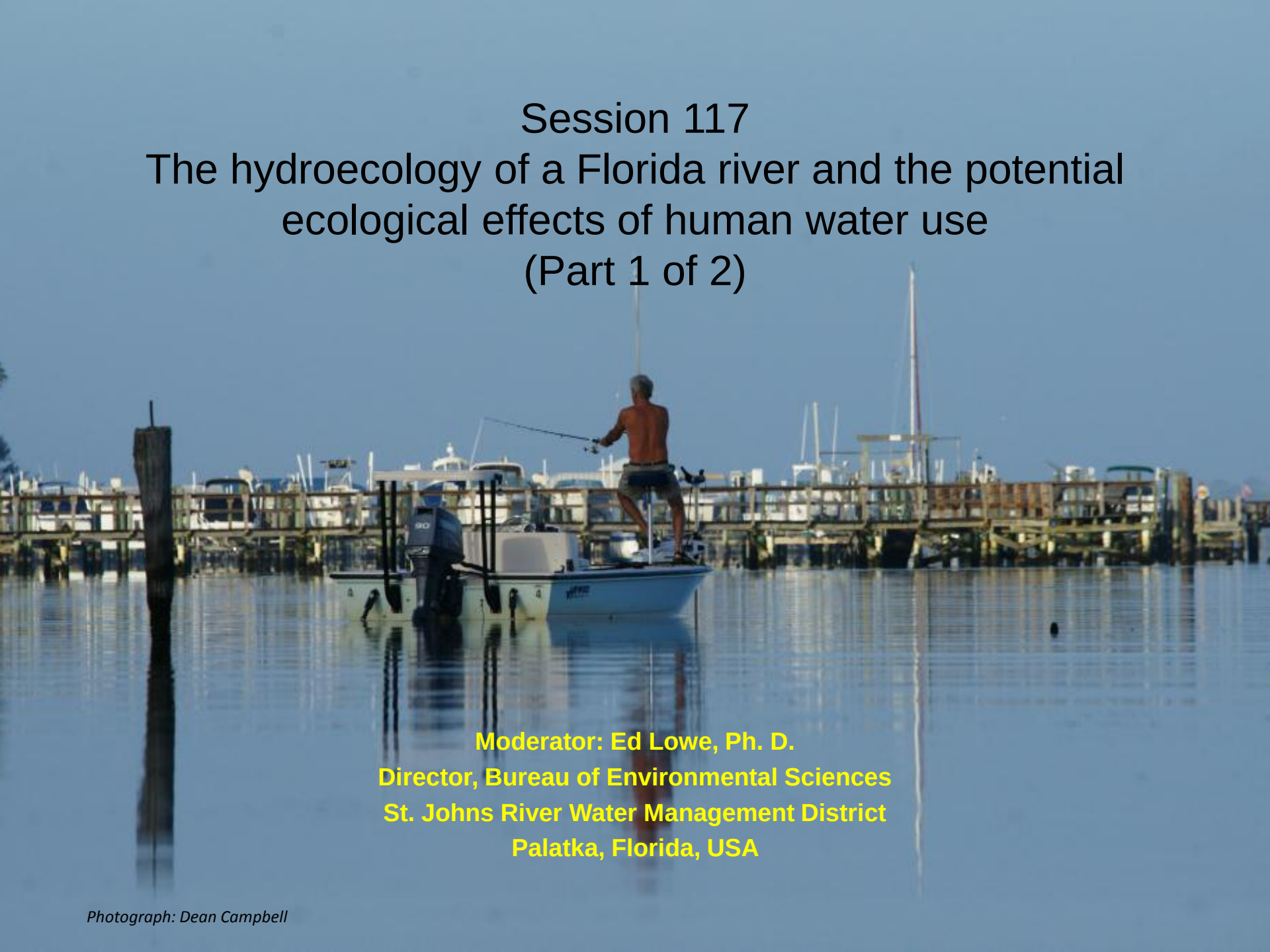
Session 117
The hydroecology of a Florida river and the potential ecological effects of human water use
(Part 1 of 2)



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St. Johns River Water Management District
Palatka, Florida, USA

Photograph: Dean Campbell


Session Overview

Earth

- Water - 1.4 billion km^3
- FW – only about 2.5 %
- FW – 90% in glaciers or deep GW
- Circulating FW – ca. 120,000 km^3
- Human demand – ca. 7,500 km^3
- Uneven distribution of fw resources in time and space creates deserts, rain forests, floods, droughts

Florida

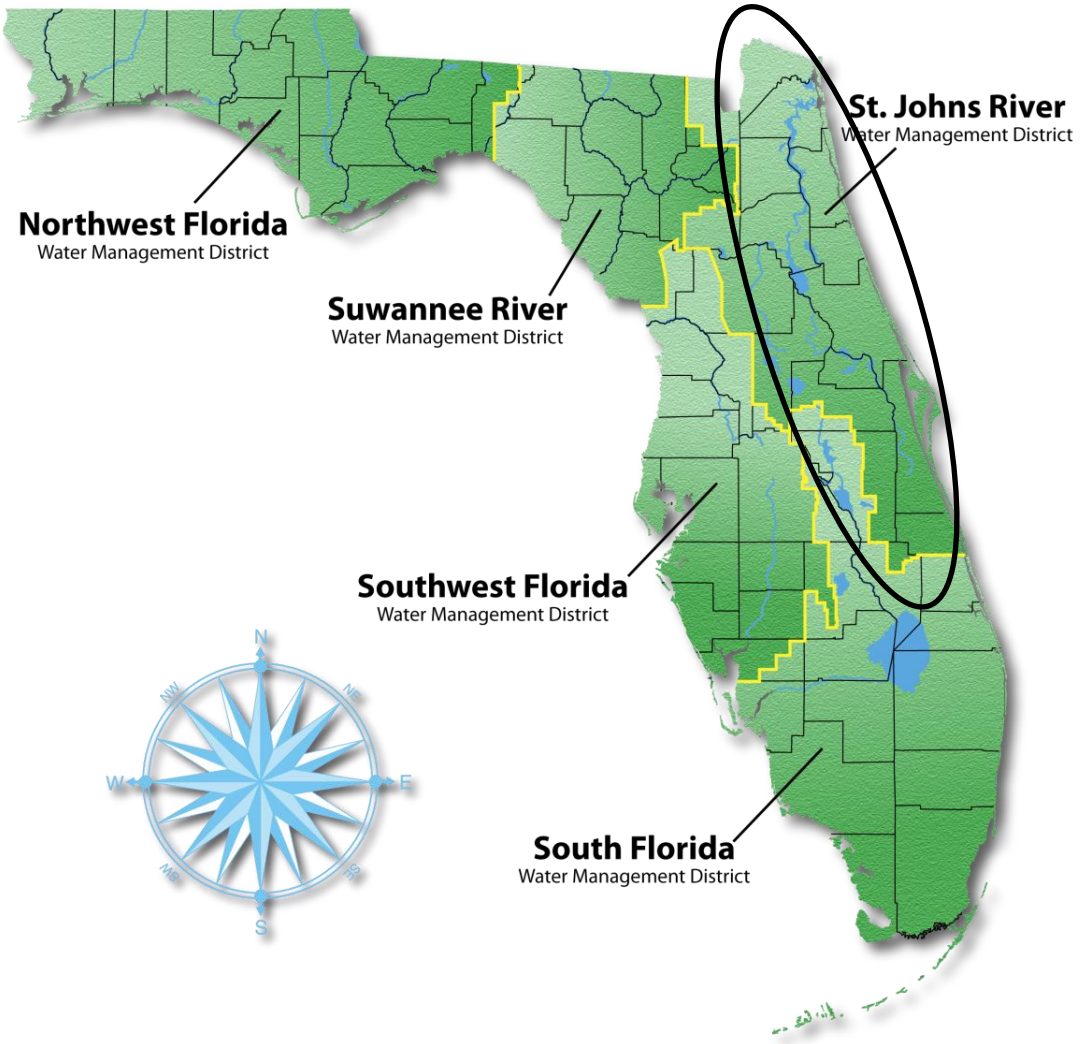
- Avg. Rainfall ca. 135 cm y^{-1}
- 7,800 lakes
- 1,700 rivers and streams
- > 700 artesian springs
- Vast areas of fw wetlands
- Extensive coastal wetlands
- Lagoons, Bays, Estuaries
- 3.8 trillion m^3 fresh groundwater
- 2005 Human water use ca. 13 % of total combined flow of all major rivers

High rates of evapotranspiration, high water requirements for natural systems, growing human population

