An Overview of the Energy-Water Nexus at Regional Scales

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Outline

- Basin-Scale and Regional Energy and Water Systems
- The “Nexus” in Energy-Water Nexus
- A specific basin-scale example
- Variability and time-scales in Energy-Water Systems
- Non-energy objectives in energy-water decision-making

Water Resources Systems

Inherent uncertainty, conflicting priorities

Multiple demands:

- Flood damage reduction
- Water supply
- Ecological provision and management
- Commercial navigation
- Recreation and aesthetics
- Energy Supply

Complexities:

- Uncertainty reigns!
- Diverse stakeholder priorities
- Context-driven priorities
- Data, science, technology gaps between decision variables and outcomes

Hydrologic Units

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Electric Power Systems

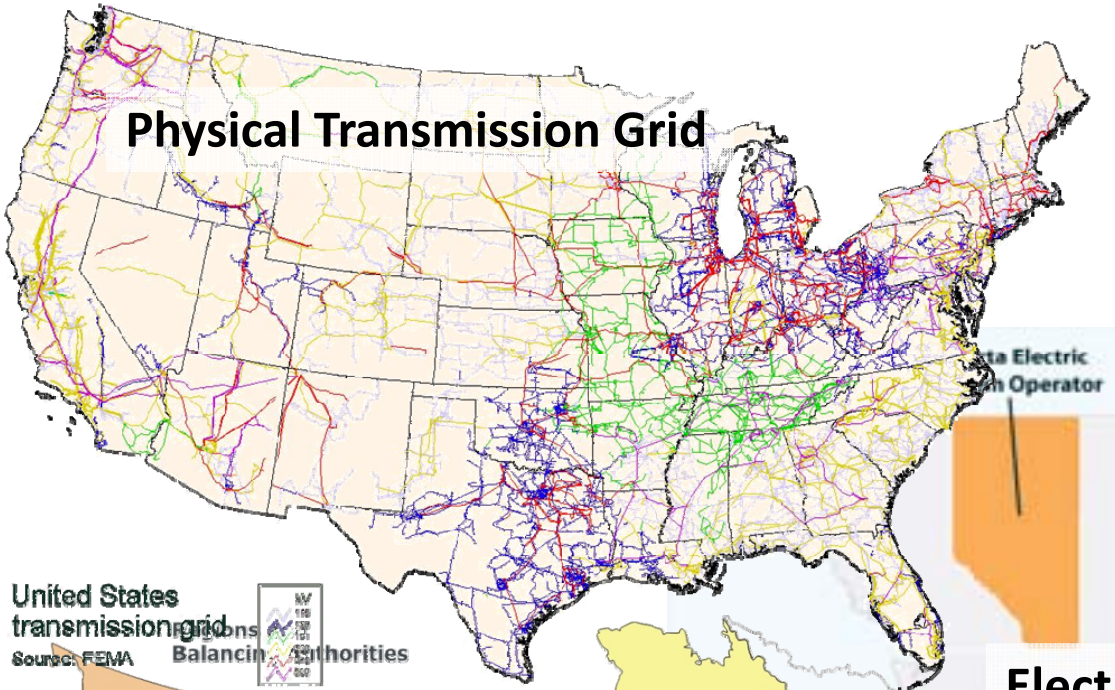
Evolving and Emergent Complexity

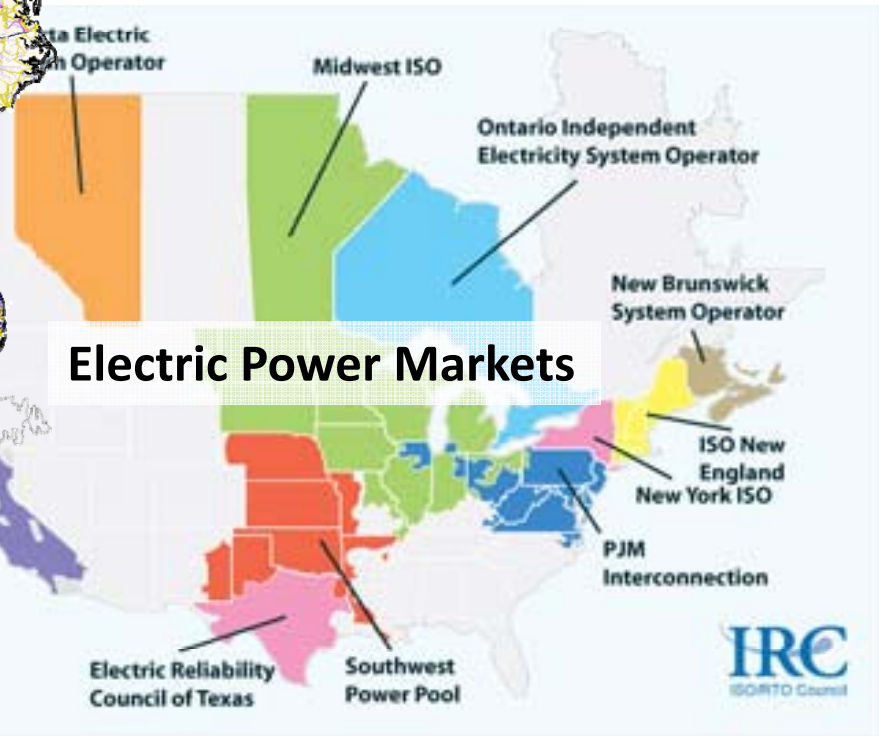
Power System Features:

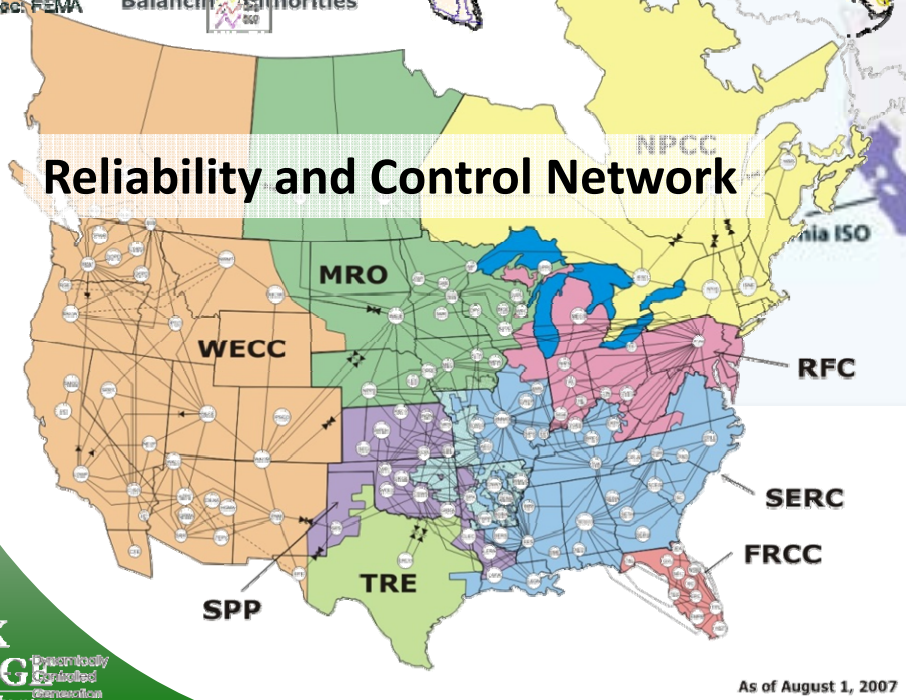
- Multiple asset types
  - Nuclear, Coal, Gas, Hydro
  - Wind, Solar, Hydro, Bio, Geo
  - Demand response
  - Energy storage
- Interconnected capacity-limited transmission system
- Multiple constraints and costs
  - Supply = Demand
  - Reliability standards
  - Security goals
  - Fuel supply
  - Emissions goals
  - Environmental impacts
  - Initial cost and project financing

Complexities:

- Multiple evolving markets for energy and services
- Mature, deploying, and emerging generation technologies with differing cost trajectories
- National, regional, and state energy policy uncertainty
- "System of systems" architecture

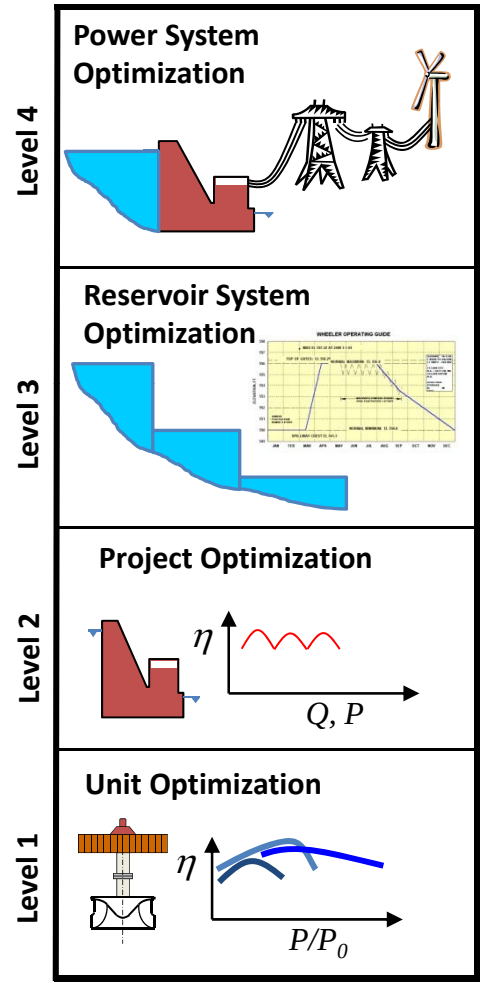

Physical Transmission Grid
United States transmission grid
Source: FEMA


Electric Power Markets
Midwest ISO
Ontario Independent Electricity System Operator
New Brunswick System Operator
ISO New England
New York ISO
PJM Interconnection
Electric Reliability Council of Texas
Southwest Power Pool
IRC


Reliability and Control Network
NPCC
MRO
WECC
RFC
SERC
FRCC
TRE
SPP
As of August 1, 2007

Water for Energy Linkages

- Nuclear generation
  - Cooling water requirements
  - Waste assimilation
- Coal-fired generation
  - Cooling water
  - Emissions control systems
  - Ash-handling and waste assimilation
- Combined-Cycle Gas
  - Cooling water
- Hydropower
  - Water-in-storage
- Bio-energy
  - Crop irrigation
  - Refining process water
  - Cooling water



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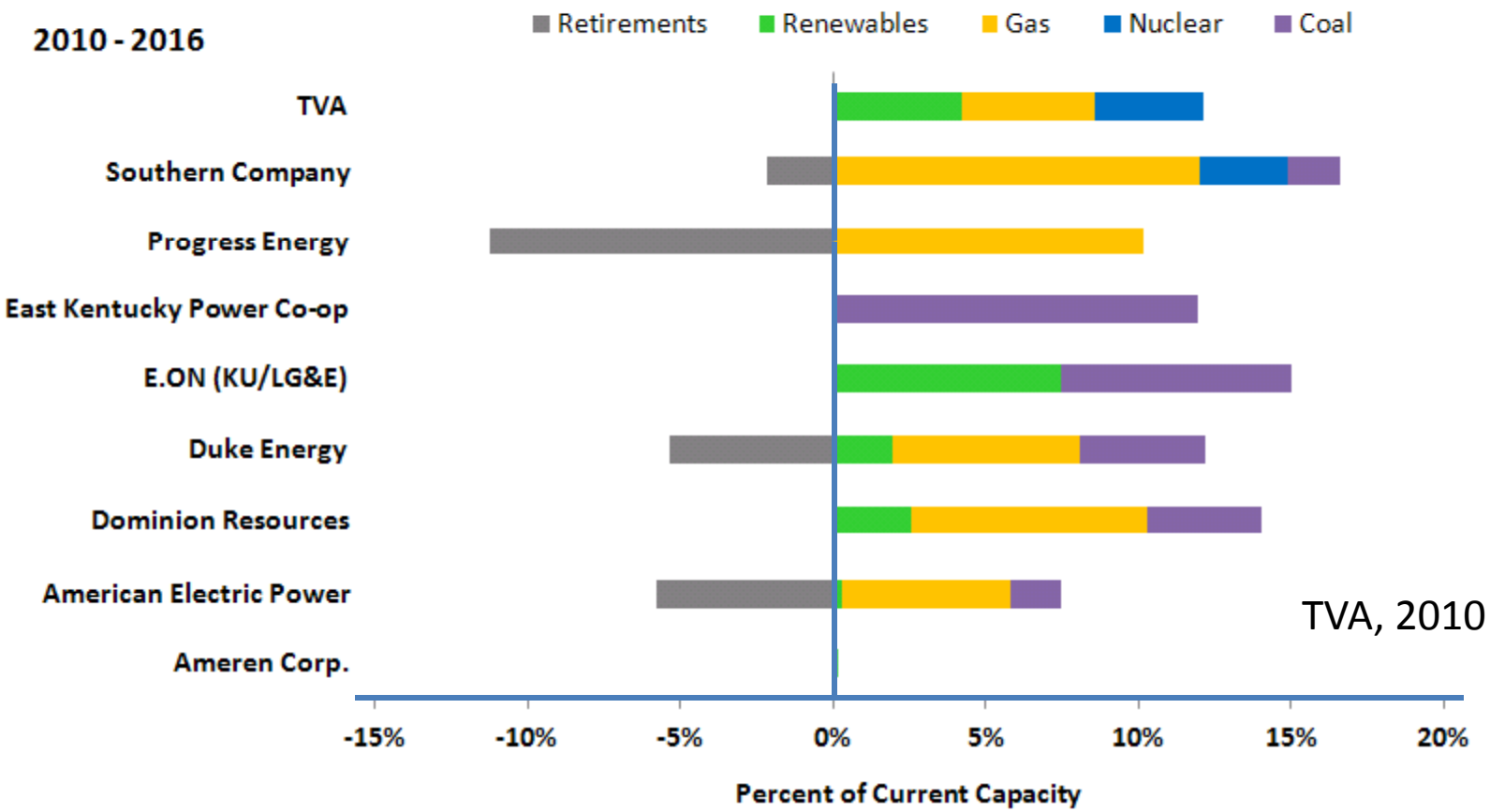
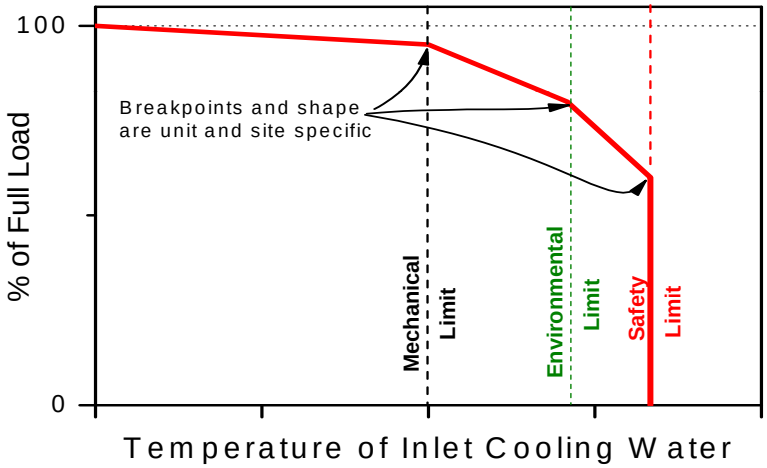
Near-Term Capacity Projections



