

# WHAT DO FISH CARE ABOUT HYDROGEOMORPHOLOGY? – A Survey of the Latest Techniques at a Full Range of Spatial Scales

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Noah Snyder



DSRRN 2013 Meeting  
January, 2013



## PURPOSE OF OUR TALKS....

- Review state-of-the science methods for characterizing diadromous fish habitat at **different scales**
  - How to take the snap shot?
  - How to measure the dynamics?



**John Waldman** asked us all:

Does more heterogeneity = more life history variation =  
more population resilience?



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## DYNAMIC RIVERS = HEALTHY ECOSYSTEMS

- We *believe* this...
- Lots of cool studies showing feedbacks and links...



- We *know*: to get and maintain heterogeneous habitat, we need dynamic systems

## HOW DO WE CHARACTERIZE HABITAT?

- What sort of new tools/toys are out there?

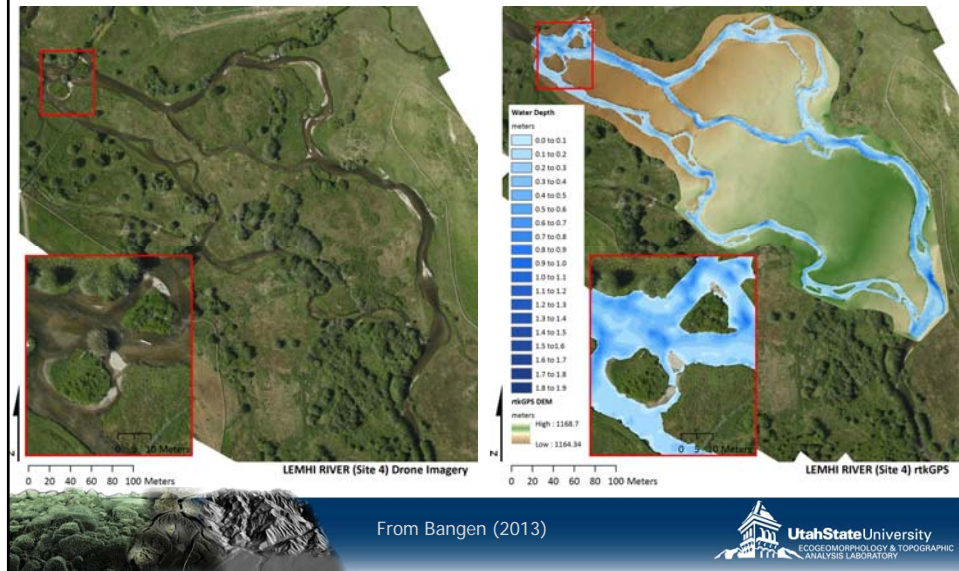


- How do they help us paint a quantitative picture?

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## HOW TO PAINT THAT PICTURE?

- Take a Picture
- Make a Topographic Map



## LOTS OF WAYS TO TAKE PICTURES (APs)

- Satellite (2m – 50 m;  
Free)
- Fixed-Wing Aircraft (10  
cm to 100 cm; Min \$5K for  
flight, some free)
- Tethered Blimps,  
Balloons (2 cm to 25 cm;  
\$3K for blimp; time; \$50-  
\$200 per flight for helium)
- Drones (8cm to 15 cm;  
\$4K to \$25K for drone,  
need FAA certification)



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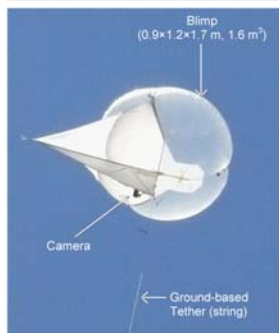


## NEW WAYS TO TAKE PICTURES...

- Poles, blimps, drones, RC helicopters

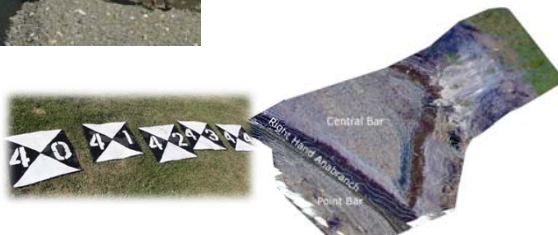


## POOR MAN'S AERIAL PHOTOGRAPHY



- As low-tech as it gets
- Ortho-rectification registration errors on the order of 25- 75 cm
- Flying height of up to 500 m

- Great for context
- Grain size extraction
- Habitat mapping / classification
- Drape over a DEM



Vericat et al. (2008): RRA  
DOI: [10.1002/rra.1138](https://doi.org/10.1002/rra.1138)



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## WHAT CAN YOU DO WITH AN IMAGE?

- Draw Habitat Units
- Derive water depths
- Derive grain size maps

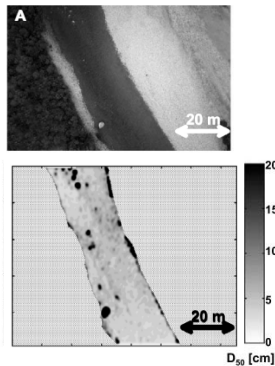


Figure 1. (a) Sample image from the Sainto-Marguerite River study site located at 48.38°N, 70.20°W. (b) Median grain size map for the dry exposed area in Figure 1a. Carbonneau et al. (2005): WRR DOI: 10.1029/2005WR003994

Wilby et al. (2010): TSE  
DOI: 10.1016/j.scitotenv.2010.05.014



## LOTS OF TOPO OPTIONS

Has many ways of acquiring high-resolution topography  
Remotely Sensed or Aerial Surveys

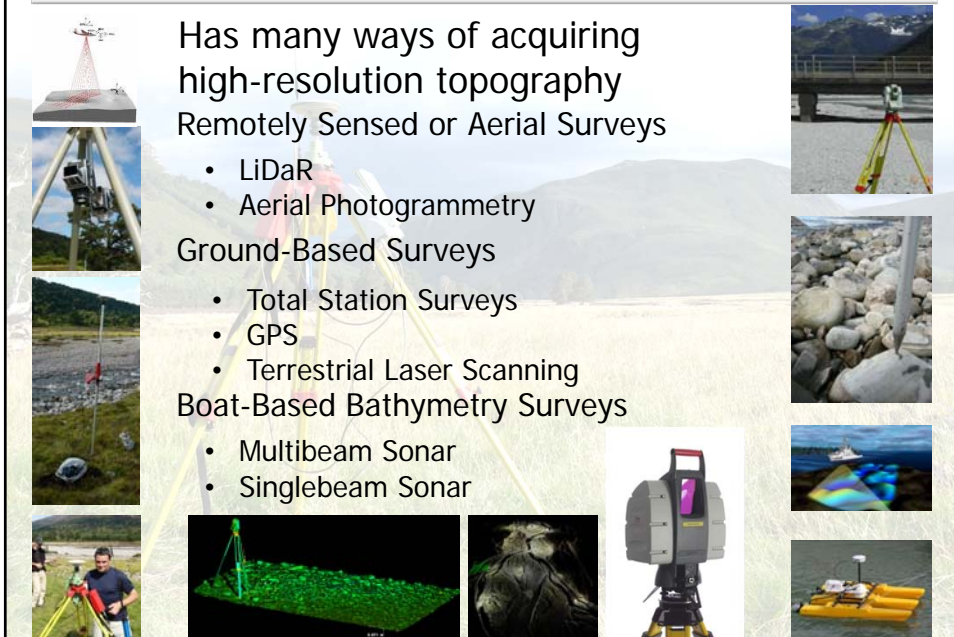
- LiDaR
- Aerial Photogrammetry

Ground-Based Surveys

- Total Station Surveys
- GPS
- Terrestrial Laser Scanning

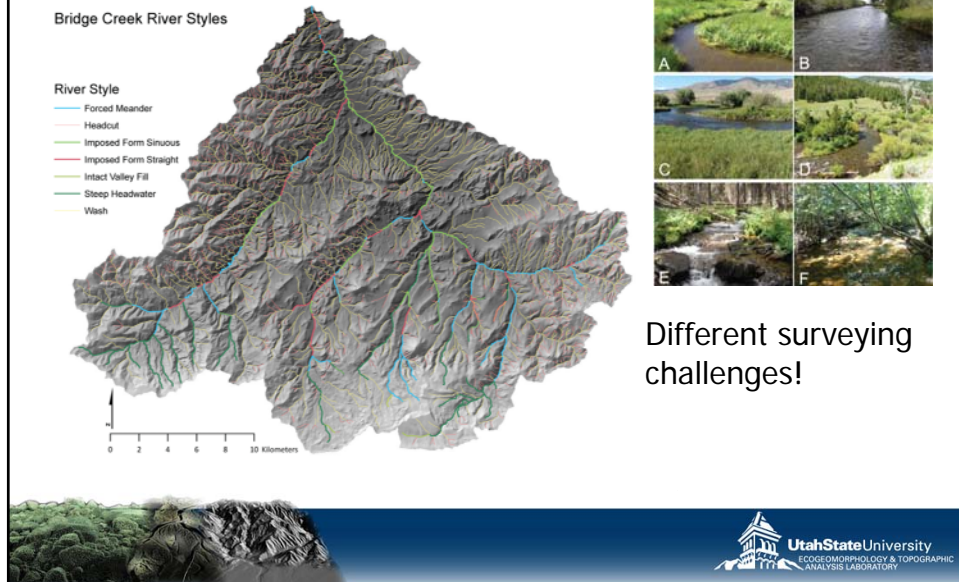
Boat-Based Bathymetry Surveys

- Multibeam Sonar
- Singlebeam Sonar



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## GIVEN DIVERSITY OF RIVERS & STREAMS