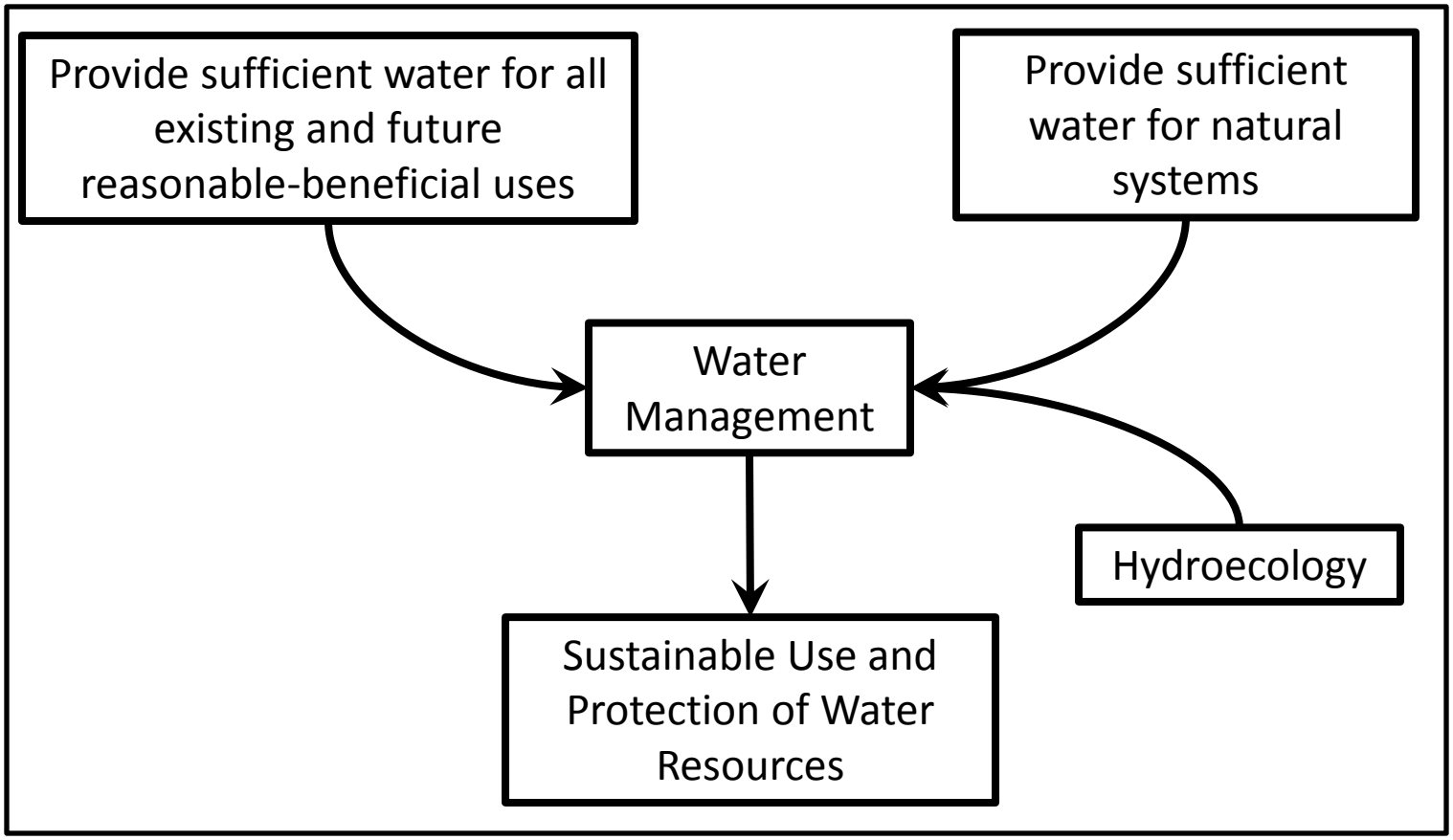
Water Management in Florida - The St. Johns River Water Management District (SJRWMD) is one of five WMDs in Florida, each delineated by a major drainage basin.

SJRWMD

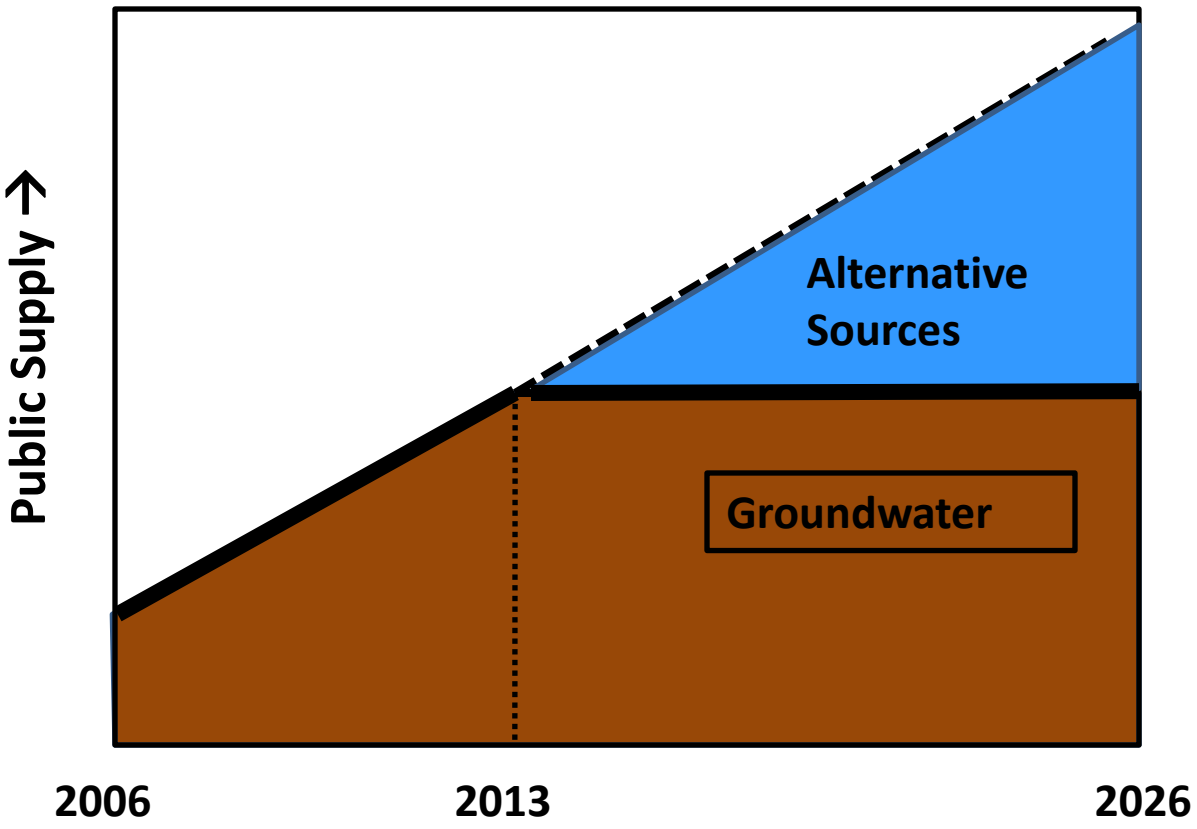
- 12,283 square miles
- Covers all or part of 18 counties in northeast and east-central Florida



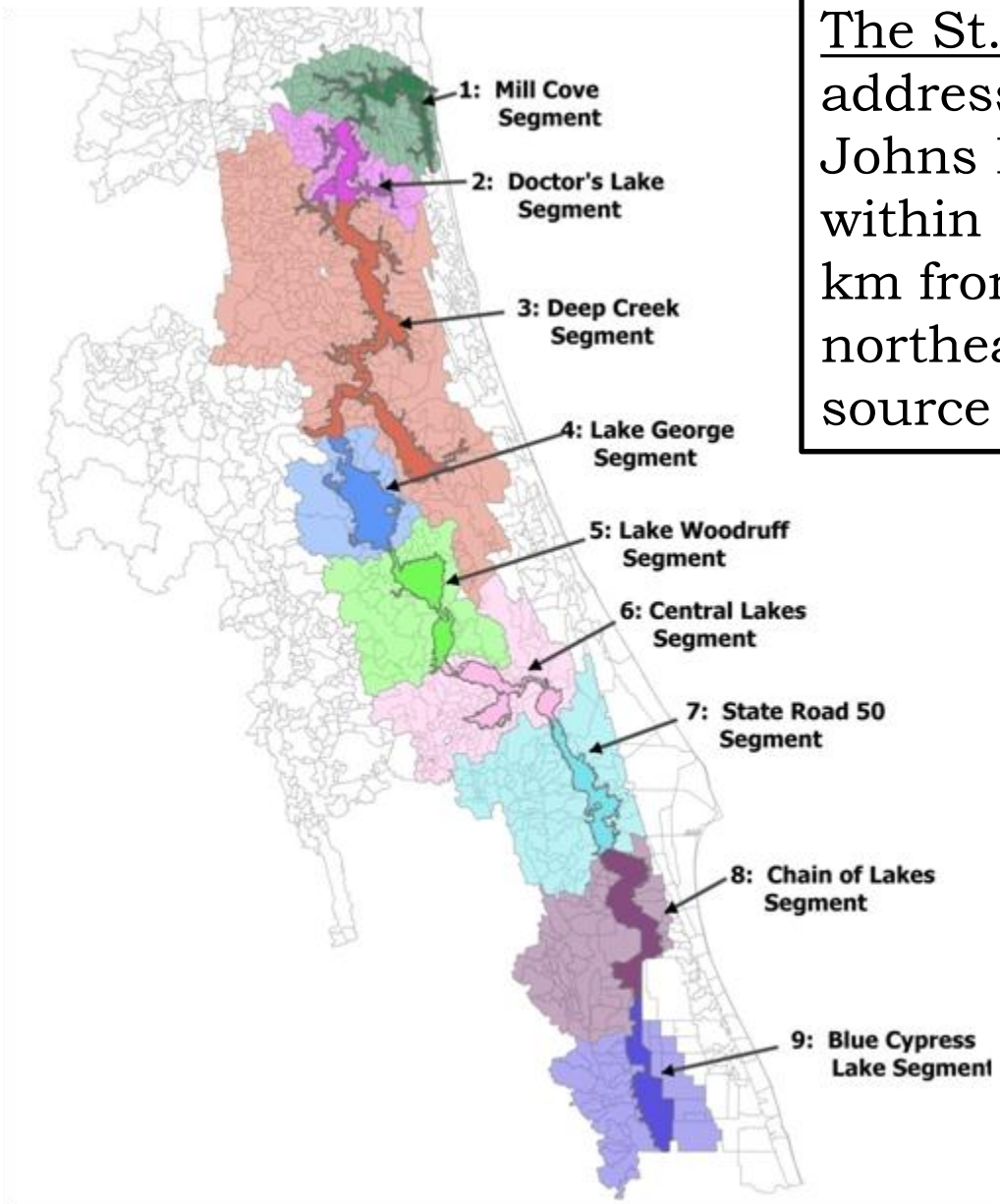
Florida's water policy -- provide sufficient water for all reasonable-beneficial uses and for natural systems. Hydroecological understanding is required to ensure sustainable use of water resources and to balance direct benefits (consumptive uses) and indirect benefits (goods and services of provided by natural systems) of water resources.



