Challenges of Water Availability

Can we Eat, Drink AND Turn on the Lights?

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Kappe Lecture

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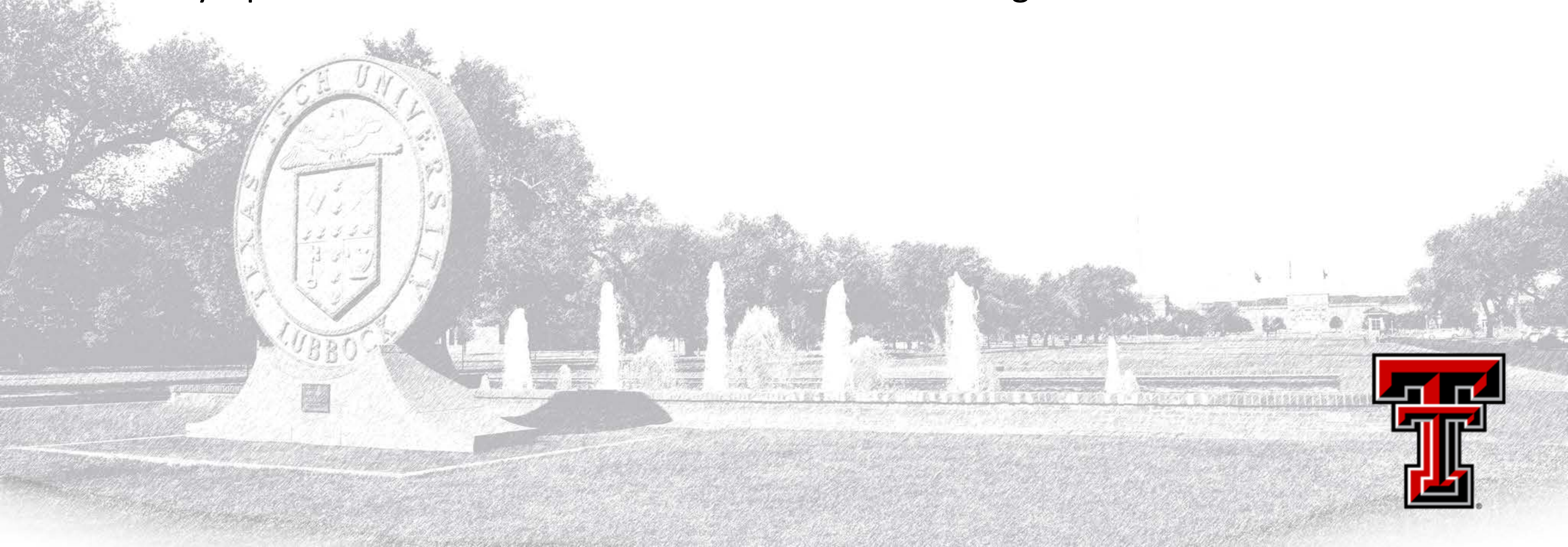


Topic?...The “Golden Girls” say “*Simply Fabulous*”

But others say
“ Do I have to stick around for this?”

Perspective on the "Global Water Crisis"

- A global water crisis doesn't mean the extent of the crisis or its solutions are uniform
- We don't really value water
- Irrigated agriculture is largest user, lowest value user and largest exporter of water from arid areas
- Municipal and industrial water users are much more resilient than agriculture – they can afford technological solutions
- There are substantial opportunities for conservation and reuse as well "new" water sources
- Despite this, there will be disruptions in supply due to climate variability, market instability and lack of long-term planning

Challenges

- **Water is not valued**
  - ✓ Value added by 1 acre-ft of water in agriculture <$100 (<$0.10/m^3)
  - ✓ Municipal value of water $1000-2000/acre-ft ($1-2 /m^3)
  - ✓ Hydraulic fracturing for oil and gas >$100,000/acre-ft ($100/m^3)
  - ✓ Compare to oil at $40/bbl = $314,000 acre-ft ($330/m^3)
- **Disposal of water is cheaper than treating/recycling**
  - ✓ Social/economic resistance to "toilet to tap"
  - ✓ Produced water disposal wells $0.10/bbl to $2-3/bbl ($0.01-0.24 /m^3)
- **All water problems and solutions are local**
  - ✓ Economics deter any trans-watershed solutions
  - ✓ Legal- social impediments pose challenges to trans-watershed solution
  - ✓ Ideally water should be fit for use but does the local use fit your water?

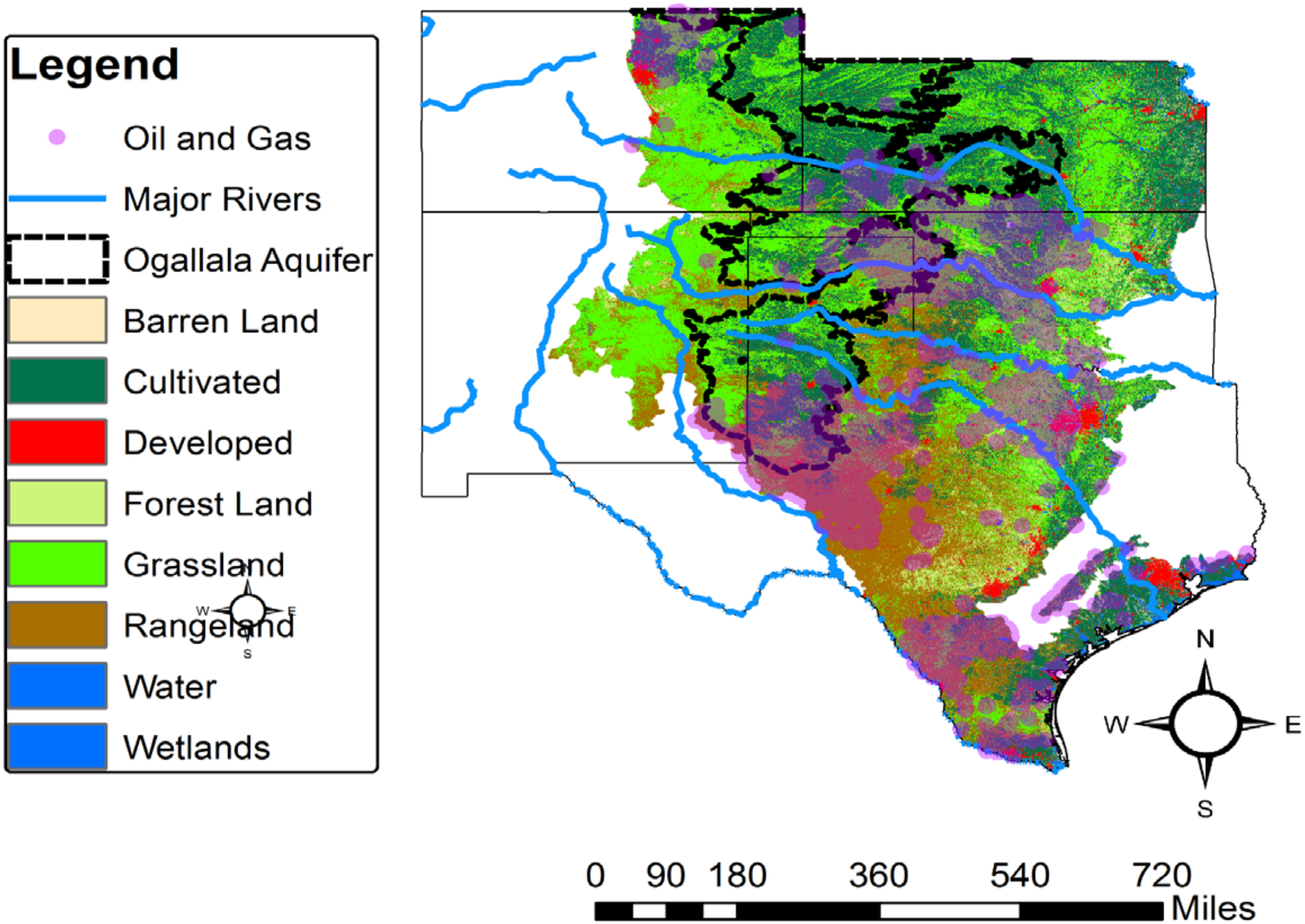
Our Focus

- **Technologies and practices to produce more resilient water systems**
- **Large urban areas have financial, technical and human resources to manage water problems**
  - ✓ Deficiencies from poor planning not lack of capacity?
- **Small western rural and agricultural communities do not have resilient water supplies and do not have the human, technical and financial resources to resolve these problems**
  - ✓ Energy resource development often further stresses water supplies

Water Challenges

- **Too little water**
  - ✓ Population shifts, particularly to the arid southwest, have increased conflicts among urban, agricultural, industrial and environmental needs for water.
  - ✓ Water requires energy, energy requires water and food requires both
  - ✓ Conflicts between human and ecological needs for water increasing
- **Too much water**
  - ✓ Flooding is responsible for 2/3 of all federally declared disasters in the US and their economic and environmental impacts are likely to worsen as climate changes
- **Poor water quality**
  - ✓ Groundwaters of marginal quality throughout much of west
  - ✓ Legacy of contamination from point and distributed sources
  - ✓ Potential new and replacement sources of water generally of poorer quality
- **Inadequate water and wastewater infrastructure**
  - ✓ Aging infrastructure contributing to water loss and quality challenges
  - ✓ Infrastructure inadequately protected from human and natural hazards

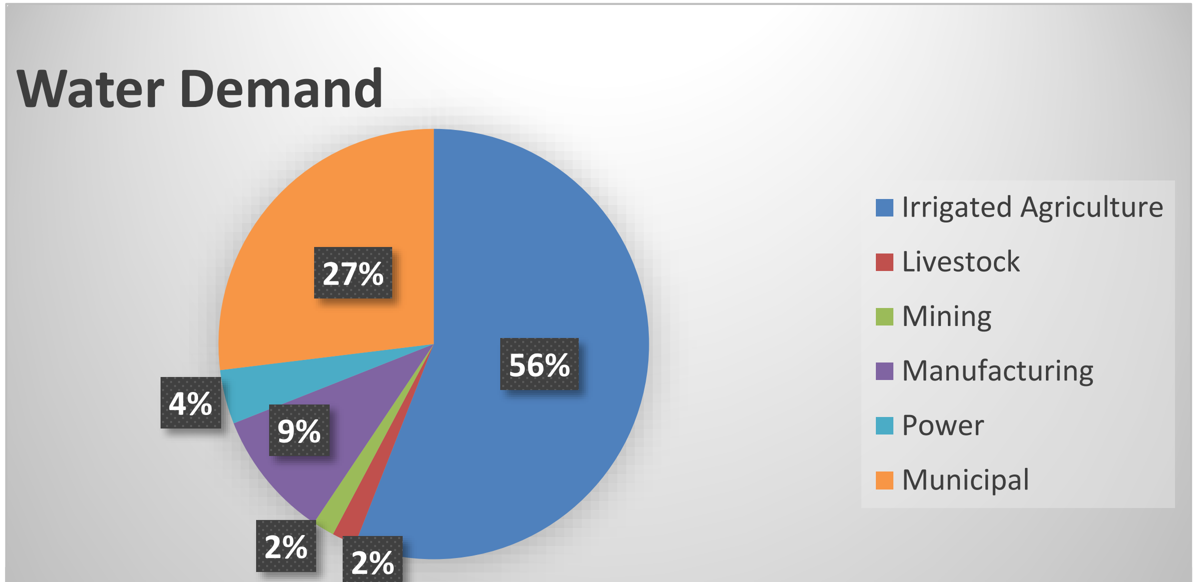
Southern Great Plains
Food, Energy, Water, Ecology Nexus