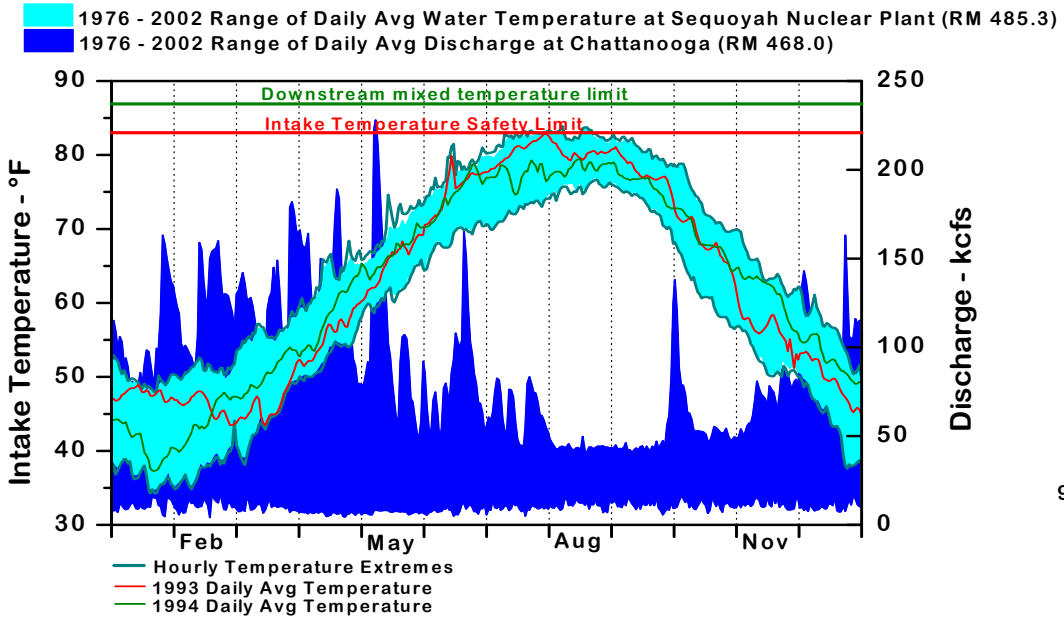
TVA, 2010

Thermoelectric Cooling Water



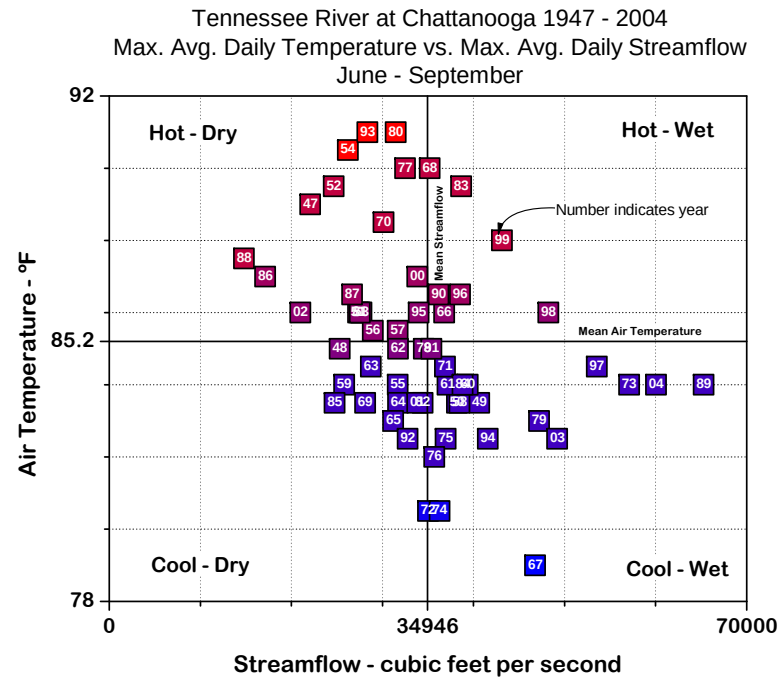
- Once-through cooling
  - Effluent and instream temperature constrain generation and reduce efficiency
  - Low-flow conditions degrade water conveyance systems
- Closed-loop
  - Consumptive use can become critical during low-flow periods
  - Air-temperature variability becomes important input for decision-making