## NO SINGLE SILVER BULLET

TECHNOLOGY	EXTENT (Reach Lengths)	RESOLUTION (pt./m <sup>2</sup> )
Airborne LiDaR	10's – 100's km	1-8
Bathymetric LiDaR	10's – 100's km	0.5 – 4
Aerial Photogrammetry	10's – 100's km	0.1 – 1
Total Station Surveying	100 – 5,000 m	0.1 – 4
rtkGPS Surveying	100 – 5,000 m	0.1 – 4
Terrestrial Laser Scanning (aka ground-based LiDaR)	100 – 5,000 m	10 – 10,000
SFM	100 – 1000 m	100 – 10,000
Multi-beam Sonar	1 – 25 km?	10- 10,000
Single-beam Sonar	5 – 100 km?	0.05 – 5



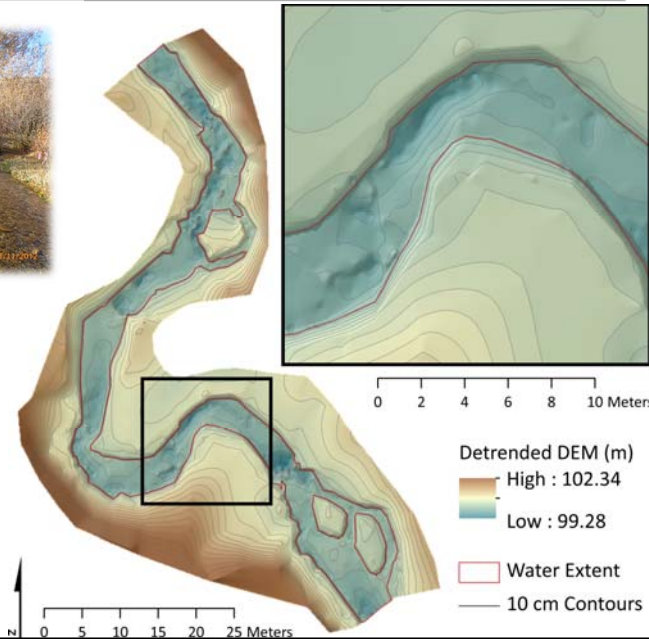
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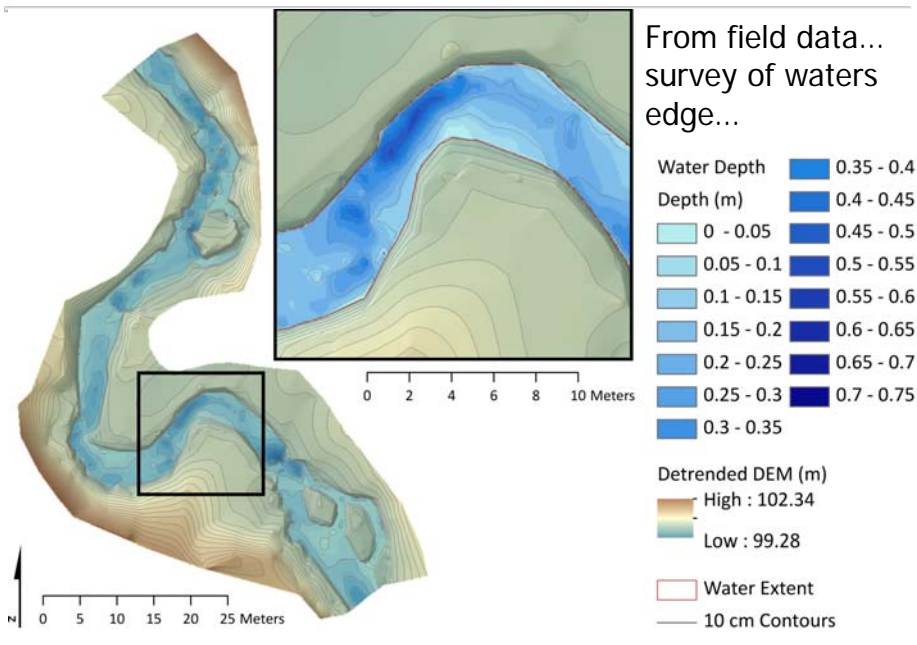
## WHAT DO YOU DO WITH TOPO SURVEY?



1. Build TIN
2. Convert to DEM
3. Detrend
4. Morphology  
Pops out
5. Flood....

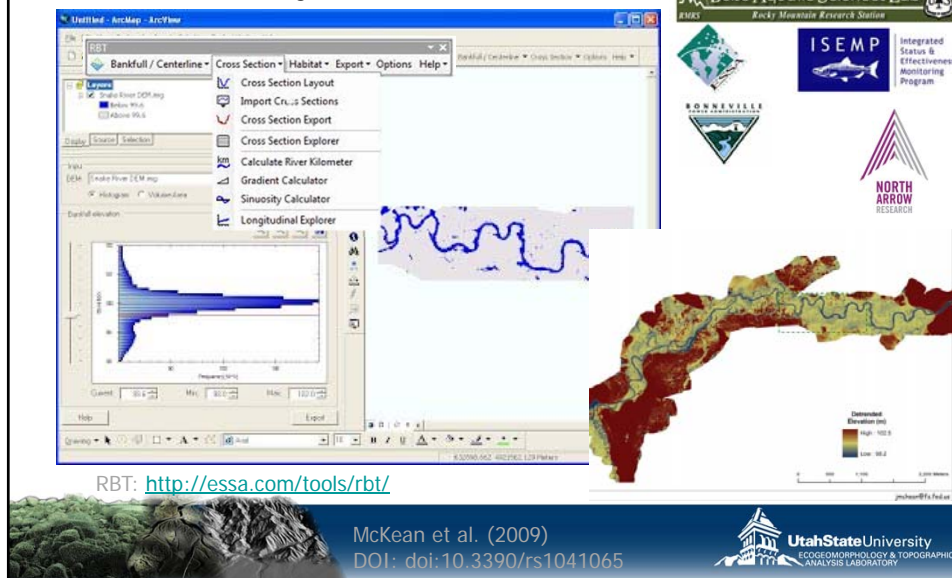


## ADD WATER DEPTH – TEMPLE FORK, UT



# RIVER BATHYMETRY TOOLKIT

- Poor Man's Hydraulic Model...

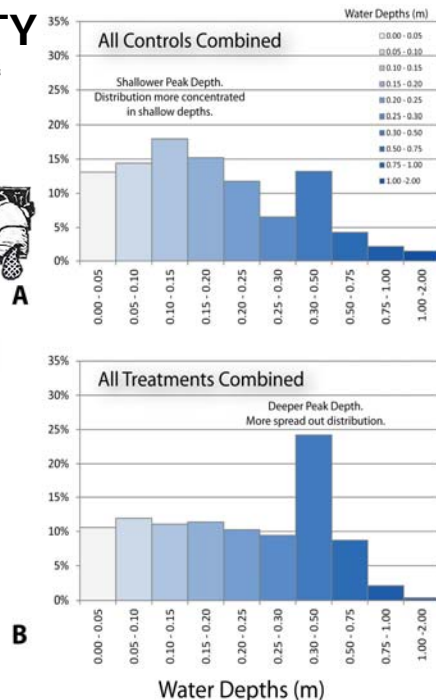
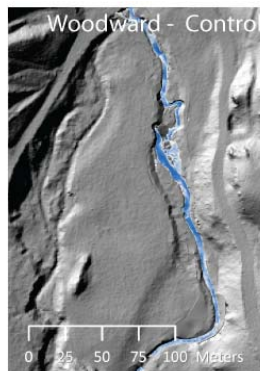
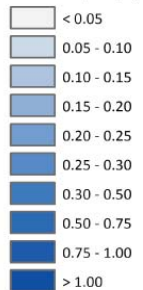


## DEPTH HETEROGENEITY

- Use depth distributions to look at one form of diversity of hydraulic habitat
- Comparison of restoration treatment (using beaver) & controls

### Legend

#### Water Depth (m)

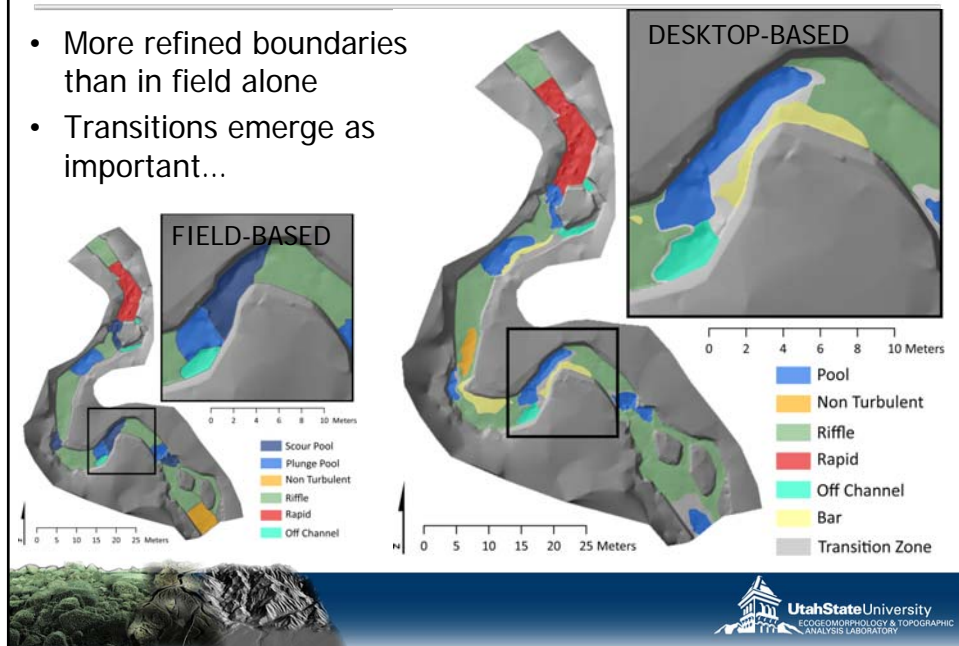


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## DERIVE HABITAT UNITS FROM TOPO & WD

- More refined boundaries than in field alone
- Transitions emerge as important...



