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Mathematical calculation of inundation threshold to determine biological health in Alabama streams

Stream water level's connection to biological health :

36 Pilot Sites Across Alabama

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Inundation Threshold

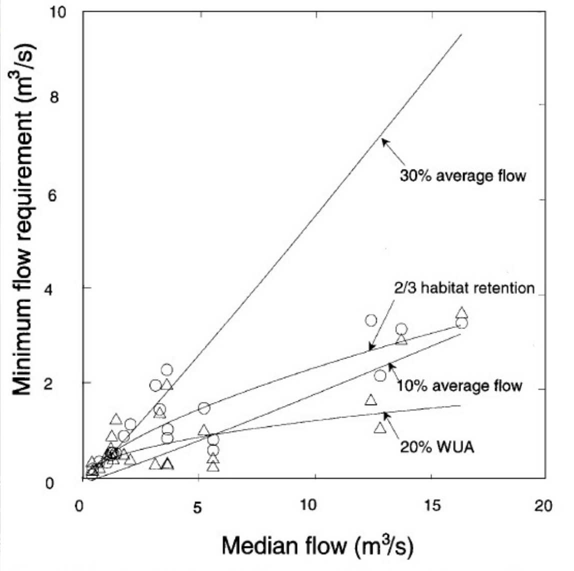
Biological Health Indicator: Previous methods

Physically and biologically based studies (eco-hydraulics)

- **Detailed and costly**
- **Reach-specific measurements**
- **Mostly commercial species**
- **Incremental analyses or simulation models**

Broad Statistical Characterization (eco-hydrology)

- **General and less costly**
- **Emphasize magnitude, frequency, duration, timing, rate of change**
- **30% of mean annual discharge (Tennant 1976)**
- **Indicators of Hydrologic Alteration (Richter et al, 2006)**
- **Hydrologic Integrity Toolkit (171 relevant statistics)**
- **Ten year drought – 7Q10**
- **Median flow for August or September**



Trend lines of relationships between median flow and minimum flow requirements assessed using 10 % average flow, 30% average flow, minimum of 20% food-producing WUA, and retention of two-thirds of the food-producing habitat at median flow. Minimum flow requirements based on minimum habitat are shown as triangles, those based on habitat retention are shown as circles. Minimum flow requirements based on 10 and 30% average flow were close to the fitted lines and are not shown for clarity.

INSTREAM FLOW METHODS: A COMPARISON OF APPROACHES, I. G. JOWETT

Regul. Rivers. Vol. 13, 115–127 (1997)

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Inundation Threshold

Biological Health Indicator: What is missing from these methods?

- Identification of a low-magnitude streamflow that is biologically relevant

- Bed inundation threshold --streamflow needed to keep the streambed wet

  --Protective of riffle habitats

  --Provides a variety of habitats during high-stress periods

  (high temps, low DO)

- Assuming that aquatic communities will fare better when:

  --Longitudinal mobility is preserved

- Can these thresholds be defined according to region?

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Inundation Threshold

Biological Health Indicator: Developing a bed inundation threshold

<u>**Things we know:**</u>

- **Flow cross-sectional area is a function of basin size and unit discharge**
- **Riffle habitat is associated with inundation of bed control**
- **Maximum inundation may occur where width is greatest for a given depth relative to discharge**

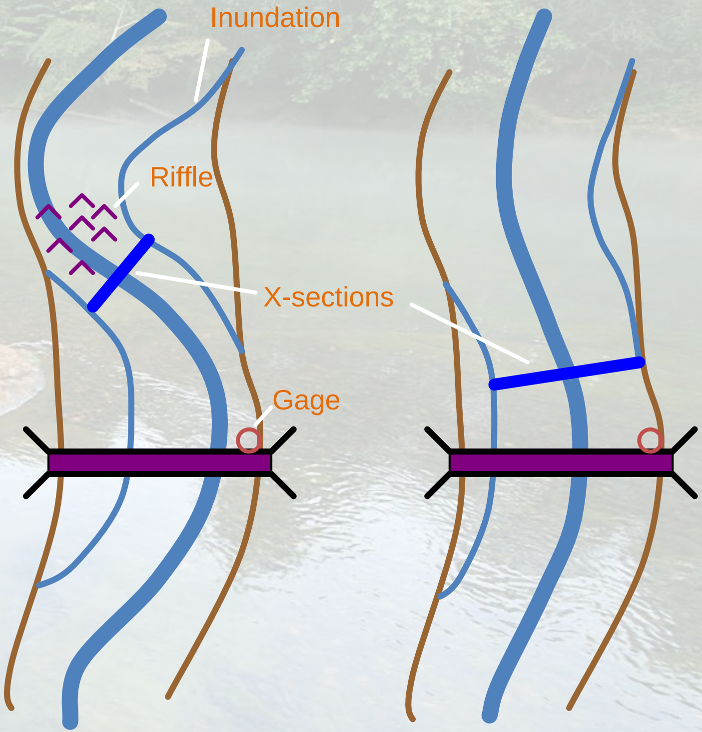
<u>**Things we do not know:**</u>

- **How do we determine streamflow associated with maximum bed inundation?**
- **Does the streamflow associated bed inundation vary between regions?**

Inundation Threshold

How do we determine streamflow associated with maximum bed inundation?