Texas Water Demand and Value

Sources:
Texas Water Development Board
Office of State Comptroller

Irrigated agriculture 56% of consumptive water demand but 0.6-0.8% of economy



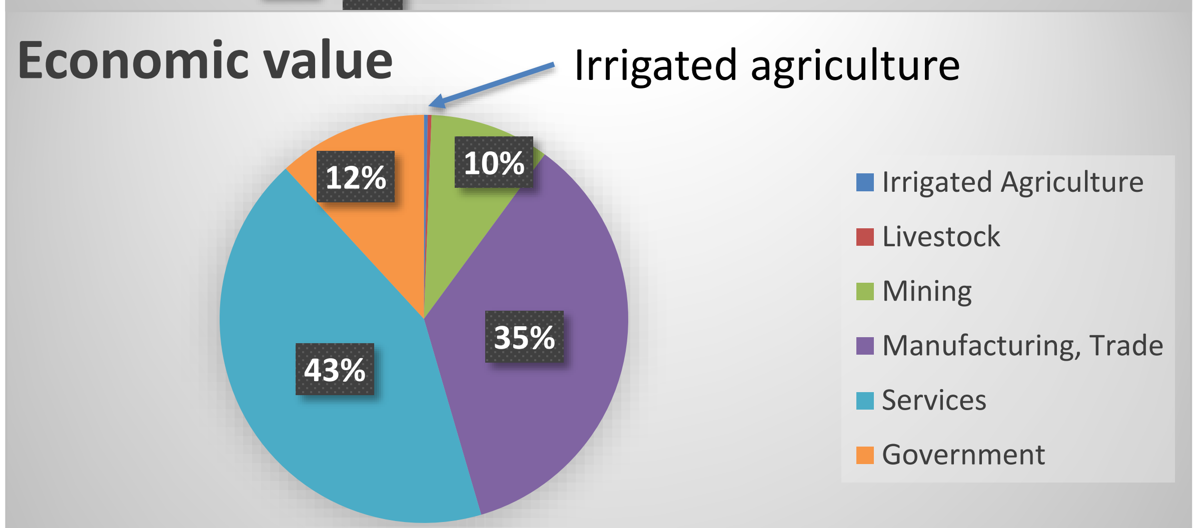
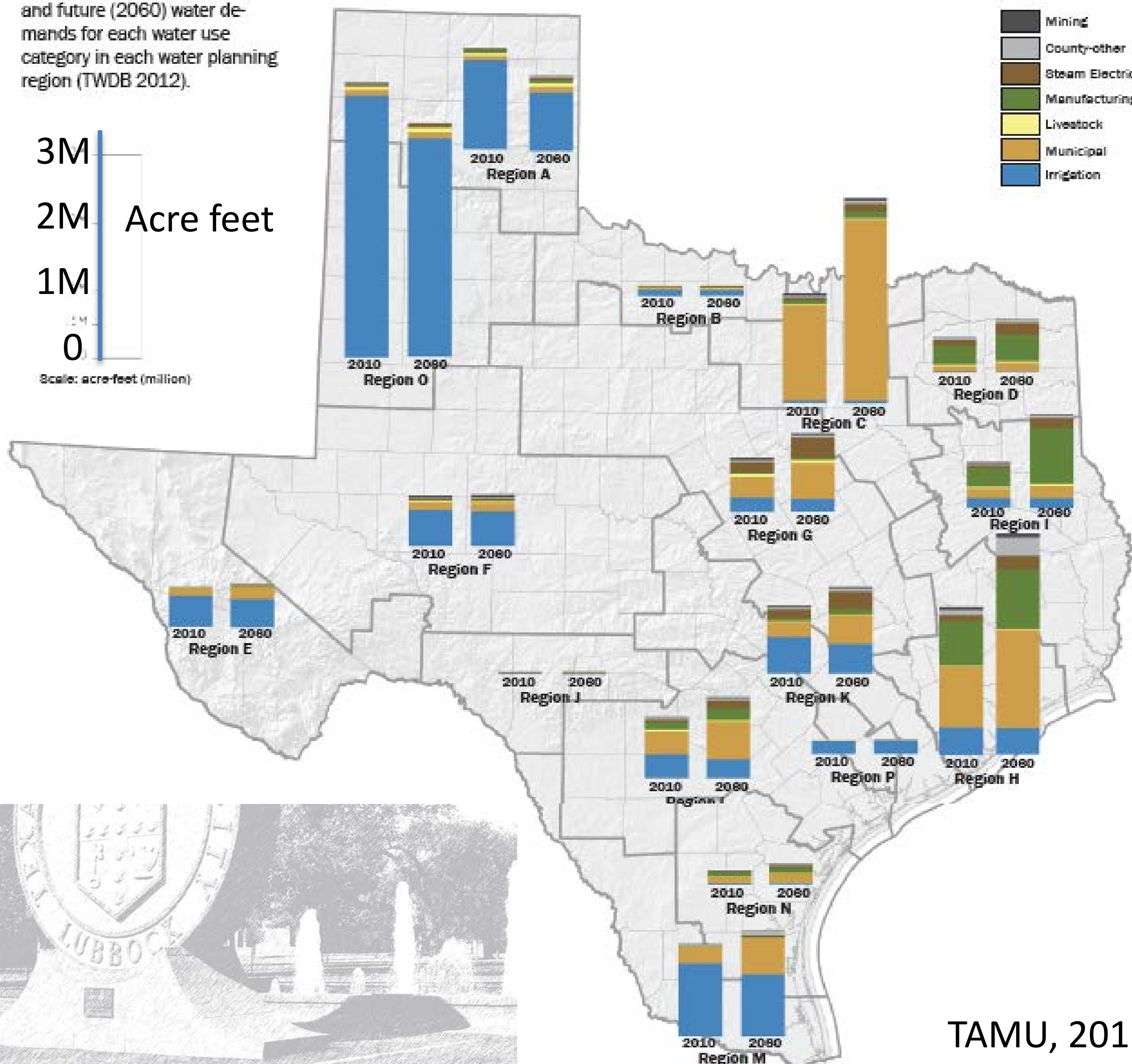


Figure 4. Existing (as of 2010) and future (2060) water demands for each water use category in each water planning region (TWDB 2012).



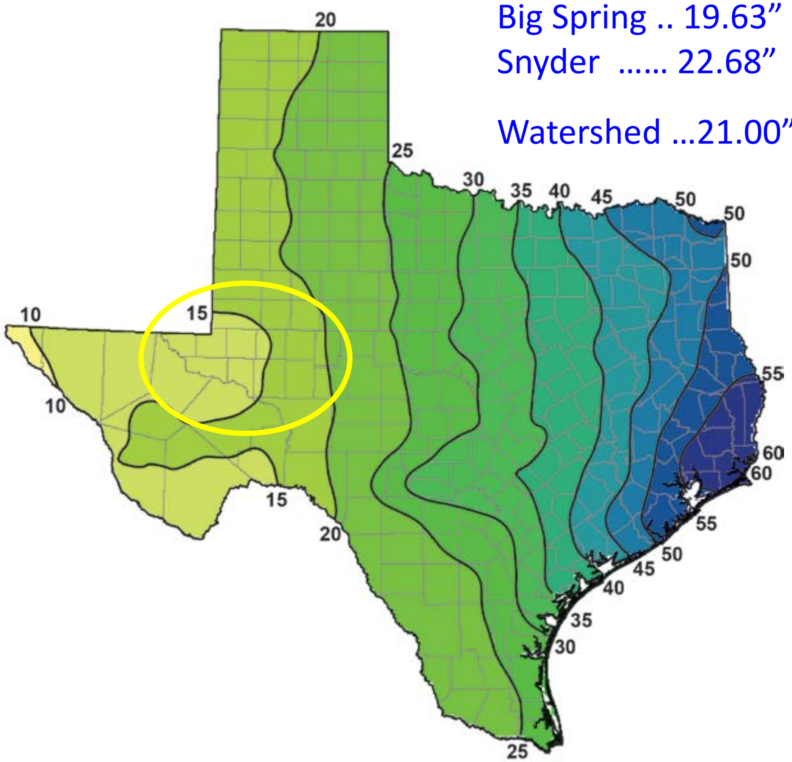
TAMU, 2012

Water Allocation and Demand

Texas Rainfall/Evaporation Map

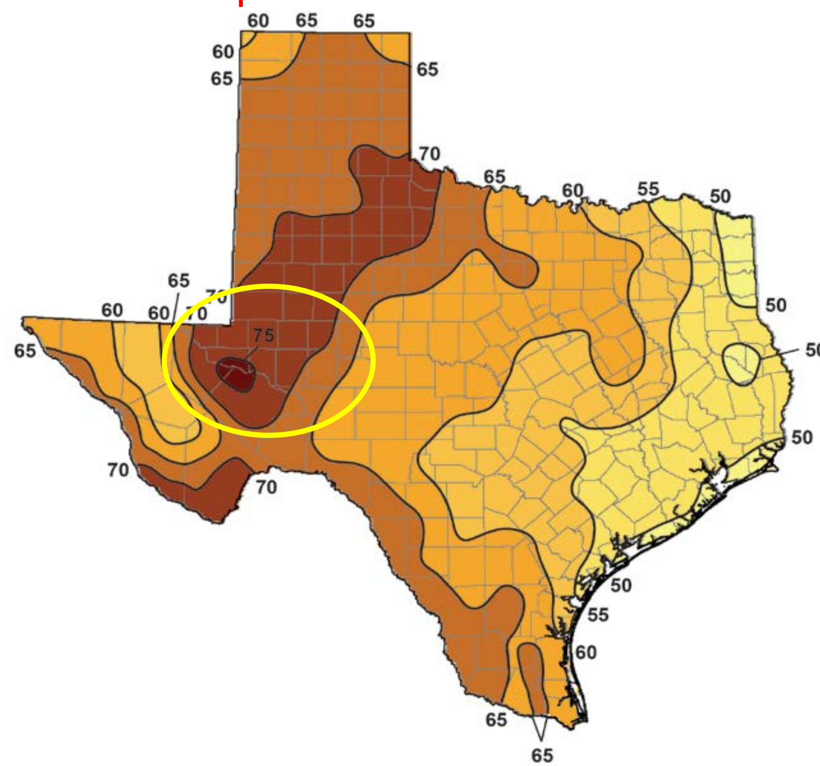
Odessa ….. 14.48”
Big Spring .. 19.63”
Snyder …… 22.68”

Watershed …21.00”



Precipitation

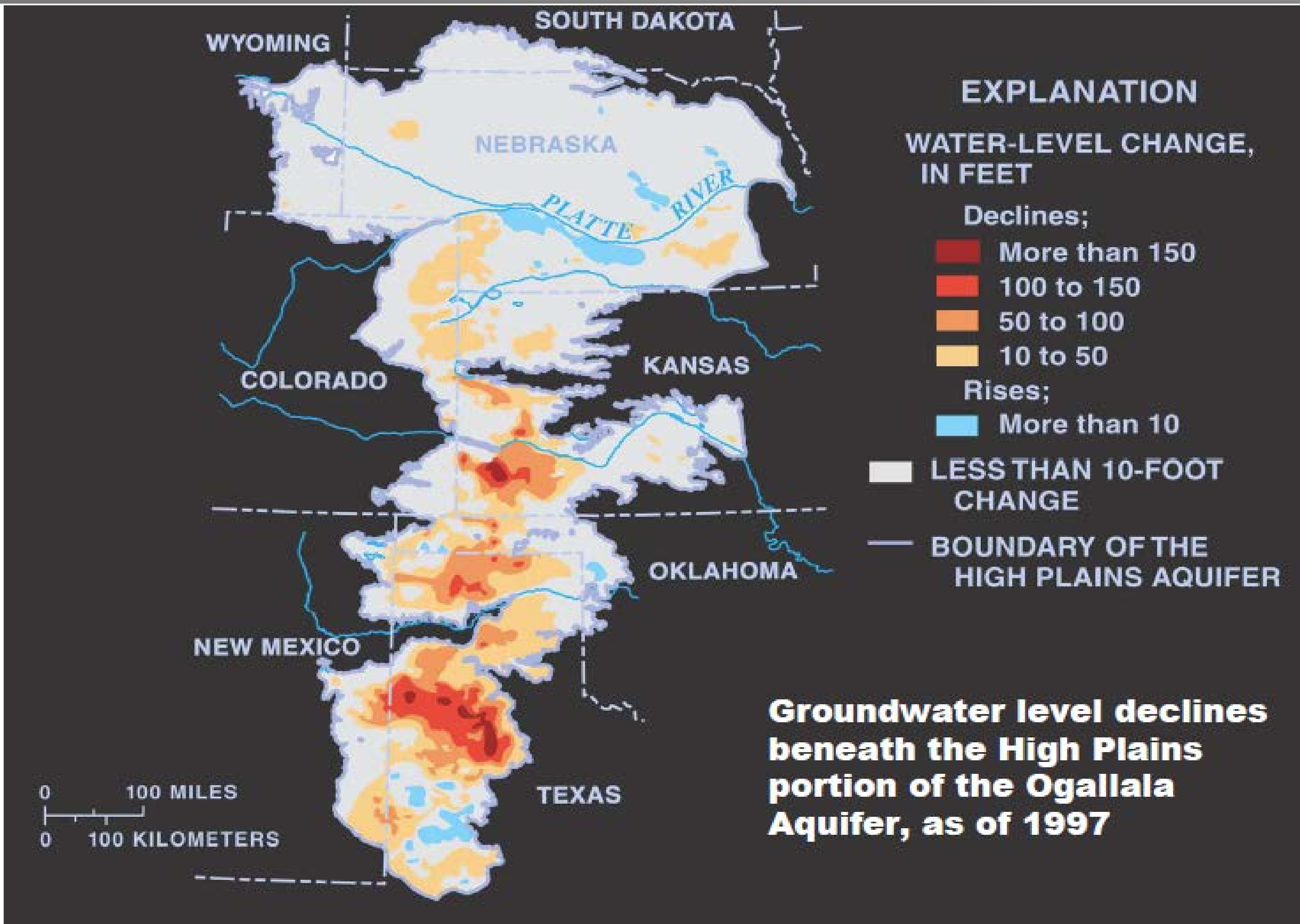
Evaporation- Watershed ….. 61.00”



