Quantifying Produced Water Treatment and Reuse Risks: A National and Regional Approach

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Presentation Overview

- System-level considerations for energy system design, operation, and performance – political and public perceptions
- The role of oil and gas and produced water in a national water and energy dialogue
- Doing the science to quantify the costs and benefits of treating produced water to:
  - address fresh water supply stress
  - support regional economic development
  - support a secure and resilient energy infrastructure
  - minimize public and environmental health risks

System Evaluation of 100% Carbon-free Energy by 2050

	REF ~AEO 2019	E+ high electrification	E- less-high electrification	E- B+ high biomass	E+ RE- renewable constrained	E+ RE+ 100% renewable
CO_2 emissions target		- 0.17 $GtCO_2$ in 2050				
Electrification	Low	High	Less high	Less high	High	High
Wind/solar annual build	n/a	10%/y growth limit	10%/y growth limit	10%/y growth limit	Recent GW/y limit	10%/y growth limit
Existing nuclear	50% → 80-y life	50% → 80-y life	50% → 80-y life	50% → 80-y life	50% → 80-y life	Retire @ 60 years
New nuclear	Disallow in CA	Disallow in CA	Disallow in CA	Disallow in CA	Disallow in CA	Disallowed
Fossil fuel use	Allow	Allow	Allow	Allow	Allow	None by 2050
Maximum CO_2 storage	n/a	1.8 Gt/y in 2050	1.8 Gt/y in 2050	1.8 Gt/y in 2050	3 Gt/y in 2050	Not allowed
Biomass supply limit	n/a	13 EJ/y by 2050 (0.7 Gt/y biomass) *[No new land converted to bioenergy]*		23 EJ/y by 2050 (1.3 Gt/y biomass)	13 EJ/y by 2050 (0.7 Gt/y biomass) *[No new land converted to bioenergy]*	

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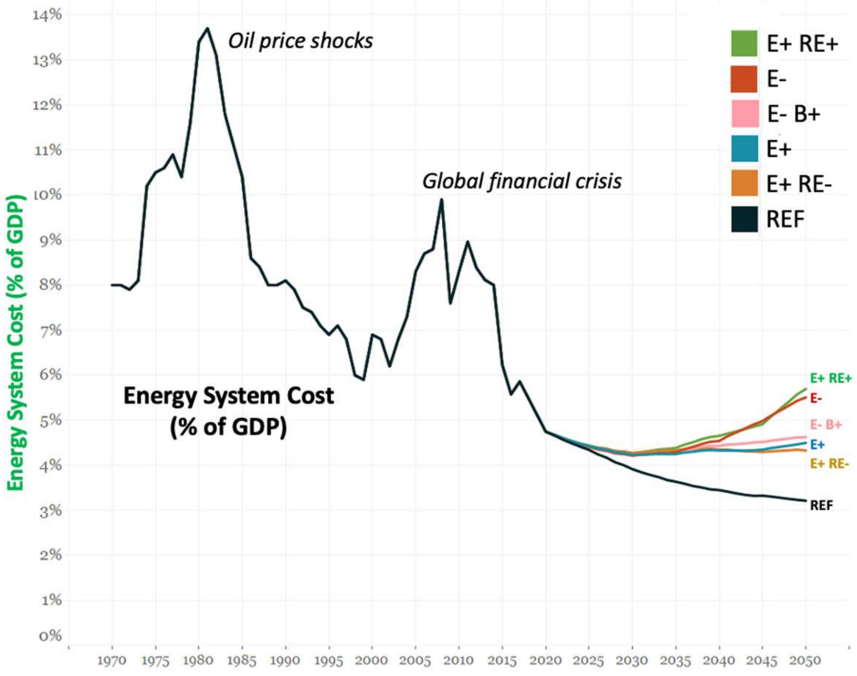

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Included – air, CO2 storage, energy mix, more transmission and batteries, cost

Not included – water, security, resiliency, socio-economic impacts, other CO2 sources

Technical Drivers for Optimized 2050 Energy Portfolio

- Collectively, EEI's member companies are on a path to reduce their carbon emissions at least 80% by 2050, compared with 2005 levels.
  - The switch from coal to natural gas and renewable energy has been the single most effective tool over the past decade for reducing carbon emissions
  - all of this has been done while keeping rates steady and while ensuring that electricity remains affordable and reliable.
- It is important to us that we lead on clean energy in a way that gives us all the options, including making sure that we maintain existing nuclear and that we are still able to use natural gas to help achieve our clean energy targets..

Tom Kuhn, president of the Edison Electric Institute, the association of U.S. investor-owned electric companies. Jan. 26, 2021

- Natural gas land use is 1/100 the land use for an equivalent size solar plant
- Natural gas reliability and capacity factor is 97% compared to solar 25% and wind 30%
- Natural gas is ½ the water consumption and ½ the GGHG emissions of coal
- Natural gas is shipped by pipelines, electricity by overhead transmission lines – permitting and reliability concerns
- Natural gas combined cycle and wind currently are the lowest levelized cost for electric power

Public and Environmental Health and Safety Drivers in Oil and Gas Development

< 0.25 miles from oil and gas operations

- Highest level of acute public health impacts and concerns
- Highest occurrence of environmental impacts - noise, air, land. and water pollution and contamination

0.25 - 0.50 miles from oil and gas operations

- Significanlty reduced public health impacts
- Significantly reduced environmental impacts or damage from operations or accidents

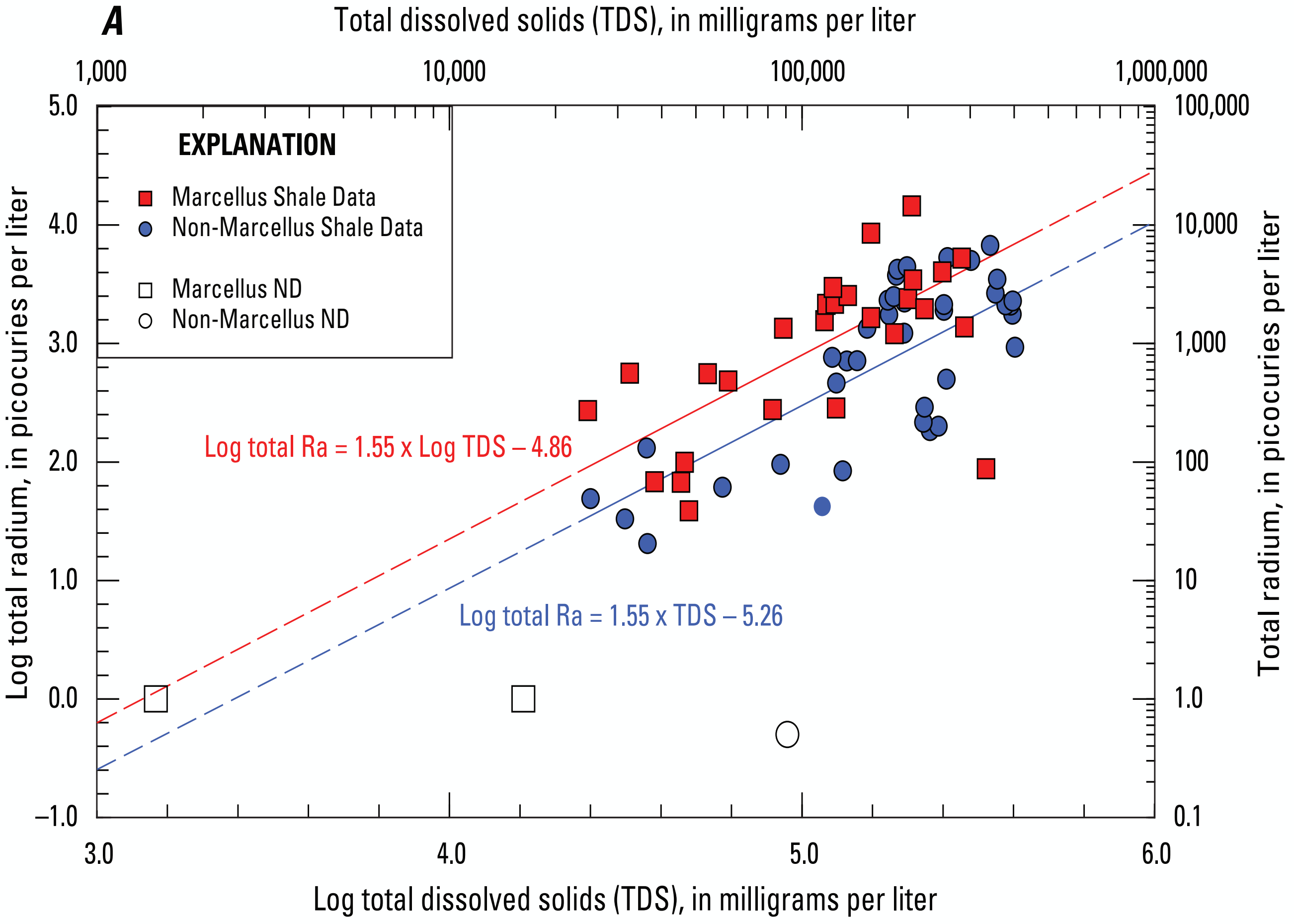
> 0.50 miles from oil and gas operations

