Development and utility of a Hydrologic Condition Index

by

Gino Lucchetti and Jeff Burkey
King County Dept. Natural Resources and Parks
Seattle, WA

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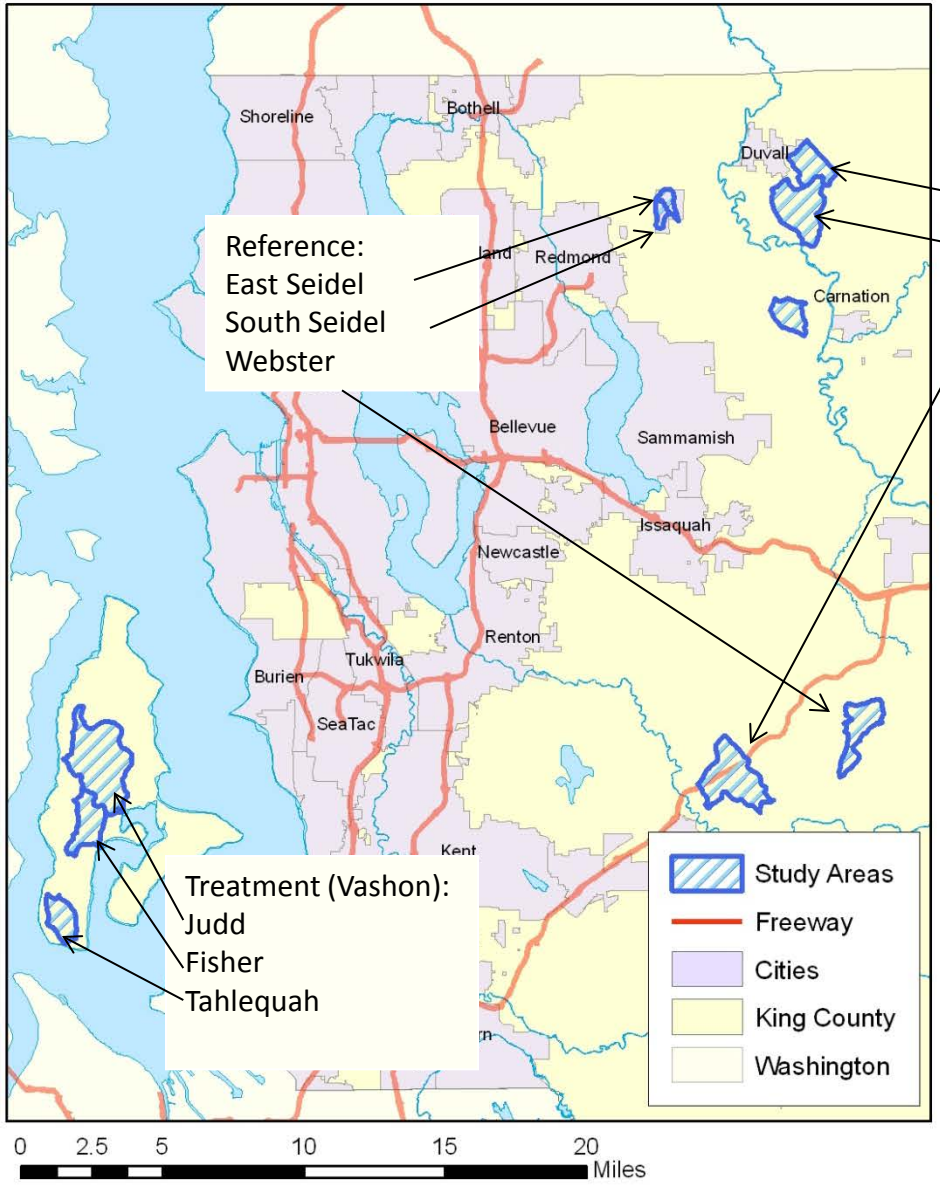
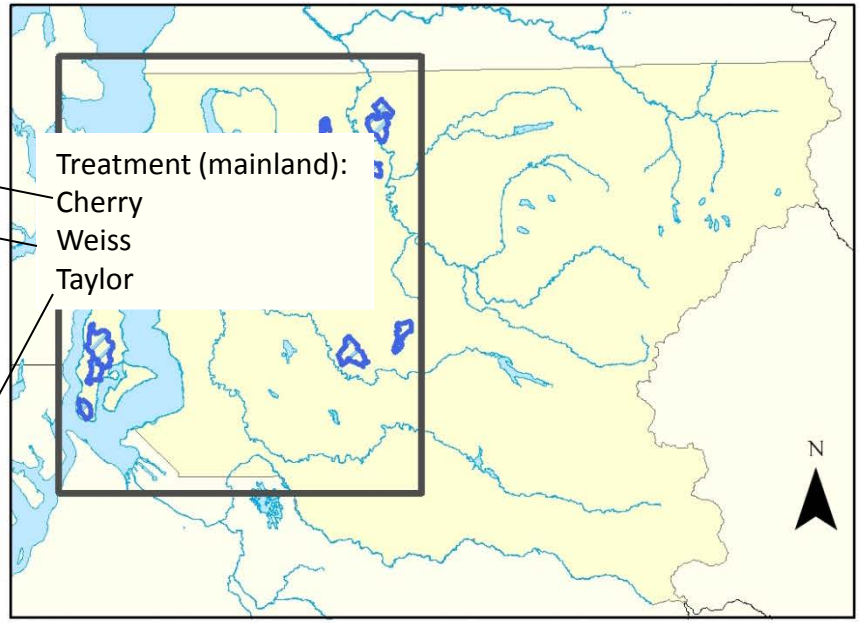
Regulatory Effectiveness (*aka* "The CAO") Study

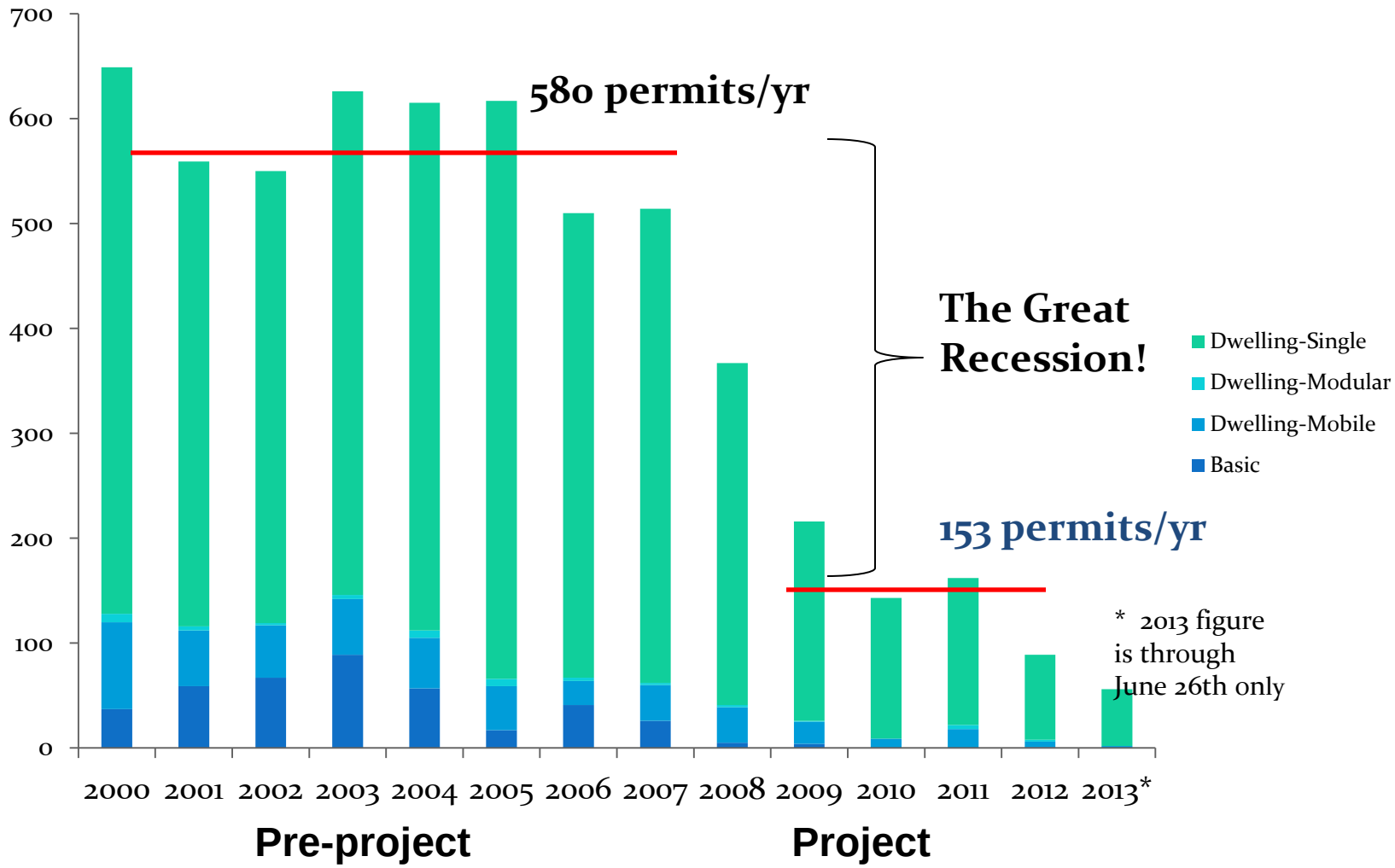




Selection Criteria:

- **Puget Lowland Ecoregion - common geology (mostly till), morphology and climate.**
- **Small headwater watersheds (60 to 1260 ha) w/ fish-bearing channels, no lakes, minimal wetlands**
- **Single jurisdiction and set of regulations**
- **Treatment basins: ongoing development with high potential for more**
- **Reference – forested, no development**

A slight problem along the way…
…building permits declined 75%



Land Cover Scenarios
(putting the present in perspective)

- **Past (~1900 to 2007)**
- **Present (2007 – 2102)**
- **Future -** Full Build-out “worst case”
- **Urban** – 2007 Juanita Creek

