Land Application of Treated Produced Water in the Western U.S.

PERMIAN BASIN WATER IN ENERGY CONFERENCE
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NM STATE NEW MEXICO PRODUCED WATER RESEARCH CONSORTIUM

Summary of On-shore Produced Water Surface Discharge

Table 1: On-Shore Oil and Natural Gas Wastewater (Except Coalbed Methane)

Discharging Facility	Surface Discharge Purpose	Applicable ELGs	TBELs
On-shore oil and natural gas extraction facility	General discharge	40 CFR part 435, subpart C	No discharge of pollutants to surface waters
On-shore oil and natural gas extraction facility	West of the 98th meridian for specific uses in livestock or wildlife watering	40 CFR part 435, subpart E	Must be of good enough quality; also, daily maximum effluent limit for oil and grease of 35 mg/L
Stripper wells	General discharge	40 CFR part 435, subpart F	No specified limitations; TBELs developed by permitting authority on a BPJ basis
Coalbed methane (CBM) extraction facility	General discharge	40 CFR part 435, subpart H	No specified limitations; TBELs developed by permitting authority on a BPJ basis
Centralized waste treatment (CWT) facility	N/A	40 CFR part 437	For specific pollutant and limitations, see 40 CFR part 437

Ref: Oil and Natural Gas Produced Water Governance in New Mexico – Draft White Paper November 2018

Federal Guidelines on Produced Water Reuse

- 40 CFR 435 Subpart C– Oil and Gas Extraction Point Source Category
  - Defines produced water as “the water brought up from the hydrocarbon-bearing strata during the extraction of oil and gas, and can include formation water, injection water, and any chemicals added downhole or during oil/water separation process”
  - Unconventional produced water prohibited through a POTW
  - Zero discharge of produced water unless sent to a centralized water treatment (CWT) facility, **with one exception, west of the 98th Meridian**

General Oily Waste Discharge Regulations from a CWT

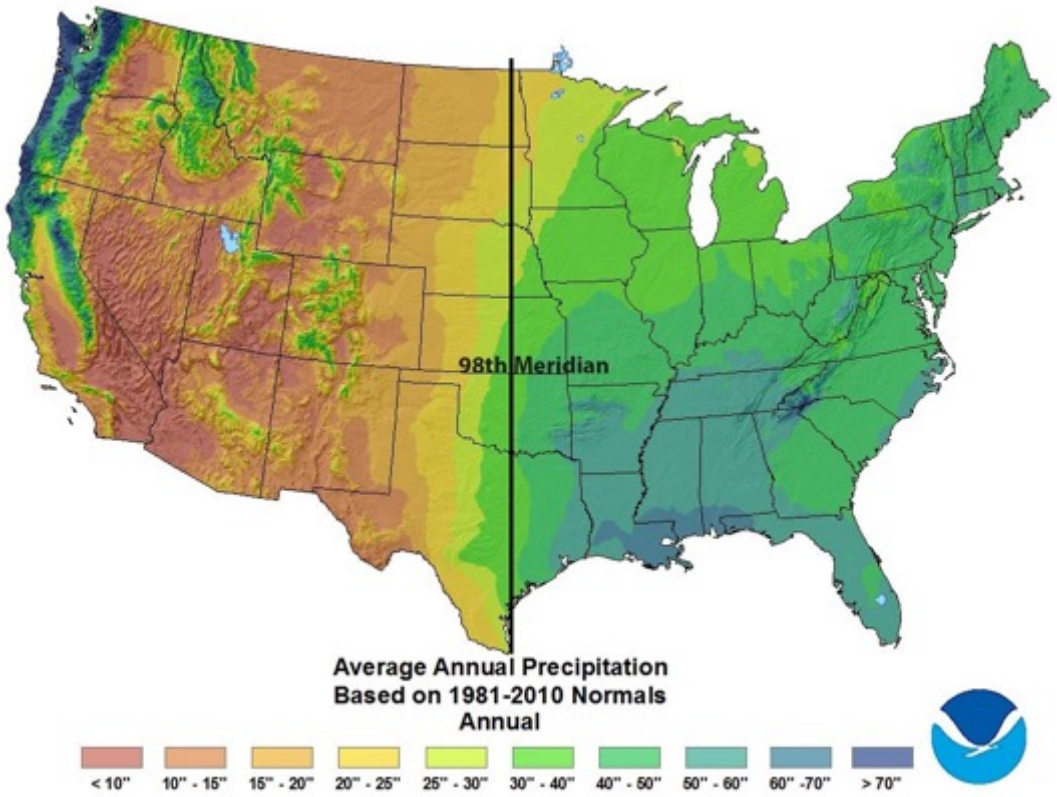
- 40 CFR 437 Centralized Water Treatment Point Source Category
  - Generally, produced water for reuse must be sent to a centralized water treatment (CWT) facility.
- 40 CFR 437 Subpart B – Oily Waste Water Treatment and Reuse
  - Minimum requirements in table at right,

    pH 6-9, all others mg/L
- Oily waste regulations usually considered not really appropriate for produced water