- Little observed acute or chronic public health and safety or environmental impacts
- Especially in open, flat, and non-wooded operational areas

- Highest impacts in populated areas, especially in wooded, rolling terrain
- Highest impacts to permanent residents on small private land parcels in closely aggregated operations
- NM DOH has no record of fracking damaging a personal water supply

Physicians for Social Responsibility-Colorado Symposium - Health Effects of Oil and Gas Development, December 4, 2020.

Public Perception of Produced Water Risks



NORM Constituent	Typical NM Surface Water Concentrations	Typical NM Ground Water Concentrations
Uranium	0.005-.020 mg/L	0.005-1.0 mg/L
Total Radium 226 and 228	0.5-1.5 pCi/L	0.5-8.0 pCi/L

NORM Constituent	Typical NM Produced Water Concentrations
Uranium	0.2-0.5 mg/L
Total Radium 226 and 228	1.0-1.5 pCi/L

Water-related Economic Concerns by 2030

Today one in five people live in areas of water stress.

This is expected to rise to two in three.

Demand for water is set to outstrip supply by 40%.

Business as usual water management will put at risk $63trillion or 1.5 times today's entire global economy.

Water will have more rapid and unavoidable consequences for some businesses than carbon

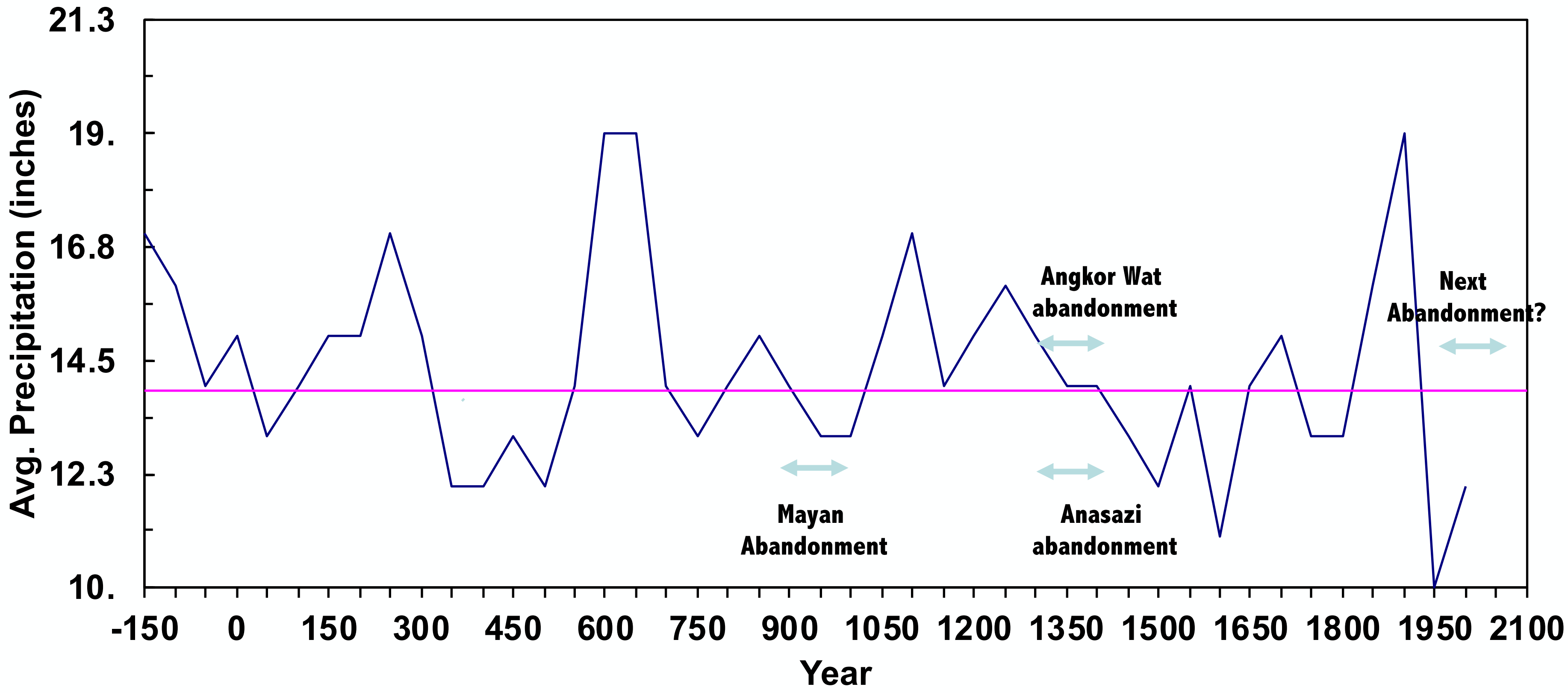
Goldman Sachs

" Investors know how damaging inaction, inappropriate action or delaying interventions on water-related issues can be… The global economy will favor business that take a pro-active approach to water stewardship."