The Past - Data Timeline*

1907-08 1911 1936 1948 1965 1986 1991 1995 1999 2002 2007

Eastern and Control

Vashon

Timber

Soil Survey

Vashon and Control

All Basins

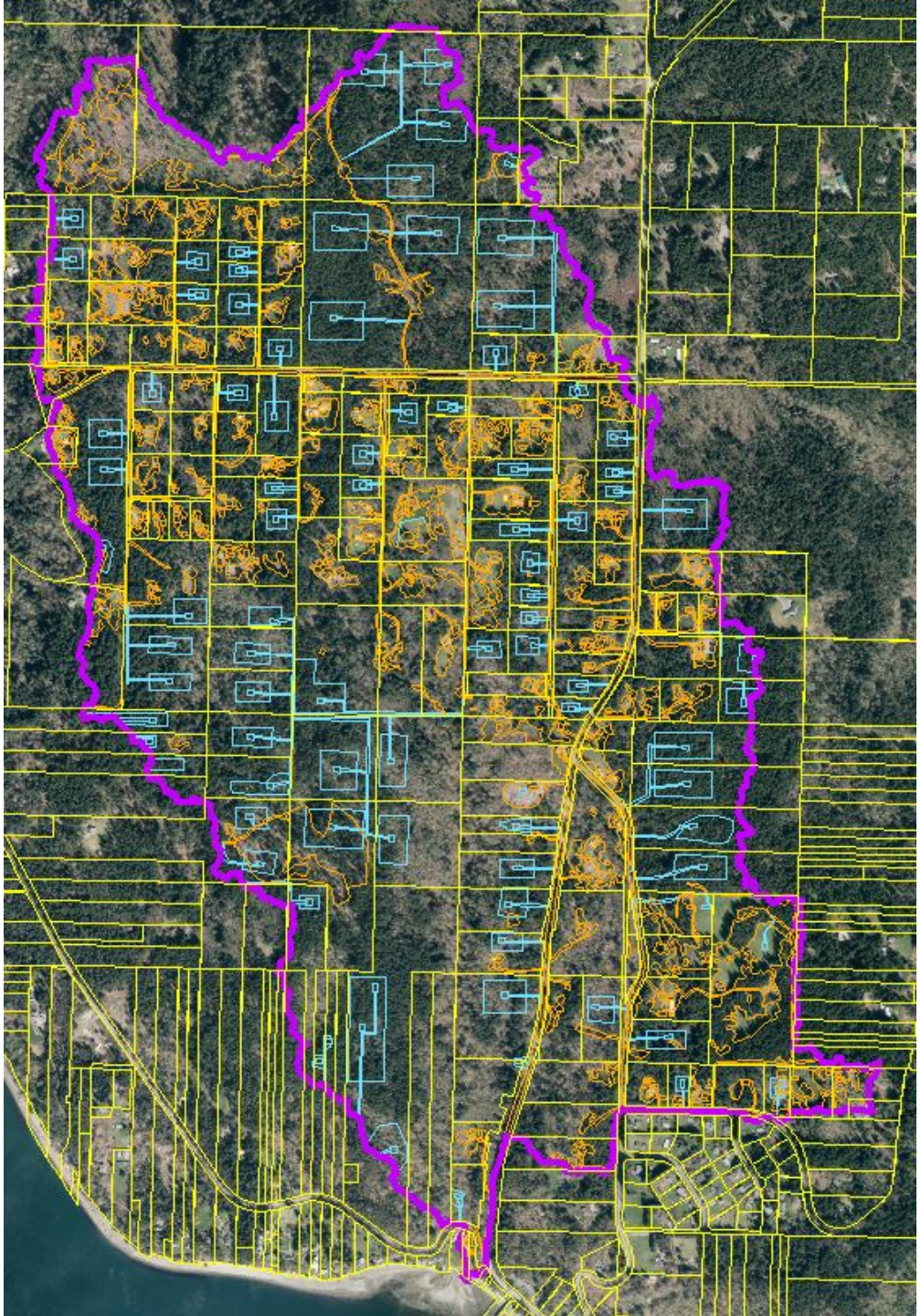
Aerials

All Basins

Land Cover
30 m pixels

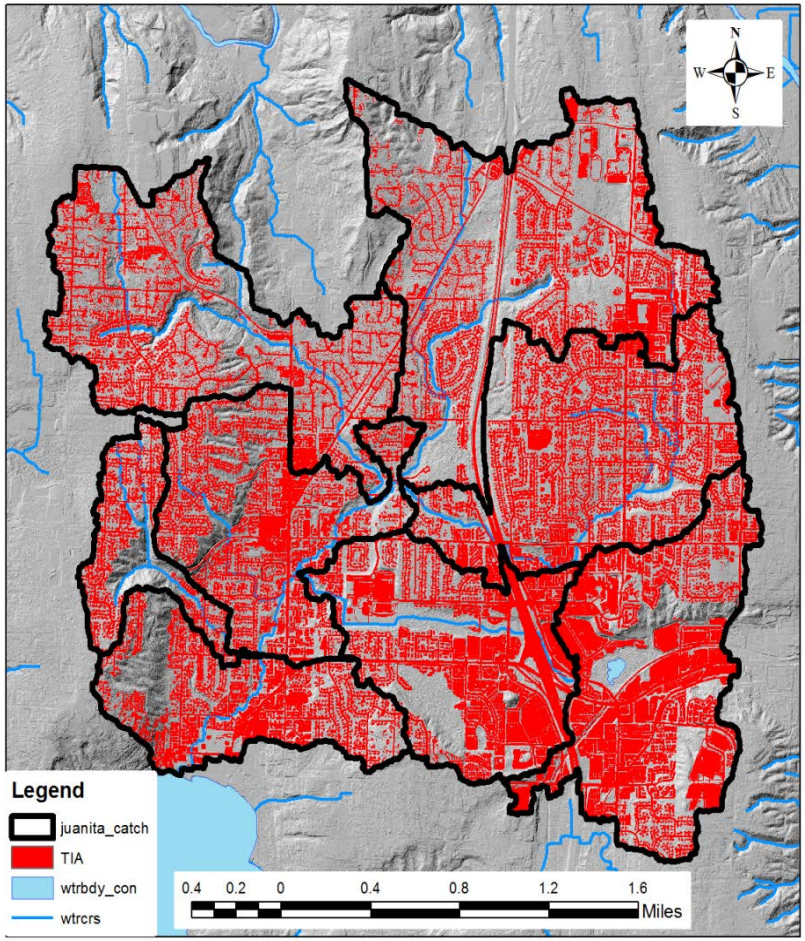
*Michalak e t al. 2013.

Tahlequah – Full Build-Out



An Urban Comparison - Juanita Creek

Orthophoto



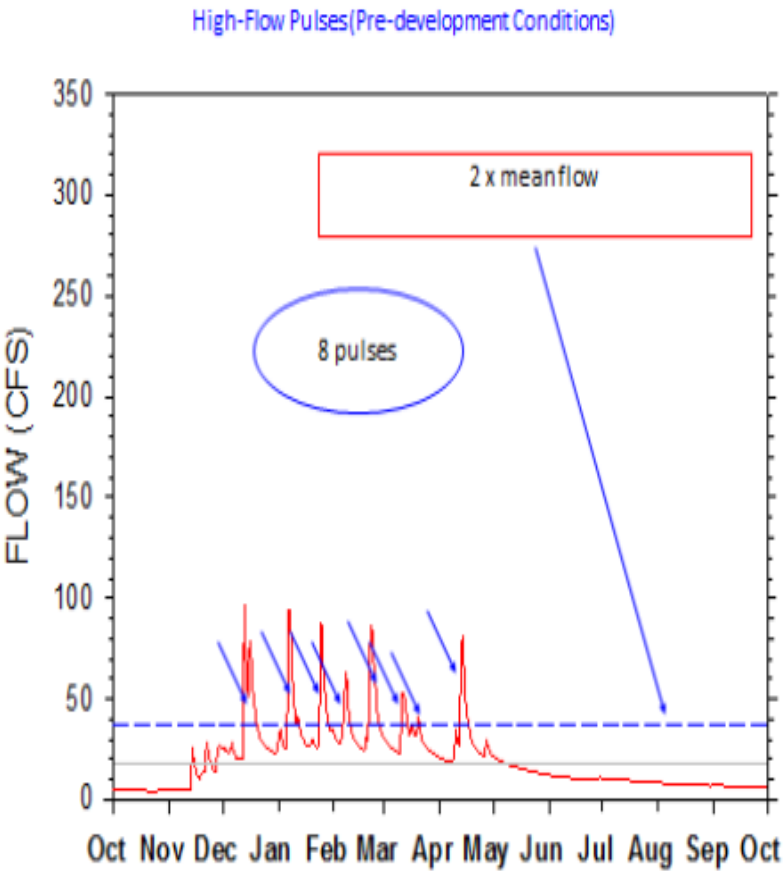
Impervious cover

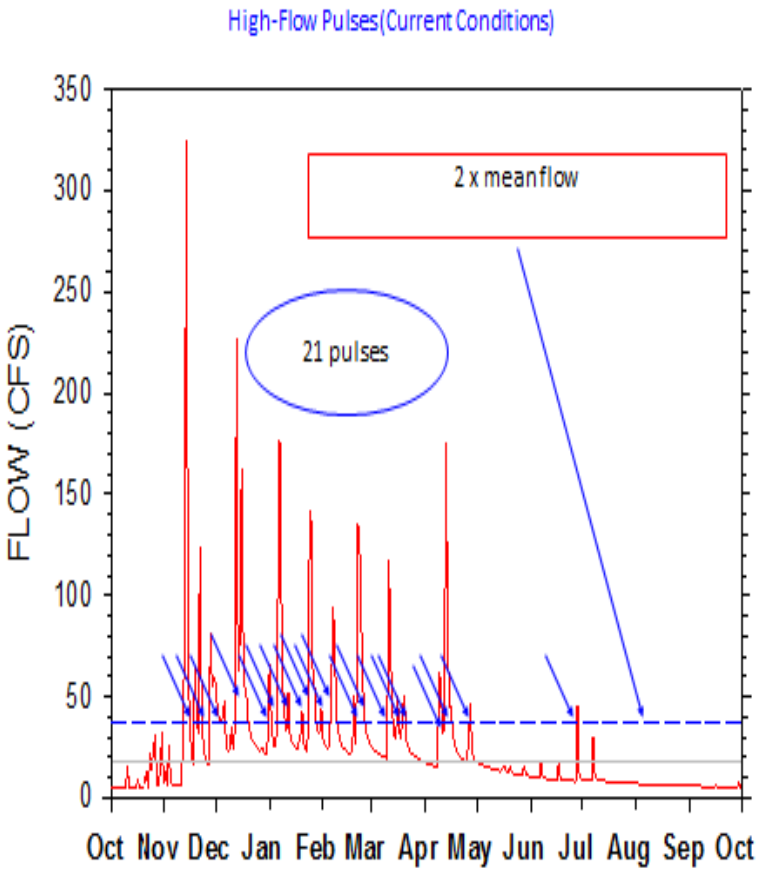
To compare scenarios quantify <u>the effect</u> of land cover change (not just the change)

Hydrology the primary driver for response

“Flashiness” most strongly correlated with Biology (DeGasperi et al 2009), so…..