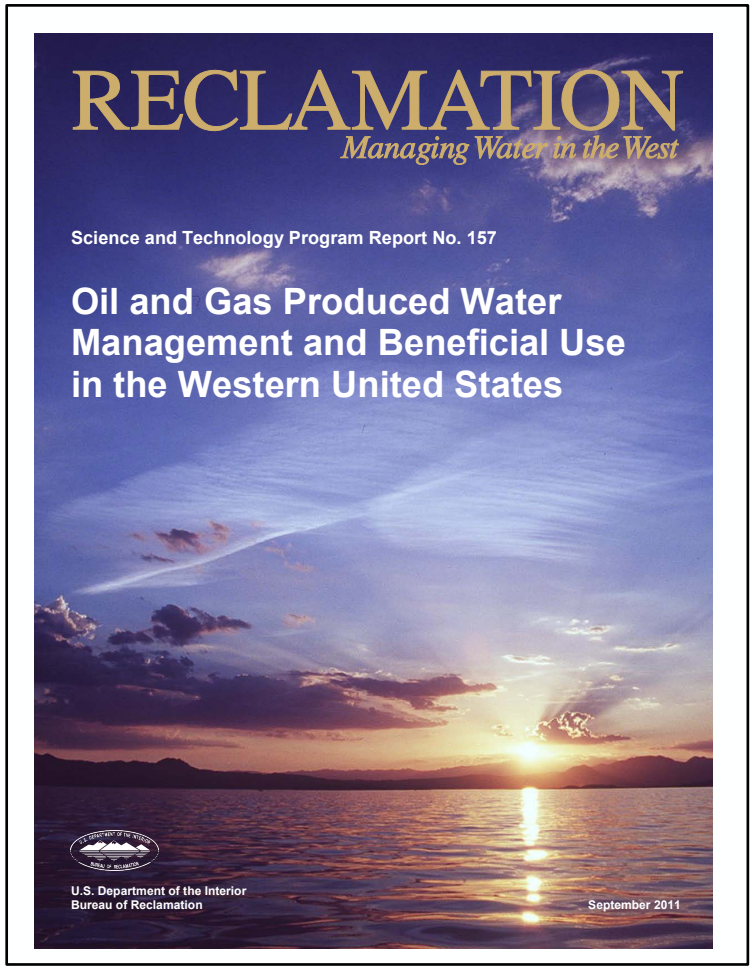
Regulated parameter	Maximum daily[1]	Maximum monthly avg.[1]
Conventional Parameters		
O&G	127	38.0
pH	([2])	([2])
TSS	74.1	30.6
Metal Parameters		
Arsenic	2.95	1.33
Cadmium	0.0172	0.0102
Chromium	0.746	0.323
Cobalt	56.4	18.8
Copper	0.500	0.242
Lead	0.350	0.160
Mercury	0.0172	0.00647
Tin	0.335	0.165
Zinc	8.26	4.50
Organic Parameters		
Bis(2-ethylhexyl) phthalate	0.215	0.101
Butylbenzyl phthalate	0.188	0.0887
Carbazole	0.598	0.276
n-Decane	0.948	0.437
Fluoranthene	0.0537	0.0268
n-Octadecane	0.589	0.302

Produced Water Reuse In Western Agriculture

- 40 CFR 435 (Subpart E) – On shore facilities west of the 98th Meridian can discharge produced water if it has a use in agriculture or wildlife propagation when discharged to waters of the U.S.
- 40 CFR 435.51(c) "can be used if produced water is of good enough quality for wildlife or livestock water or other agricultural uses and is actually put to such use during periods of discharge
- 40 CFR 435.52(b)
  - Max oil and grease – 35 mg/l



