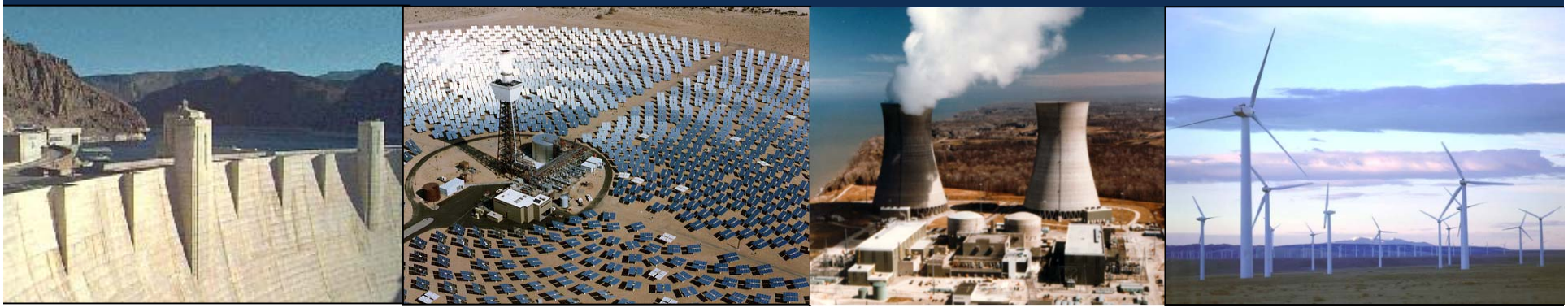
Exceptional service in the national interest

Sandia National Laboratories



Exploring Energy-Water Issues in the United States

Vince Tidwell, Peter H. Kobos and Barbie Moreland
Sandia National Laboratories
Haibo Zhai and Ed Rubin
Carnegie Mellon University

Crosscutting Research and Rare Earth Elements Review

April 20, 2016

U.S. DEPARTMENT OF ENERGY NNSA

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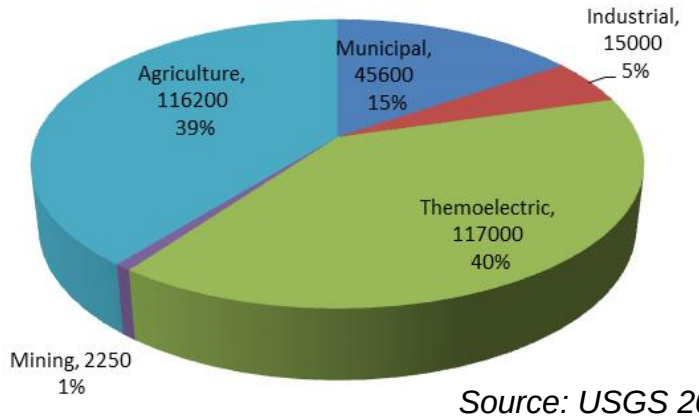
Challenge

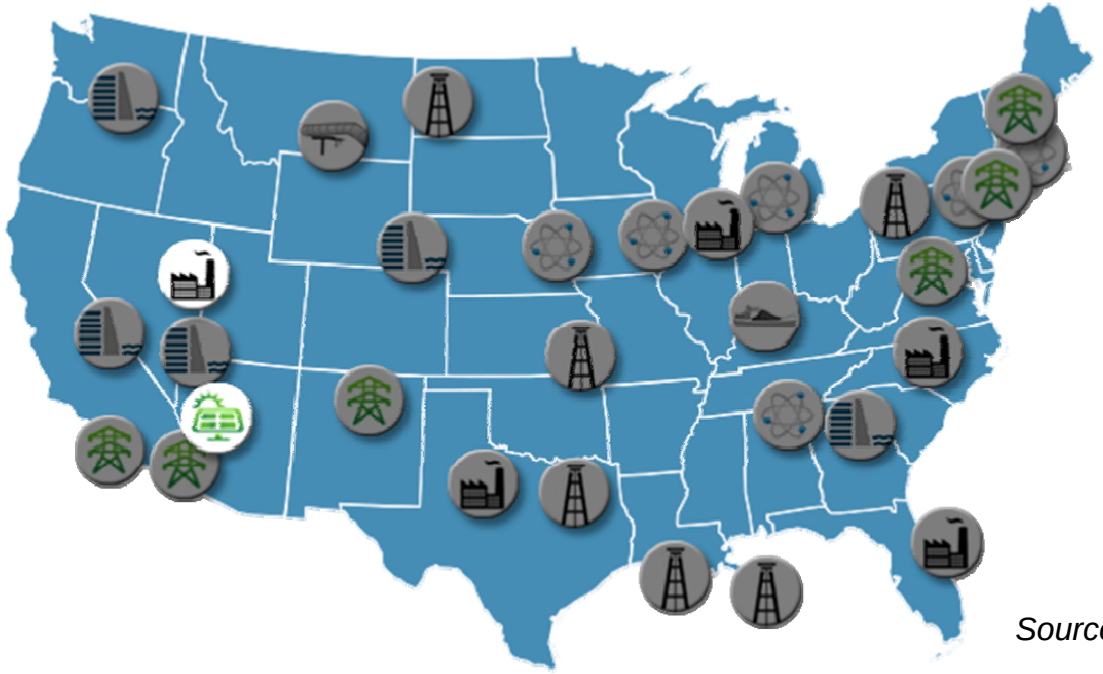
Thermoelectric energy production withdraws more water in the U.S. than any other use sector.



Source: USGS 2014

Energy-Water Nexus Issues are playing out all across the U.S.

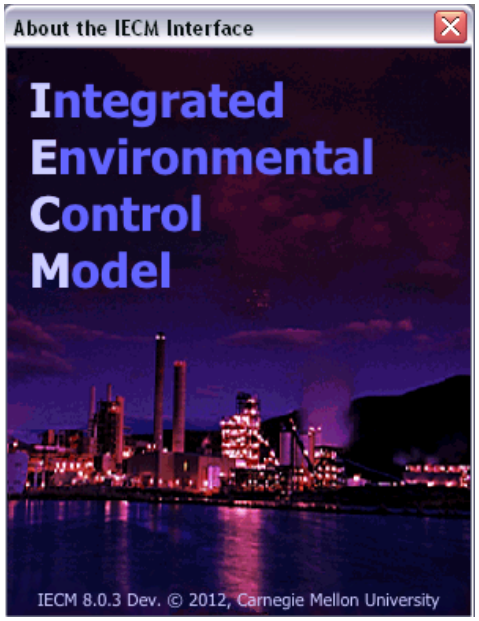
- Power plant outages
- Constrained hydropower
- Infrastructure damage by extreme events
- Curtailed energy resource extraction
- Permitting of New Facilities



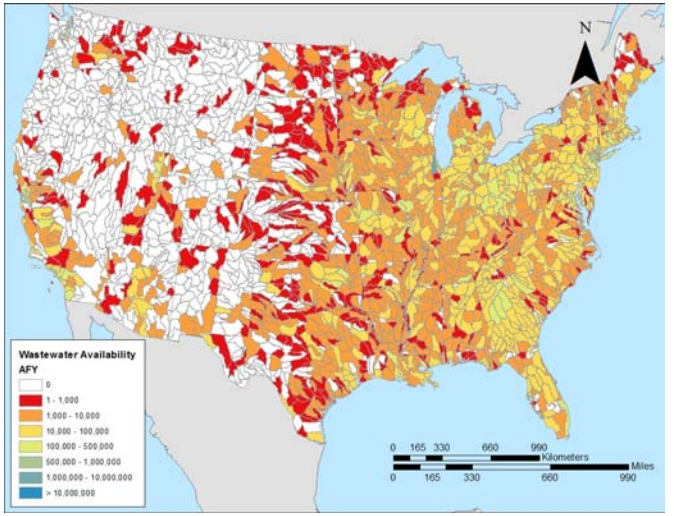
Source: DOE 2013

Objectives

- Extend capabilities of the Integrated Environmental Control Model (IECM) to assess alternative options for designing and managing power plant water systems at the unit level.
- Develop a National Water Atlas, estimating water availability, cost and projected future demand at the watershed level (8-digit HUC, or roughly 2250 watersheds)