Fresh groundwater is reaching its sustainable limit. In central Florida, the water management districts recognized that in the near future alternative water sources would be needed to avoid harm to wetlands, lakes, and springs.

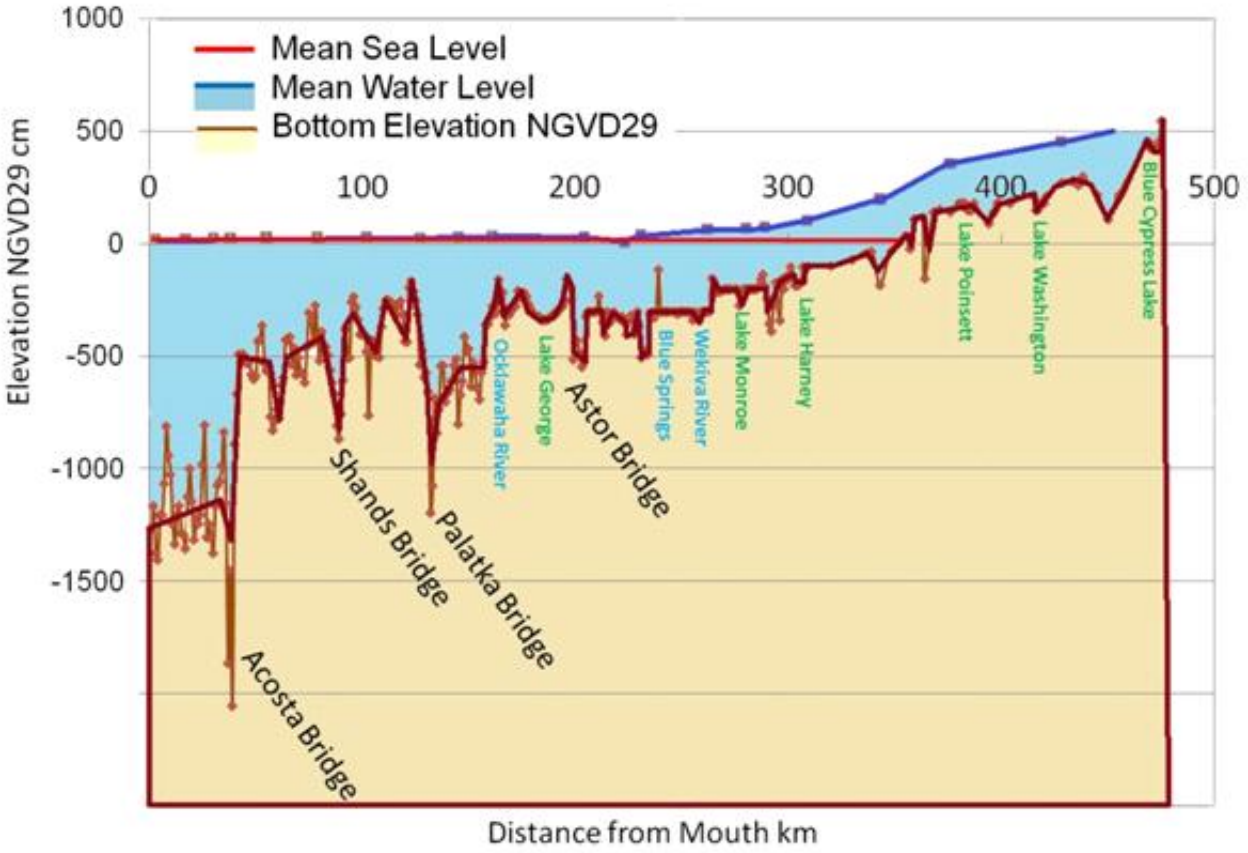


The Districts agreed that groundwater use would be capped at the 2013 demand. Alternative sources would be needed.



The St. Johns River – This session addresses the hydroecology of the St. Johns River, the longest river wholly within Florida, stretching over 500 km from headwaters to mouth in northeast Florida. It is a potential source of public water supply.

An important characteristic of the river is that it is a low-gradient system with a fall in mean water level of only about 7 m over its 500 km length. It is tidally influenced far upstream.



St. Johns River Bottom Elevation NGVD29 cm

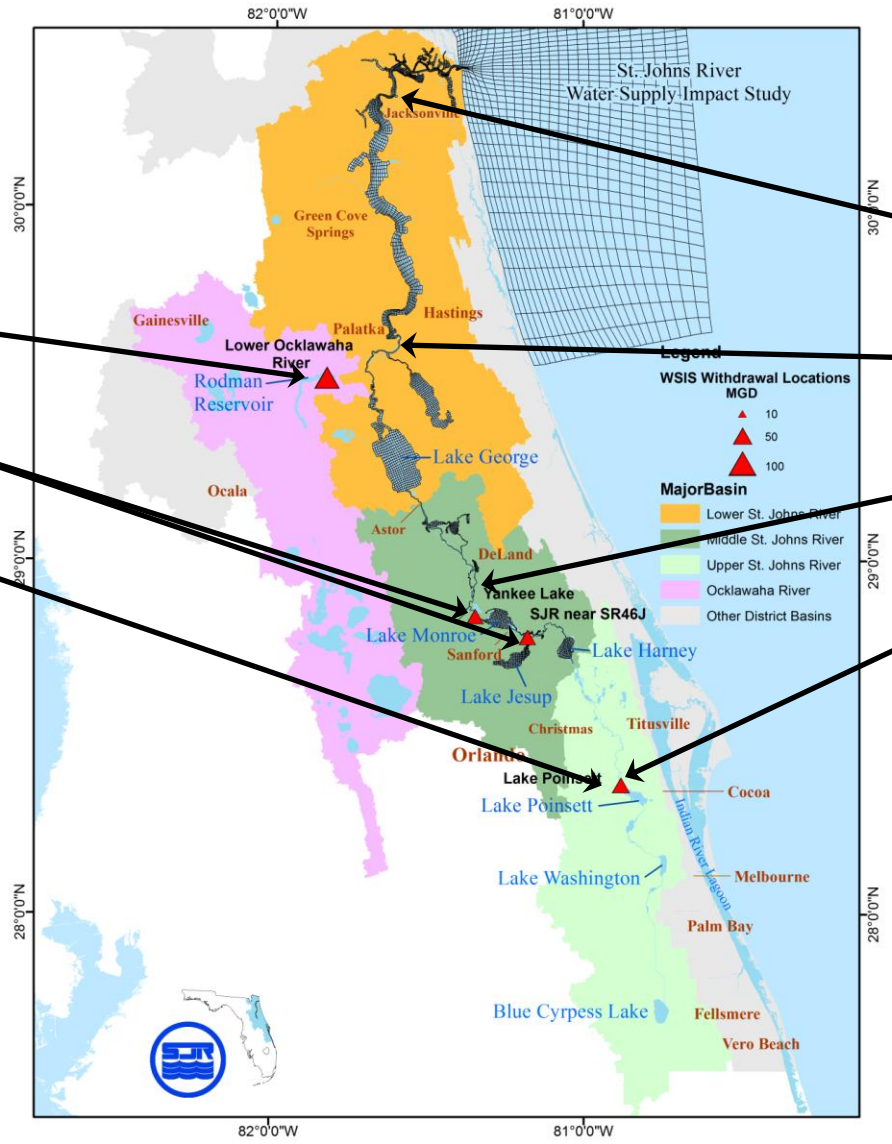
The work reported here stems from a comprehensive study to assess the potential ecological effects of increased use of surface water from the St. Johns River system. We examined the potential effects of withdrawals from four points totaling up to 11.48 $m^3 s^{-1}$.