High Pulse Counts*



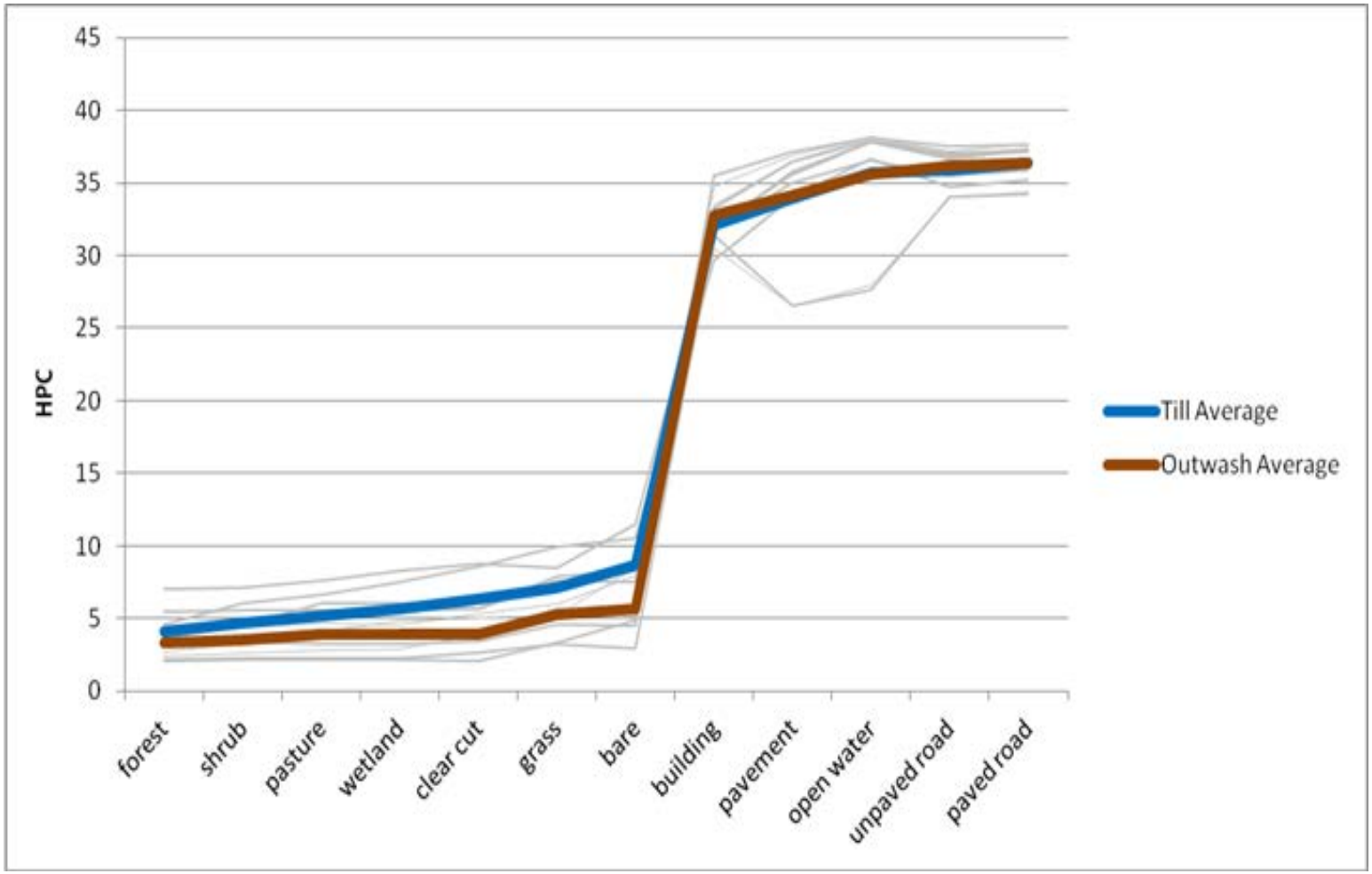


Pre-development

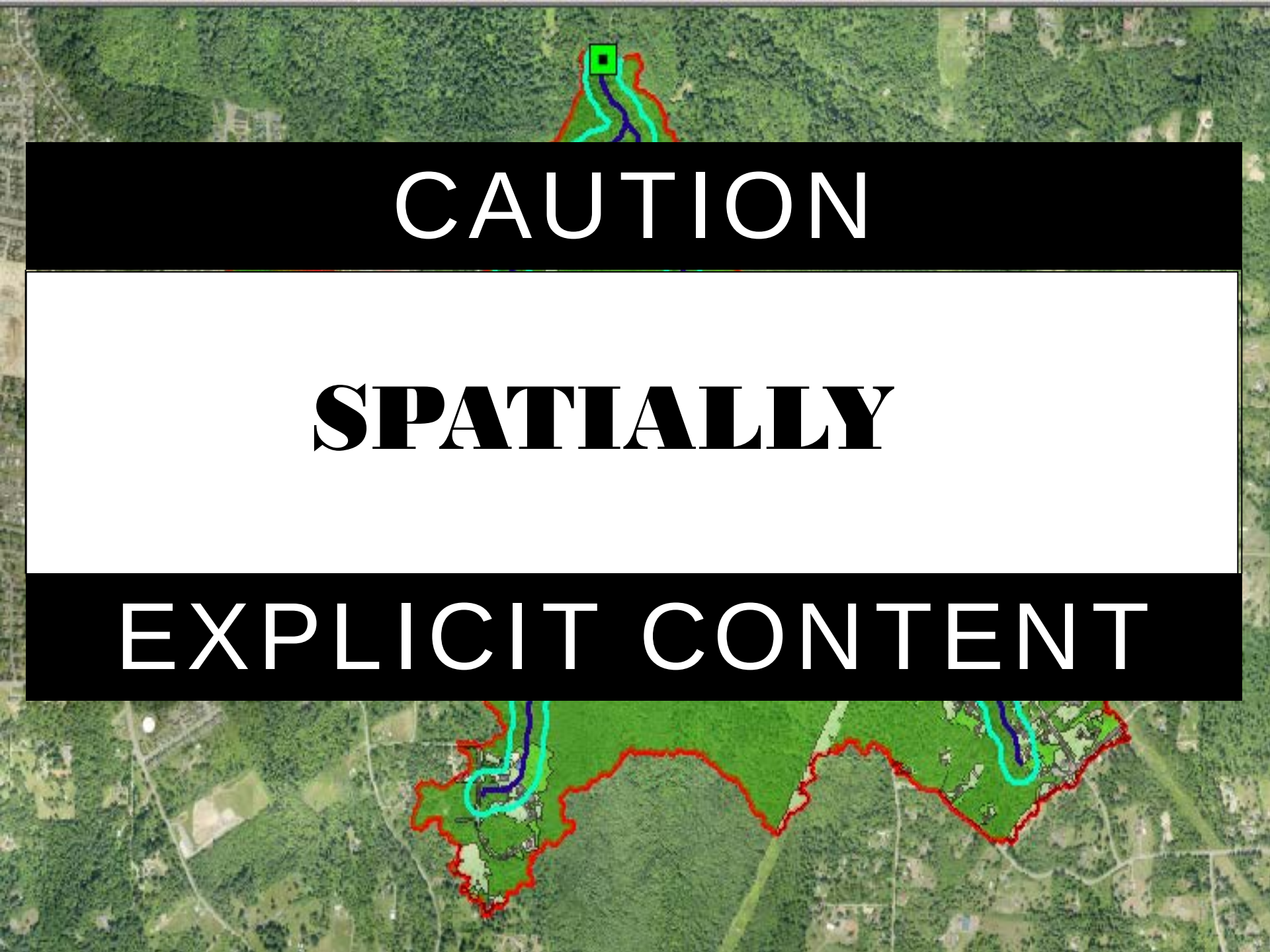
Post-development

*** From Horner 2013**

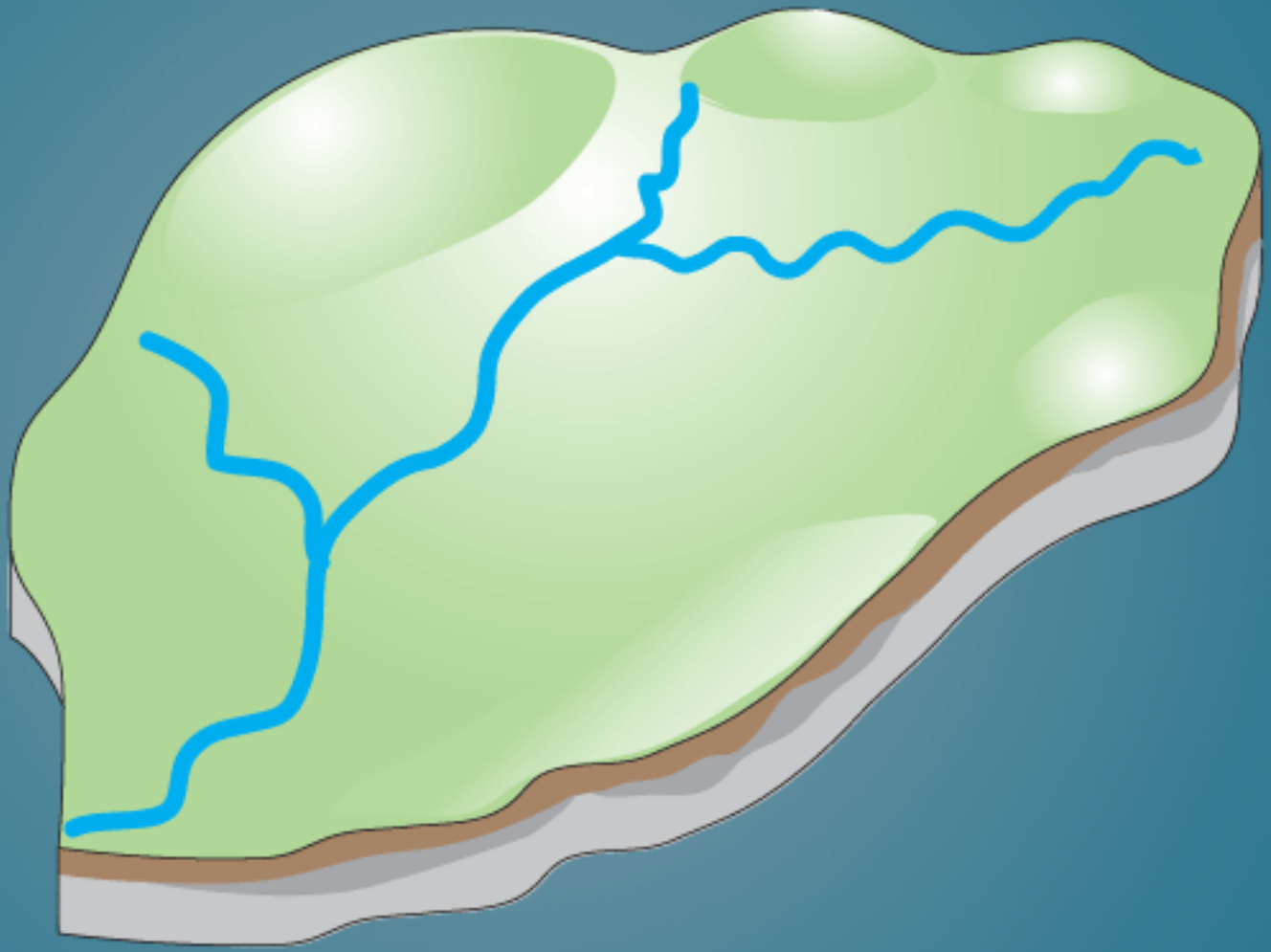
High Pulse Counts*
Effect of geology and land cover