Evaporation

CRMWD
Colorado River Municipal Water District

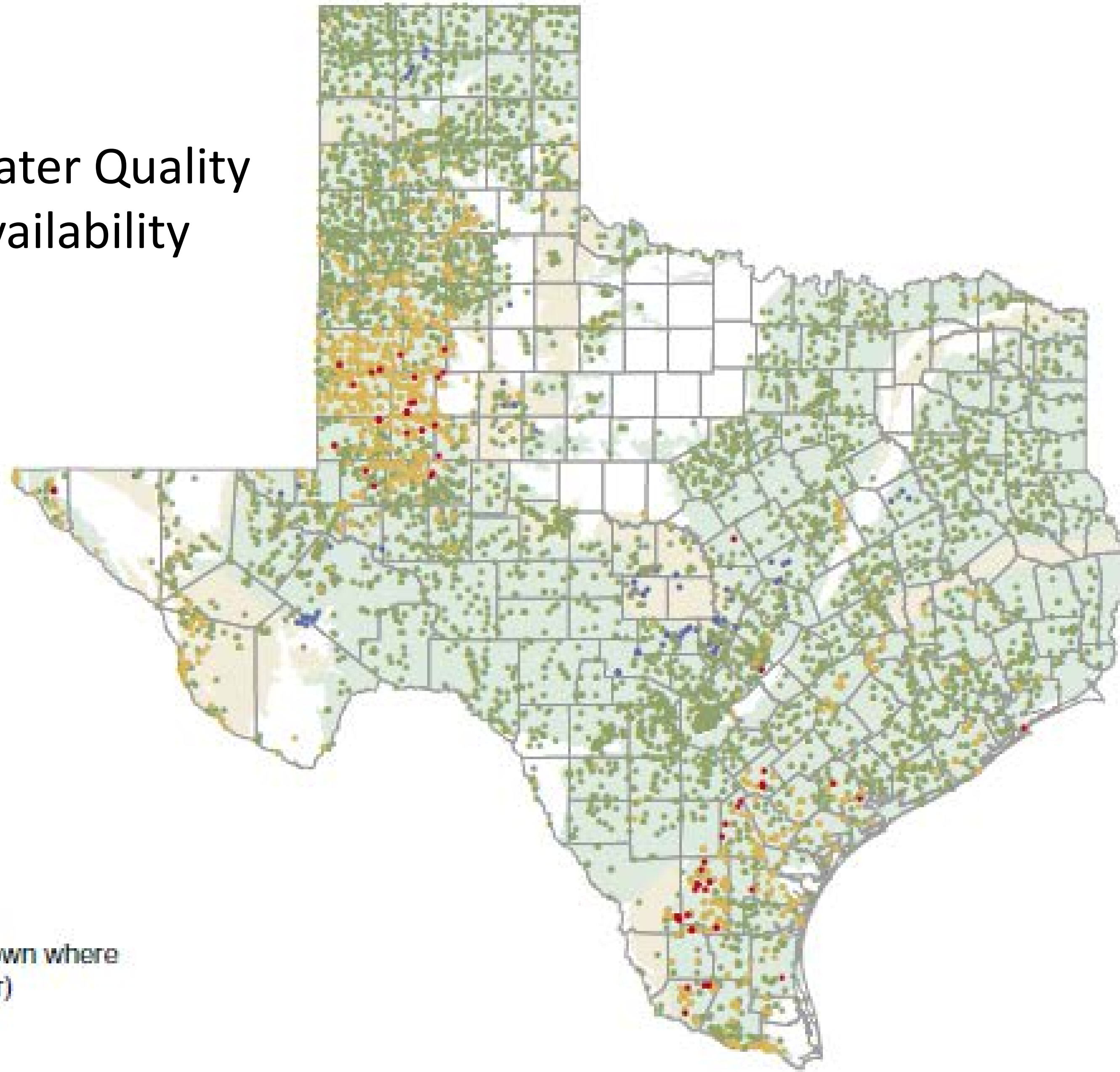
Ogallala groundwater level declines



Groundwater level declines beneath the High Plains portion of the Ogallala Aquifer, as of 1997

IMPAIRED GROUNDWATER WELLS/AQUIFERS FOR ARSENIC.

Challenges to Water Quality
In Addition to Availability

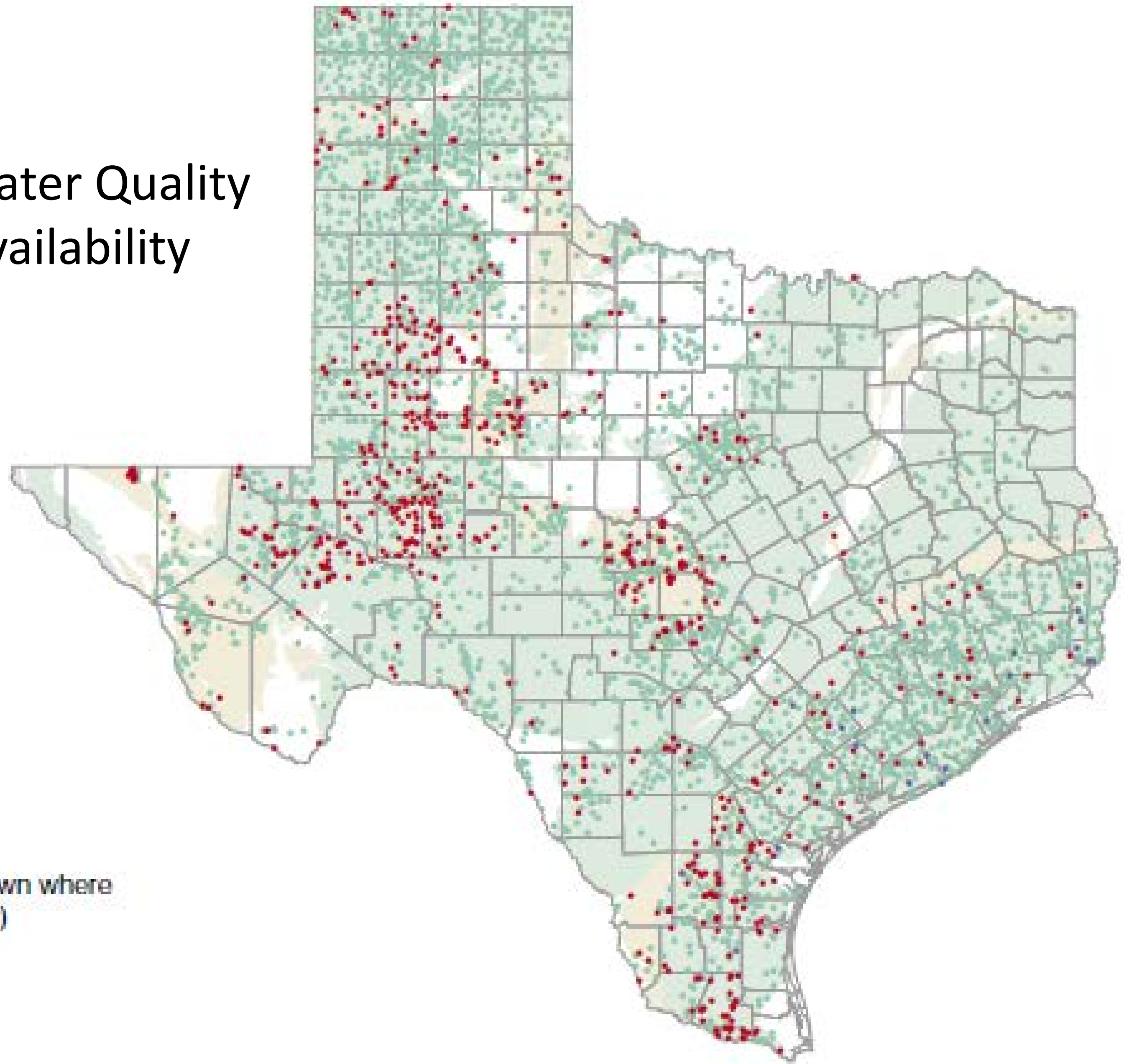


Arsenic concentrations in micrograms per liter

- less than 1
- 1 to 10
- 10 to 50
- greater than 50
- Major aquifers
- Minor aquifers (only shown where there is no major aquifer)

IMPAIRED GROUNDWATER WELLS/AQUIFERS FOR RADIONUCLIDES.

Challenges to Water Quality
In Addition to Availability

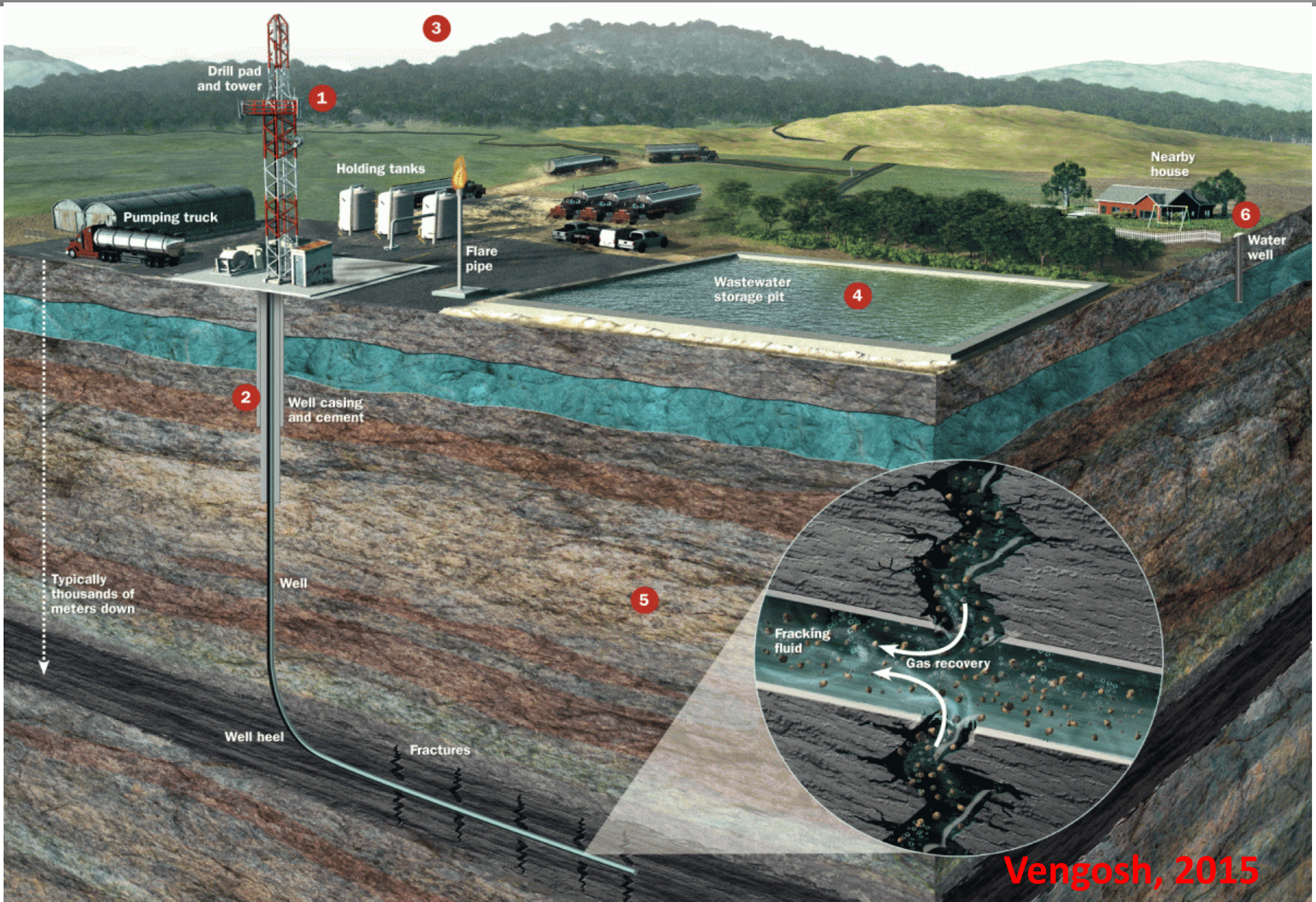


Gross alpha radiation in picocuries per liter

- less than 0.1
- 0.1 to 15
- greater than 15
- Major aquifers
- Minor aquifers (only shown where there is no major aquifer)