- Numerous streamflow measurements
- Riffle locations associated with aquatic habitat
- Detailed X-sections (width and depth)
- Narrowest point in run nearest “control”
- Repeated over time and range of discharge



“Control” is the channel feature that determines water-surface elevation for a given flow rate

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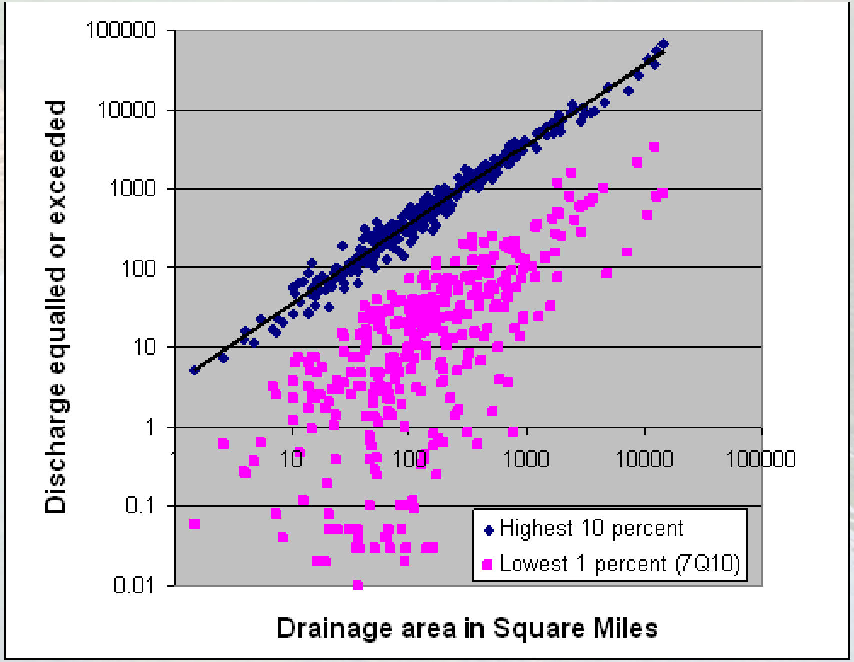
Inundation Threshold

Does the streamflow associated bed inundation vary between regions?

- **High flows are consistently related to basin area**
- **Streams are <u>sized</u> by basin area (high flows) and <u>shaped</u> by underlying geology**
- **Low flows vary regionally with geology (storage)**
- **How these interact affects aquatic habitat**



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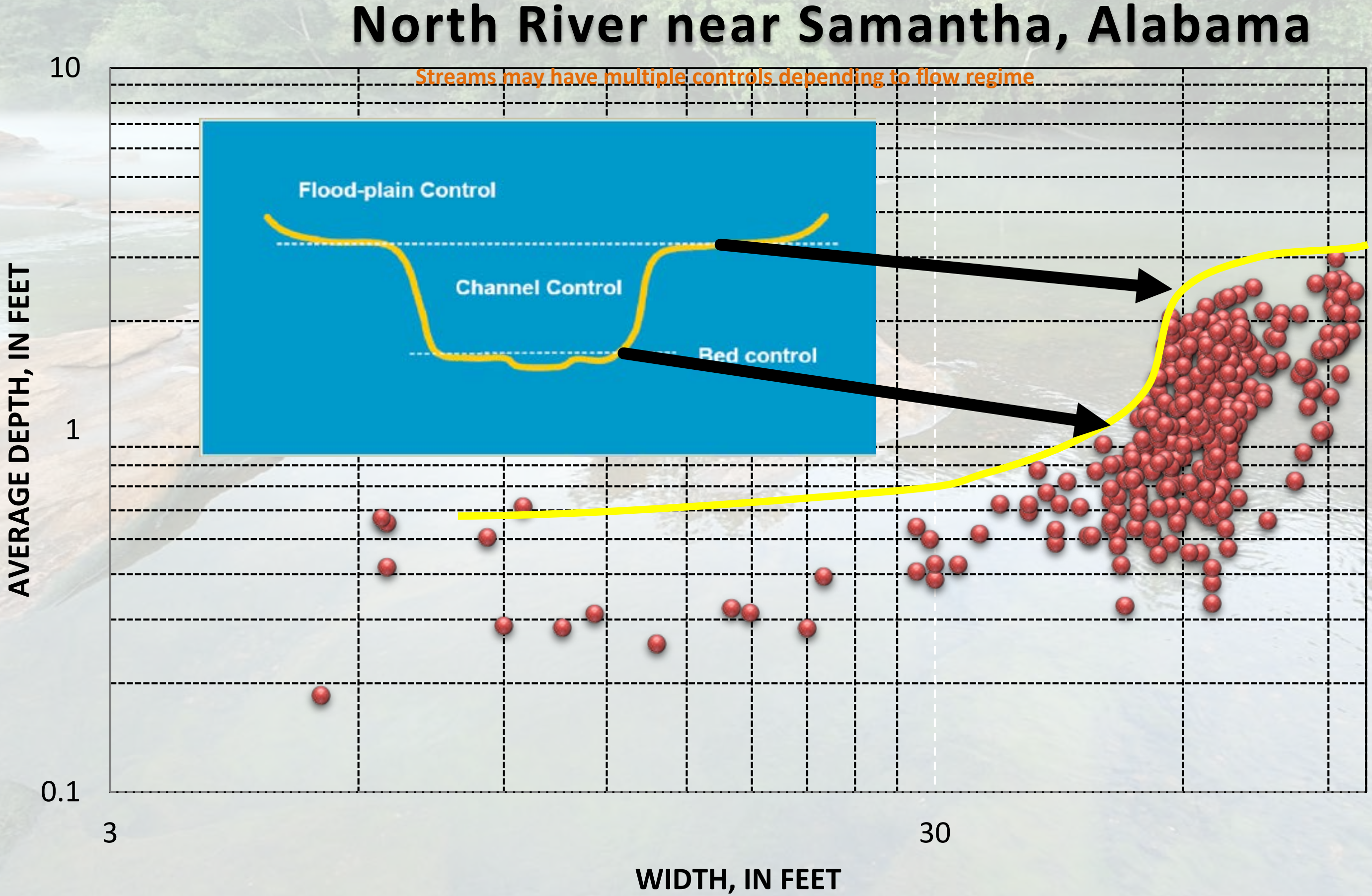
Inundation Threshold

How do we determine streamflow associated with maximum bed inundation?