Annual Average Withdrawal

≤4.69 $m^3 s^{-1}$

≤ 4.38 $m^3 s^{-1}$

≤ 2.41 $m^3 s^{-1}$



Average Discharge

241.5 $m^3 s^{-1}$

146.1 $m^3 s^{-1}$

40.3 $m^3 s^{-1}$

12.0 $m^3 s^{-1}$

Primary Hydroecological Drivers

Driver	Definition	Key Ecological Attributes Potentially Affected
Discharge	Flow rate as volume per unit time (m^3/s or mgd)	Populations of fish, benthic macroinvertebrates, and wildlife in the estuary
Residence Time	Days required for a parcel of water to traverse a portion of the river – we used water age as a more specific metric for residence time (days)	Phytoplankton blooms – longer residence time increases blooms by increasing the growing time
Water Level	Elevation of the water surface above sea level (m) – important derivatives of water level are hydroperiod (days), depth (m), frequency of inundation	Wetland vegetation and wildlife, submersed aquatic vegetation, benthic macroinvertebrates, nutrient releases from floodplain soils
Salinity	Concentration of dissolved salts as practical salinity units (psu) – roughly, parts per thousand	Populations of fish, benthic macroinvertebrates, and wildlife in the estuary; submersed aquatic vegetation in the estuary

Water Supply Impact Study Objectives

- Determine the potential hydroecological effects on the St. Johns River of withdrawing additional surface water from the river and from its major tributary, the Ocklawaha River.
- Base the analysis on best available expertise and information
- Subject the analysis to rigorous peer review – National Research Council -
- Ensure that the analysis is transparent, open, and objective
- Develop tools to support evaluation of specific proposals for water withdrawals.

Major Conclusions

- Appreciable amounts of water from the St. Johns River can be used as an alternative water supply source with no more than negligible or minor effects.
- Future land use changes, completion of the regional water management projects, and sea level rise will reduce the effects of water withdrawals.
- Potential for environmental effects varies along the river's length.
- The study provides peer-reviewed tools for use by the District and others.

The hydroecology of a Florida river and the potential ecological effects of human water use
Part 1 of 2

- **Edgar Lowe**, St. Johns River Water Management District, Palatka, Florida – *General method for evaluating potential ecological effects of altered hydrologic regimes*
- **Lawrence Keenan,** St. Johns River Water Management District, Palatka, Florida – *Hydroperiod effects on annual release rates of N, P, and DOC in a floodplain wetland*
- **Michael Coveney,** St. Johns River Water Management District, Palatka, Florida – *Relationships between residence time and cyanobacterial blooms in a nutrient-rich river system*
- Dean Dobberfuhl, St. Johns River Water Management District, Palatka, Florida – *Impacts to submerged aquatic vegetation associated with hydrologic changes in the St. Johns River estuary, Florida*

General method for evaluating potential ecological effects of altered hydrologic regimes

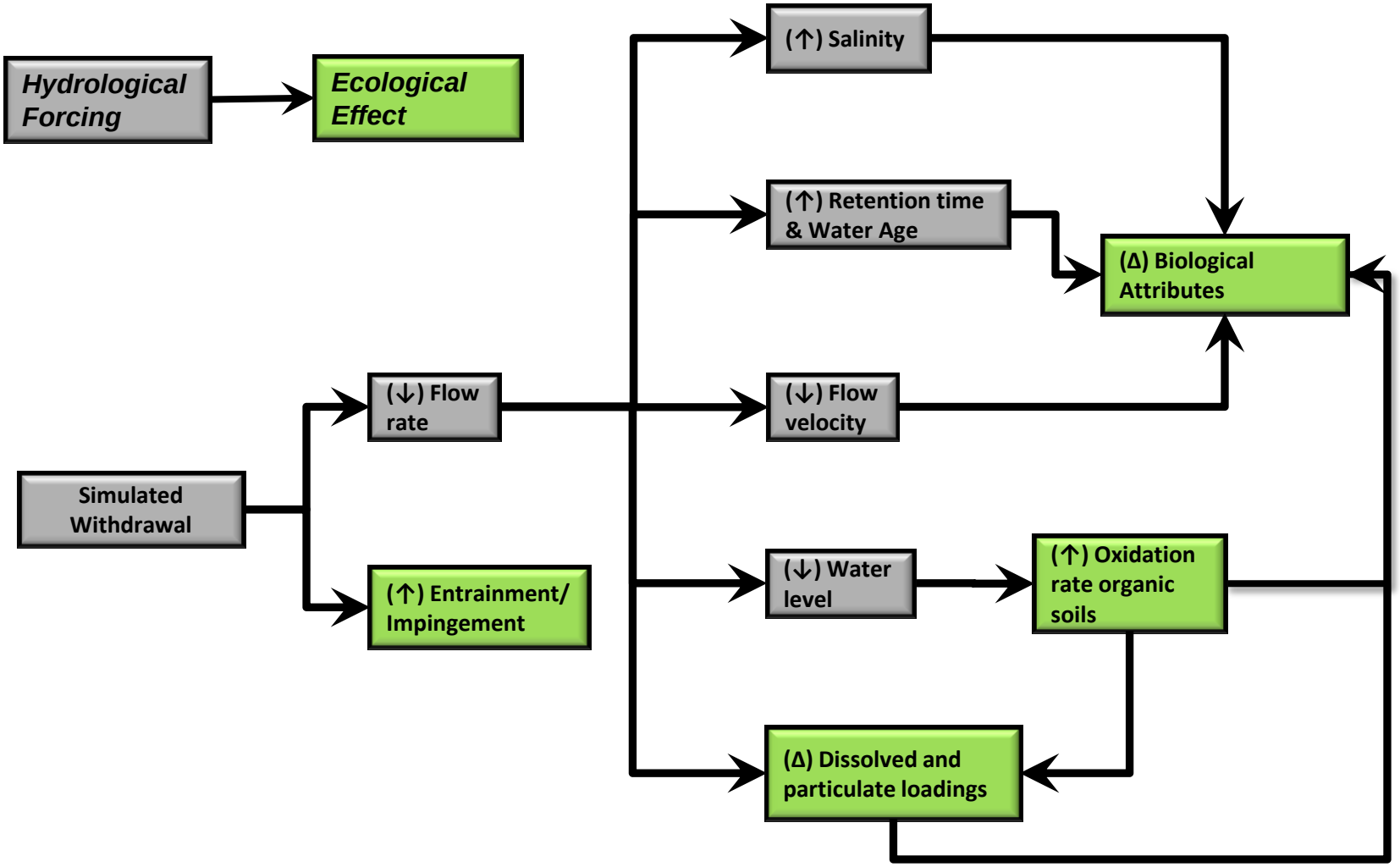
Ed Lowe, Larry Battoe, Dean Dobberfuhl, Mike Cullum, Pete Sucsy, Tim Cera, John Higman, Mike Coveney, Donna Curtis, Lawrence Keenan, Palmer Kinser, Rob Mattson, and Steve Miller

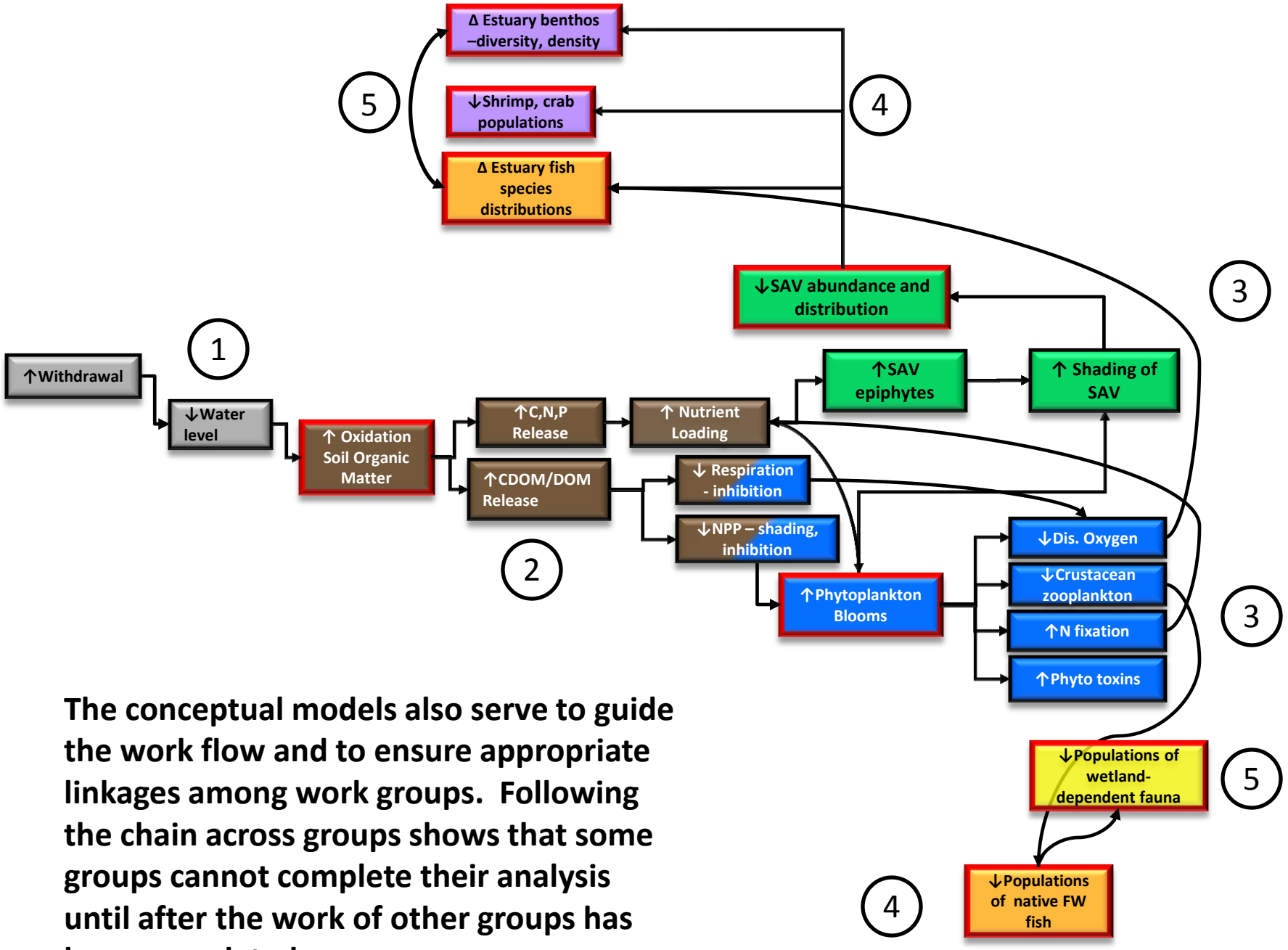
St. Johns River Water Management District

