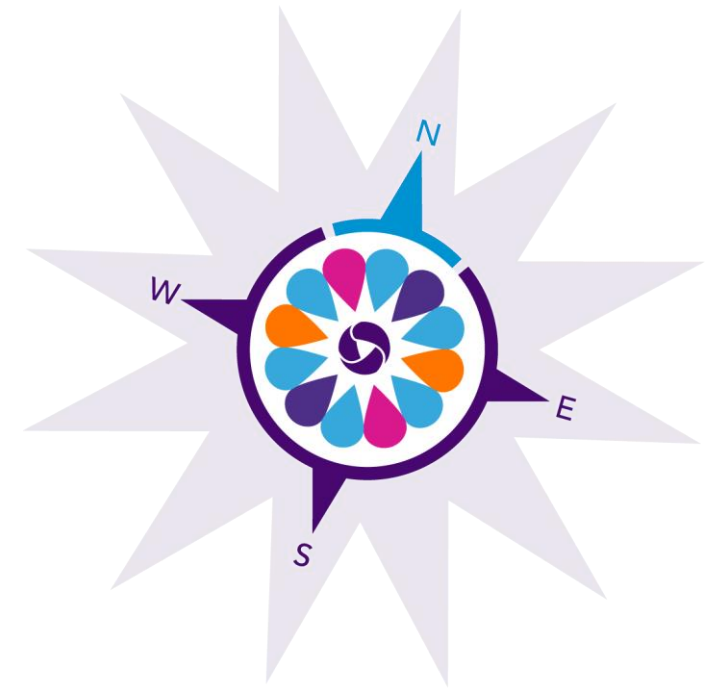


PRODUCED WATER REUSE EFFORTS IN SUPPORT OF THE NATIONAL WATER REUSE ACTION PLAN

NATIONAL COORDINATION AND
ASSOCIATED CHALLENGES

MIKE HIGHTOWER, PROGRAM DIRECTOR
NEW MEXICO PRODUCED WATER RESEARCH
CONSORTIUM

MODIFIED FOR TxpWC MARCH 9, 2022



2022 WateReuse
SYMPOSIUM

SHAPING OUR PAST &

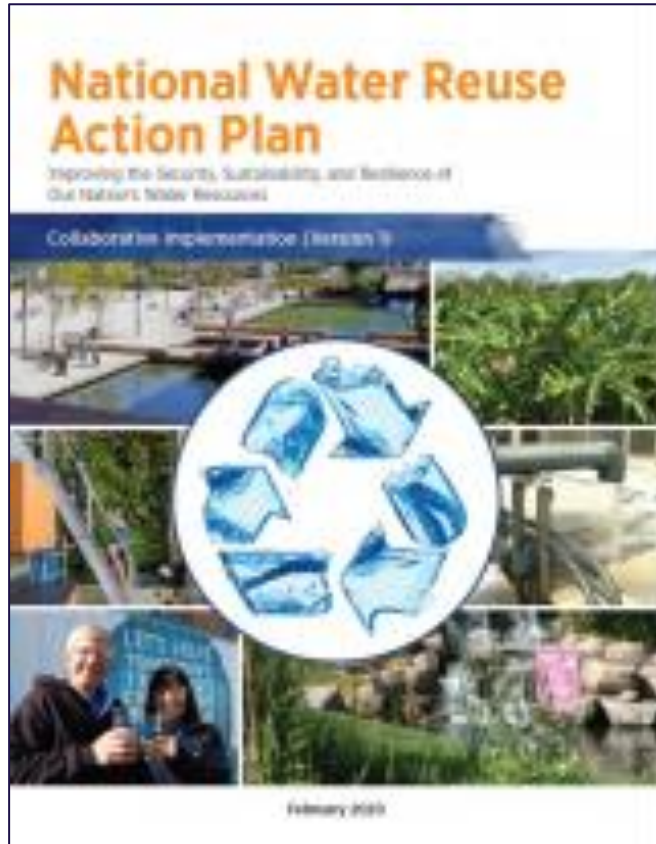
CHARTING OUR FUTURE

Presentation Overview

- EPA's National Water Reuse Action Plan and produced water
- The technical and health and safety challenges of the treatment and fit-for-purpose reuse of produced water
- National collaboration framework for produced water treatment and reuse
- State-of-the-science research to support the treatment and safe reuse of produced water