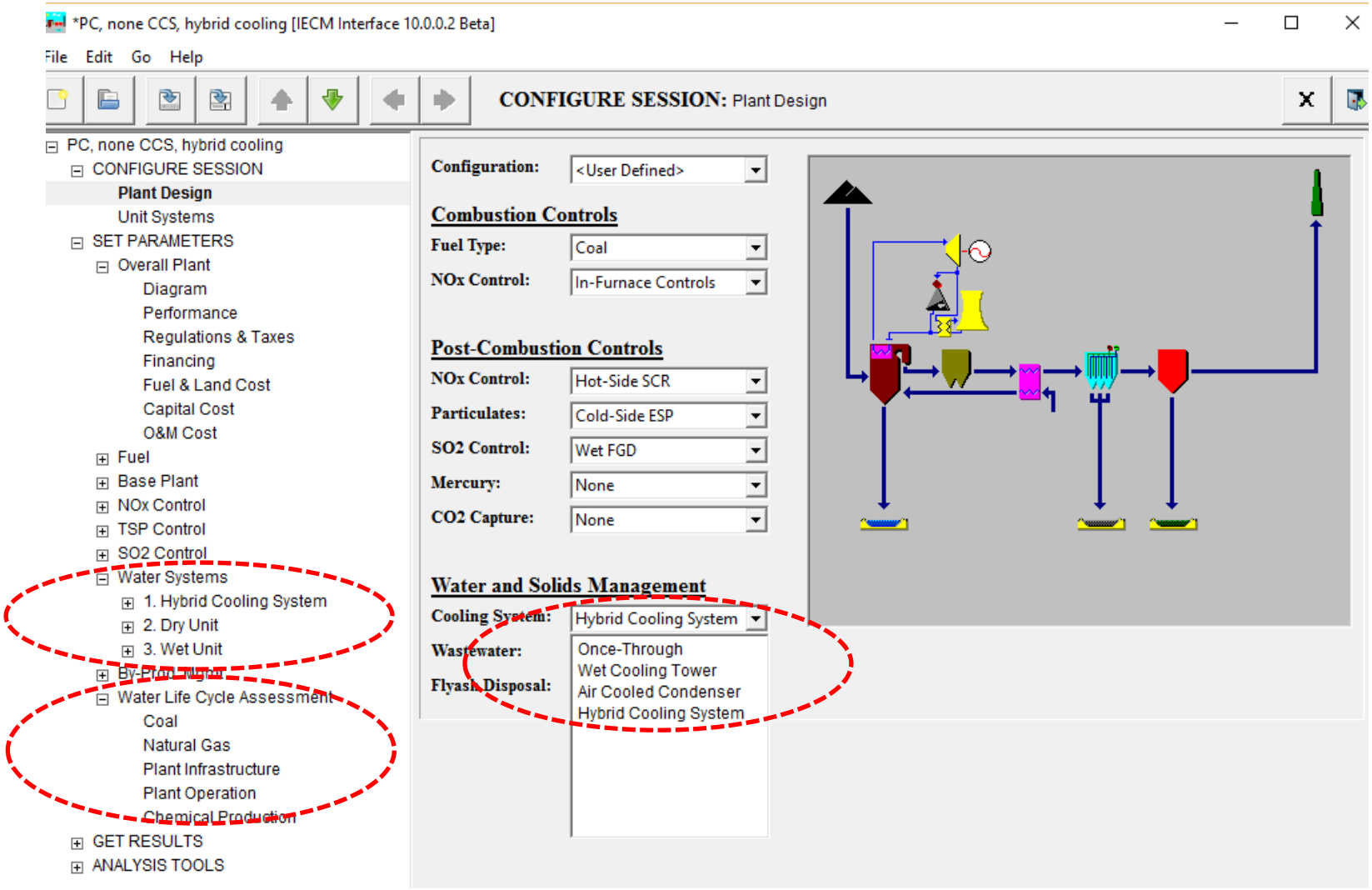


Available Wastewater

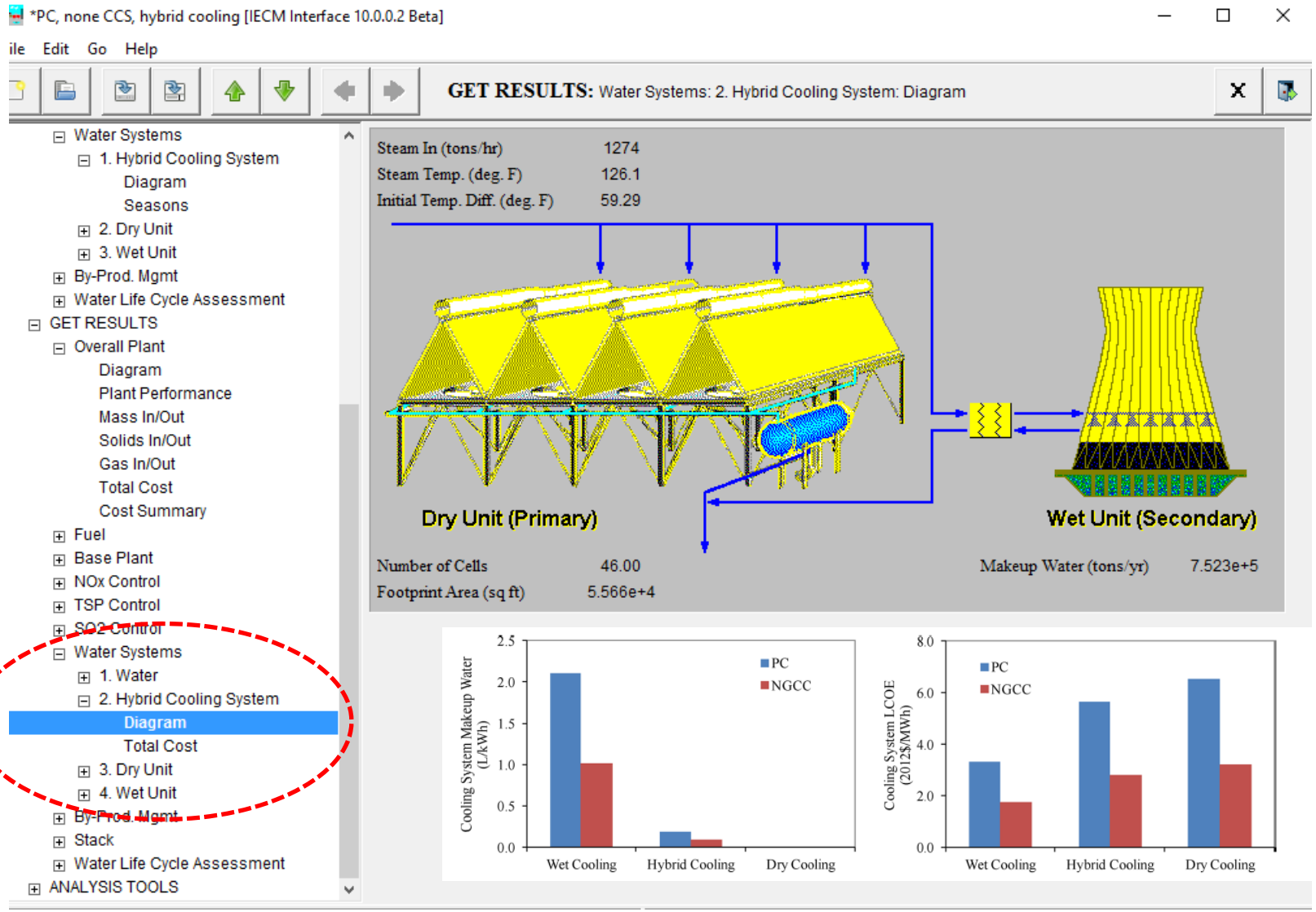


Power Plant Lifecycle Water Use

Configure a Plant with Wet or Dry or Hybrid Cooling to Assess Plant-Level and Life Cycle Water Use



Hybrid Cooling System



Life Cycle Water Use

water LCA [IECM Interface 10.0.0.2 Beta]

ile Edit Go Help

GET RESULTS: Water Life Cycle Assessment: Water Withdrawals

- Performance
- Regulations & Taxes
- Financing
- Fuel & Land Cost
- Capital Cost
- O&M Cost
- Fuel
- Base Plant
- NOx Control
- TSP Control
- SO2 Control
- Water Systems
- By-Prod. Mgmt
- Water Life Cycle Assessment
  - Coal
  - Natural Gas
  - Plant Infrastructure
  - Plant Operation
  - Chemical Production
- GET RESULTS
  - Overall Plant
  - Fuel
  - Base Plant
  - NOx Control
  - TSP Control
  - SO2 Control
  - Water Systems
  - By-Prod. Mgmt
  - Stack
  - Water Life Cycle Assessment
    - Water Withdrawals
    - Water Consumption
- ANALYSIS TOOLS

	A	B
1	Process/Chemical	Water Withdrawal (gal/MWh)
2	Fuel Extraction	2.170
3	Fuel Processing	13.01
4	Fuel Transport	0.7234
5	Total Fuel Supply	15.90
6		
7	Plant Infrastructure	16.30
8		
9	Ammonia	1.030
10	Limestone	2.479
11	Amine (30-wt% MEA)	0.0
12	Total Chemical Production	3.509
13		
14	Plant Operation	657.5
15		
16		

