Deducing Dominant Drivers of Discharge Dynamics: Simultaneously Testing Multiple Causal Hypotheses of Changes in Spring Flow

UF Water Institute Symposium

February 25th, 2020

Nathan Reaver

Acknowledgements

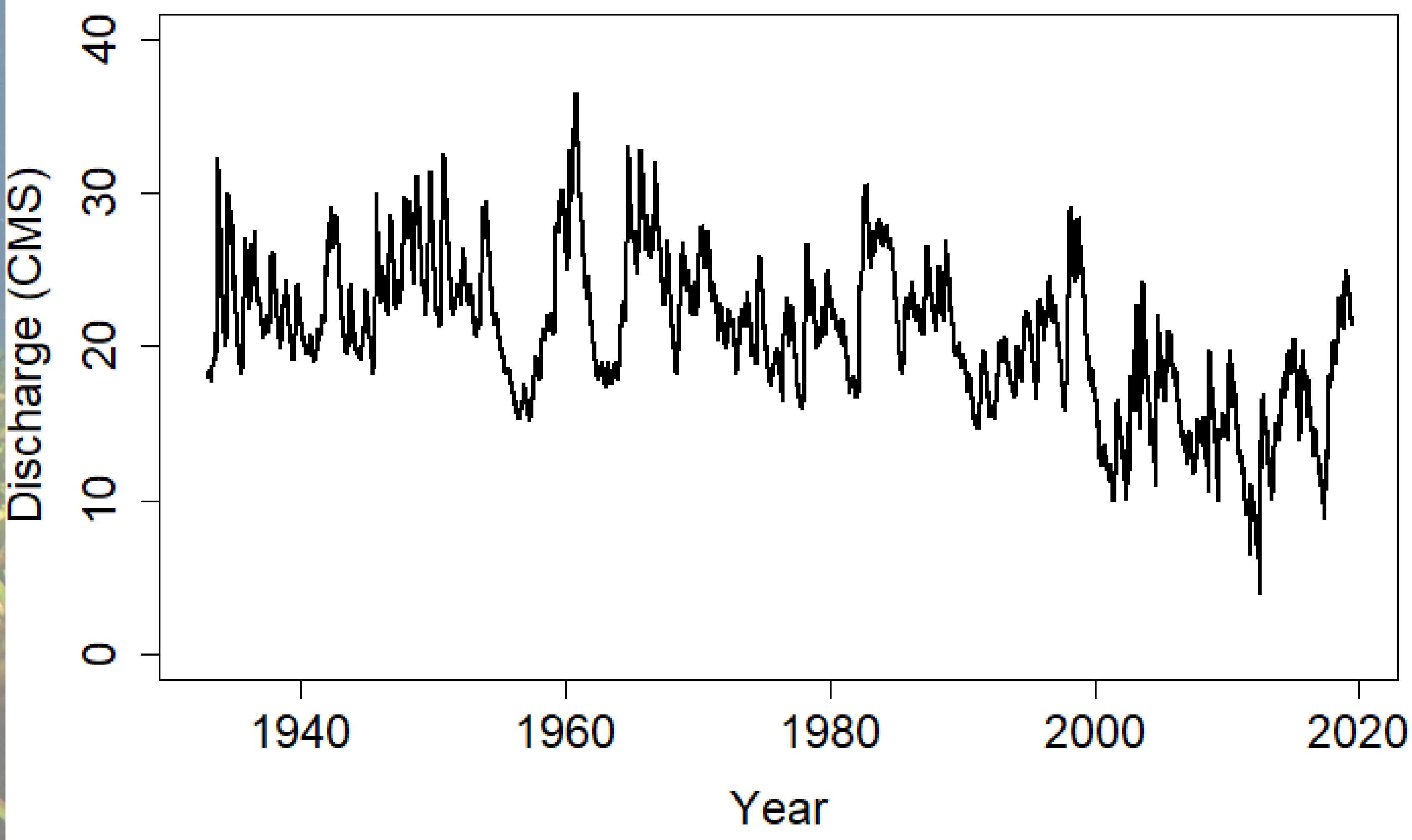
Why is Flow in Silver Springs Declining?

Florida Fish and Wildlife Foundation
Contract No. PFS 1819-06

https://www.floridastateparks.org/learn/geology-silver-springs


https://www.floridastateparks.org/silversprings

Silver Springs Flow Decline



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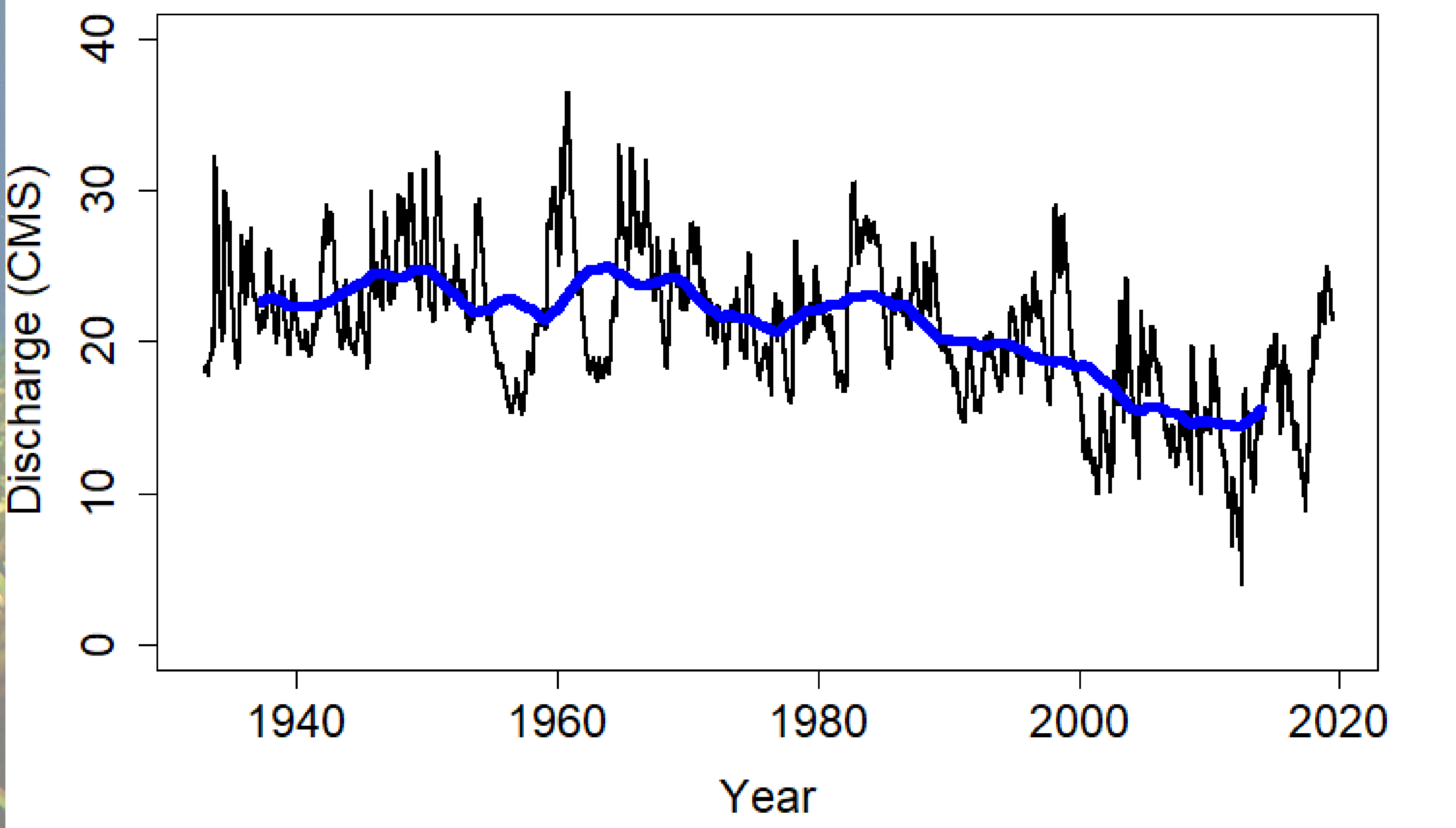

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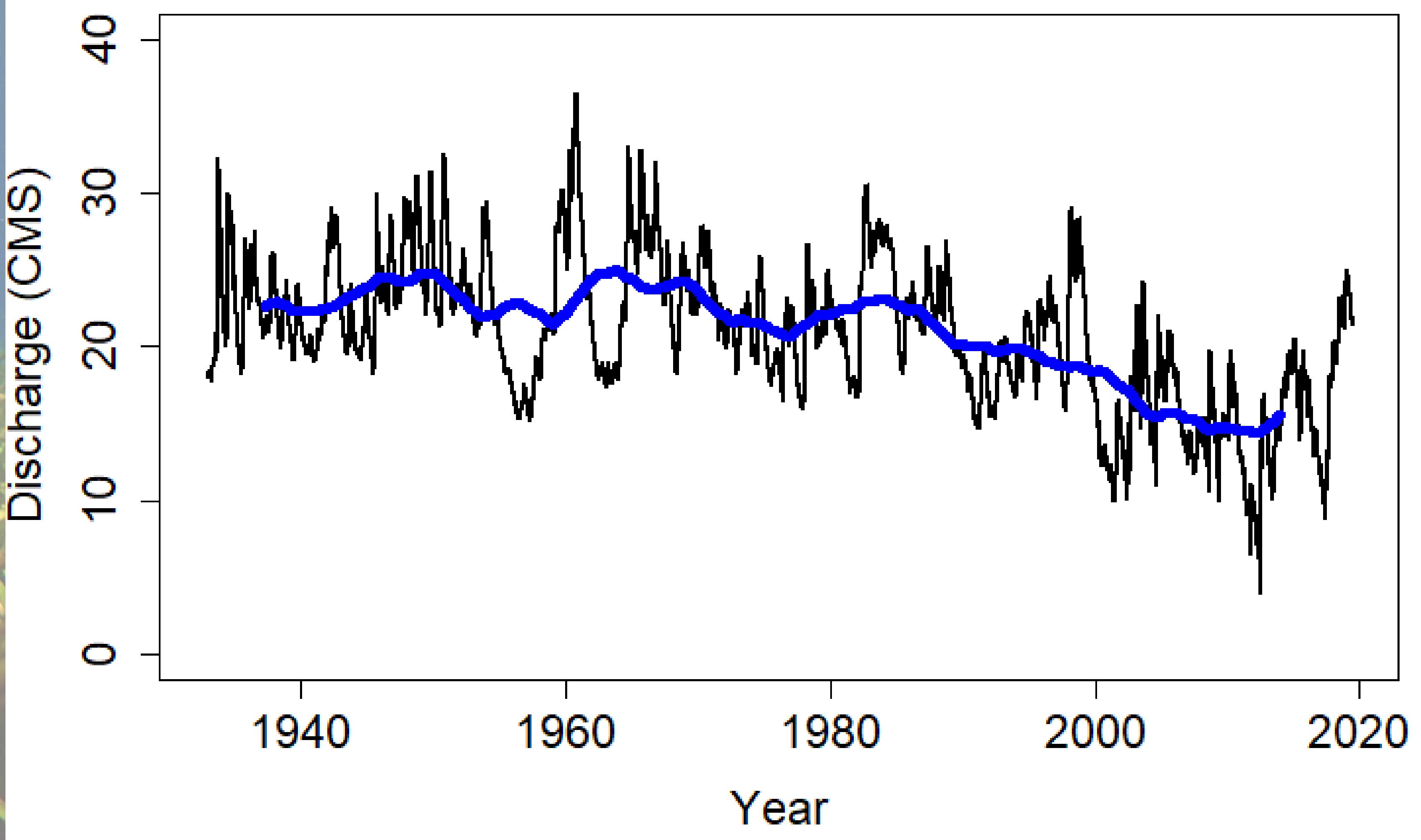

Why is Flow in Silver Springs Declining?

Proposed flow decline mechanisms

H1-Springshed area decline

H2-Recharge decline due to climate shifts

H3-Groundwater pumping

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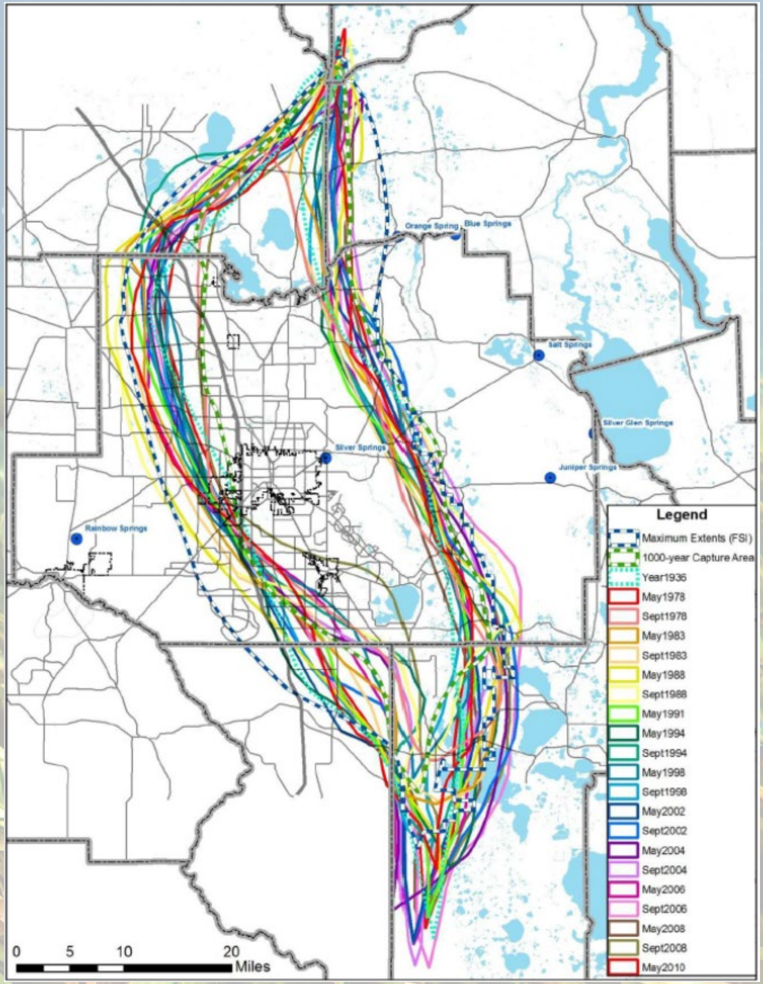

