Simulating the Effects of Ridge Elevation and Geometry on Ridge-Slough Landscape Hydrology

Subodh Acharya[1], David A. Kaplan[2], Matthew J. Cohen[1], James W. Jawitz[3],

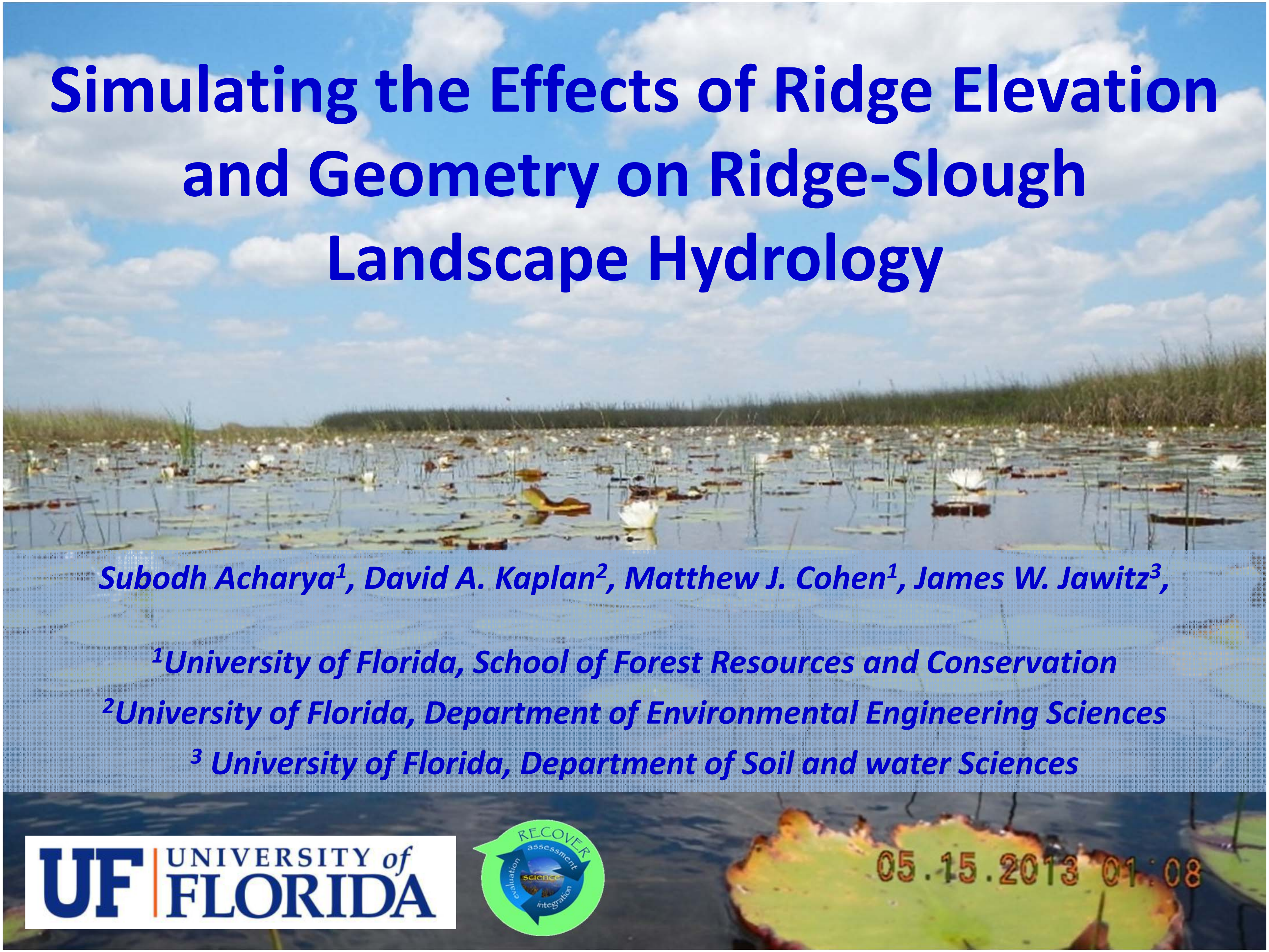
[1]University of Florida, School of Forest Resources and Conservation

[2]University of Florida, Department of Environmental Engineering Sciences

[3] University of Florida, Department of Soil and water Sciences

UNIVERSITY of FLORIDA

RECOVER assessment science integration evaluation



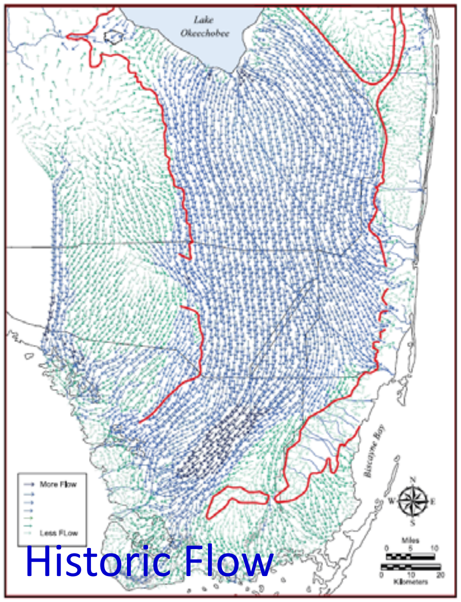
Ridge-Slough Pattern and Degradation

<u>Historic System</u>:

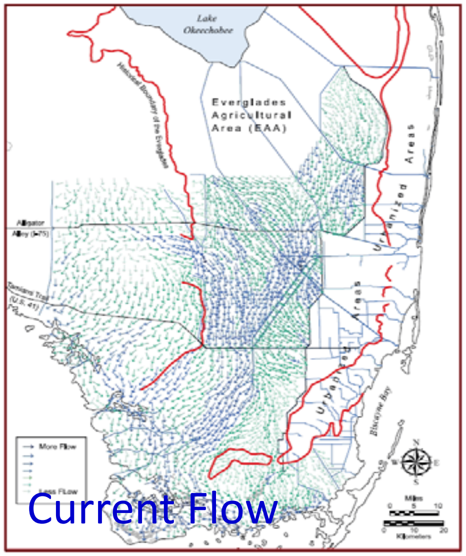
- Parallel sawgrass ridges interspersed by sloughs, elongated in flow direction
- Heterogeneous ecosystem, high diversity

<u>After Hydrologic Modification</u>:

- Drainage for agriculture (EAA); compartmentalization
- Flow volume significantly reduced due to water diversion
- Loss pattern to a more homogeneous system
- Loss of diversity; other negative ecological impacts