	A	B
1	Process/Chemical	Water Withdrawal (gal/MWh)
2	Fuel Supply	15.90
3	Plant Infrastructure	16.30
4	Chemical Production	3.509
5	Plant Operation	657.5
6	Total Life Cycle	693.2
7		
8		
9		
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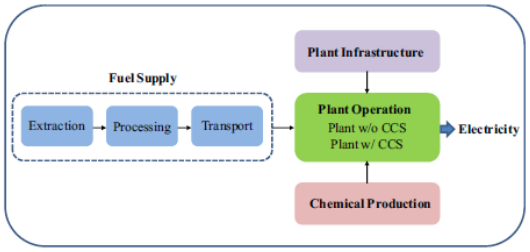
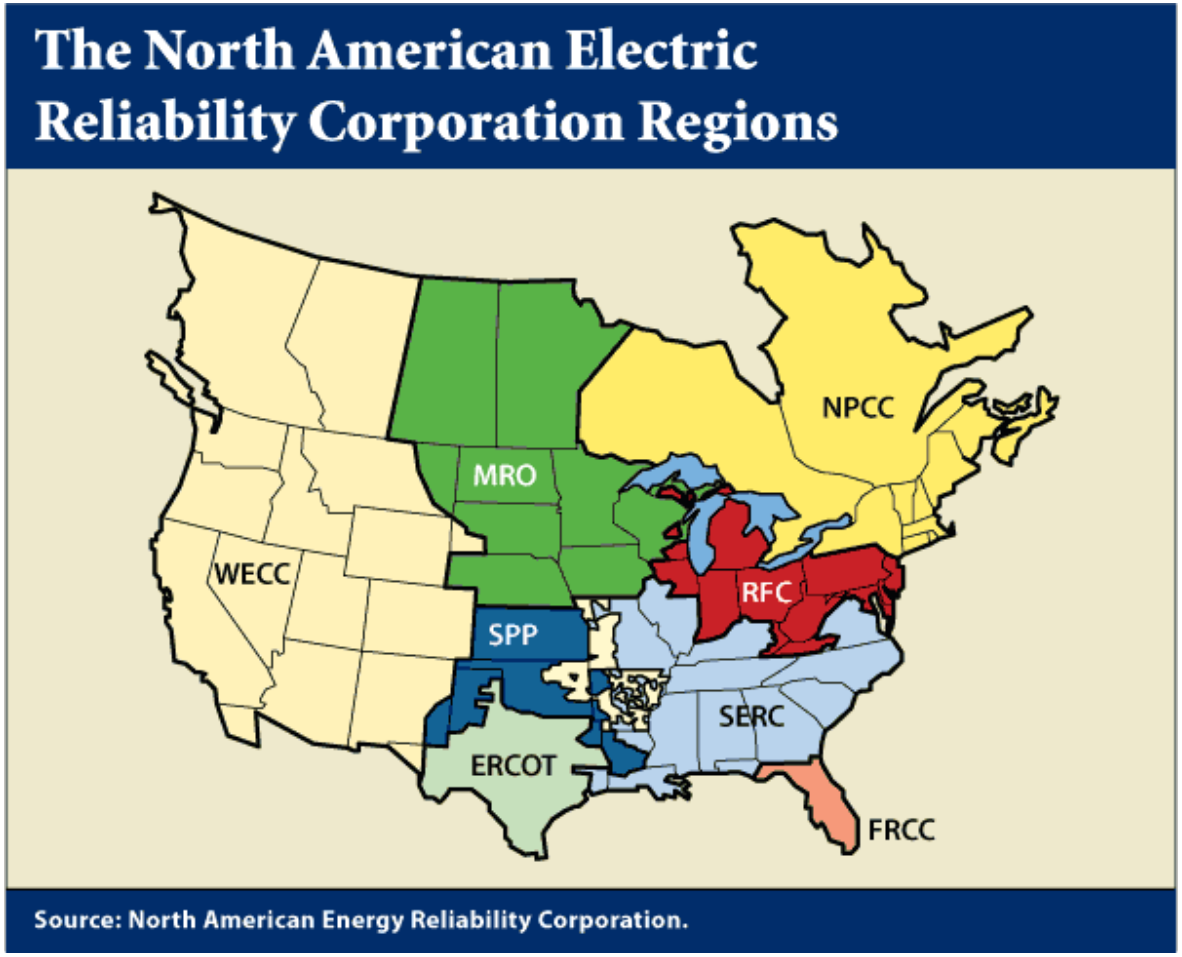
16		



Water for Thermoelectric Development

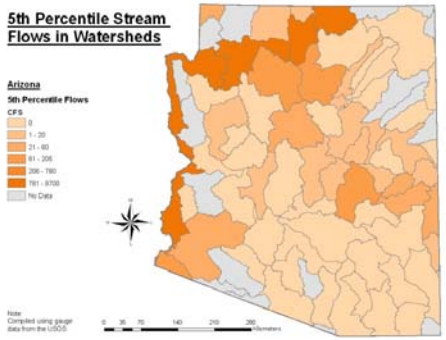
Integrated Transmission Planning

- Interconnections are conducting long-range transmission planning (20 yrs.)
  - Siting of new power plants
  - New transmission capacity
- Address water issues:
  - Reduce impact of development on water resources,
  - Reduce vulnerability of system to “water interuptions”

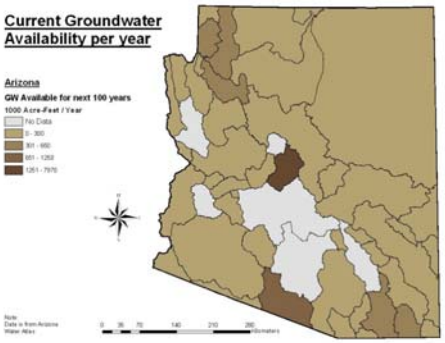


Methods: Collected Data from States

Water Supply

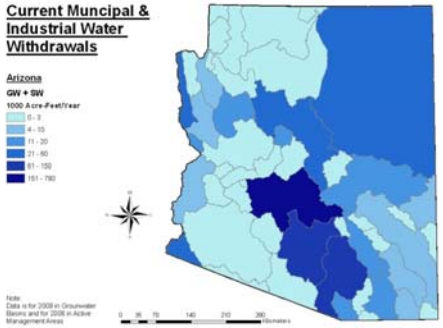


Mean Gauged Streamflow

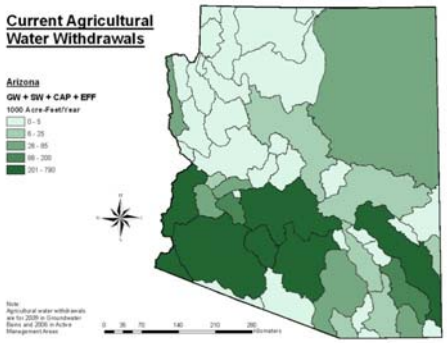


Groundwater Depletion

Water Demand

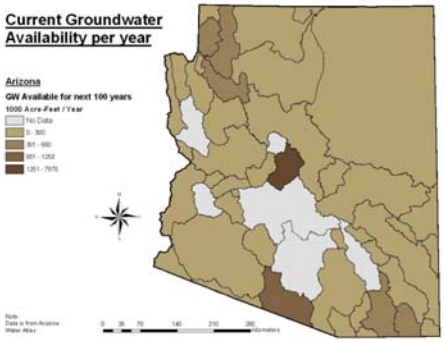


Municipal Demand

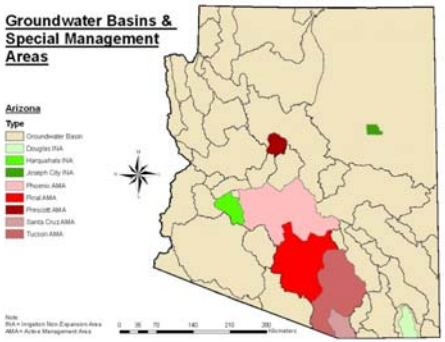


Irrigation Demand

Water Institutions



Unappropriated Water



Administrative Control Areas

Methods: Metric Development

- **Data on “available water” are rare**
- **As such, metrics were estimated from available information**
- **Assisted by volunteer team from WSWC**
  - **Bret Bruce (USGS)**
  - **Dan Hardin (TX)**
  - **Sara Larsen (WSWC)**
  - **Dave Mitamura (TX)**
  - **Andy Moore (CO)**
  - **Ken Stahr (OR)**
  - **Todd Stonely (UT)**
  - **Steve Wolff (WY)**
  - **Dwane Young (WSWC)**

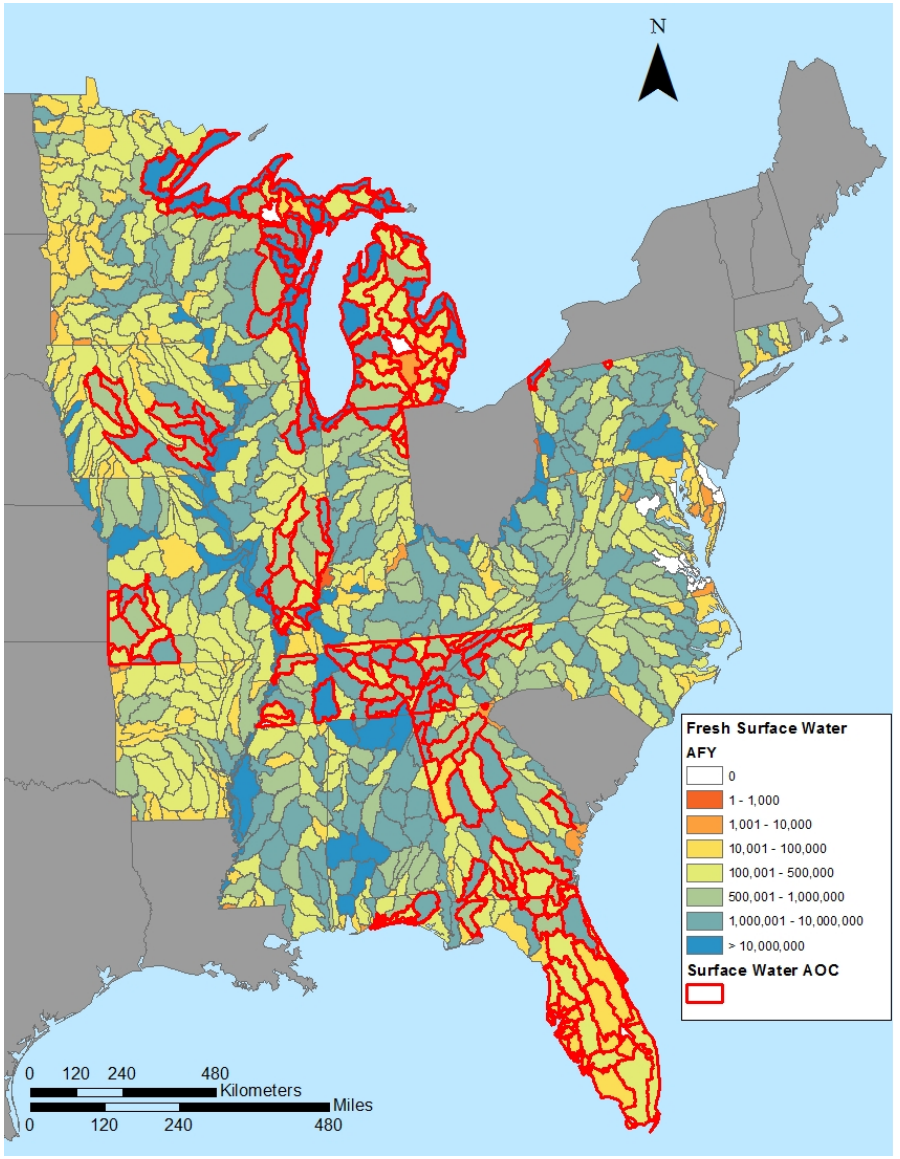
Methods: Water Sources

- **Potable Water**
  - **Unappropriated surface water**
  - **Unappropriated groundwater**
  - **Appropriated water (rights transfers)**
- **Non-Potable Water**
  - **Municipal/Industrial wastewater**
  - **Shallow brackish water**