Seven Aspects of the General Method

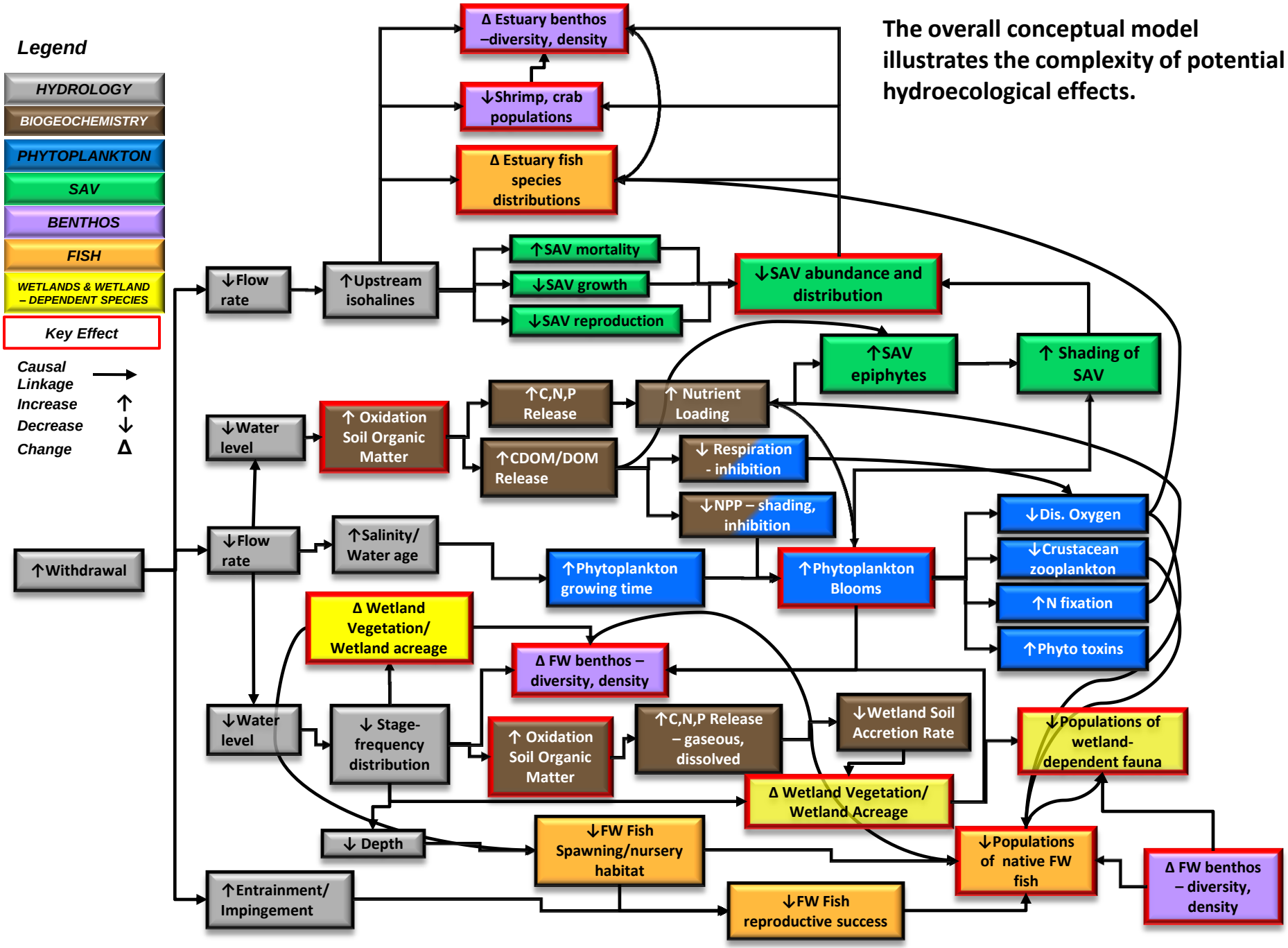
- Develop Conceptual Models – chain of causation, drivers, key ecological attributes, predictive models
- Develop predictive hydroecological models
- Predict forcings and effects as deviations from a baseline condition
- Divide the work into ecological components and ecological regions
- Develop a general scale for assessment of the importance of potential effects
- Develop a general scale for assessment of scientific uncertainty
- Integrate findings across workgroups, scenarios, and ecological regions

1. <u>Develop Conceptual Models of Plausible Chains of Causation</u> - The hydroecological models were supported by a plausible chain of causation that illustrated the causal linkage between a simulated water withdrawal and the potential ecological effect. The models also identified hydrologic and hydrodynamic drivers and key ecological attributes