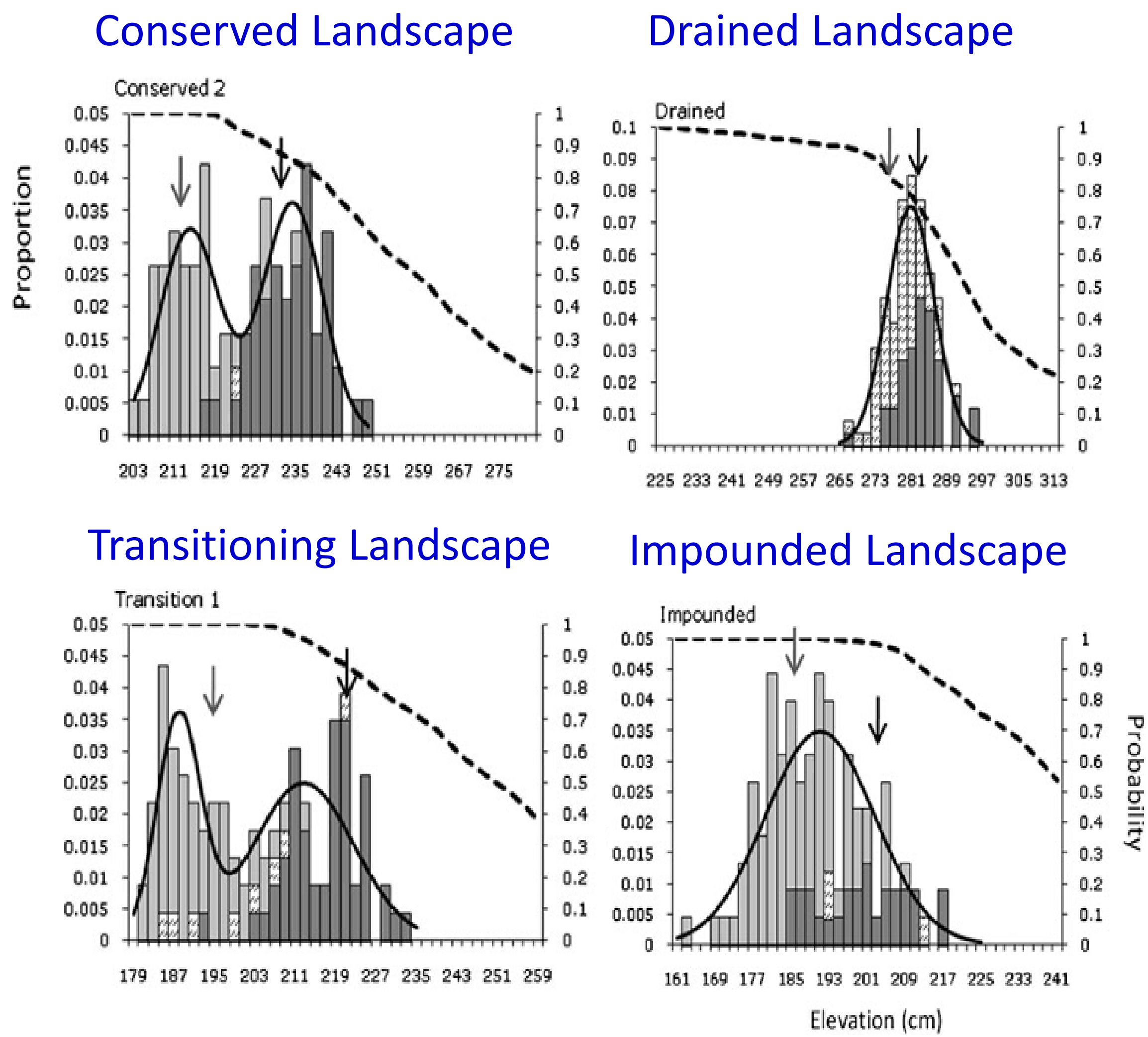
Conserved RS Landscape



Degraded RS landscape

Loss of Peat in the RS Landscape

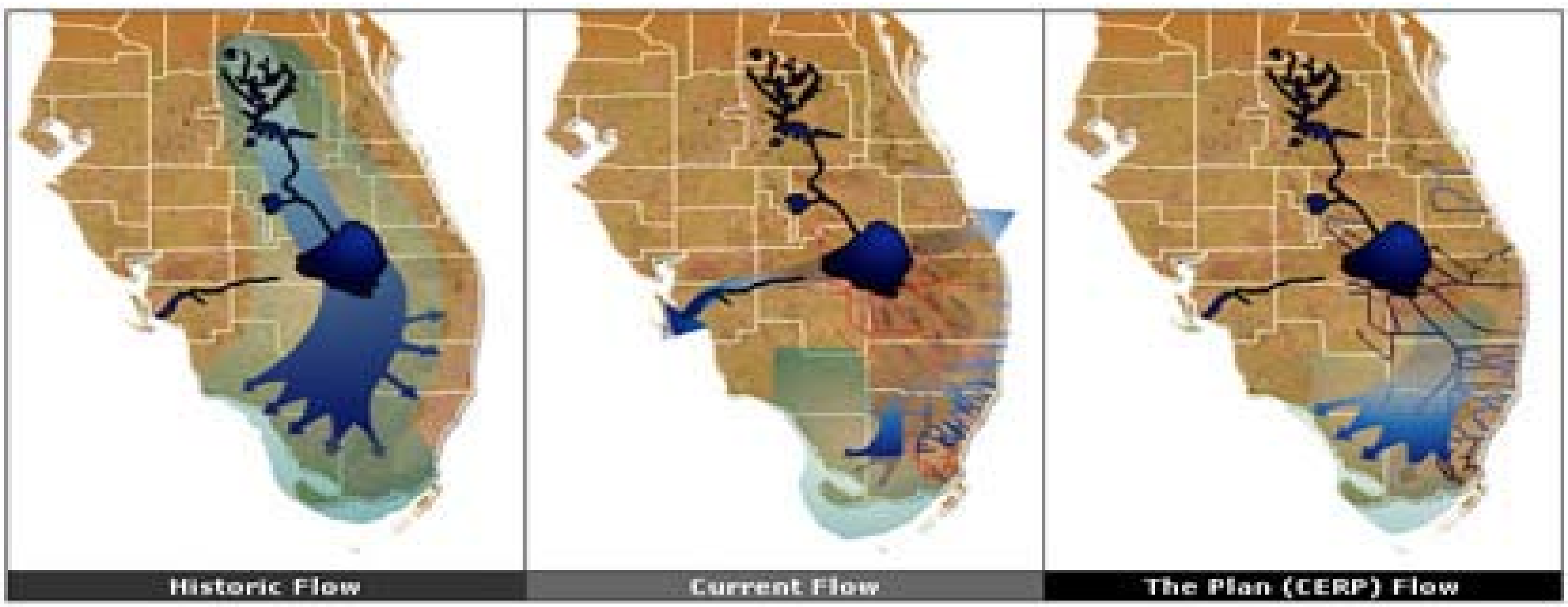
- Historic ridge elevation may have ranged from 60 – 90 cm (*SCT, 2003*)
- Currently conserved landscapes have approx. 25 cm ridge elevations (*Watts et al., 2010*)
- Reduction in flow = reduction in annual inundation frequency (**Hydroperiod**)
- Rapid oxidation of carbon



