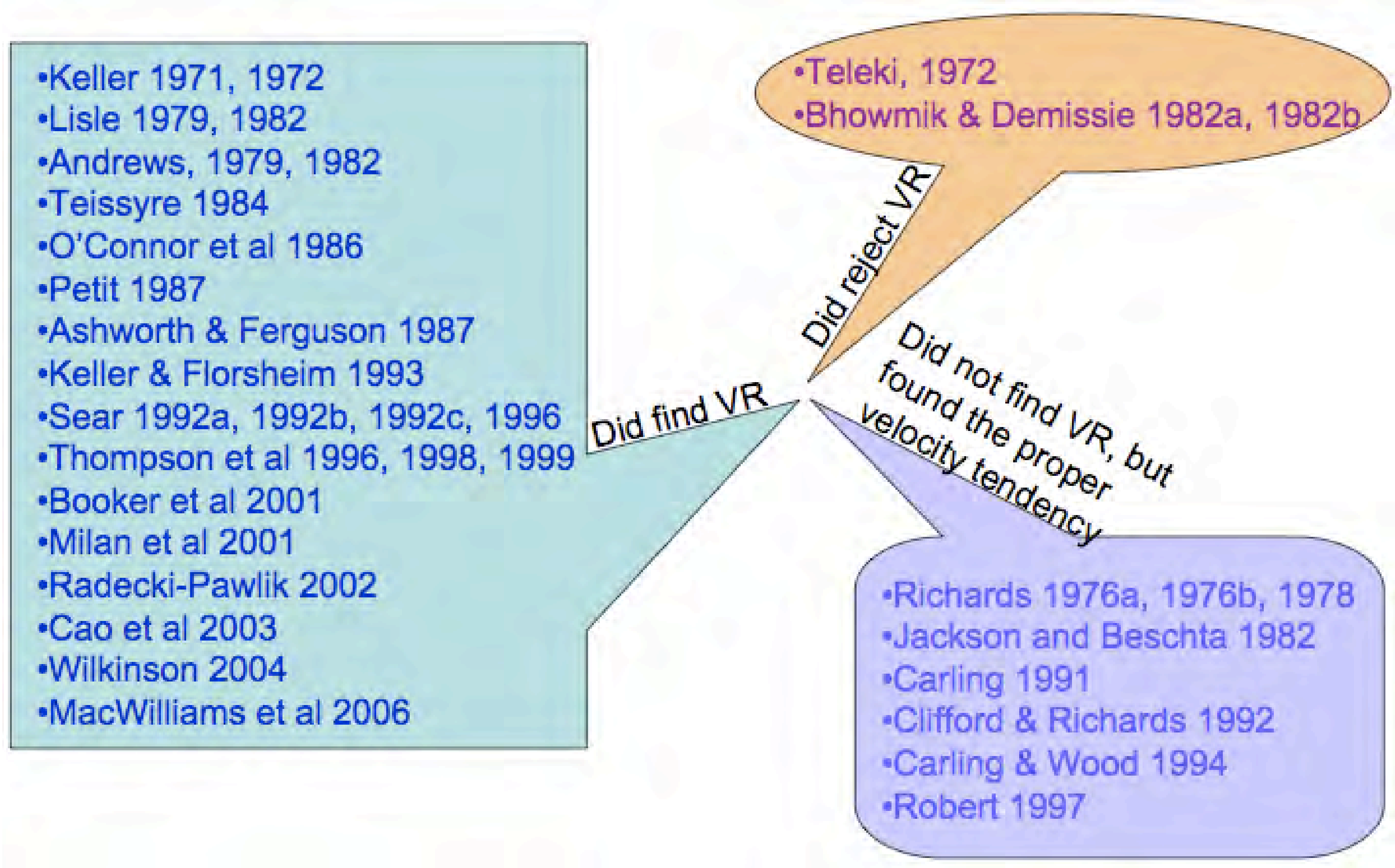
A Possible Mechanism for Pool Sustainability

Velocity Reversal Hypothesis for Pool-Riffle Sequences [Keller; Keller and Florsheim]



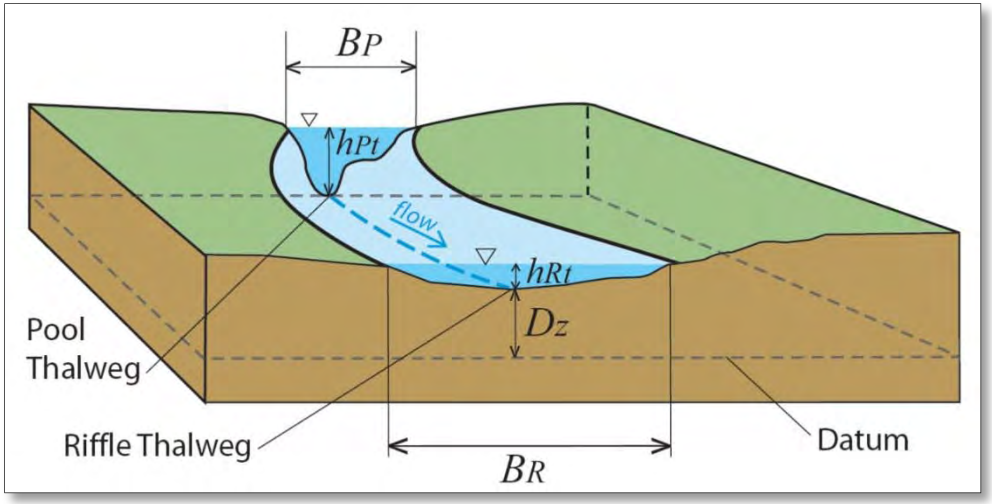
Data from Keller (1971)

Findings differ:



Theoretical Background

$$\frac{B_R}{B_P} - 1 = \frac{D_z}{h_{Rt}}$$

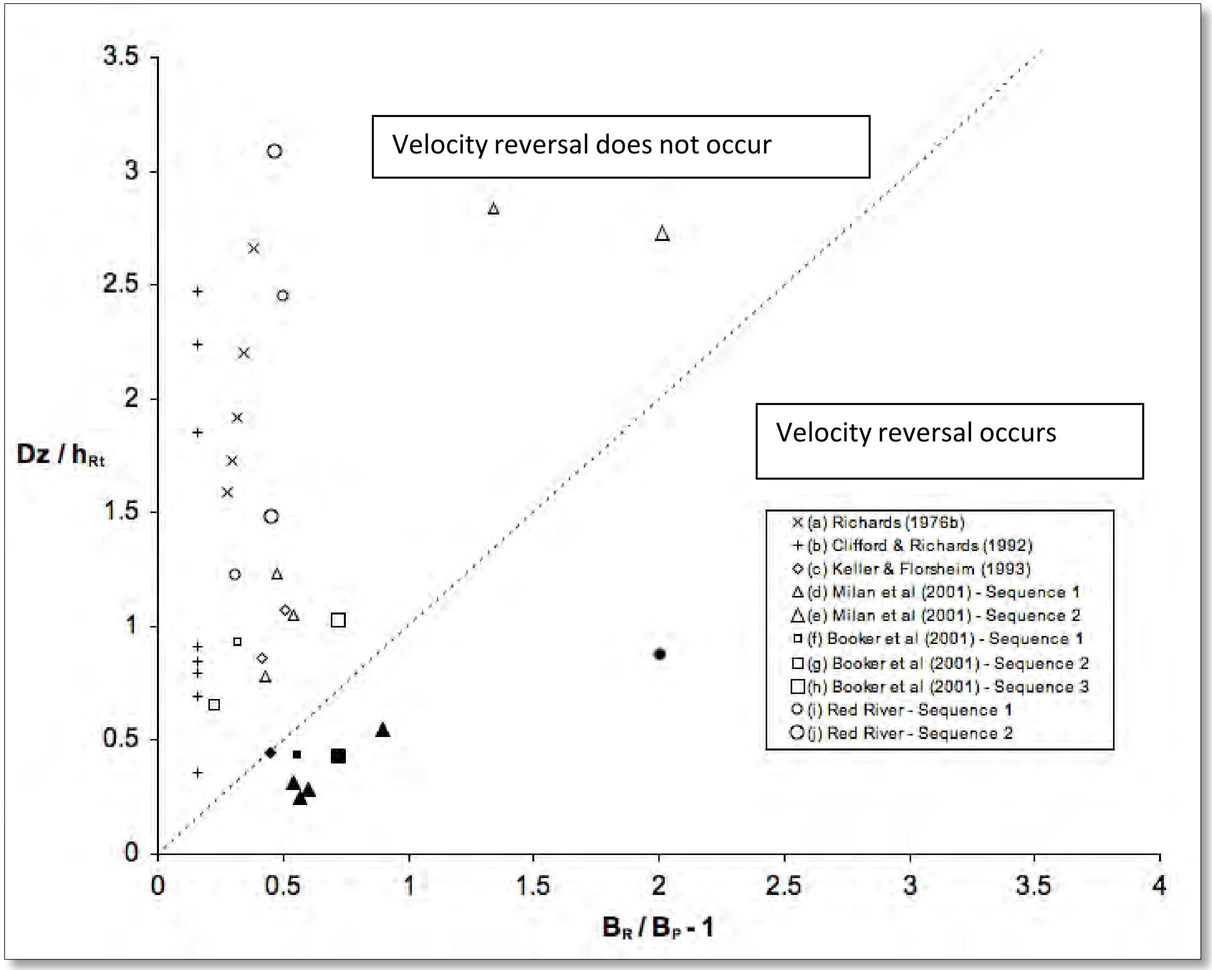


Where:

z_{Pt}, z_{Rt}	=	pool and riffle thalweg elevations
h_{Pt}, h_{Rt}	=	pool and riffle thalweg water depths
B_P, B_R	=	pool and riffle water surface widths
D_z	=	residual pool depth defined as the difference between
$(z_{Rt} - z_{Pt})$	=	the pool and riffle thalweg elevations

Caamaño, D*., Goodwin, P., Buffington, J.M., Liou, J.C., Daley-Laursen, S., 2009. A unifying criterion for velocity reversal hypothesis in gravel-bed rivers. Journal of Hydraulic Engineering. ASCE. 135(1). 66-70.

Velocity Reversal Condition



Velocity Reversal Occurs:

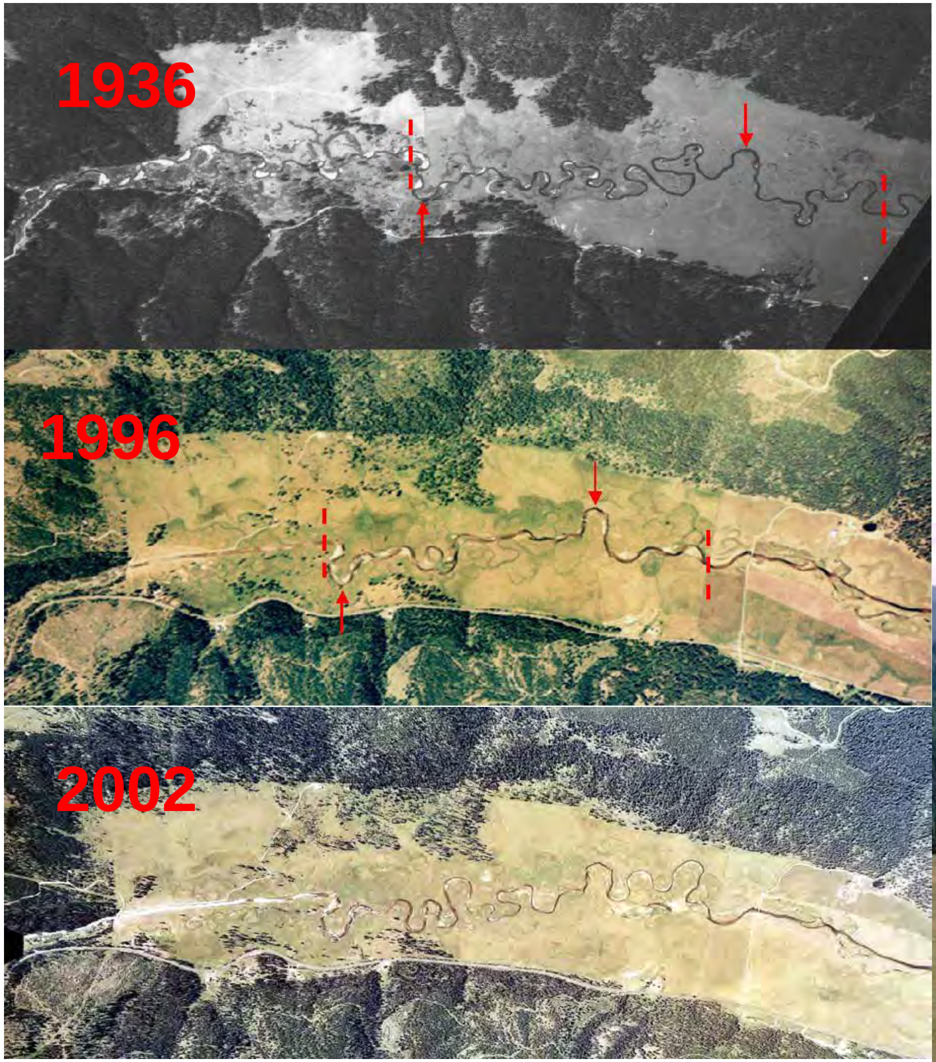
$$\frac{B_R}{B_P} - 1 > \frac{D_z}{h_{Rt}}$$

Velocity Reversal Does NOT Occur:

$$\frac{B_R}{B_P} - 1 < \frac{D_z}{h_{Rt}}$$

Red River Wildlife Management Area

Red River Wildlife Management Area



- Rare and valuable habitat
- Impacted by hydraulic mining (straightened, incised), grazing, wildfire
- Restoration completed in 2001
- 10 years of post-restoration monitoring
- 4 phases of restoration, 6 different restoration designs

Summary of 2010 Field Survey

- No forced pools disappeared and none had velocity reversal (VR) – 17%
- All unforced pools that met VR criteria persisted - 38%
- All unforced pools without VR disappeared – 17%
- New unforced pools - self-formed with VR criteria satisfied – 11%

- Unforced pools were self-formed where VR criteria not met – 17%

  Other processes at work – transient woody debris? Pool translation?