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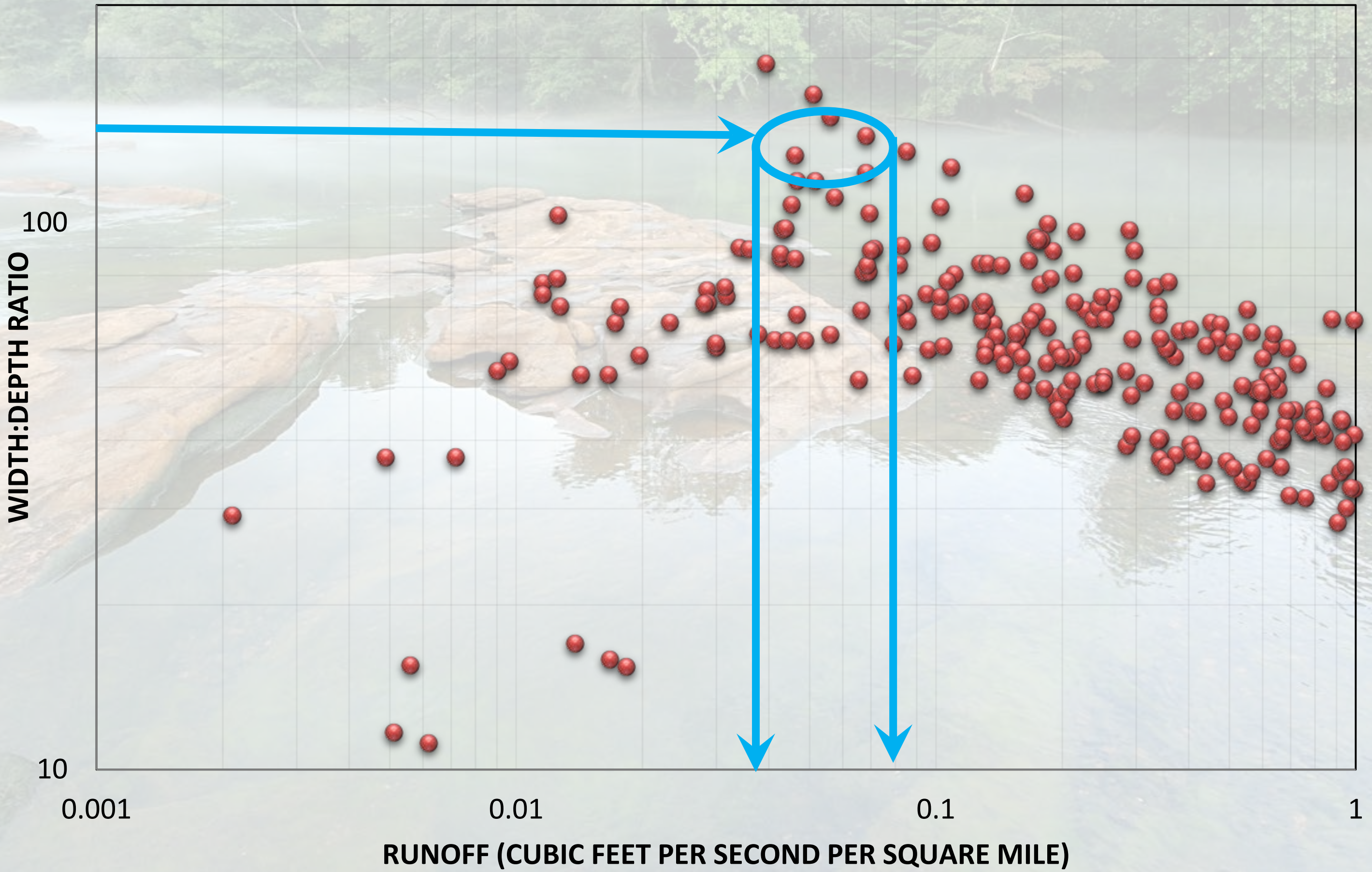
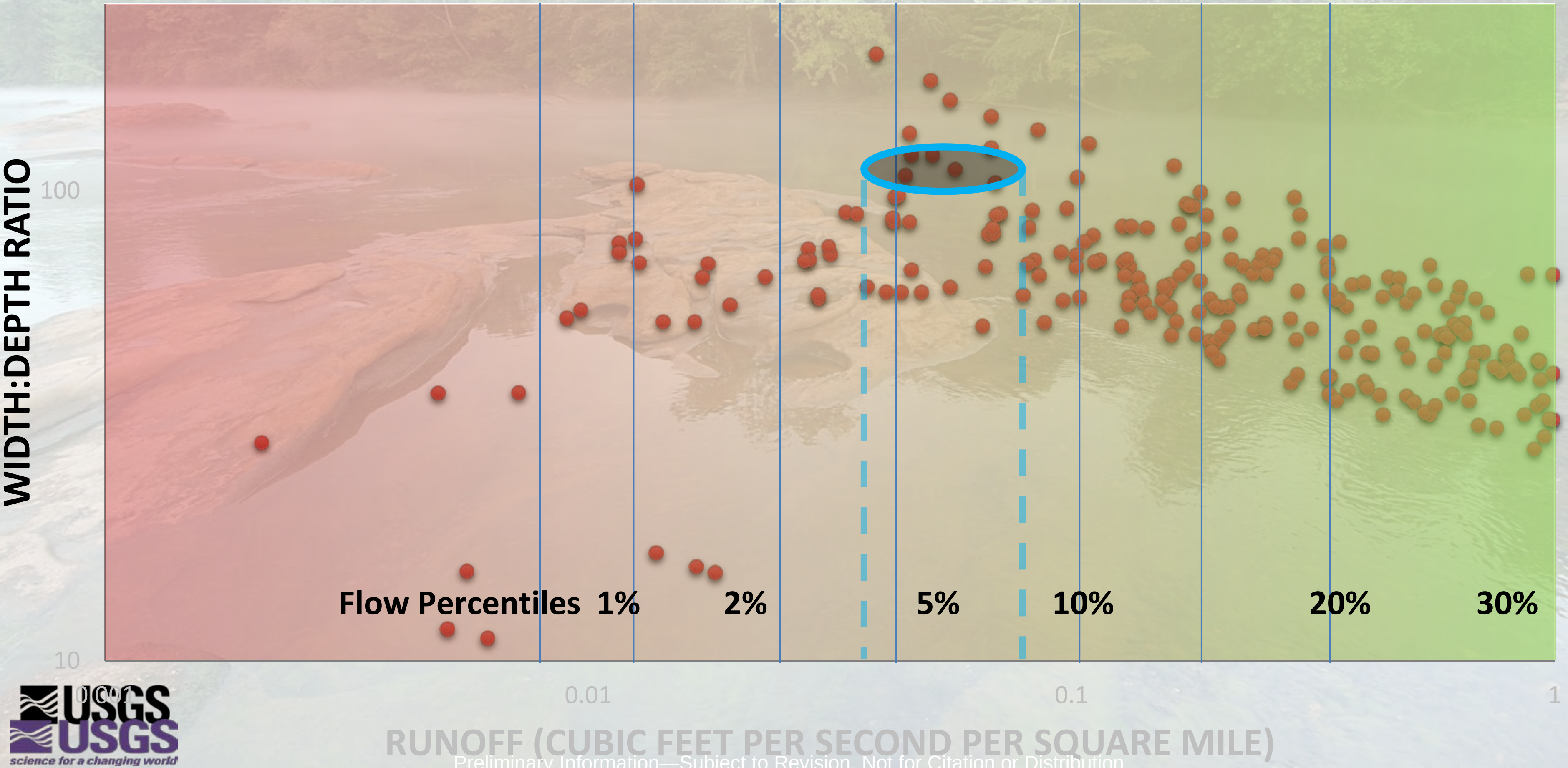
North River near Samantha, Alabama