*** Modeled 61-year averages for pre-existing watershed models used to model the HCI**

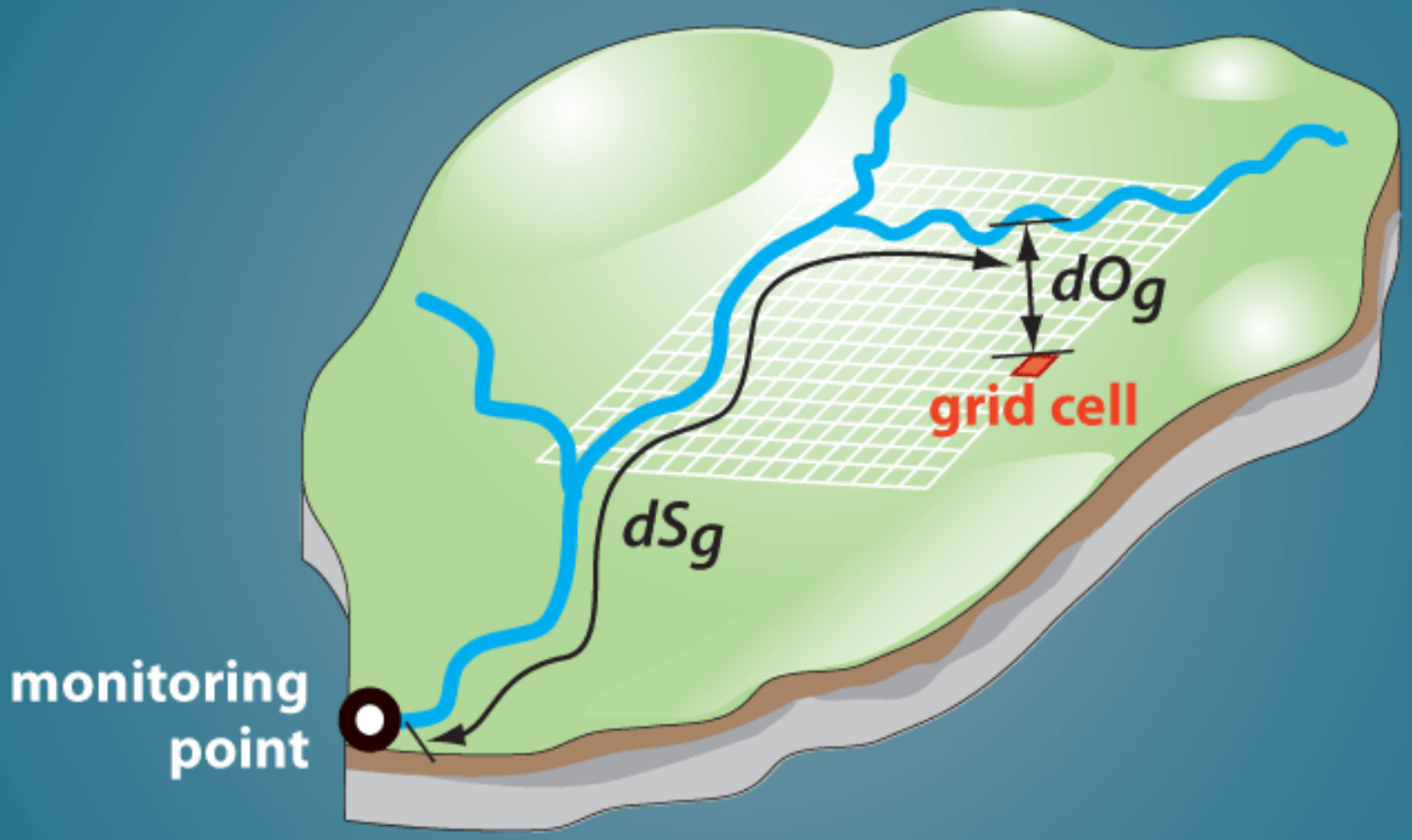

CAUTION
SPATIALLY
EXPLICIT CONTENT

Study Basin

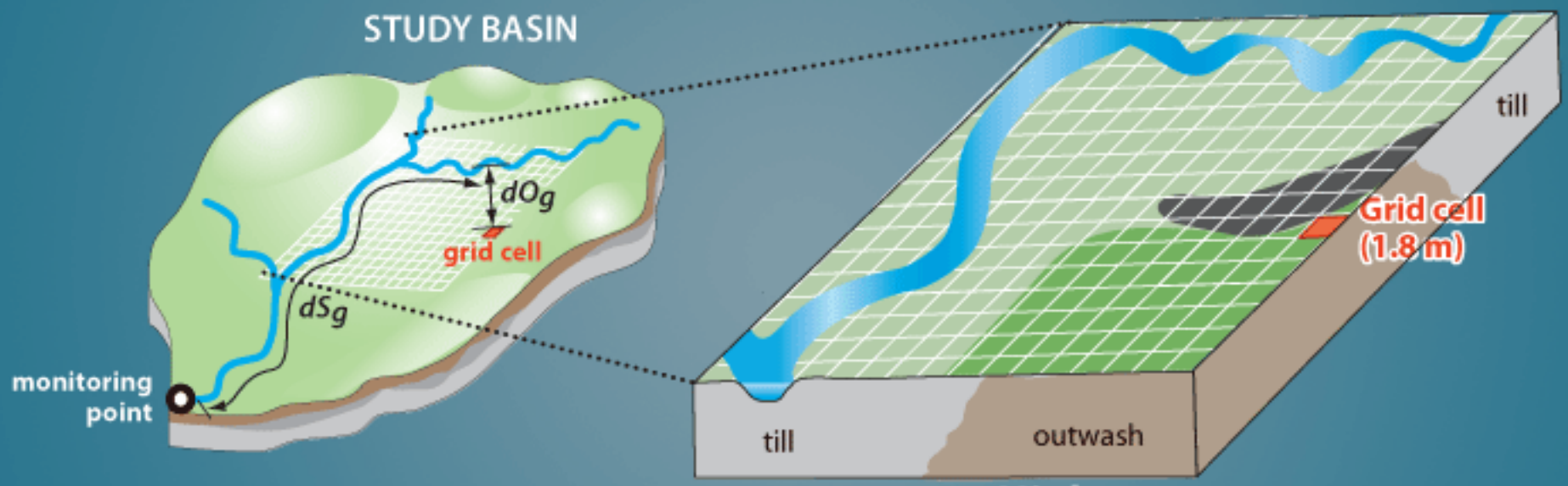


Setting Up the Study Area

Calculation of Grid Cell Distances

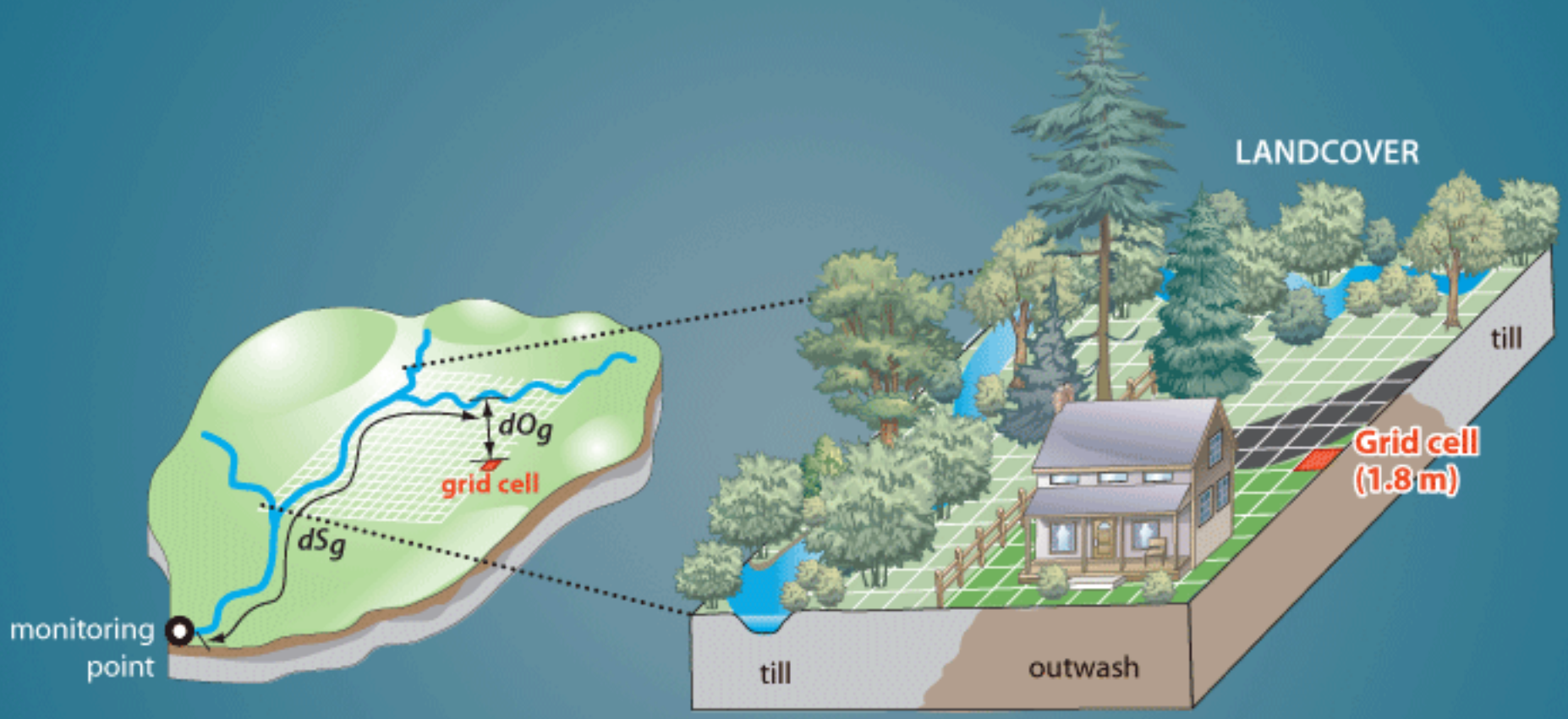


Surficial Geology



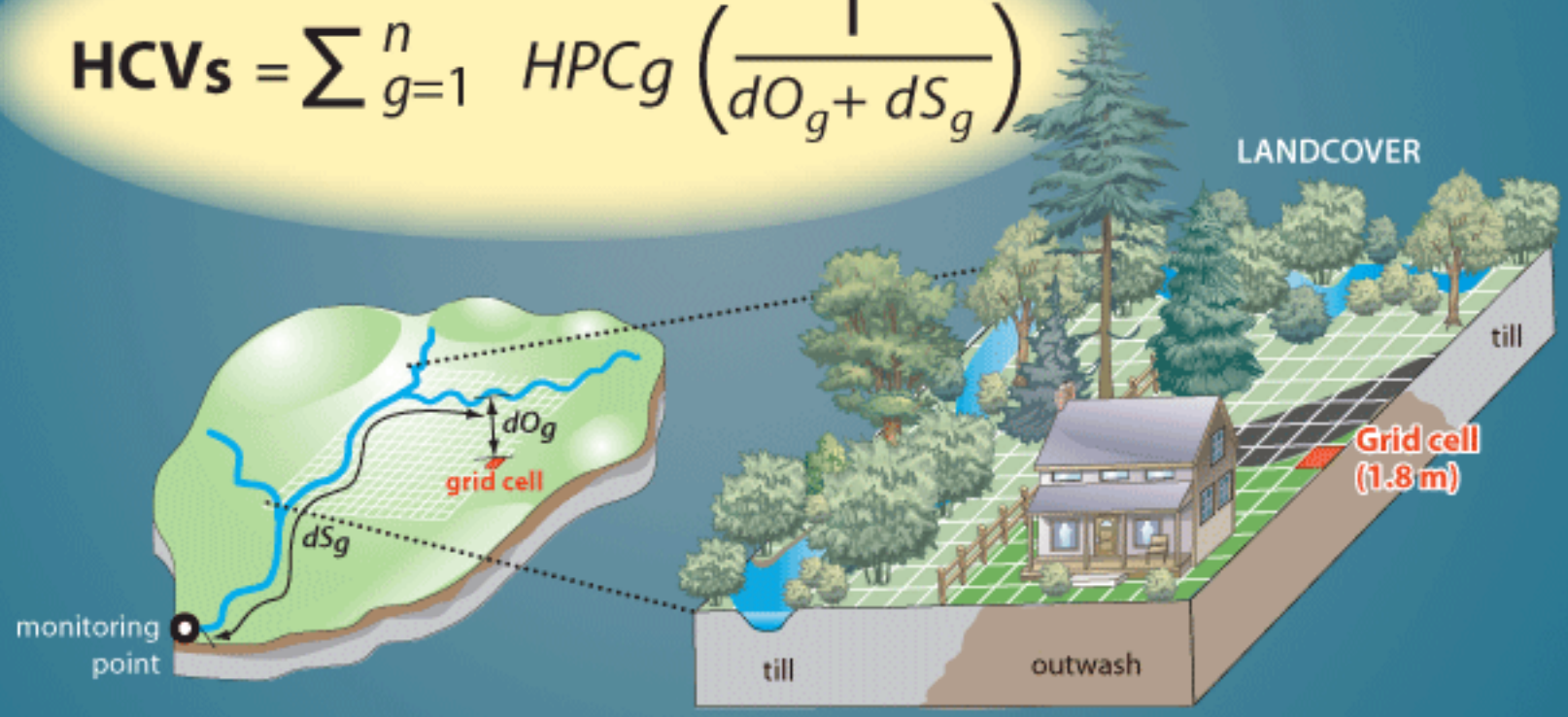
Low vs. High Permeability

Factoring in Landcover



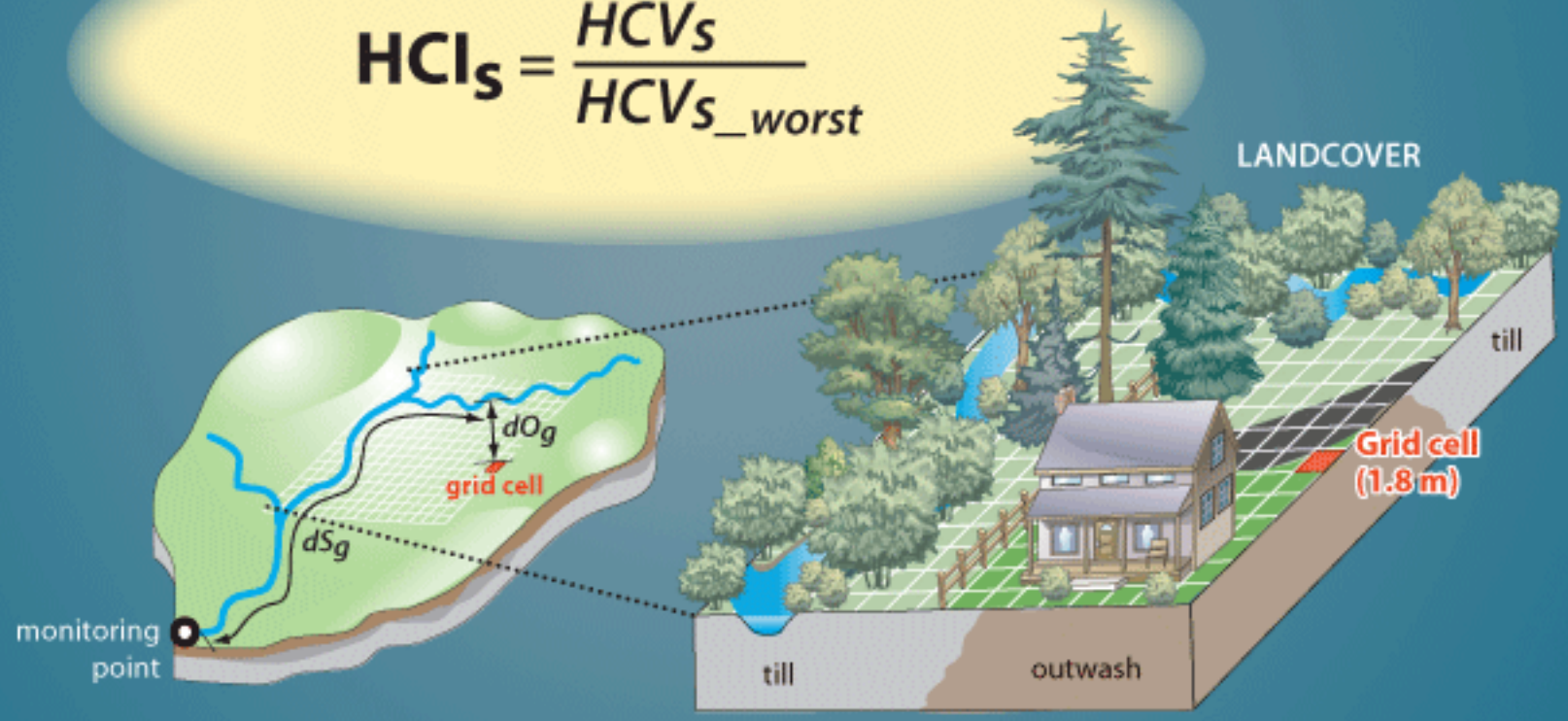
Calculating the Hydrologic Condition Index...Step 1

$$\mathbf{HCVs} = \sum_{g=1}^{n} HPCg \left(\frac{1}{dO_g + dS_g} \right)$$

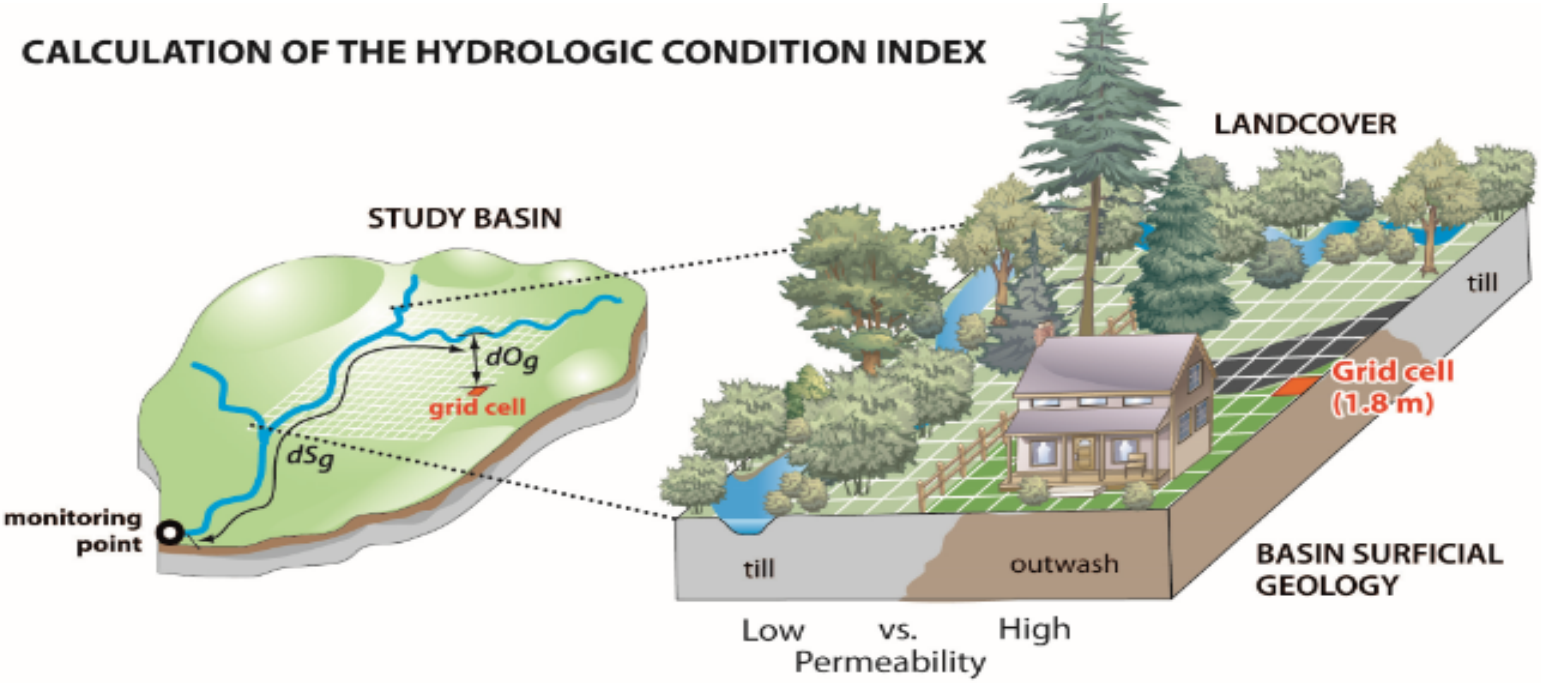


Calculating the Hydrologic Condition Index...Step 2

$$HCI_S = \frac{HCV_S}{HCV_{S_worst}}$$



CALCULATION OF THE HYDROLOGIC CONDITION INDEX



$$HCI_s = \frac{HCV_s}{HCV_{s_worst}}$$

$$HCV_s = \sum_{g=1}^{n} HPCg \left(\frac{1}{dO_g + dS_g}\right)$$

HCIs=the hydrological condition index for a stream site in a watershed, ***s***, given the LULC pattern for a particular year or simulated level of development

HCV*s* = the hydrological condition value for a stream site in a watershed, ***s***, given the LULC pattern for a particular year or simulated level of development

g = an index from 1 to n for all the grid cells within a watershed

HPCg = an average high pulse count value for each grid cell type, g. There are 24 values for HPC based on the combination of 12 LULC types and 2 underlying geology types

dOg = overland distance (Euclidean) from the grid cell, g, to the stream channel

dSg = stream channel distance measured from the intersection of the overland distance to the grid cell, g, to the sampling point downstream.

File: 0308_3363L_RegMonitorMODEL.ai Ipre

Accuracy and utility

Watershed hydrologic models:

- Fair ($r^2 \geq 0.6$) to excellent ($r^2 \geq 0.9$) simulating hourly flow rates and HPCs,

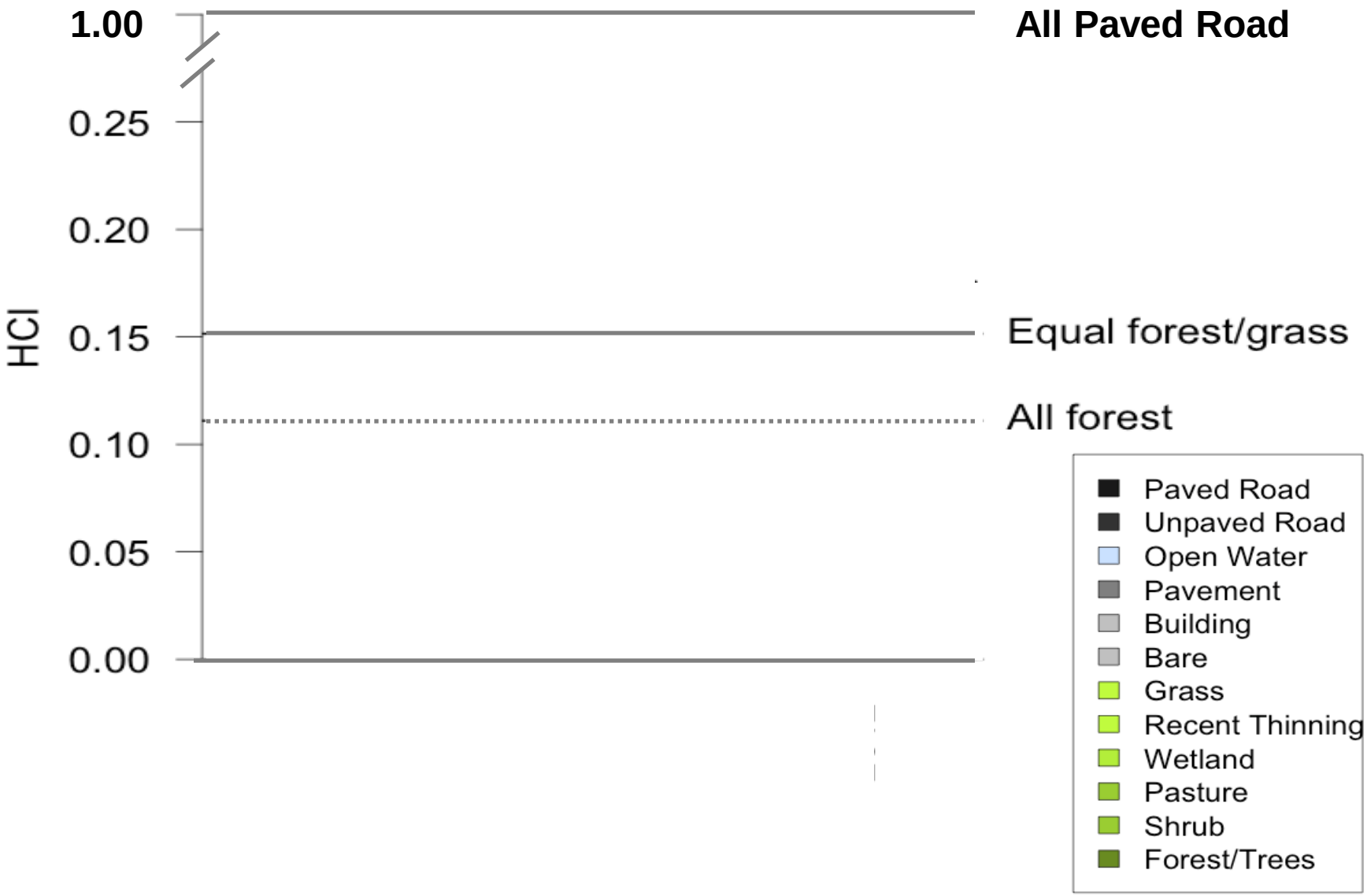
- used for other major assessments (e.g., WRIA 9 Stormwater Retrofit Planning)