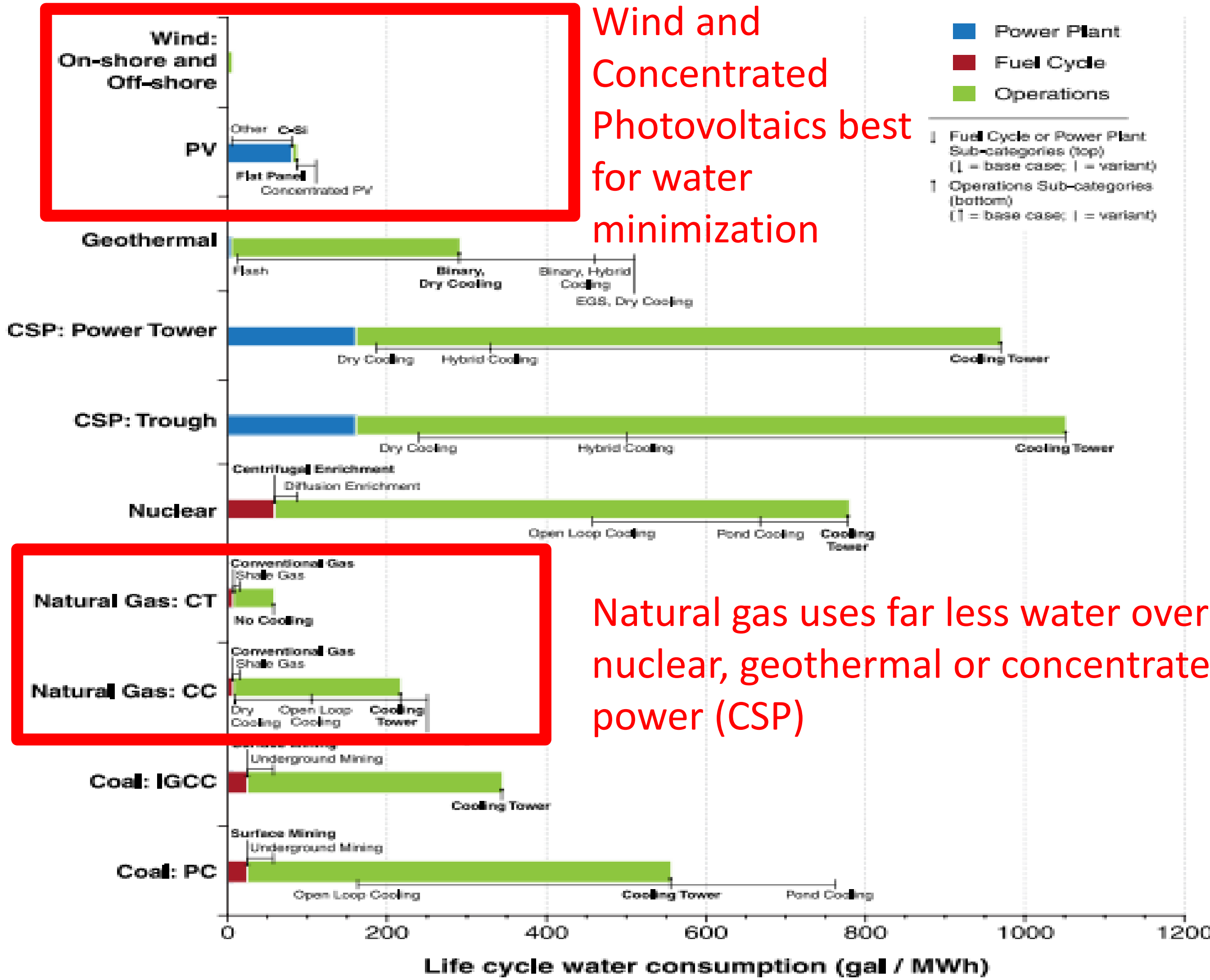
Water Needs for Energy

Hydraulic Fracturing?



Vengosh, 2015

Water Preferred Power Sources



Wind and Concentrated Photovoltaics best for water minimization

Natural gas uses far less water overall than coal, nuclear, geothermal or concentrated solar power (CSP)

Meldrum et al. 2014

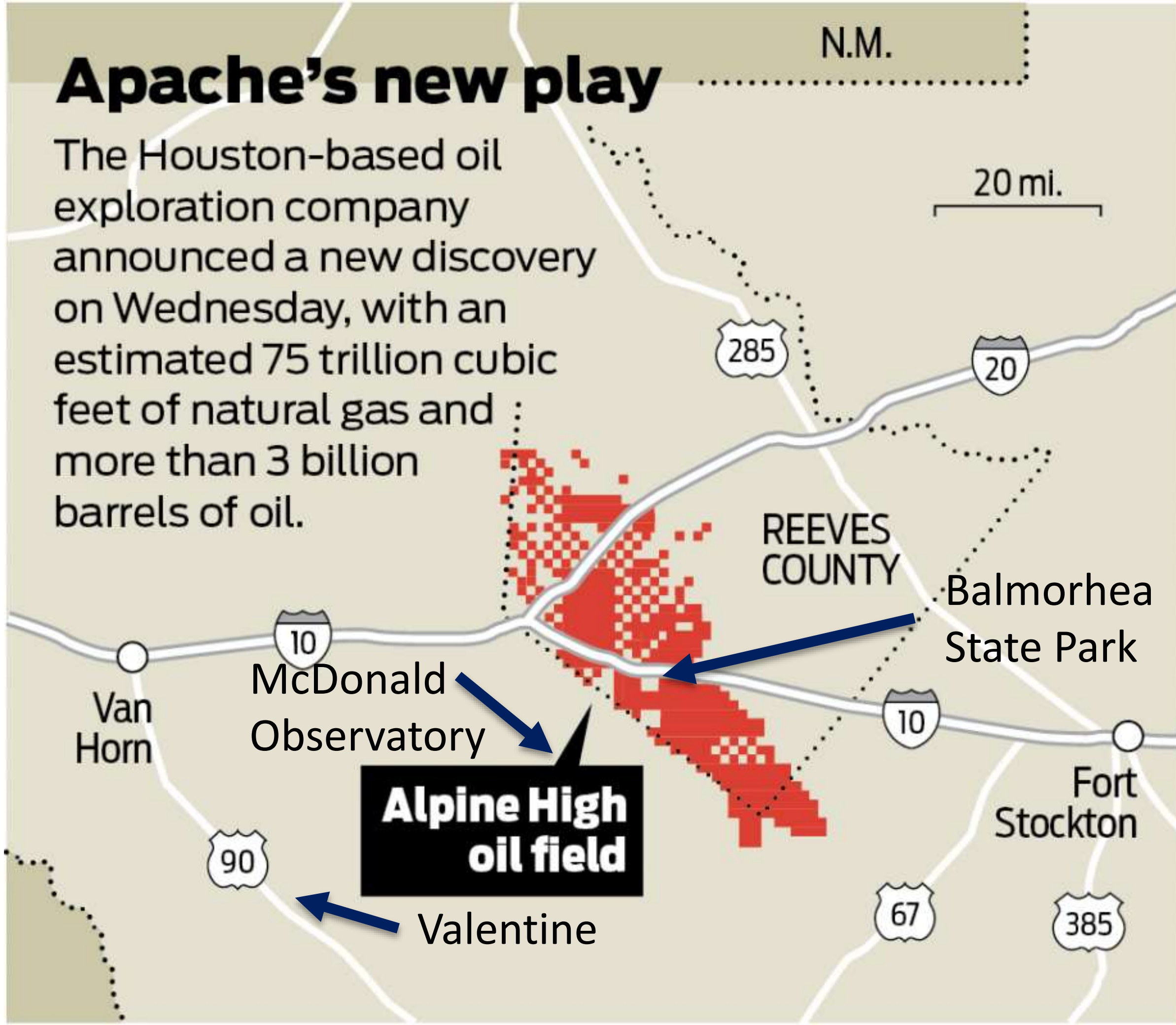
Water Needs and Availability Hydraulic Fracturing

- **Typical hydraulic fracturing water needs**
  - ✓ 1000 gal/ft (1128 L/m) of horizontal extent
  - ✓ Total Water needs 4-10 M gallons (15-40,000 m^3)
- **Overall small part of water needs**
  - ✓ Texas ~125,000 acre-ft/yr (~ 0.5% of state total use)
  - ✓ Hydraulic fracturing for gas one of most water-efficient technologies for energy
- **But local challenges- Eagle Ford Play in South Texas**
  - ✓ Water demand- 5-6.7% of total (Jester, 2011)
  - ✓ But local use can be much higher
  - ✓ Projected water needs as % of total water use by county in Eagle Ford
    - **Webb – 5.2%**
    - **De Witt – 35%**
    - **Karnes – 39%**
    - **Live Oak – 12%**
    - **Dimmit – 55%**
    - **La Salle – 89%**

Increasingly rural and lower overall water use
(Nicot & Scanlon, 2012)