North River near Samantha, Alabama



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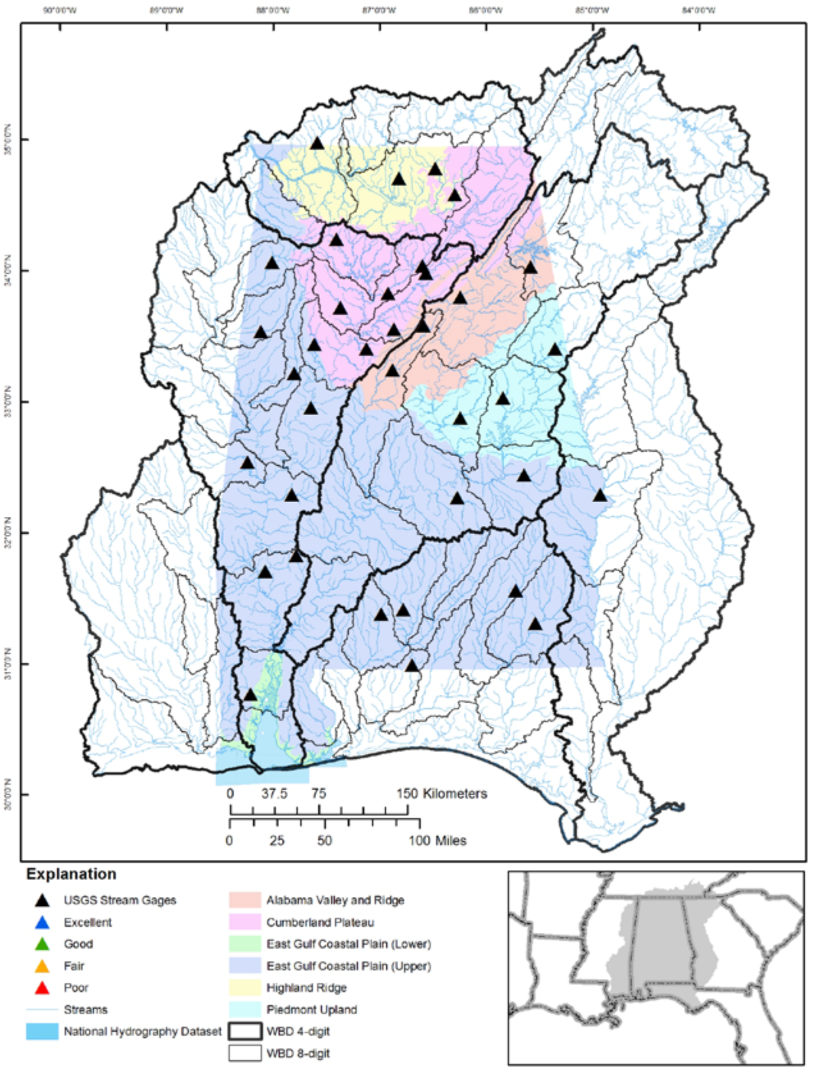
Bed Inundation Threshold