Caamaño, D.*, P. Goodwin and J. Buffington, 2010. Flow structure through pool-riffle sequences and a conceptual model for their sustainability in gravel-bed rivers. River Res. Applic. 26: 1–13

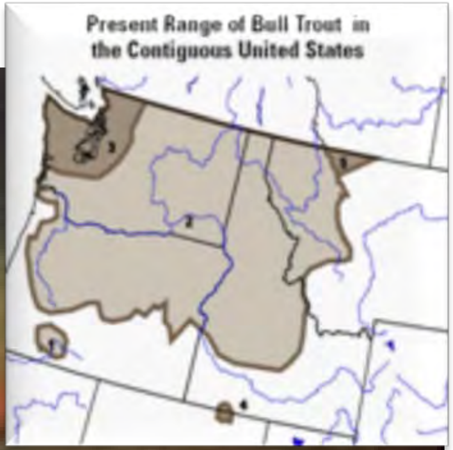
Parkinson, S*., D. Caamaño, P. Goodwin and R. Benjankar, 2011. Field Evaluation of Pool Sustainability in Gravel Bed Rivers. 34th IAHR World Congress. Balance and Uncertainty: Water in a Changing World. Brisbane, Australia, June 26-July 1, 2011. 3706.

Example: Is it possible that managing reservoirs to minimize downstream impacts [flows, temperature, habitat] can adversely impact upstream conditions?

- ✓ **Develop a real-time system for tracking bulltrout and their aquatic environment**
- ✓ **Link the fish tracking with detailed models of hydrodynamics, food web and bioenergetics**

System Approach to Ecosystem Management

Bull Trout – Columbia River Distinct Population Segment



- Threatened -1998

- Causes of decline:
  - habitat degradation
  - poor water quality
  - fragmentation
  - blockage of migration
  - past fishery management practices
  - nonnative species

Bull trout overview

- Resident form
    - complete entire life cycle in the tributary (or nearby) streams in which they spawn and rear

- Migratory forms
    - spawn in tributary streams where juvenile fish rear 1-4 years
    - migrate to a lake, river, or saltwater, where maturity is reached

- Lifecycle
    - Spawn Aug – Nov in declining water temperatures
    - Eggs incubate 3-5 months
    - Fry remain in substrate for weeks to months; emerge April - May
    - Rear 1-4 years in tributaries then migrate
    - Mature sexually at 4-7 years
    - Spawn annually or in alternate years
    - Live up to 12 years

Deadwood Study Team 2007 – 2012

U.S. Bureau of Reclamation

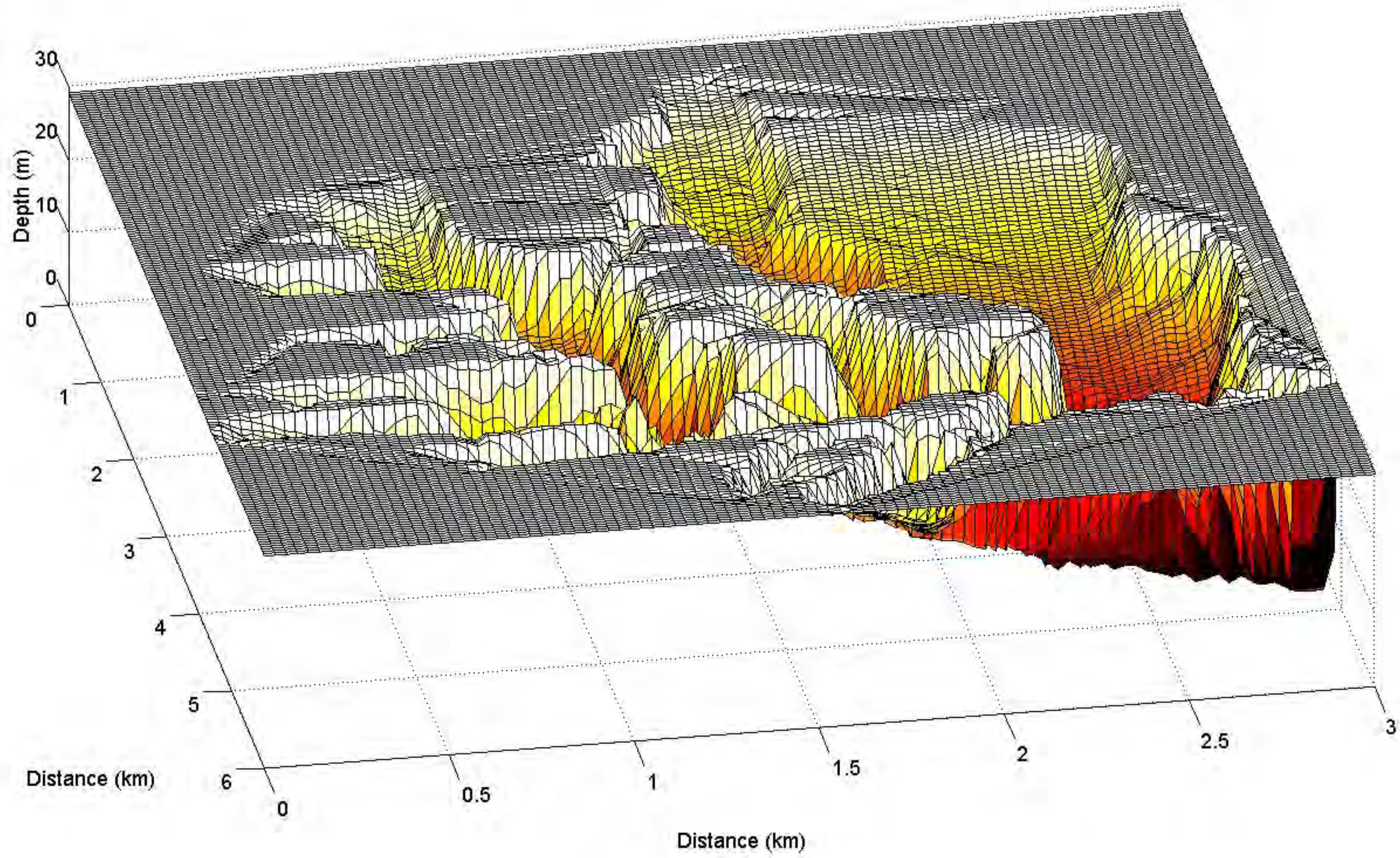
U.S. Forest Service – Rocky Mountain Research Station

University of Idaho – Center for Ecohydraulics Research

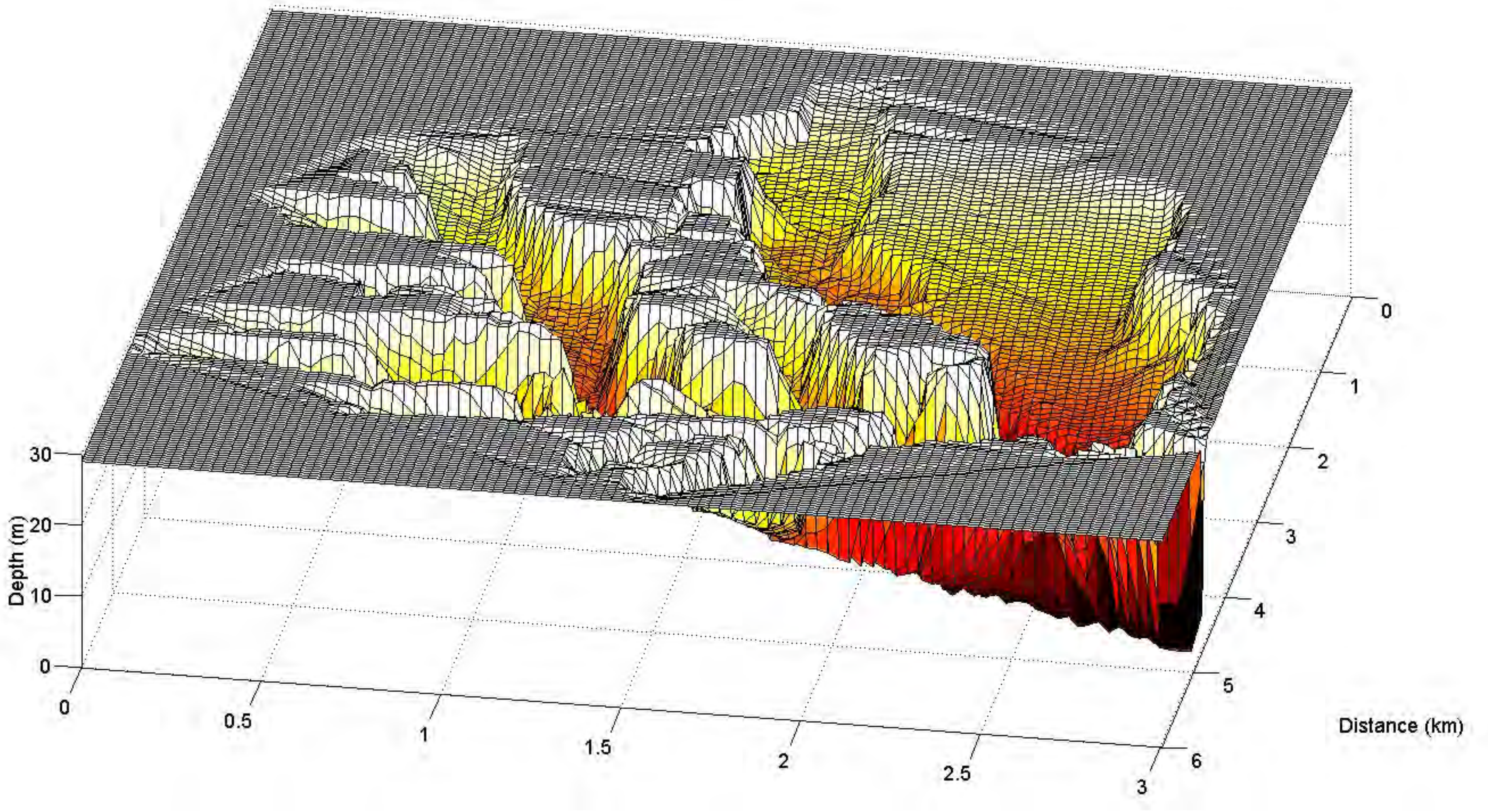
University of Western Australia – Centre for Water Research