Thermoelectric Cooling Water



- Water management must include consideration of water temperature and availability over hourly, daiily, seasonal and annual time horizons

- Joint probability of low-flow and high temperature is important risk factor for generation availability
- Advanced forecasting and decision-support are required to avoid de-ratings and shutdowns



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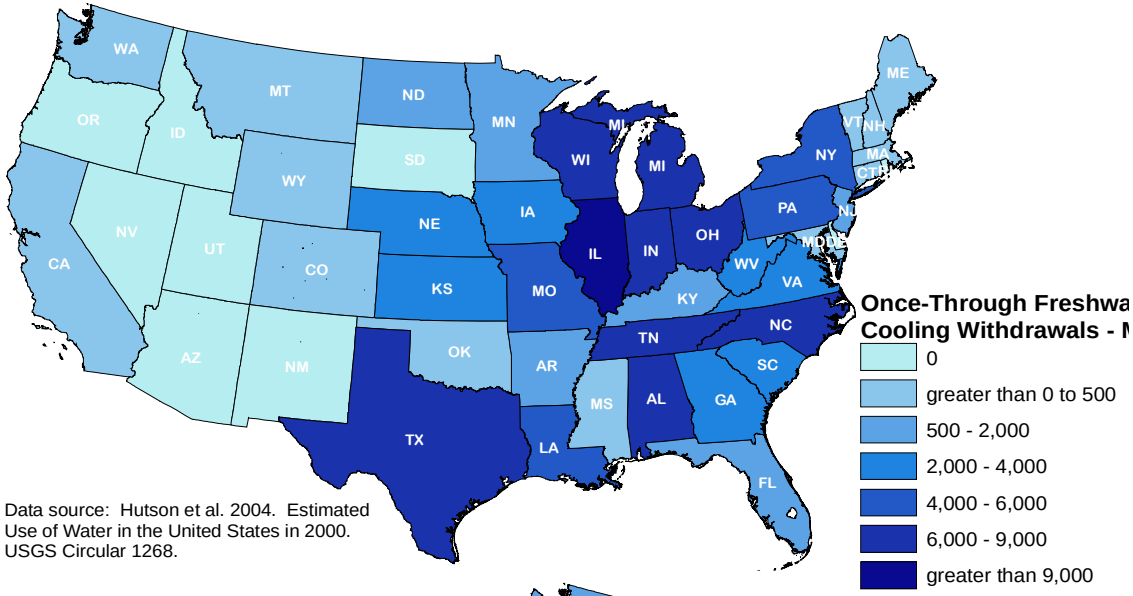
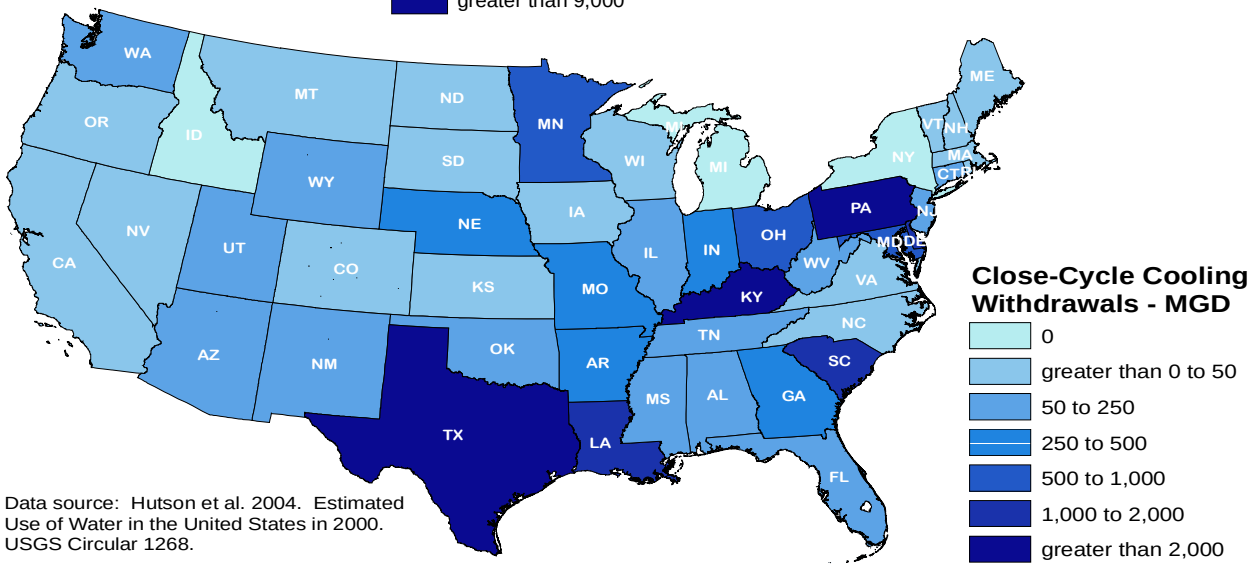
Thermoelectric Cooling Water



Data source: Hutson et al. 2004. Estimated Use of Water in the United States in 2000. USGS Circular 1268.

Thermoelectric cooling water withdrawal and consumptive use is intense in the Southeast