Alabama Pilot Study: 36 Sites

Alabama Physiographic Region

- **36 sites**
- **By watershed (WBD 4 and 8)**



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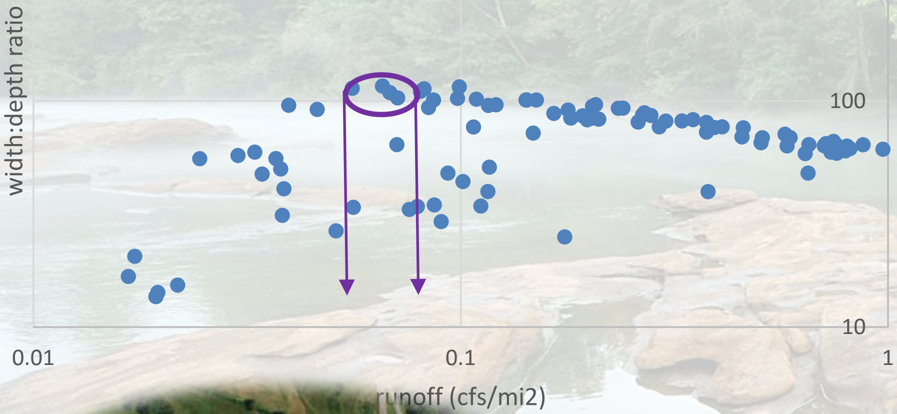
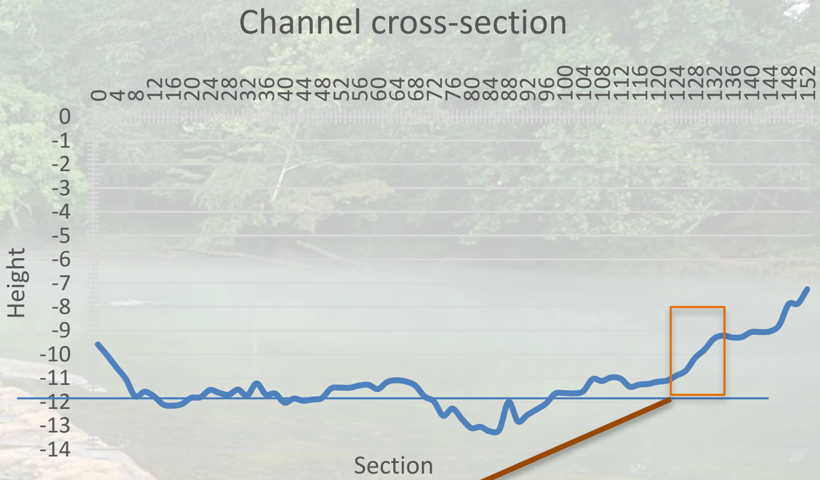
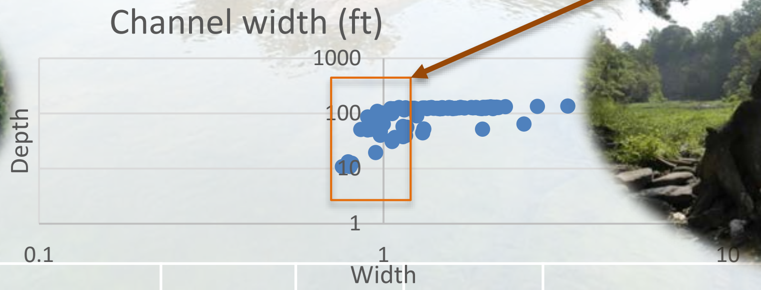
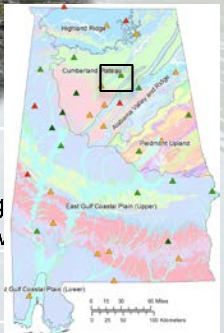
Inundation Threshold

Locust Fork near Cleveland, AL









Station ID	Station Name	Lowflow Meas. Count	Average cfs/mi2	Average width:depth ratio	Average Gage Height (ft)	Average streamflow (cfs)	Averag channel w
02455000	LOCUST FORK NEAR CLEVELAND, AL.	307	0.06	110	1.05	20.6	115