- BAS

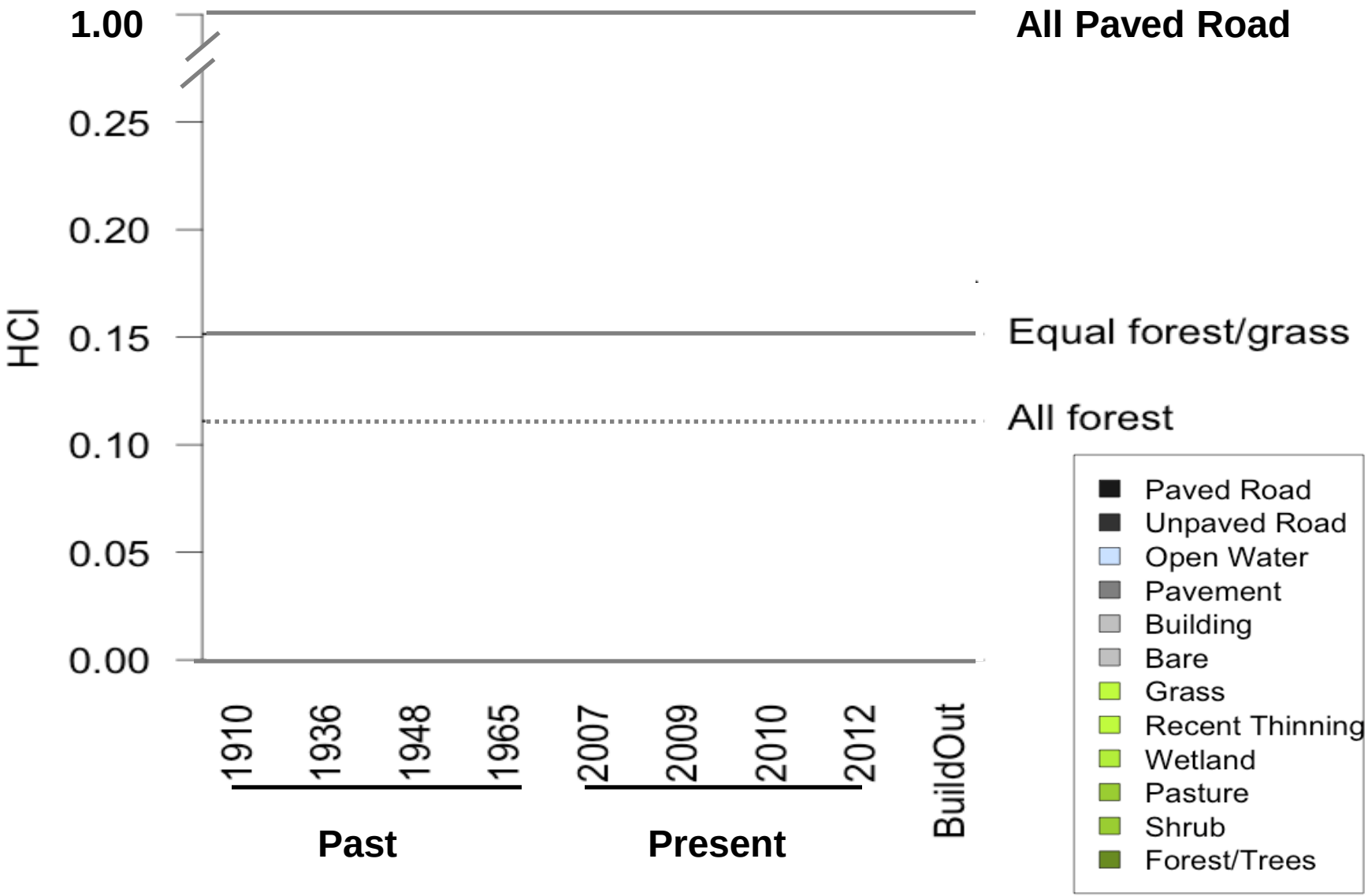
Project timeframe averages for six treatment watersheds	Average Watershed HCI		Average Regulatory Stream Buffer HCI	
	r	p-value	r	p-value
Watershed Percent Impervious	**0.94**	**<0.01**	0.68	0.07
Watershed Percent Forest	**-0.91**	**<0.01**	-0.58	0.12
Average Watershed HCI	-	-	0.71	0.06
Average Regulatory Stream Buffer HCI	0.71	0.06	-	-
Ratio of watershed and buffer HCIs	0.05	0.46	-0.66	0.08
High Pulse Count	**0.88**	**0.01**	**0.96**	**<0.01**
Average Annual Temp at Baseflow	0.20	0.36	0.6	0.10
Conductivity at Baseflow	0.08	0.44	-0.24	0.33
Percent Pool Length of Thalweg	0.44	0.19	-0.03	0.96
CV of Thalweg Depth	-0.44	0.19	-0.55	0.13
Average Velocity at MAD	0.36	0.24	0.85	0.02
Average Residual Pool Depth	0.08	0.44	0.68	0.07
Large Wood per 100m	0.64	0.09	0.55	0.13
Percent Silt and Sand	-0.36	0.24	-0.78	0.03
BIBI	0.42	0.21	0.56	0.12
X7DADMax	0.94	<0.01	0.68	0.07

Putting it all together

Hydrologic condition over time



Hydrologic condition over time



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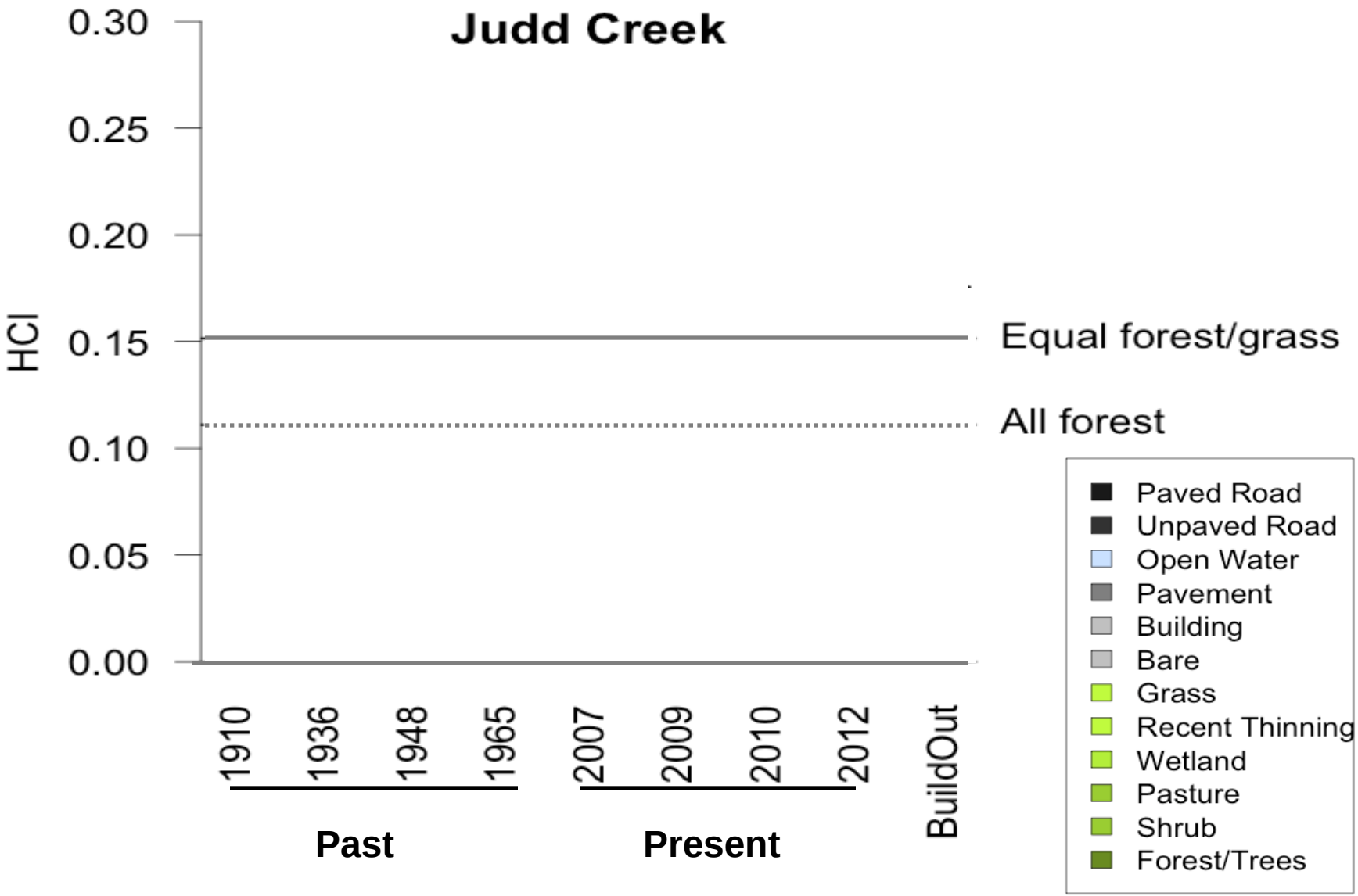

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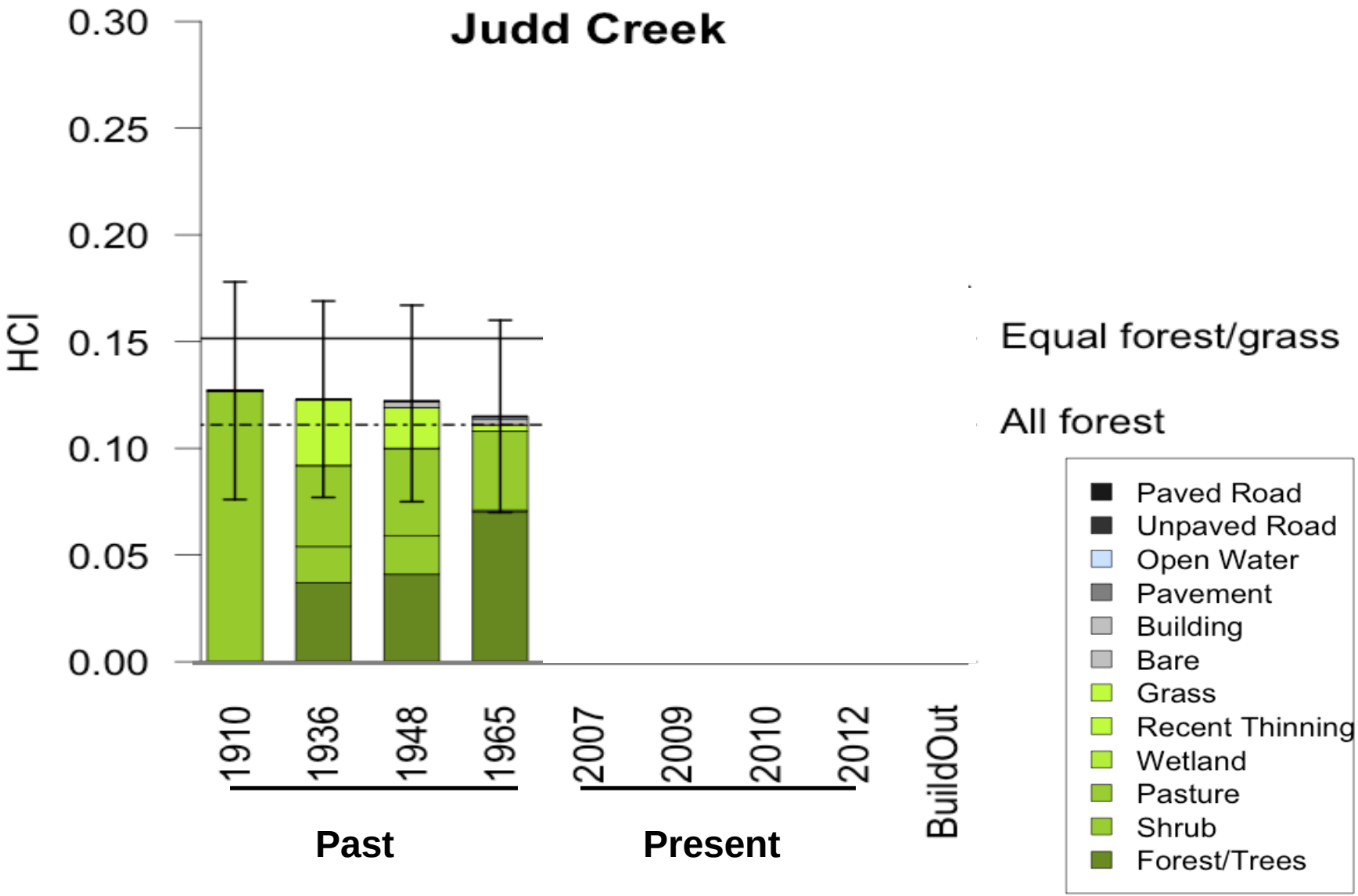