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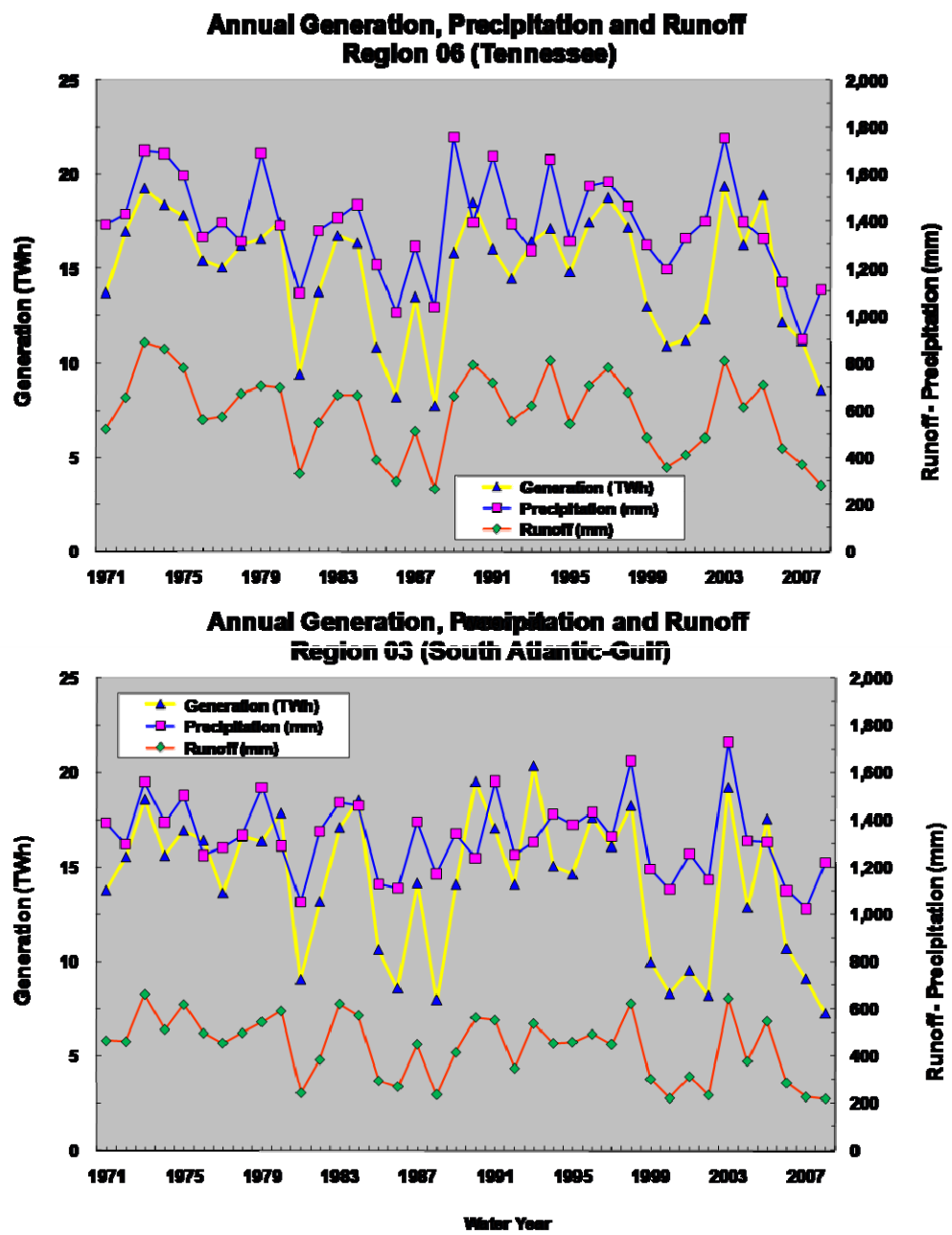
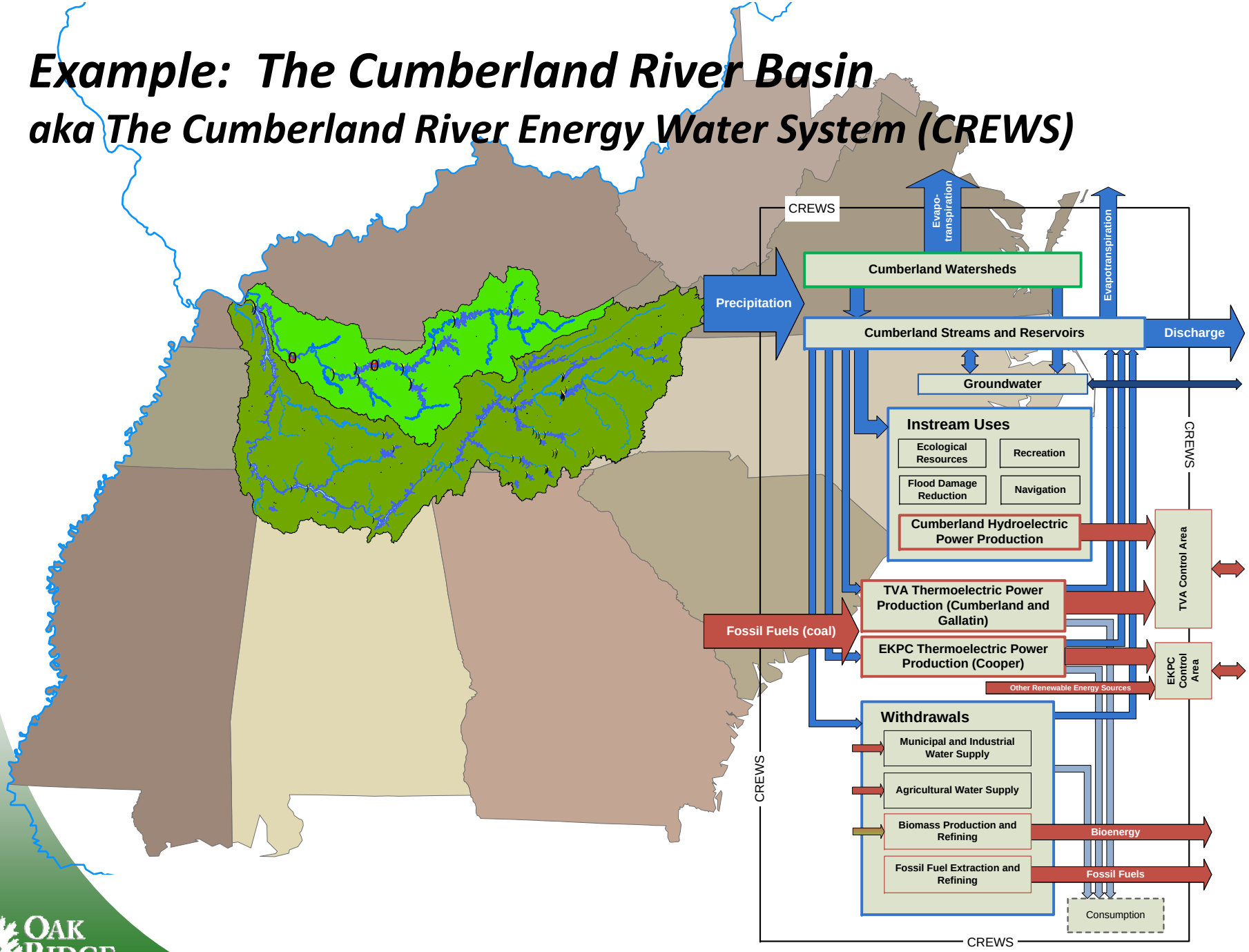
Hydropower Production

- Aging infrastructure may reduce reliability of generation without new investment
- Increased water management constraints limit flexibility and value as dispatchable asset
- Environmental mitigation technologies are emerging
- Small-hydropower opportunities exist



Example: The Cumberland River Basin

aka The Cumberland River Energy Water System (CREWS)