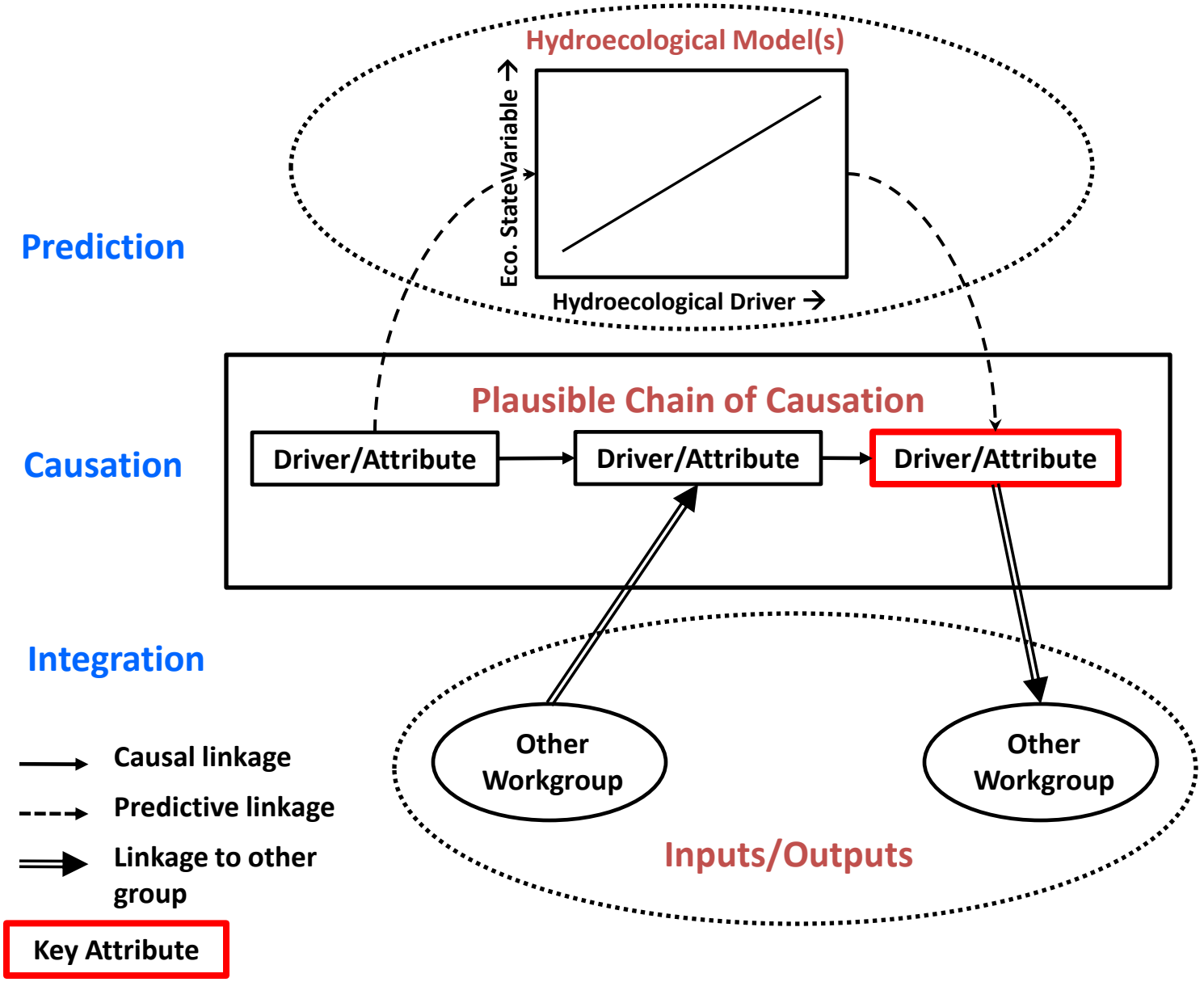




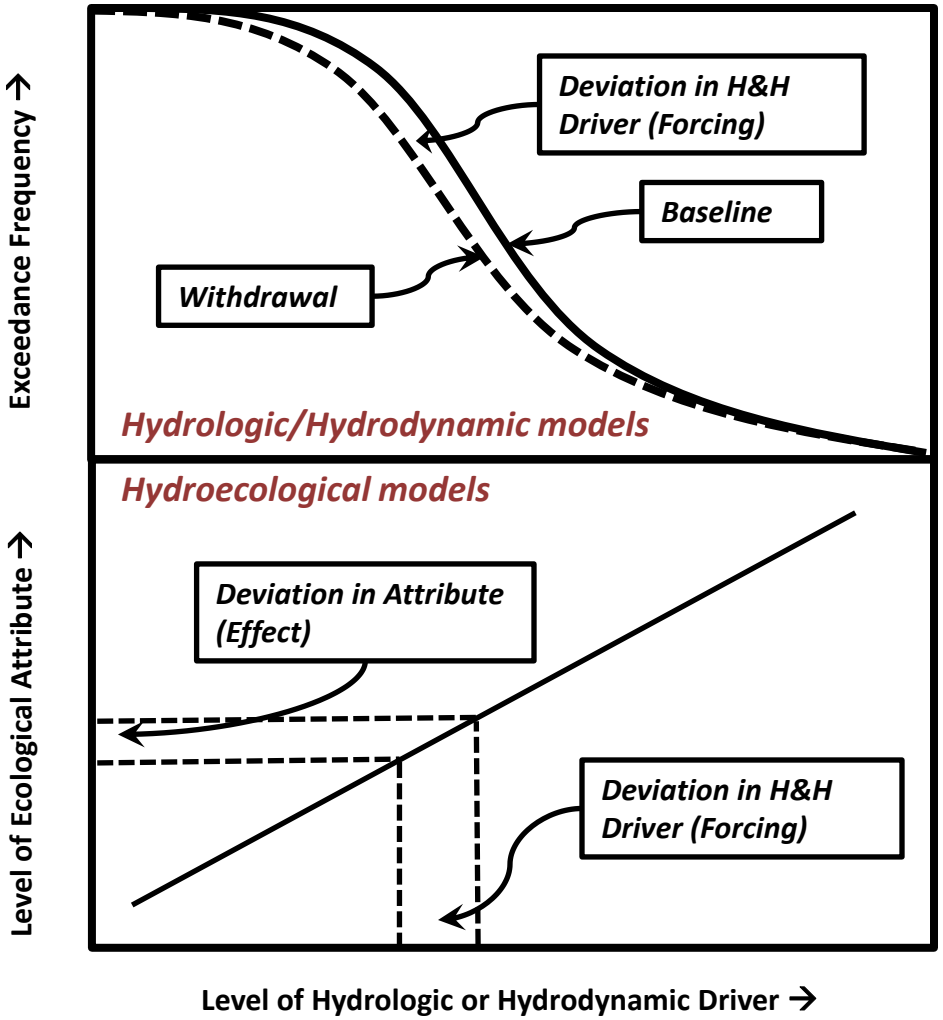
The conceptual models also serve to guide the work flow and to ensure appropriate linkages among work groups. Following the chain across groups shows that some groups cannot complete their analysis until after the work of other groups has been completed.


Legend
HYDROLOGY
BIOGEOCHEMISTRY
PHYTOPLANKTON
SAV
BENTHOS
FISH
WETLANDS & WETLAND – DEPENDENT SPECIES
Key Effect
Causal Linkage
Increase
Decrease
Change
The overall conceptual model illustrates the complexity of potential hydroecological effects.
Δ Estuary benthos –diversity, density
↓Shrimp, crab populations
Δ Estuary fish species distributions
↓Flow rate
↑Upstream isohalines
↑SAV mortality
↓SAV growth
↓SAV reproduction
↓SAV abundance and distribution
↑SAV epiphytes
↑ Shading of SAV
↓Water level
↑ Oxidation Soil Organic Matter
↑C,N,P Release
↑CDOM/DOM Release
↑ Nutrient Loading
↓ Respiration - inhibition
↓NPP – shading, inhibition
↑Withdrawal
↓Flow rate
↑Salinity/ Water age
↑Phytoplankton growing time
↑Phytoplankton Blooms
↓Dis. Oxygen
↓Crustacean zooplankton
↑N fixation
↑Phyto toxins
Δ Wetland Vegetation/ Wetland acreage
Δ FW benthos – diversity, density
↓Water level
↓ Stage-frequency distribution
↑ Oxidation Soil Organic Matter
↑C,N,P Release – gaseous, dissolved
↓Wetland Soil Accretion Rate
↓Populations of wetland-dependent fauna
Δ Wetland Vegetation/ Wetland Acreage
↓ Depth
↓FW Fish Spawning/nursery habitat
↓Populations of native FW fish
Δ FW benthos – diversity, density
↑Entrainment/ Impingement
↓FW Fish reproductive success

2. Develop predictive hydroecological models - Underlying each assessment of an effect is a conceptual model (path or causal diagram) showing the plausible chain of causation for the effect. Predictive models are needed to quantify the effects of the chain of causation.



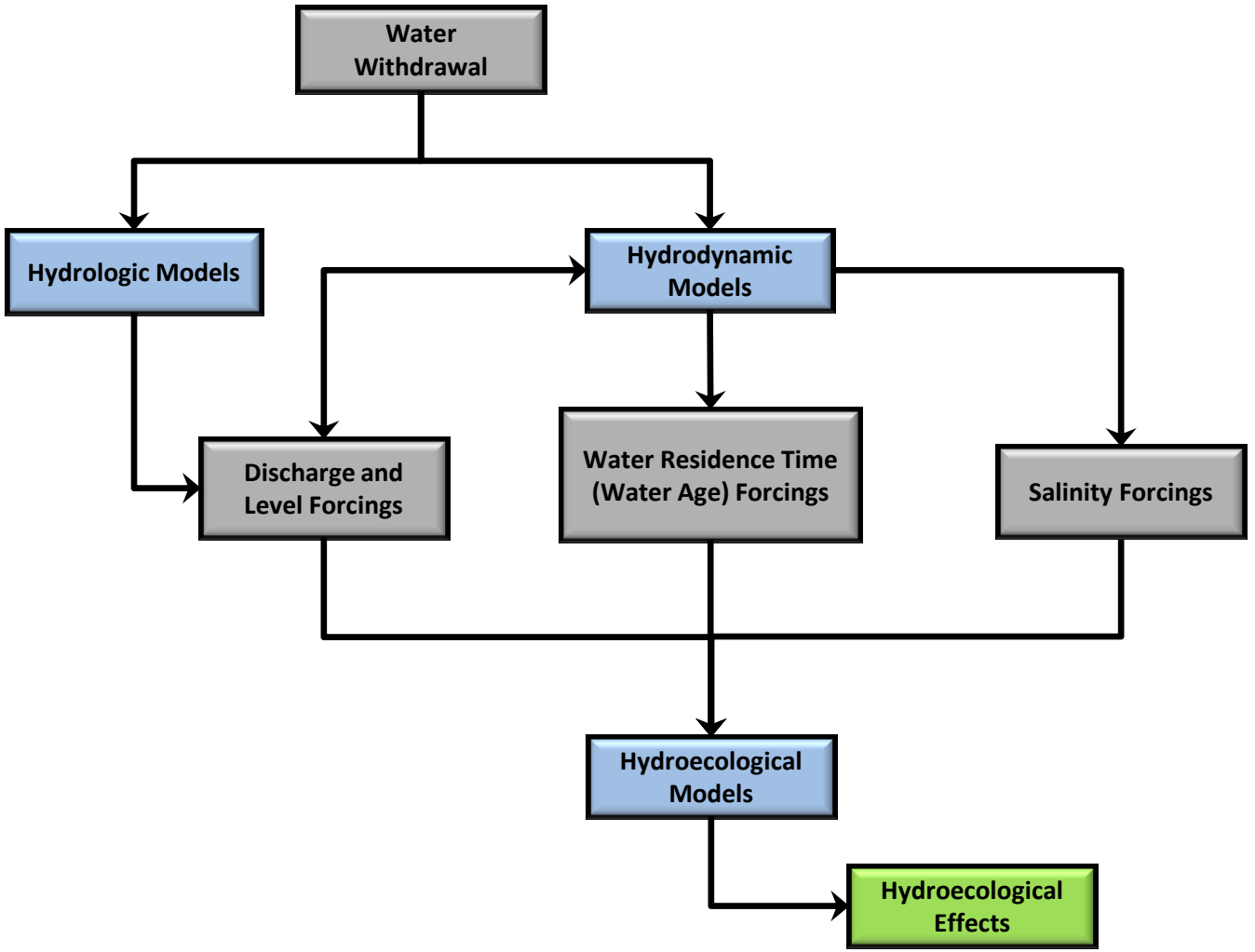
3. <u>Predict forcings and Effects as Deviations from a Baseline Condition</u>: The baseline condition is the basis for assessment of forcings and effects. Forcings (deviations in hydrologic and hydrodynamic (H&H) drivers from the baseline condition) caused by a water withdrawal (top panel) are inputs to hydroecological (HE) models that predict the potential ecological effects (deviations in ecological attributes from the baseline condition) (bottom panel).