USGS

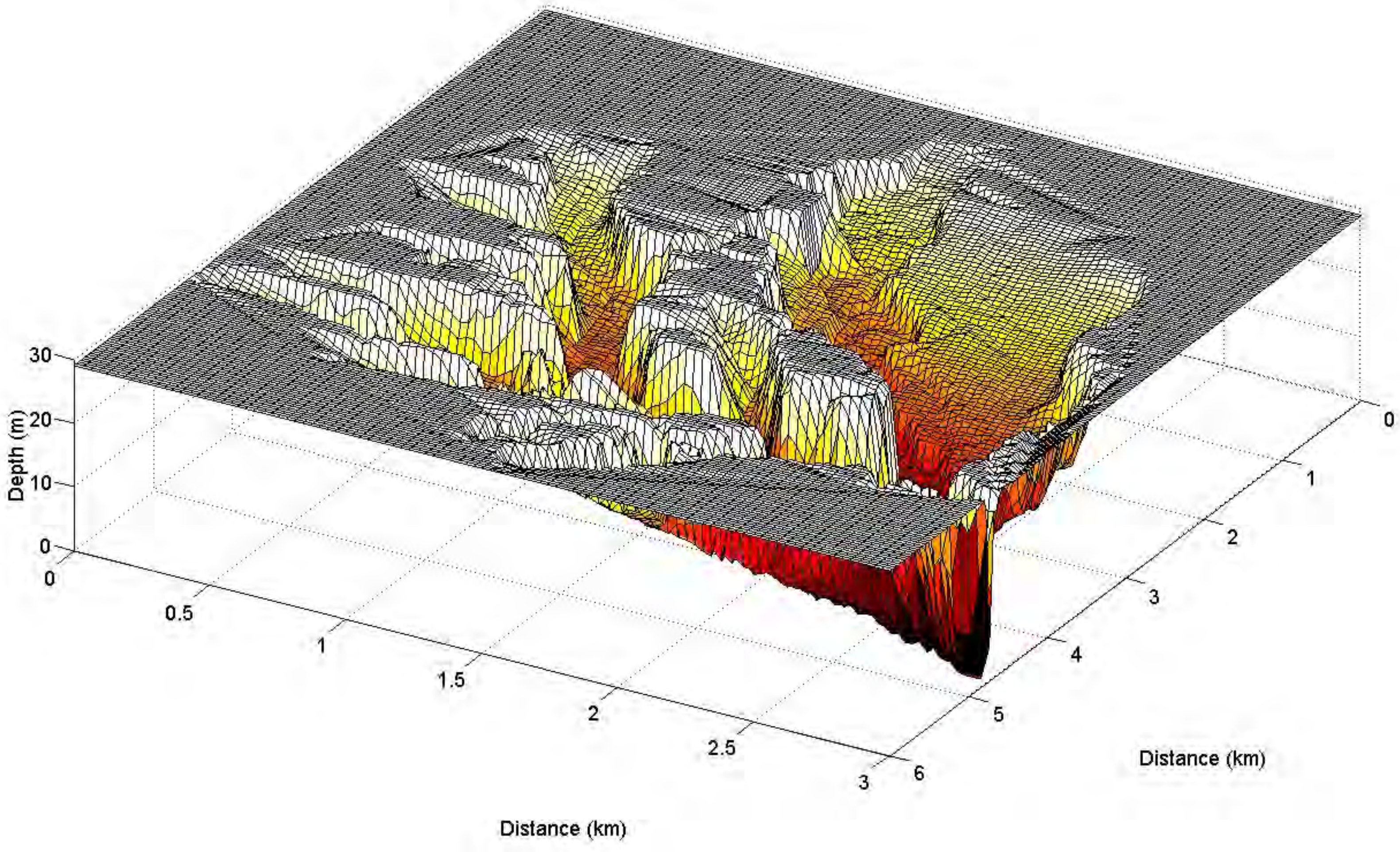
Deadwood Reservoir Bathymetry



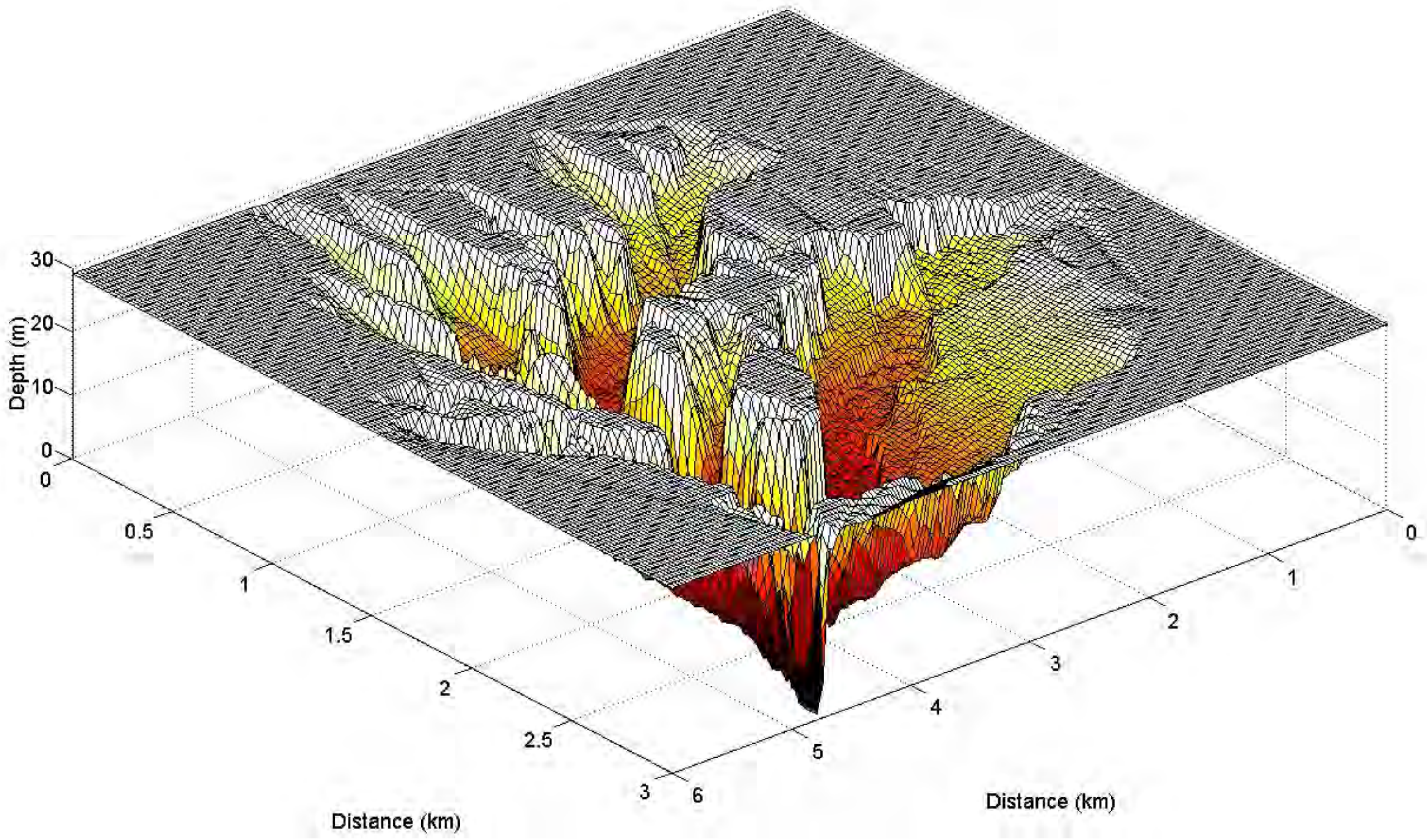
Deadwood Reservoir Bathymetry



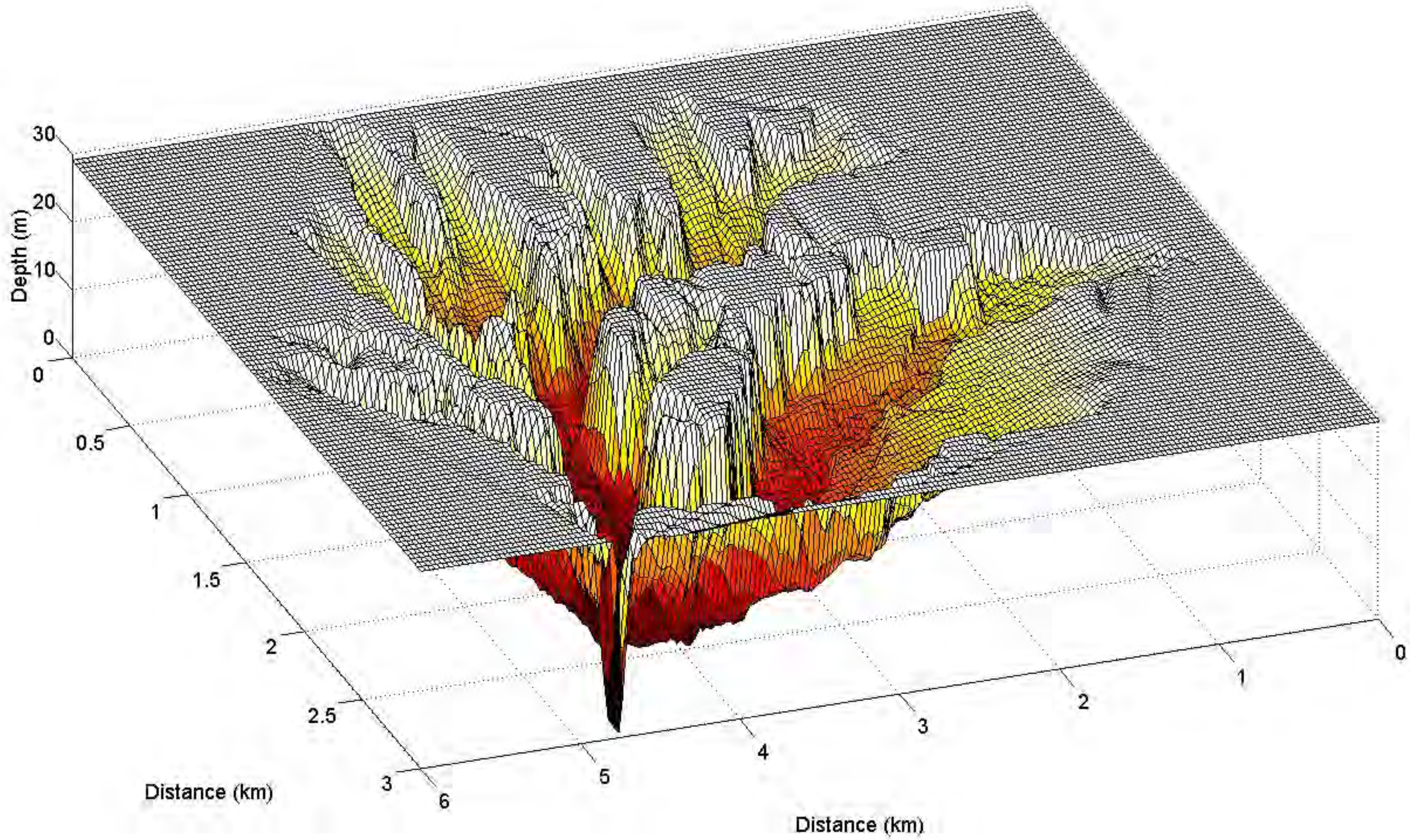
Deadwood Reservoir Bathymetry



Deadwood Reservoir Bathymetry



Deadwood Reservoir Bathymetry



Project Objectives

Describe the factors likely to limit bull trout growth and survival

→ *bioenergetic and foodweb modeling*

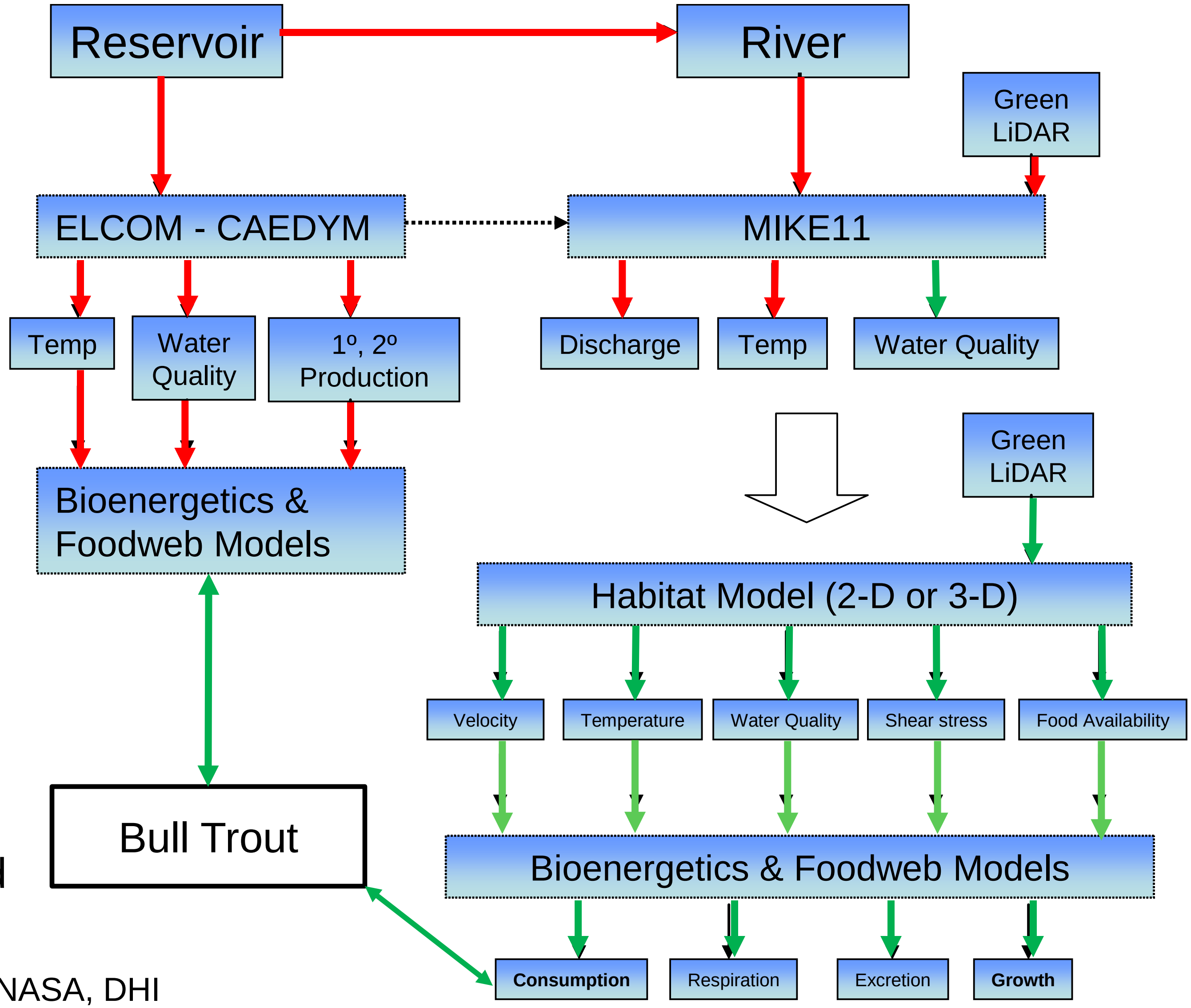
Investigate how background conditions and reservoir operations interact to influence these limiting factors