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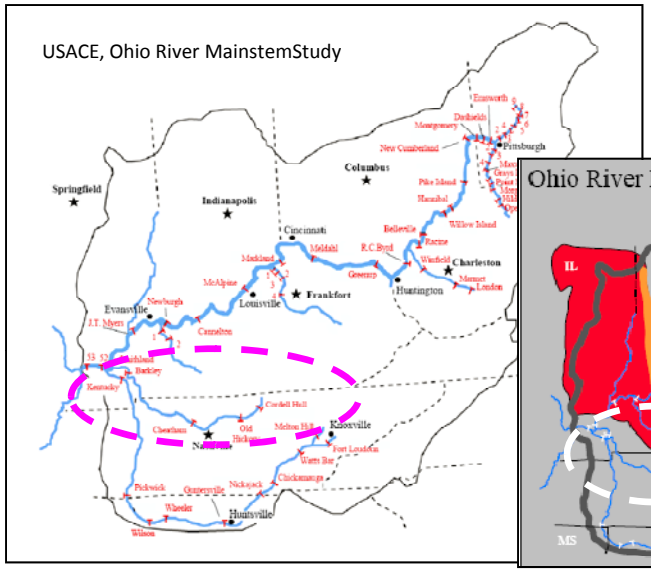
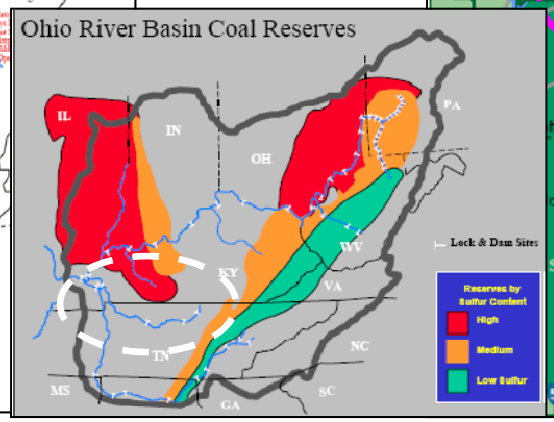
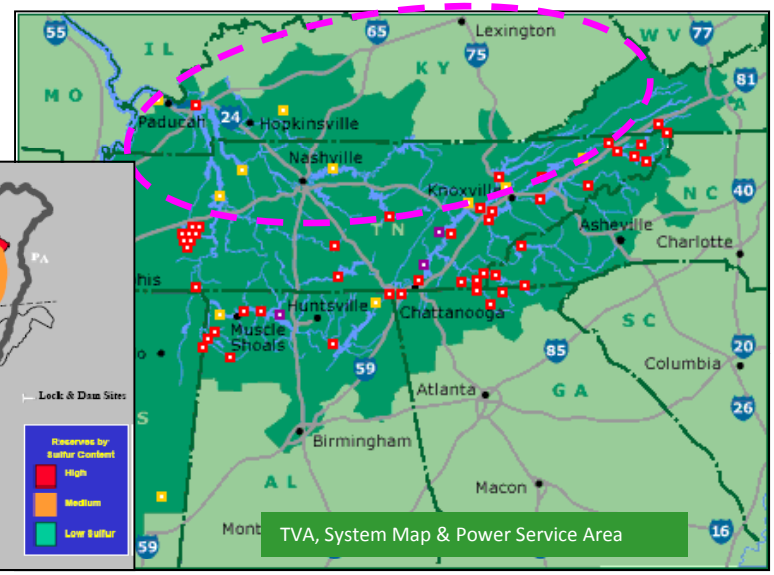
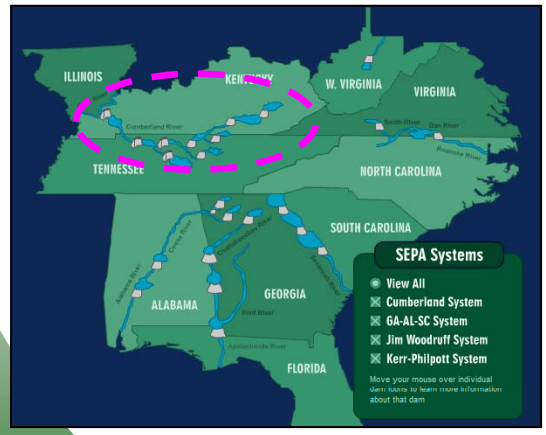
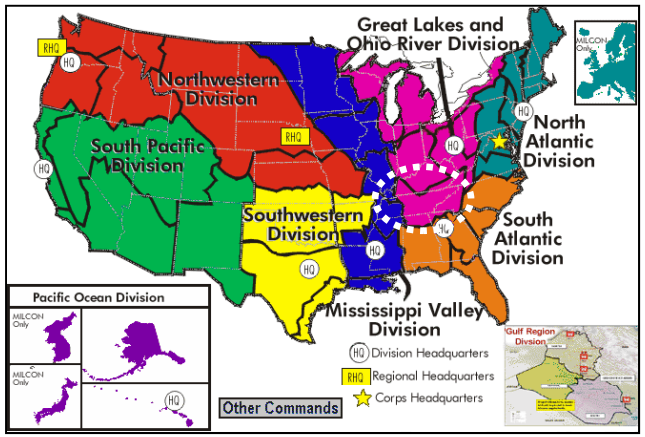
Cumberland River Institutional Perspectives