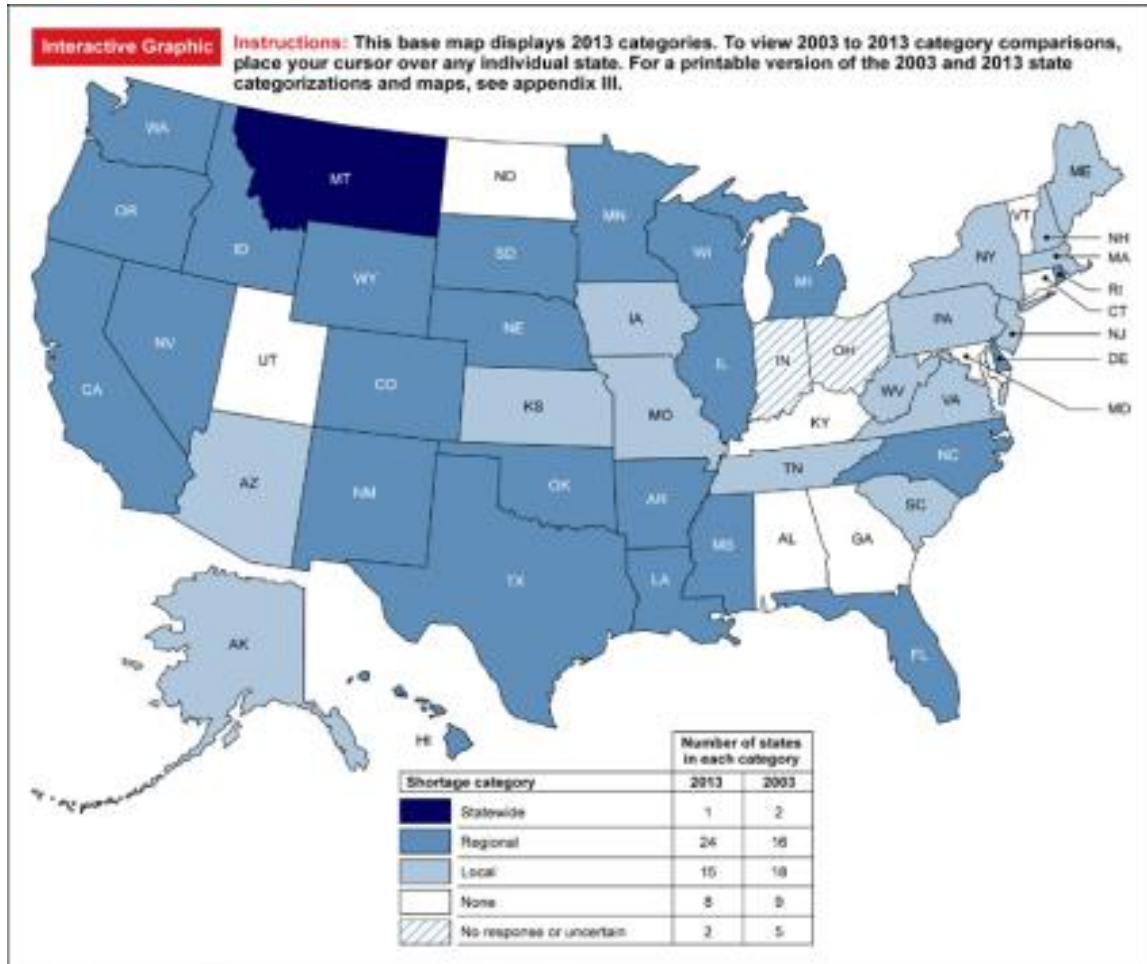
EPA National Water Reuse Action Plan



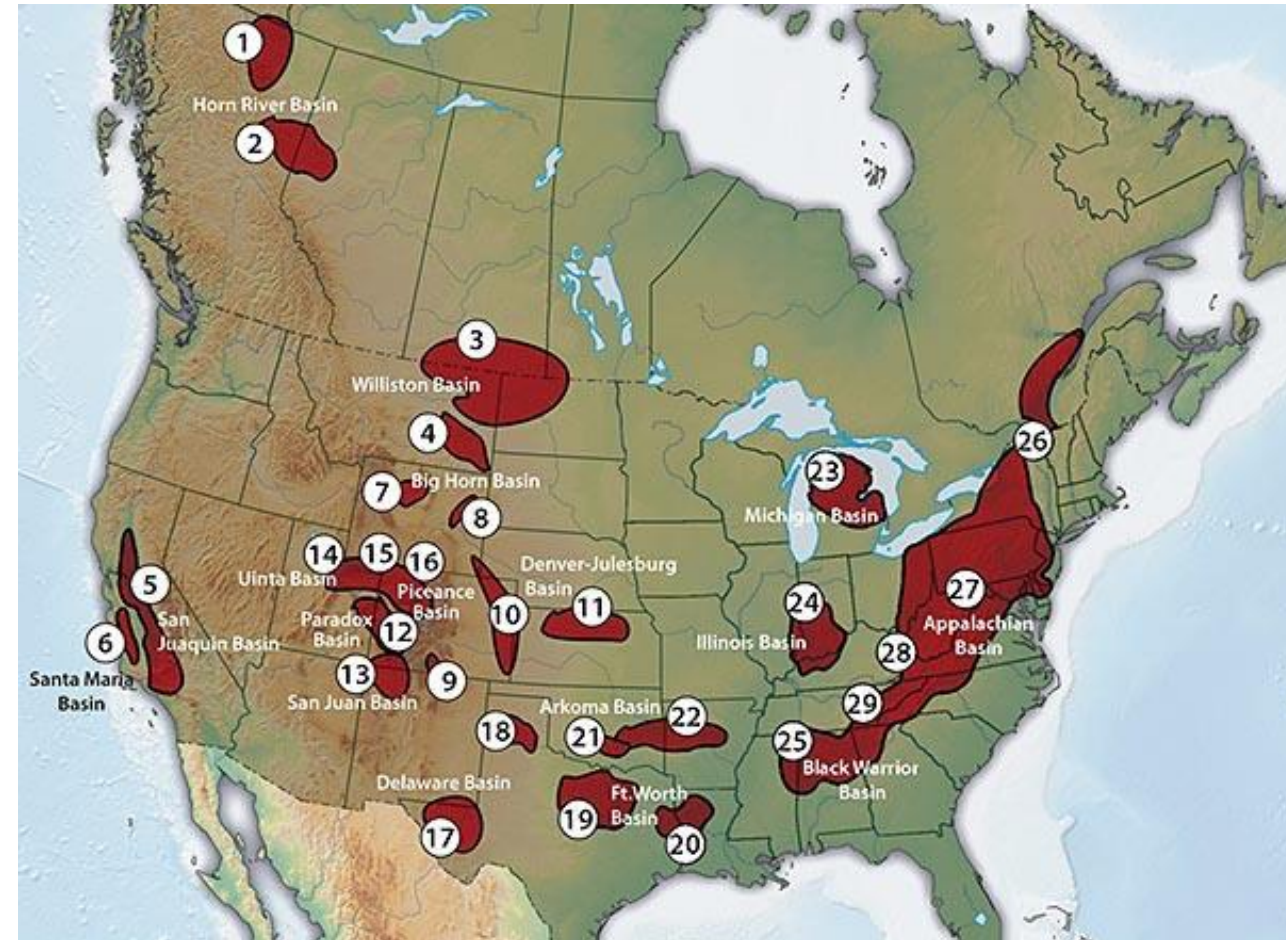
Two of the United Nations' **Sustainable Development Goals** identify **water reuse** as **key to a more sustainable future**.