Alpine High Oil and Gas Play

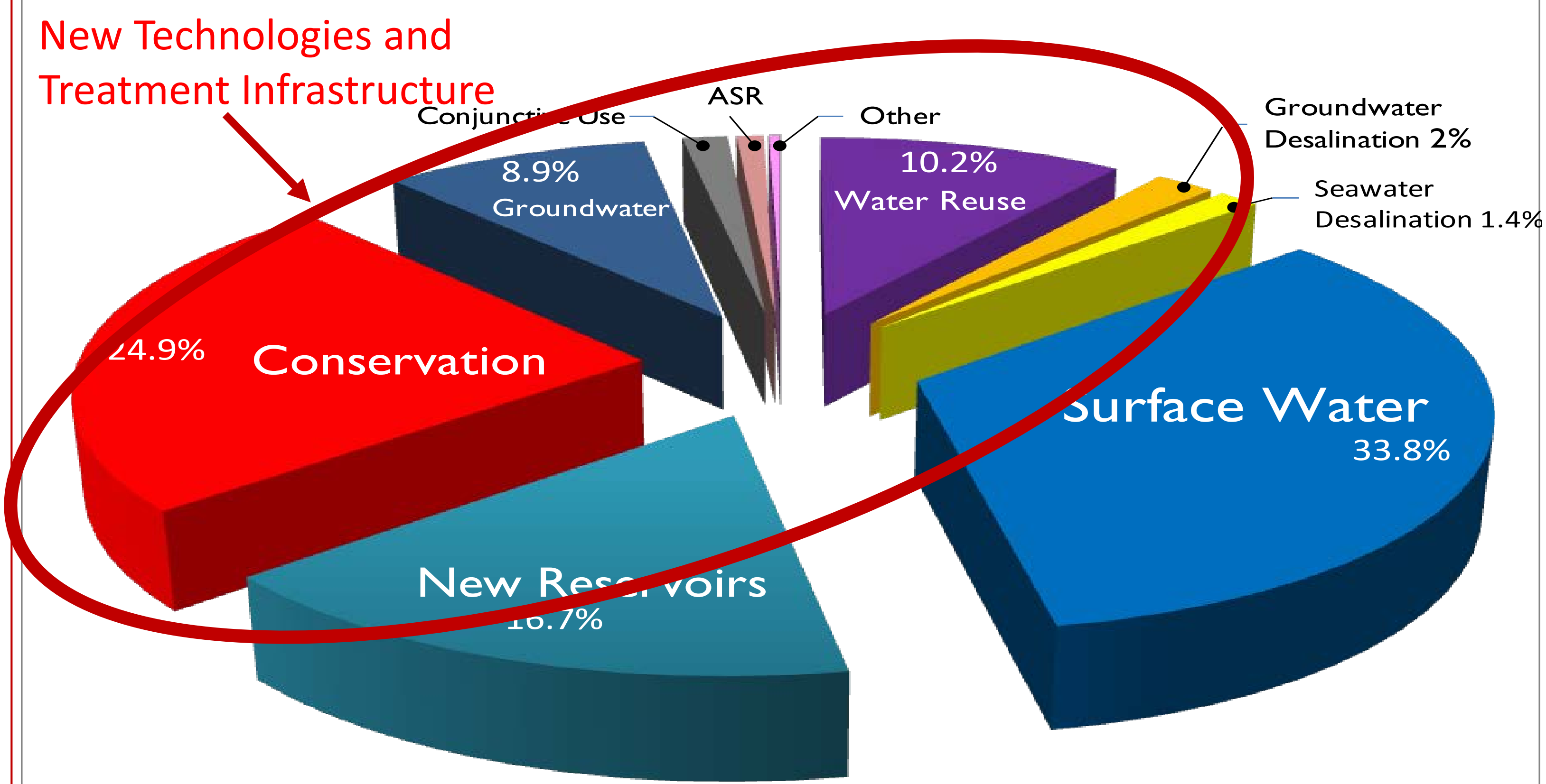
- **Limited water resources**
  - 10 in rain/yr
  - Ephemeral rivers
- **Sensitive areas**
- ***Development Controlled by Water Availability!***



Source: Apache

Houston Chronicle

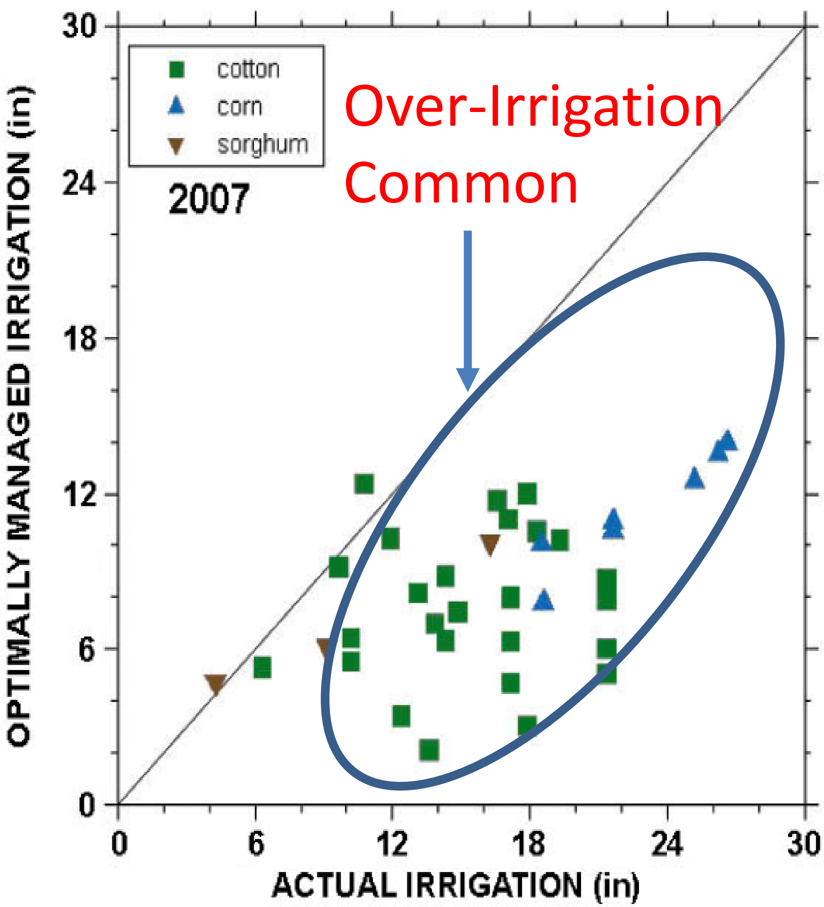
Building Resilience….Strategies



Developed by Regional Water Management Districts: Cost- $53 Billion

Texas Water Development Board, 2012

Agricultural Irrigation



Approaches

– Appropriate crop selection
  – Efficient hybrids
– Efficient Irrigation Systems
  • Drip irrigation
– Efficient scheduling
  • Canopy Temperature Control
  • Satellite Soil Moisture Sensing
– Target ~80% of crop ET needs

evapotranspiration needs

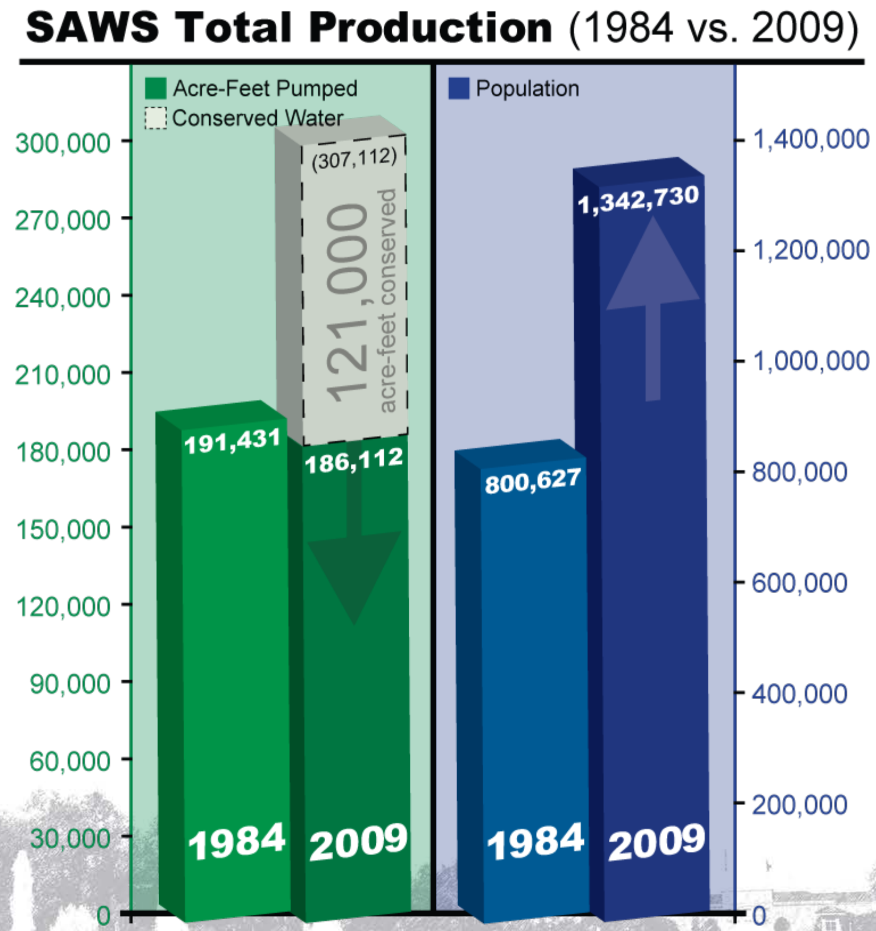
West, 2014

Municipal Conservation

San Antonio 1984-2009

Customers ↑ 67%

Water ↑ 0%



Puente, 2012

Alternative Water Sources

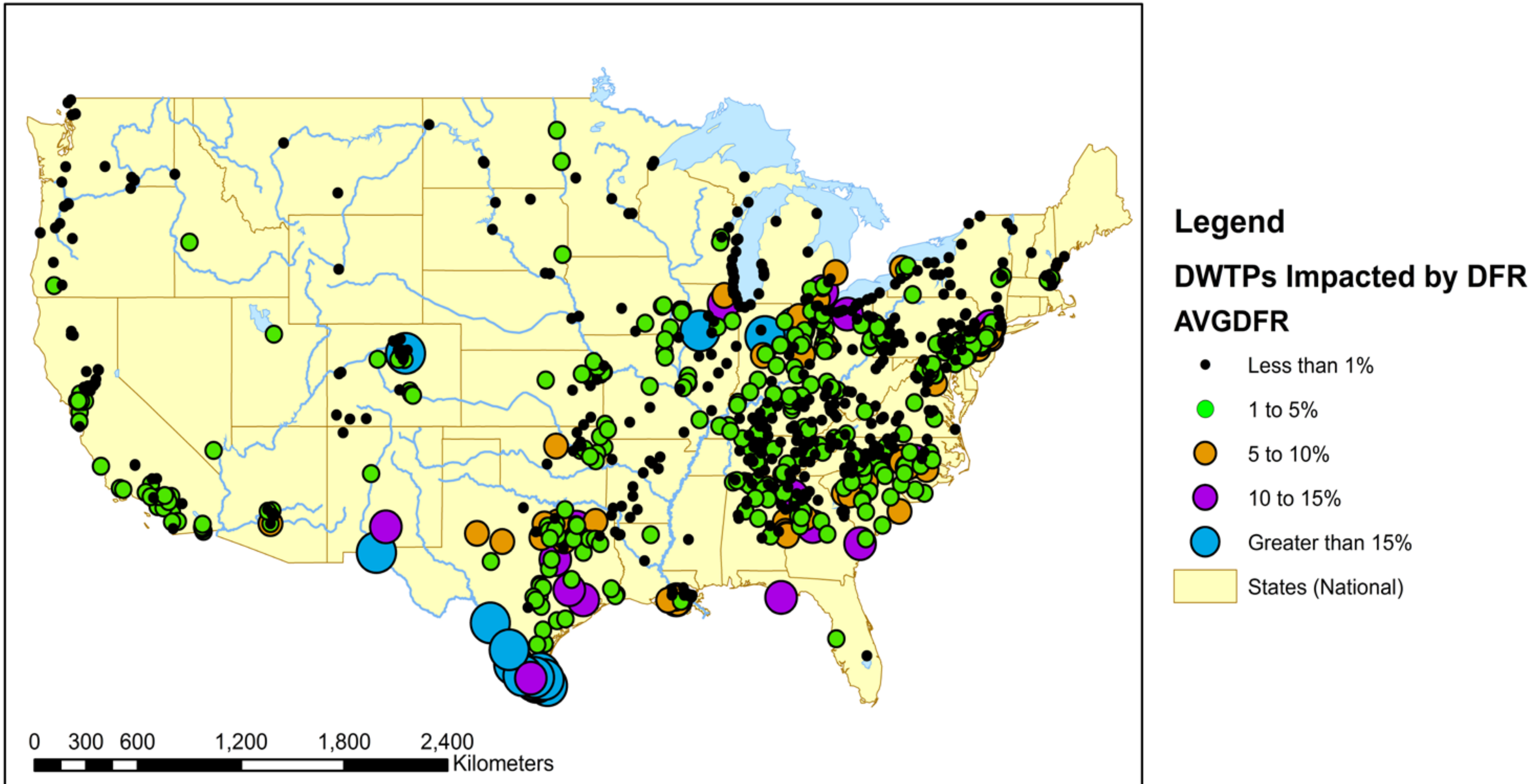
Location, Location, Location……

- **Employ Municipal Wastewaters**
  - ✓ Available in sufficient volume near point of use?
  - ✓ Limited by any requirements for effluent return to surface waters
  - ✓ Can quality be guaranteed for direct reuse?