Relative Availability and Cost

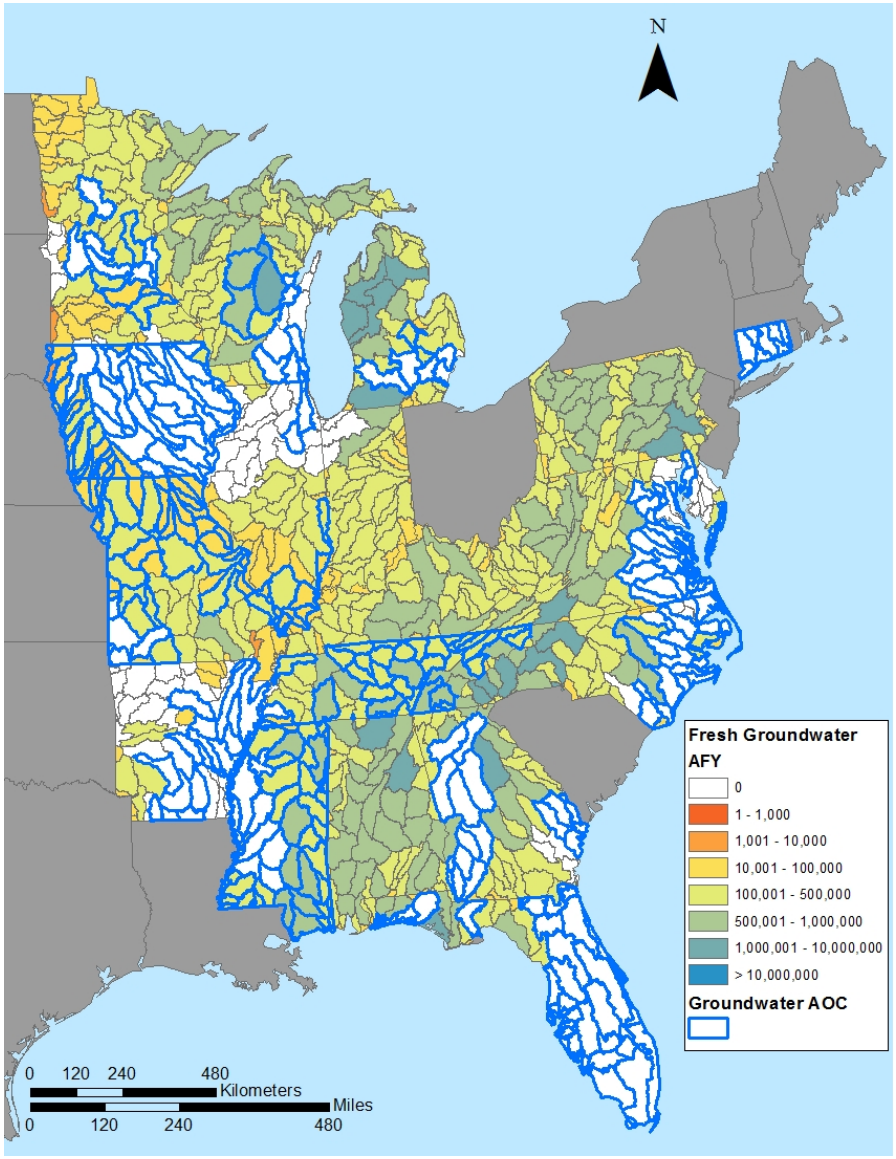
Water Availability: Fresh Surface Water

- **Surface water beyond current use that is available for new development.**
- **Based on environmental constraint:**
  - $Q_{sw}^{j} = 0.5 * (Q_{p}^{j} + C^{j}) - C^{j}$
- **Areas of Concern (basins outlined in red) designated regions requiring additional permitting.**



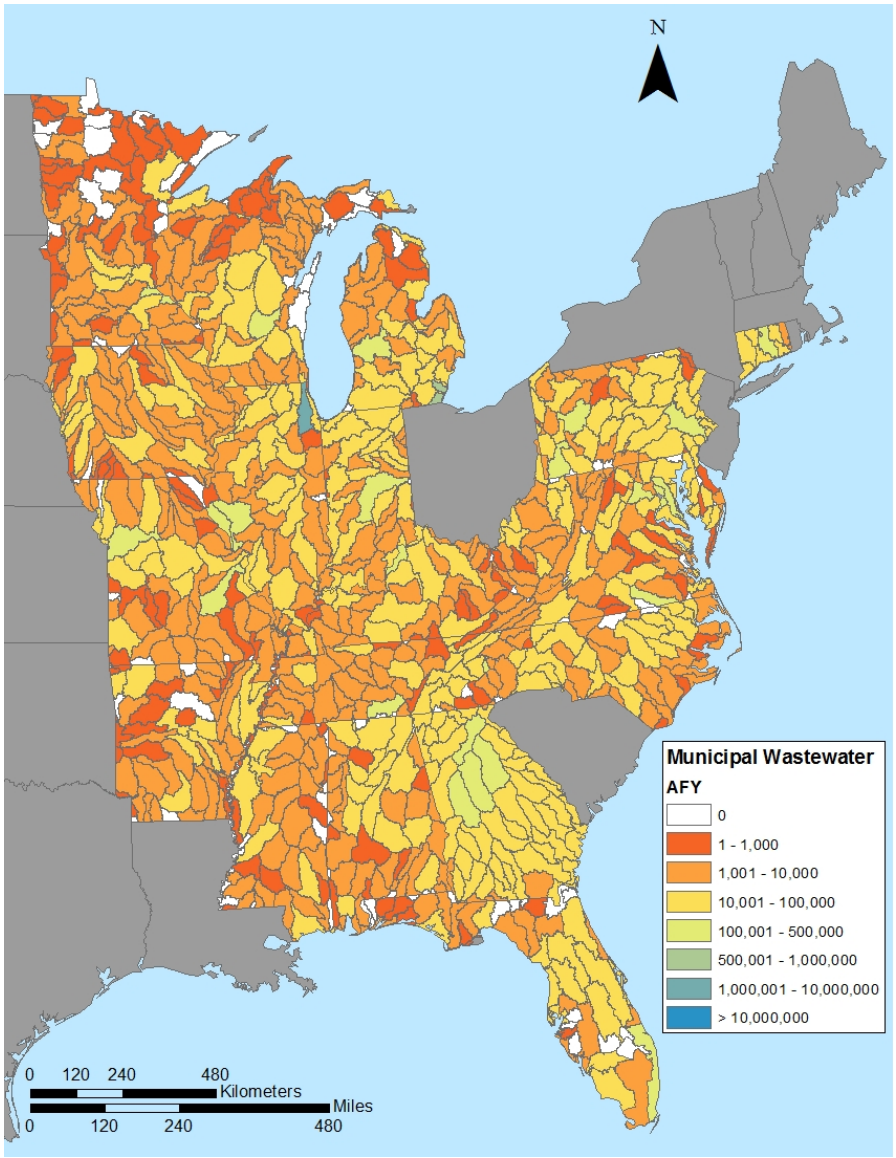
Water Availability: Fresh Groundwater

- **Groundwater beyond current use that is available for new development.**
- **Difference between sustainable recharge and pumping while considering:**
  - **Areas of overdraft, and**
  - **Principle aquifers.**
- **Areas of Concern (basins outlined in blue) designated regions requiring additional permitting.**



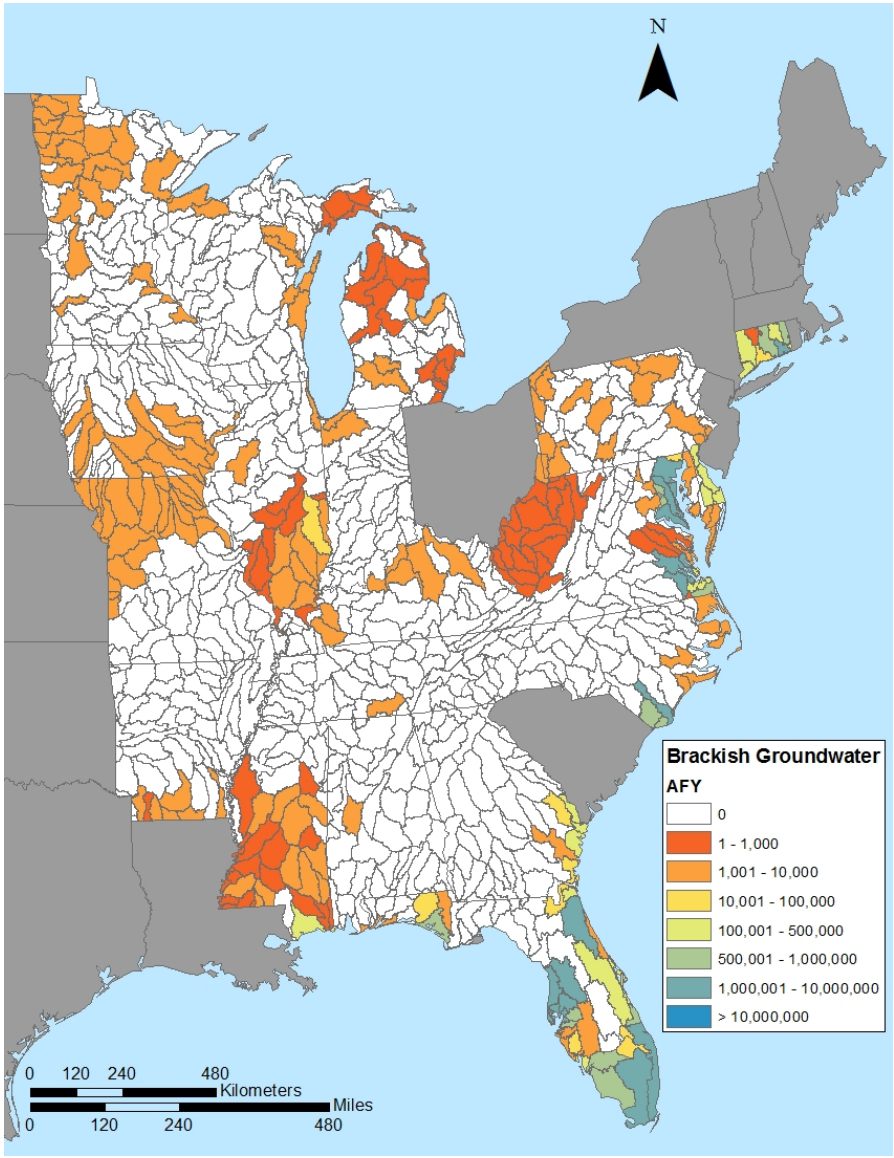
Water Availability: Wastewater

- **Projected future wastewater (2030) available for re-use.**
- **Reflects wastewater currently being reused.**