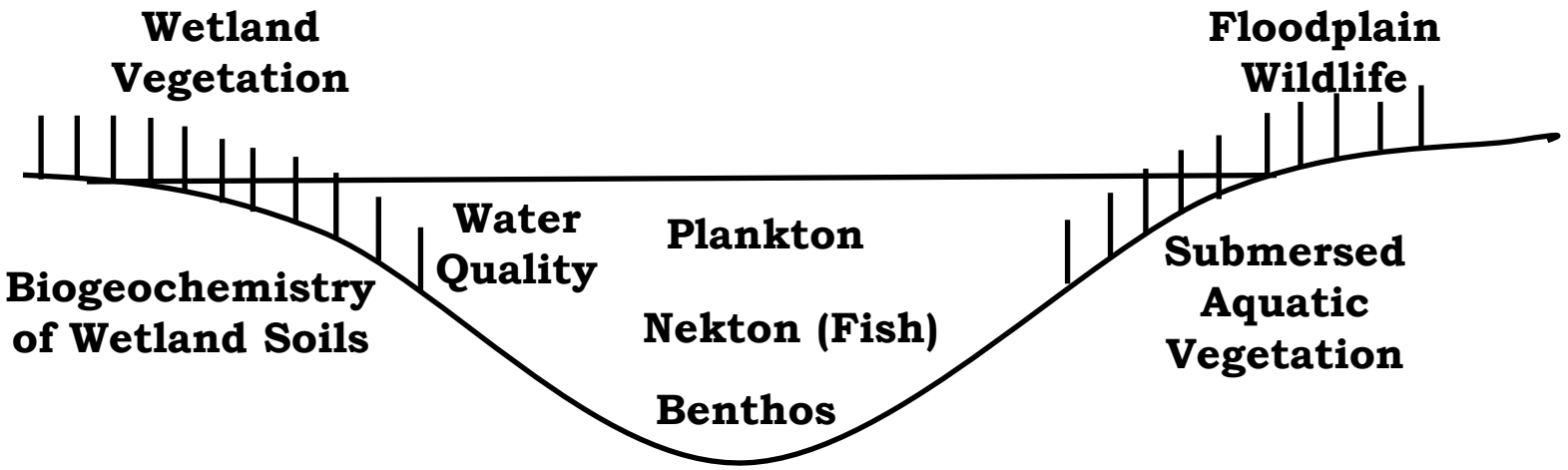
Forcings – deviations from the baseline condition in hydrologic and hydrodynamic (H&H) drivers

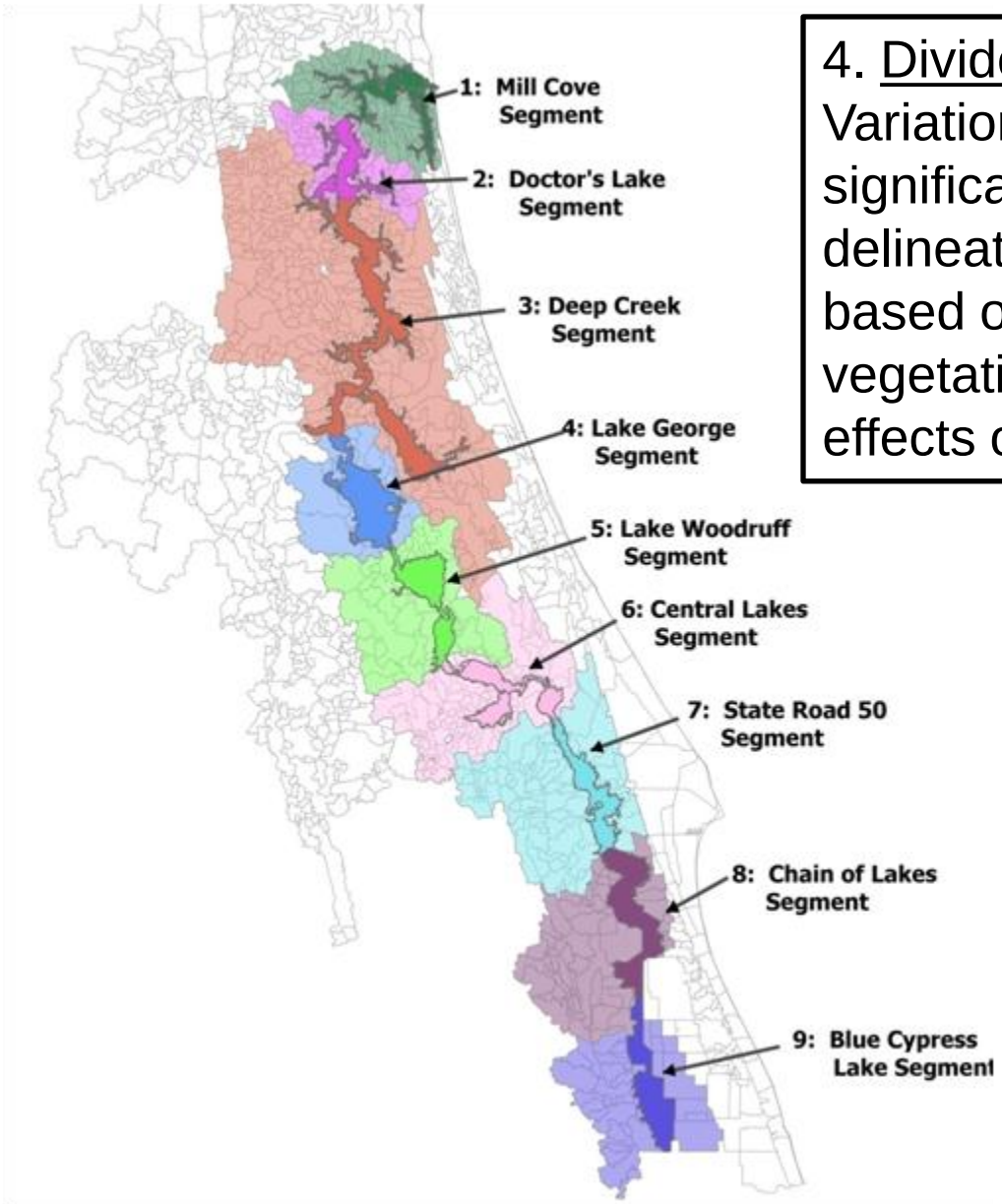
Effects – deviations from the baseline condition in ecological attributes

3. <u>Predict forcings and effects</u>. In our prospective analysis, forcings were outputs from Hydrologic and Hydrodynamic models.



4. <u>Divide and Conquer</u>: Ecological Components. Changes in hydrology can affect all components of the riverine ecosystem. We used separate workgroups to examine the potential effects on each component.





4. <u>Divide and Conquer</u>: Longitudinal Variation. Because the river varies significantly along it length, we delineated ecologically similar segments based on geomorphology, water quality, vegetation, and hydrology. Potential effects on each segment were assessed.

5. Develop a general scale for judging the importance of effects – We evaluated the importance of an effect by considering its persistence, strength, and diversity.