- Focus on fit-for-purpose treatment and reuse of waste water
- Five major areas:
 - Thermo-electric cooling water
 - Agricultural waste water
 - Municipal waste water
 - Produced water
 - Storm water
- EPA asked the NMPWRC to lead efforts coordinating treatment and reuse of produced water outside oil and gas
- NMPWRC established a state coordinating council to improve collaboration and funding opportunities (NM, AZ, TX, WY, OK, CO, PA)

State Water Stress Driving Produced Water Reuse



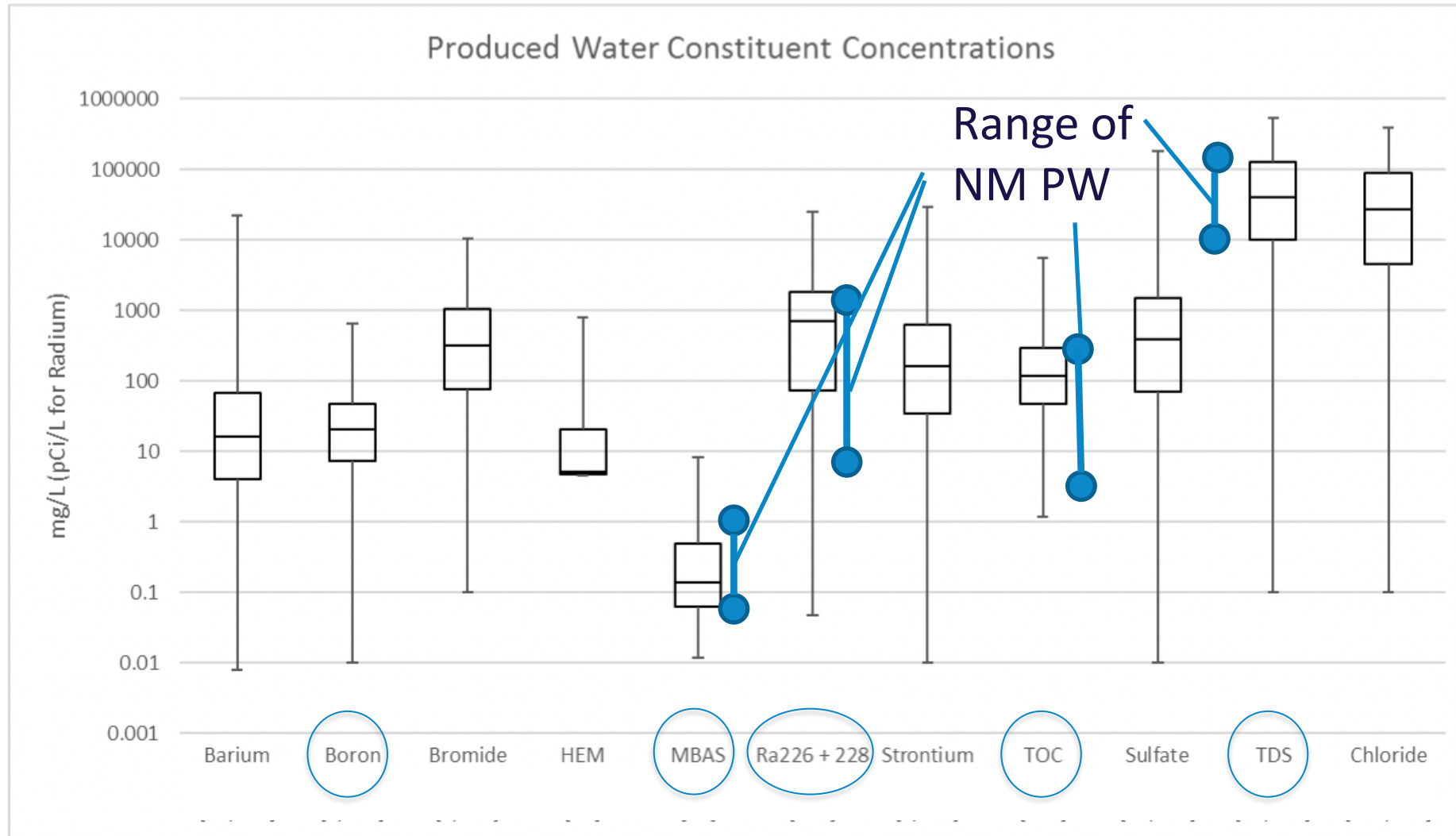
Sources: GAO analysis of state water managers' responses to GAO survey; Map Resources (msr).