- **Eurizon Capital**

CDP

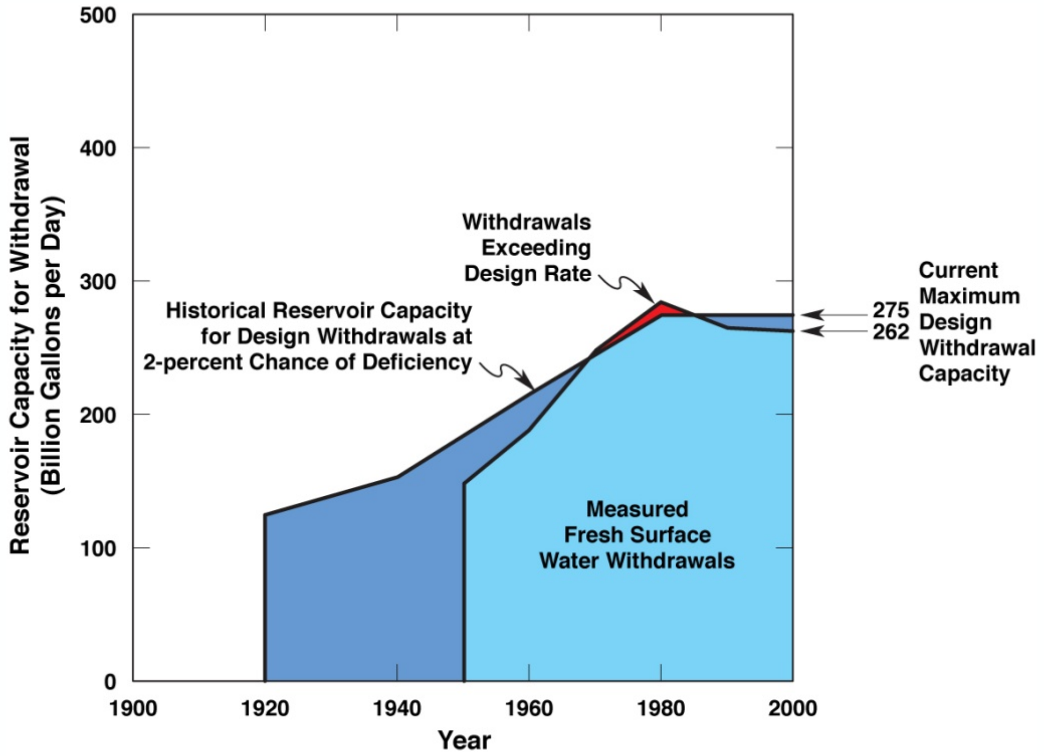
Southwest Climate History from Tree Ring Data



Univ. of Arizona – Tree Ring Lab – 50 year averages

The southern U.S. and the mid-latitudes are in the 130th year of a 300 year arid cycle - not a drought

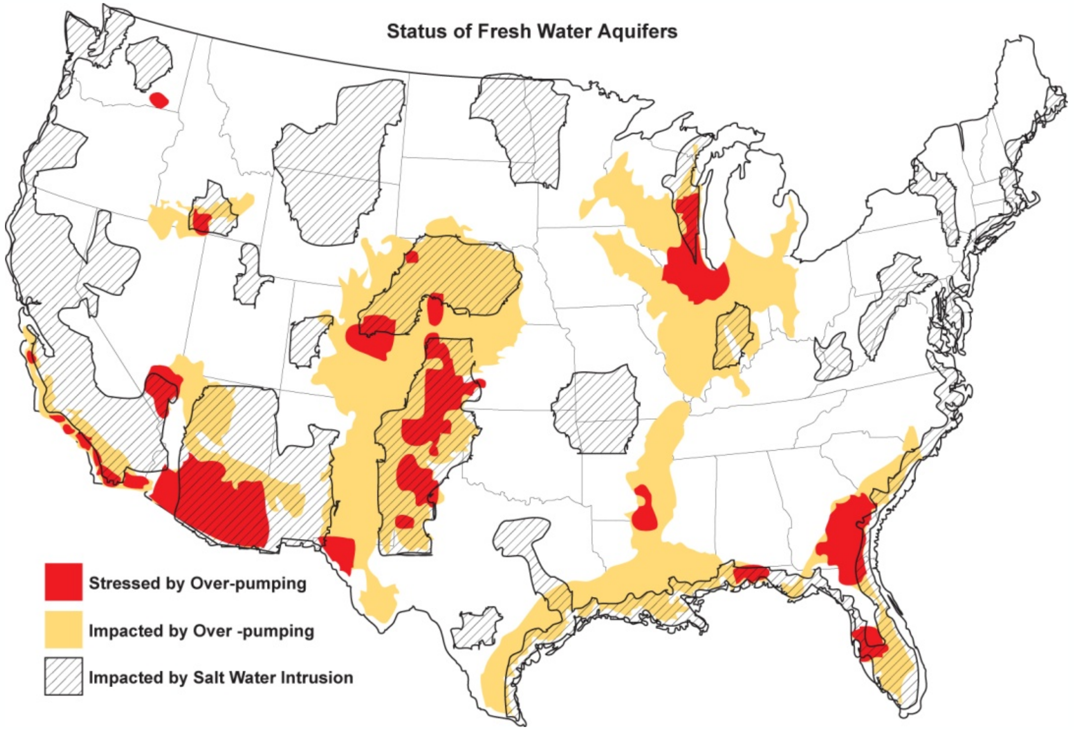
Fresh Water Availability Issues Driving Non-traditional Water Use



(Based on USGS WSP-2250 1984 and Alley 2007)

- No new surface water storage capacity since 1980

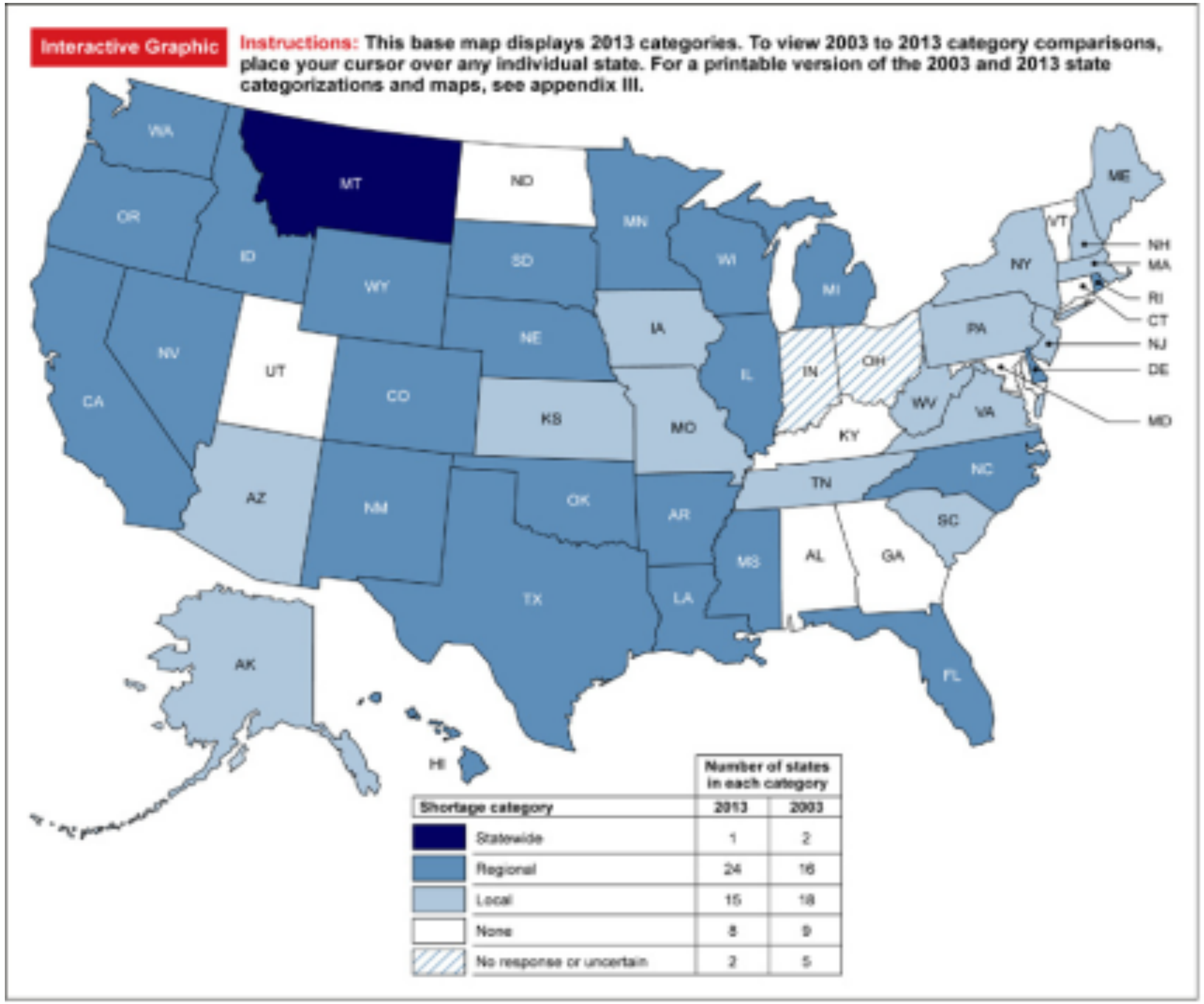
- All major groundwater aquifers overstressed