→ *hydrological and limnological modeling*

Evaluate flexibility of operations to minimize effects on bull trout in the Deadwood River below the dam

→ *use linked models to simulate combinations of background and operational scenarios*

Study Overview:



Real-time data transmission and modeling:

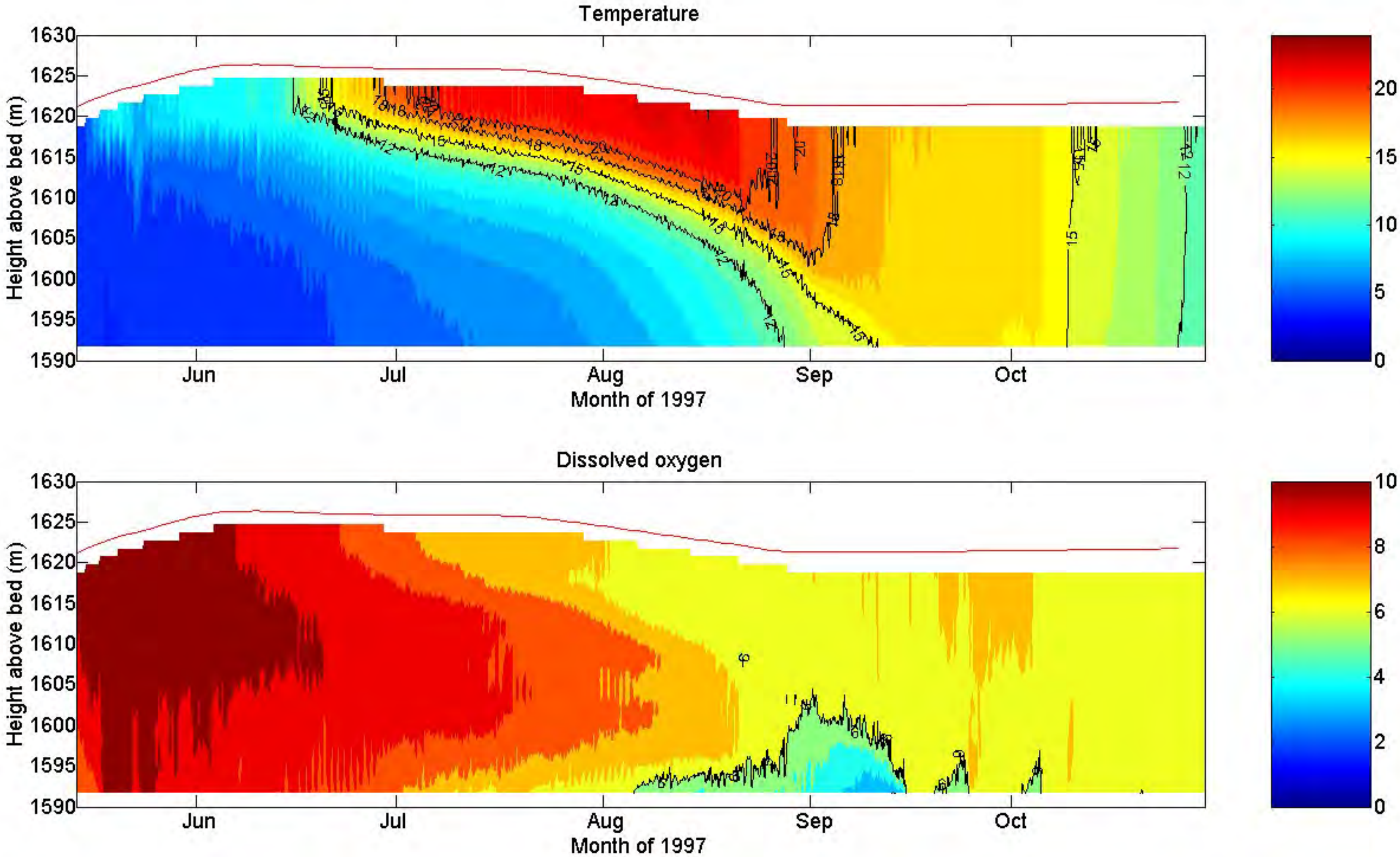
Reclamation, USFS, NASA, DHI (Denmark), CWR (Australia), ,PME, UI

Lake Diagnostic System

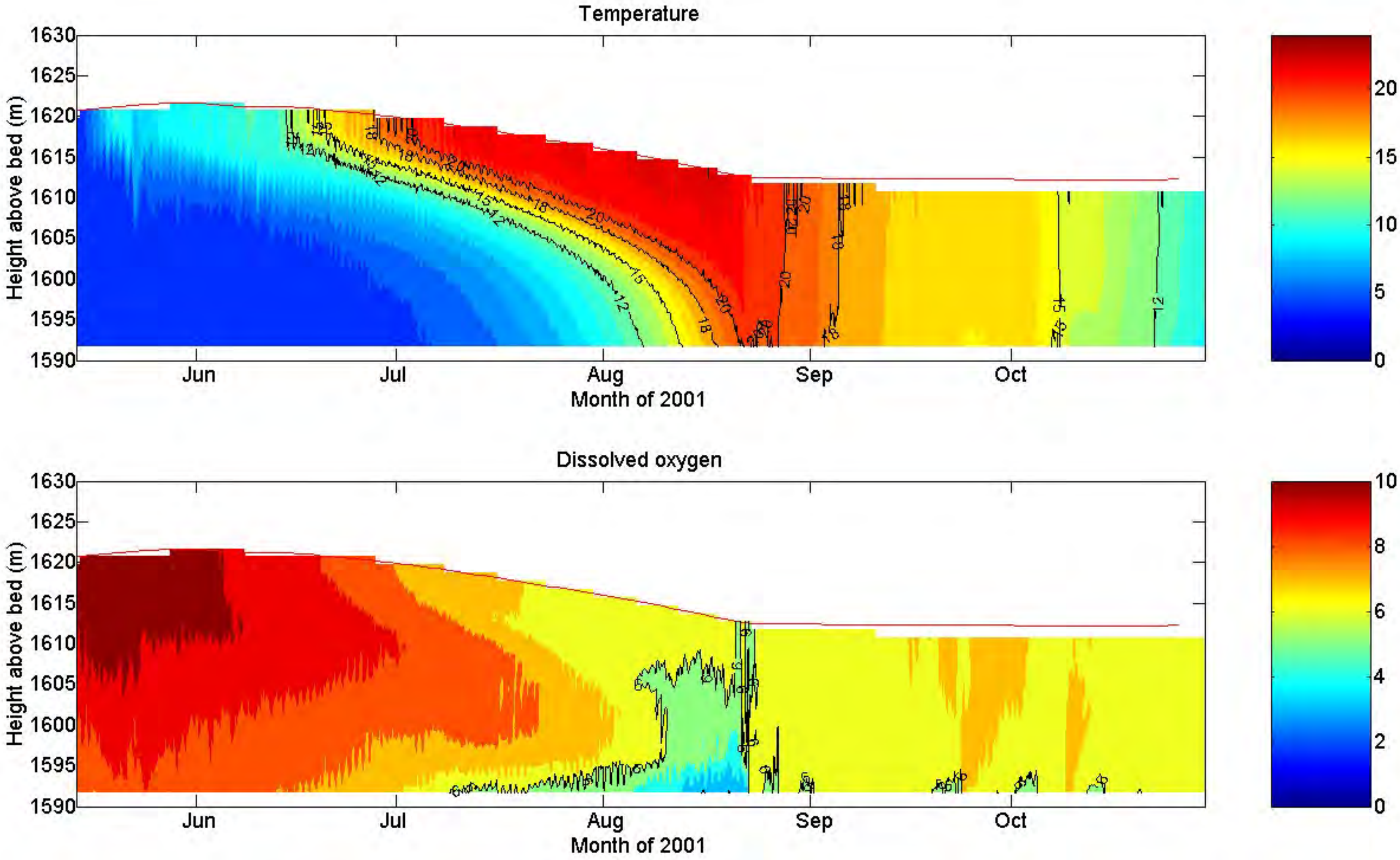
- Meteorological station
- 33 thermistors
- 7 dissolved oxygen sensors
- “Summer” and “winter” configurations, to allow for ice



1997 – wet BIOP

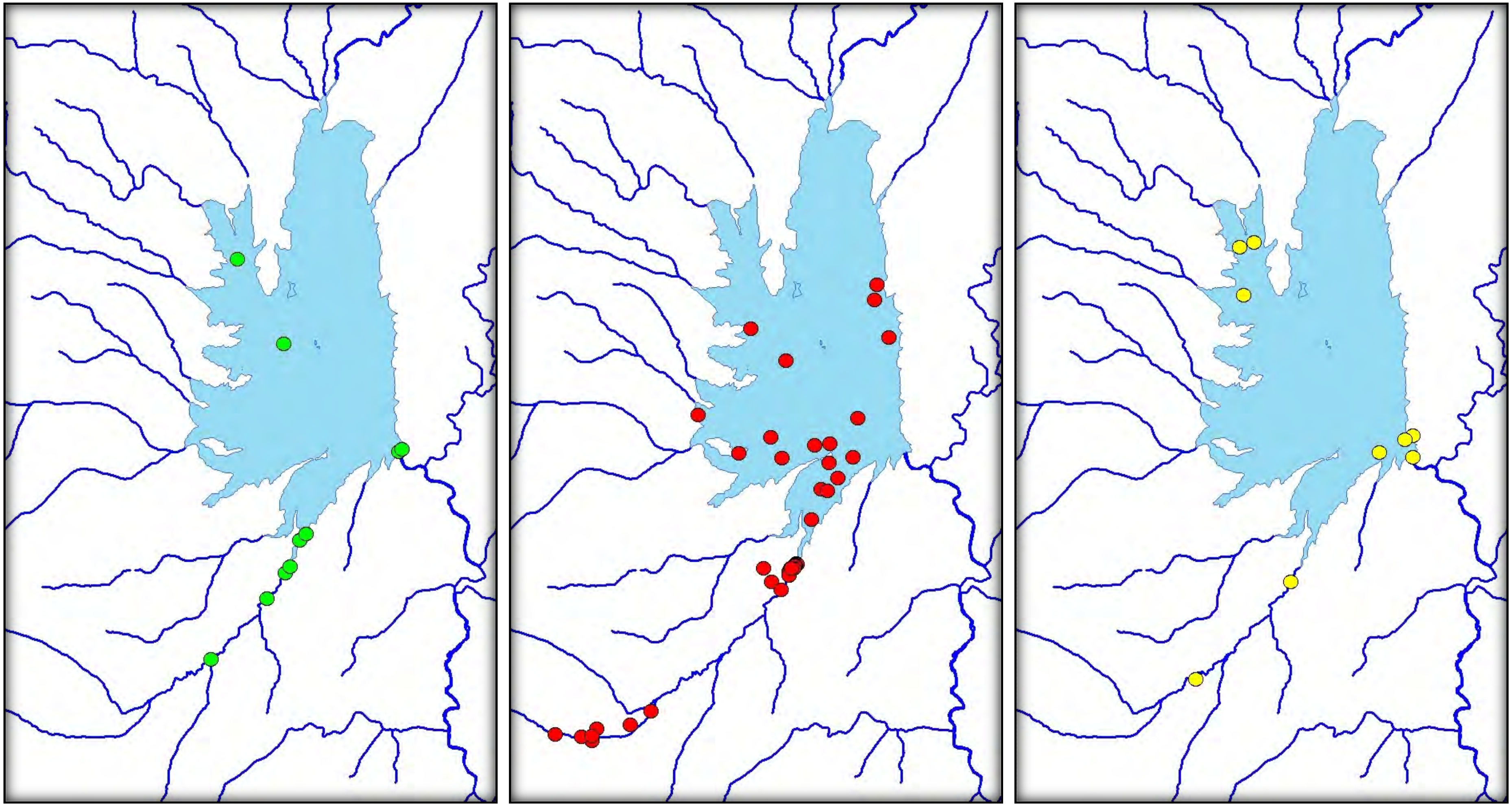


2001 – dry BIOP



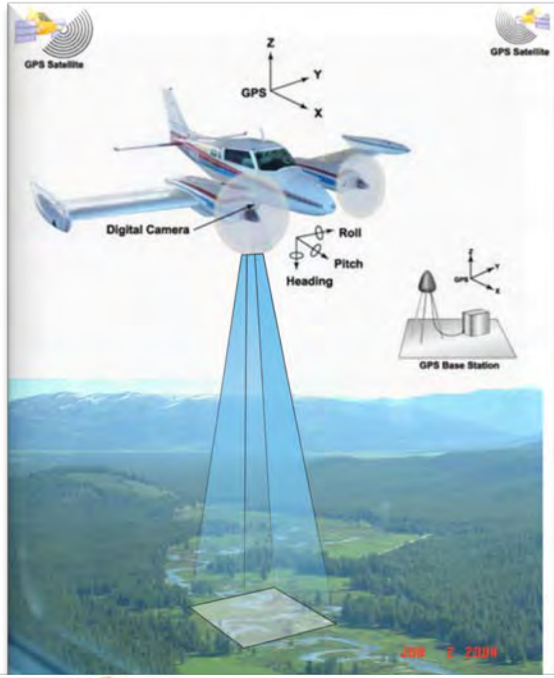
Reservoir Sampling, Tagging and Tracking - 40