Howard T. Odum Florida Springs Institute (2014). Silver Springs Restoration Plan

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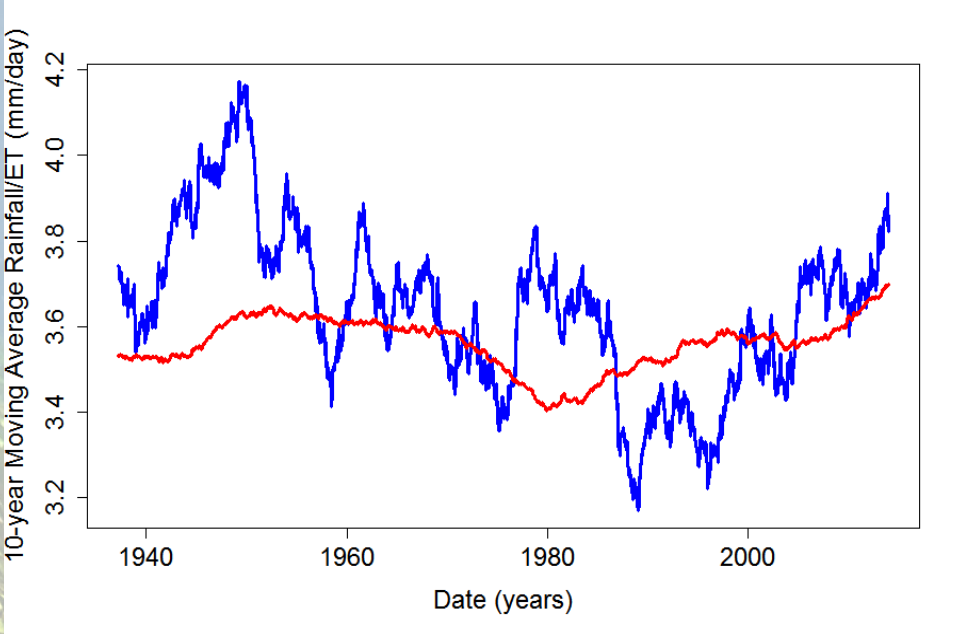

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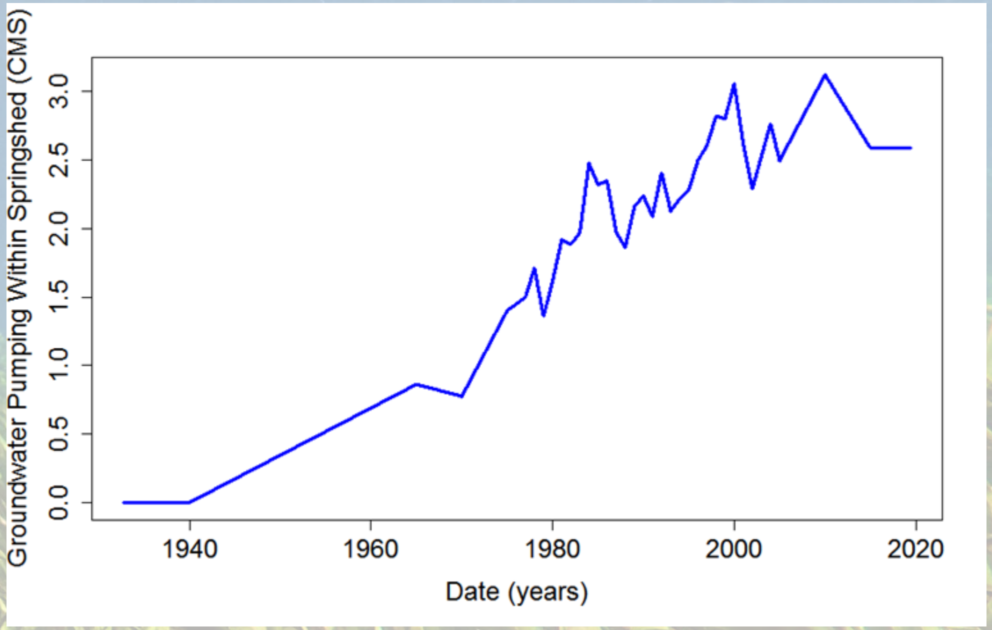

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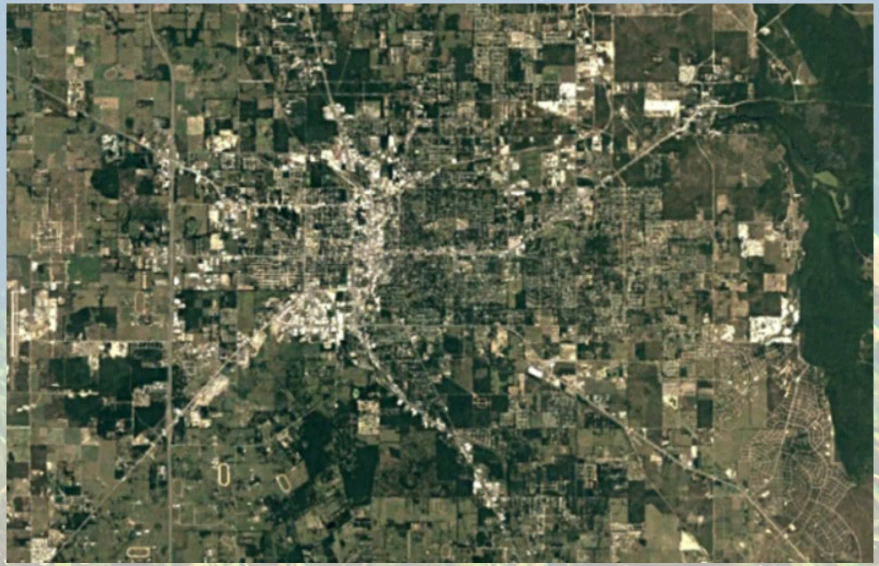

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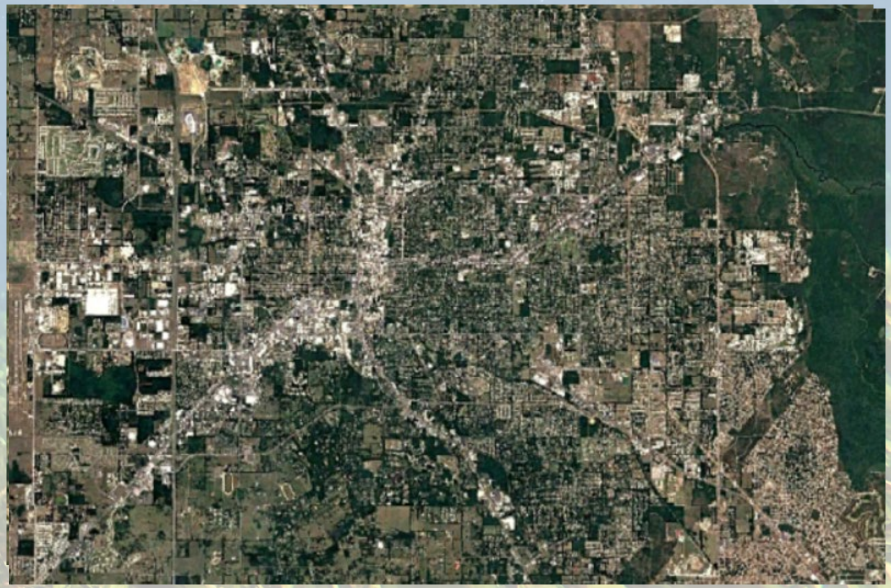

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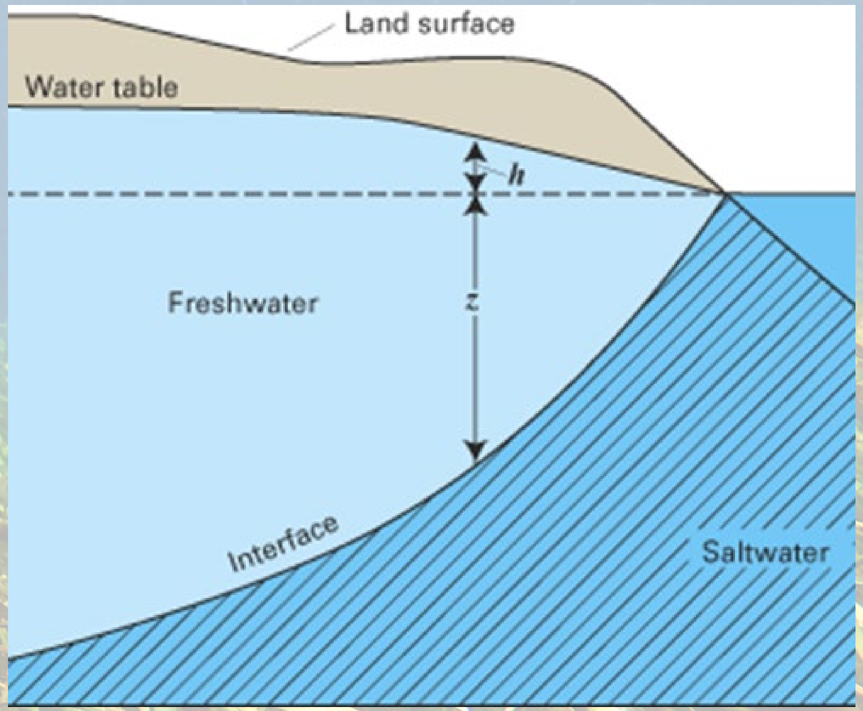

Barlow, Paul M. (2003). Ground Water in Freshwater-Saltwater Environments of the Atlantic Coast. USGS. Retrieved on 2009-03-21. Figure B-1

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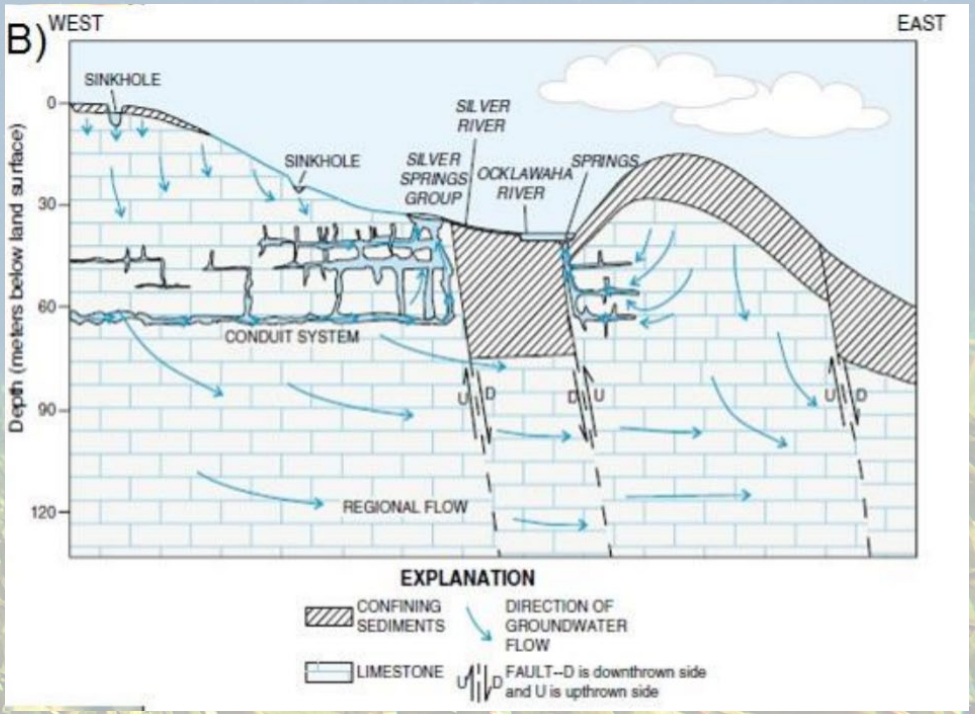

Knowles et al. 2010

Simultaneously Testing Multiple Hypotheses

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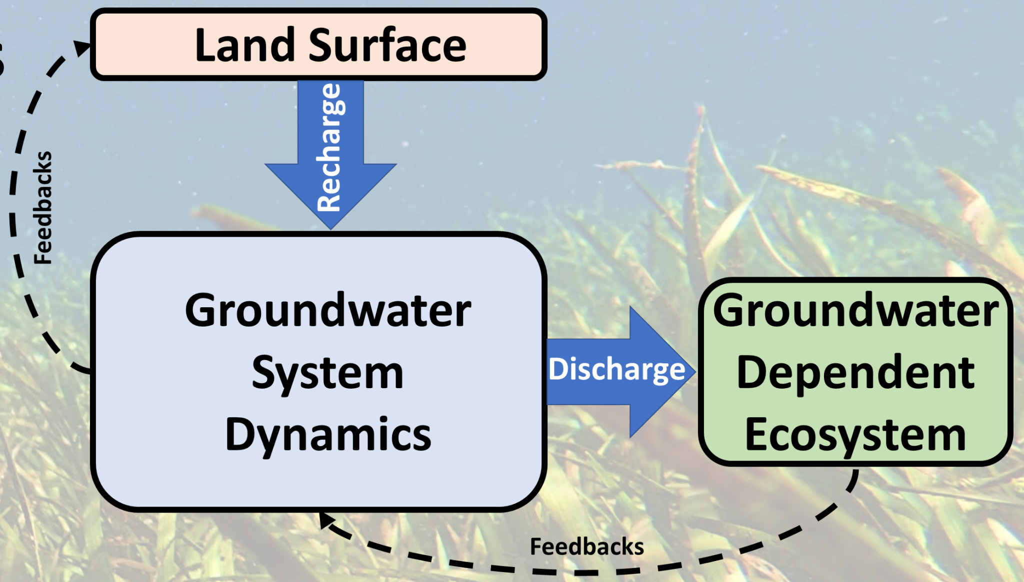