(Shannon 2007)

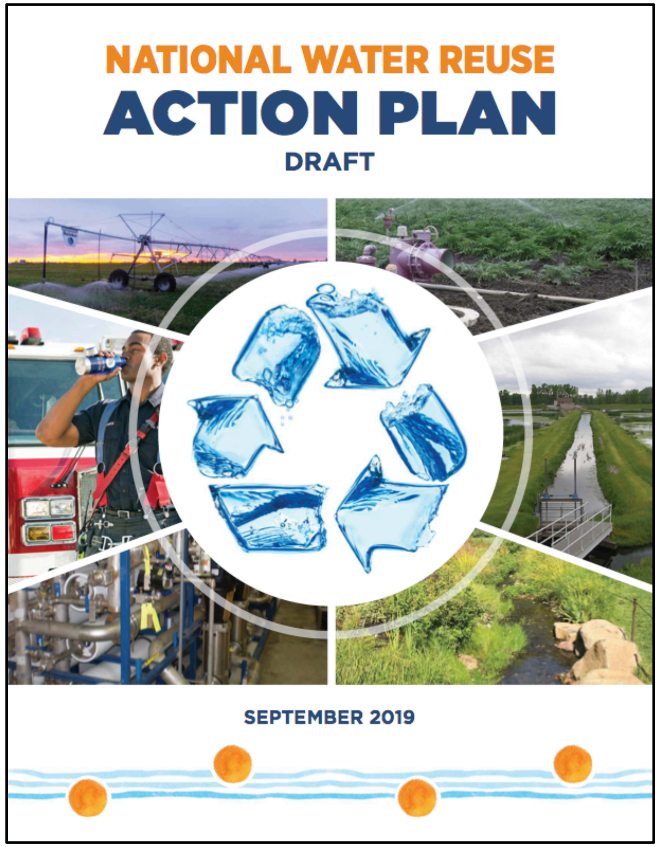
National Initiative in Non-traditional Water Reuse

GAO 2003 and 2013



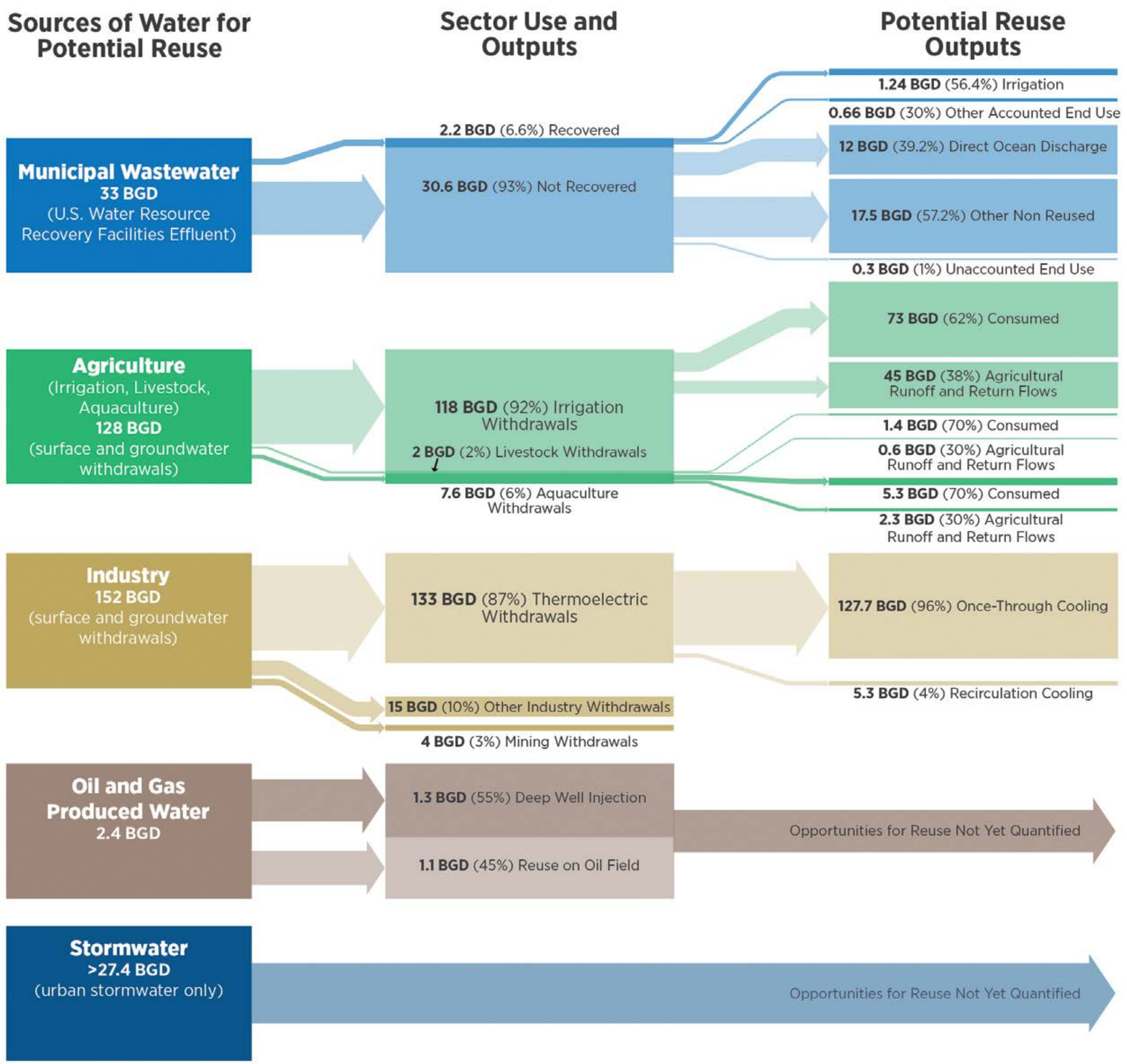
Sources: GAO analysis of state water managers' responses to GAO survey; Map Resources (map).