## LOTS OF DIFFERENT WAYS OF GETTING AT SAME THING....

Ways of defining habitat units

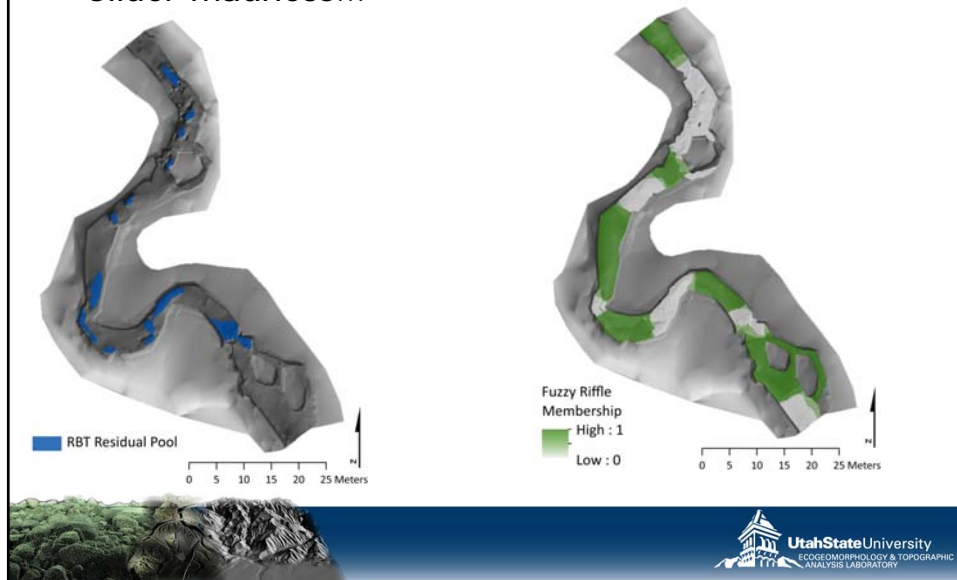
- Topographically (2D morphometrics)
- Topographically (1D profile)
- Field-Based (CHaMP channel spanning)
- Field-Based (geomorphic mapping)
- Desktop-Based (geomorphic mapping on APs)
- Auxillary data streams & correlations (e.g. roughness, width expansion/constriction, depth, velocity, etc.)



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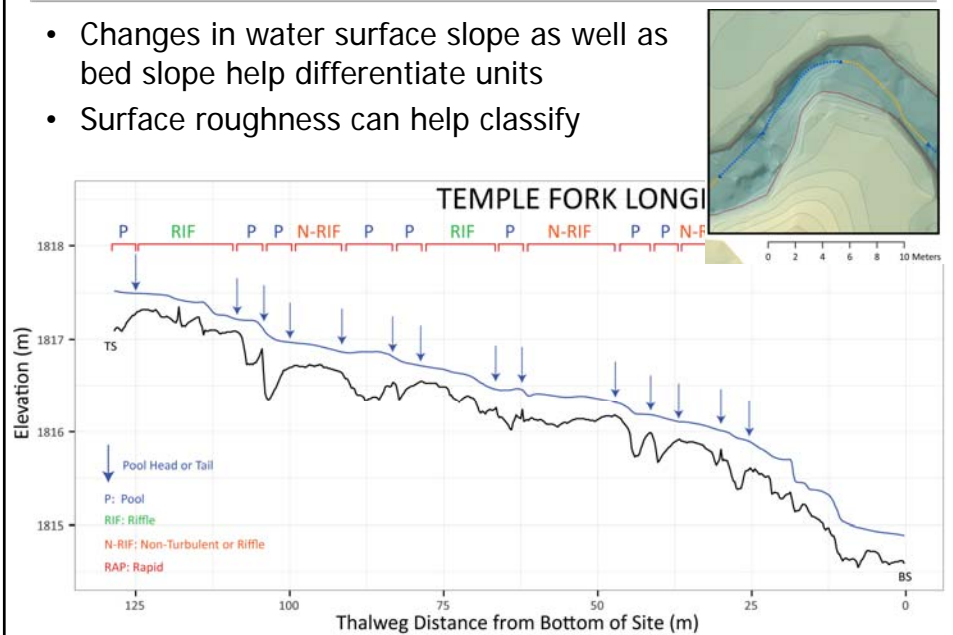
## RBT RESIDUAL POOLS VS BARS...

- Slider madness...



## WE CAN PULL A LONG PRO OFF DEM

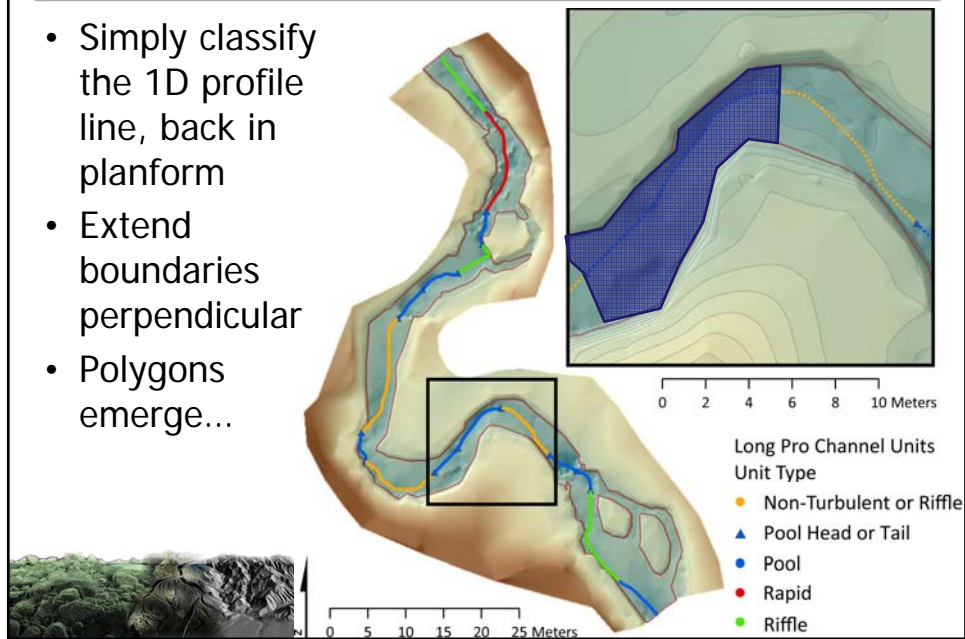
- Changes in water surface slope as well as bed slope help differentiate units
- Surface roughness can help classify



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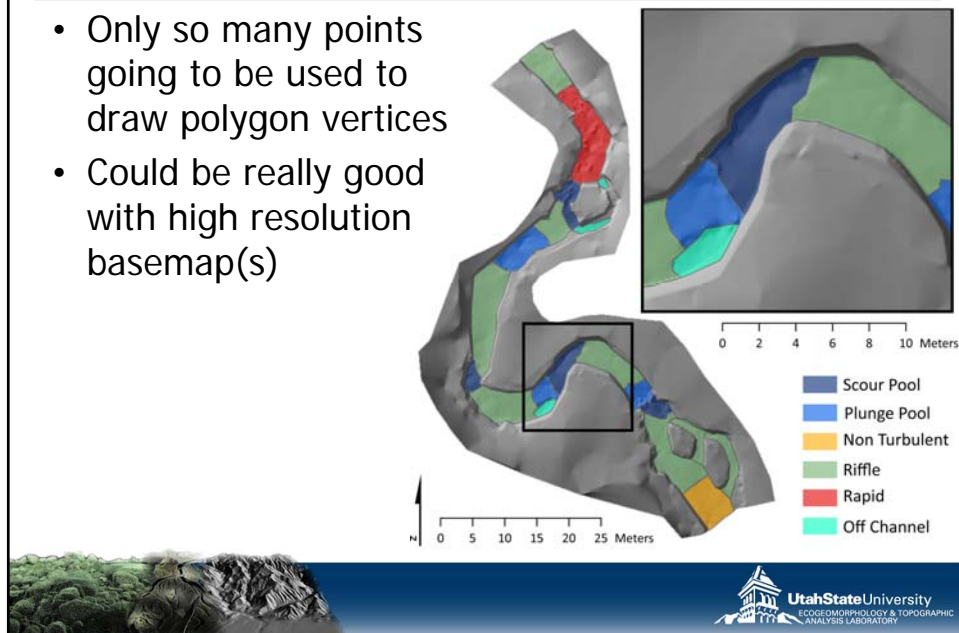
## TRANSLATE 1D BACK TO 2D...