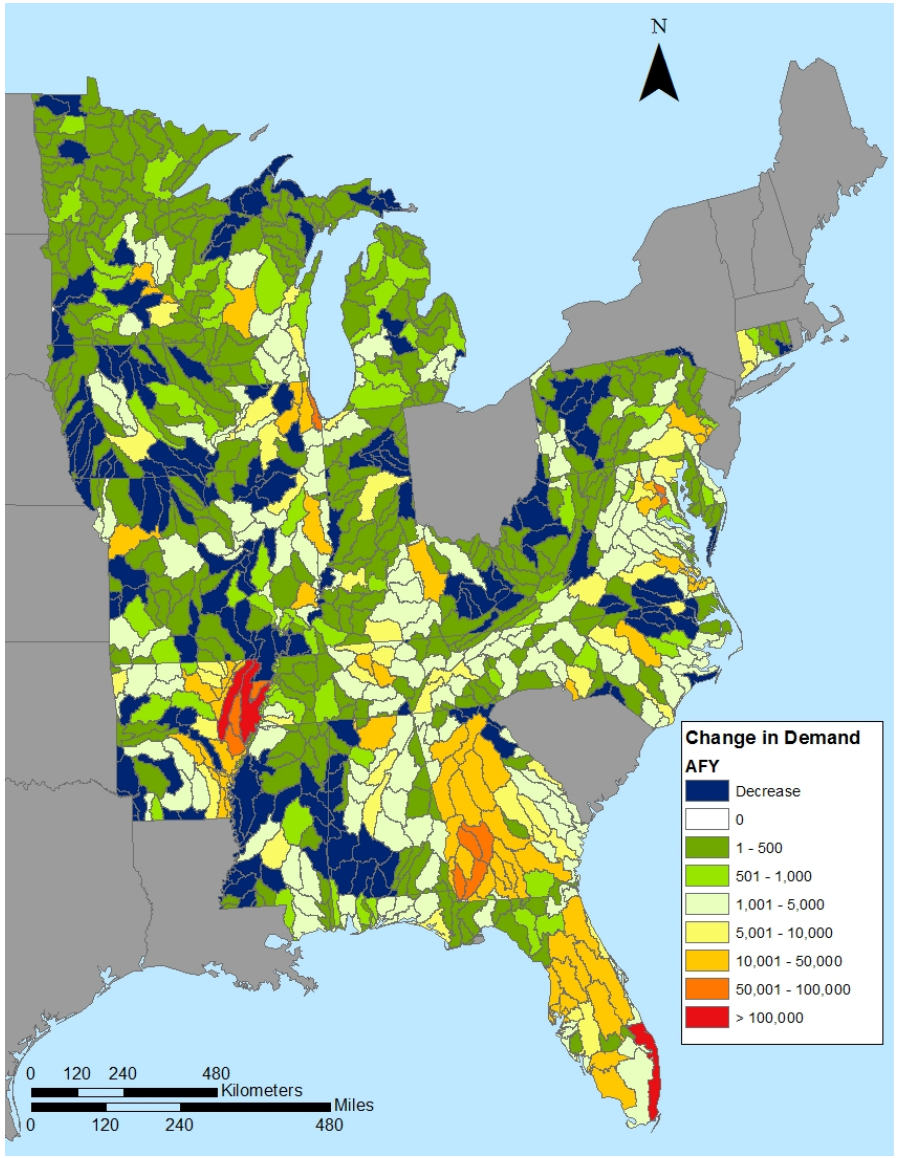
Water Availability: Brackish Groundwater

- Brackish water defined by salinities between 1,000 and 10,000 ppm TDS no deeper than 2500 ft.
- Estimates are data limited based on:
  - Current brackish water use, and
  - USGS well logs that indicated brackish water availability.



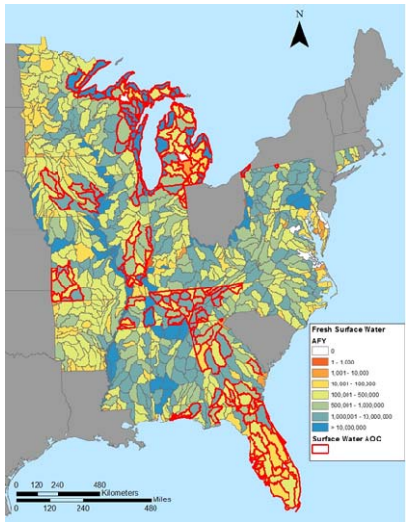
Projected Future Use 2010-2030

- Water needed for development after 2010.
- Based on estimates directly from states.
- Does not include thermoelectric water demand.

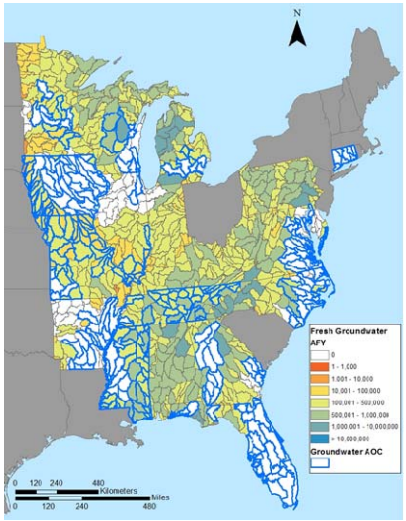


Water Supply Availability

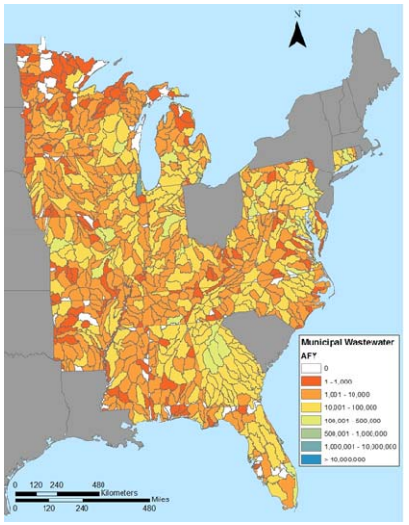
Fresh Surface Water



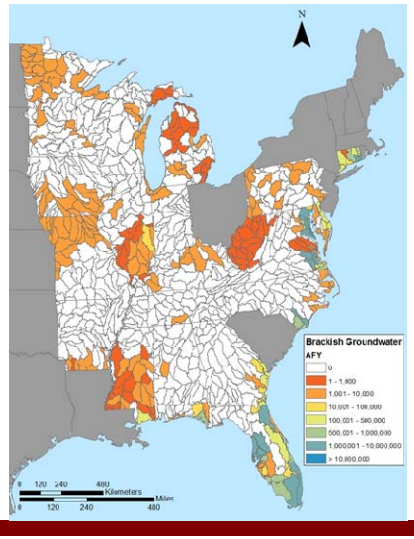
Fresh Groundwater



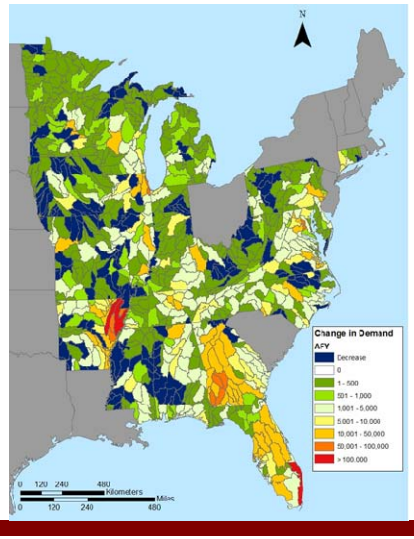
Municipal Wastewater



Brackish Groundwater



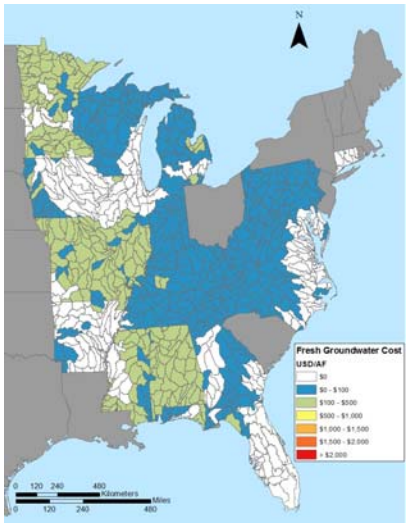
Consumptive Demand 2010-2030



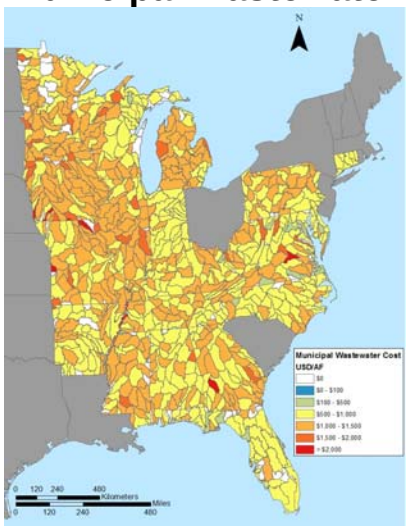
Water Cost

- Goal is to establish a consistent and comparable measure of cost to deliver water of potable quality to the point of use
- Basic costs considered:
  - Capital costs:
    - Purchase water,
    - Wells,
    - Conveyance, and
    - Treatment.
  - Operation and Maintenance:
    - Electricity,
    - Labor,
    - Consumables, and
    - Disposal.