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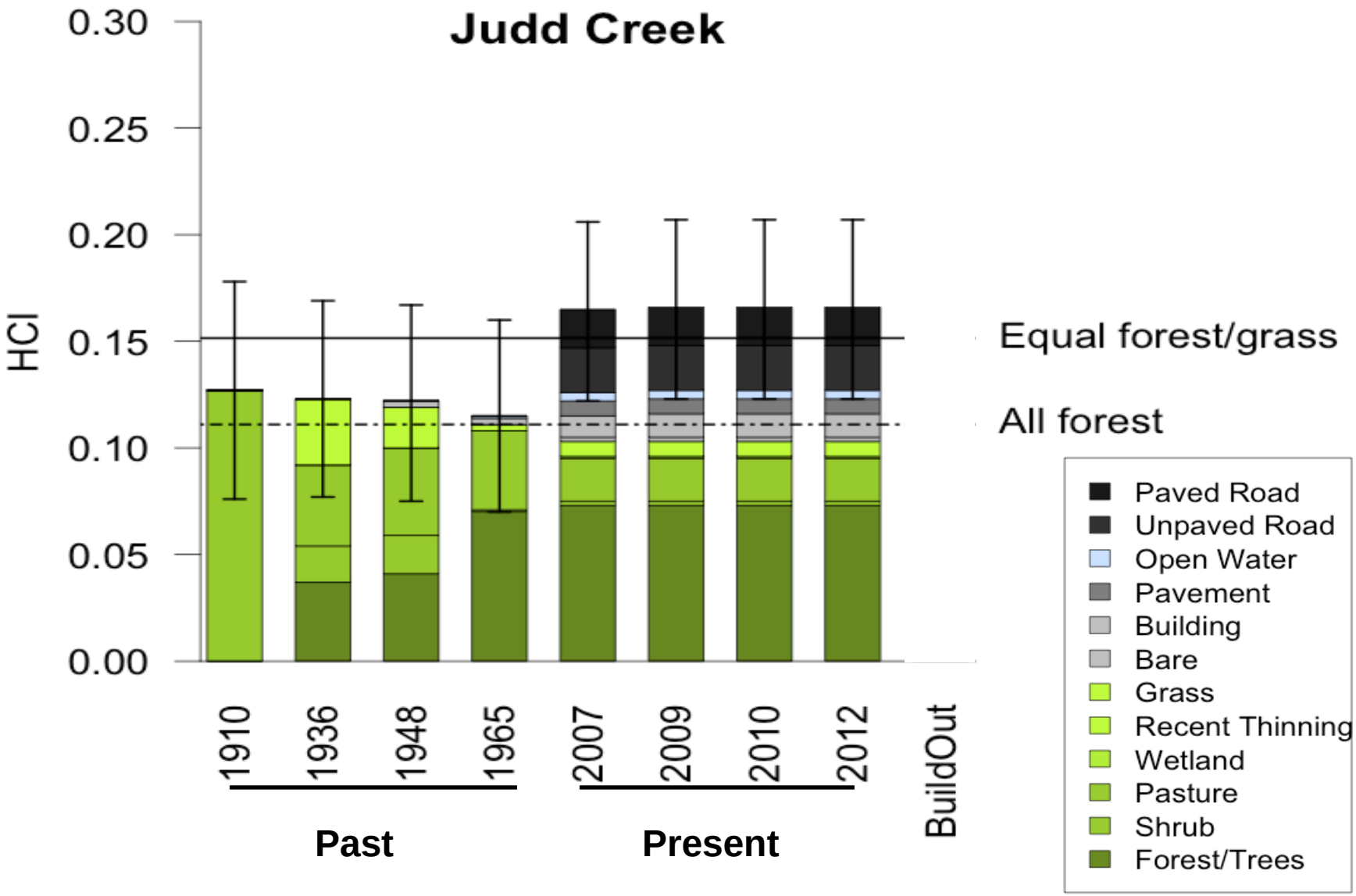
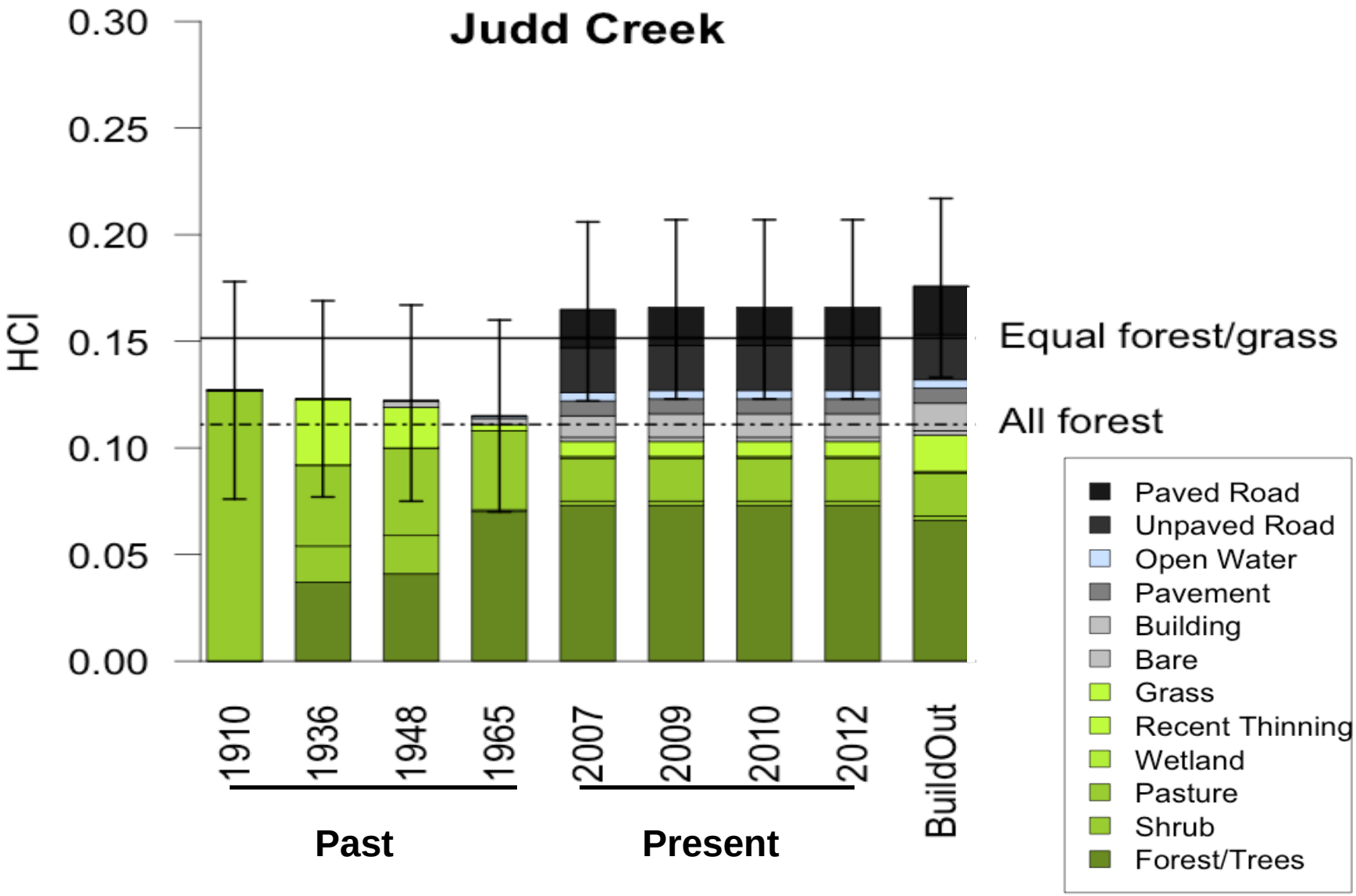
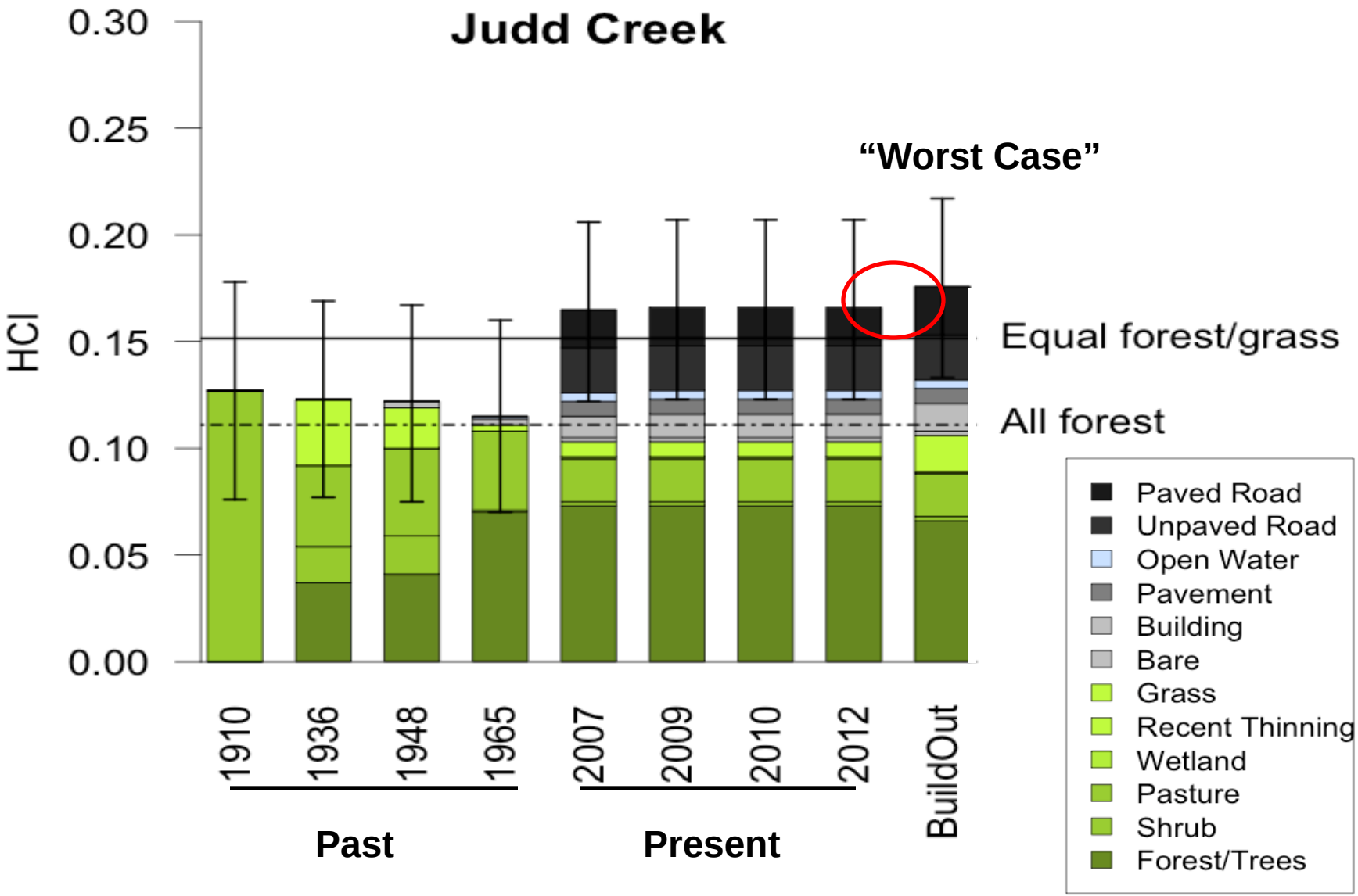