- Simply classify the 1D profile line, back in planform
- Extend boundaries perpendicular
- Polygons emerge...



## FIELD-BASED MAPPING

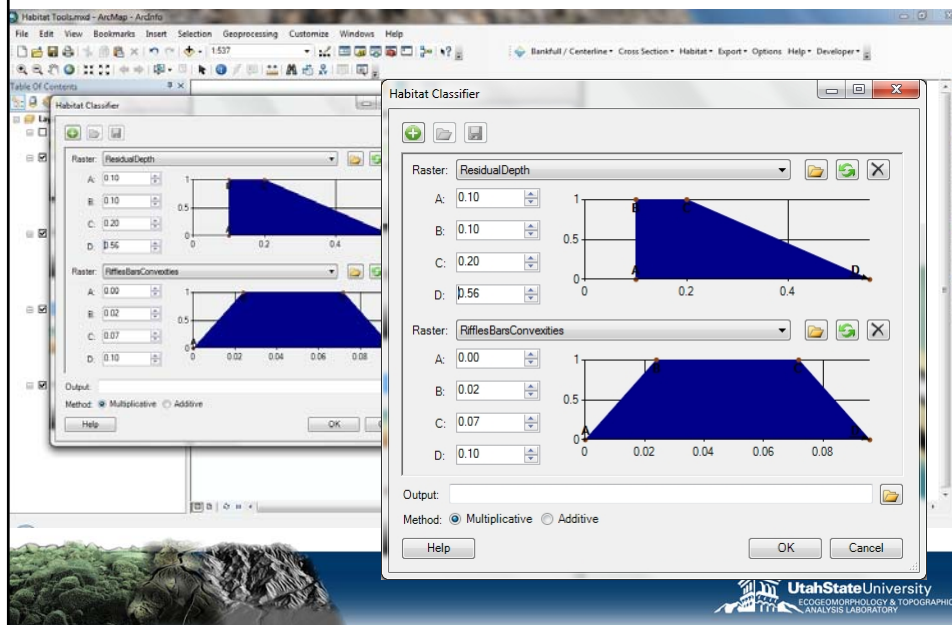
- Only so many points going to be used to draw polygon vertices
- Could be really good with high resolution basemap(s)



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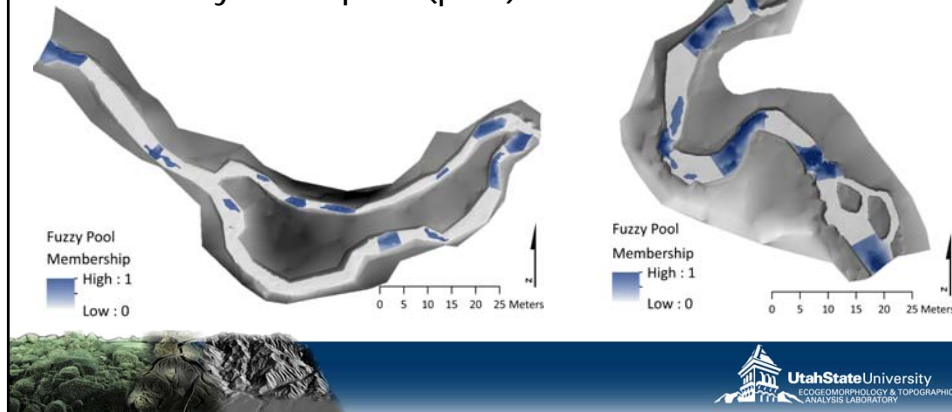


## HABITAT CLASSIFIER - RBT-BETA



## COMBINE ALL WAYS OF DEFINING POOL

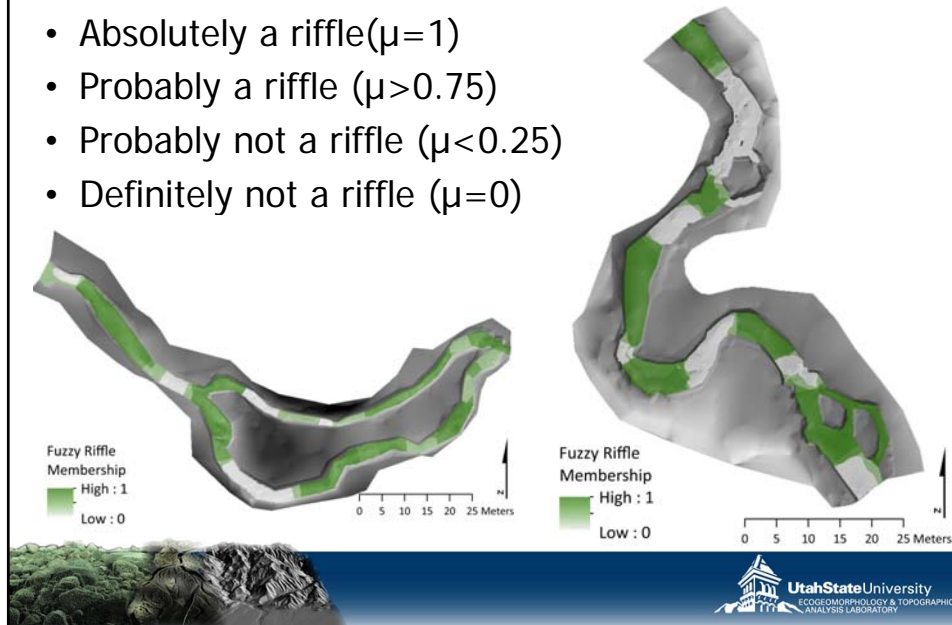
- Absolutely a pool ( $\mu=1$ )
- Probably a pool ( $\mu>0.75$ )
- Probably not a pool ( $\mu<0.25$ )
- Definitely not a pool ( $\mu=0$ )



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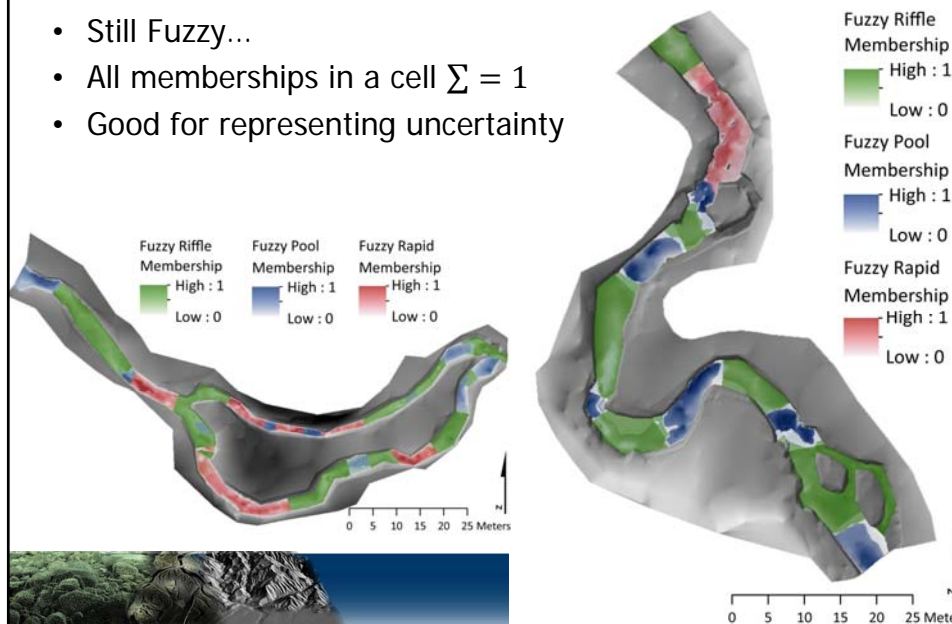
## COMBINE ALL WAYS OF DEFINING RIFFLE

- Absolutely a riffle ( $\mu=1$ )
- Probably a riffle ( $\mu>0.75$ )
- Probably not a riffle ( $\mu<0.25$ )
- Definitely not a riffle ( $\mu=0$ )



## PUT ALL CATEGORIES TOGETHER

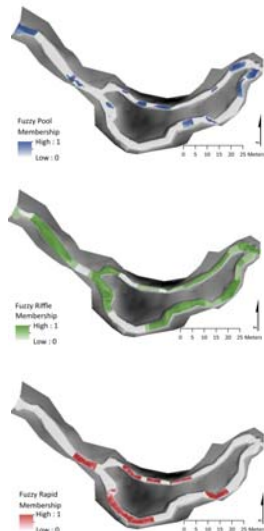
- Still Fuzzy...
- All memberships in a cell  $\sum = 1$
- Good for representing uncertainty



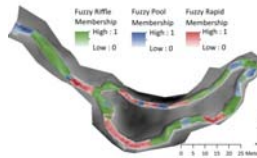
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## COMPLETE HABITAT UNIT CLASSIFICATION

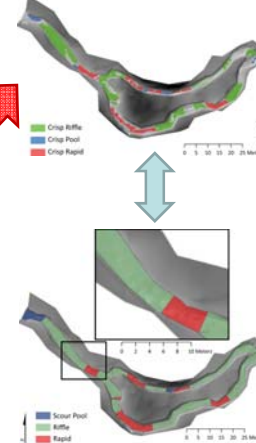
1. Combine information to classify each cell for each habitat category independently