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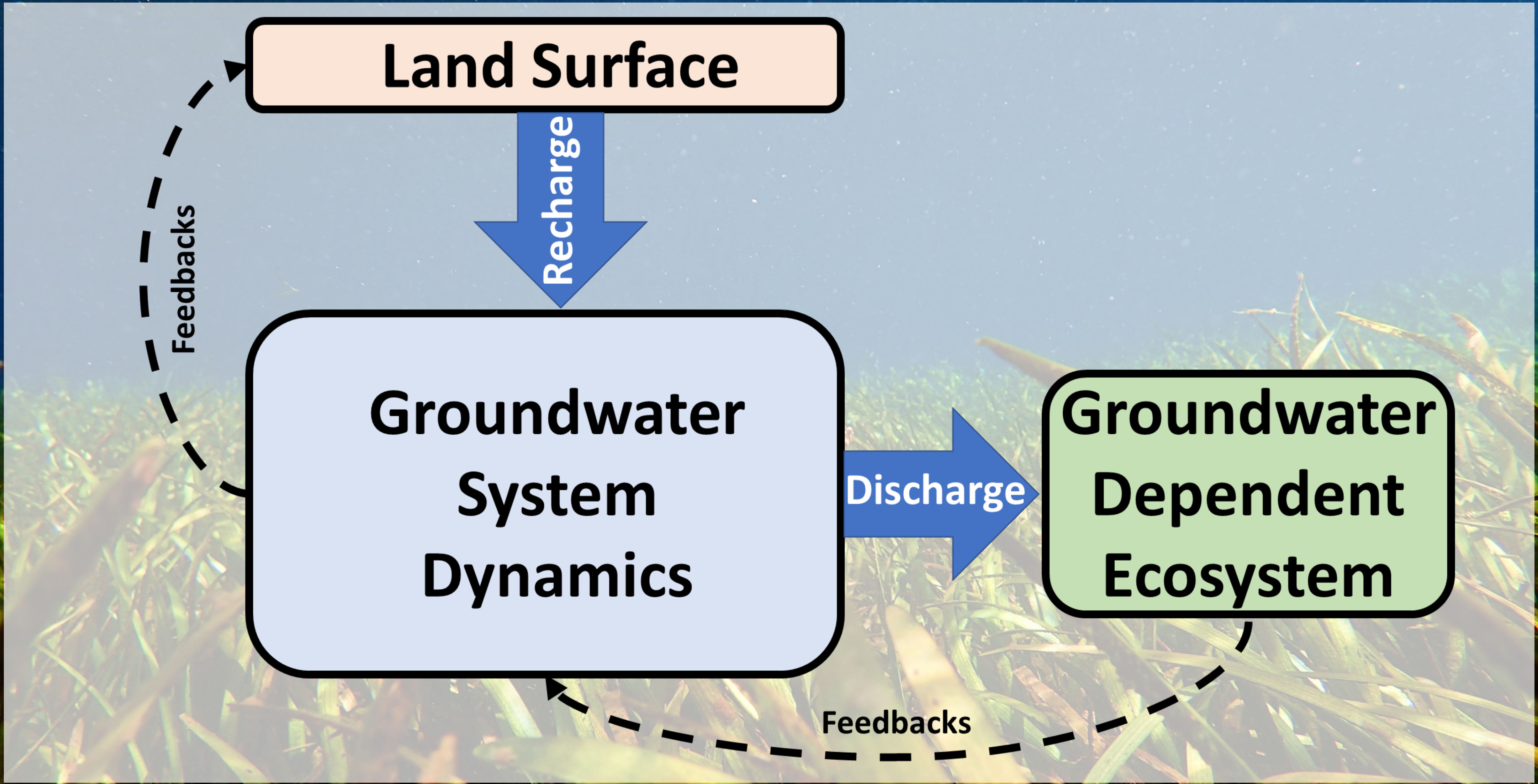

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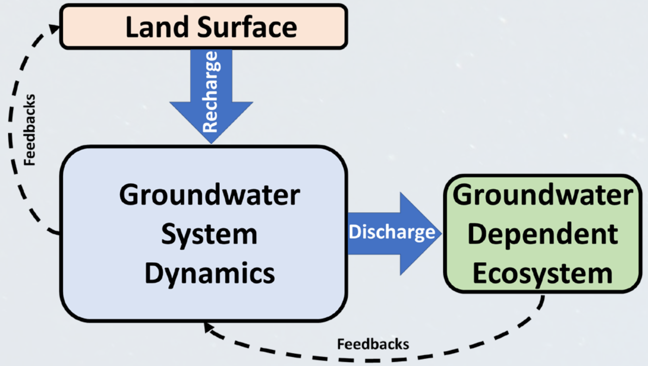
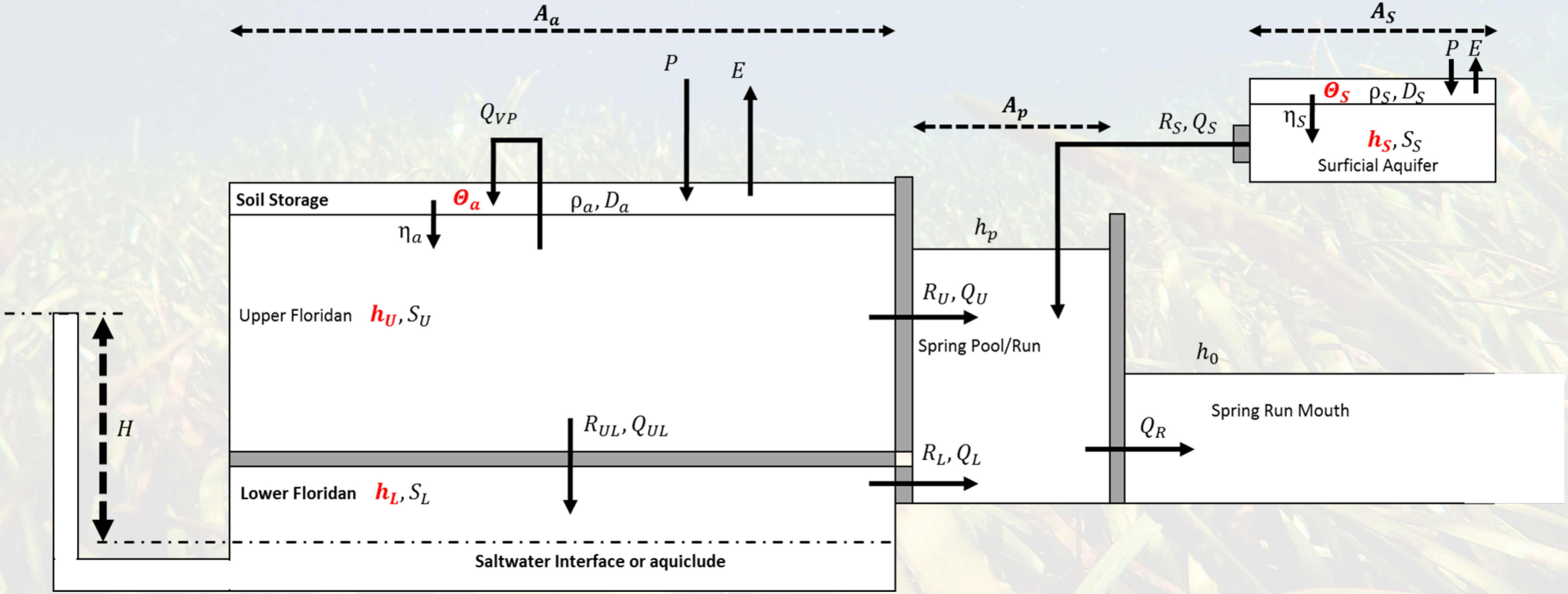


Process-Inclusive Model



Simultaneously Testing Multiple Hypotheses

Proposed flow decline mechanisms

H1-Springshed area decline – **allow time varying springshed area**

H2-Recharge decline due to climate shifts – **drive model with climate observations**

H3-Groundwater pumping – **drive model with pumping estimates**

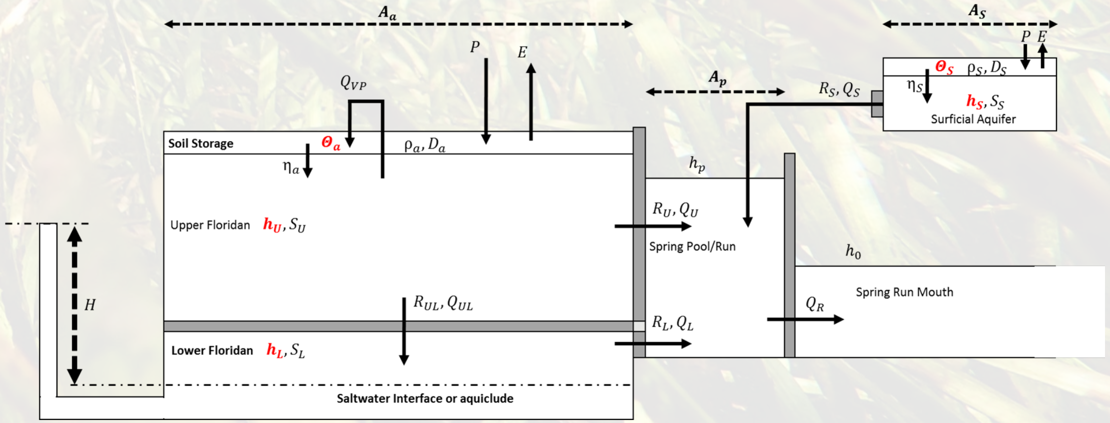
H4-Landuse change - **allow time varying soil storage capacity**

H5-Ghyben-Herzberg principle – **storativity of lower aquifer**

H6-Vegetative "damming" of the spring – **allow time varying river resistance**

H7-Surficial aquifer "damming" of the spring – **size of surficial aquifer**

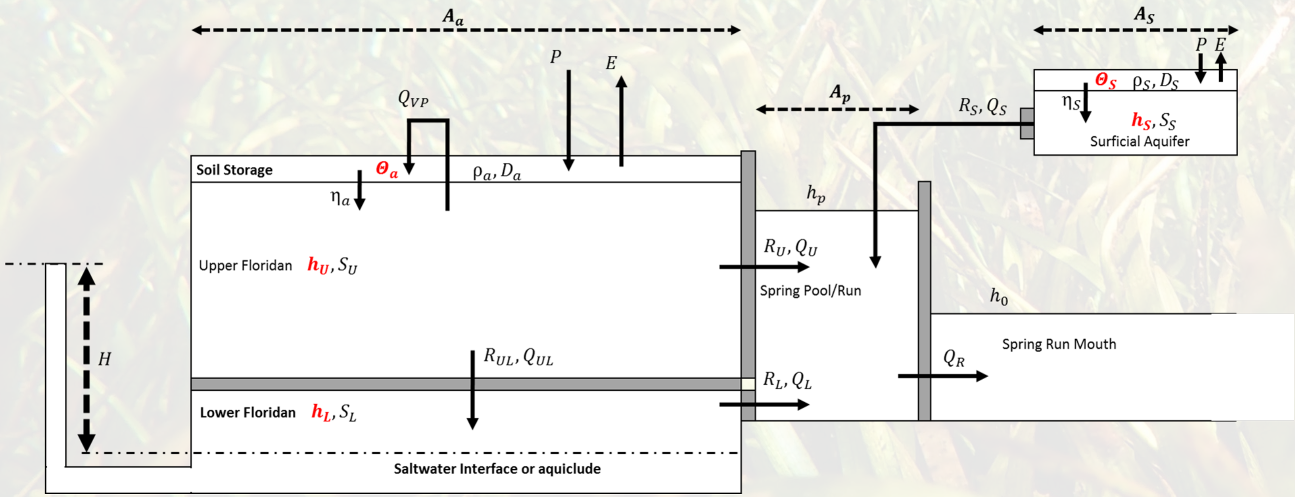
Process-Inclusive Model



Simultaneously Testing Multiple Hypotheses

Calibrating to Data:

$$Pr(H|D) \propto Pr(D|H)Pr(H)$$



Available Groundwater Observations

Process-Inclusive Mechanistic Model

D H

$$Pr(D|H)Pr(H)$$

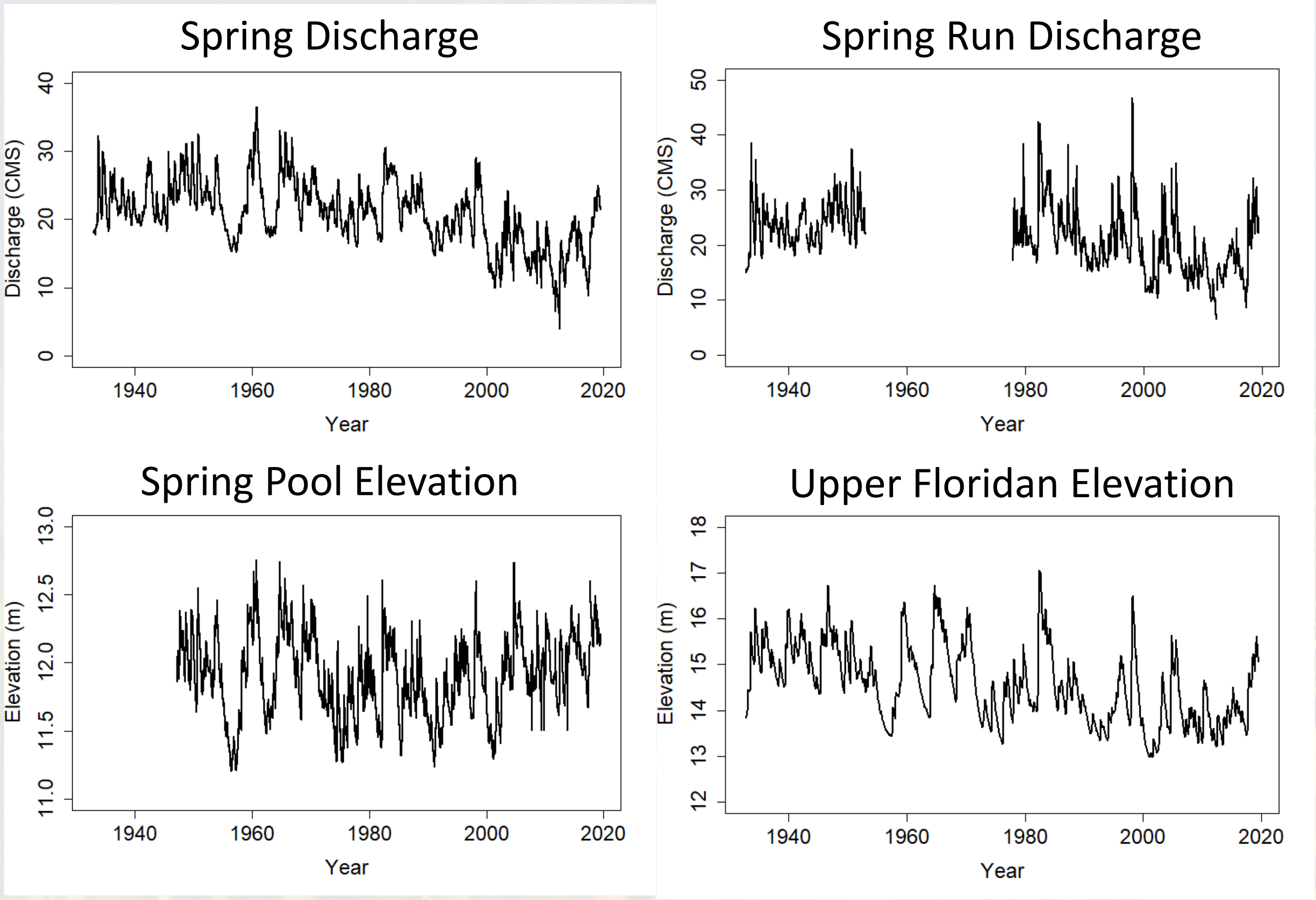
Calibration

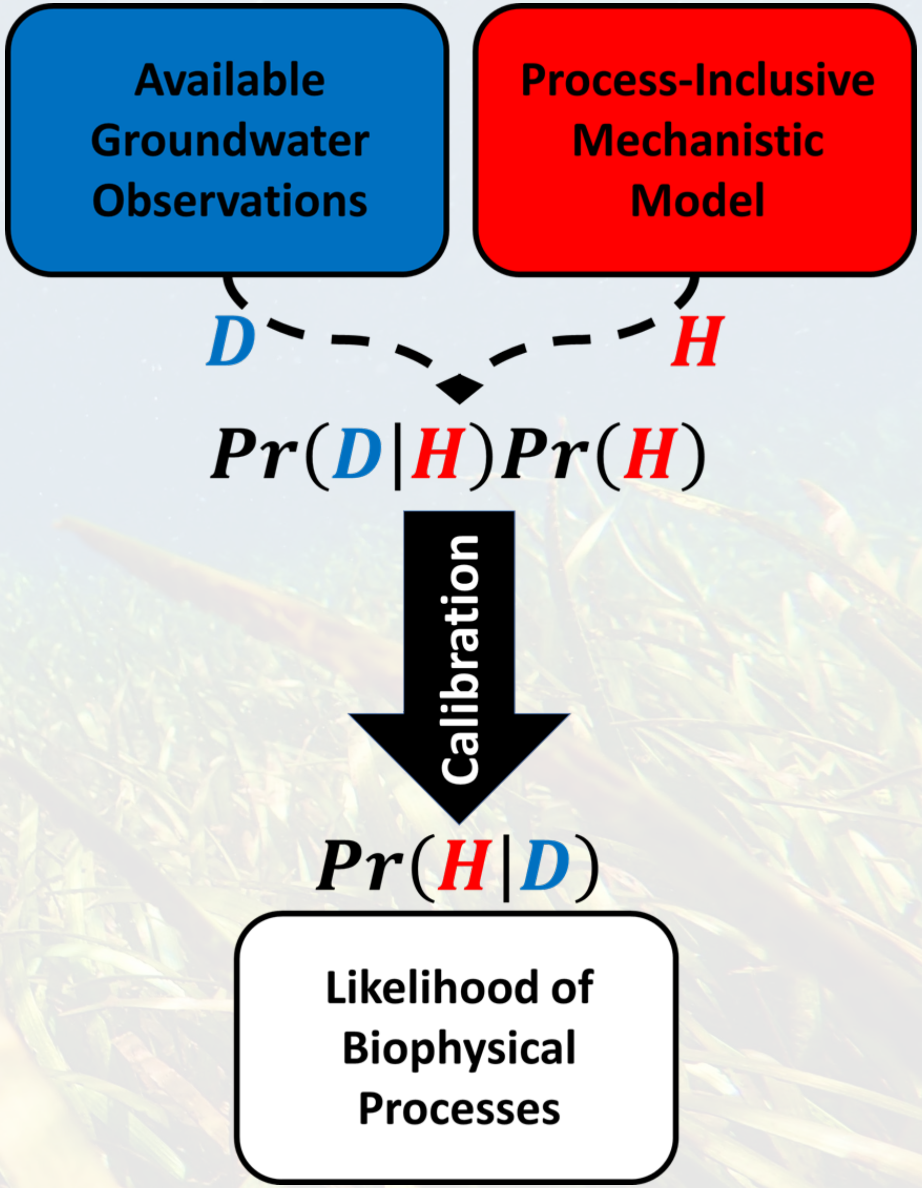
$$Pr(H|D)$$

Likelihood of Biophysical Processes

Simultaneously Testing Multiple Hypotheses

Available Data:





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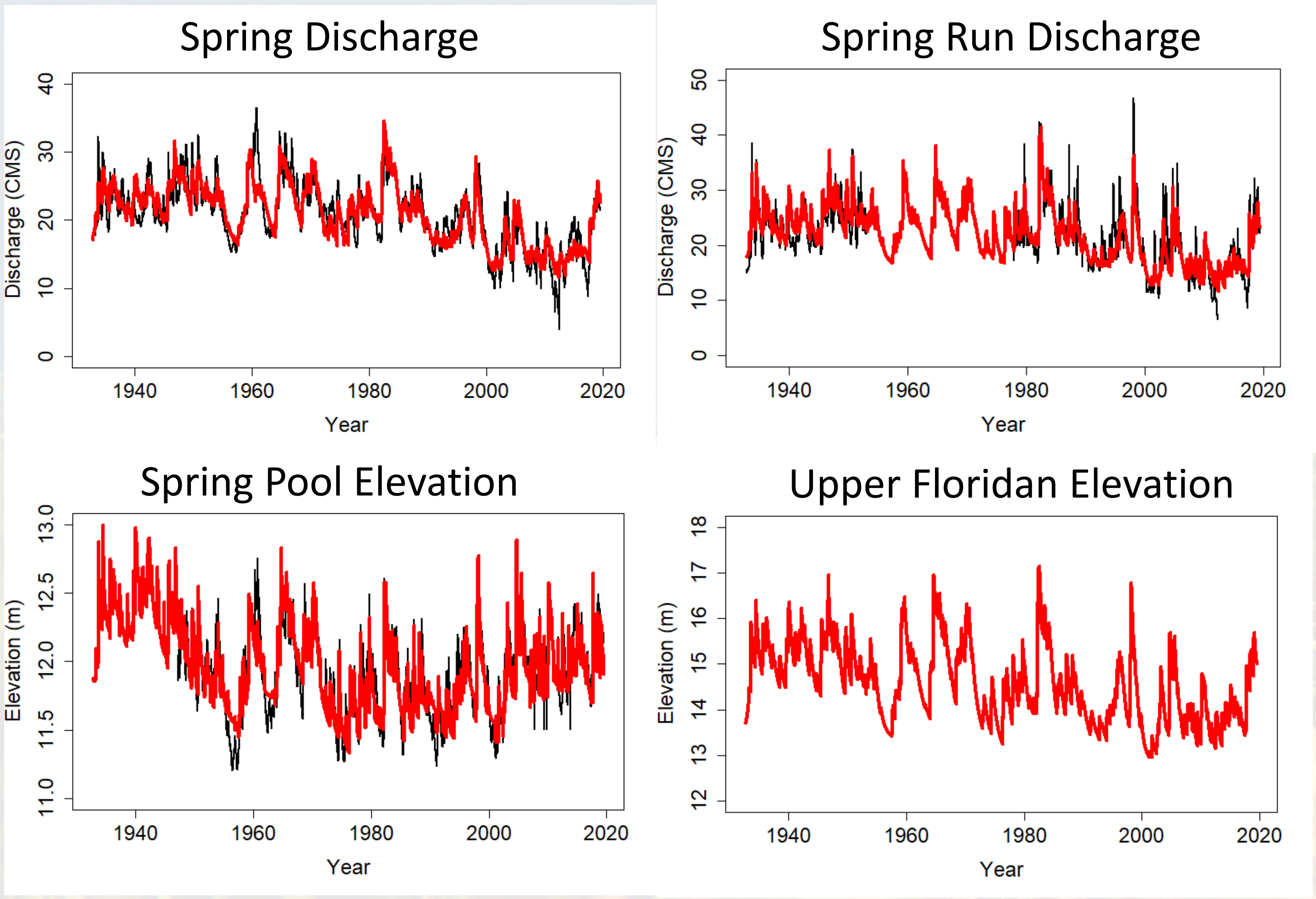

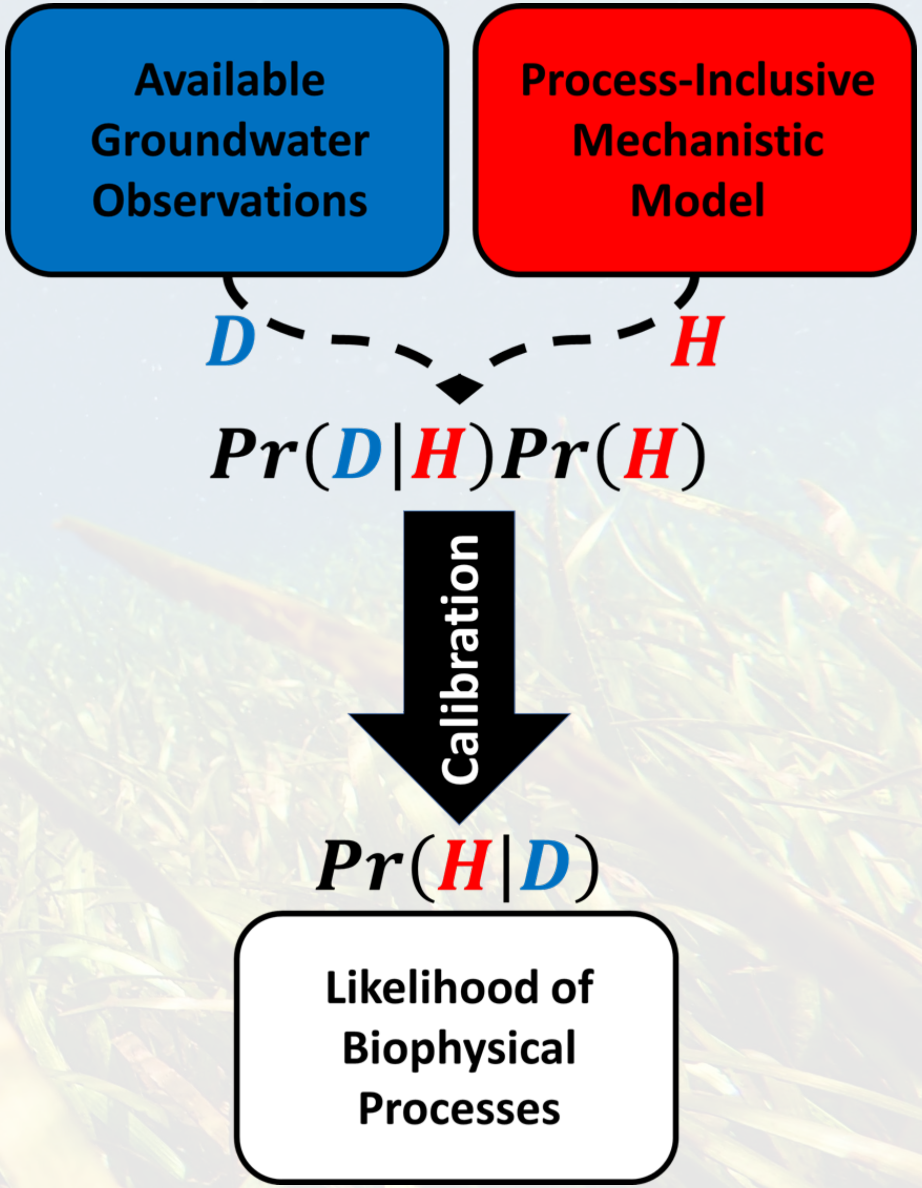

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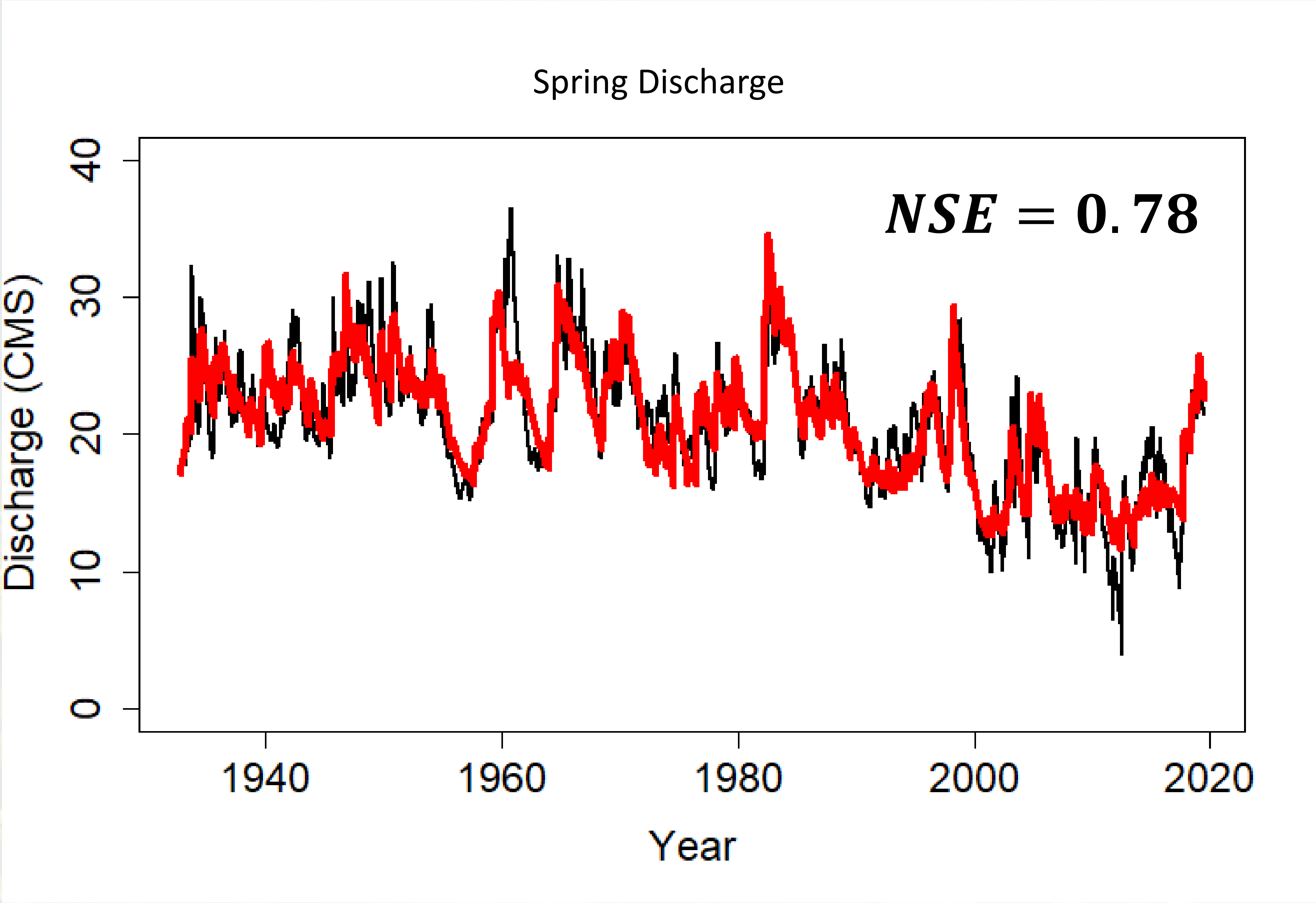