EPA 2019



EPA National Water Reuse Action Plan Focus Areas

- Clear potential to reclaim more waste waters for beneficial use
- Sources of water for priority reuse:
  - ➢ 33 BGD - Municipal wastewater
  - ➢ 128 BGD - Agriculture
  - ➢ 152 BGD - Industry
  - ➢ 2.4 BGD - Oil and gas produced water
  - ➢ >27.4 BGD – Storm water
- Focus on treatment for beneficial reuse
- Leads selected for each area - GWPC and NMPWRC selected to lead produced water efforts



EPA definition of Produced Water

- "Produced water is the fluid (often called brine) brought up from the hydrocarbon bearing strata during the extraction of oil and gas….."
  - brine – water with a salinity greater than sea water (>35,000 ppm) total dissolved solids (TDS)
  - formation water – naturally occurring water in the geologic formation
  - injection water - water and chemical additives used in hydraulic fracturing to enhance production.
- Produced water = 4-10 times oil produced

Summary of Input on Oil and Gas Extraction Wastewater Management Practices Under the Clean Water Act

EPA-821-S19-001

U.S. Environmental Protection Agency

Engineering and Analysis Division

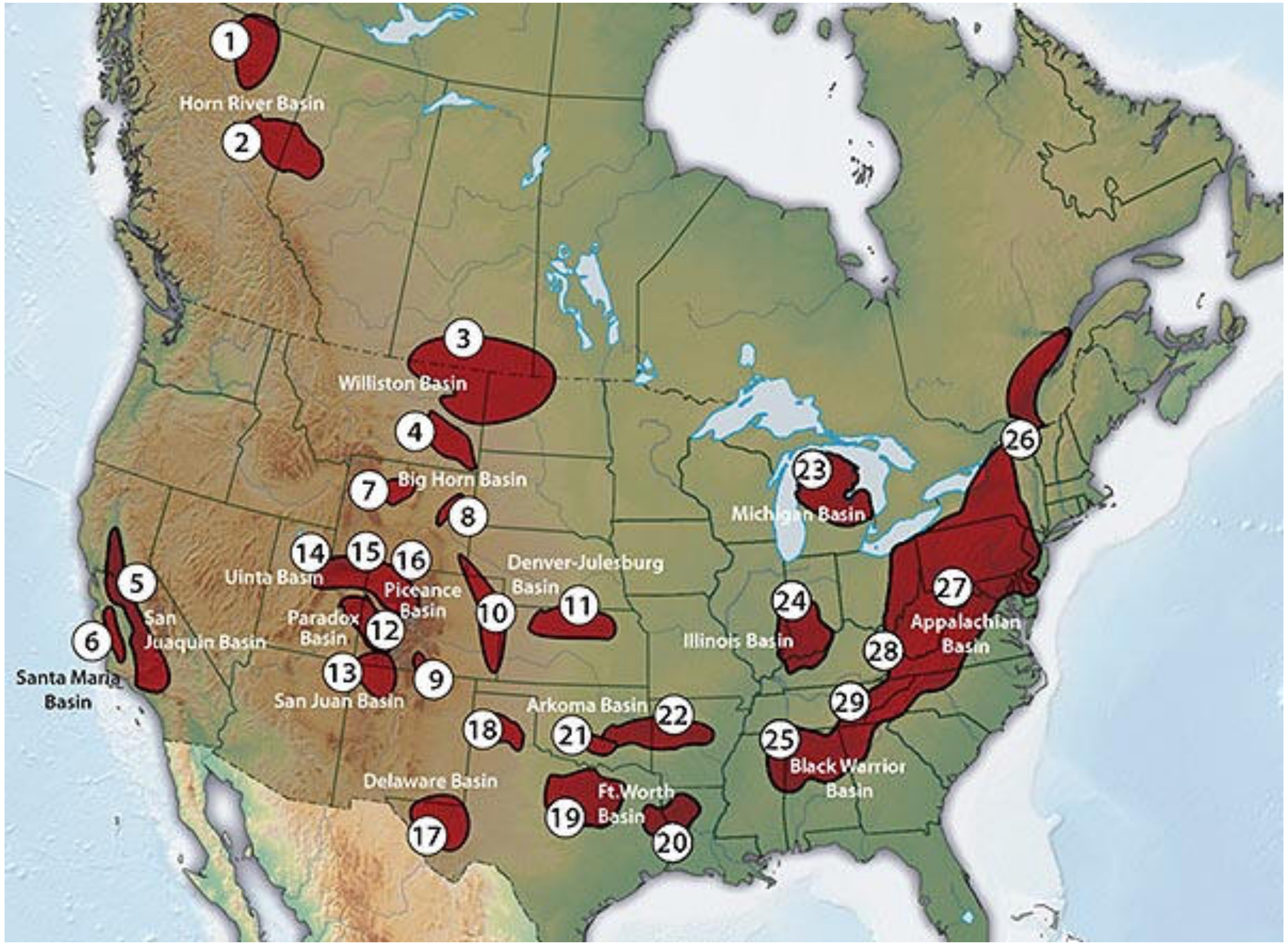
Office of Water

1200 Pennsylvania Avenue, NW

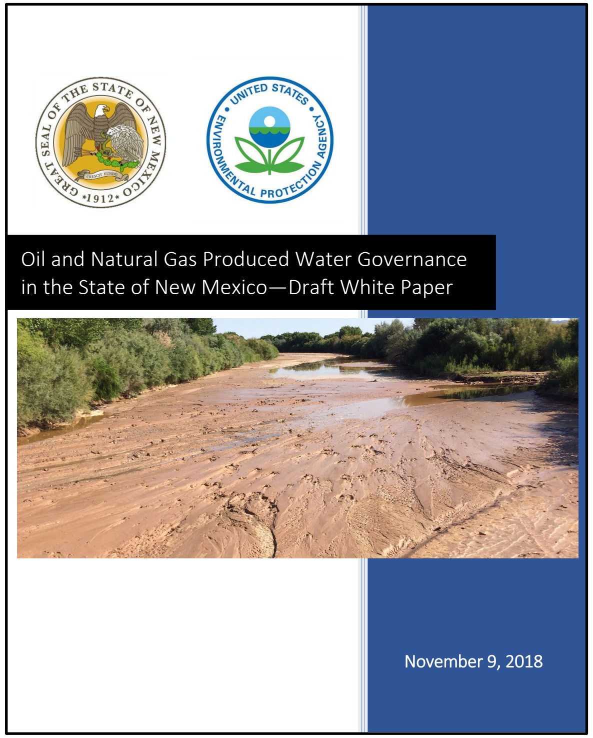
Washington, D.C. 20460

Final May 2020

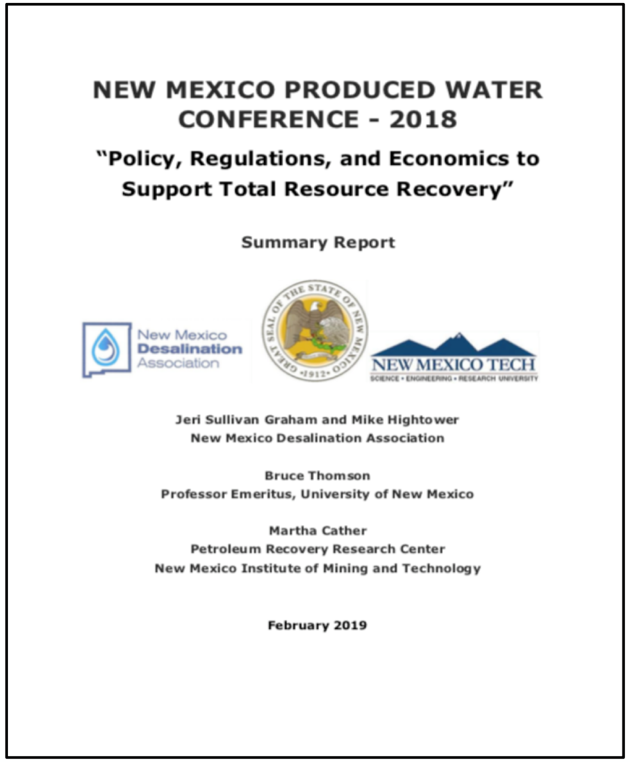
Oil and gas shale produced water management is an area of national impact and interest