Characteristic	Description
Persistence	Recovery time relative to return interval
Strength	Intensity and scale (area affected)
Diversity	Breadth of ecosystem attributes affected

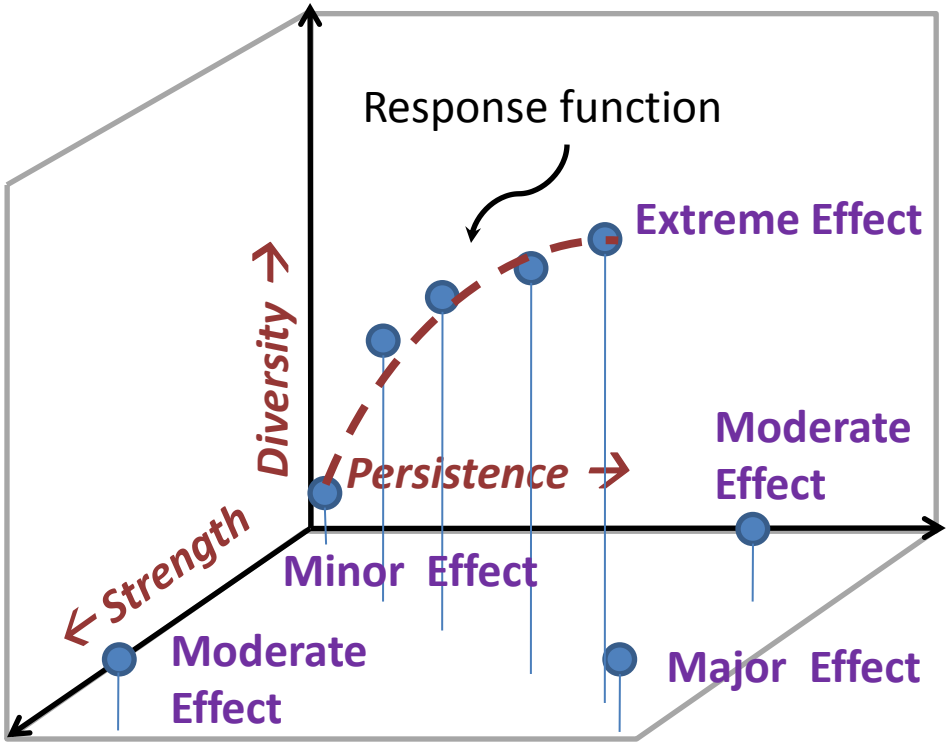
Extreme Effect – persistent, strong, & diverse; significant change in natural resource values
Major Effect - persistent & strong, not diverse, significant change in natural resource values
Moderate Effect – ephemeral or weak, no significant change in natural resource values
Minor Effect – ephemeral & weak; no significant change in any ecosystem component
Negligible Effect – no appreciable change in any ecosystem component

The importance of effects can be viewed as points in a 3-dimensional effects space.

1. Strength – intensity, extensivity

2. Persistence – recovery time relative to return interval

3. Diversity – number of ecosystem components affected

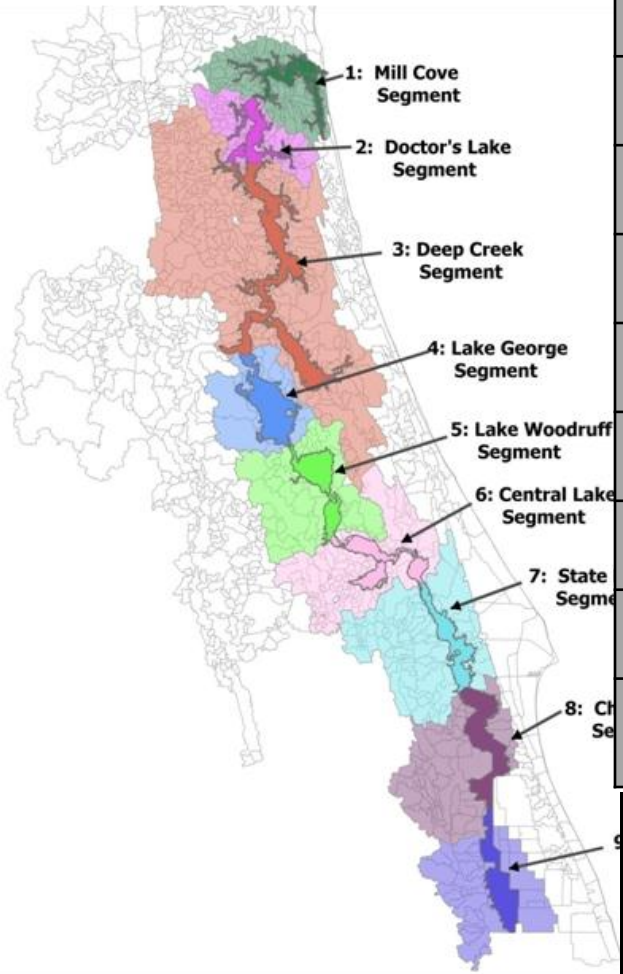


Note: Axes scales could be numerical or categorical (ordinal, interval, or nominal)

6. Develop a general scale for assessing the level of scientific uncertainty - We evaluated the level of uncertainty associated with a potential effect by considering the strength of predictive models, the strength of supporting evidence, and our understanding of the causative mechanism(s).

Level of Uncertainty	Criteria
Very low	Very strong quantitative evidence - Strong predictive model (PM), strong supporting evidence (SE), good understanding of mechanism (UM)
Low	Strong quantitative evidence – Strong PM and either SE or UM
Medium	Moderate quantitative evidence or strong qualitative evidence - PM or both SE and UM
High	Weak quantitative evidence or moderate qualitative evidence – no PM but either SE or UM
Very high	Weak qualitative evidence – no PM, weak SE and UM - weak in all three areas

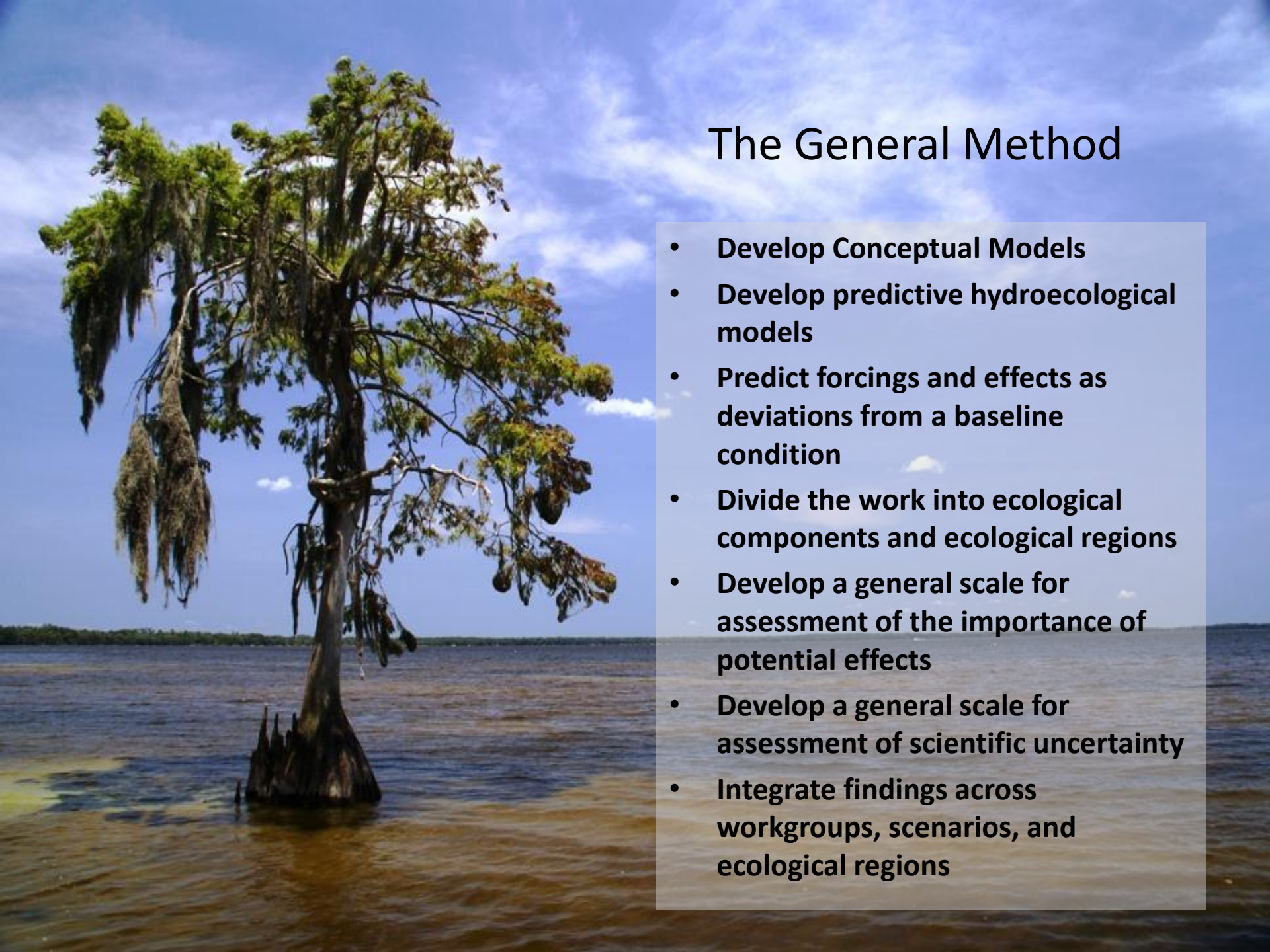
7. Integrate findings across workgroups and ecological regions using general scales for significance and uncertainty.



River Segment	Water Quality	Plankton	SAV	Wetland Plants	Benthos	Fish	Wildlife
1	*	NA	NA	*	**	**	*****
2	*	**	**	*	***	**	*****
3	*	**	**	*	***	**	*****
4	*	*	**	*	*****	***	NA
5	*	NA	***	***	*****	***	NA
6	*	*	***	***	****	***	****
7	**	NA	***	***	****	***	****
8	*	**	***	**	****	***	****

	Negligible effect
	Minor effect
	Moderate effect
	Major effect
	Extreme effect

*	Very low uncertainty
**	Low uncertainty
***	Medium uncertainty
****	High uncertainty
*****	Very high uncertainty



The General Method

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www.sjrwmd.com/watersupplyimpactstudy

Photograph: Dean Campbell