2. Combined fuzzy classification



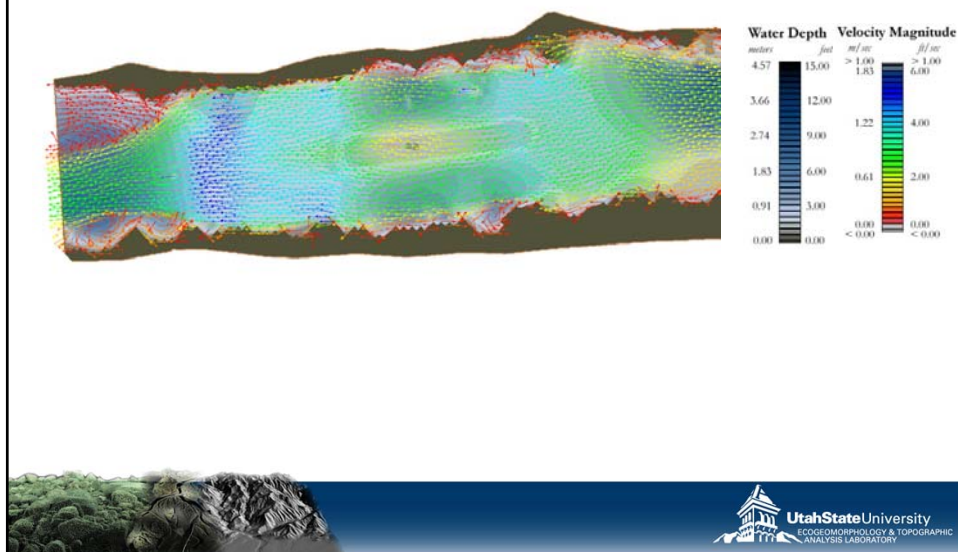
3. Go Crisp



4. Compare with field derived...

## TOPO ALSO SUPPORTS: HYDRAULIC MODELS

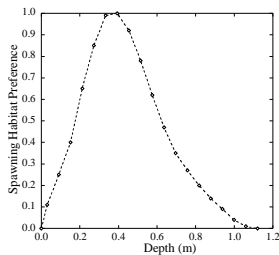
- Can be 1D, 2D or 3D....



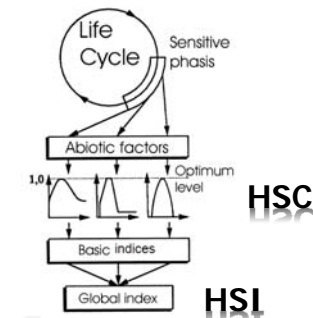
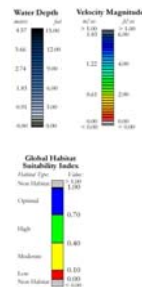
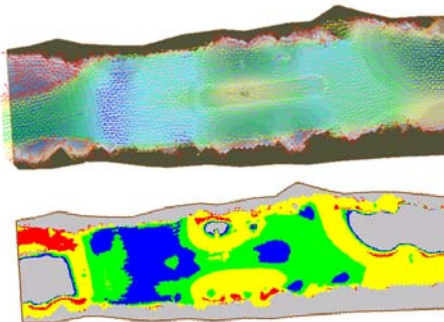
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## ECOHYDRAULIC MODELS...



- Relate physical habitat preferences (empirically through observations) to abiotic variables
- Habitat suitability curves are species and lifestage specific

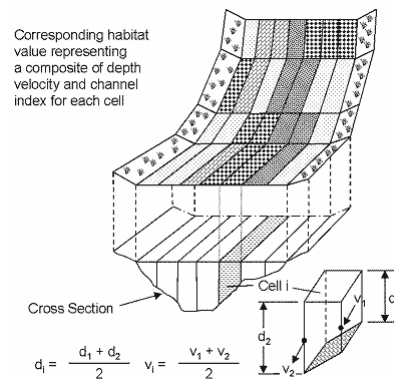


Building a classical fish preferendum model  
From LeClerc (2005)

## PHABSIM...

<http://www.fort.usgs.gov/products/software/phabsim/>

- Physical Habitat Simulation Software
- Technique developed in mid 1970s
- Most widely used ecohydraulic model
- This is an HSC technique... Can be applied in 1D, 2D or 3D



Bovee KD and Milhous R. 1978. *Hydraulic simulation in instream flow studies: theory and techniques*. Instream Flow Information Paper 5. FWS/OBS-78/33, U. S. Fish and Wildlife Service, Fort Collins, CO, 156 pp. Available at:

<http://www.fort.usgs.gov/Products/Publications/22457/22457.pdf>.



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## MID 90's... PEOPLE STARTED SAYING



- 1D is not realistic

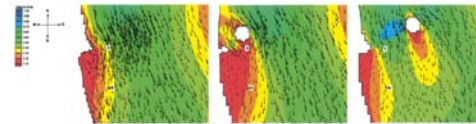
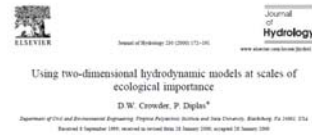


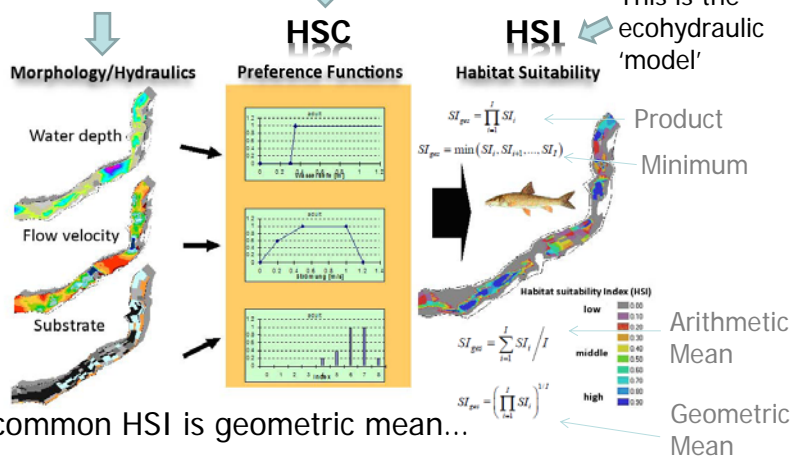
Fig. 8. The effect obstruction size and placement has on local habitat conditions. The plots represent averaged values of habitat conditions near the obstruction. Velocity conditions indicated are along the river reach. The plots are the surface of a 3.0 x 1.0 m<sup>2</sup> obstruction placed near the bank. (a) Obstruction in the flow channel produced by a single 2.0 x 1.0 m<sup>2</sup> obstruction placed far from the river.

## SAME HSC DRIVEN APPROACH... BETTER

This is the abiotic input

This is the empirical biotic input

This is the ecohydraulic 'model'



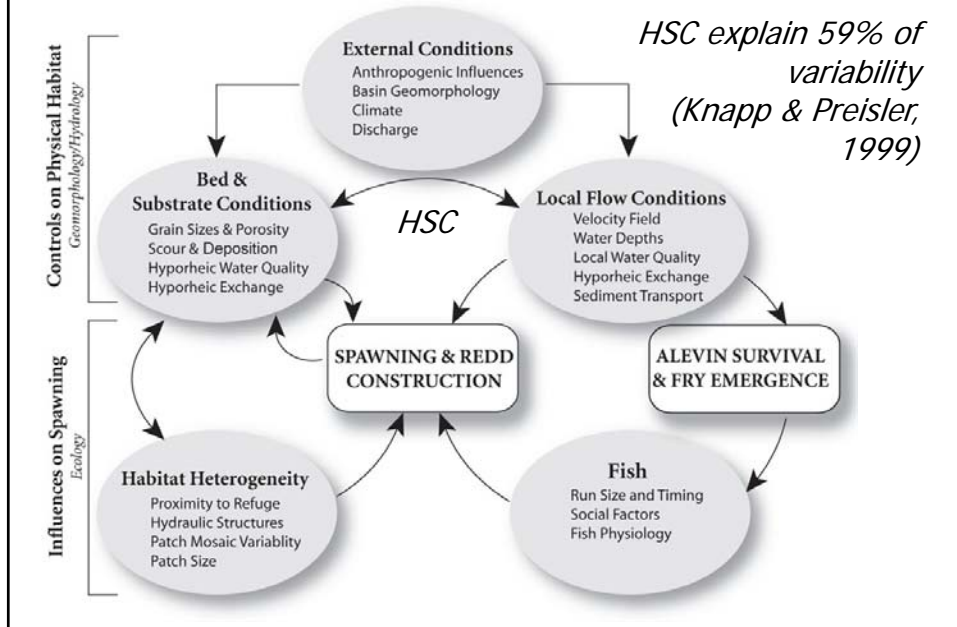
- Most common HSI is geometric mean...
- You can also weight individual HSCs

[http://www.casimir-software.de/data/CASiMiR\\_Fish\\_Handb\\_EN\\_2010\\_10.pdf](http://www.casimir-software.de/data/CASiMiR_Fish_Handb_EN_2010_10.pdf)



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## IF MODEL PERFORMS POORLY...



## IS HETEROGENEITY IMPORTANT TO A SPAWNING FEMALE SALMON?

Habitat Heterogeneity is usually assumed to support species diversity (assumed to be good).



What are specific ecological benefits of habitat heterogeneity to spawning salmonids?





## THREE TYPES OF REFUGIA...

1. **Predation** Refugia – (Cover) Protection from Predation
2. **Energy** Refugia - Resting Areas (i.e. shear zones)
3. **Thermal** Refugia – Get away from the mean!