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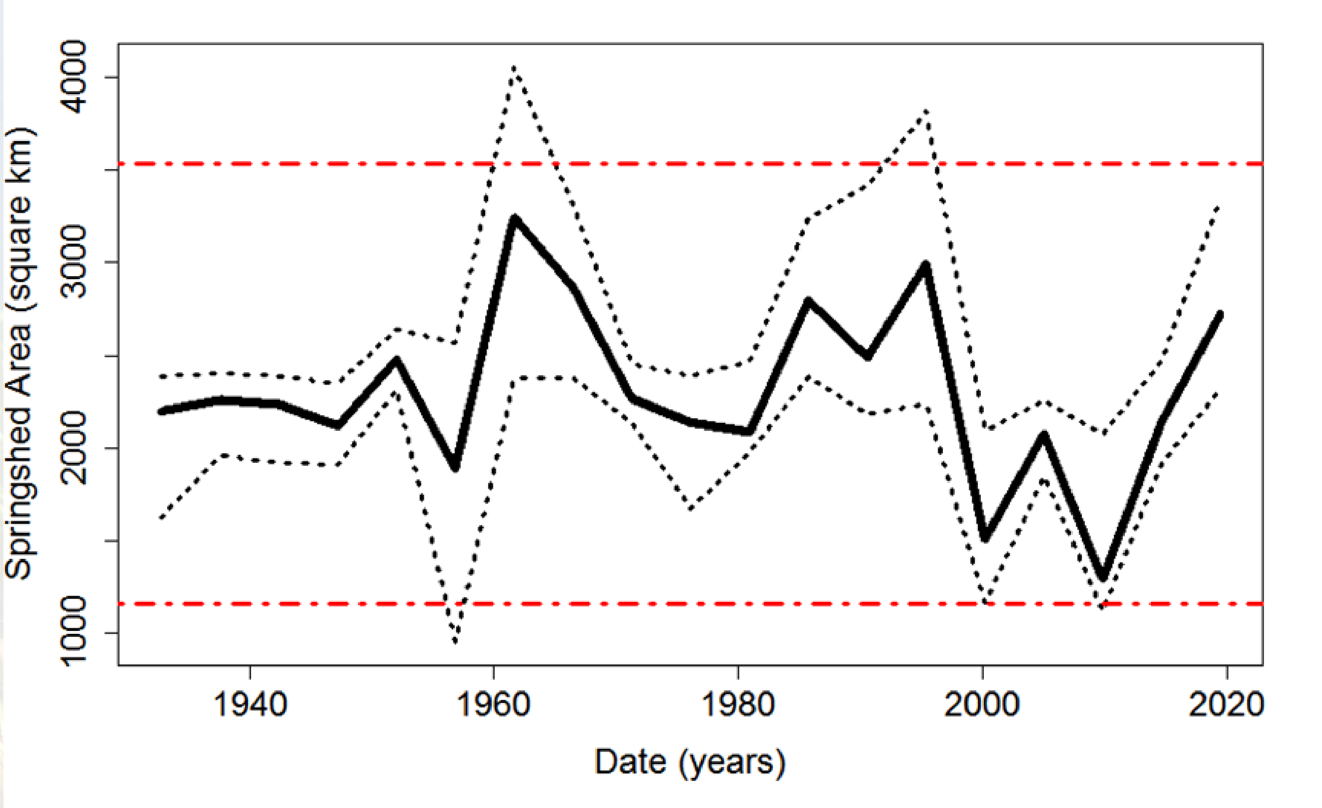

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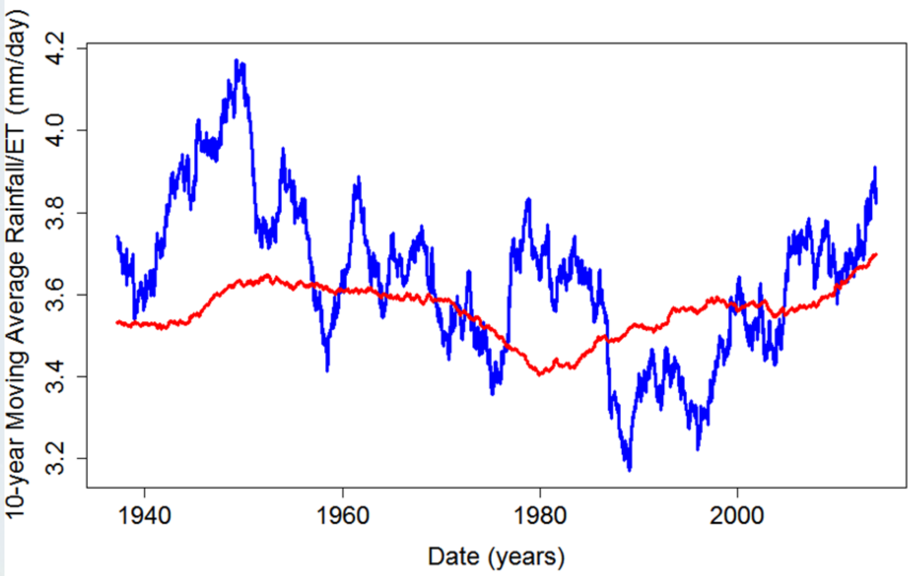

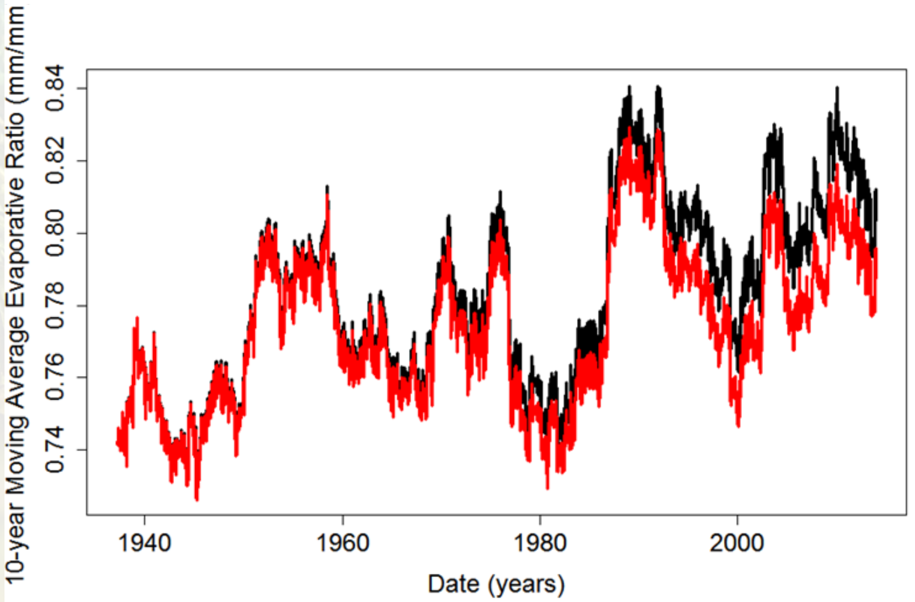

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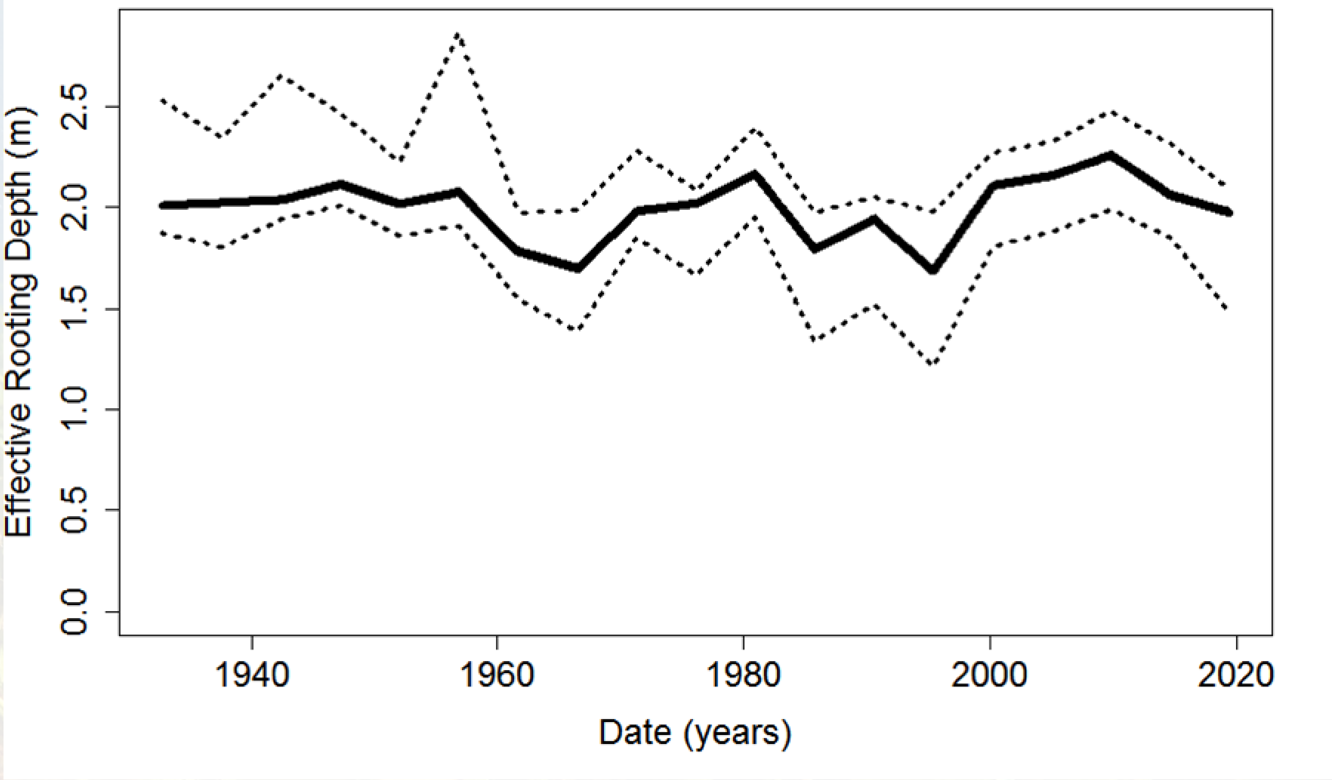

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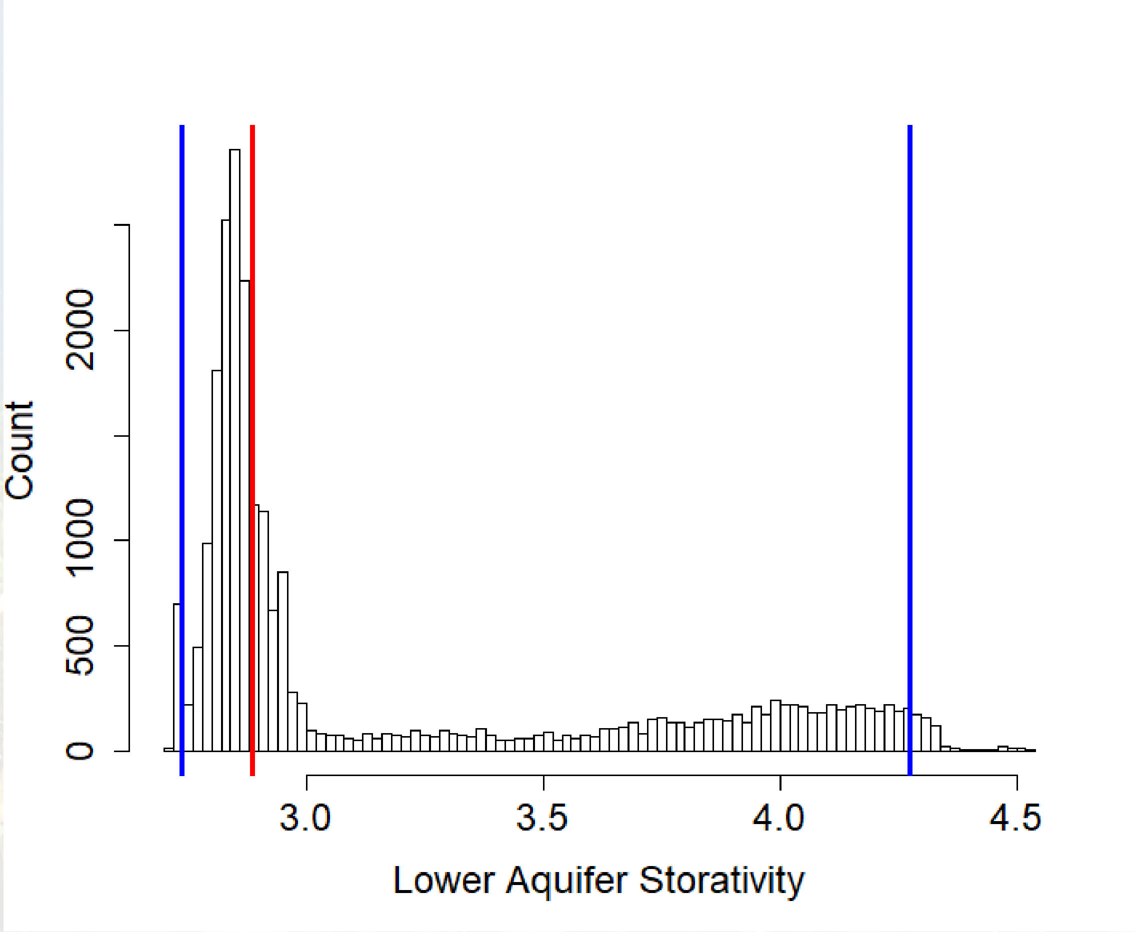