Treatment Requirements for Fit-for-Purpose Reuse

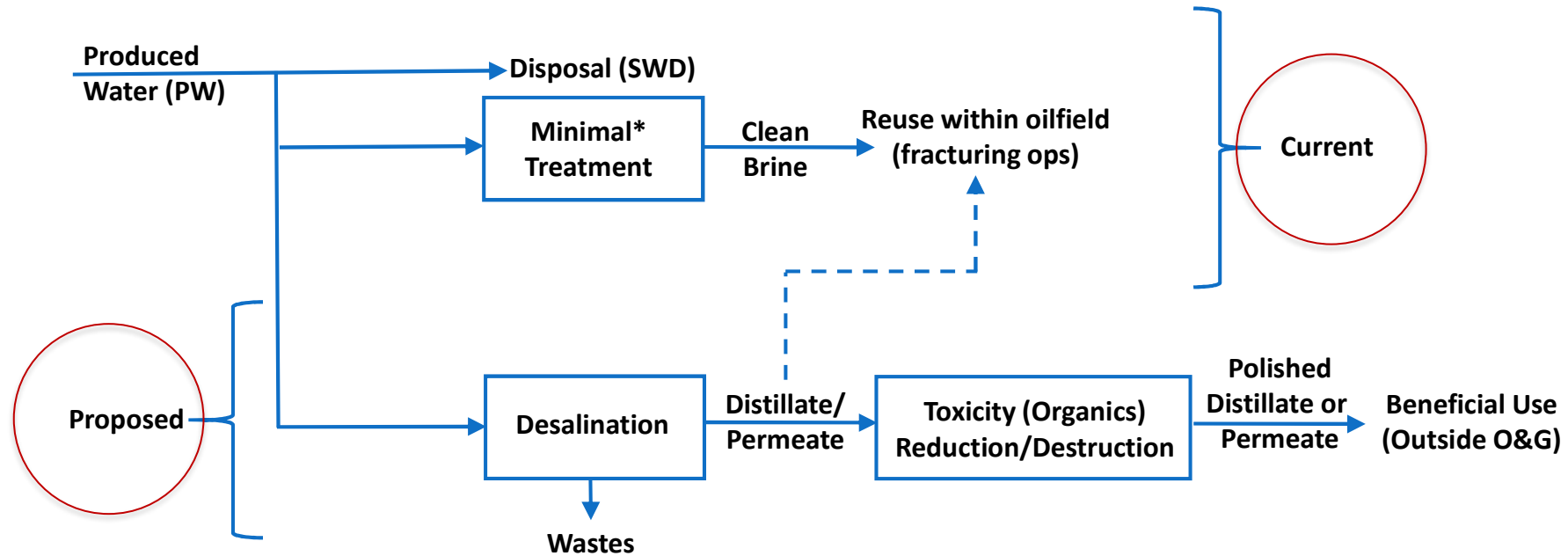
Produced Water Quality (ppm) TDS	Application	Common Water Quality Requirements (ppm) TDS
Conventional 10K to 50K 50%<35K 50%>35K	Water Supply Augmentation	300-3,000
	Agriculture	Class 1 <700, <60% Na, B<0.5 Class 2 2,000, 60-75% Na, B<2.0 Class 3 >2,000, 75% Na, B~2
	Rangeland restoration	4,000 – 10,000
	Industrial applications	1,000-2,000
	Mineral Recovery	>100,000
Unconventional 60K to 300K 50%<100K	Road Construction	Up to 100,000
	Solution Mining (K, Li)	Up to 250,000

Produced Water Will Require Treatment for Reuse



[EPA-821-S19-001]

PW Treatment and Fit-for-Purpose Reuse Considerations



Enhance fresh water sustainability
Reduce fresh water use in oil and gas
Support economic development
Reduce seismicity

Assure public and environmental health and safety through state-of-the-science risk and toxicology assessment
Assure social and environmental justice

Our Goal – A National Framework for Produced Water Treatment and Reuse

- **Collaborative process** – inclusive of multi-state health and resource agencies
- **Common produced water data collection and portal** – public and industry access to consistent water quality and quantity data
- **Standard technology testing and evaluation approach** - consistent independent assessment of health, safety, performance, and cost data
- **Standard risk and toxicology testing and analysis** – consistent water analysis, and public and environmental health, safety, and risk analysis to support consistent, science-based, treatment and reuse regulations and policies
- **Standard socio-economic cost/benefit analysis** - quantify ESG metrics to encourage appropriate, sustainable, and safe treatment and reuse applications

Benefits Public, Regulators, Industry, Technology Vendors

NM Produced Water Research Consortium

- MOU between the NMED and NMSU
 - Support NMED and state agencies in assessing produced water reuse
 - Coordinate research and development of fit-for-purpose treatment and reuse of produced water outside oil and gas
- Fill current science and technology gaps
 - **Use collaborative process - government, industry, university, and public**
 - **Assure reuse is protective of public and environmental health and safety**
- Initial 3-yr funding thru sponsorships
- Currently 80 organizations, 120 participants, 150 interested parties

20 state and federal agencies

60 industry, NGOs, associations, academia, consultants



Modeled after federal environmental technology verification programs



Produced Water Data Portal



Disposal Water Quality and Quantity data by ¼ Township.