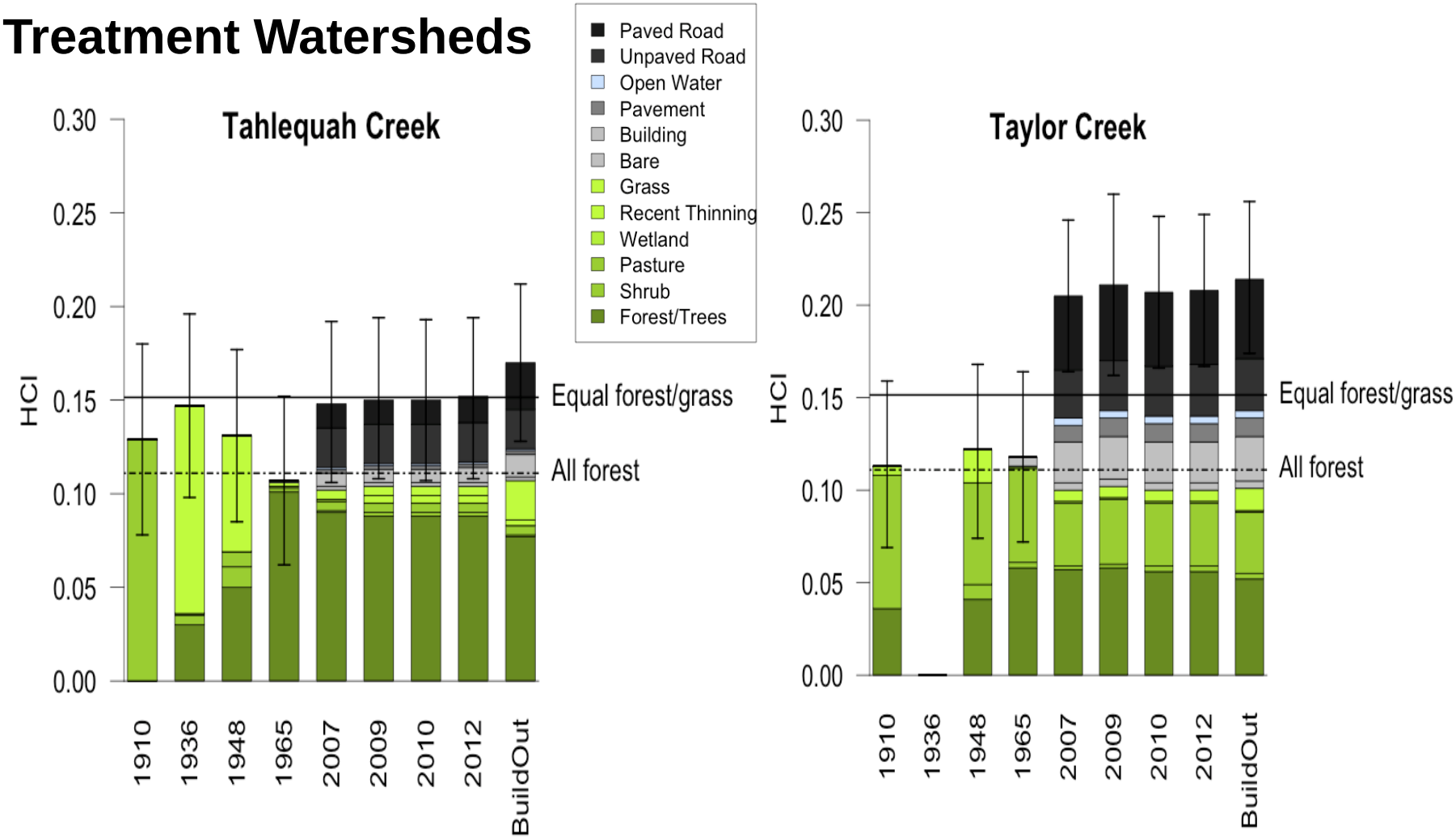
Hydrologic condition over time



Hydrologic condition over time



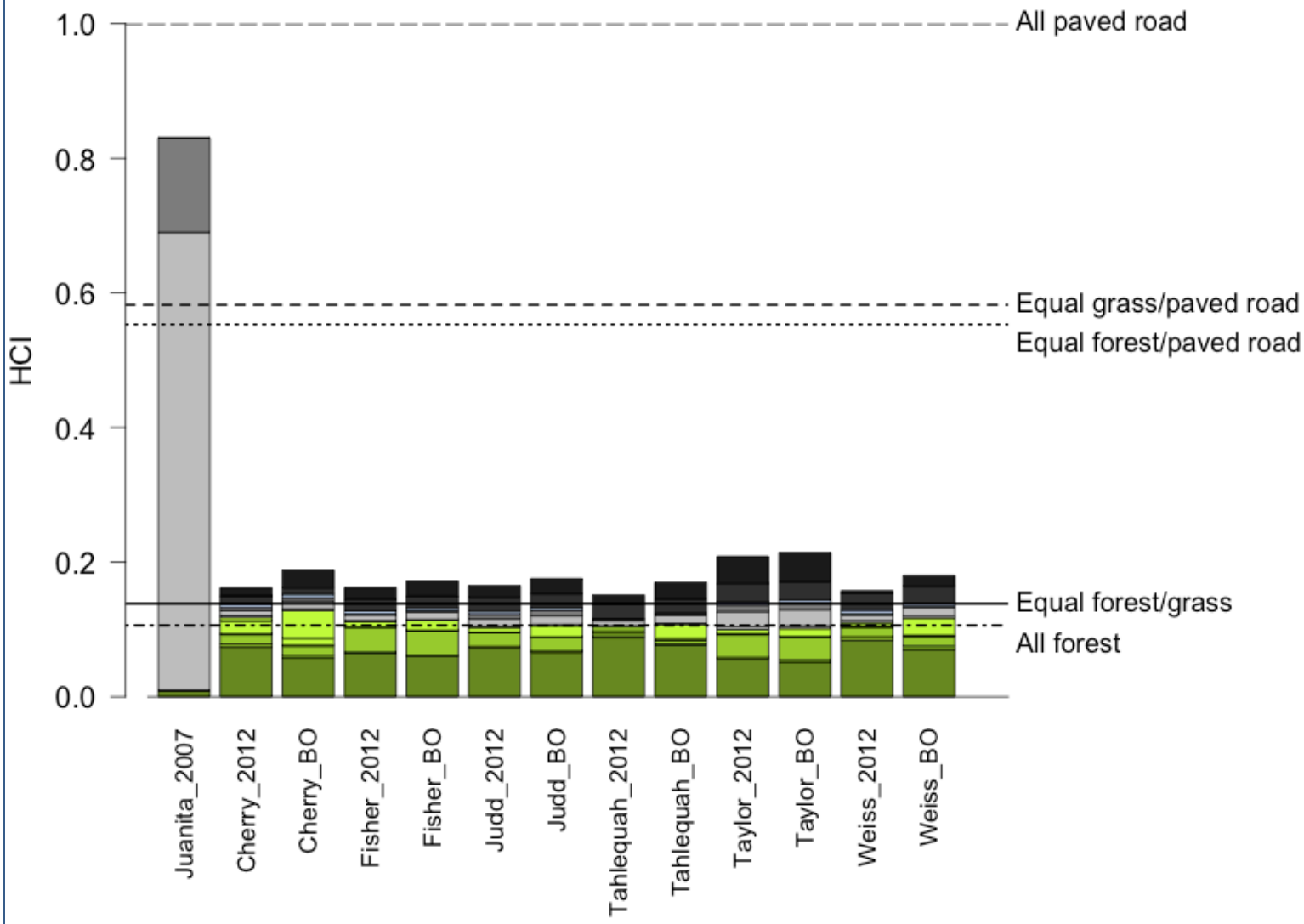
Treatment Watersheds

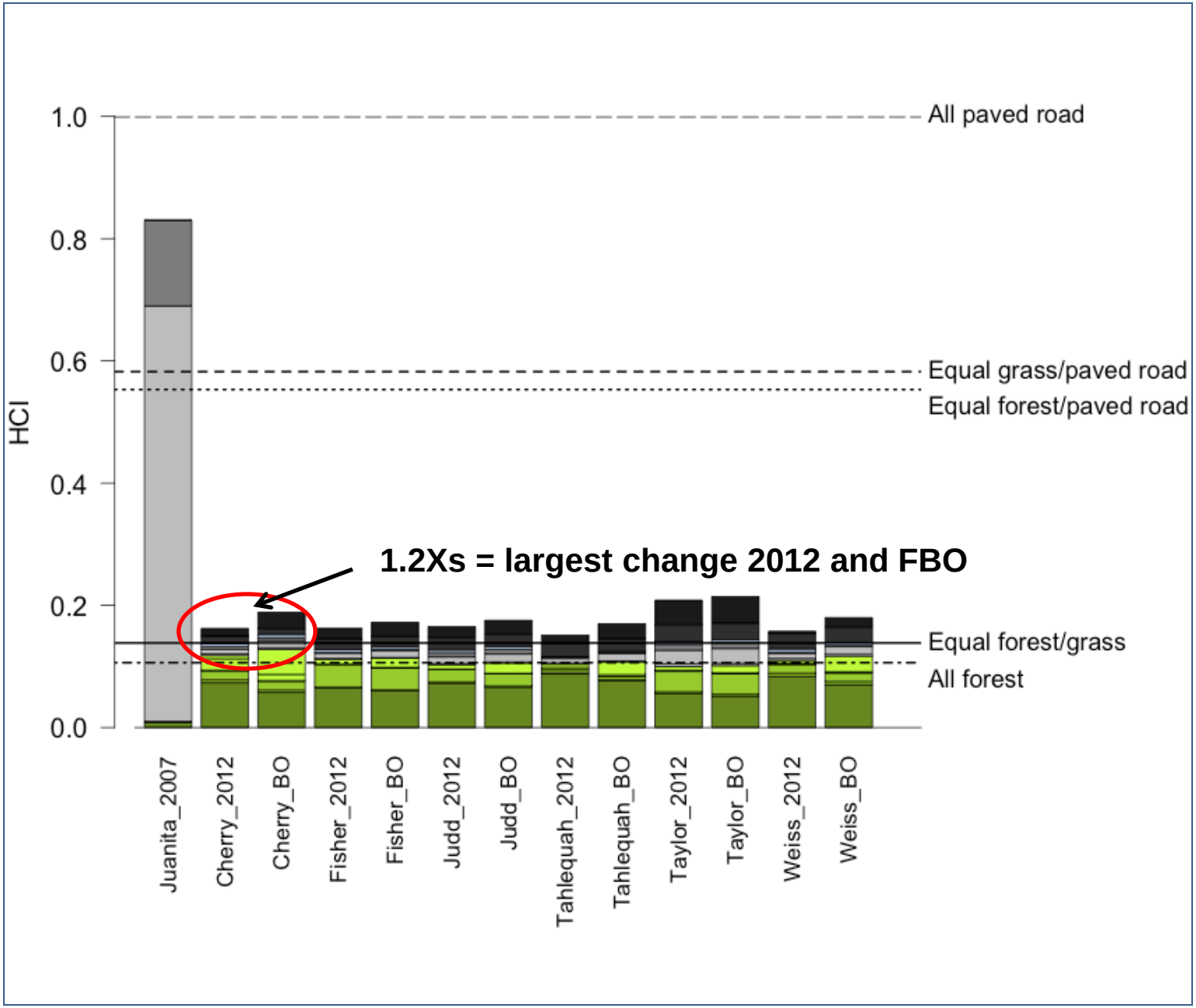


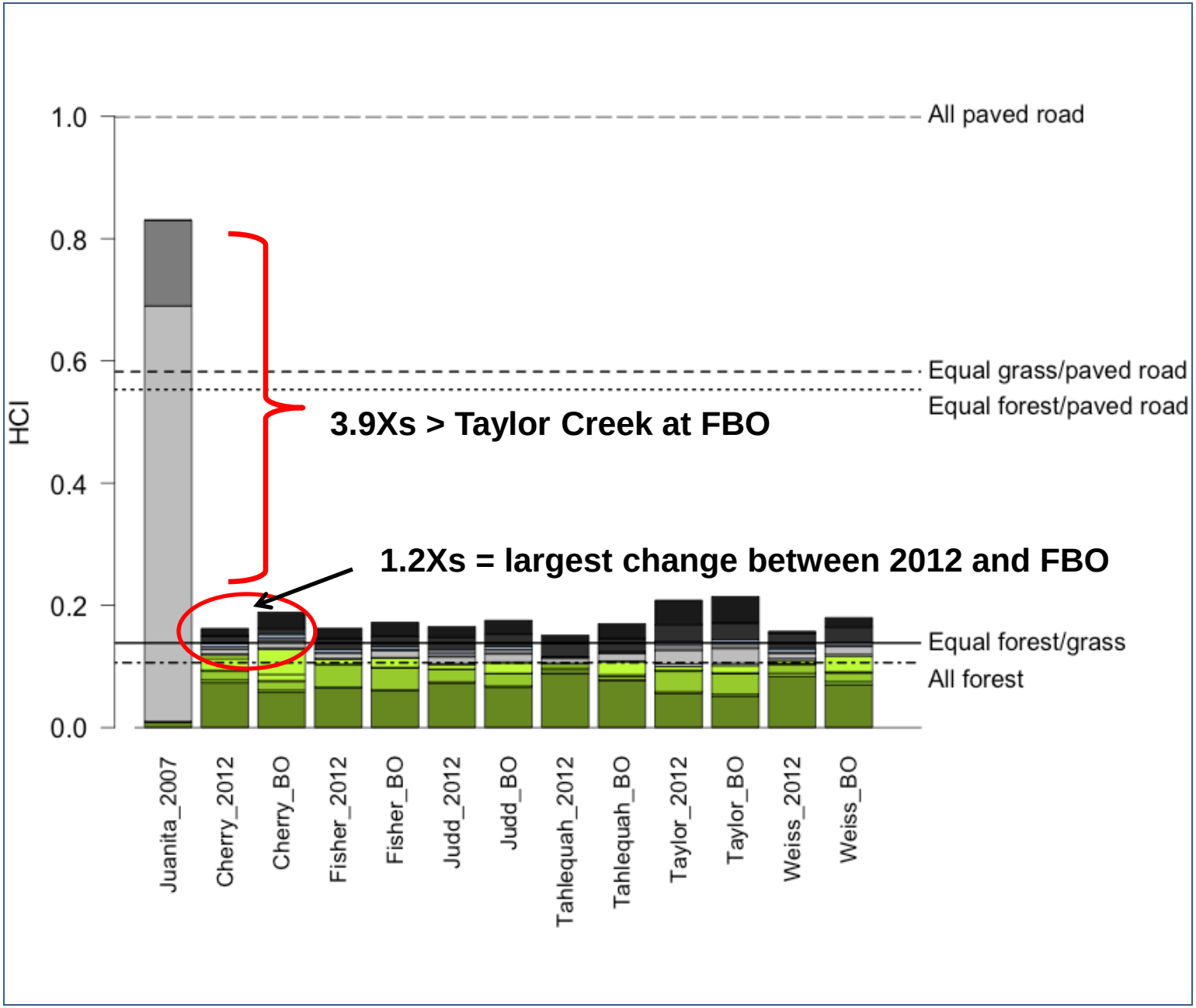
Least ⟷ **Most**

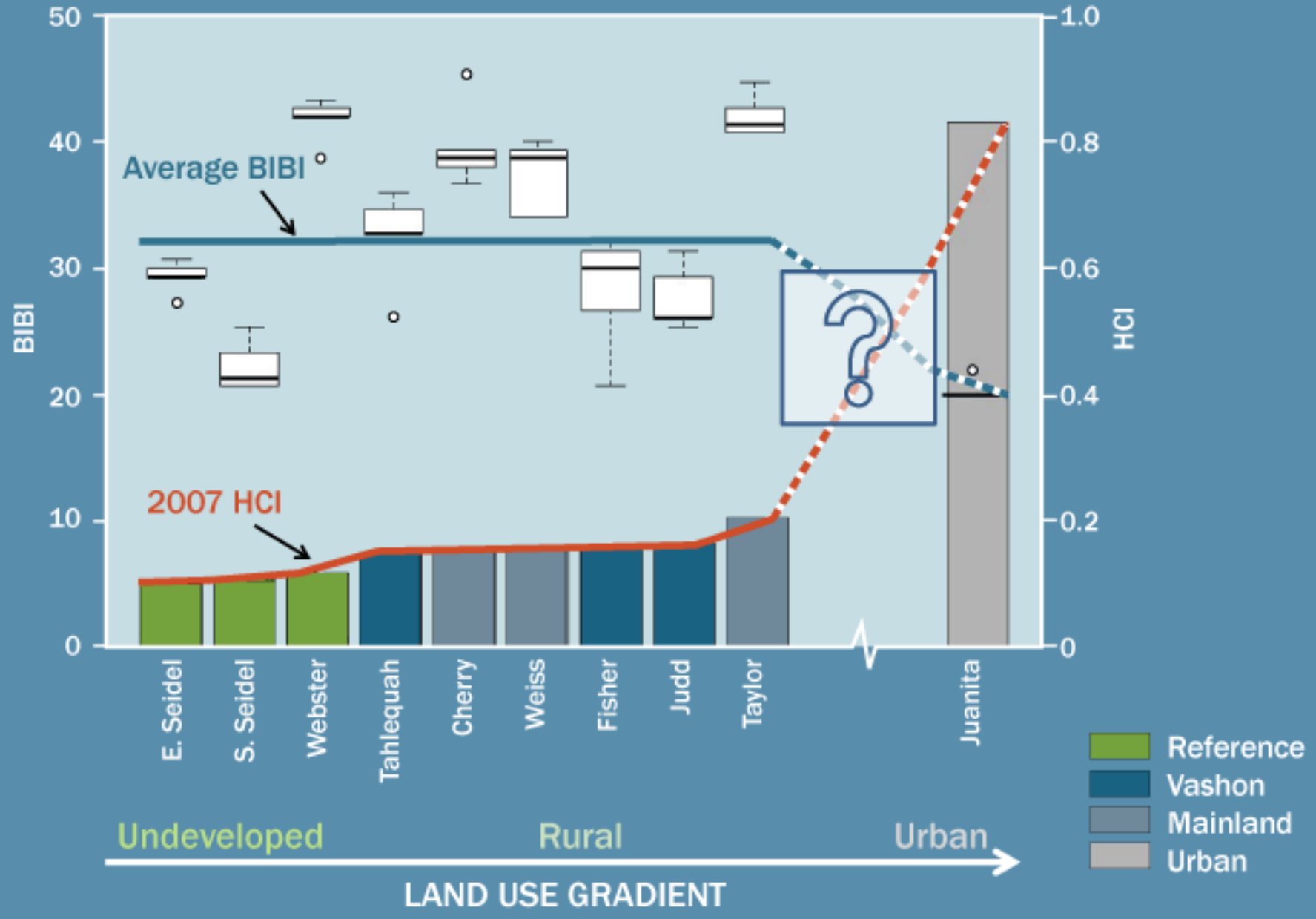
Level of current development

Juanita Creek (urban) comparison




1.0
0.8
0.6
0.4
0.2
0.0
HCI
All paved road
Equal grass/paved road
Equal forest/paved road
1.2Xs = largest change 2012 and FBO
Equal forest/grass
All forest
Juanita_2007
Cherry_2012
Cherry_BO
Fisher_2012
Fisher_BO
Judd_2012
Judd_BO
Tahlequah_2012
Tahlequah_BO
Taylor_2012
Taylor_BO
Weiss_2012
Weiss_BO


1.0
0.8
0.6
0.4
0.2
0.0
HCI
All paved road
Equal grass/paved road
Equal forest/paved road
Equal forest/grass
All forest
3.9Xs > Taylor Creek at FBO
1.2Xs = largest change between 2012 and FBO
Juanita_2007
Cherry_2012
Cherry_BO
Fisher_2012
Fisher_BO
Judd_2012
Judd_BO
Tahlequah_2012
Tahlequah_BO
Taylor_2012
Taylor_BO
Weiss_2012
Weiss_BO


BIBI
HCI
50
40
30
20
10
0
1.0
0.8
0.6
0.4
0.2
0
Average BIBI
2007 HCI
E. Seidel
S. Seidel
Webster
Tahlequah
Cherry
Weiss
Fisher
Judd
Taylor
Juanita
Reference
Vashon
Mainland
Urban
Undeveloped
Rural
Urban
LAND USE GRADIENT