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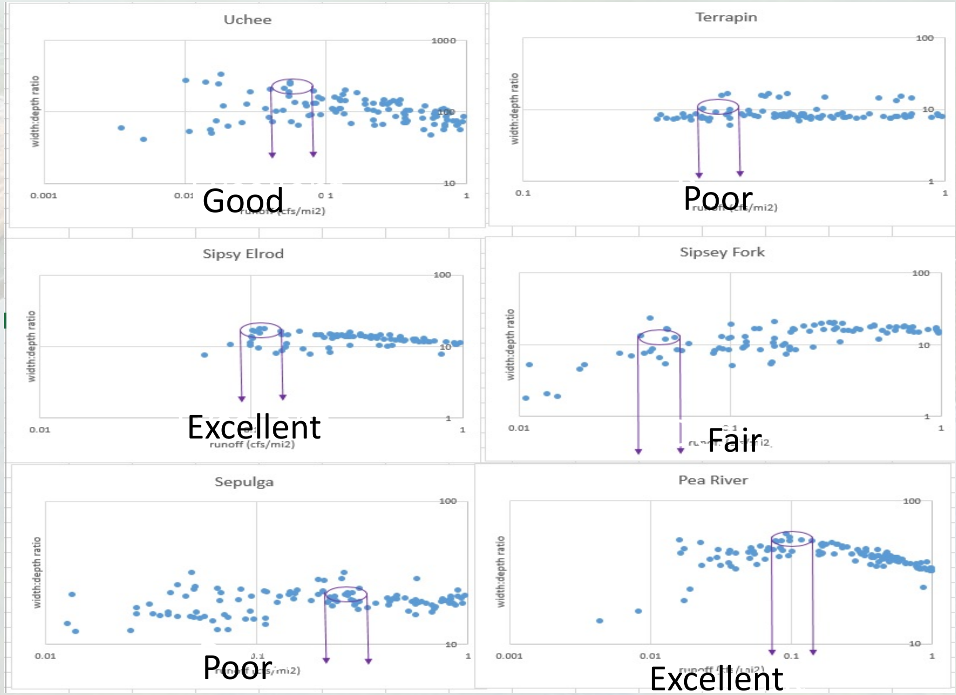
Qualitative Ranking of Site Bed Inundation Threshold : Excellent, Good, Fair, and Poor