- **Use of Produced Water**
  - ✓ Typically very poor quality limits its use to industrial (hydraulic fracturing)
  - ✓ Sufficient production wells near point of use?
  - ✓ Discouraged by water owners, regulatory issues
  - ✓ Cost of any necessary treatment competitive with disposal

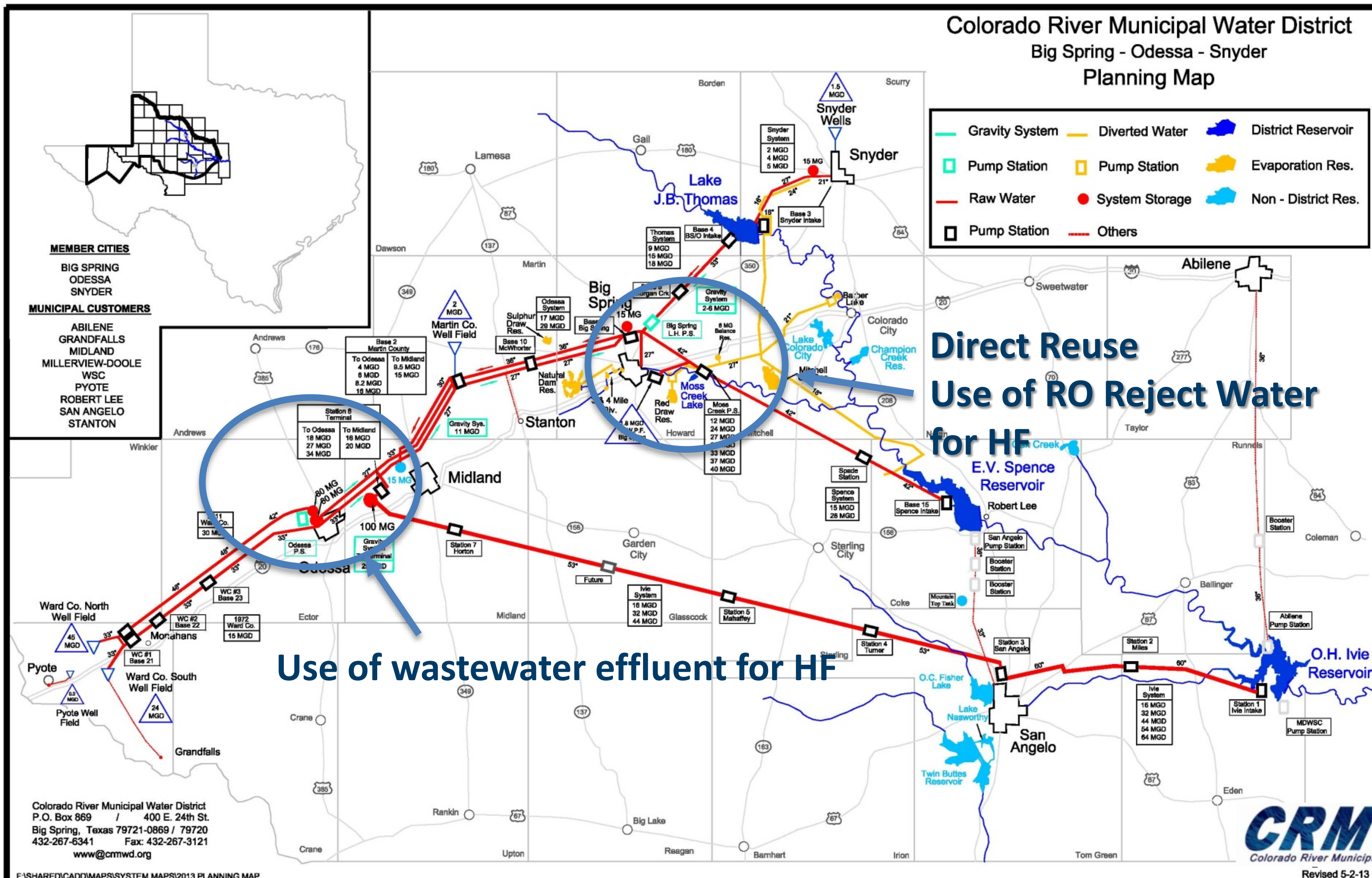
- **Employ Brackish Waters**
  - ✓ Infrastructure, cost and energy requirements for treatment?
  - ✓ Available in sufficient volume near point of use?
  - ✓ Who owns access rights?
  - ✓ Limited by variable chemistry and aquifer characteristics
  - ✓ Connections to surface water and other aquifers?

Magnitude of de facto reuse

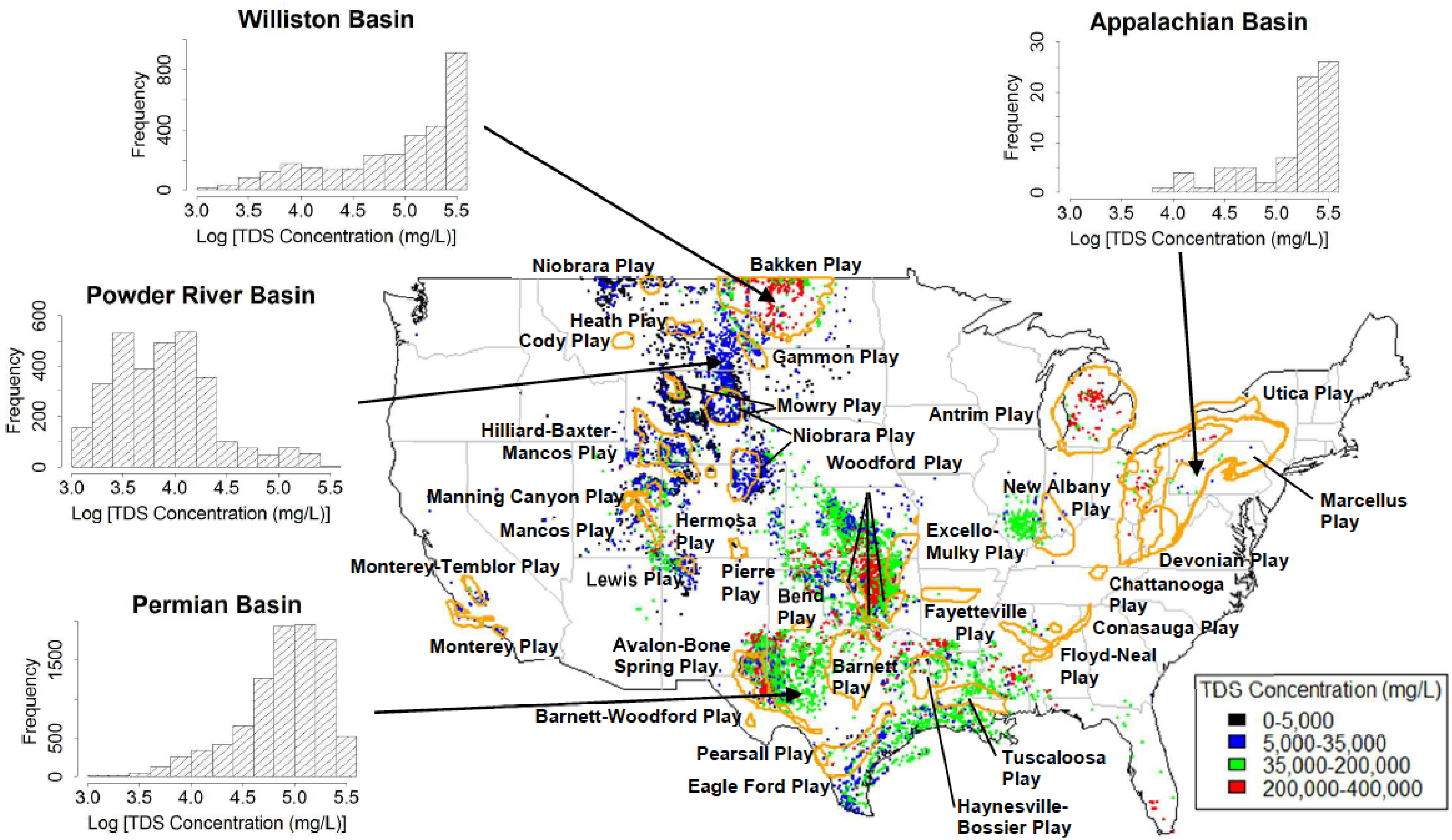


Rice, J. and Westerhoff, P. "Spatial and Temporal Variation in De Facto Wastewater Reuse in Drinking Water Systems across the USA", *ES&T*, 49:982-989 (2015)

Reuse Municipal Effluents



Reuse Produced Water?



Too Saline for anything except industrial uses such as for hydraulic fracturing

Barriers to Use of Produced Water

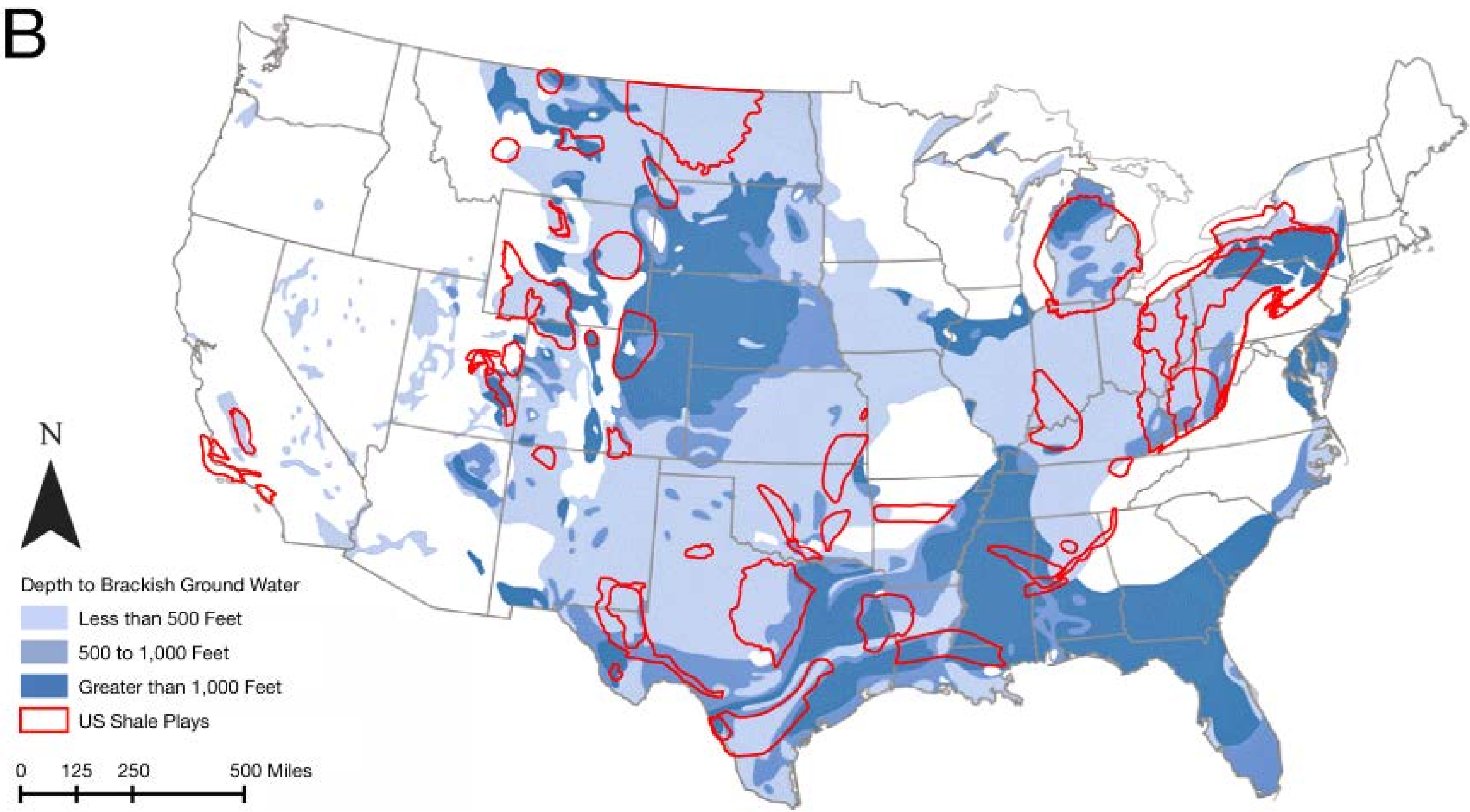
- **Poor water quality limits options for beneficial use**
  - ✓ Brackish waters far easier to divert to other beneficial uses than produced water
  - ✓ Cheaper to desalinate seawater and pump to west Texas than desalinate produced water?
- **Primary option for produced water is use as hydraulic fracturing fluid but barriers remain**
  - ✓ Low disposal costs
  - ✓ Imbalance between produced water and fracturing needs
    - **Volume**
    - **proximity**
  - ✓ Availability of fresh or brackish waters
    - **Landowner benefits from fresh or brackish water sales**
  - ✓ Regulatory impediments
    - **Inability to redirect produced water to non-O&G uses**

Recycling Example in Region of High Well Density

- Dense well field owned by operator
- Approximate balance of produced water and fracturing needs
- Minimal treatment requirements (ClO_2)

Saline Groundwater (Brackish Water)?