- Data from OCD, USGS, NM Tech, NMSU, NMPWRC
- Dashboard – of monthly injected and quality data

Four levels of data:

- Tier 1 - General Public
- Tier 2 – Detailed Public
- Tier 3 – Application
- Tier 4 – Regulatory (Proprietary Need to Know)

Quarter Township Explorer

ID	Quantity Last Year (BBL)	Quantity Last Five Years (BBL)	Quantity Well Count
0105 032E NE	4931		1
0105 032E NE	6434	25973	1
0115 032E NE	0	12071	1
0115 032E NE	130	136870	1
0115 032E NE	205042	976493	3
0121 032E NE	267744	1025092	2
0121 032E NE	1935	30469	4
0121 032E NE	7662	477087	1
0121 032E NE	106295	533630	3
0121 032E NE	7094794	46457787	4
0165 032E NE	487152	2892052	2
0165 032E NE	7520	260977	1
0171 029E NE	3213337	23152566	7
0171 031E NE	198779	1002584	3
0171 031E NE	3380979	11987731	4
0171 031E NE	1342179	13892090	2
0185 027E NE	6585503	47355896	7
0185 032E NE	1342671	10661504	6
0185 032E NE	171990	656021	1

QTS ID: 20846

Location
 ID: 0195 032E SE Township: 19
 Township Dir: S Range: 32
 Range Dir: E Quarter: SE

Produced Water Quality
 Water Quality (TDS): 153034.47 Water Quality (pH): 6.76
 Water Quality (Cl): 86732.52 Quality Well Count: 5
 Quality Sample Count: 22

Produced Water Quantity
 Quantity Last Year: 1823329 Quantity Last Five Years: 15091377
 Quantity Well Count: 2

0125 034E NE	1555	30169
0145 033E NE	76802	477097
0155 033E NE	1062950	5336320
0155 037E NE	7094794	46457787
0165 032E NE	437152	2892652
0165 033E NE	7520	260977
0175 029E NE	3213337	23152566
0175 031E NE	198779	1002584
0175 036E NE	3380979	21397731
0175 038E NE	1342179	13892090
0185 027E NE	6585503	47355896
0185 028E NE	1342671	10661504

<http://nm.waterstar.org>

Waste Water Treatment and Reuse is Challenging



**Raw Municipal
Waste Water**

~60 major
constituents



**Raw Pecos River
Water**

~70 major
constituents




**Raw Produced
Water**


~90 major
constituents

NMSU found similar results for Permian produced water and Pecos River water based on nine samples each, collected in 2021 and monitored for 300 constituents

Produced water in most basins has nominally 100 +/- 20 constituents

Raw Waste Water Quality Analysis and Unknowns

Produced Water Samples		Average	Max	Min
Oil and Others				
Diesel Range Organics (C10-C20)	ug/L	45750	130000	22000
Gasoline Range Organics [C6 - C10]	ug/L	21625	46000	13000
Motor oil/lube range organics (MRO) (C20-C34)	ug/L	32444	97000	12000
Tributyl phosphate	ug/L	34.6	74	3.3
 Tentatively Identified Compound	ug/L	531	1000	280

Pecos River water samples		Average	Max	Min
Oil and Others				
Gasoline Range Organics [C6 - C10]	ug/L		54	ND
Motor oil/lube range organics (MRO) (C20-C34)	ug/L	230	310	180
Tributyl phosphate	ug/L	3.6	5.7	1.7
 Tentatively Identified Compound	ug/L	-	55	-

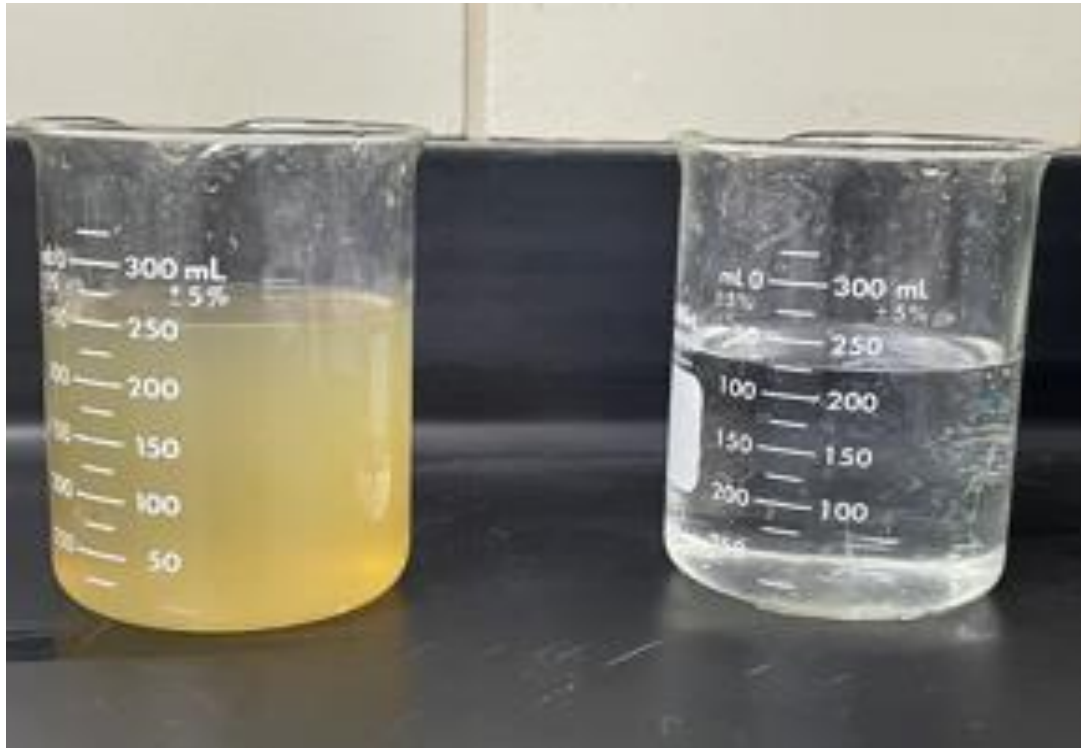
GC-MS TIC analysis is used for unknown identification in raw water