Watts et al., 2010

Everglades Restoration

- Extensive restoration efforts under the Comprehensive Everglades Restoration Plan (CERP); >$10.5 billion over 30+ years
- One of the several goals is to restore the flow
  - Increased flow = longer annual hydroperiod (HP)
  - Longer HP = longer reduced state; peat conservation/accretion

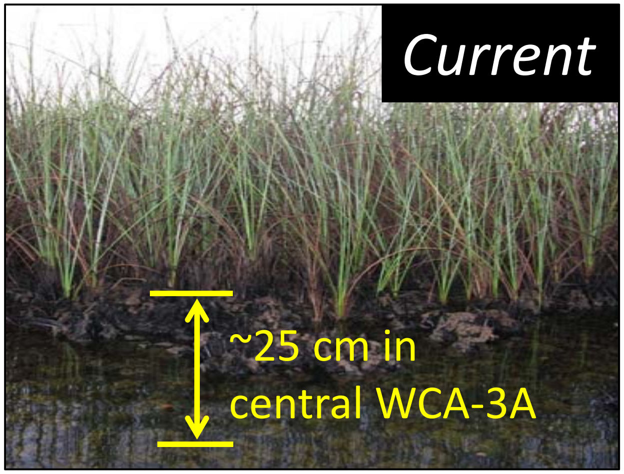


http://www.nps.gov/ever/learn/nature/cerp.htm

Flow Restoration in the Ridge/Slough

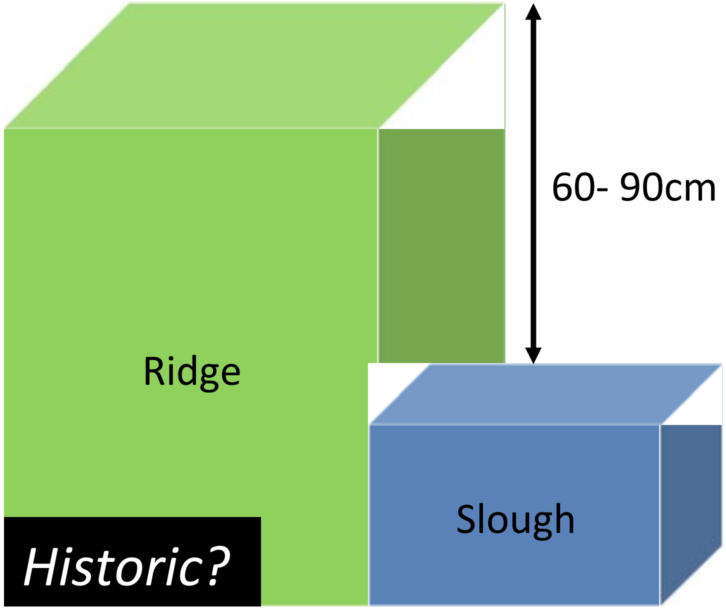
Overarching Questions

- What were the historic flows ?
- How will the R-S landscape respond to higher flow regime?
- Will historic patterns and ridge heights return?



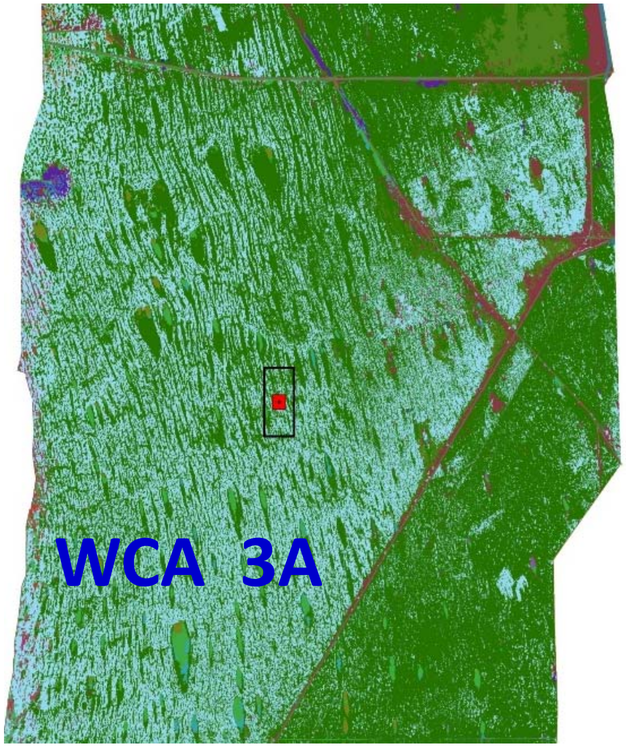
Specific Research Goals:

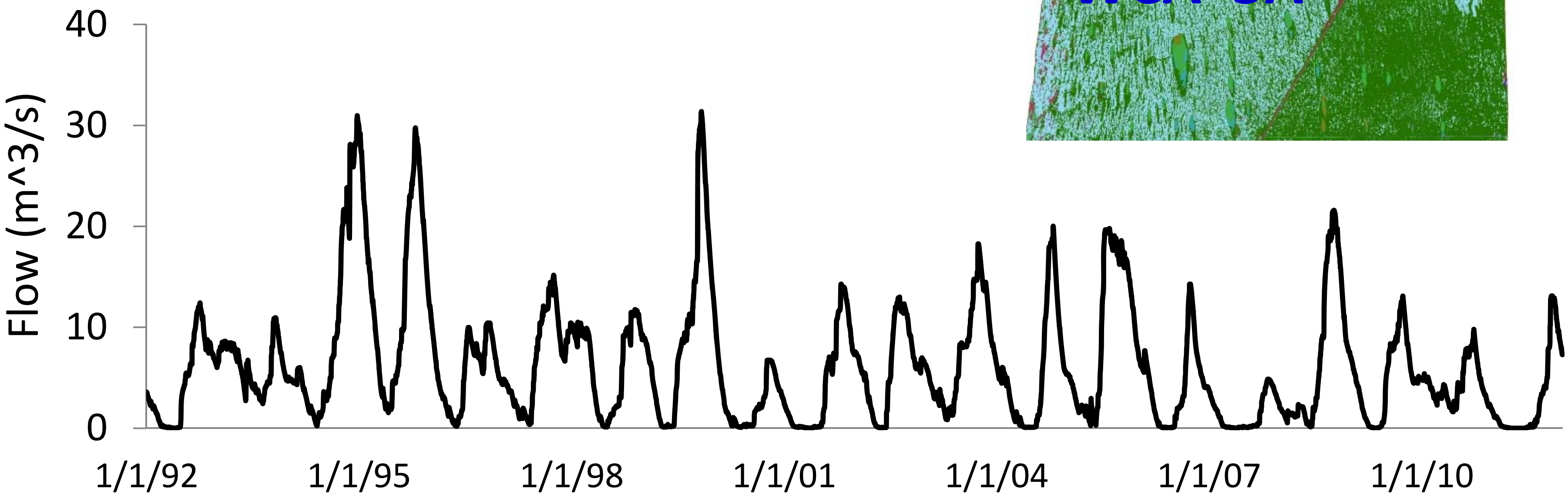
- Model hydroperiods under current and restored flow regime given higher ridge elevations
- Estimate potential ridge heights under restored flow regime
- Estimate flow required to maintain sufficient HP with higher ridges