Mauter et al, 2014

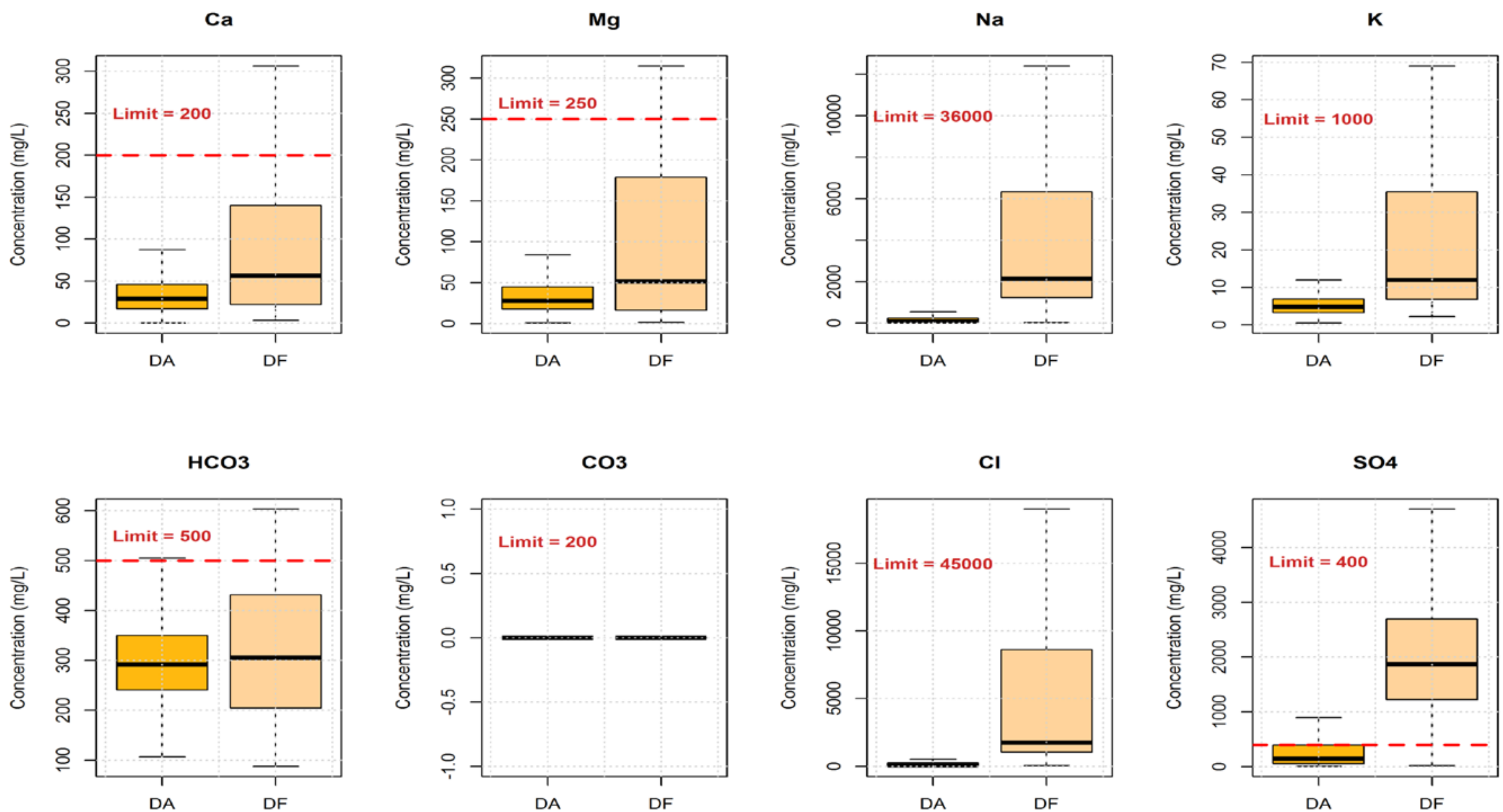


Low Salinity Brackish Water Uses

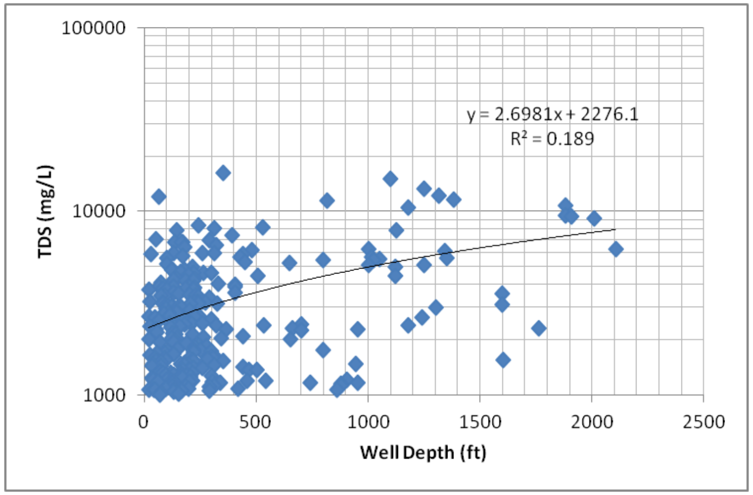
- **Substantial water reserves**
  - ✓ 10 times Great Lakes in Southwestern US
- **Requires better assessment**
  - ✓ Chemistry and implications
  - ✓ Productivity of aquifers, aquifer characteristics
- **Requires efficient use of technologies for utilization**
  - ✓ FIT FOR USE! Change the use not the water
  - ✓ Variability a significant challenge to conventional technologies
  - ✓ Opportunities such as electrosorptive (capactive deionization) technology for flexible scalable minimal treatment options
- **There is not “one” solution nor “one” water source**

Brackish Water Characteristics

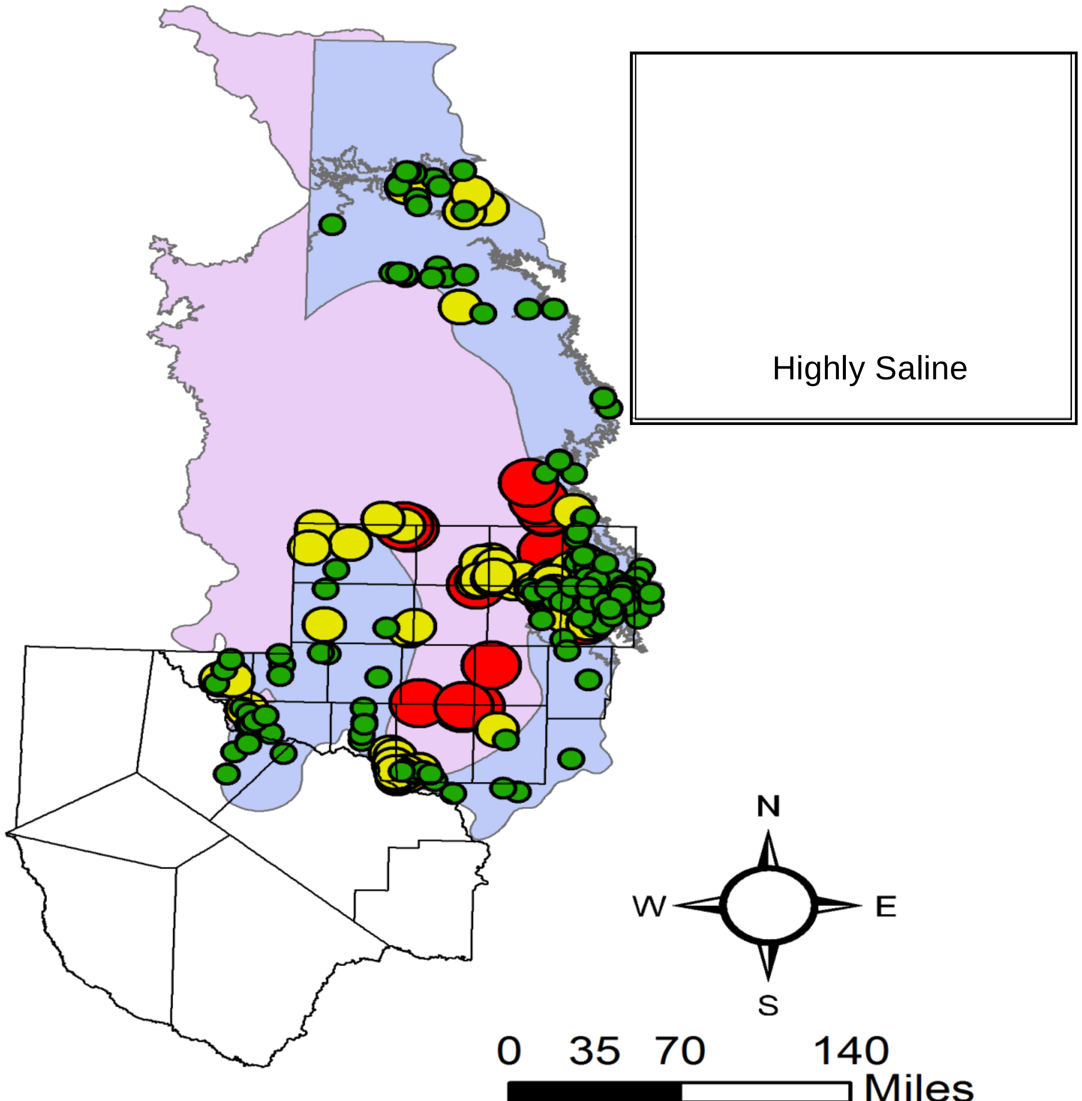
Variability makes use technologically challenging



Brackish Aquifer -Dockum



Extreme Spatial Variability
General increase with depth

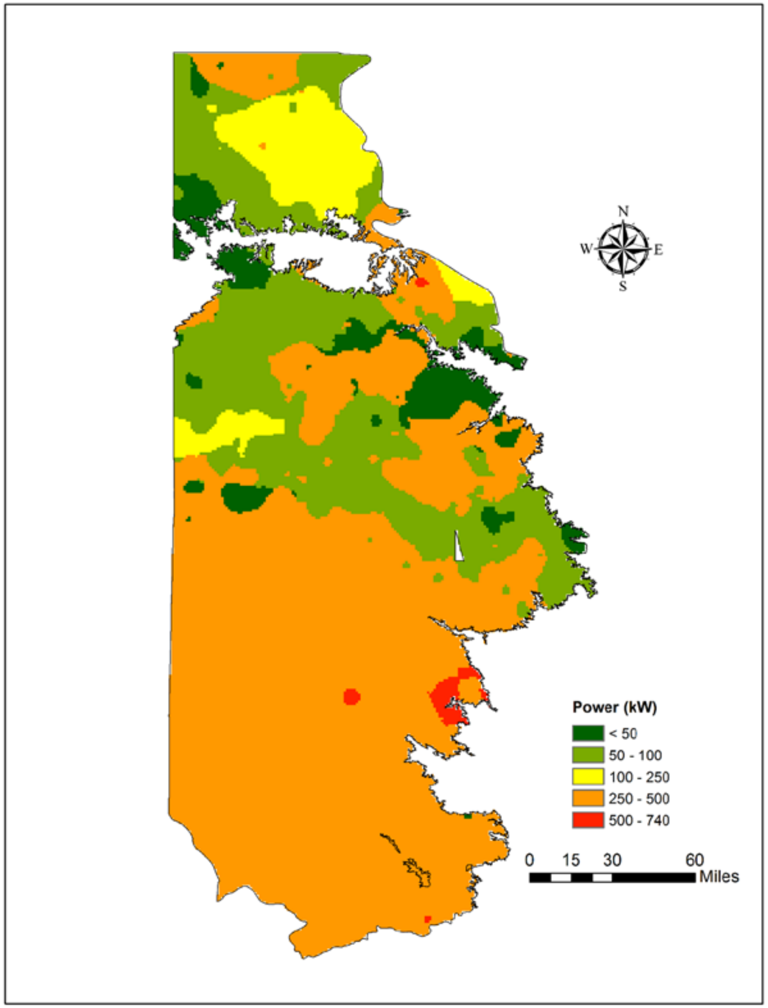


Uddameri, 2016

Energy Requirements for Desalination

- **Direct use of Dockum aquifer under Ogallala limited by Water quality**
  - ✓ TDS > EC > SAR > B