Predation Refugia from:

- Bank Vegetation
- LWD
- Boulders
- Deep Pools

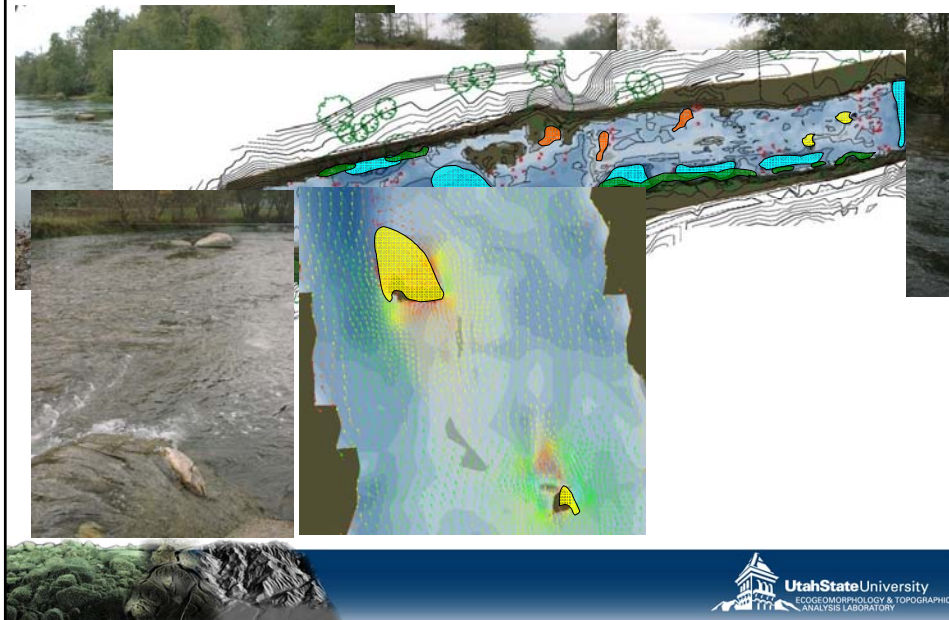
Energy Refugia from

Shear Zones induced by:

- Irregular Banks
- LWD
- Boulders
- Bed Forms



## DEFINING HABITAT HETEROGENEITY - REFUGIA



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## WE CAN MAP 1 & 2 REFUGIA ZONES...

- Can just use an iPad



## BIOENERGETICS MODEL:

$$\text{Consumption} = \text{Growth} + \text{Respiration} + \text{Egestion} + \text{Excretion}$$

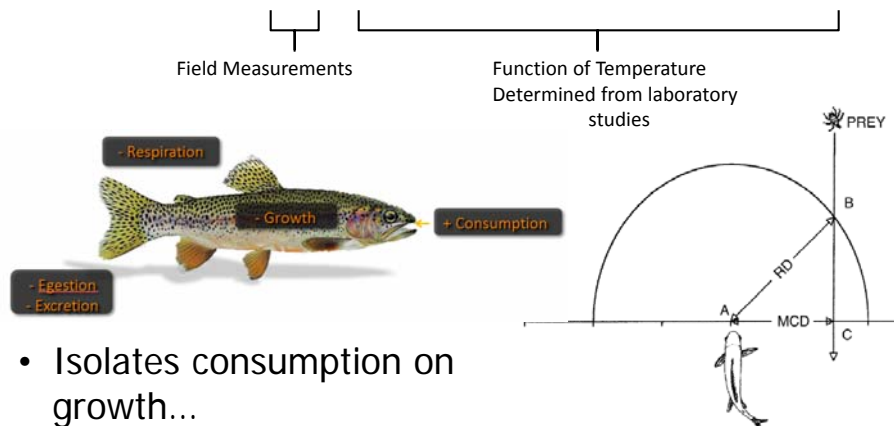
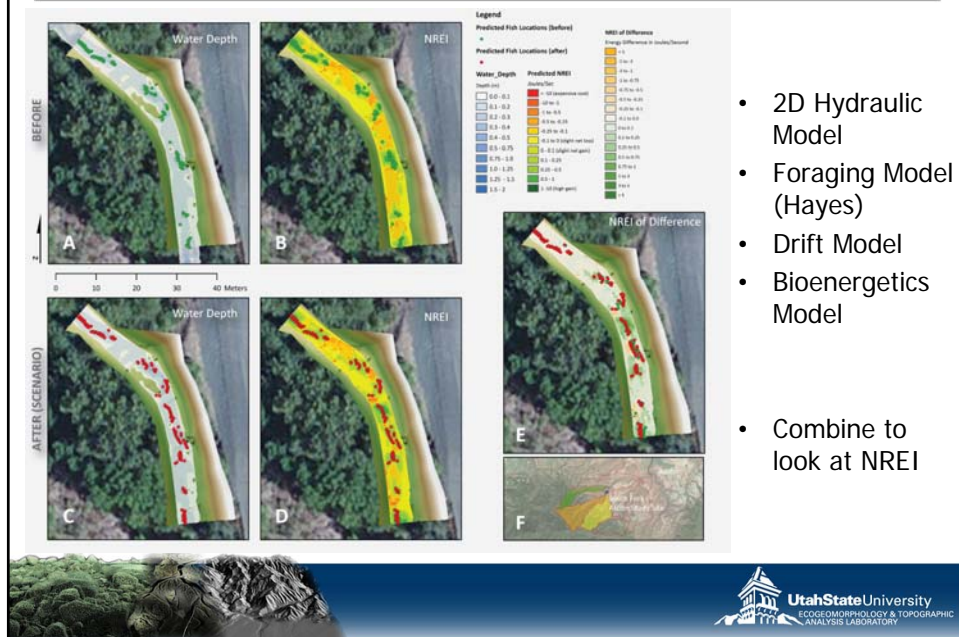


Fig. 3 ~ Plan view of the foraging model showing the geometry of prey interception. The fish is assumed to

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## NET RATE OF ENERGY INTAKE – BIOENERGETICS

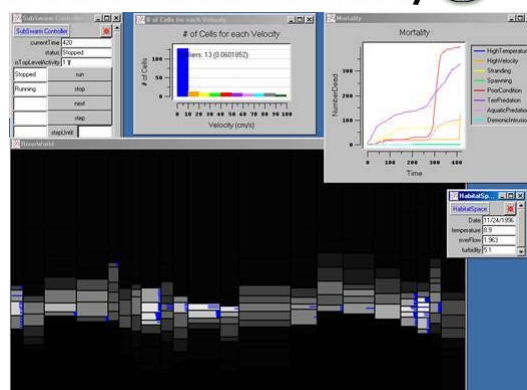


- 2D Hydraulic Model
- Foraging Model (Hayes)
- Drift Model
- Bioenergetics Model
- Combine to look at NREI

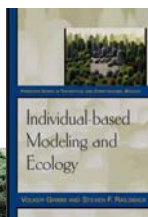
## inSTREAM

### Individual-Based Modeling and Ecology at Humboldt State University

- Fancy rules for spatially and temporally varying hydraulics, temperature, turbidity and food availability
- Crude 1D model



Railsback & Harvey (2002) Ecology;  
Book: Grimm & Railsback (2005)



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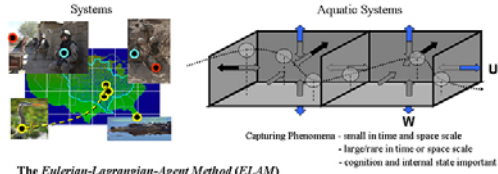


# ELAM

## Cognitive Ecology & Ecohydraulics Research

Using Cognition in the Analysis & Forecasting of Behavior within Complex Environments

- Fancy 3D CFD hydraulics and sophisticated agent-based model of cognitive response to sensory input



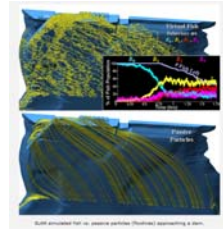
### The Eulerian-Lagrangian-Agent Method (ELAM)

- Eulerian** framework: governs physical, hydraulic, water quality, terrestrial, avian, and cultural/social domains.  
→ math composed of fields.
- Lagrangian** framework: governs sensory perception and movement of individuals.  
→ continuous directional trajectory composed of discrete locations.
- Agent** framework: governs cognitive domain responsible for conversion of sensory input into behavior.  
→ mathematics of sensory perception/processing, learning, acclimatization, memory, and internal state.

### Ecohydraulics: Fish Passage & Guidance



Engineering design when the decision making of animals dictates success.



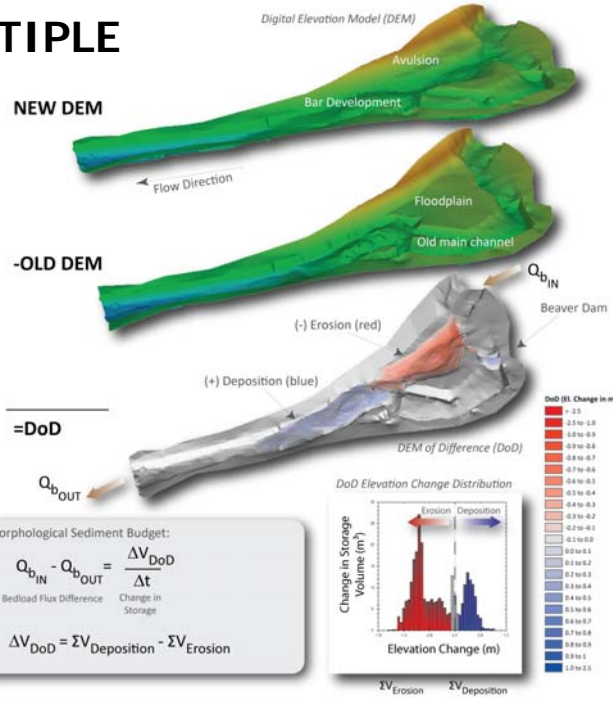
(Click Here for Analysis of Specific Individual Fish)

<http://el.erdc.usace.army.mil/emrrp/nfs/fishpassage.html> State University

## WHAT IF MULTIPLE TOPOS?

A little background...