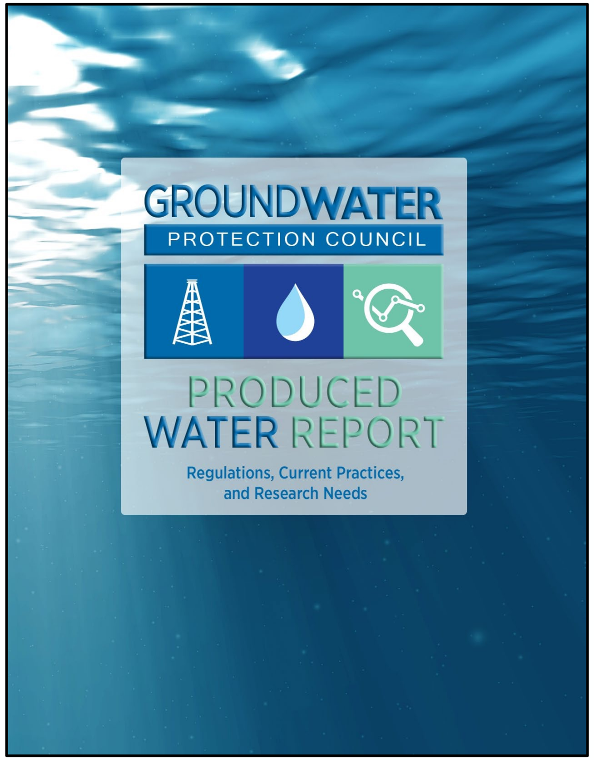
Recent New Mexico Efforts on Produced Water Treatment and Reuse



NMED, OSE, EPA 2017-18



NMED, OSE, EMNRD 2017-19



EMNRD 2016-19

NM 2019 Produced Water Act, HB 546

- Through the Act, statutory and regulatory authority for the reuse of produced water was modified:
  - Reuse inside oil and gas sector remains under the Oil Conservation Division (OCD) of the NM EMNRD,
  - **Reuse outside the oil and gas sector, was designated to the NM Environment Department (NMED).**
- The Act encourages produced water reuse outside oil and gas to:
  - enhance fresh water sustainability,
  - reduce or eliminate fresh water use in the oil and gas sector,
  - support new economic development opportunities,
  - maintain public and environmental health and safety.

This regulatory transition is an emerging trend in the oil and gas sector – OK, TX, CA