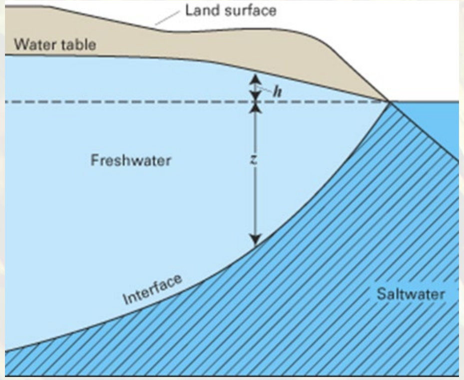

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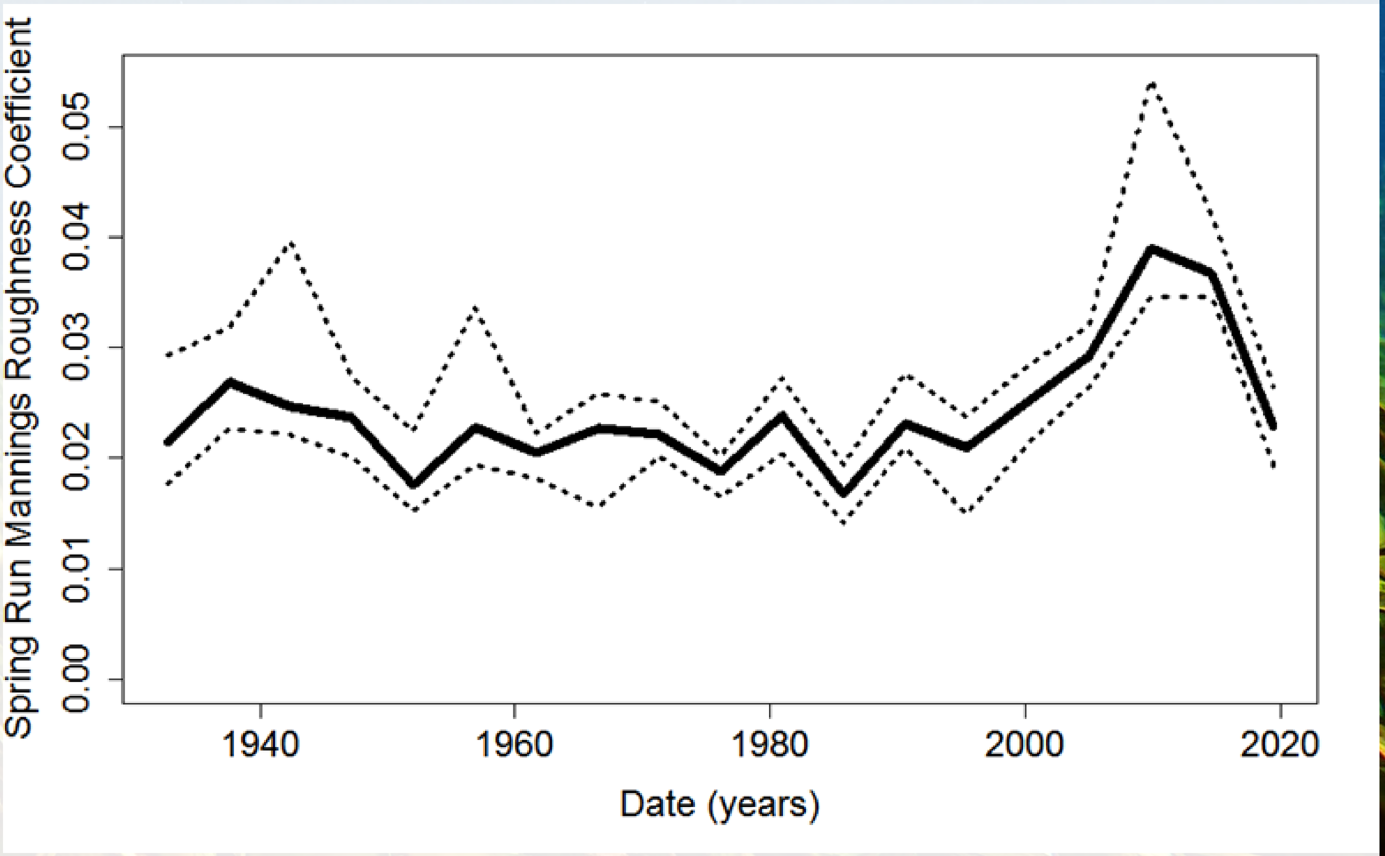

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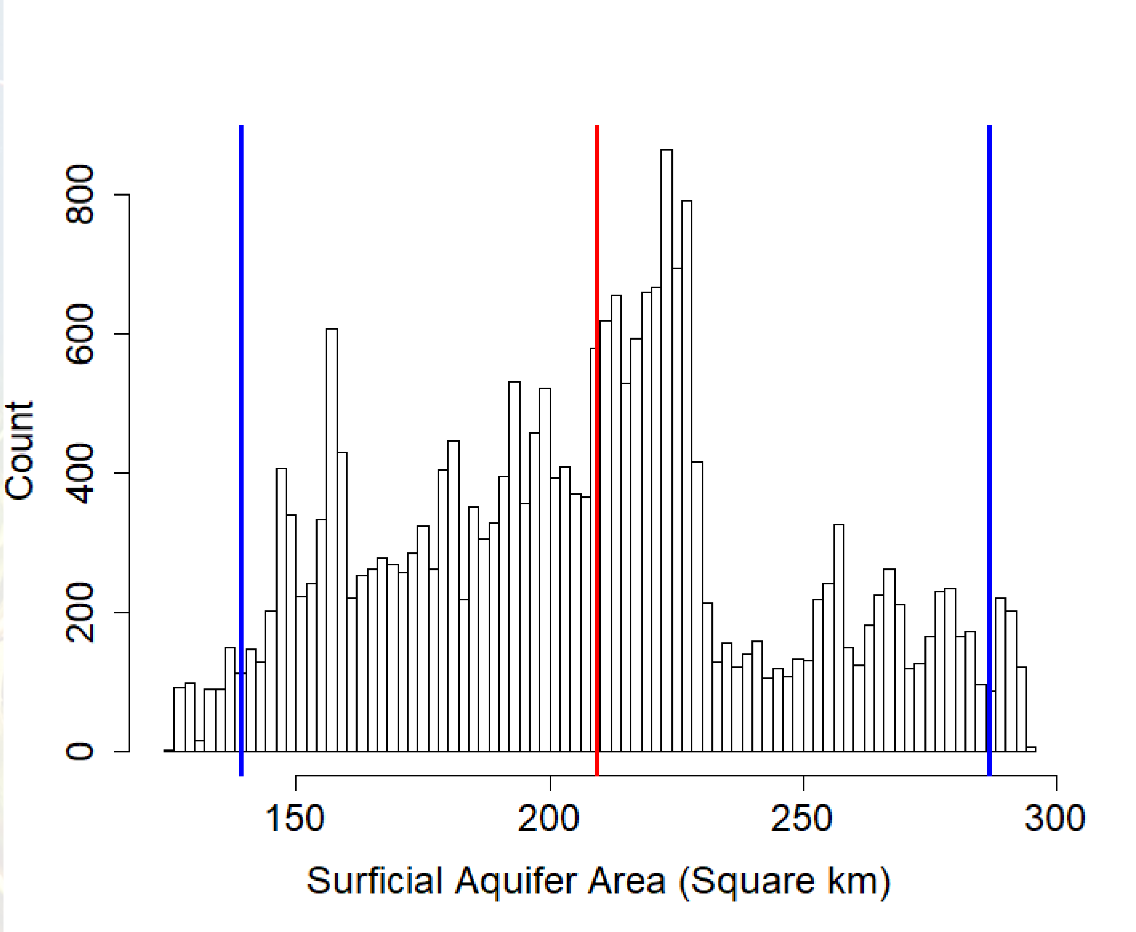
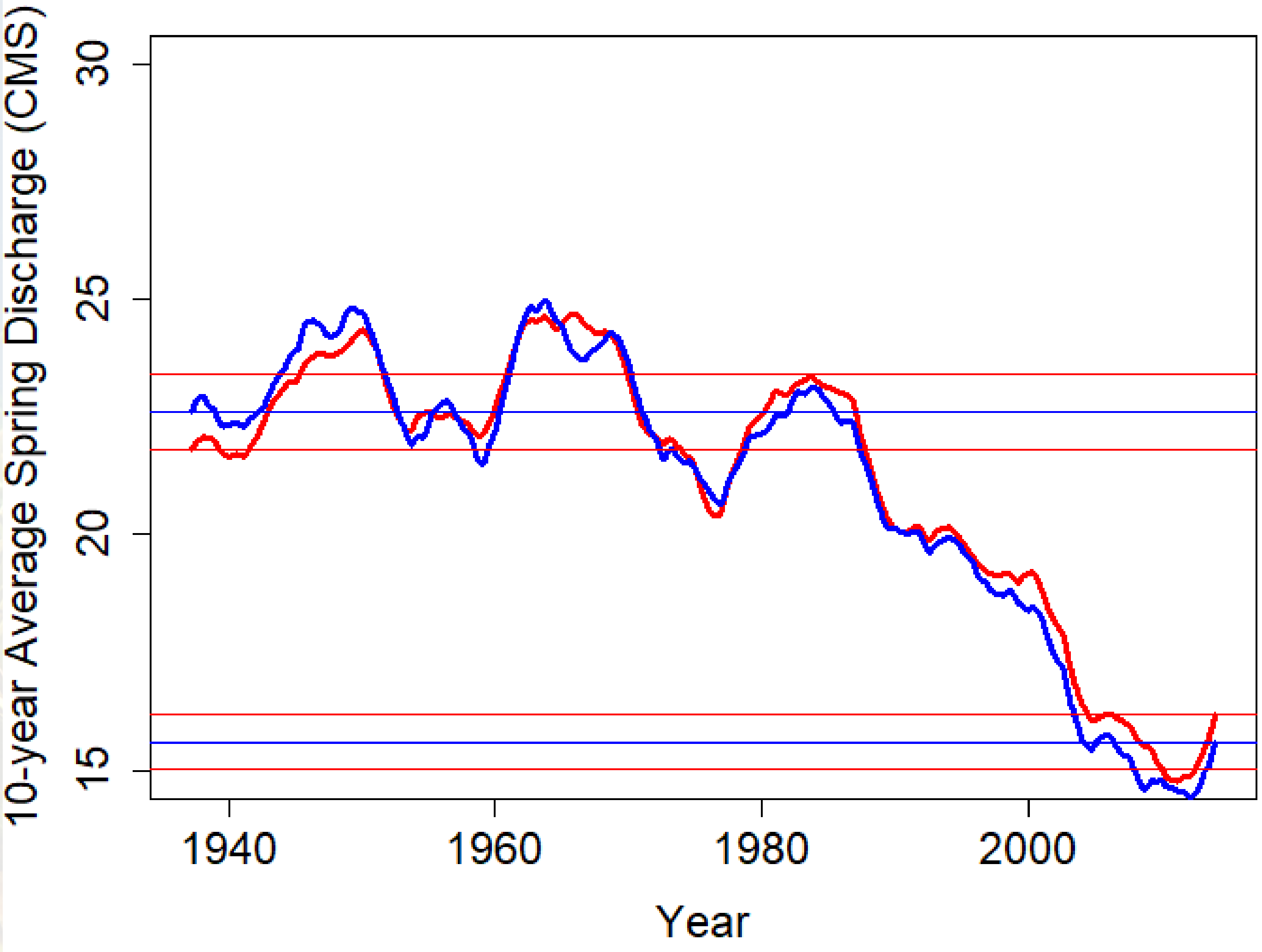


Flow Decline Attribution

Calibrated model vs. Observed Data



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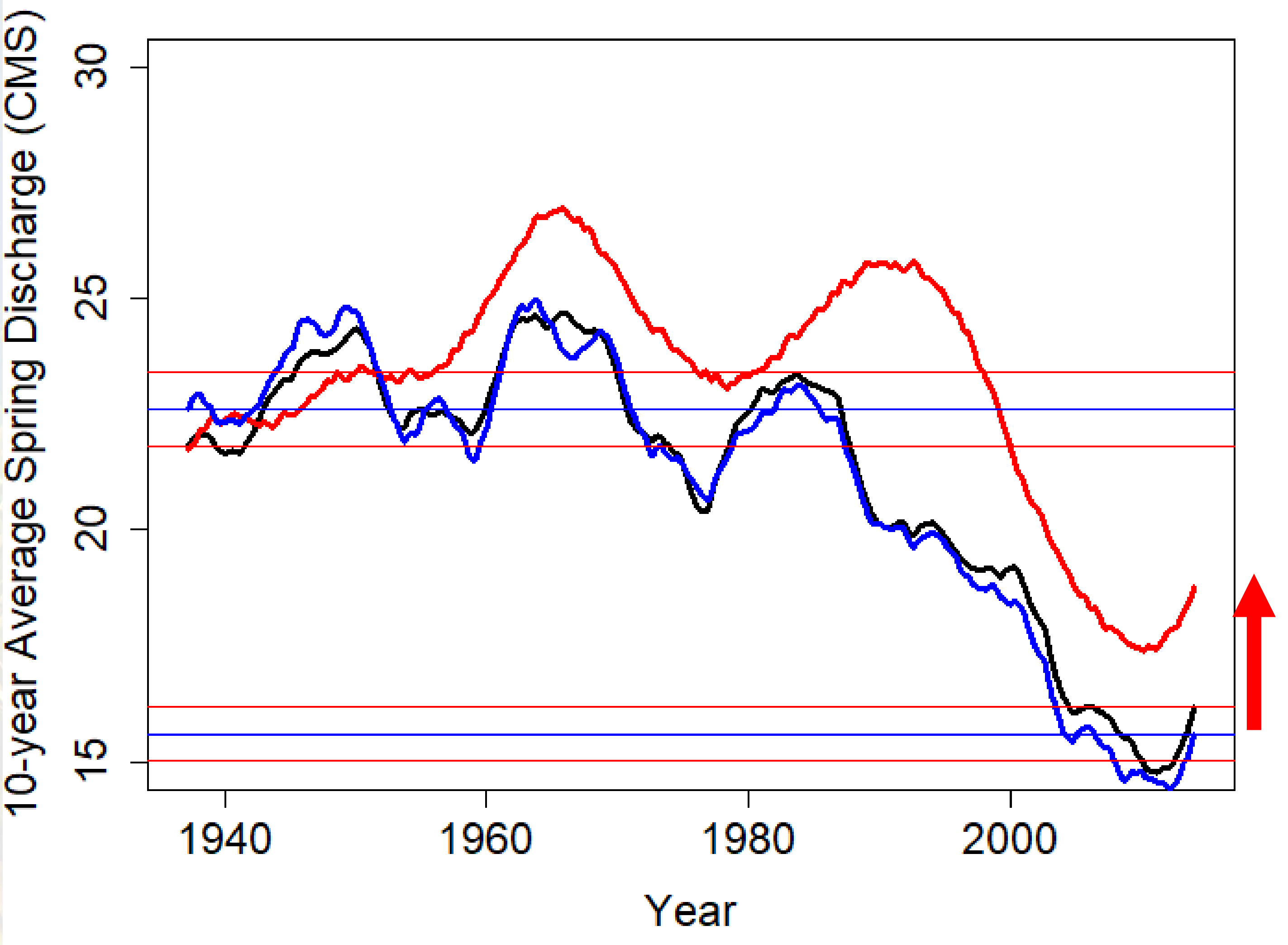
Stationary Climate