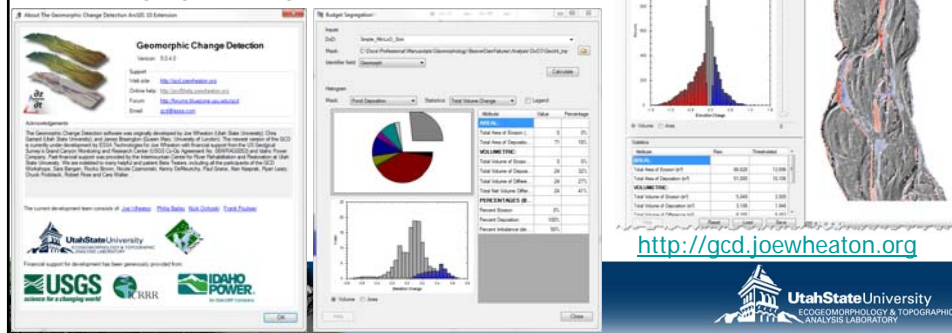
- DEM -> digital elevation model
- GCD -> geomorphic change detection



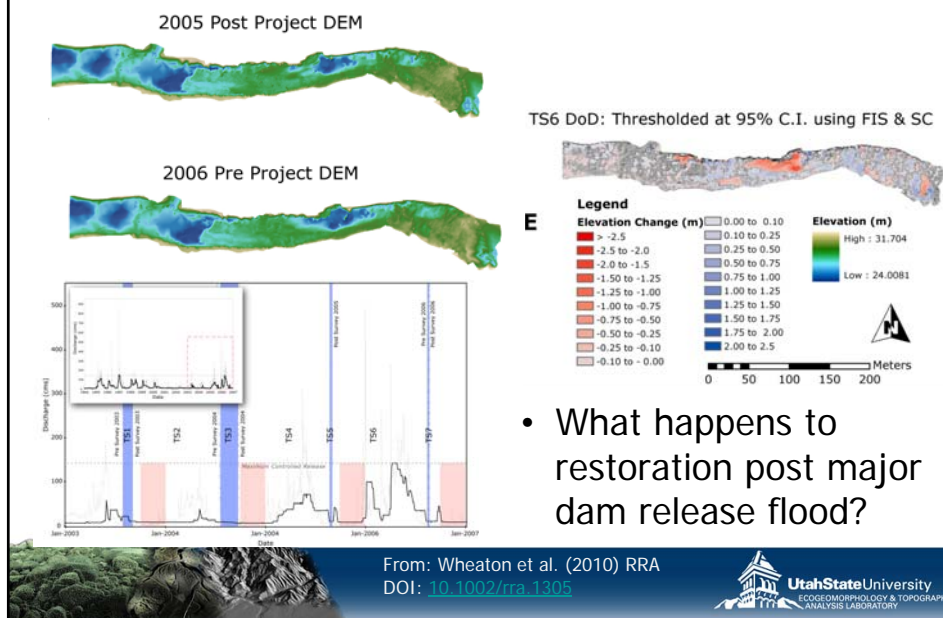
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## GCD SOFTWARE

- **GCD 5** makes it easy to:
  - Robustly estimate errors in DEMs
  - Determine significance of uncertainty on DoD & Sediment Budget
  - Calculate change in storage sediment budgets (with +/- vol.)
  - Quantitatively interpret and spatially segregate budget



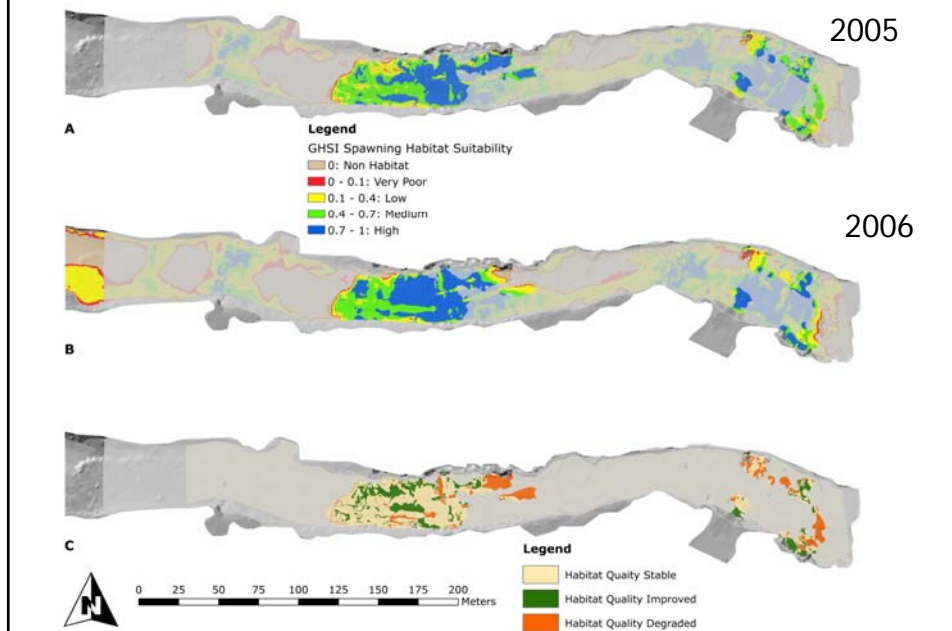
## DO GEOMORPHIC DYNAMICS MATTER TO FISH?



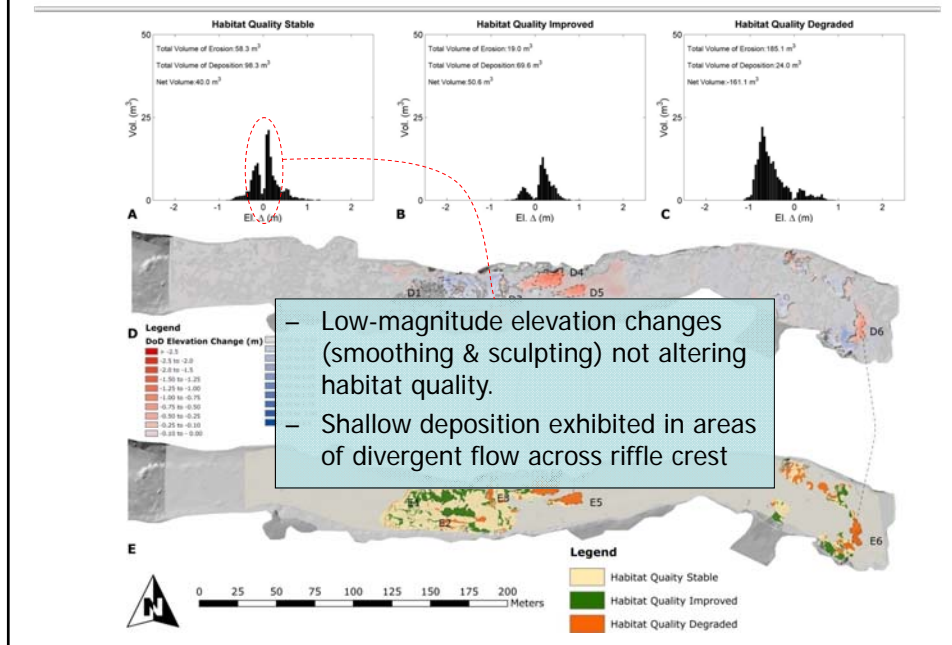
- What happens to restoration post major dam release flood?