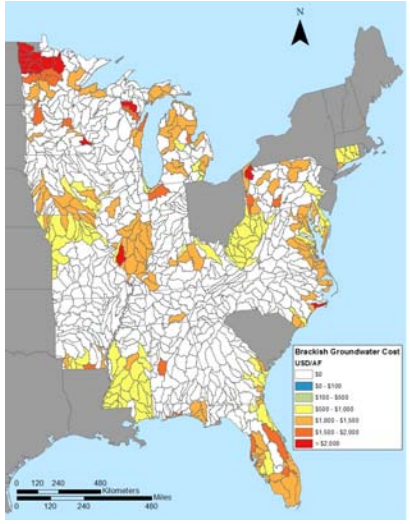
Fresh Groundwater



Municipal Wastewater

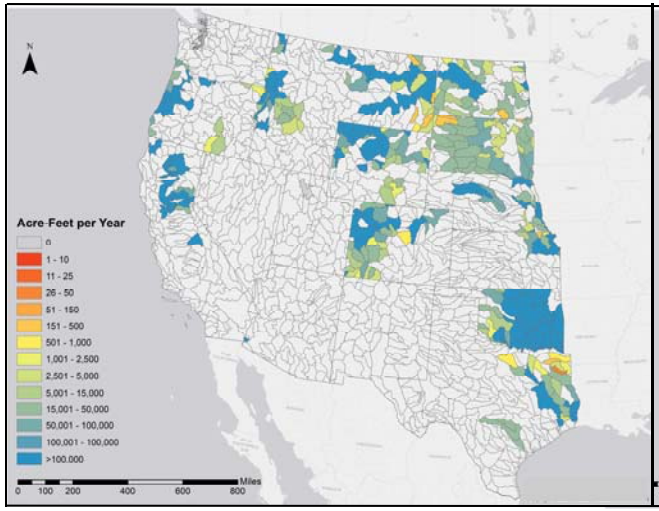


Brackish Groundwater

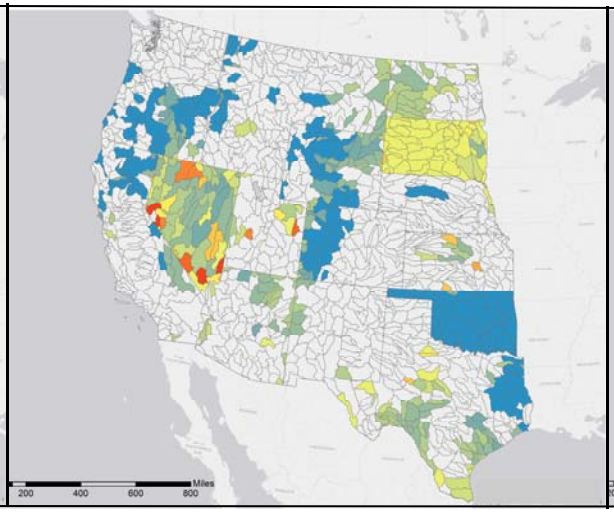


Water Supply Availability: West

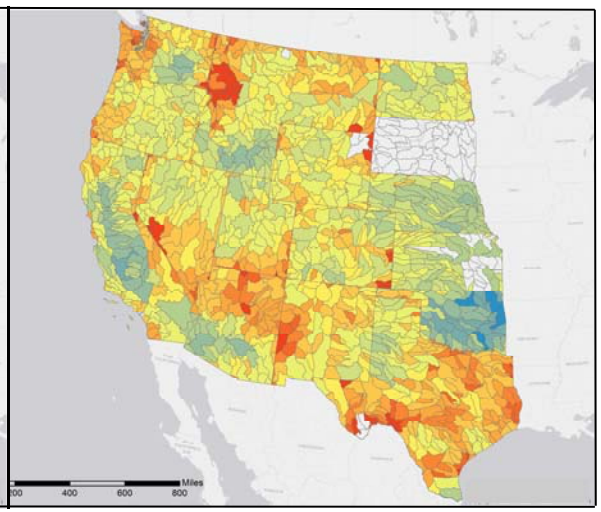
Unappropriated Surface Water



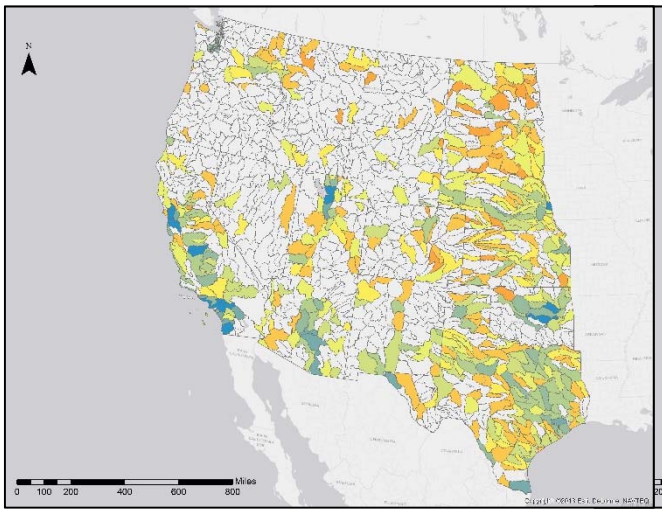
Unappropriated Groundwater



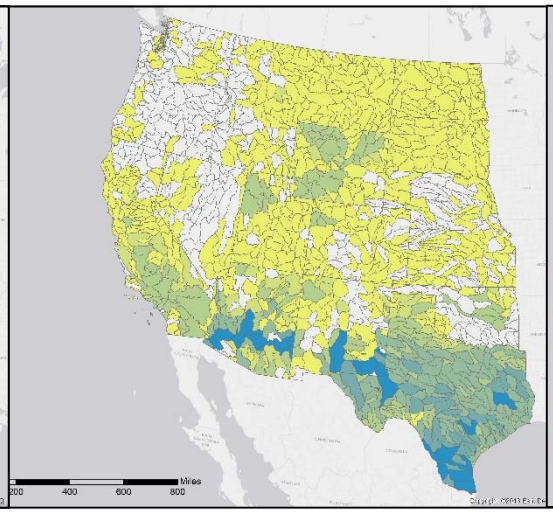
Appropriated Water



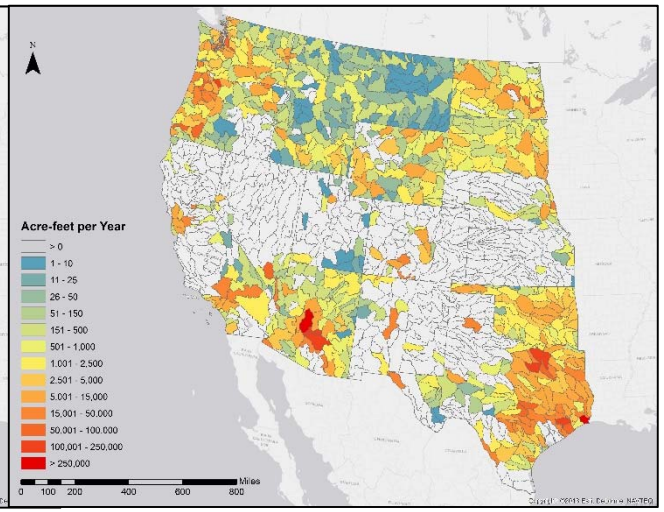
Municipal Wastewater



Brackish Groundwater

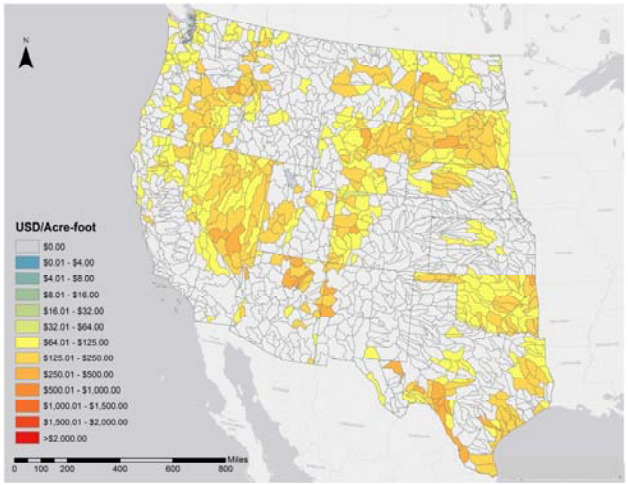


Consumptive Demand 2010-2030

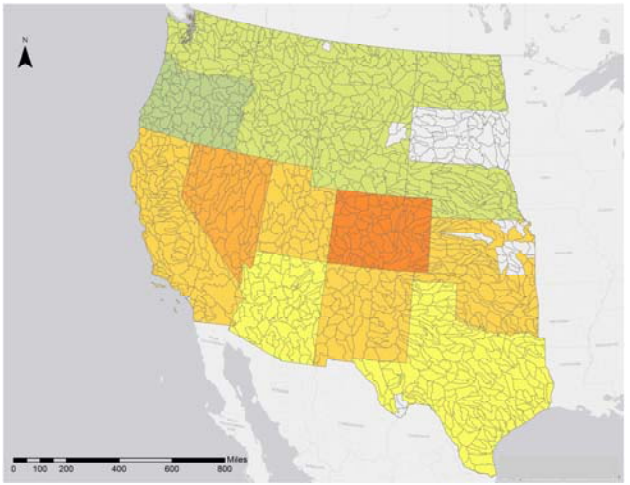