High Resolution Liquid Chromatography Mass Spectroscopy (HRLCMS) is being used to identify/quantify unknowns in treated produced water, by measuring molecular weights and comparing to data on 400,000 chemicals

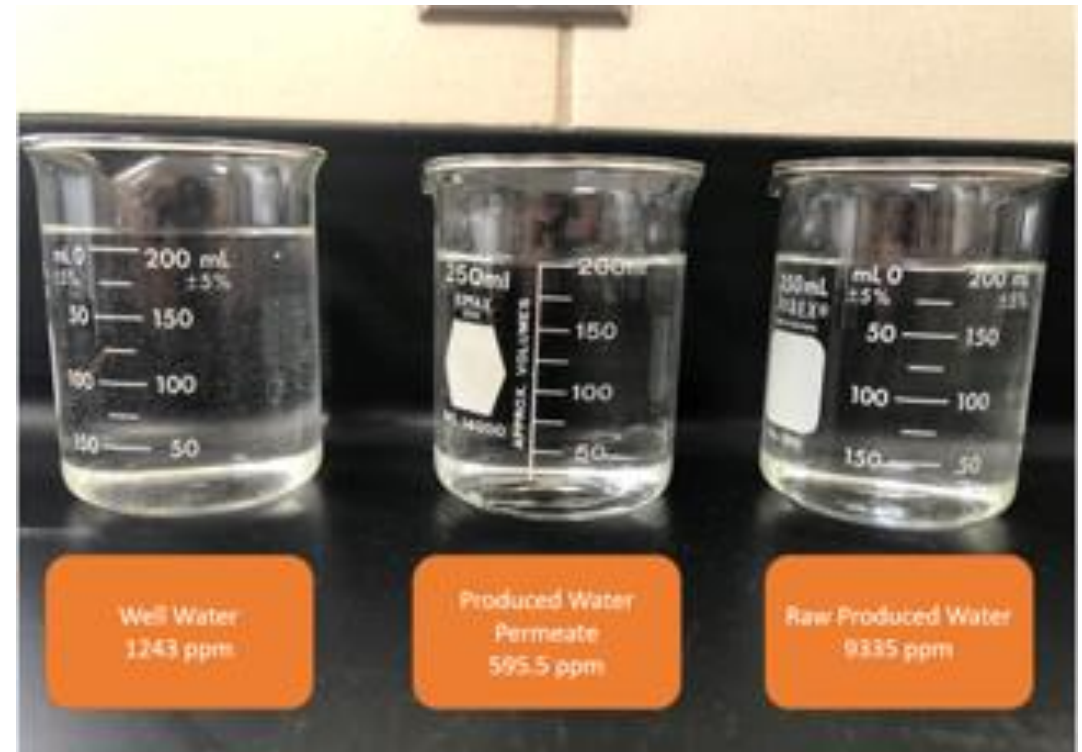
2021 Testing and Results

Company	Process	Location and Dates	PW Quality	Scale	Current Status
2021					
Kanalis Resources (self-funded)	Single pass RO - bench scale	BGNDRF April 2021	10K TDS San Juan Basin	20 bbls	Completed treatment with 30% single pass recovery, <500 ppm TDS permeate, all other constituents very low, Boron 2 ppm Green house study of range grasses w/treated PW completed in Dec 2021, no yield reduction
z-NANO	Composite ceramic/polymer pre-treatment membrane-bench-scale	BGNDRF June-July 2021 (4-6 weeks)	100K SWD Permian Basin	100 bbls per week/ 1-3 gallons per minute	Started June 15, completed August 12- Able to meet PWS 'clean-brine' standard
Crystal Clearwater	Thermal treatment field pilot-scale	Permian Basin site November - December 2021	150K SWD Permian Basin	4 weeks at 500 bbls/day	Coordinated with Cimarex and Solaris - Used waste heat from compressor station, <500 ppm TDS distillate, 40% recovery - ammonia and some organic carryover.