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## DIFFERENT $\alpha_z/\alpha$ LEADS TO DIFFERENT $HSI$

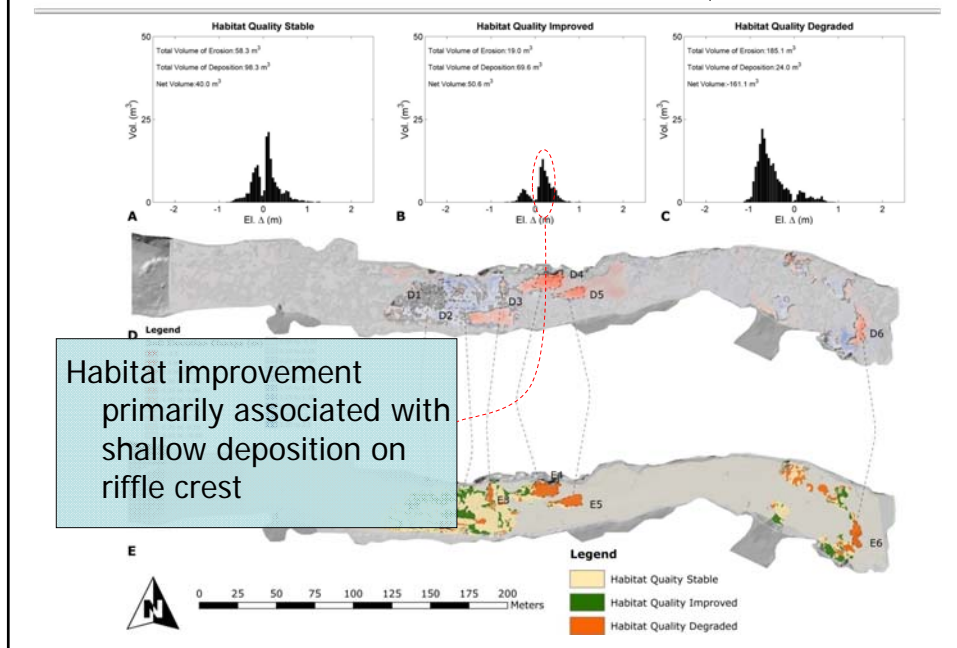


## EXPLAIN $\Delta HSC$ IN TERMS OF $\alpha_z/\alpha$

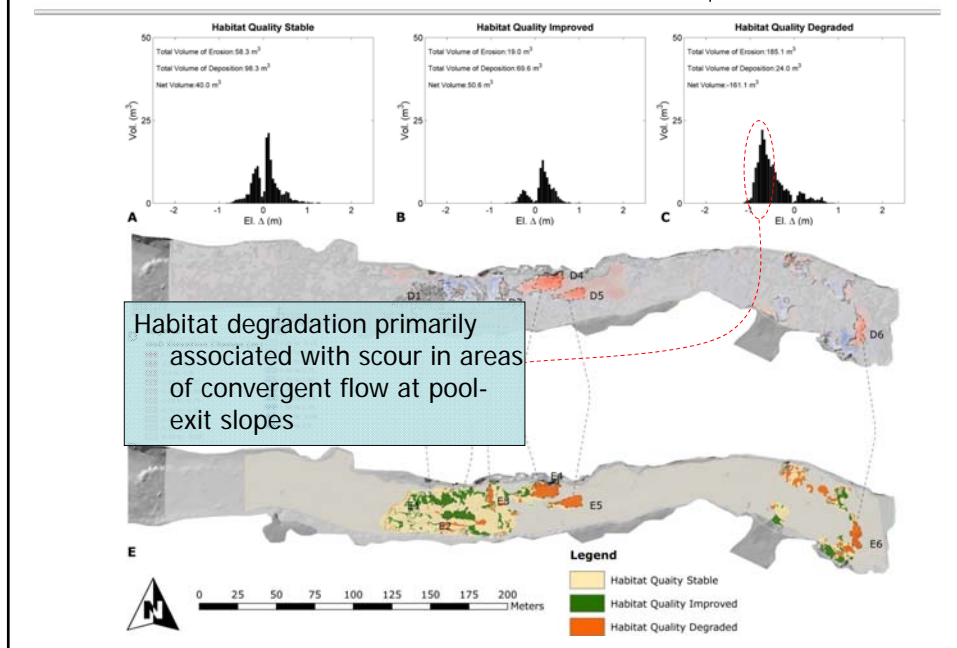


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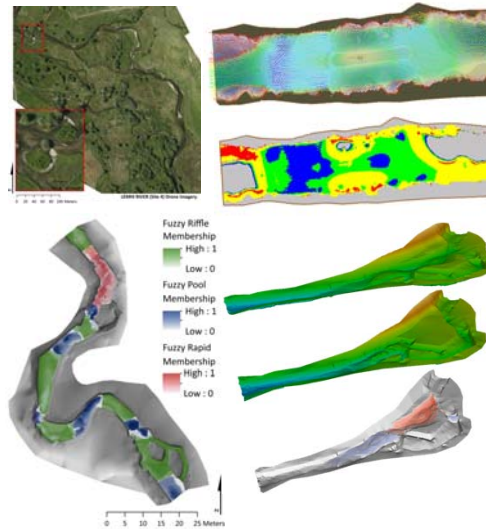


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## SO... PAINTING QUANTITATIVE PICTURES

- An Aerial Photo
  - Habitat Mapping
  - Grainsize Mapping
- A Topo
  - Habitat Units
  - Habitat Heterogeneity
  - Hydraulic Models
  - Ecohydraulic Models
- Multiple Topos
  - Geomorphic Change Detection



## CHEAP DESIGN & MONITORING APPs...

- Transparently document design intent
- Articulate explicit, testable design hypotheses (THE EXPERIMENT)
- Combines design, installation & monitoring into one App

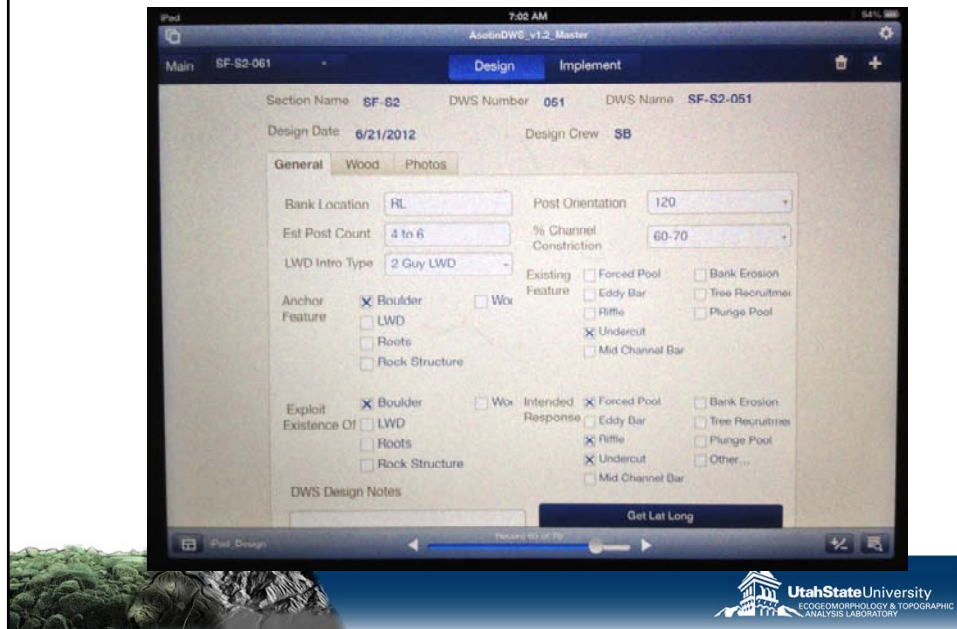


Nick Weber of Eco Logical Research, Inc.



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## DWS DESIGN APP...



## WHEN IT DOES NOT FIT IN THE FORM...

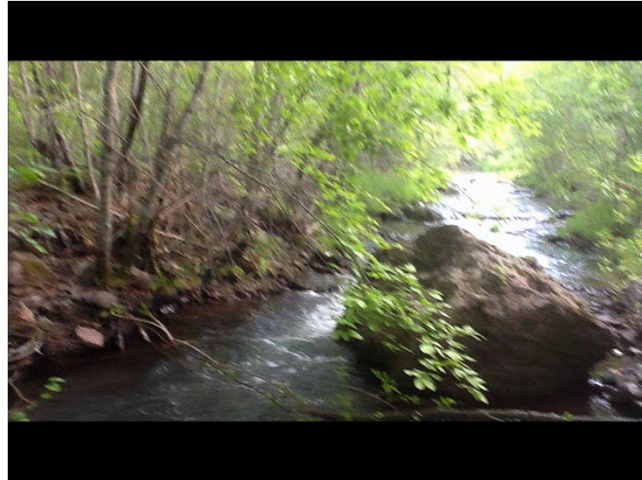
- A geotagged video or voice note captures the observations...
- Don't let technology stifle the power of observation
- Designers record video & optionally installation crew records video



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## TYPICAL YouTube CAT DESIGN VIDEO

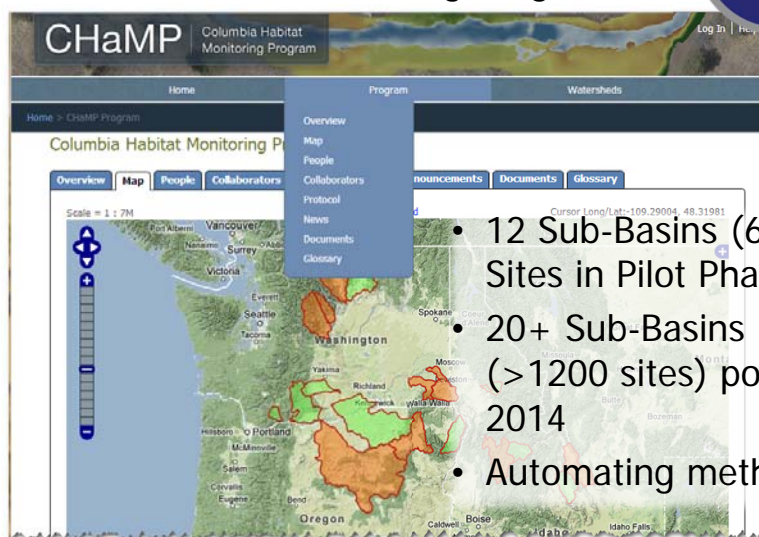
- Not going to win any



## THIS IS NOT JUST ACADEMIC...

- Columbia Habitat Monitoring Program

CHaMP



- 12 Sub-Basins (600 Sites in Pilot Phase)
- 20+ Sub-Basins (>1200 sites) post 2014
- Automating methods

Visit: <http://champmonitoring.org>

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