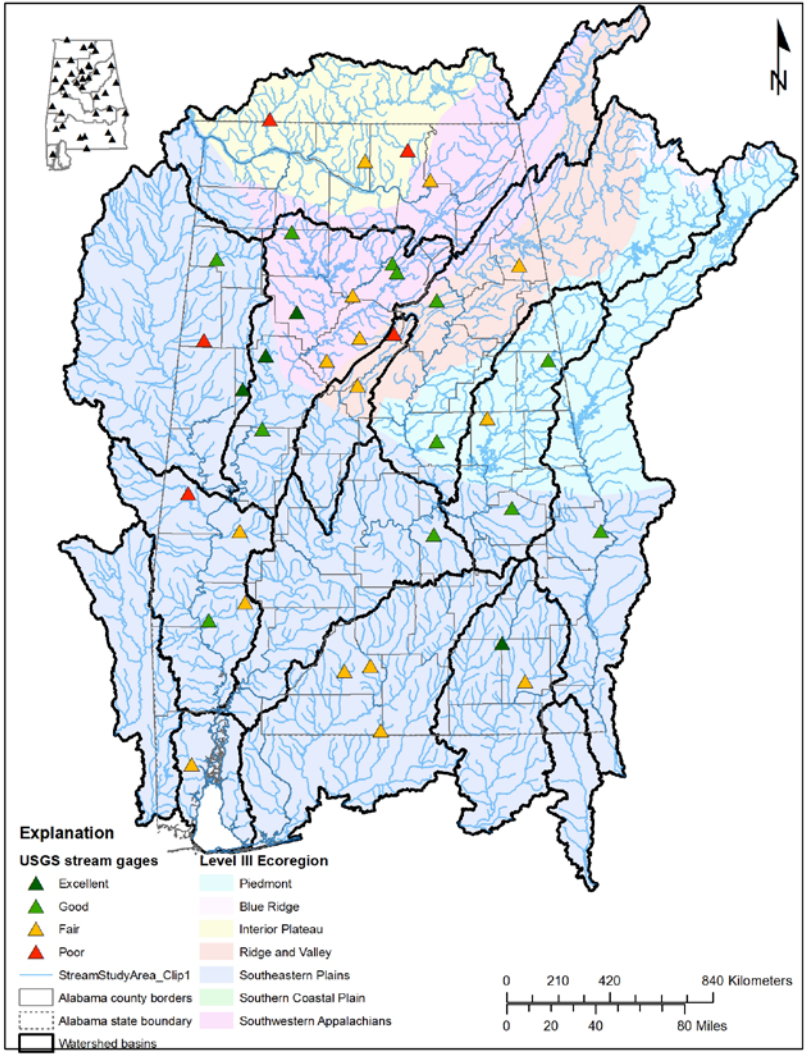


Bed Inundation Threshold

Qualitative Ranking of Method

Alabama Level III Ecoregions

- **By ecoregion**
- **By basin size**



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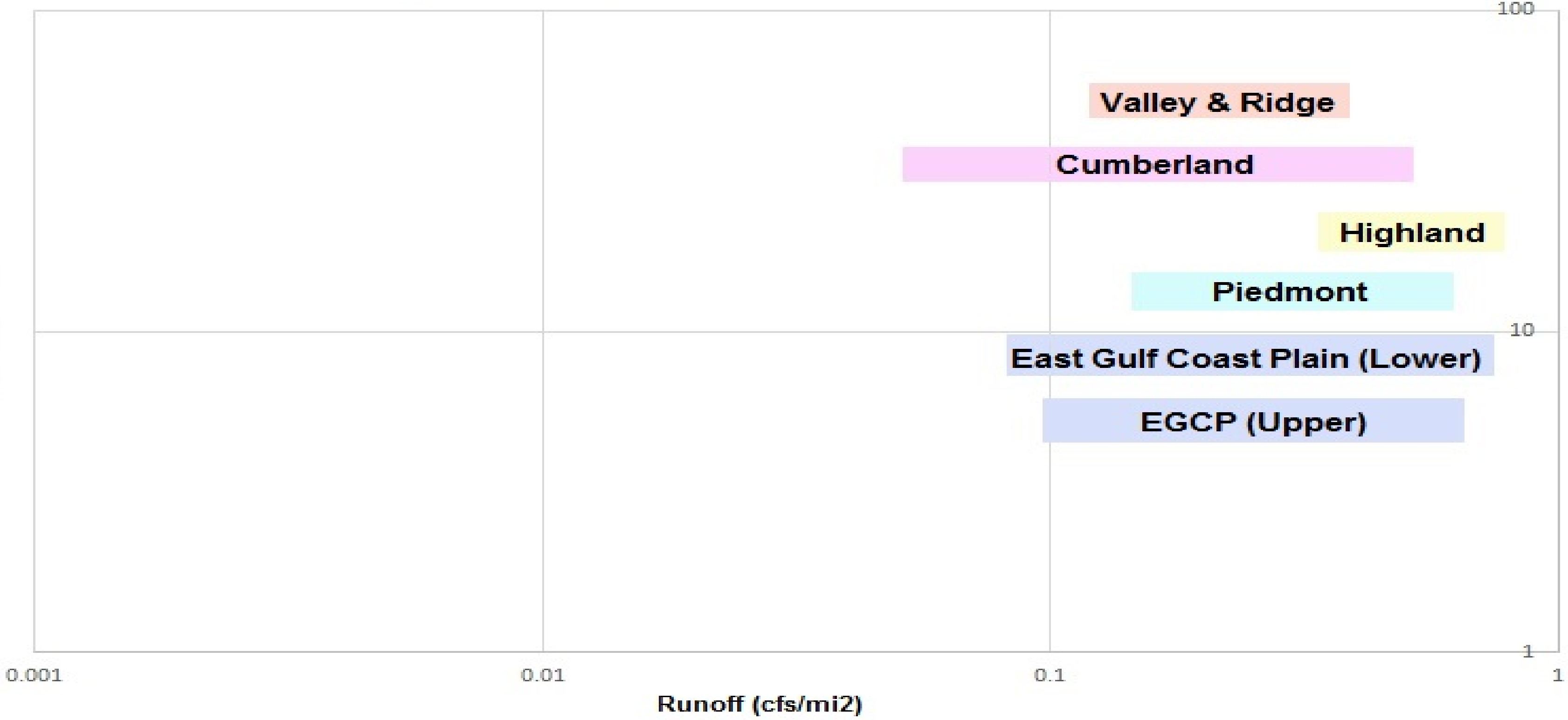
Eco-Region Range for Bed Inundation Threshold



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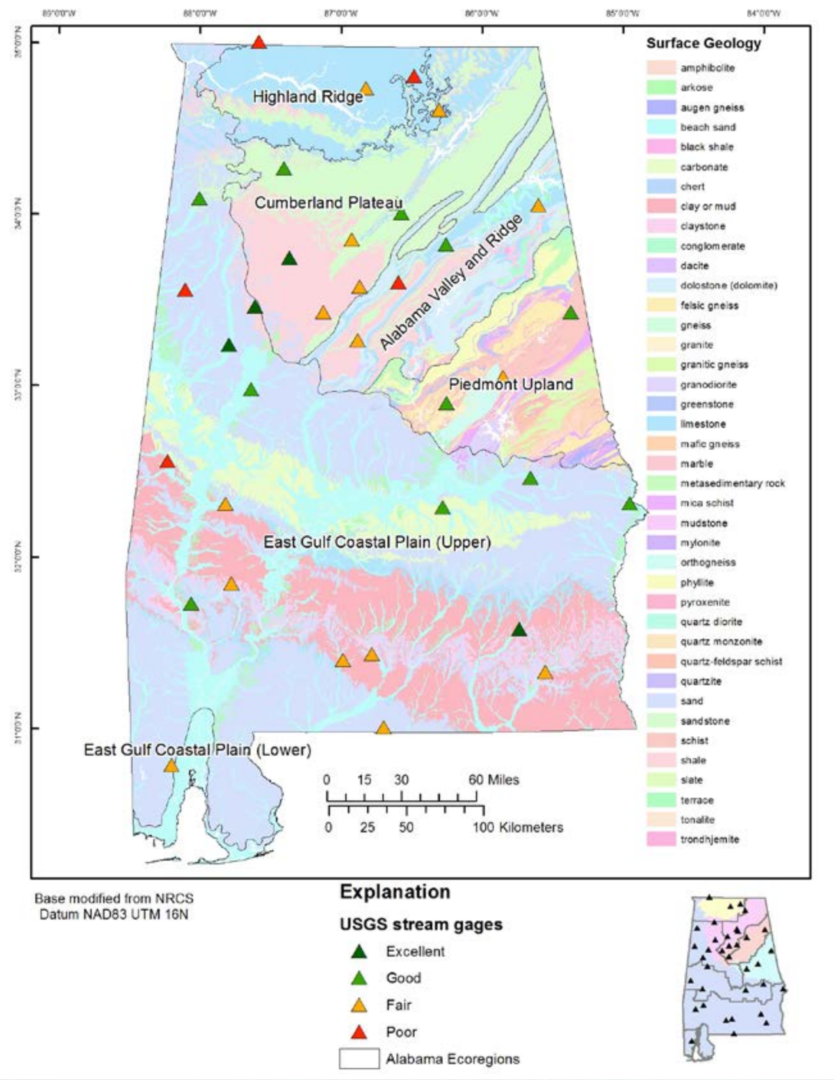
Bed Inundation Threshold

Surface Geology

<u>Surface Geology</u>

- **Geology of stream channel**
- **Geology of drainage basin**
- **Sampling of streams in varied geologic units**