<u>FIRST</u>: Need to Estimating *Contemporary* Flow

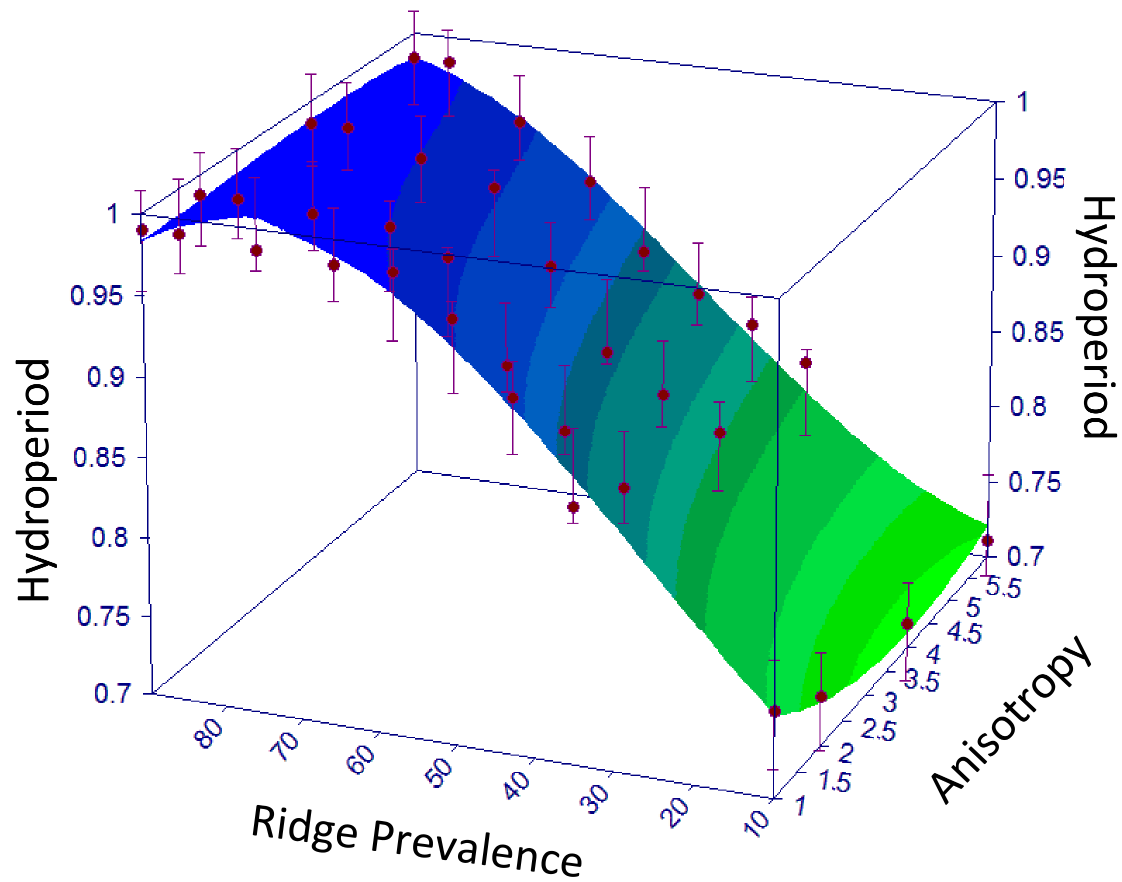
- EDEN Site 64: 20-year time series of water levels
- Use SWIFT2D (USGS, 2004) to model flows **in conserved (benchmark) landscape**
- Calculate "discharge competence"





NEXT: Effect of Ridge Prevalence and Geometry

- SWIFT2D used to develop relationships between pattern (ridge prevalence and anisotropy) and hydroperiod
- Assumes contemporary flow and ridge height (ΔZ) = 25 cm
- Estimated hydroperiod in the benchmark landscape = 0.86



Acharya et al., 2015, HESS (In Press)