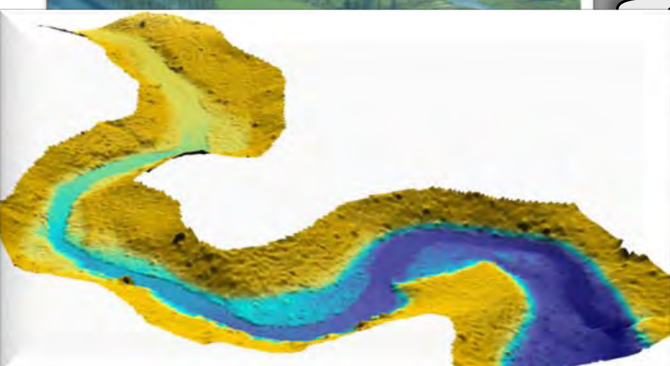
Fish 12: 2006 2007 2008

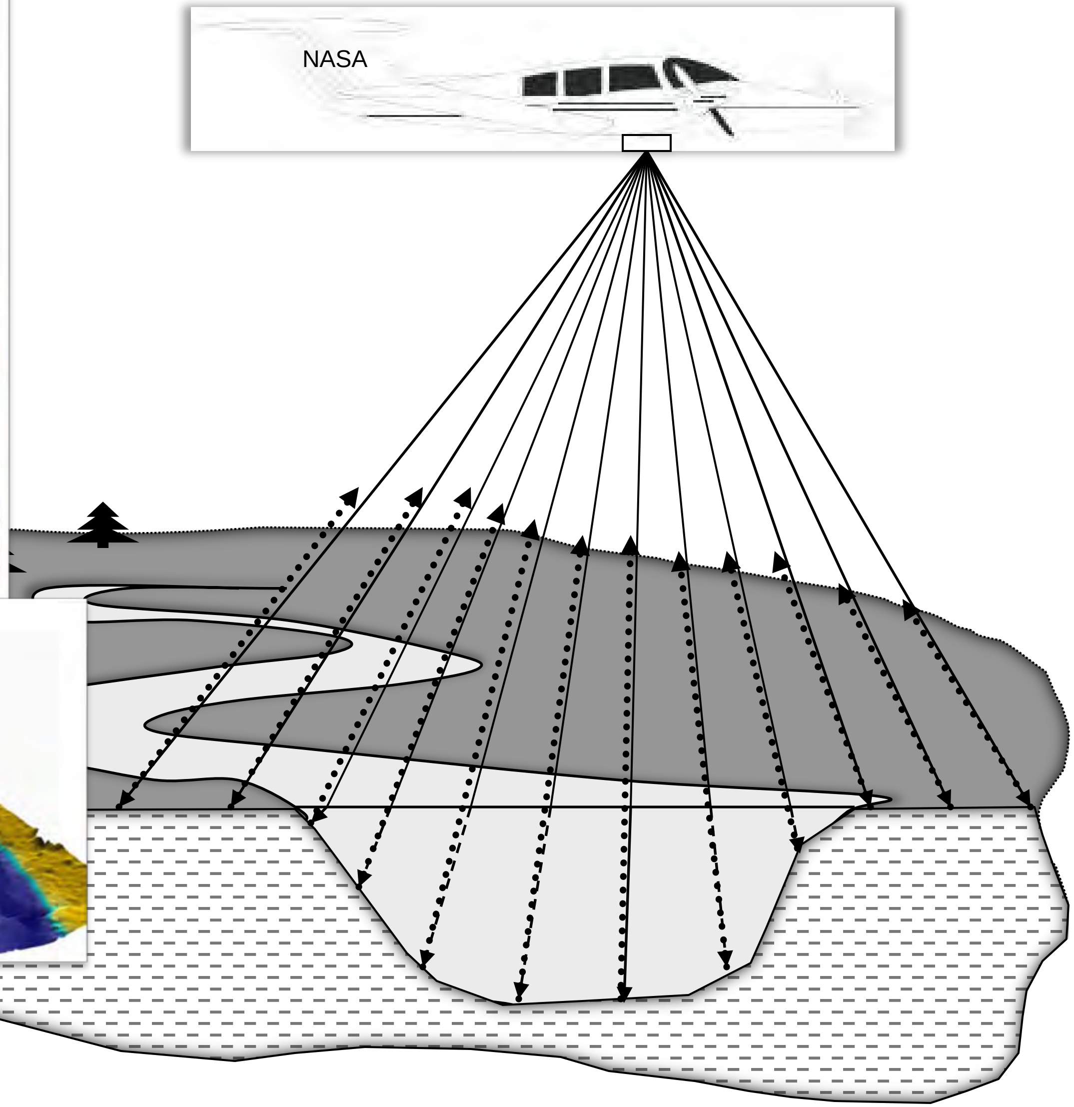


Drawdown Affects On Migration

EAARL Lidar





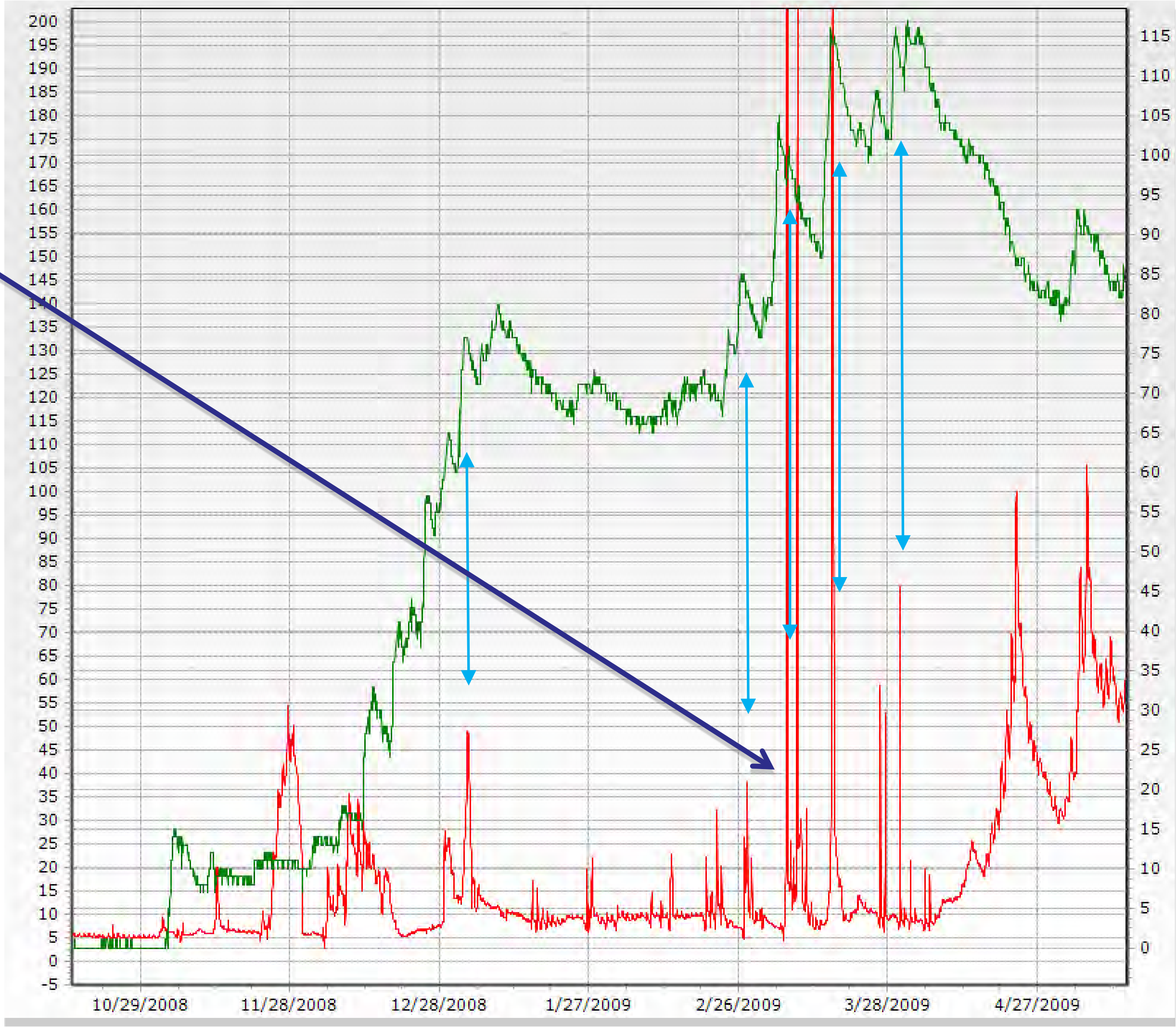


BOISE AQUATIC SCIENCES LAB
RMRS

Wayne Wright (USGS), Jim McKean (USFS)
and Daniele Tonina (CER)