Relative Cost of Water: West

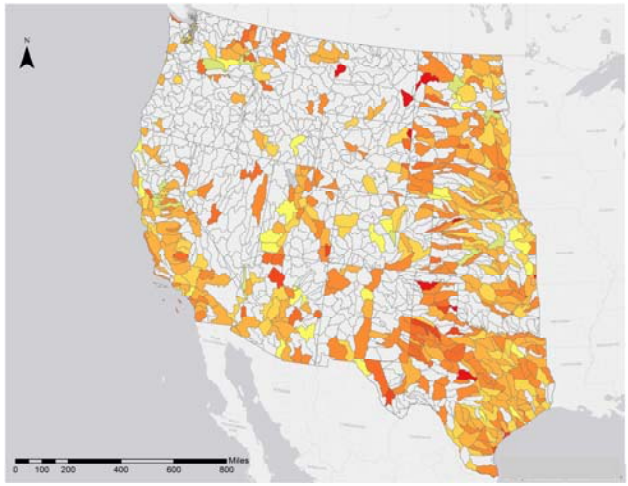
Unappropriated Groundwater



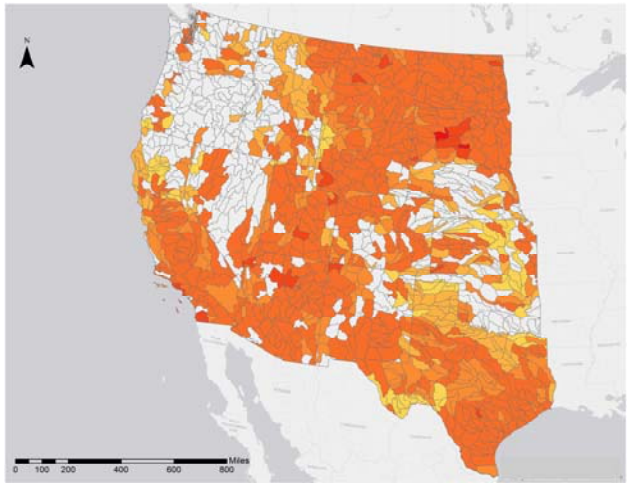
Appropriated Water



Municipal Wastewater

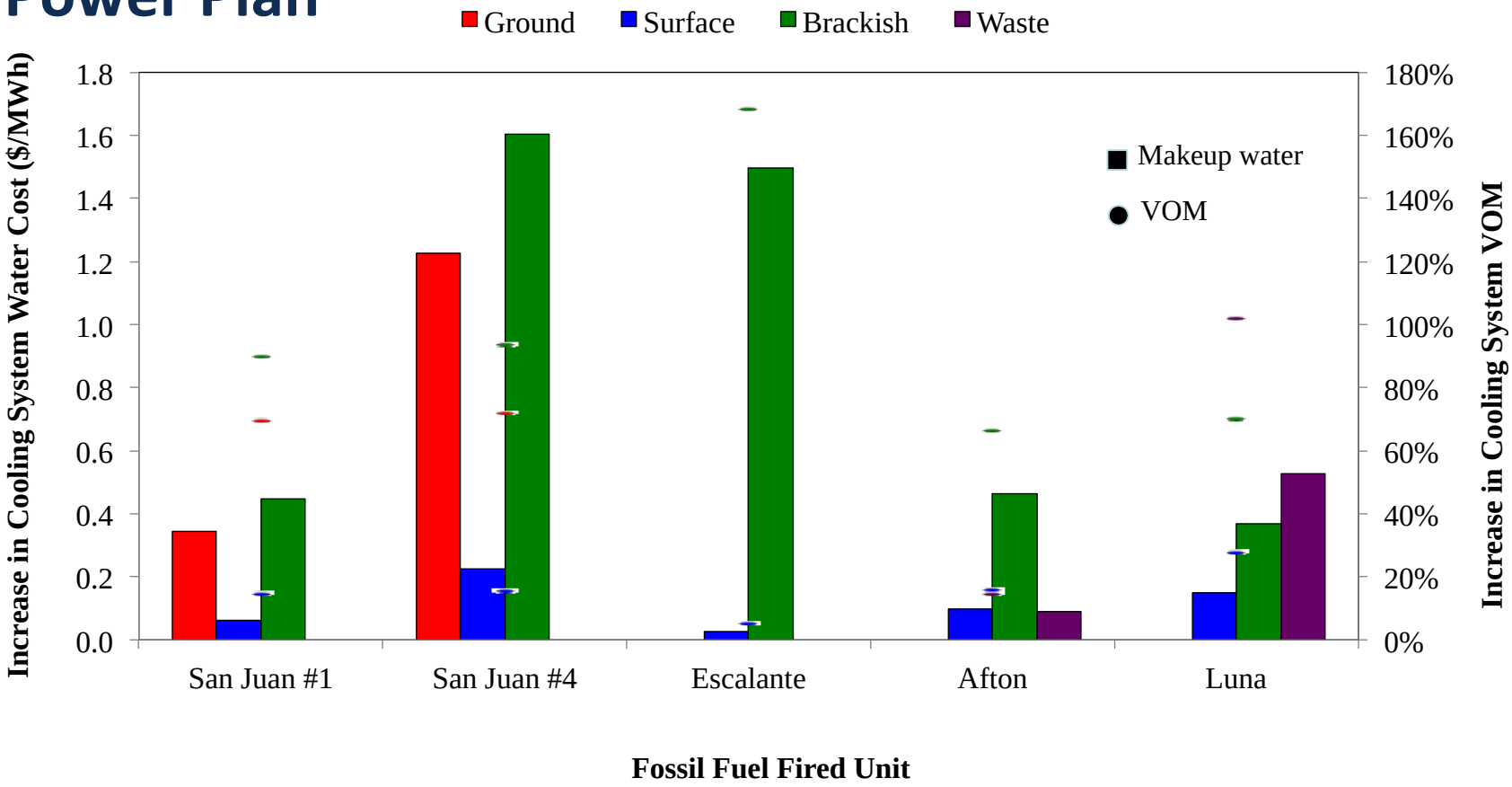


Brackish Groundwater



Integrated Energy-Water Planning

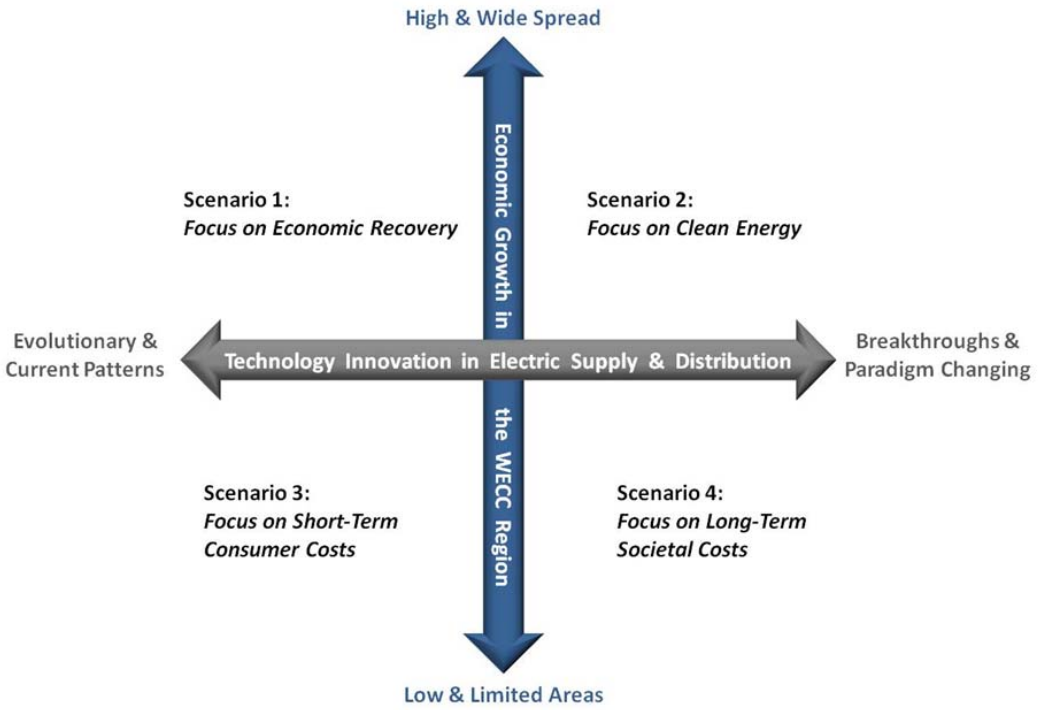
Effects of Alternative Water Sources as Makeup Water for Cooling System on Annual Levelized Water Use Cost and Total Variable O&M Cost for Units under the Rate-based Emission Standard outlined by Clean Power Plan*



*In the base case, the water price for fresh water already in use is assumed to be $0/kgal.