NM PWR Consortium Organization

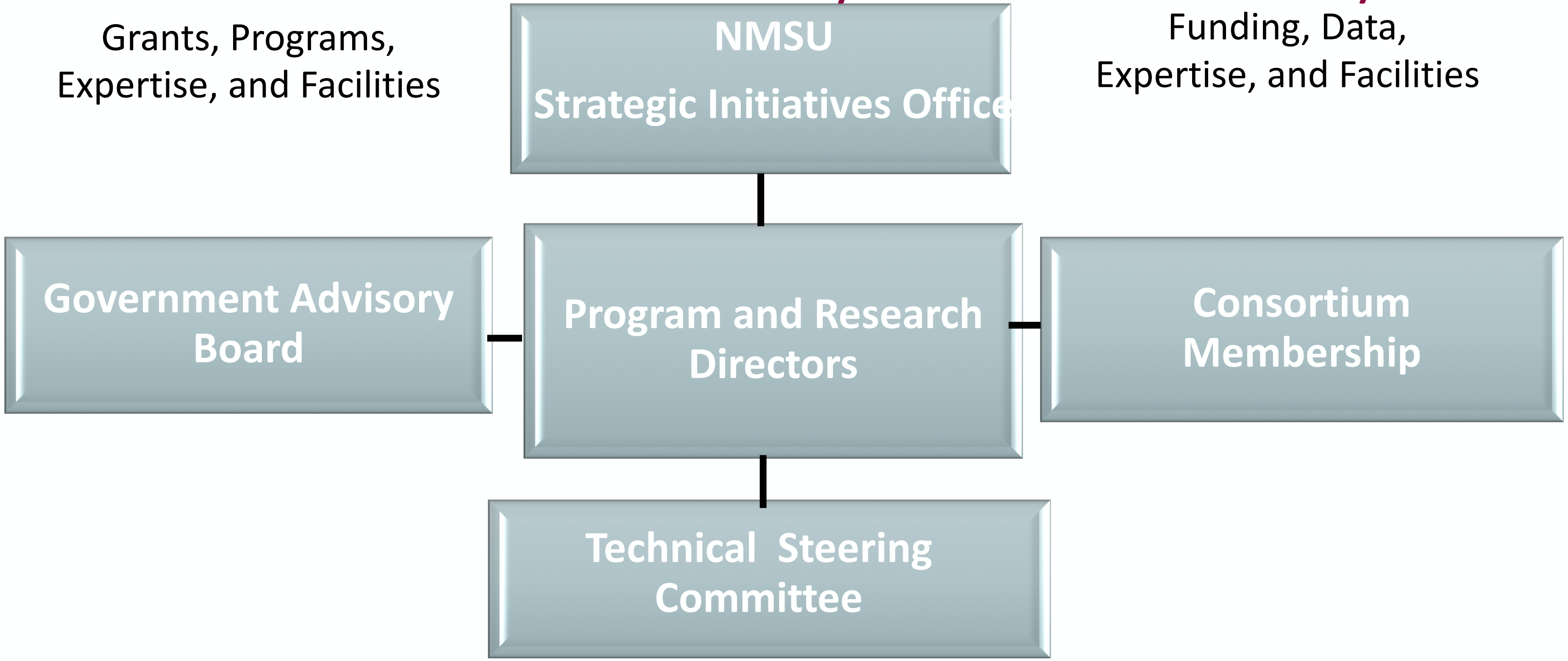
Government

Grants, Programs, Expertise, and Facilities

University

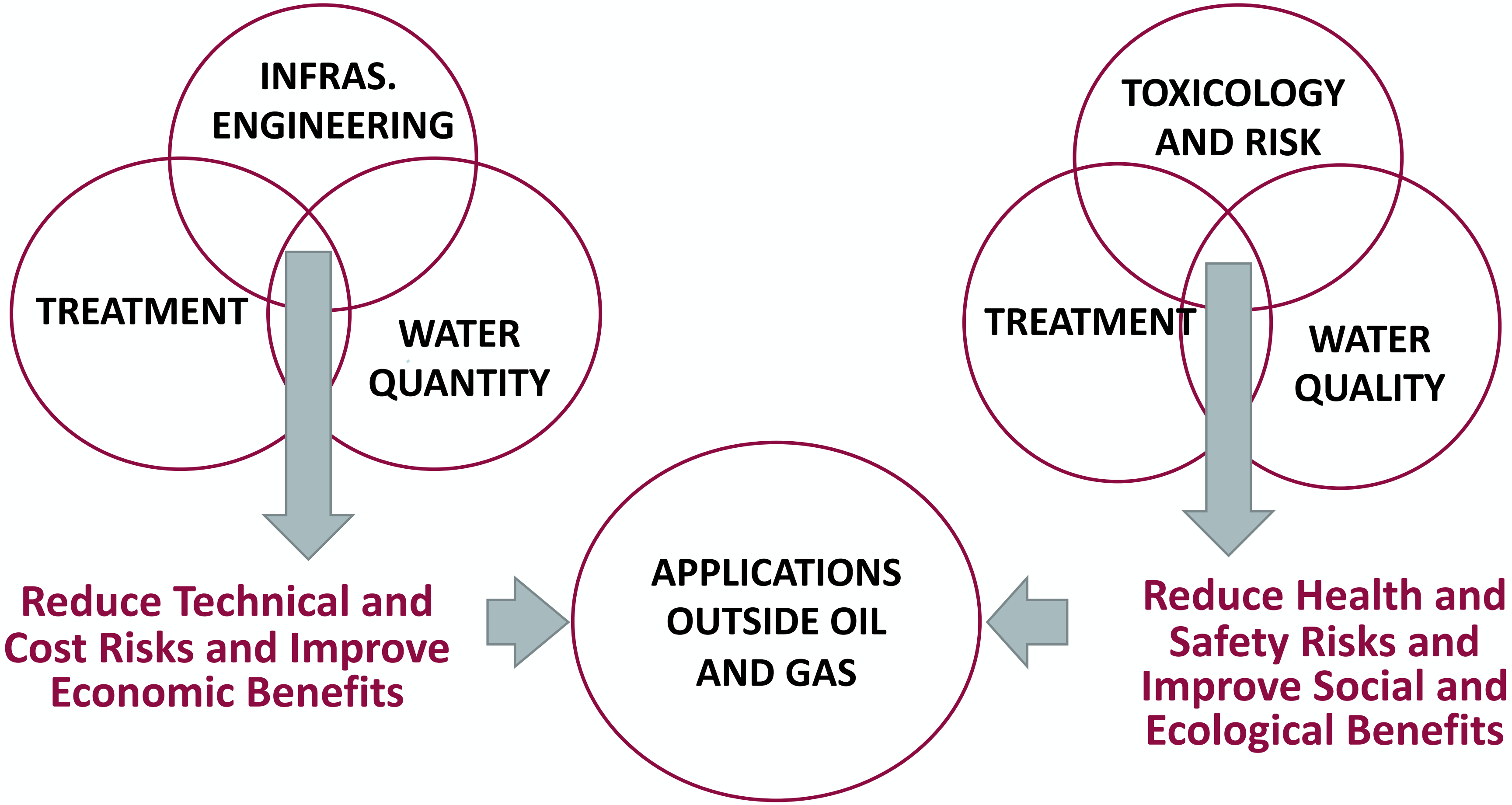
Industry

Funding, Data, Expertise, and Facilities



Modeled after DOE Innovative Treatment Remediation Demonstration Program and EPA Environmental Technology Verification (ETV) Program

Technical Organizational and Operational Structure



NM Produced Water Research Consortium Focus

- Accelerate innovative technology cost and performance testing to fill science and technology gaps to :
  - address fit-for-purpose treatment for various applications - industrial, road construction, agriculture, rangeland, municipal, aquifer storage, surface supplies.
- Provide approach for socio-economic environmental cost benefit and risk analysis for producers, public, and economic development groups.
- Make sure treatment requirements are protective of public, environmental, ecological, and watershed health and safety.
  - Especially relative to other water supply sources (produced water vs toilet water)
  - Improved WET testing and risk analysis in cooperation with the EPA
- Make sure all data collected is coordinated with regulatory agencies to accelerate science–based regulations and policies.
- Make sure all information is available to the public and produced water users in an easily accessible data portal.

Aqua Zia Produced Water Data Portal with GWPC

- Near-term
  - Update the NM Petroleum Recovery Research Center (PRRC) GoTech produced water data base with water quantity and quality data from 2016-2020
  - Establish data QA/QC, API, and Tiered Data query framework
- Midterm
  - Integrate GoTech data into GWPC Aqua Star produced water data management and analysis system with GWPC financial support
  - Provides a direct Interface with updated Well Finder and Frac Focus to improve data accuracy and timeliness
  - Meets the needs of a national produced water reuse platform:
    - 2-D and 3-D plotting, mapping, contours, time series analysis, charts, etc.
    - Applicable for state agencies, the public, as well as engineering/economic evaluations
    - Web-based and enables integration of metadata
    - Meets Findable, Accessible, Interoperable, Reusable, and Reliable data requirements

Frac Focus
Chemical Disclosure Registry

Quantitative Treatment Data at Scale

- Produced Water Treatment Testing and Evaluation
  - Providing a step-by-step for bench and pilot-scale testing
  - Is based on several federal agency – EPA, DOE, and DoD innovative treatment programs
  - Accurately collect operational cost and performance data for independent 3rd party review
- Will be testing 6-8 treatment and pretreatment technologies in 2021 – some pilot and some bench scale
- Open for additional testing opportunities

Planning

- Experiment Design
- Sampling and Analysis Plan
- Set Performance Goals
- Process Flow
- SOP
- Site and Water Selection
- Cost and Schedule
- Data Management Plan
- Waste and Environmental Risk Plan
- 3rd Party Oversight
- Laboratory Data Completion