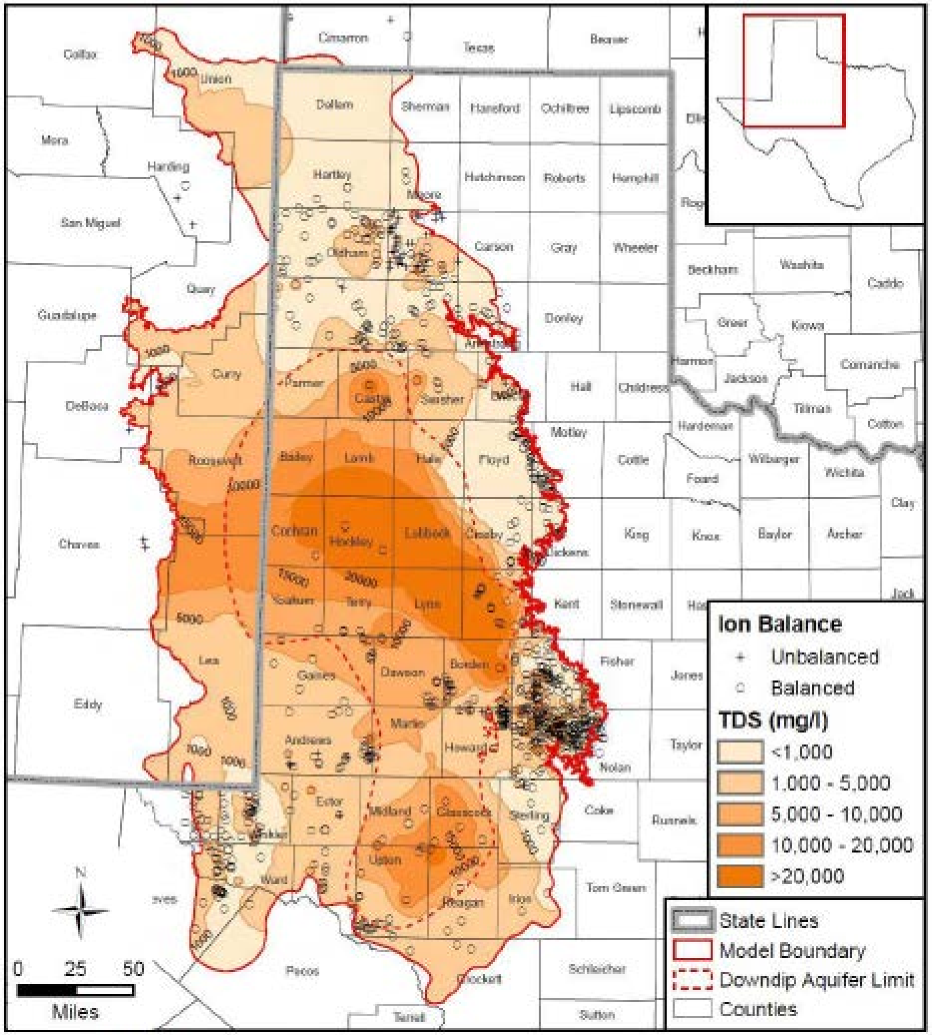
- **Energy needs are highest were water is more scarce**



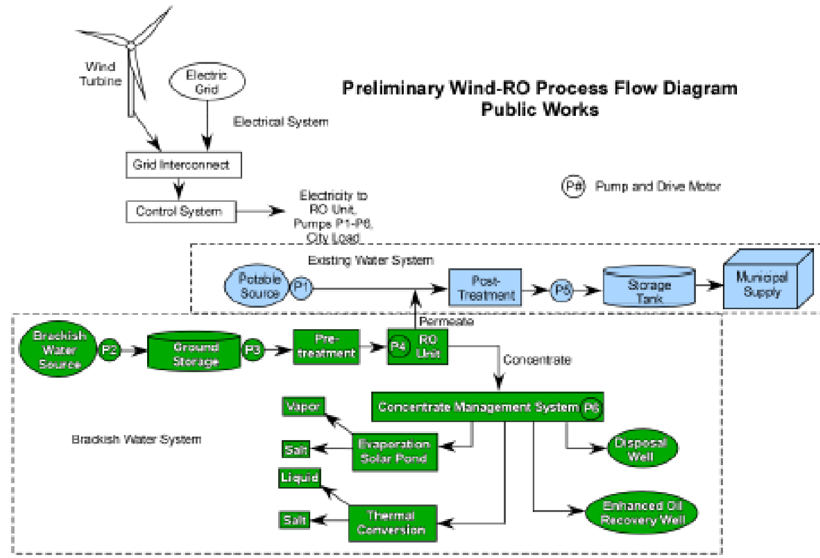
Uddameri and Reible, 2017

Wind Driven Reverse Osmosis Desalination

K. Rainwater, A. Swift



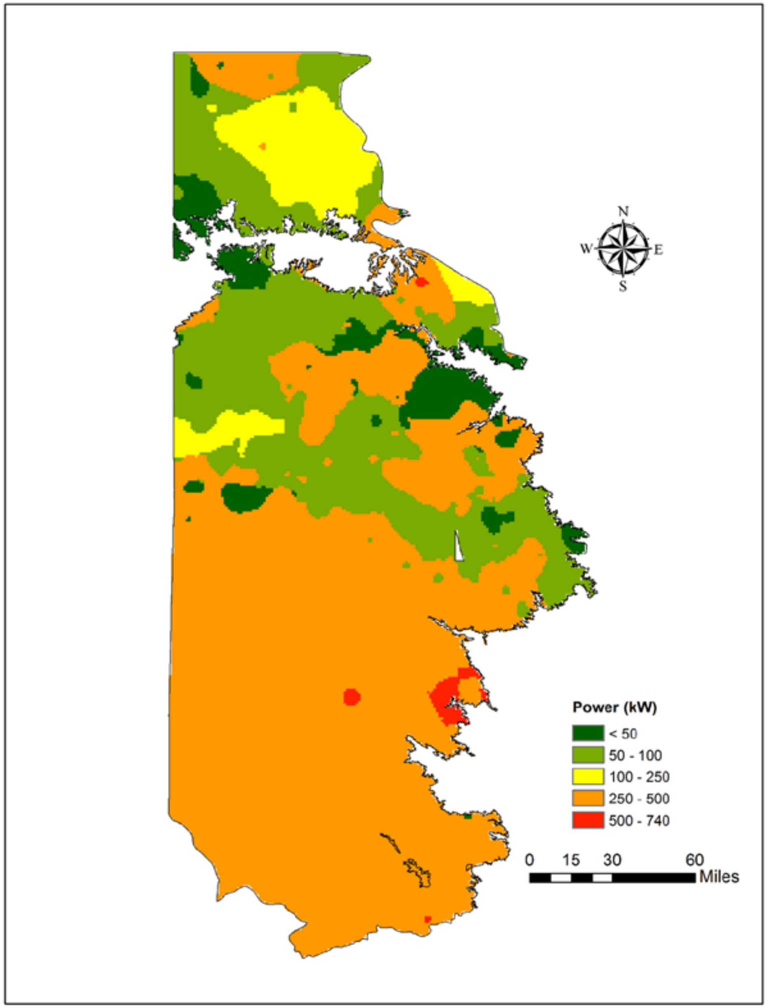
Source: TWDB, Panhandle GCD; USGS/New Mexico; Hart and others (1976)

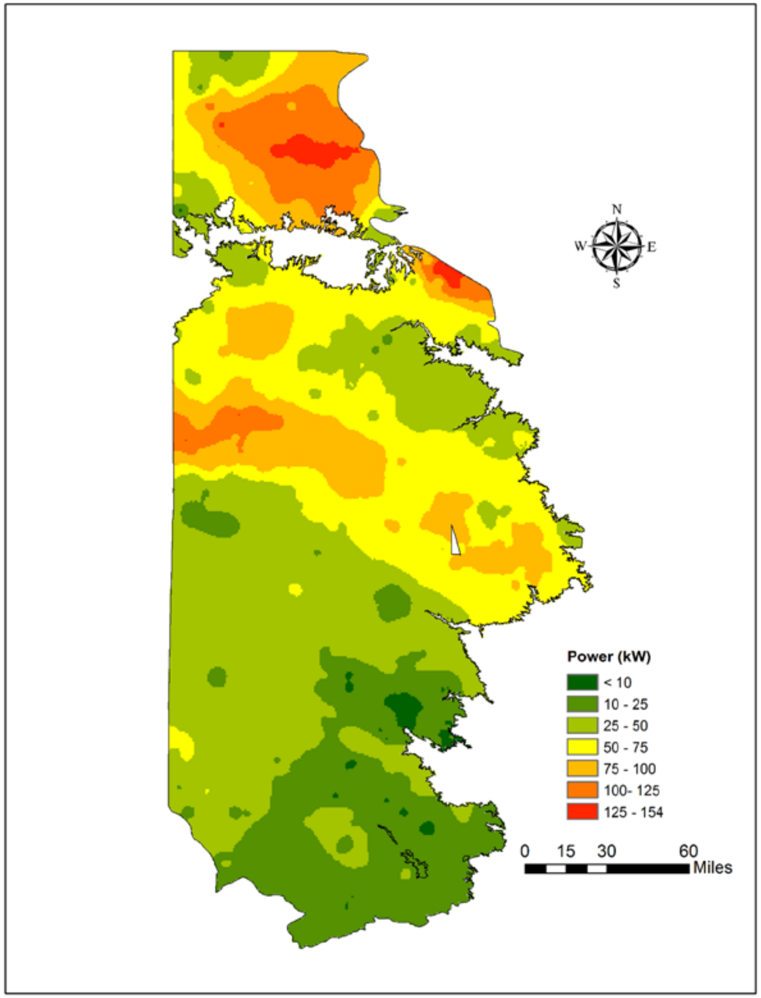


Other uses for brackish water ?

Energy cost of desalinating vs blending for Ag

Uddameri and Reible, 2017





An Alternative Vision for Water Delivery

- **Current practice**
  - ✓ Deliver high quality water for all uses
    - **~2% is used for drinking and cook**
  - ✓ Attempt to move toward segregation of grey water and expand reuse
- **A model more consistent with "fit for use"**
  - ✓ Deliver marginal quality water
    - **Blend with freshwater for non-potable uses?**
    - **To allow for inadvertent consumption likely must be treated for pathogens**
  - ✓ Employ simple scalable technologies to treat water for human consumption
    - **Need simple, low maintenance technologies**
    - **Energy requirements not a significant concern due to low volumes required**
  - ✓ Implementation
    - **New community/development structured as demonstration**
    - **With infrastructure for delivery of non-potable waters**

Conclusions

- **Energy development and agriculture place significant demands on water and often in water scarce areas**
  - ✓ Freshwater use can be minimized and sources extended by alternatives
  - ✓ Alternatives for avoiding freshwater use for oil and gas development and hydraulic fracturing
    - **Flowback and Produced Water**
    - **Brackish Water**
  - ✓ Alternatives for increasing high quality water availability
    - **Use of brackish waters with innovative treatment and appropriate blending with freshwater**
  - ✓ Challenges are often logistical rather than technical due to low value of water and cost of transportation and treatment
  - ✓ Should we rethink our paradigm of high quality water for all uses?

Can we Eat, Drink AND Turn on the Lights?

Turn on the Lights? √

Water ***consumption*** is low in hydraulic fracturing and conventional power plants (although some energy sources consume much more water, e.g biofuels.)

Drink? √

But we could use high quality waters more efficiently!

Eat? ?

Agricultural cannot easily support investments necessary to achieve maximum efficiency and there are other high value needs for the water

Acknowledgements

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- Huesker
- CETCO

Department of Homeland Security
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