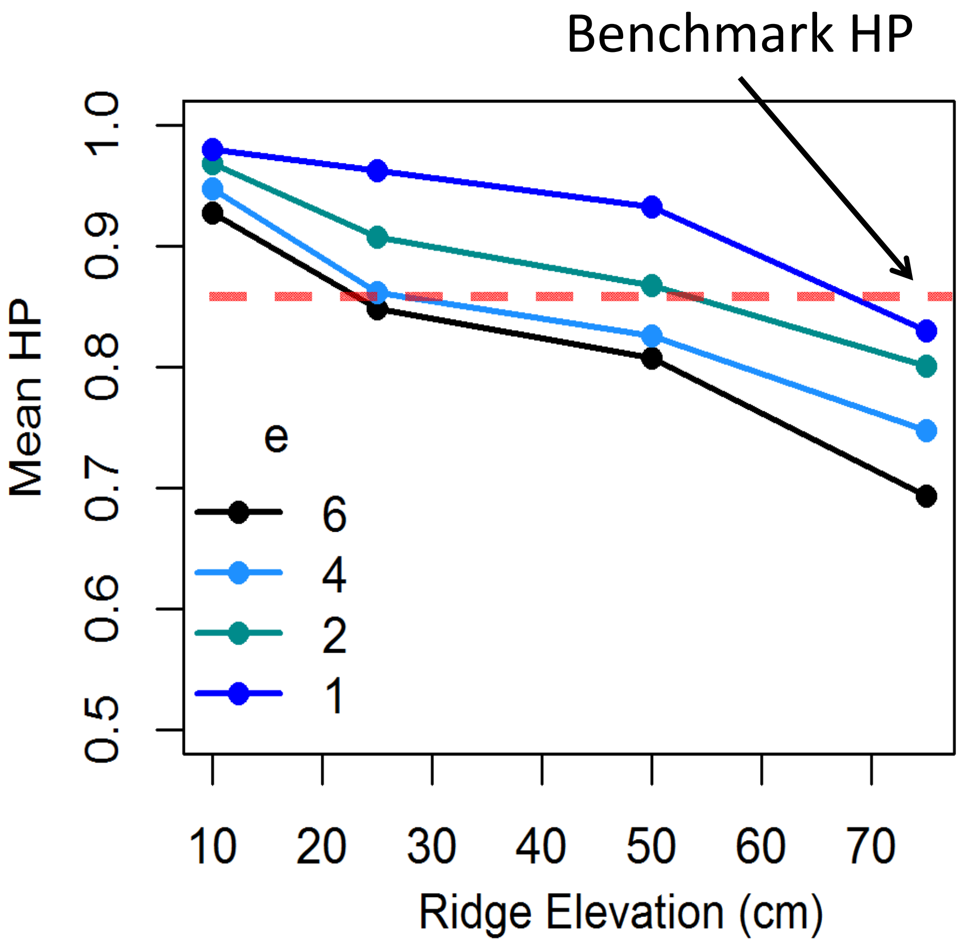
FINALLY: Incorporate Effect of Ridge Elevation (ΔZ)

Approach:

- Ridge prevalence fixed at 50%
- Anisotropy varied from 1 to 6
- ΔZ varied from 10 to 75 cm
- Applied **contemporary flows** and calculated hydroperiod

Results:

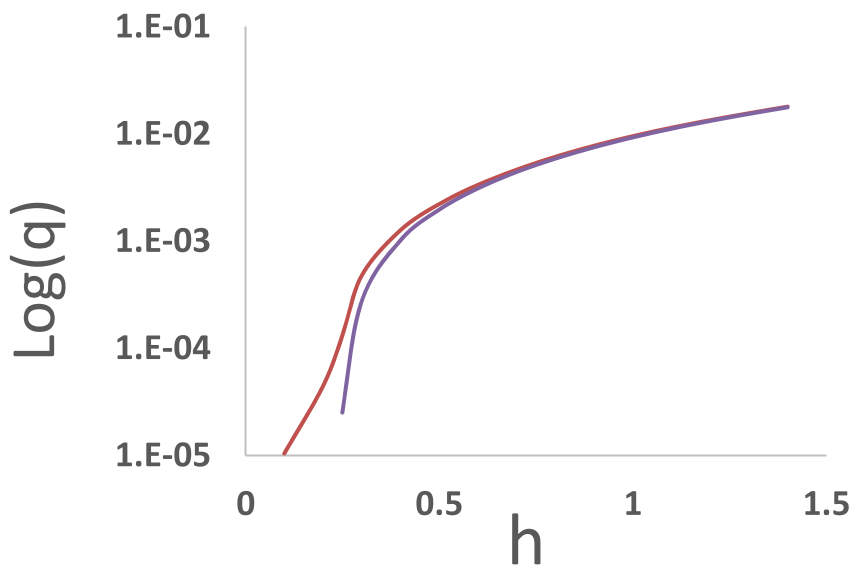
- Landscapes with ΔZ> 25 cm significantly drier, even at high anisotropy
- HP of 0.86 observed in benchmark landscape not achievable at high ΔZ



What flow would be required to achieve HP = 0.86 under ΔZ > 25 cm ?

CHALLENGE: Limited Historic Flow Information

Approach: Rating curve transformations to estimate hydroperiod

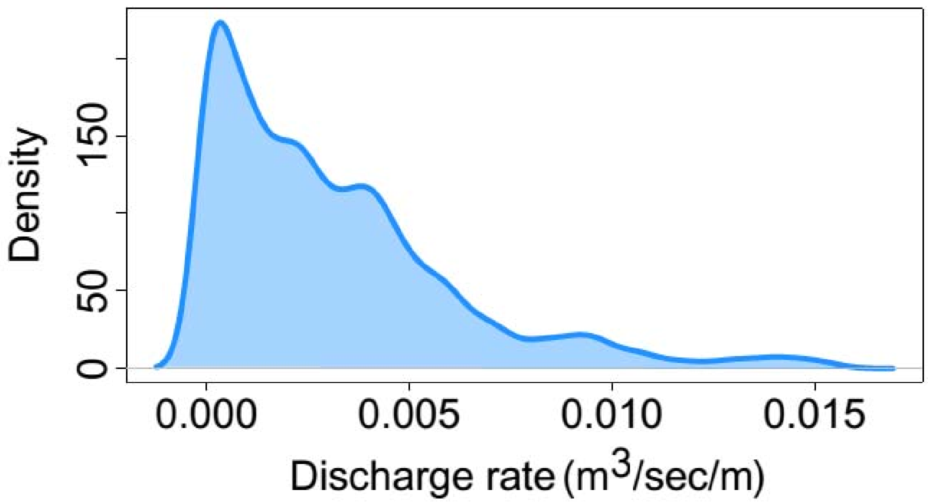


Based on the idea that the two landscapes with different spatial geometry, subject to the same flow, will have different rating curves and hence different HP.

Same Flow, Different HPs

Rating Curve Transformation (RCT): a Stochastic Technique

1. Log-normally distributed contemporary flow (mean, variance)



$$Q = a_1(h_1 - c_1)^{b_1} = a_2(h_2 - c_2)^{b_2}$$

2. Mean and variance of contemporary flow used to estimate parameters of water level distribution in different landscape

$$\mu_{\ln h_{2,s}} = \ln\left(\frac{a_1}{a_2}\right)^{\frac{1}{b_2}} + \frac{b_1}{b_2}\mu_{\ln h_{1,s}}$$

$$\sigma^2_{\ln h_{2,s}} = \left(\frac{b_1}{b_2}\right)^2 \sigma^2_{\ln h_{1,s}}$$