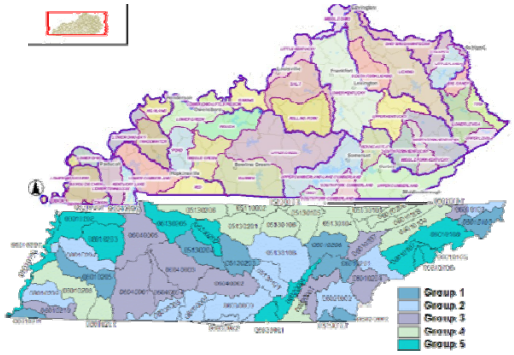












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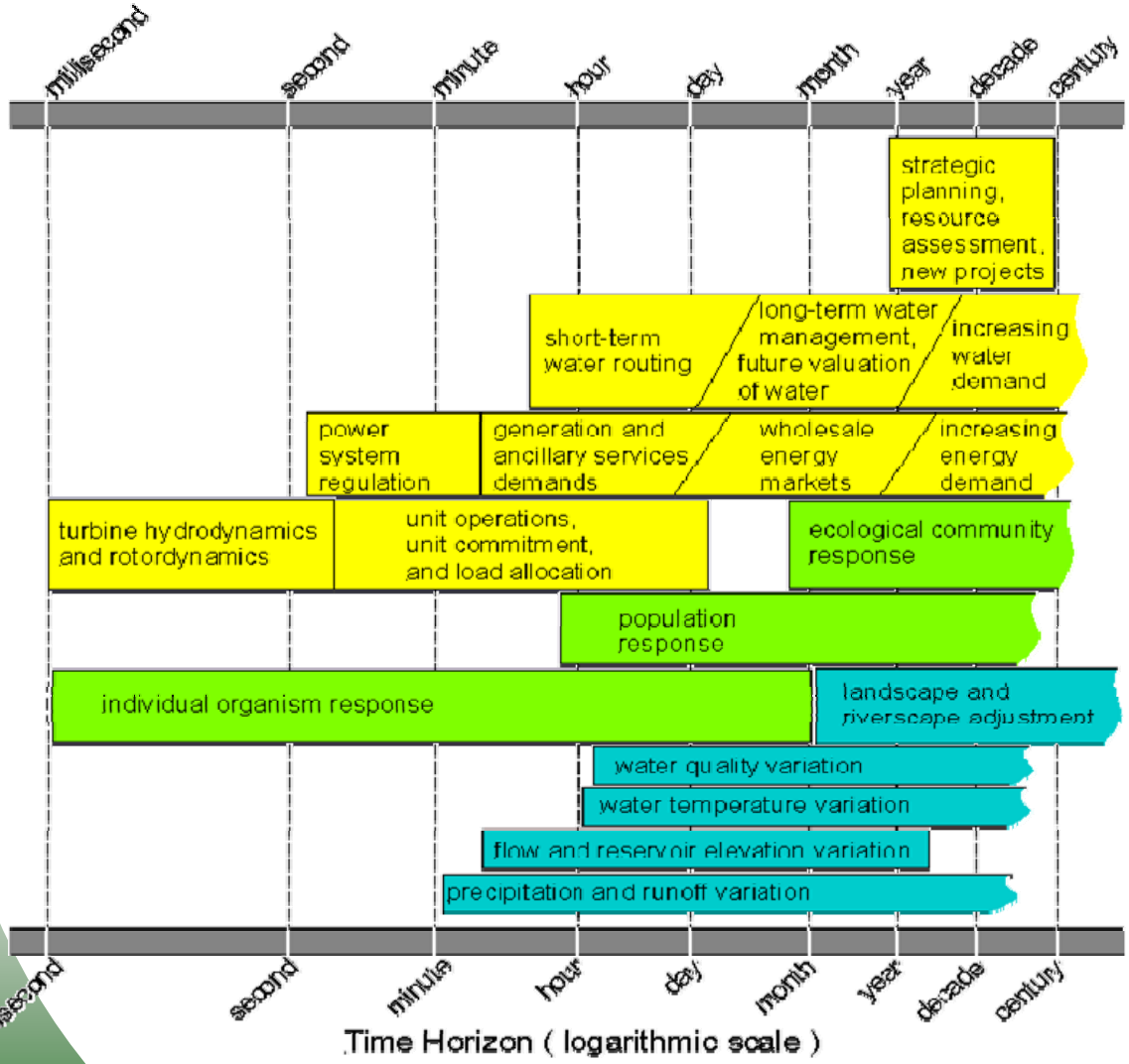
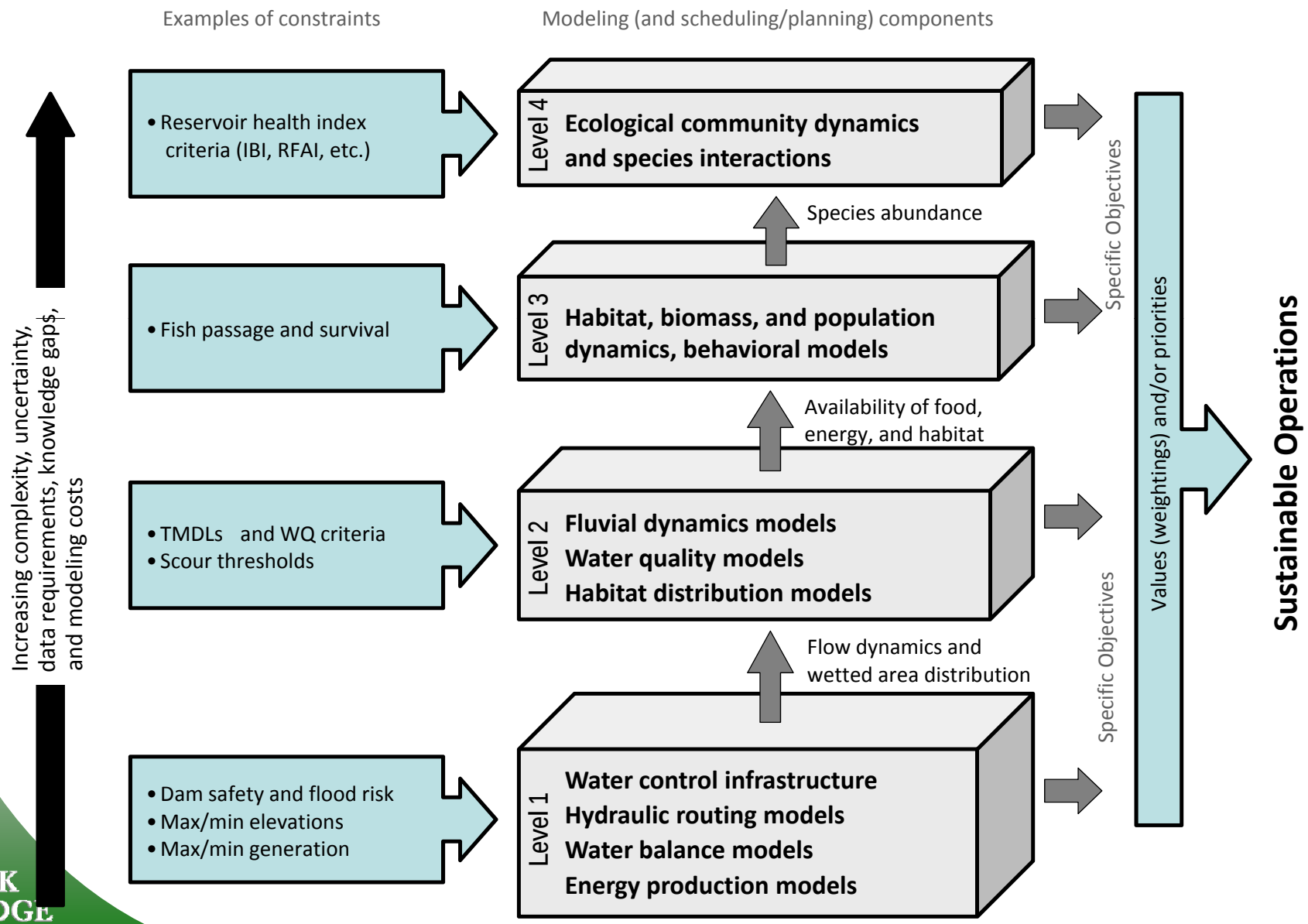
Energy-Water Temporal Variability