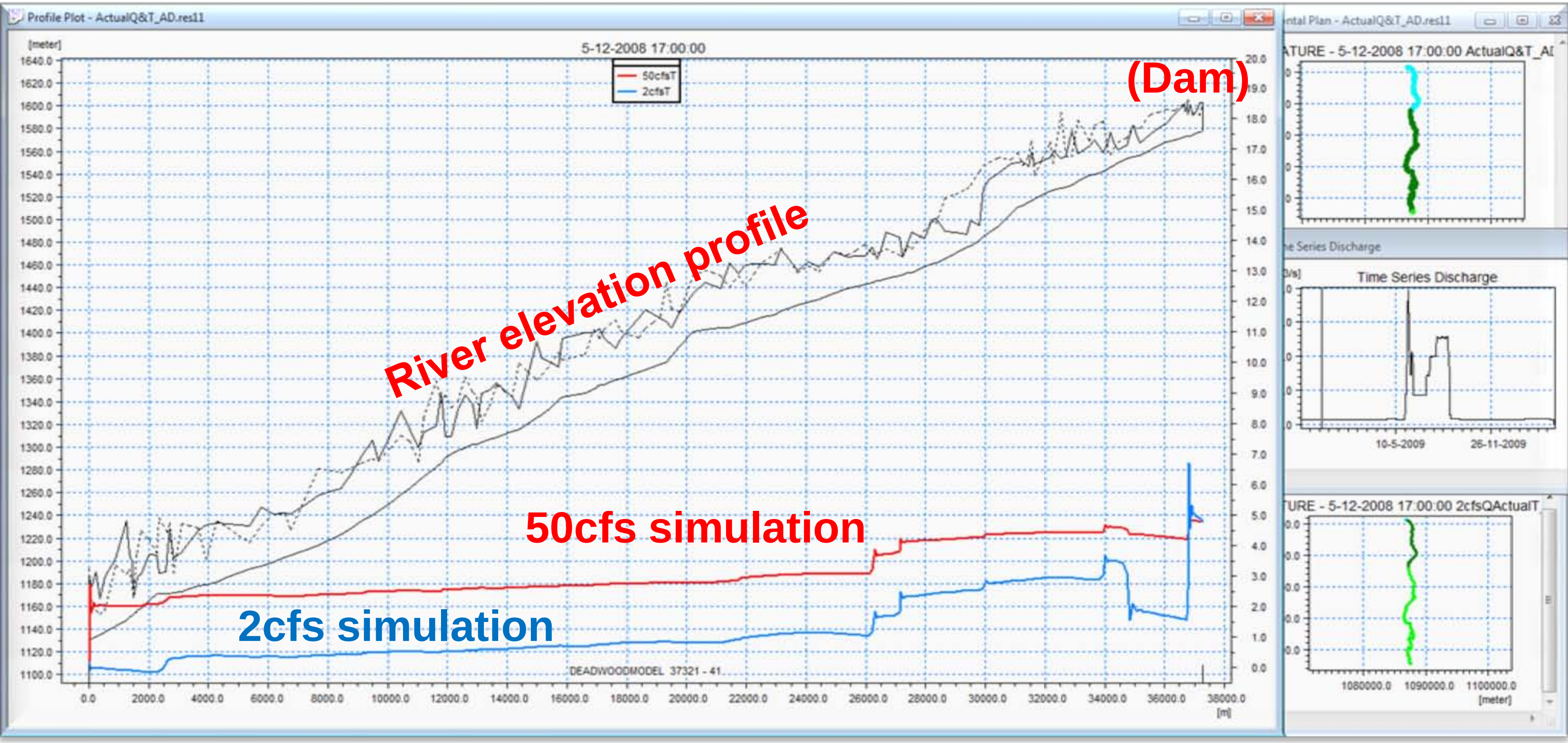
Data Anomolies – Stream Gages

Trail Creek Example

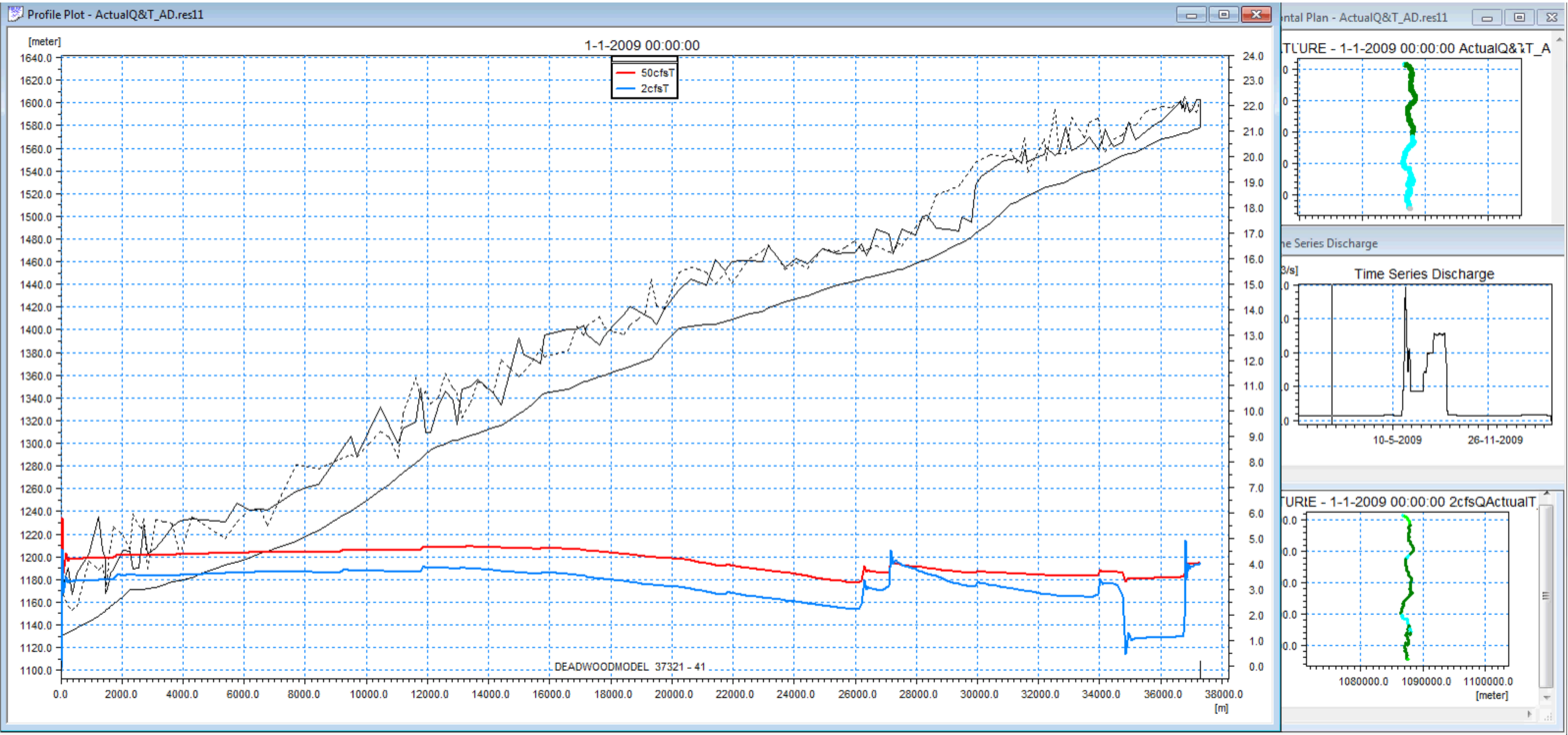


Trail Creek Spikes – real or sensor artifact?

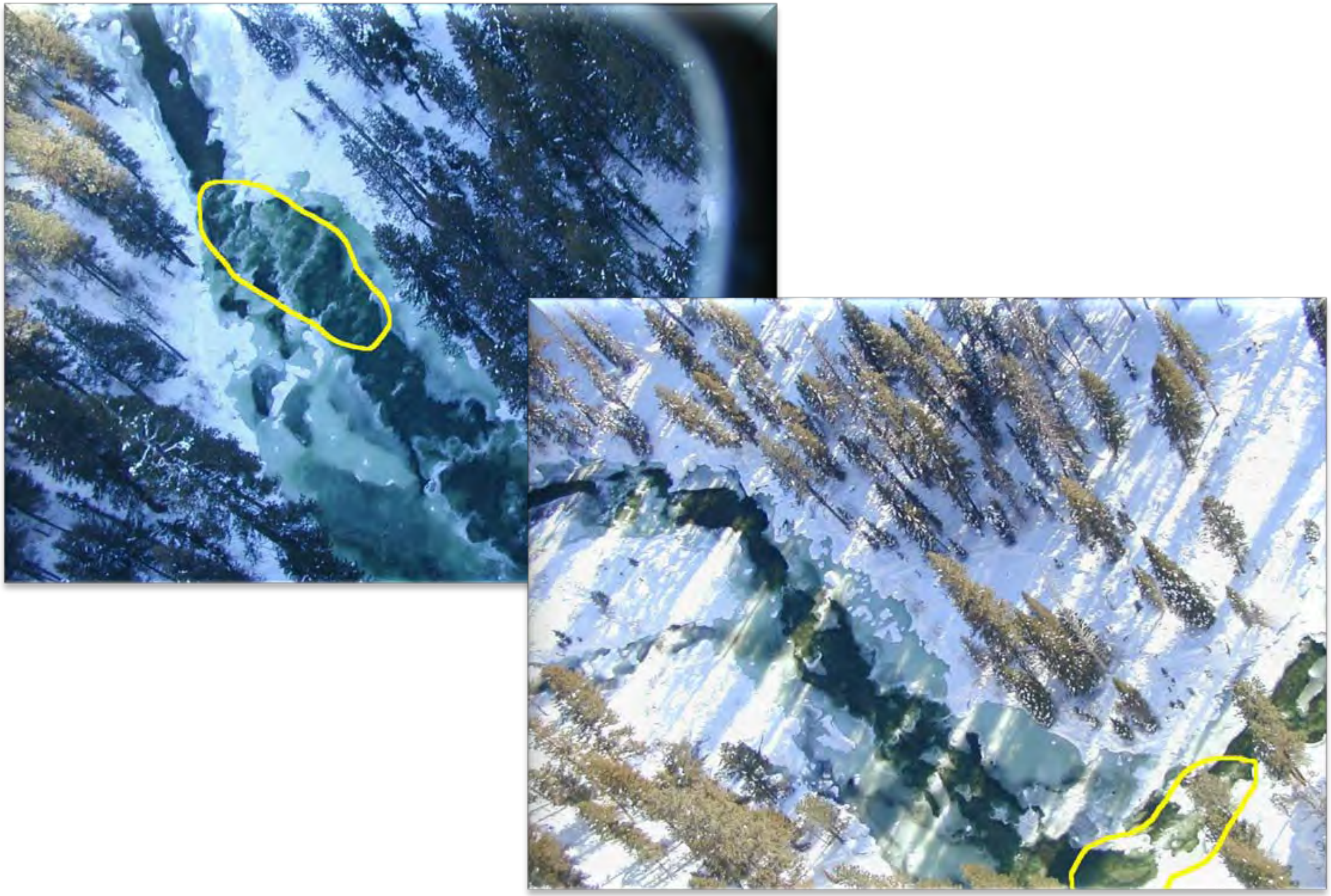
Temperature Animation



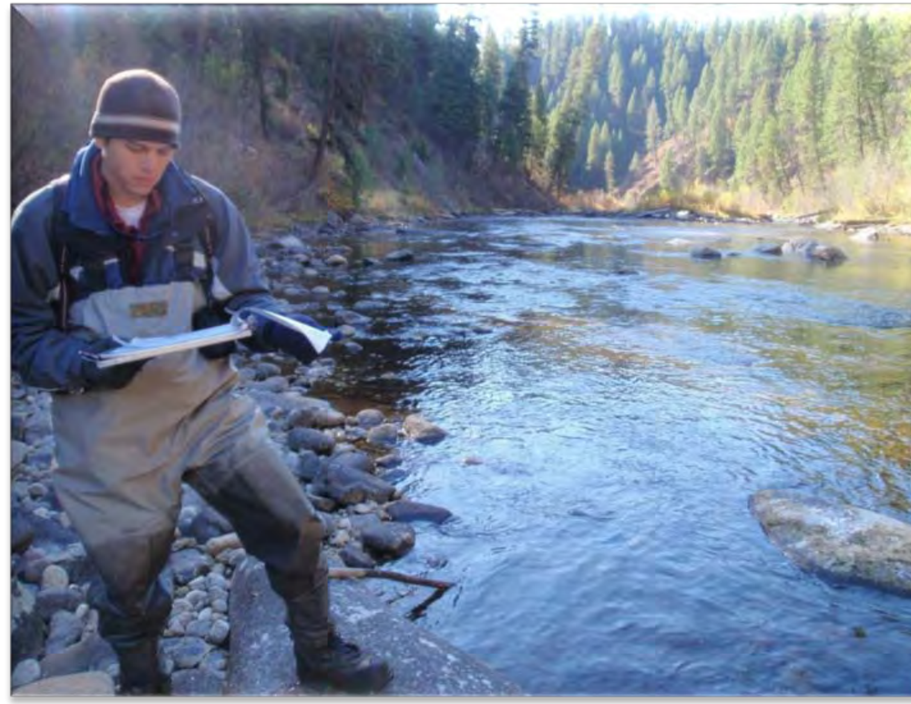
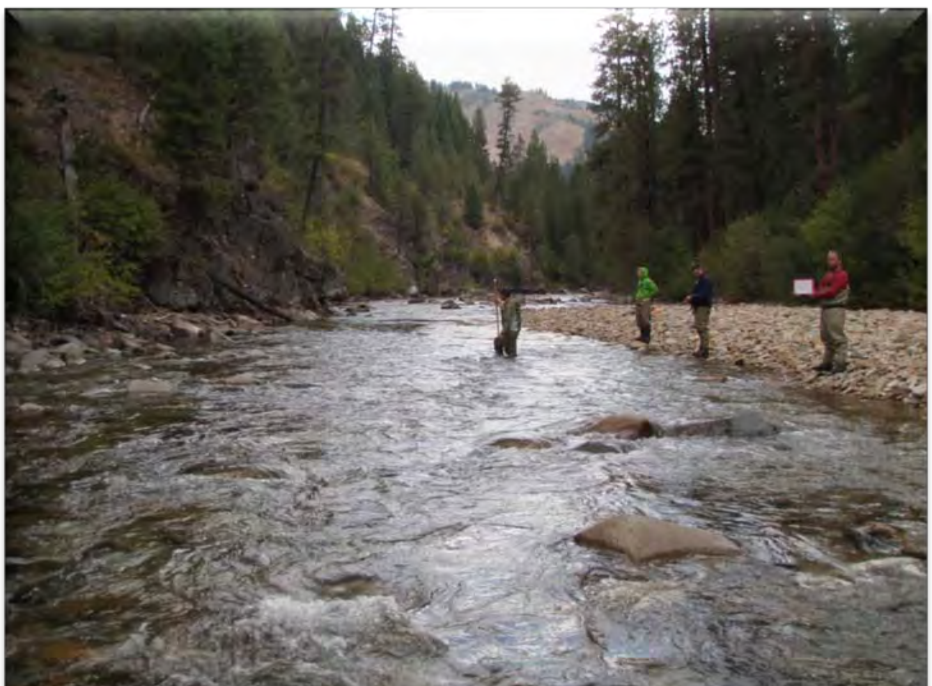
1-d Temperature Simulation



Frazil and Anchor Ice

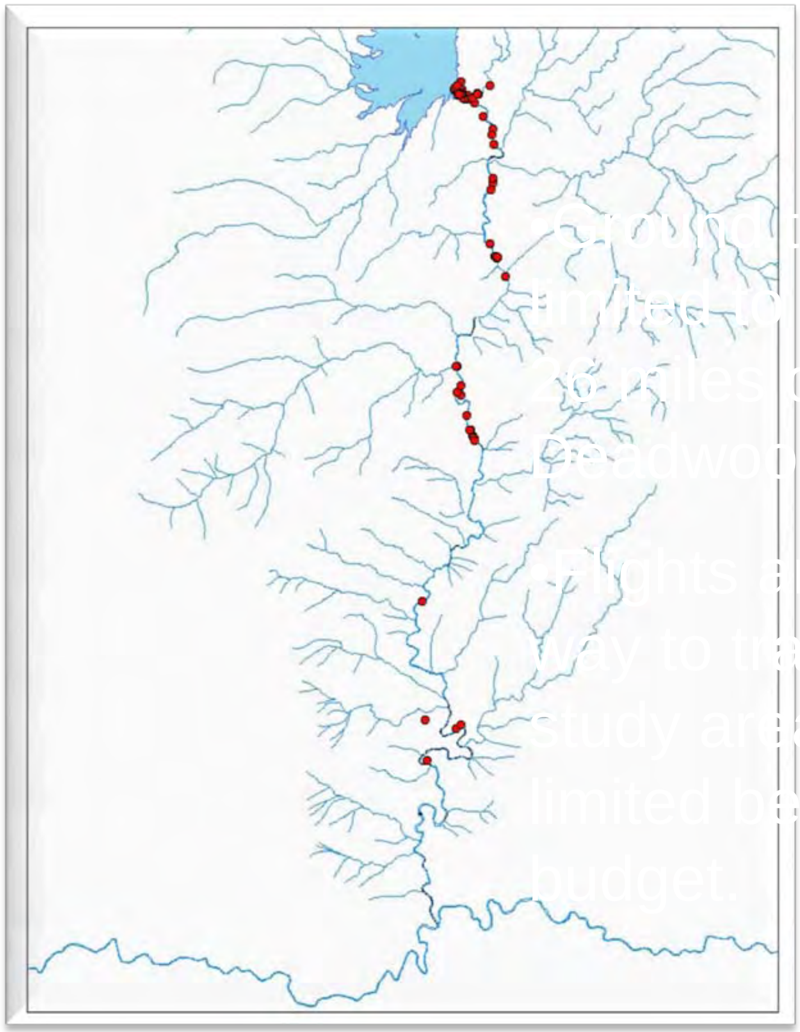


winter discharges **temperature** **ramping rates** **seasonal discharges** **entrainment**