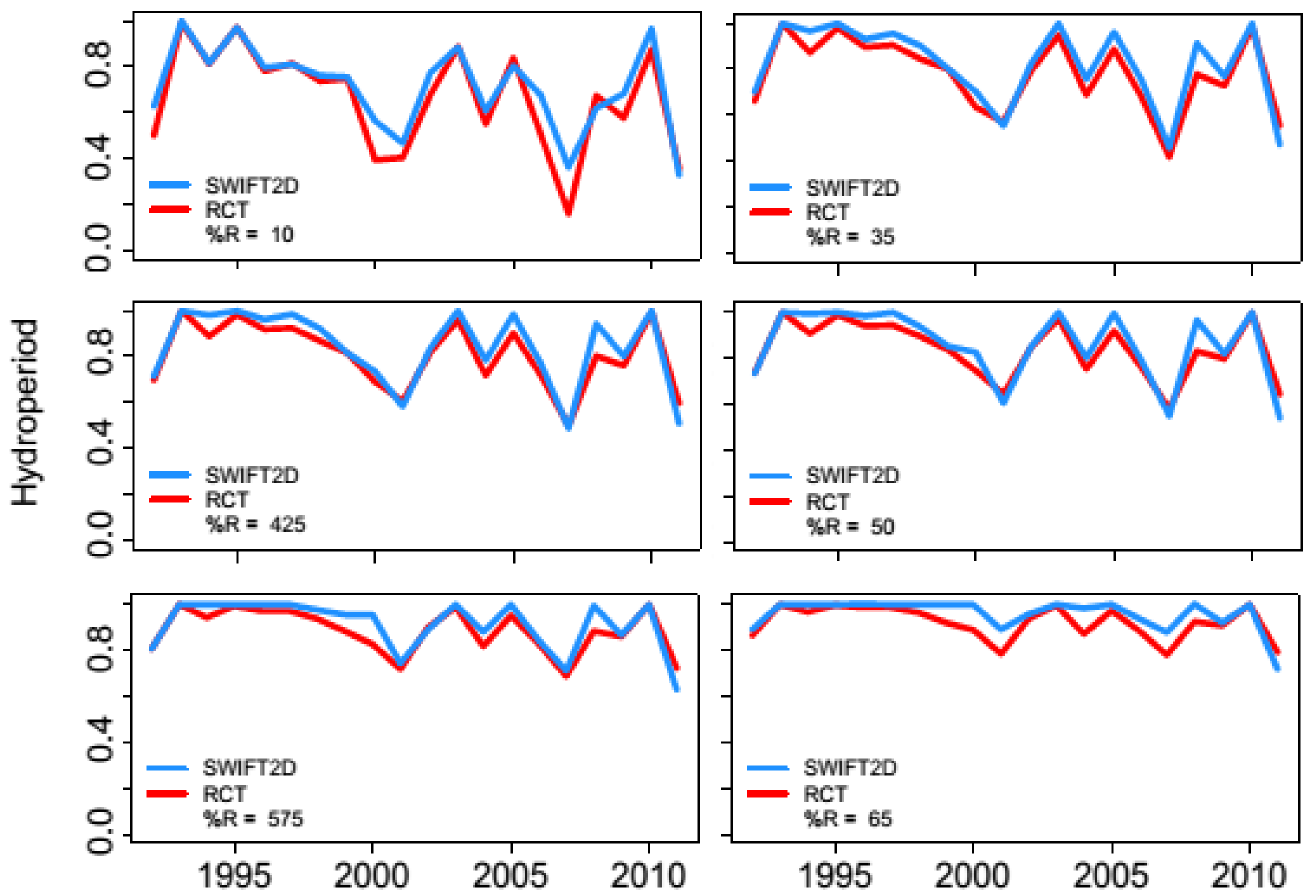
$$h_{1,s} = h_1 - c_1;\ h_{2,s} = h_2 - c_2$$

3. HP estimated as the lower-truncated zeroth-moment of the h distribution (*Jawitz, 2004, AWR*)

$$HP = m_0(h^*, \infty) = \frac{1}{2}\left(1 - \mathrm{erf}\left[\frac{\ln h^* - \mu_{\ln h_i}}{\sigma_{\ln h_i}\sqrt{2}}\right]\right)$$

Rating Curve Transformation: HP estimates

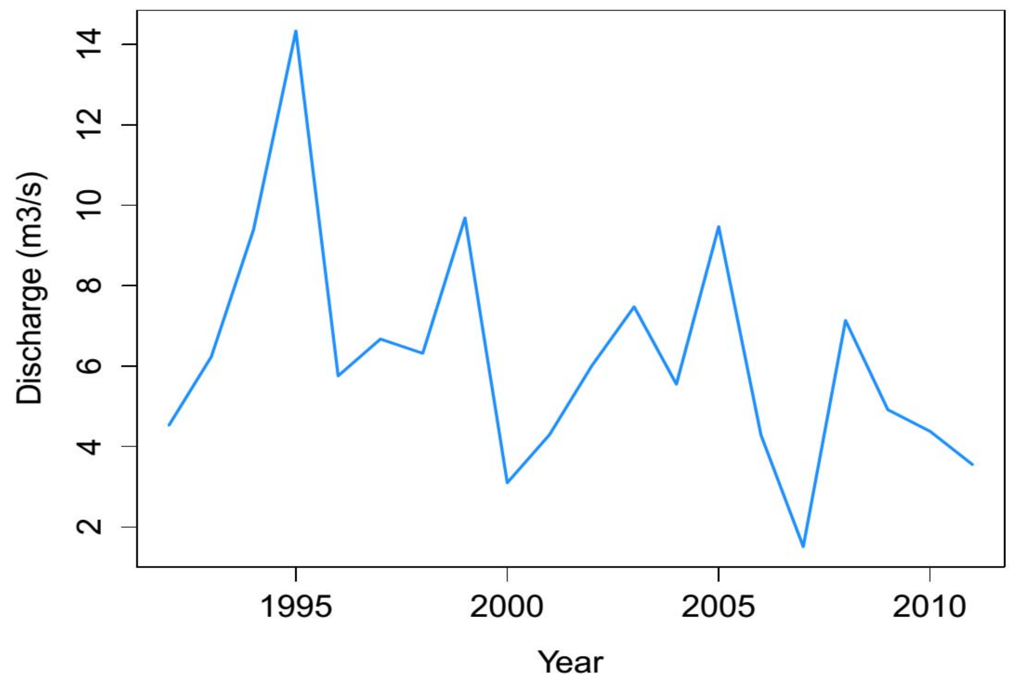
- HP calculated with RCT agrees well with SWIFT2D
- RCT only requires mean and variance of the flow distribution to estimate HP
- Allows testing of hypothesized historic flows



Estimating Hydroperiod Under Different Flows

- Statistics for 20 years of data from calculated contemporary flows
- Randomly sampled mean and variance 5000 times
- Hydroperiod estimated using RCT method for Δz = 10, 25, 50, 75cm
- **RESULT**: Hydroperiod distributions and probability of reaching the ***target 0.86 HP*** under a specific flow regime