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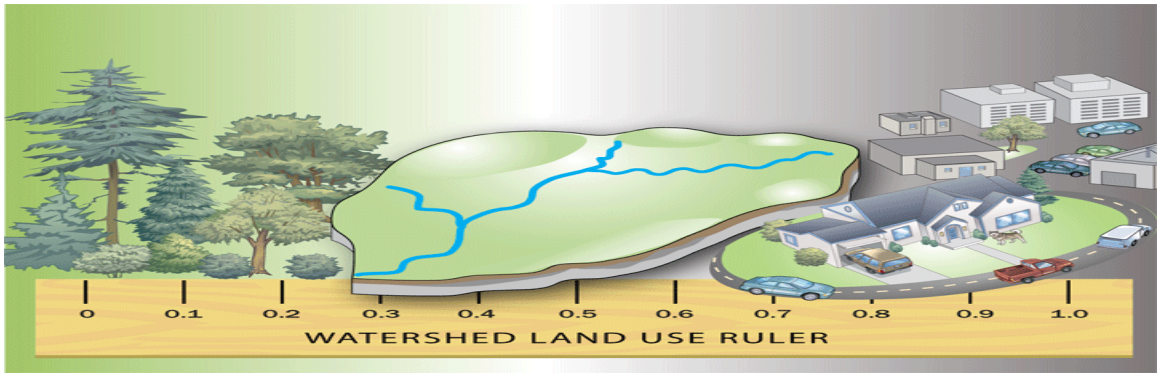
HCI =



- Watershed condition measuring stick

- Effect of distance, land covers and geology (configuration)

- Improved precision in X-axis

- No need to build hydrologic models everywhere in Puget Lowland Ecoregion

End

Context:

In 2005, Washington State Growth Management Act required Critical Areas Ordinance.

Critical Areas Ordinance required use of Best Available Science.

We used it. It survived appeals.

But, was it sufficient?

Issue:

New regulations needed assessment.

Little information… no certainty

Wanted to know:

Will new regulations be sufficient?

If not, why?

And, what would change?

Measuring Environmental Response

Hydrology – High Pulse Counts

Biology

- Macro-invertebrates
- BIBI

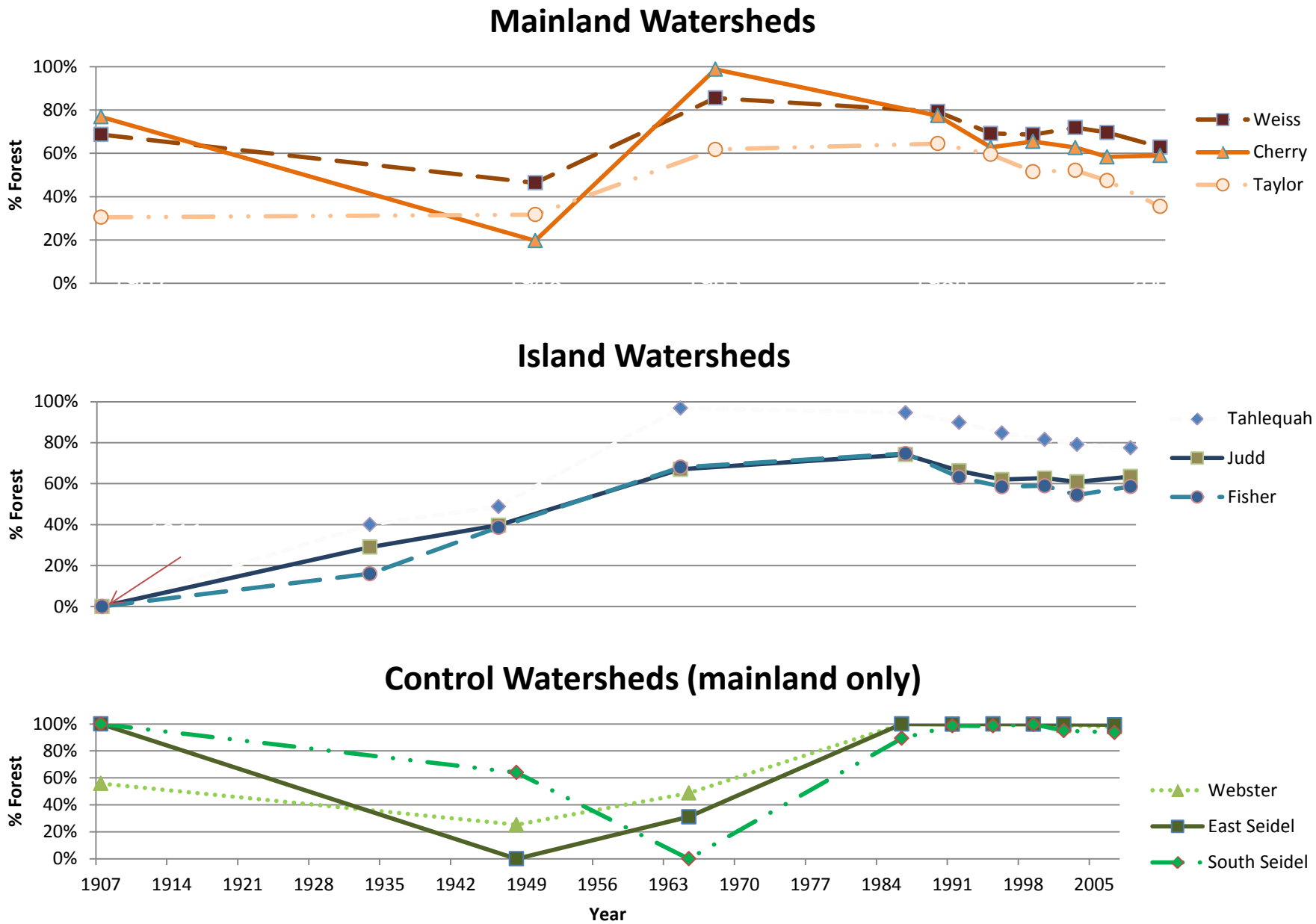
Water Quality

- Conductivity, Temperature

Channel Complexity

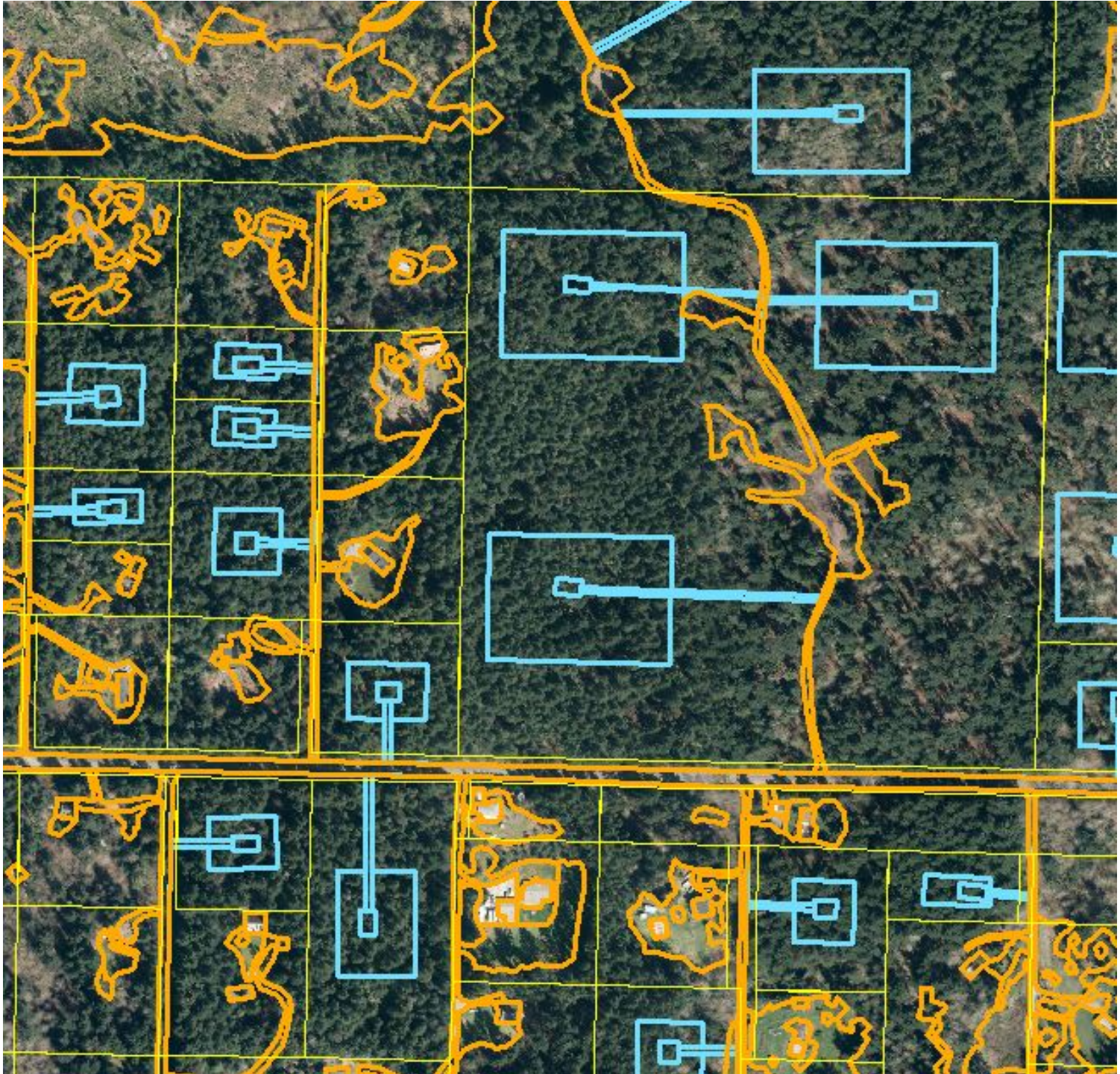
- Reach-Averaged Velocity (salt tracers)
- EMAP – substrate, thalweg, pools, LWD

Change in % Forest Cover - 1907-11 to 2007*



*Michalak et al. 2013

Estimating the Future Condition



accounting for
land cover, geology and distance

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