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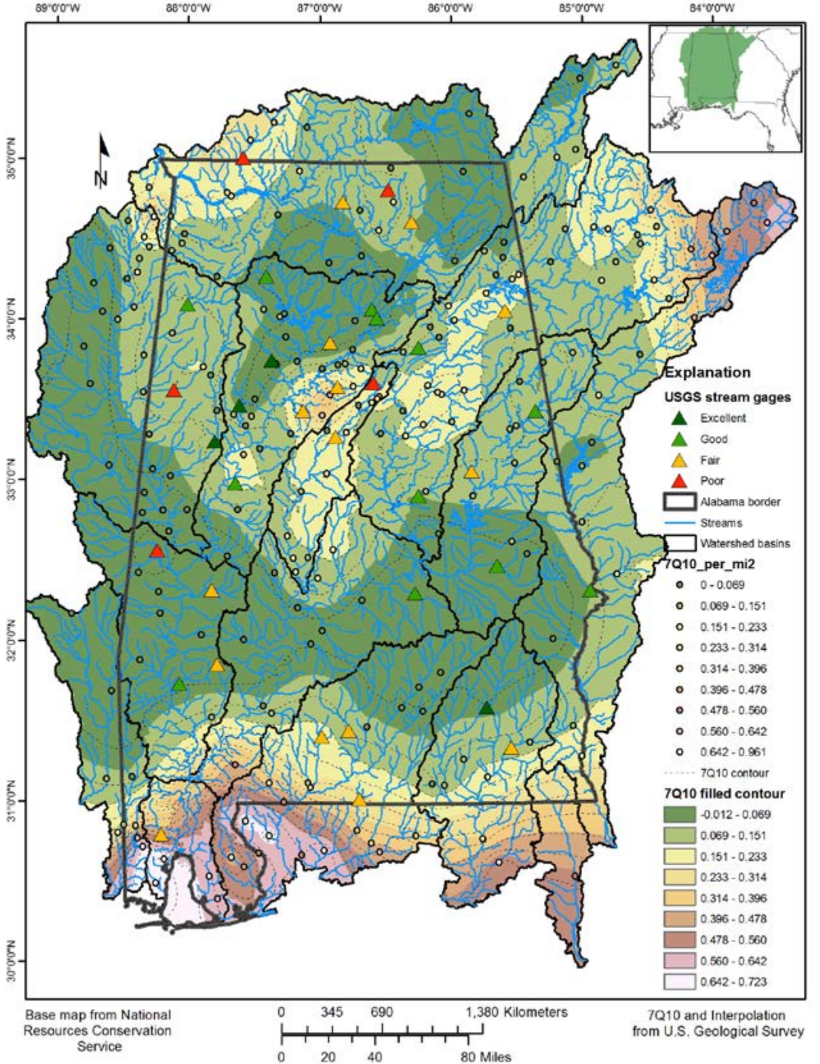
Bed Inundation Threshold

Compared to 7Q10

7Q10 Contour

- **Relationship with 7Q10**
- **Correlation**



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- Slope Curvature Peak Area Method Utilized
  - MEIFR (minimum ecological in-stream flow requirements)
- Graphically show numerically-derived MEIFR critical point (bed inundation threshold) average for each eco region to determine pattern and compare to visually-determined critical point.
- Visually picking the bed inundation threshold critical point cannot always be accurate
- This MEIFR numerical method utilized takes into account both the slope and curvature techniques and is more reliable in determining the critical point through mathematical definition of the relationship between the wetted channel and the discharge..
- Slope MEIFR method: slope being 1
- Curvature MEIFR method: corresponding to the maximum curvature
- Taking into account both the slope and curvature methods: MEIFRslope/MEIFRcurvature, as well as the visually-determined critical point, allows for cross-checking results.

$$MEIFR_{slope} / MEIFR_{curvature} = \left(\frac{2-b}{1-2b}\right)^{\frac{b}{2-2b}} = 4.47$$

Suxia et al. 2006

- Where a and b relate to channel geometry.

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Bed Inundation Threshold

Best Application

When should we use this method?

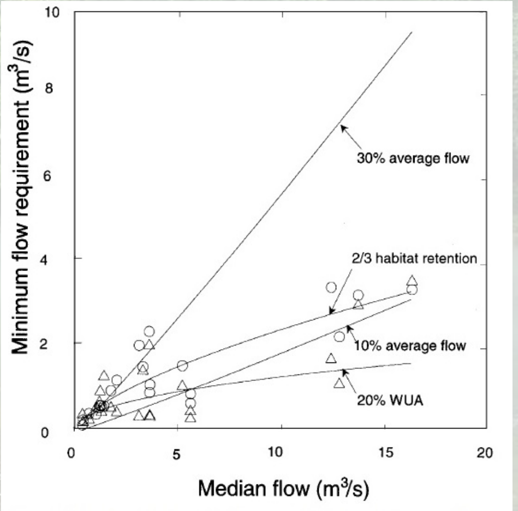
- When detailed ecological data are not available.
- When many streams need analyzing for creation of statewide flow requirements.
- Real world verification
  - Field-verify consistent wetted channel during streamflow that falls within the threshold.

Bed Inundation Threshold

Implications for future study

Where do we go from here?

- **Compare the visual and MEIFR methods (possibly the mean of these) to other methods**
- **Statewide bulk-calculation using MEIFR, with spot-verifying using visual slope and/or field data.**
- **Real world verification**
    - **Field-verify consistent wetted channel during streamflow that falls within the threshold.**



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Thank You

Questions or comments?

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