Mean daily discharge

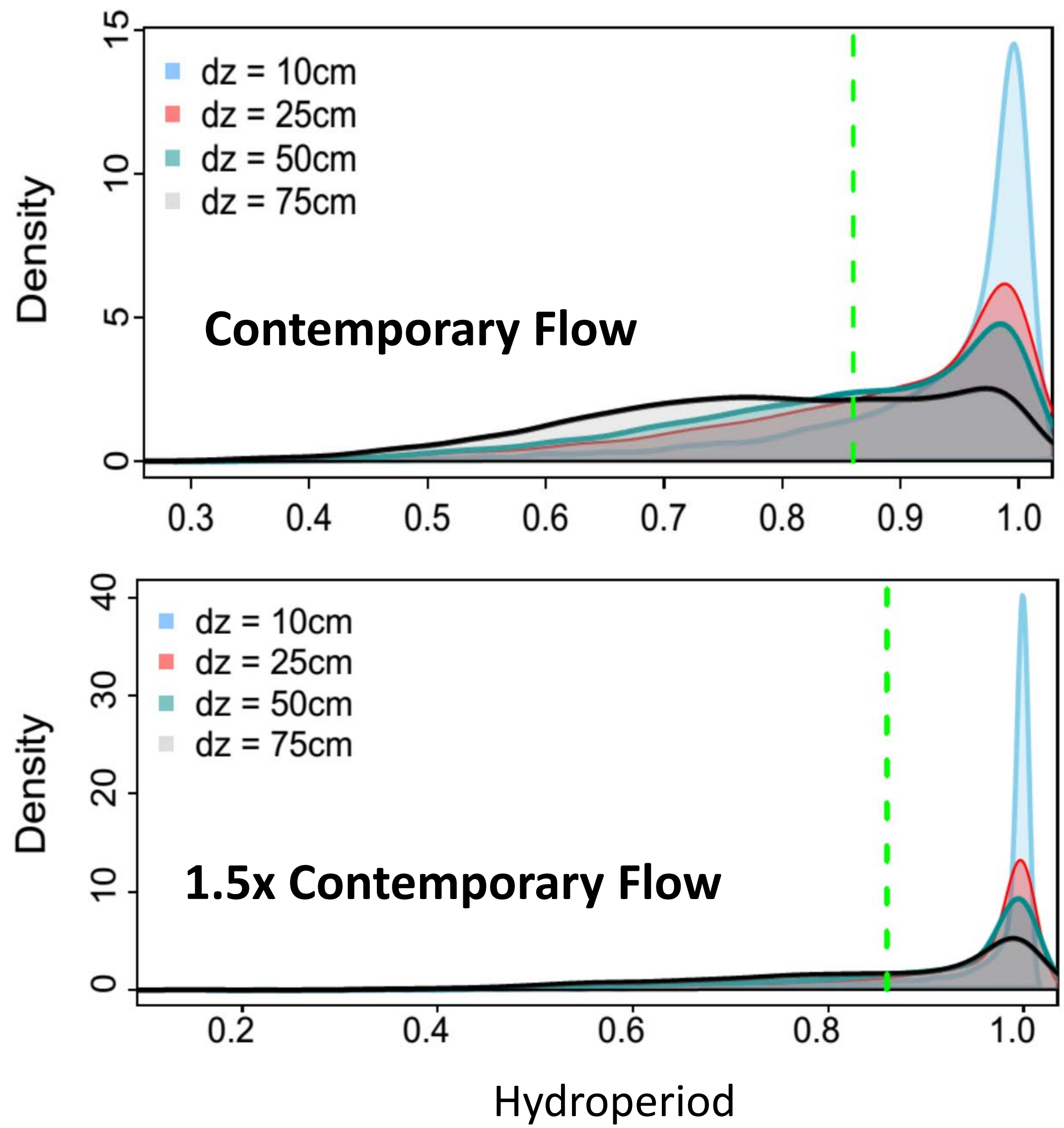


For Reference:

- Observed HP in conserved landscape = 0.86 [314 days]
- Observed 60% of the 20 years

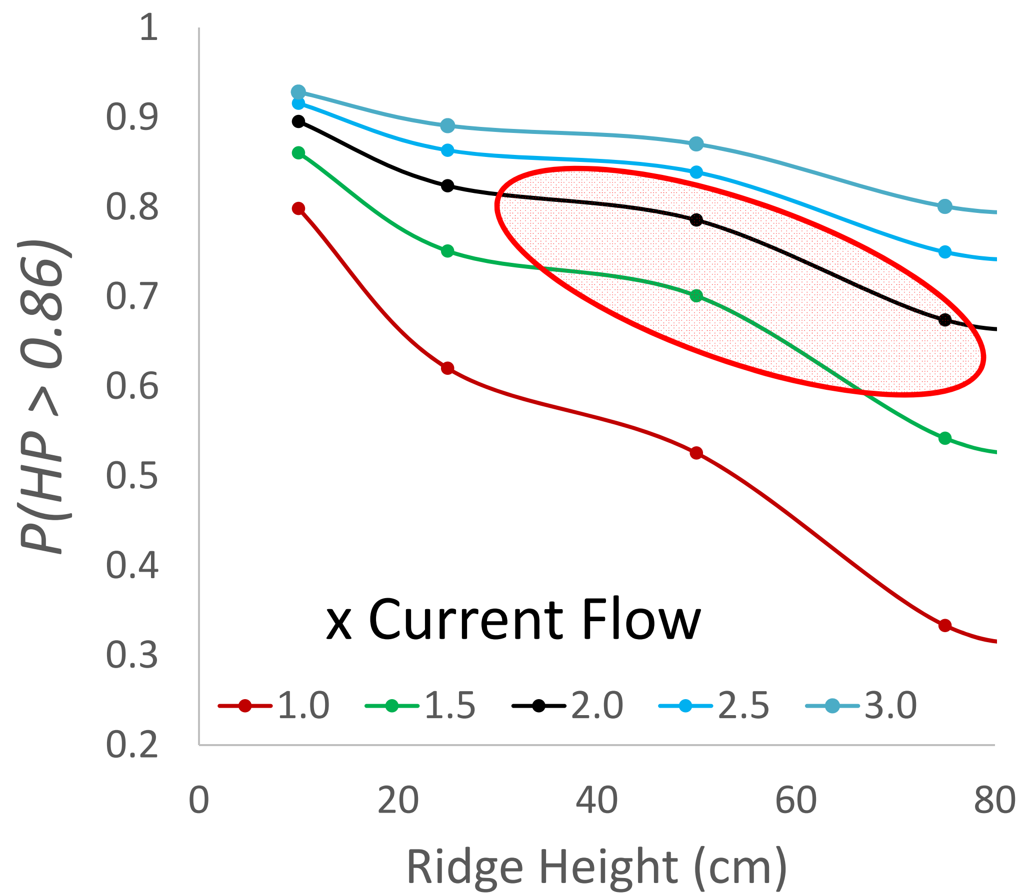
Hydroperiod Probability Distributions

- Under contemporary flow, ridge elevations greater than 25 cm would be significantly drier
- Increasing flow increases the frequency of years meeting or exceeding the target HP of 0.86