Examples of Raw and Treated Produced Water



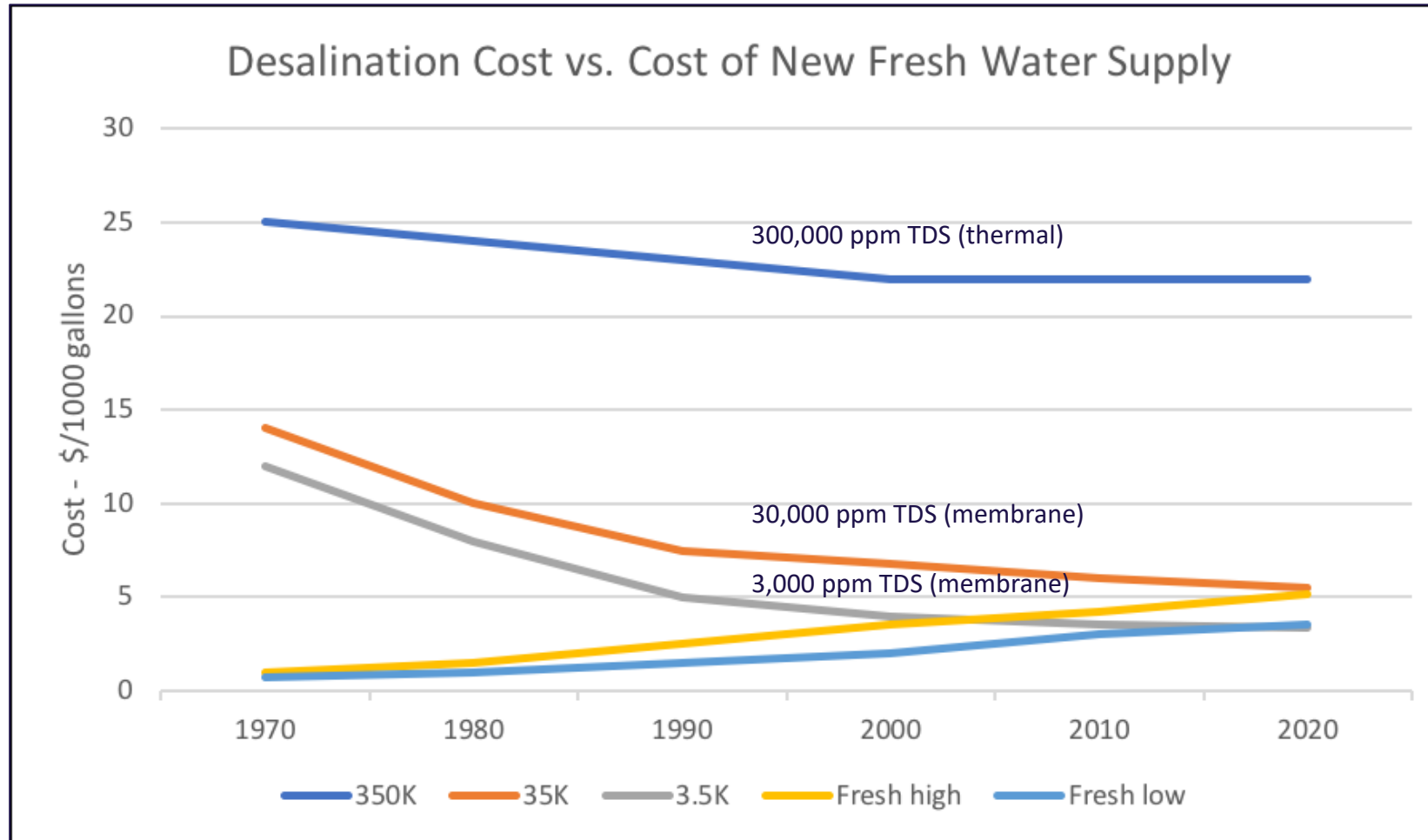
Permian Basin -100,000 TDS (left)
w/pre-treatment to remove oil, grease,
suspended solids (right)



San Juan Basin -10,000 TDS PW (right)
w/RO treatment to remove TDS (middle)

While not universal, treatment and reuse of produced water has occurred for decades in the US

Treatment Testing of Produced Water is Showing Good Economic and Environmental Performance



**Permian Basin
produced water disposal
\$15-30/1000 gal**

**Common
produced water disposal
\$25-100/1000 gal**

**Desalination treatment
results generally below
1000 mg/L TDS**

2022 Planned Treatment Testing

ZwitterCo (DOE-funded)	Zwitter ionic membrane for pre-treatment bench-scale	BGNDRF February - March 2022	100K TDS SWD Permian Basin	6 weeks, 192 hours continuous operation, ½ gal/min	Underway
New Mexico Tech (self-funded)	Membrane distillation treatment field-pilot	San Juan Basin February - May 2022	40K TDS San Juan Basin	20 bbls/day	Underway
Katz	Thermal treatment portable pilot-scale	BGNDRF March 2022	100K-150K	40 bbls/day for 10 days	March 12-20, 2022
Bechtel	Thermal treatment system upgrade pilot test	Bechtel Houston lab testing April 2022	100 K TDS Permian Basin	100 -200 bbls	Performance testing, follow on testing at field site later in 2022 if successful.
Intrepid	Sustainable solution mining, pre-treatment pilot-testing	Permian Basin July - Dec 2022	170-250K TDS	50 bbls/day	Pilot plant in design
Kanalis Resources (self-funded)	Small pilot of treated PW for ag	Southern San Juan Basin near Cuba	300 ppm TDS treated produced water from San Juan Basin	~2000 sq ft	Ag application for range grasses (8,000 gallons or 0.5 ac/ft) - Permit submitted to OCD then to NMED
Hydrozonix	Pre-treatment field pilot	Permian - Summer 2022	100K SWD	4000 bbls	Field site being identified with producer
W-Industries	Thermal Treatment	Permian - Summer 2022	100K SWD	1000 bbls/day, 10 days	Field site being identified with producer
GC Solutions	Pre-treatment evaluation using gel coagulant	BGNDRF May 2022	30K -100K TDS	4-5 different produced waters of varying TSS and VOCs - 10 gallons	Proof of concept and cost study