Reach 5
Habitat 3




Stranding Pools

Bull Trout Locations 2007-2009 (n=21)



Hells Canyon Study Area

- The study area for the HCC extends from Brownlee reservoir to Lewiston, Idaho.
- Hells Canyon is 100+ miles of unimpounded rivers
- White sturgeon is one of the largest fresh water fish
- Can exceed 3.7 meters in length and 135 kg in weight
- Lifespan can exceed 100 years

Source: Idaho Power Company

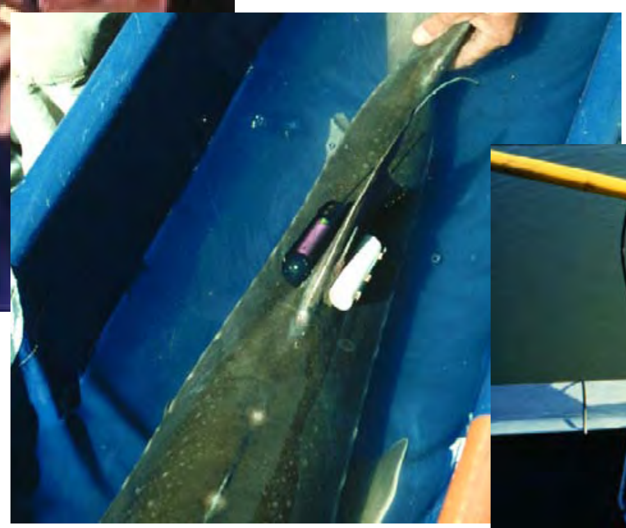
Research Objective

- How do operating strategies of a hydroelectric project affect the overall growth of white sturgeon.
- Monitor? Life history would require years…
- We need to know within a timeframe much shorter than the lifespan of a sturgeon (order of years rather than decades).

Monitoring…

Positions of 58 individual white sturgeon at two sites were monitored using sonic tags, differential GPS, and GIS.

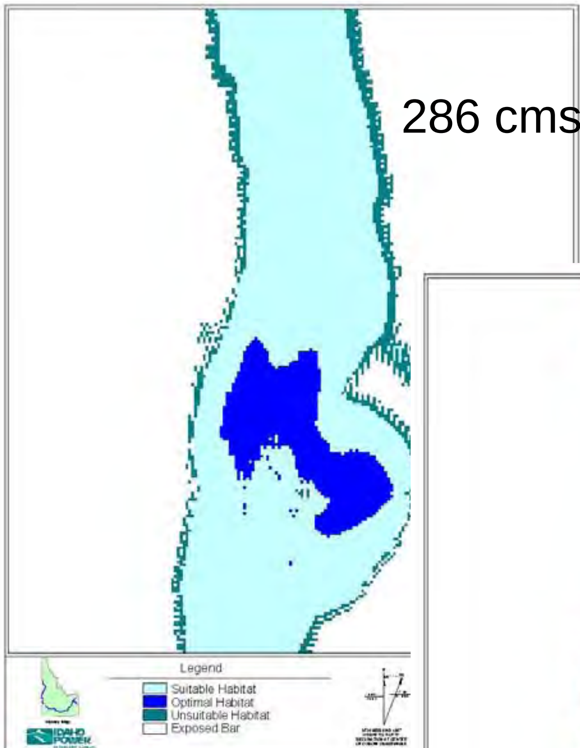
In addition, 21 of these fish had continuous transmitting Electromyogram (EMG) radio tags.

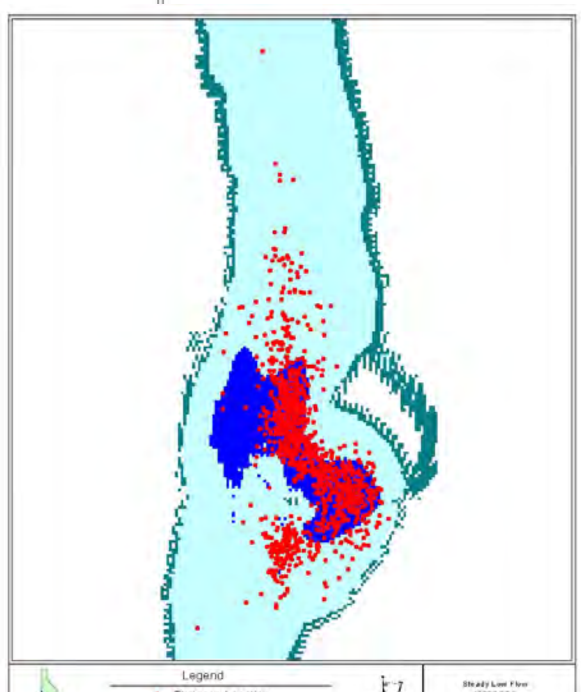


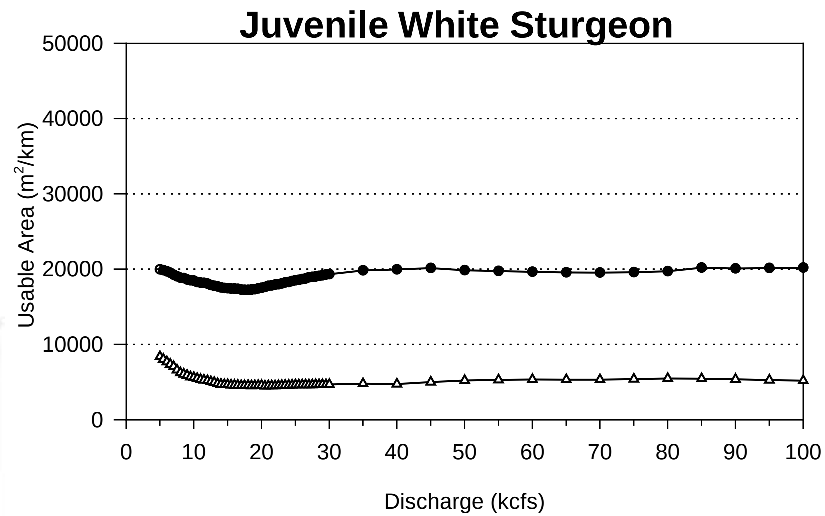
Habitat Results

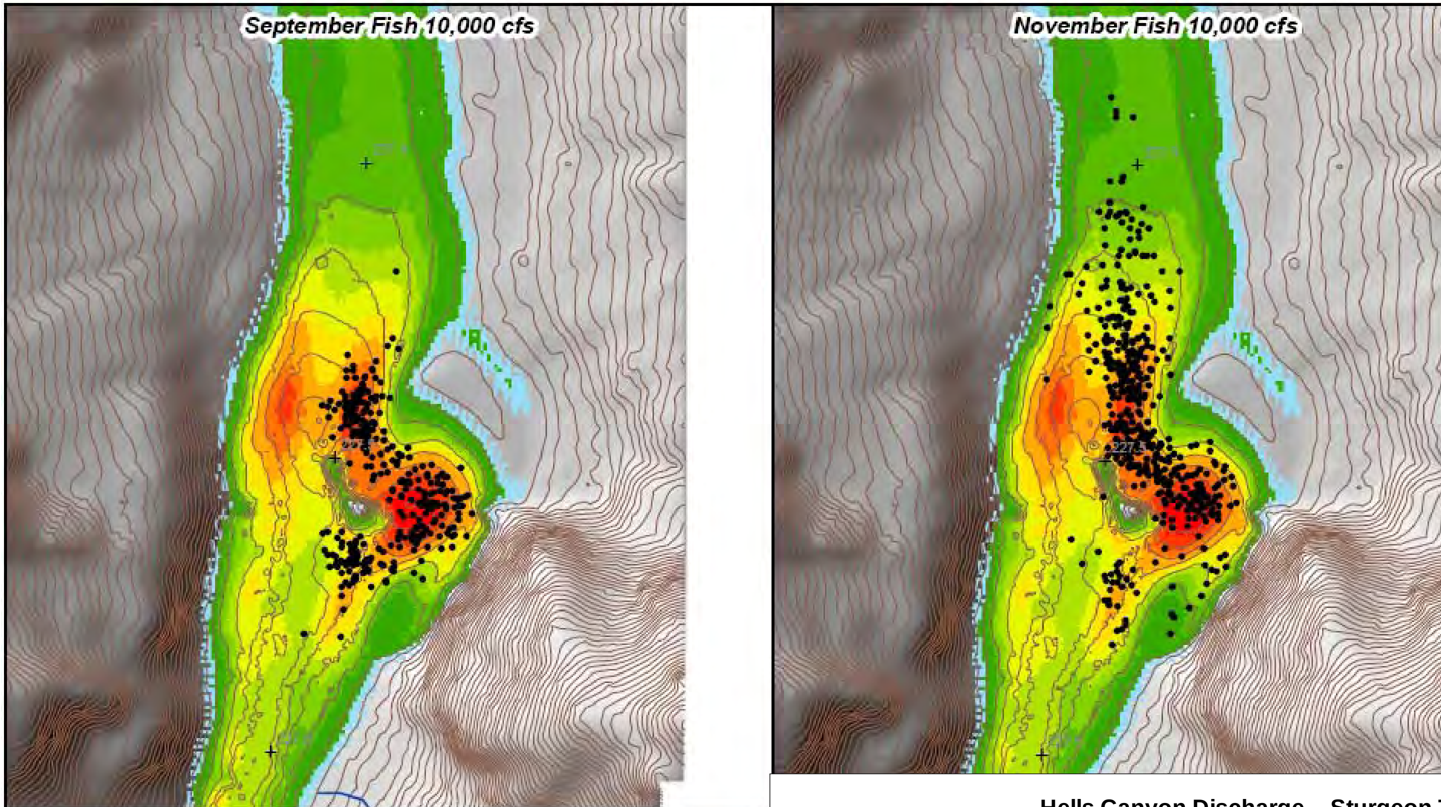
Results provide spatial and temporal habitat information throughout the study area.

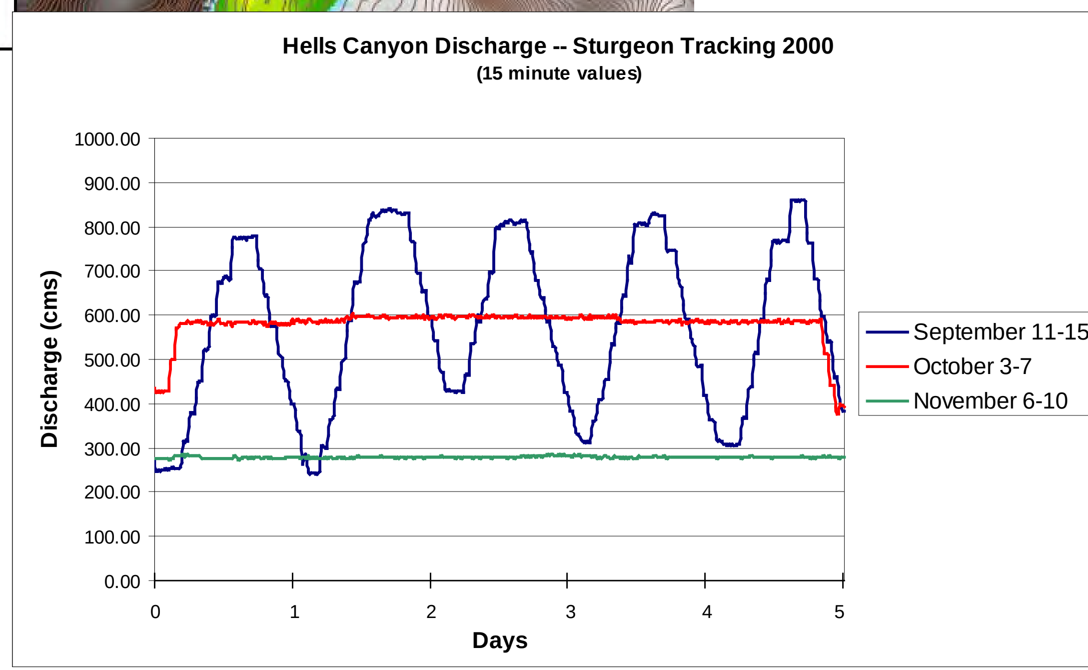
Results do not provide an indication of how flows or load following may affect growth.