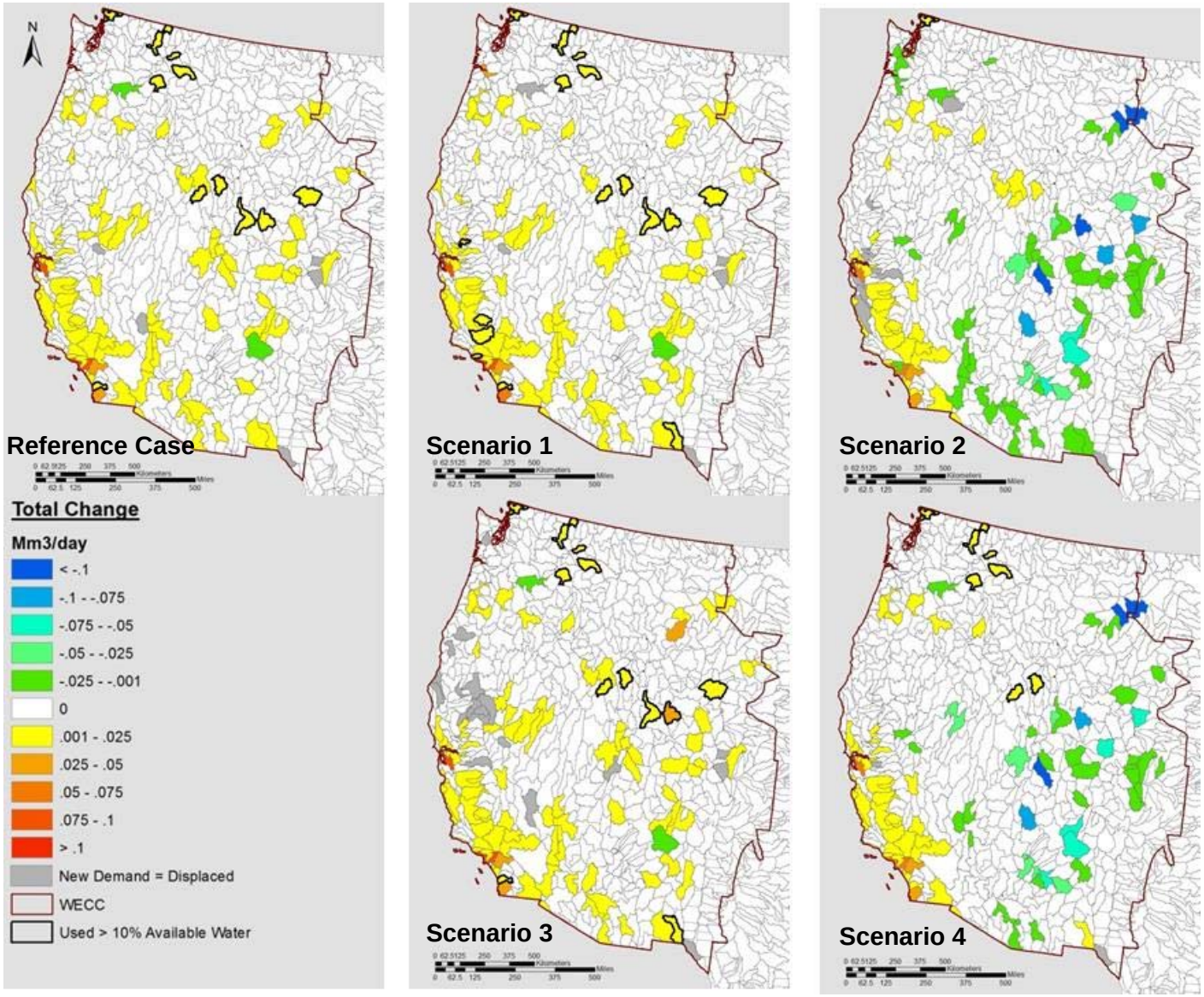
Methods: Scenario Development

- ***Reference Case:*** adopted trajectory of recent WECC planning information.
- ***Scenario One:*** favored continued trends in growing use of natural gas and renewables.
- ***Scenario Two:*** distinct shift toward renewables, energy efficiency and significant carbon tax.
- ***Scenario Three:*** reliance on traditional technologies while simply meeting current state renewable portfolio standards.
- ***Scenario Four:*** similar technology development and policies as in scenario two except limited by sluggish economic growth.



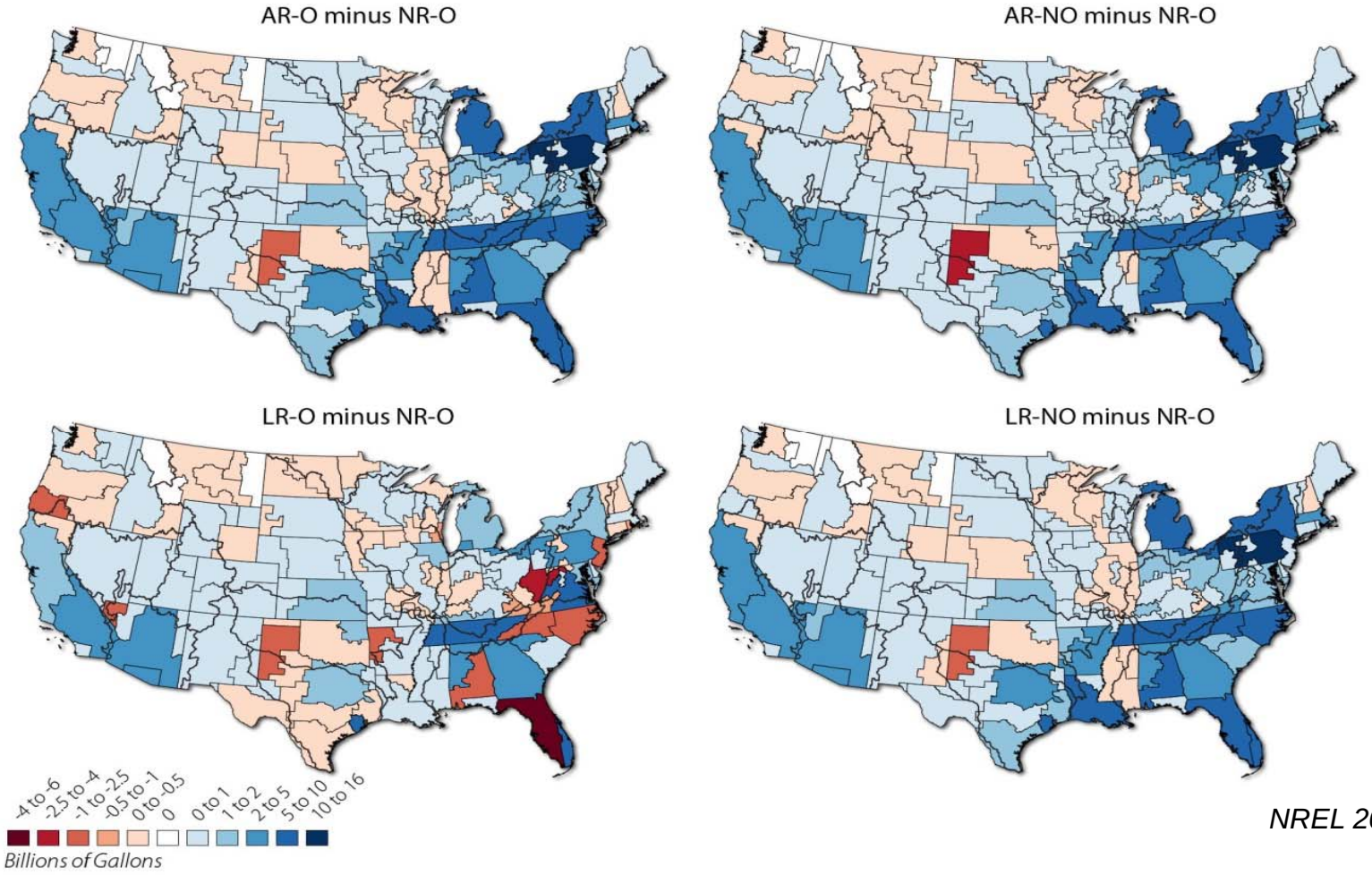
Source: WECC 2013

Data Utilization: Transmission Expansion Planning



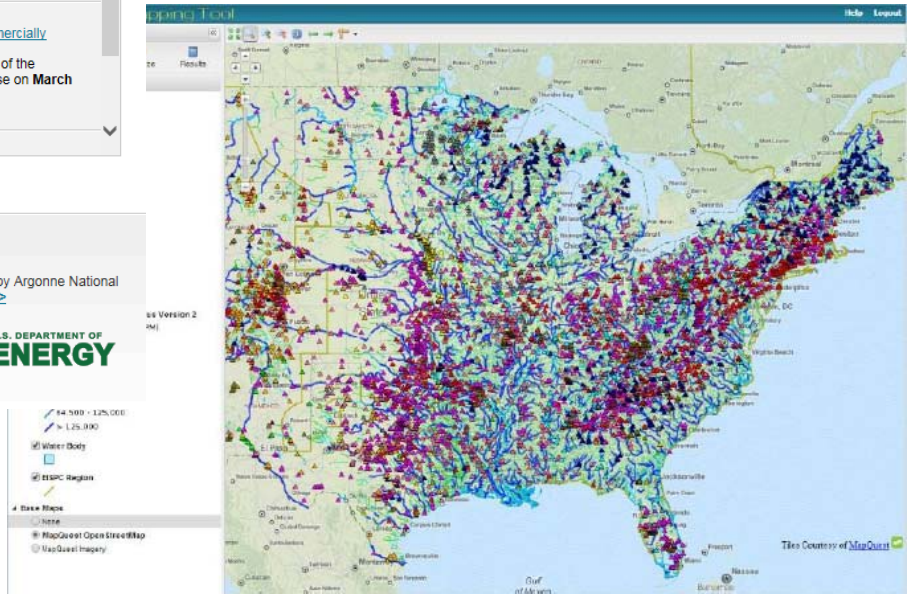
Data Utilization: Integration in Regional Energy Deployment System model (ReEDS)

Effect of Water Constraint on Future Thermoelectric Water Consumption



NREL 2015

Data Utilization: EISPC EZ Mapping Tool



Summary

- Seeing clear impacts today from the climate-energy-water nexus.
- Need data and tools to integrated water into energy planning.
- The Integrated Environmental Control Model (IECM) has been extended to aid in designing and managing power plant water systems at the unit level.
- Water Atlas is being developed to map water availability, cost and future use at the 8-digit HUC level for different sources of water.