Major Collaboration with EPA, Academia, and Industry on Treated Produced Water Risk and Toxicology Analysis

- Collaboration with commercial WET testing laboratories, NMSU, and EPA to:
 - Expand WET laboratory testing to more representative human and ecologically sensitive species (zebra fish, fresh water mussels)
 - Support EPA Region 6, 8, and ORD on Region Applied Research Effort (RARE) on human cell line risk analysis of produced water and treated produced water
- Plant and soil bioaccumulation and toxicity green house testing with associated universities
- University and industry collaboration in establishing more detailed Environmental Risk and Toxicity modeling tools
- Utilize treated and post treated produced water



Oil and Gas Impact on Public and Environmental Health



< 0.25 miles from oil and gas operations

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



0.25 - 0.50 miles from oil and gas operations

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



> 0.50 miles from oil and gas operations

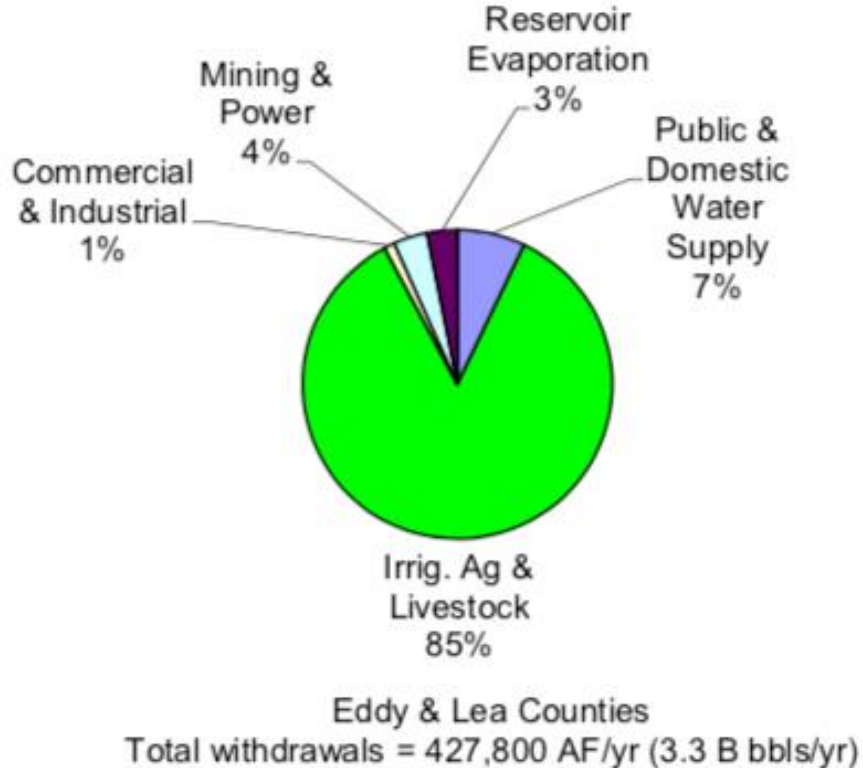
- Little observed acute or chronic public health and safety or environmental impacts
- Especially in open, flat, and non-wooded operational areas

- 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.

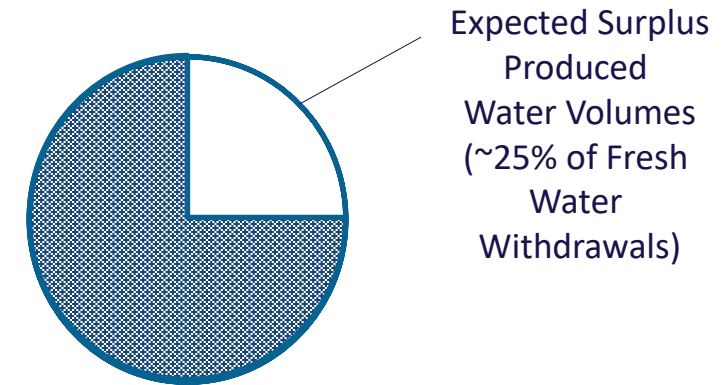
Quantitative Socio-economic Environmental Modeling of Produced Water Reuse

“Current ESG analysis and metrics is totally flawed” Kylie Wright, B3 Insight PWS 2022



Annual Fresh Water Withdrawal
[Thomson 2020]

Two county impact in NM of \$2-3 B/yr in economic development at low ecologic and human health risk



Surplus expected to be ~1 B bbls/yr (40-80 MGD)

Projected Produced Water Surplus

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NM Produced Water Research Consortium
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<https://nmpwrc.nmsu.edu>