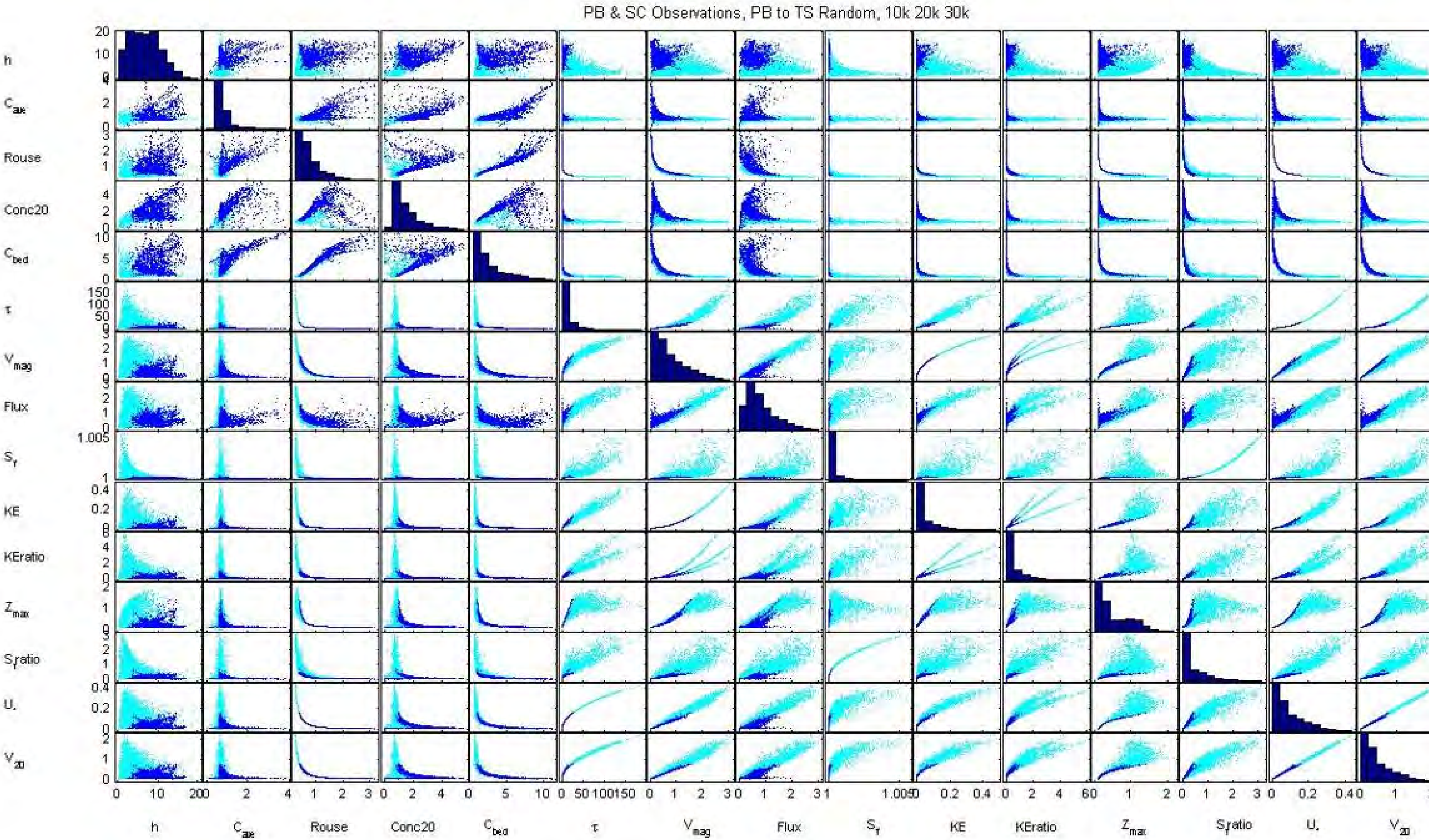


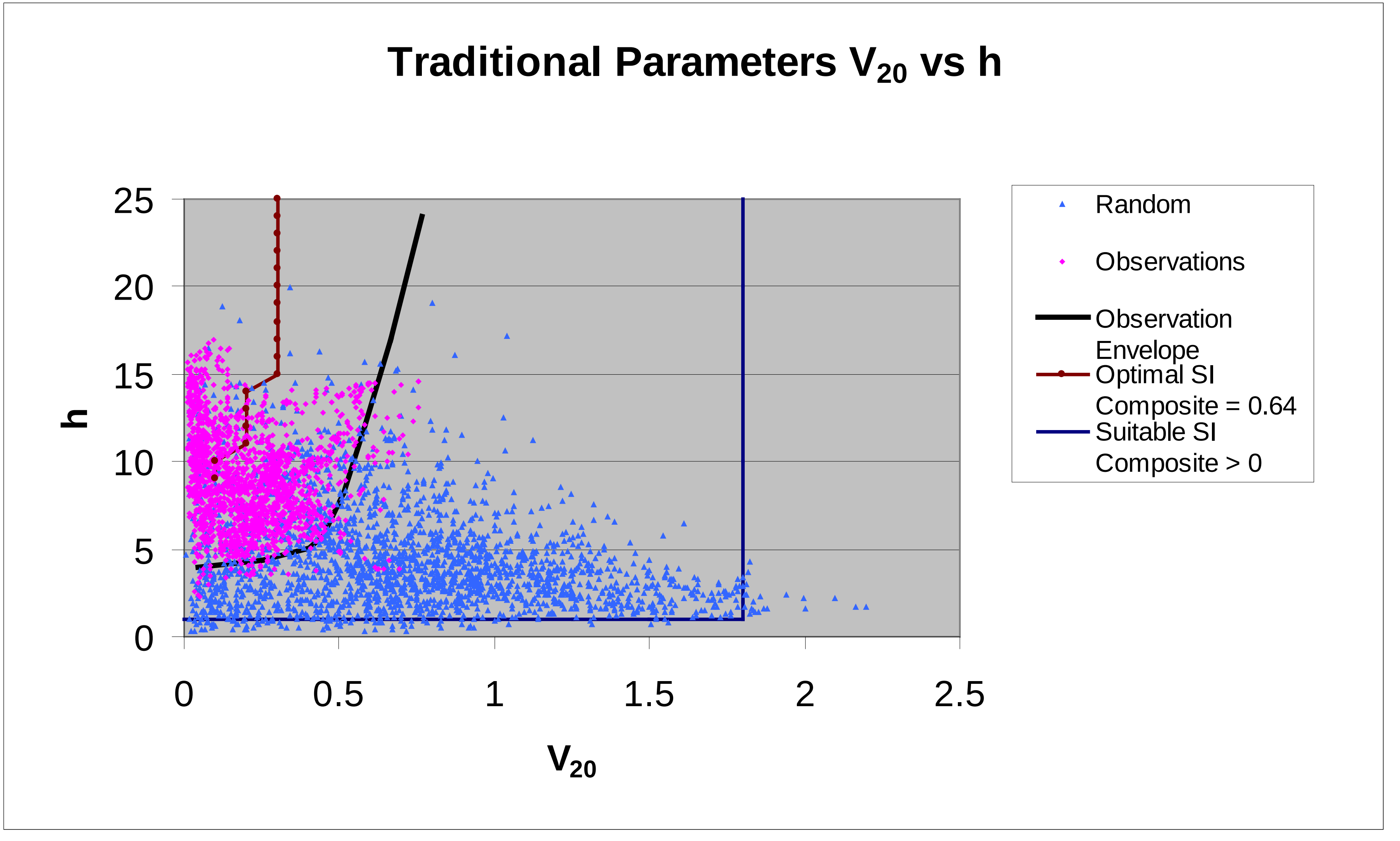




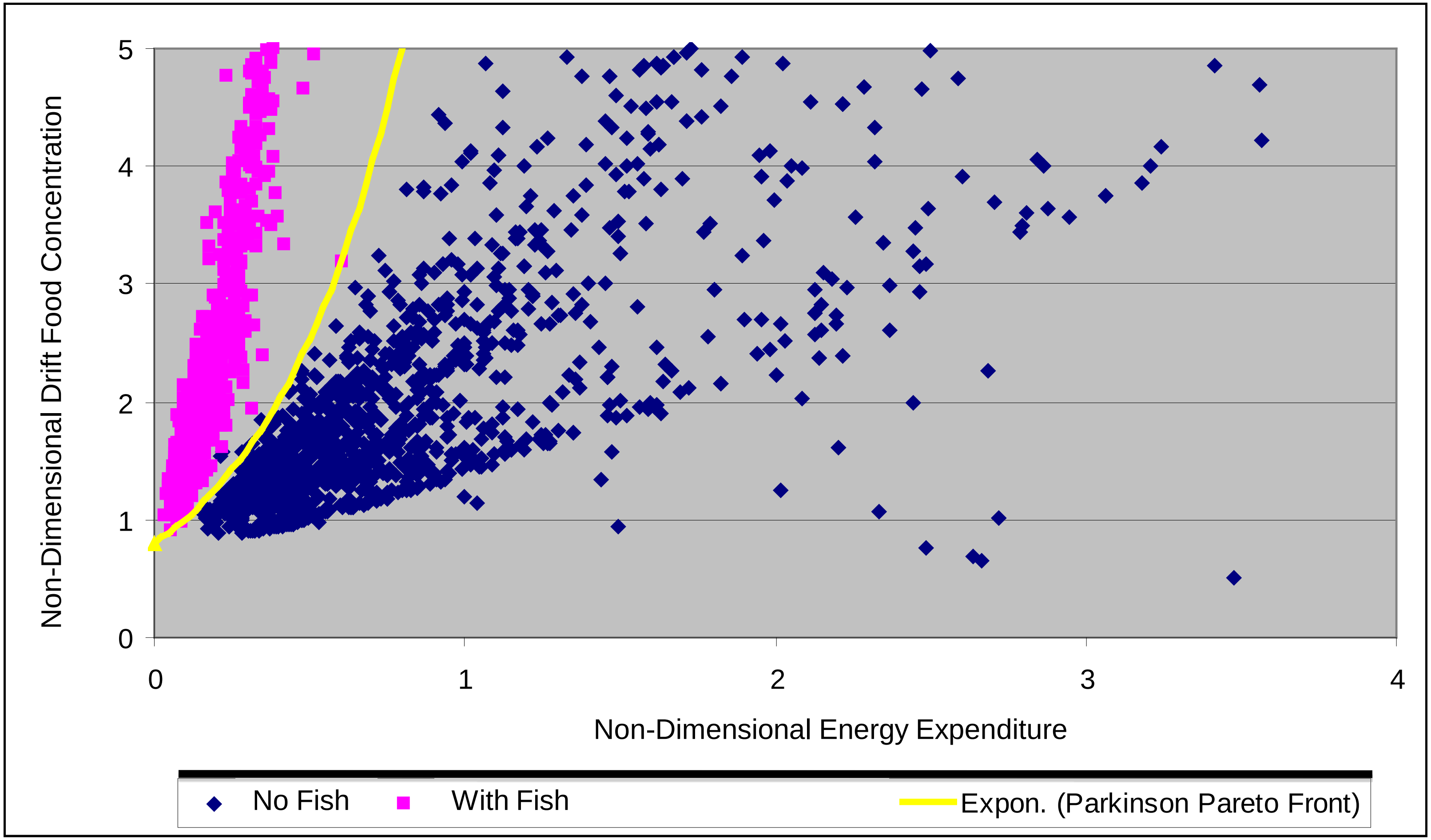

September Fish 10,000 cfs
November Fish 10,000 cfs


Hells Canyon Discharge -- Sturgeon Tracking 2000
(15 minute values)
Discharge (cms)
1000.00
900.00
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
0
1
2
3
4
5
Days
September 11-15
October 3-7
November 6-10


PB & SC Observations, PB to TS Random, 10k 20k 30k
h
Cave
Rouse
Conc20
Cbed
τ
Vmag
Flux
Sf
KE
KEratio
Zmax
Sfratio
U*
V20



Traditional Parameters V_{20} vs h
25
20
15
10
5
0
h
0
0.5
1
1.5
2
2.5
V_{20}
Random
Observations
Observation Envelope
Optimal SI Composite = 0.64
Suitable SI Composite > 0



Non-Dimensional Drift Food Concentration
0
1
2
3
4
5
0
1
2
3
4
Non-Dimensional Energy Expenditure
No Fish
With Fish
Expon. (Parkinson Pareto Front)

Conclusions

- ✓ Science and scholarship have become team sports (Blatecky, 2010)
- ✓ Scientific discovery is increasingly occurring through mining of existing data (supplemented by current monitoring)
- ✓ Creation of Science Communities – enabled by cyber-technologies
- ✓ Shared data and models improves transparency and generates trust
- ✓ Individuals and agencies must benefit from data sharing
- ✓ Experience and knowledge of discipline experts are critical in efficient interpretation.

  '*Getting the right answers for the right reasons*'

  (Kirchener, 2006)

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Idaho Department of Fish and Game
Idaho Department of Water Resources
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US Geological Survey

Thank you for your attention – any questions?