Estimated HP Probabilities

- Under contemporary flow, higher ridges would have been significantly drier. For 75 cm ridges, P(HP >= 0.86) = 0.33
- With 2x current flow, 75 cm ridges maintain hydroperiod frequencies observed in benchmark landscape



<u>For Reference</u>:

- Observed HP in conserved landscape = 0.86 [314 days]
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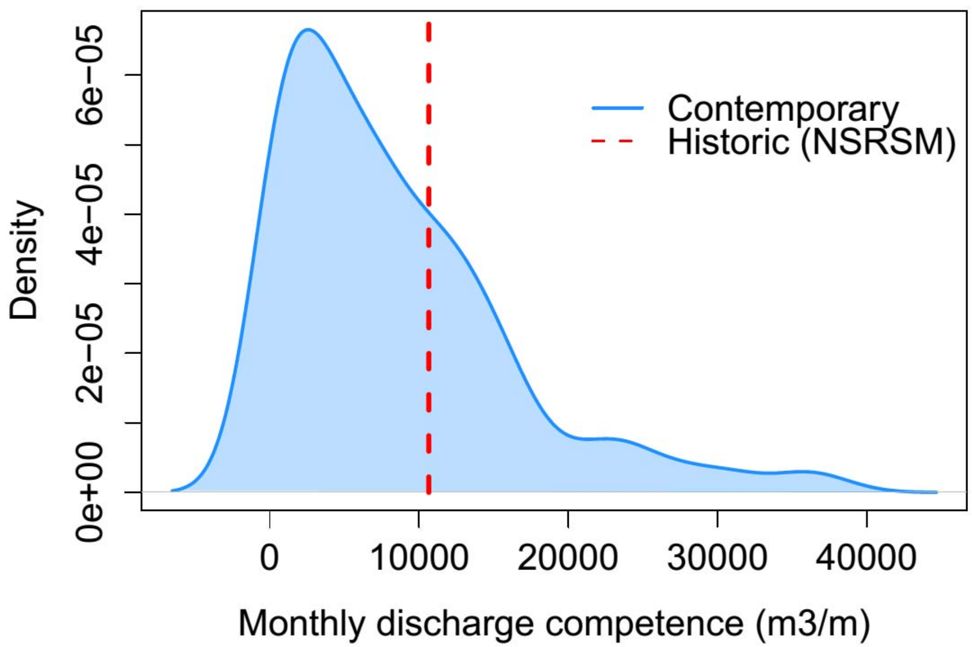
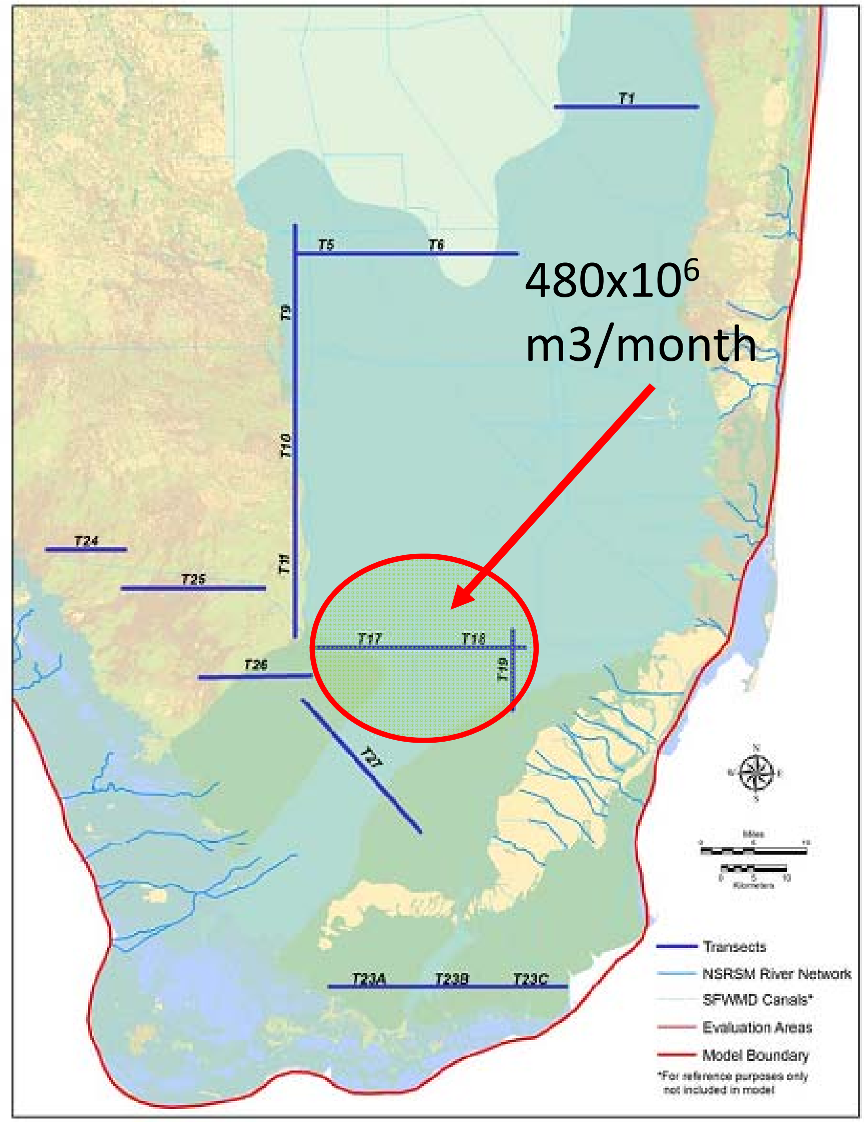
Context: What were the Historic Flows?

- Compare with estimates from the Natural Systems Regional Simulation Model (NSRSM)
- Contemporary flow most frequently less than historic





(Said and Brown, 2013)

Summary and Conclusions

- Contemporary flows in the best-conserved landscapes would not sustain higher ridge elevations
- *If we assume the best conserved landscapes are maintaining ridge elevations*, this provides support for the existence of large ridge elevations (>50 cm) in the historic ridge slough landscape
- Restoring mean daily flow by 2 times will increase the likelihood of achieving annual HPs to sustain larger ridge elevations


Thank you!
Questions?
Contact: sacharya@ufl.edu