- **Decision-making must resolve events and processes over a wide range of time scales—examples:**
  - Reproduction, mortality, growth
  - Drought, floods, climate change
  - Reservoir stratification and turnover
  - Peak energy and ancillary services valuation
- **Modeling and forecasting across time scales**
  - Aligning energy, water, and ecological model timing
  - Transferring energy, mass balance, and other constraints between nested models

Complex Objectives in Energy-Water Decision Making



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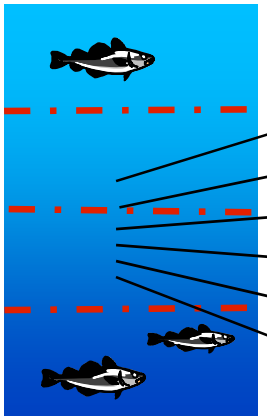
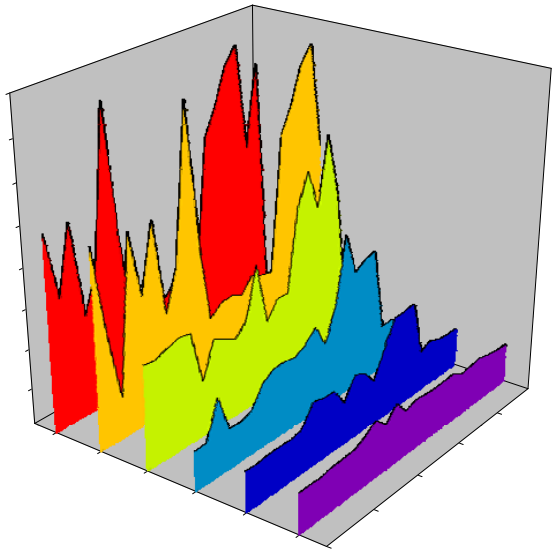
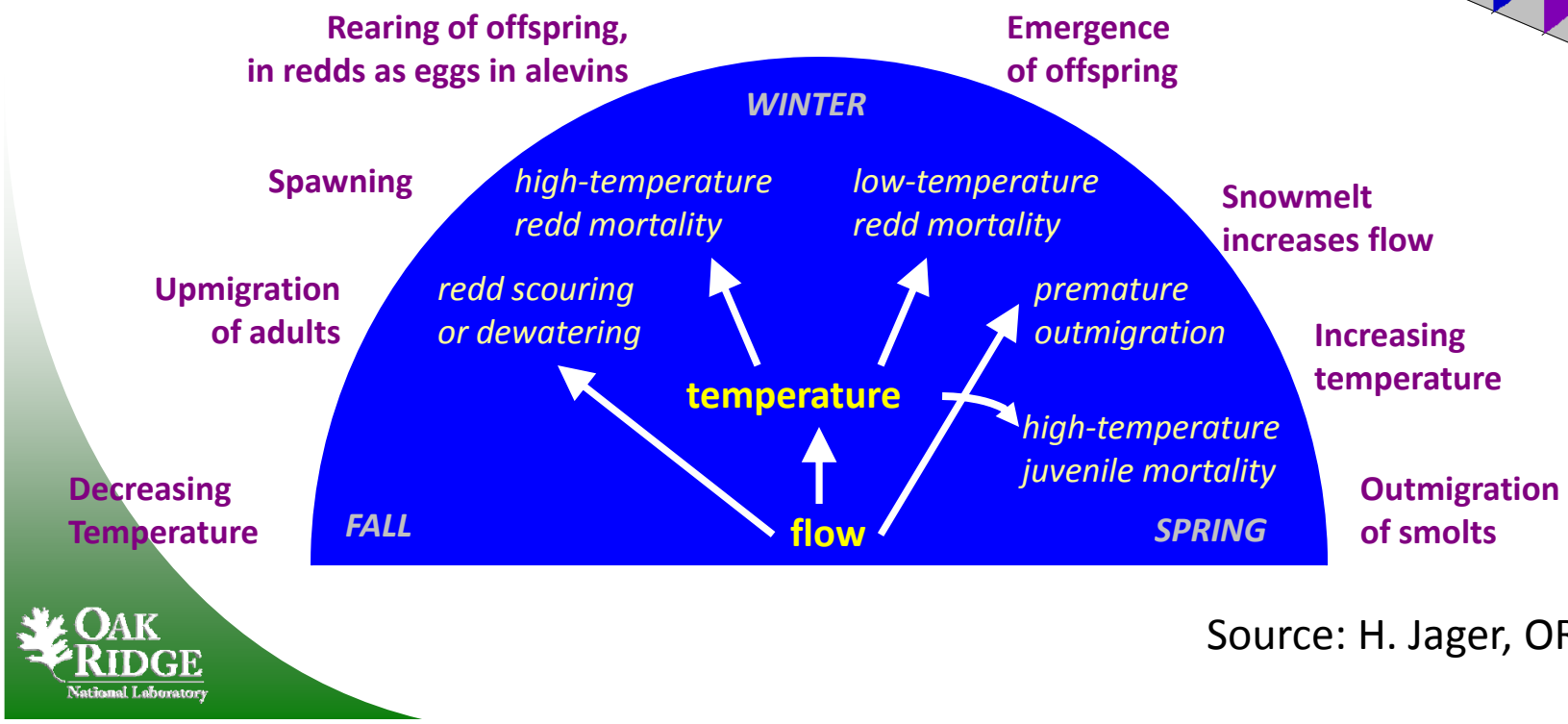
Example: Optimizing Ecological Value with the Oak Ridge Chinook Model



Water volume attributes:

- % pool vs. riffle
- number of predators
- number of overlapping spawners
- number of larger Chinook competitors
- weighted usable area
- temperature and flow





Source: H. Jager, ORNL

Important Take-Away Concepts

- Energy and water systems are connected across multiple time scales and with non-aligned boundaries.
  - Electricity already flows across hydrologic boundaries
- Energy and water systems benefit from joint analysis over a range of operational and planning time scales.
  - Water-use tradeoffs exist between energy and non-energy uses, as well as between alternative energy sources.
  - Southeast is dependent on water for baseload generation
  - What are tradeoffs between water-for-bioenergy and water-for-baseload thermoelectric?
  - Answers will come within both planning (inter-annual) and operational (intra-annual) decision-making processes.
- Our ability to model ecological implications of energy-water use scenarios is very limited.