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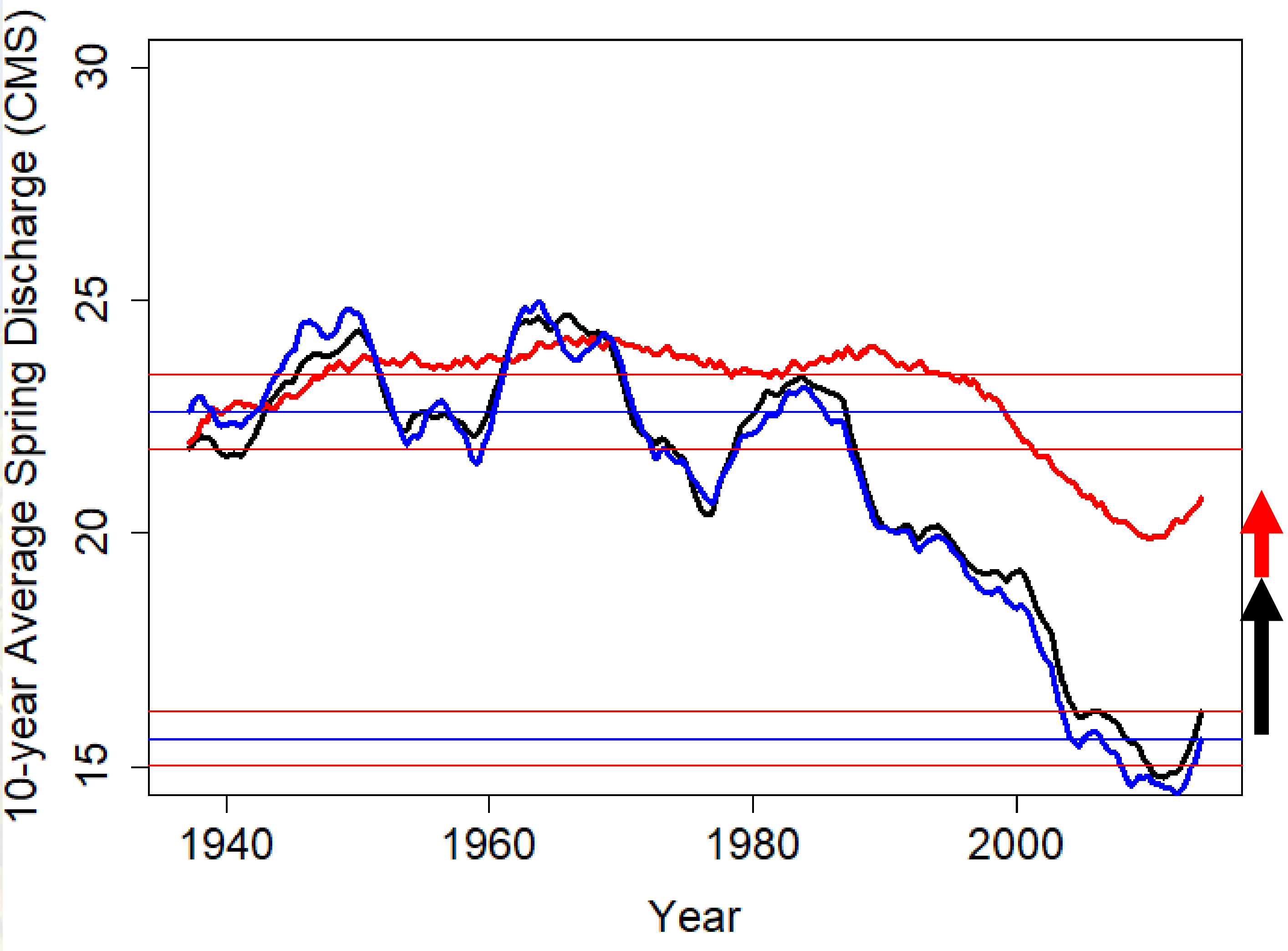

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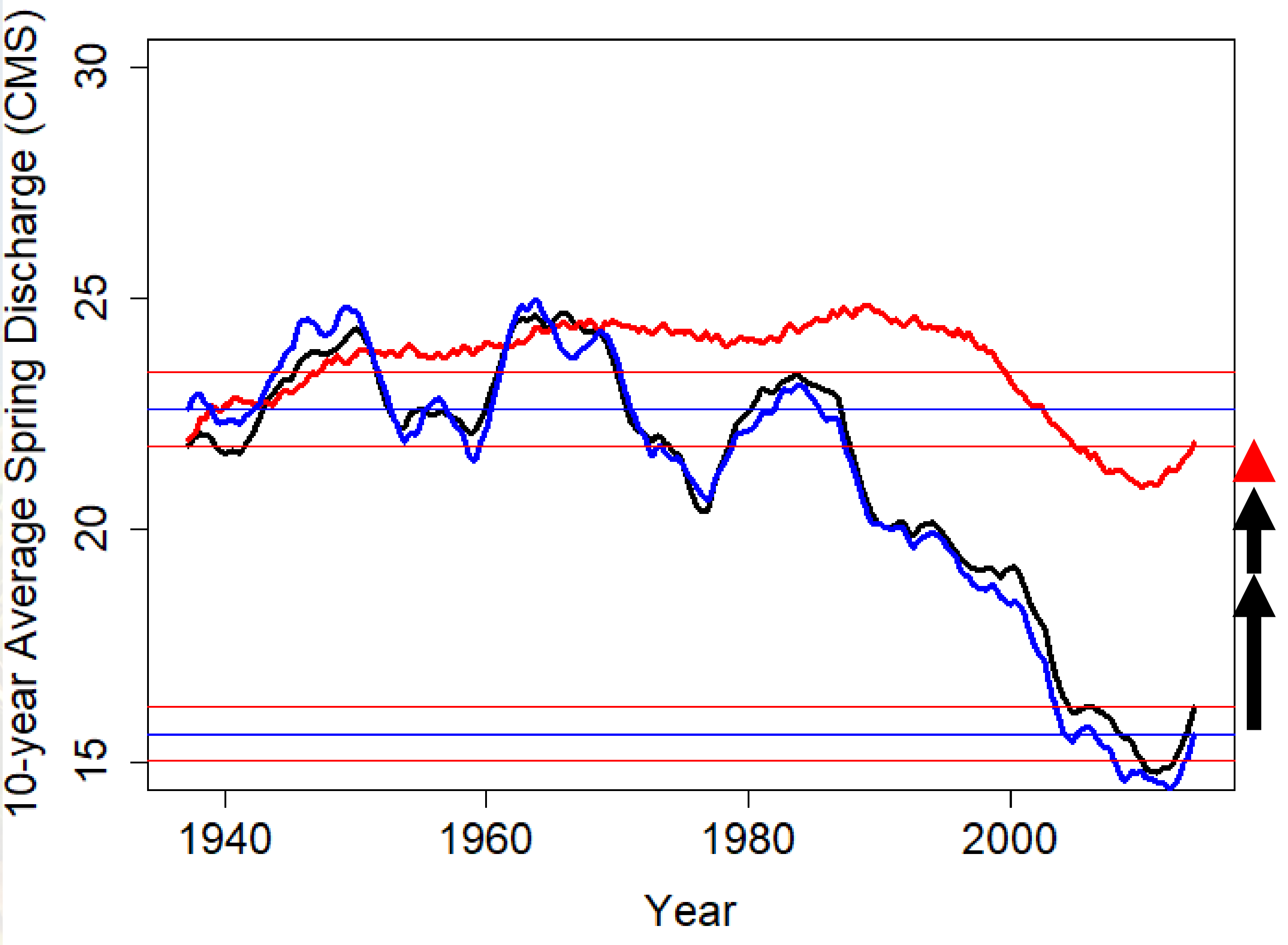
Stationary Climate

Stationary Springshed Area

Remove Groundwater Pumping



Flow Decline Attribution

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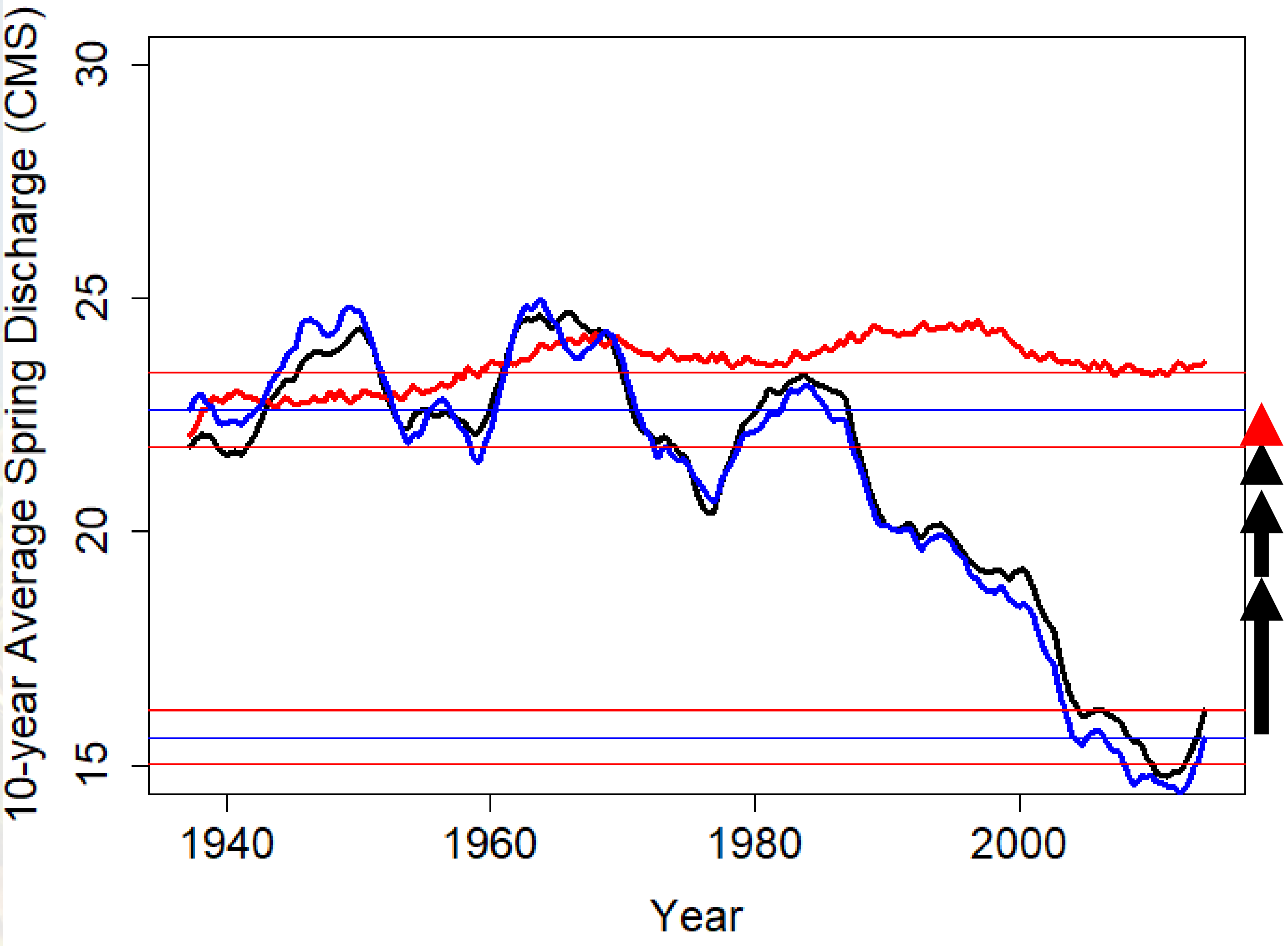
Stationary Climate