Demonstration

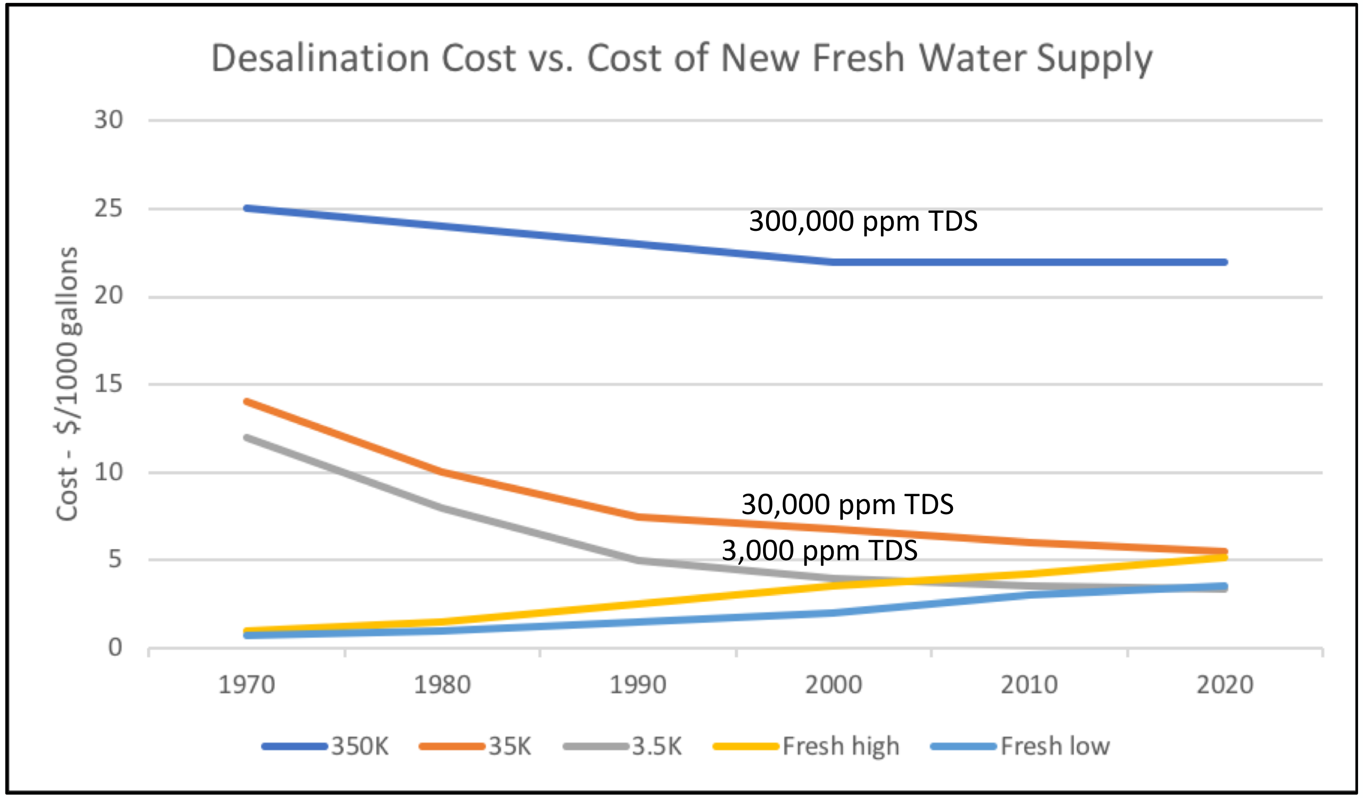
- Responsibilities & Communication
- Process Operation
- Sample and Data Collection
- Sample and Data Analysis QA/QC
- 3rd party Oversight
- Energy, process mass balance
- Photo-documentation
- Cost collection of manpower, chemiclas, energy, sampling, etc.
- Schedule & O&M Performance
- Emergency Responce Plan

Evaluation

- Data results and assessment summary
- Operational performance data and summary
- Environmental Risk Summary
- Report Findings
- 3rd Party Cost and Perforamnce Evaluation Report

Decreasing Treatment/Increasing Disposal Costs

(EWRI Hightower 2018)



2000 Permian Basin Avg. Produced Water Disposal costs $2/1000 gal

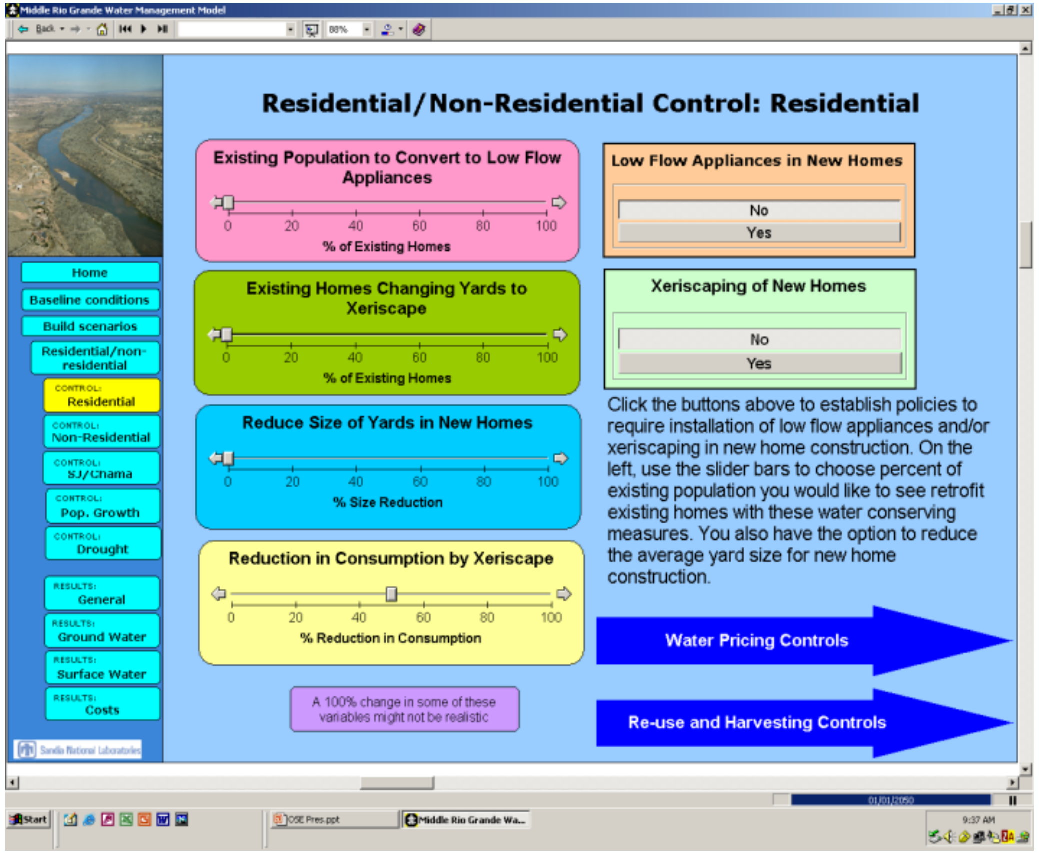
2020 Permian Basin Avg. Produced Water Disposal costs $20-50/1000 gal

Water Quality Requirements for Various Reuse Applications

Produced Water Quality (ppm) TDS	Application	Common Water Quality Requirements (ppm) TDS	Typical Treatment Process
Conventional 10K to 50K 50%<35K 50%>35K	Drinking	500-600	Chemical/membrane/thermal
	Aquifer Storage & Recovery	300-5,000	Chemical/membrane/thermal
	Agriculture and livestock	Class 1 <700, <60% Na, B<0.5 Class 2 2000, 60-75% Na, B<2.0 Class 3 >2000, 75% Na, B~2	Chemical/membrane/thermal
	Rangeland	4,000 – 10,000	Chemical/membrane/thermal
Unconventional 60K to 300K 25%<100K	Surface Flow	600-2000	Chemical/membrane/thermal
	Mineral Recovery	>100K (no discharge)	Chemical/thermal
	Road Constr.	Up to 100,000	Chemical/membrane/thermal

Quantitative Approach for Socio-economic, environmental Ecological Cost-Benefit Analysis of Produced Water Reuse

- Most important analysis attributes identified include:
  - Economic, social, environmental, ecological, sustainability, and health risk metrics
  - Allow broad stakeholder involvement
  - Provides quantitative rather than qualitative answers
- Considered several cost-benefit analysis and decision support approaches
  - Triple Bottom Line
  - Environmental, Social, Governance (ESG)
  - Holistic resource management
  - Choosing by Advantage (CBA)
- System dynamics is most flexible, most quantitative, and most amenable to stakeholder participation for multi-parameter performance optimization and relative-risk mitigation



Questions and Answers

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