Stationary Springshed Area

Remove Groundwater Pumping

Stationary River Roughness



Flow Decline Attribution

Calibrated model vs. Observed Data

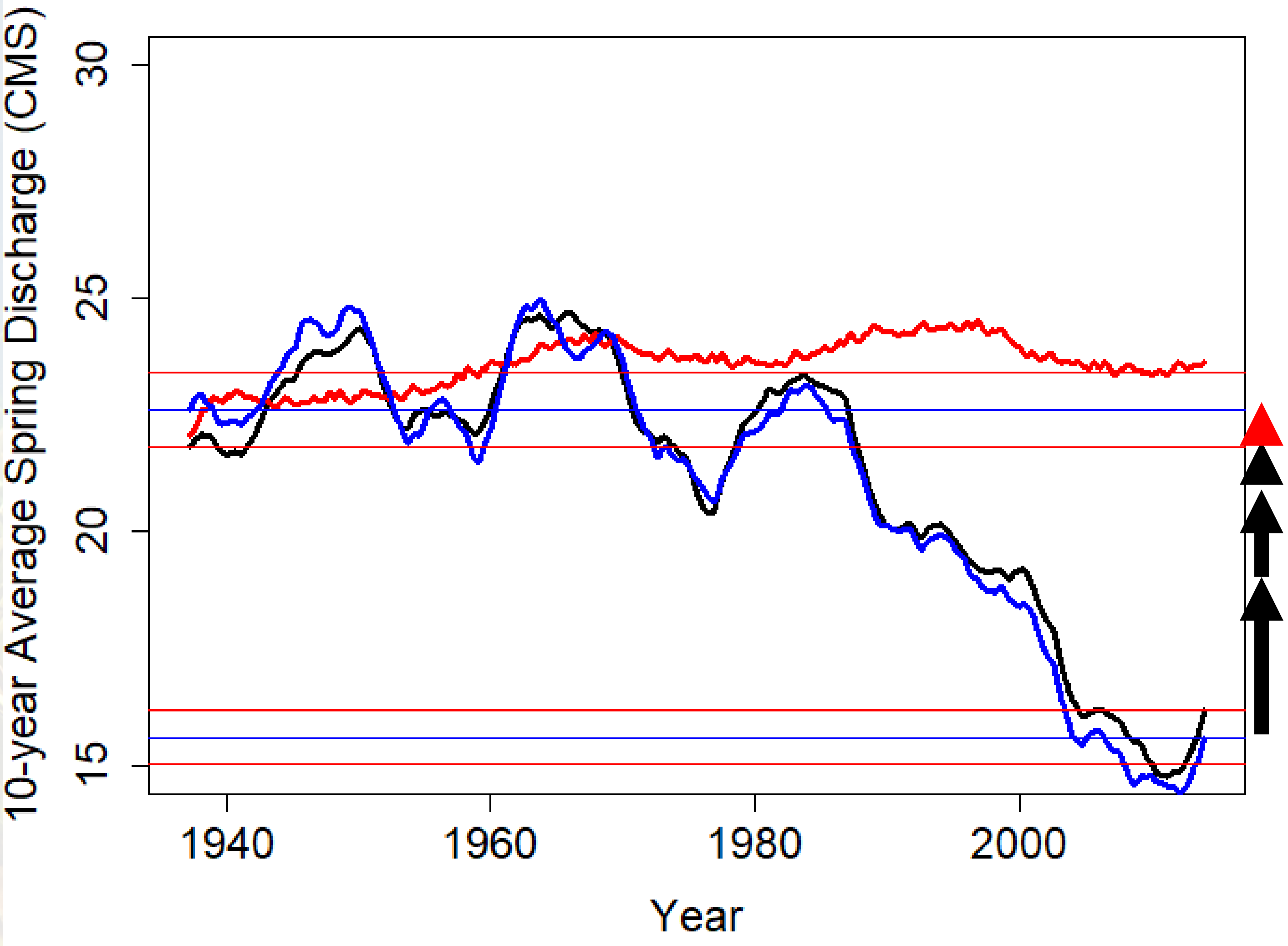
Stationary Climate

Stationary Springshed Area

Remove Groundwater Pumping

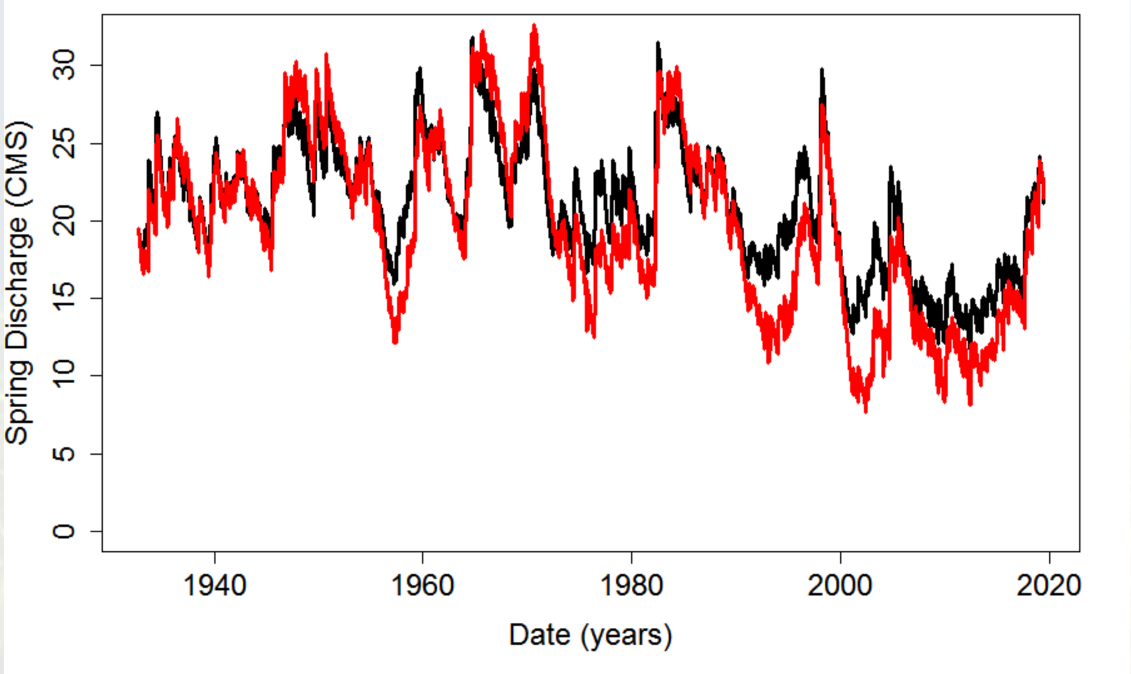
Stationary River Roughness

- **45% (3.2 m3/s)** can likely be attributed to climate
- **30% (2.0 m3/s)** can likely be attributed to springshed area changes
- **16% (1.1 m3/s)** can likely be attributed to pumping
- **10% (0.7 m3/s)** can likely be attributed to change roughness

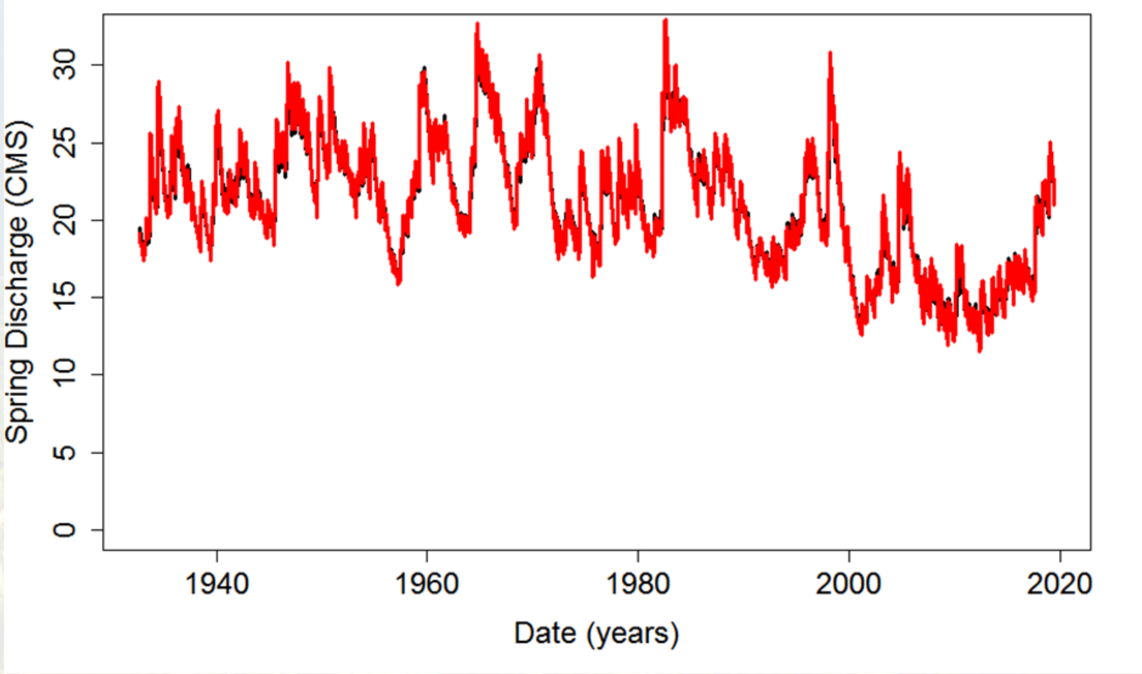


Flow Decline Attribution

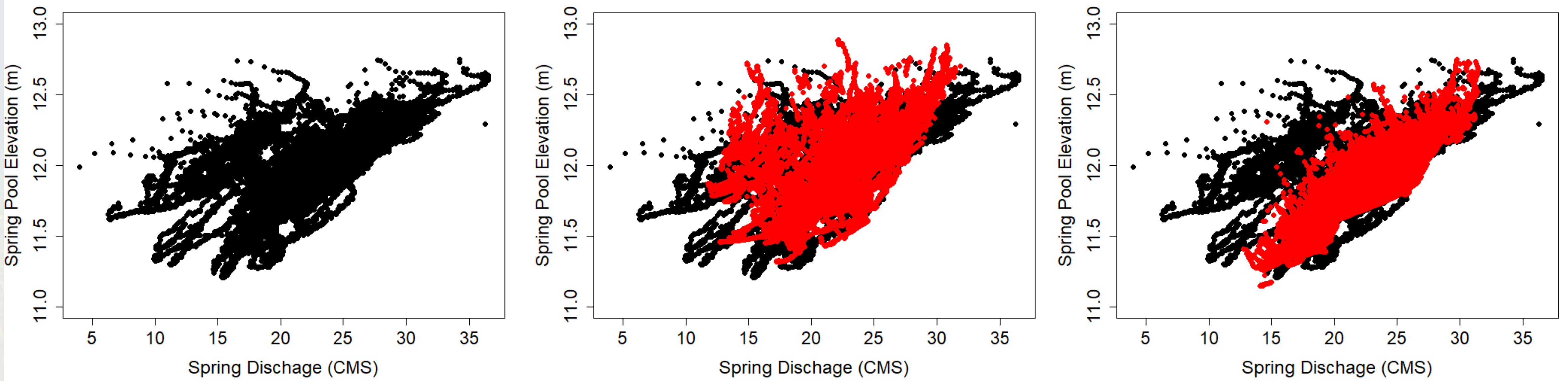
No Saltwater Interface



No Surficial Aquifer



Stage Discharge Relation



Summary

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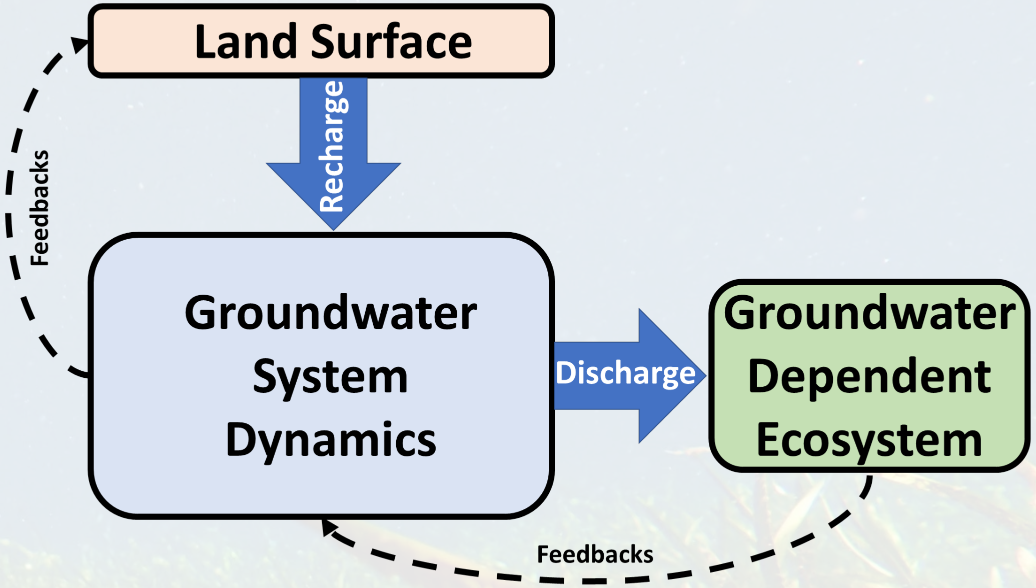

Hypothesis	Dynamics likely occurring within groundwater system	Impacts long-term average spring flow
H1	Yes	Yes, directly
H2	Yes	Yes, directly
H3	Yes	Yes, directly
H4	No	No
H5	Yes	Yes, indirectly
H6	Yes	Yes, directly
H7	Yes	No

Future of Flow in Silver Springs

Current Trends Likely to Increase or Maintain Spring Flow

1. Average rainfall appears to be in an increasing trend.
2. The springshed area is currently increasing in size.
3. The Manning's roughness is currently declining.
4. The springshed appears to be entering a "humid phase"
5. The average evaporative ratio currently declining
6. The rate of groundwater pumping appears to have leveled off

Current Trends Likely to Decrease Spring Flow

1. Average PET appears to be in an increasing trend, which will likely continue with global climate change.
2. If groundwater pumping rates could increase with projected growing population.
3. Future increases in submerged aquatic vegetation cover, for example the expansion of the invasive *Hydrilla verticillate* could drive small flow declines by increasing Silver River and/or Ocklawaha River stage

Acknowledgements

UF | UNIVERSITY of FLORIDA

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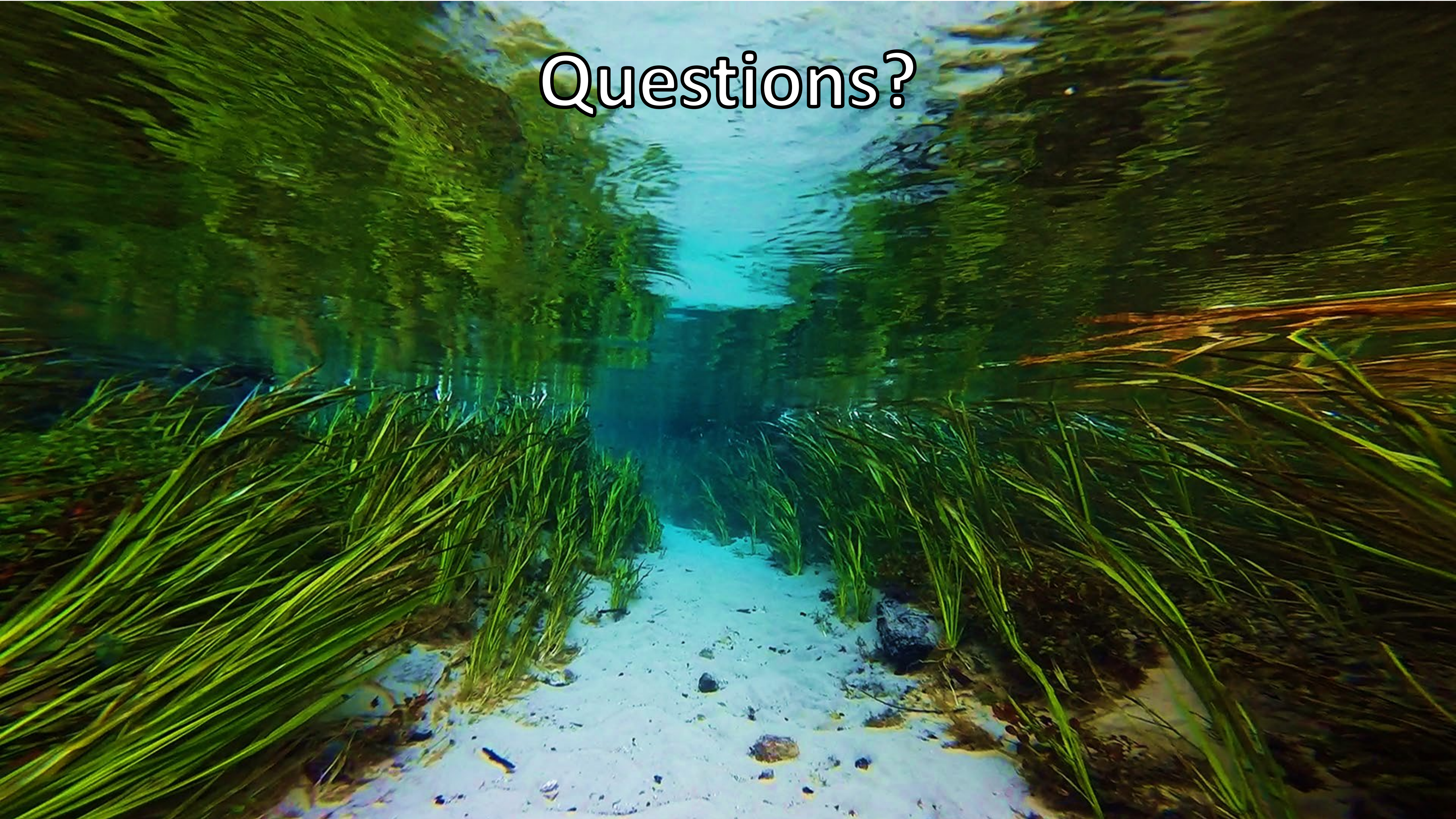
UNIVERSITY of FLORIDA

Fish & Wildlife
FOUNDATION OF FLORIDA


Questions?