Bureau of Reclamation – Changed in Western Irrigation Science

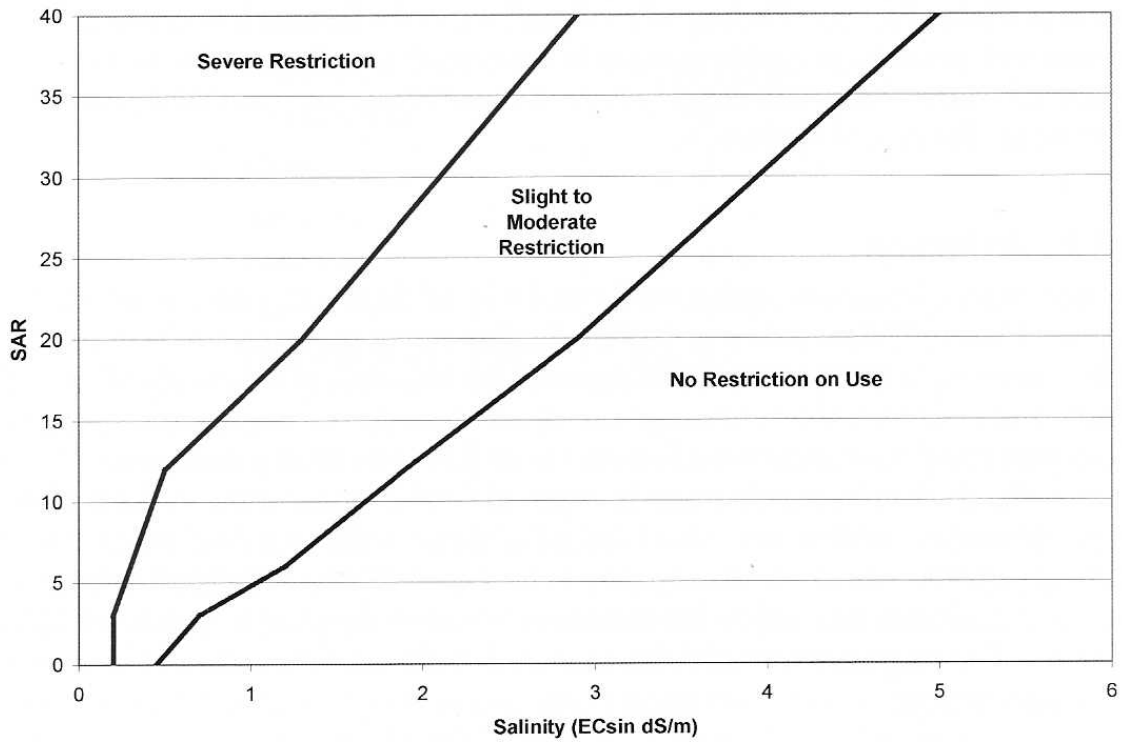


BOR Report 157, 2011

Current science on agricultural, livestock, and wildlife ecological considerations

- TDS/Electrical conductivity (Ec)
- Sodium Adsorption Ratio (SAR)
- Important individual constituents
  - boron,
  - selenium,
  - ammonia,
  - metals,
  - chlorides,
  - pH,
  - organics
  - NORM

Movement to Soil and Plant Chemistry based Irrigation Criteria Since the 1990's in Western States



- Historical classification
  - Class 1 <700 ppm TDS, <60% Na, B<0.5
  - Class 2 2000 ppm TDS, 60-75% Na, B<2.0
  - Class 3 >2000 ppm TDS, 75% Na, B~2
- Modern focus is on Sodium Absorption Ratio (SAR)

  $SAR = Na^{+}/((1/2(Ca^{2+} + Mg^{2+}))^{1/2}$
  where concentrations are expressed as milliequivalents per liter.
- Considers western alkaline soils and waters

Seeing Changes in Agricultural Water Quality Standards

Table 9. Constituent limits for irrigation water (adapted from Rowe and Abdel-Magid, 1995)

Constituent	Long-term Use (mg/L)	Short-term Use (mg/L)
Aluminum (Al)	5	20
Arsenic (As)	0.1	2
Beryllium (Be)	0.1	0.5
Boron (B)	0.75	2
Cadmium (Cd)	0.01	0.05
Chromium (Cr)	0.1	1
Cobalt (Co)	0.05	5
Copper (Cu)	0.2	5
Fluoride (F)	1	15
Iron (Fe)	5	20
Lead (Pb)	5	10
Lithium (Li)	2.5	2.5
Manganese (Mn)	0.2	10
Molybdenum (Mo)	0.01	0.05
Nickel (Ni)	0.2	2
Selenium (Se)	0.02	0.02
Vanadium (V)	0.1	1
Zinc (Zn)	2	10

Table 8. Crop tolerance to boron in irrigation water

Tolerance Level	Range of Boron Concentration	Crops
Very Sensitive	< 0.5 mg/L	Lemon, blackberry
Sensitive	0.5–0.75 mg/L	Avocado, grapefruit, orange, apricot, peach, cherry, plum, persimmon, fig, grape, walnut, pecan, cowpea, onion
Sensitive	0.75–1.0 mg/L	Garlic, sweet potato, wheat barley, sunflower, mung bean, sesame, lupine, strawberry, jerusalem artichoke, kidney bean, lima bean, peanut
Sensitive	1.0–2.0 mg/L	Red pepper, pea, carrot, radish, potato, cucumber
Moderately tolerant	2.0–4.0 mg/L	Lettuce, cabbage, celery, turnip, kentucky bluegrass, oats, maize, artichoke, tobacco, mustard, sweet clover, squash, muskmelon
Tolerant	4.0–6.0 mg/L	Sorghum, tomato, alfalfa, purple vetch, parsley, red beet, sugarbeet
Very tolerant	60–15.0 mg/L	Cotton, asparagus

pH -6.5-8.4
Chlorides < 100 mg/L
Nitrates – 10 to 45 mg/L

From BOR Report 157, 2011

Opportunity for Common Agricultural Discharge Standards

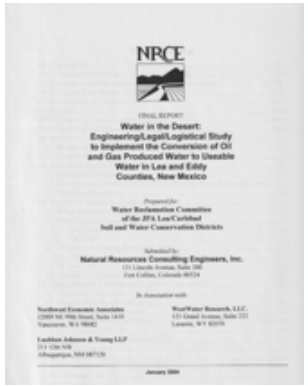
- Ag water quality standards are rather consistent in the West – CO, NM, BOR
- Emerging standards generally developed by western ag research centers
  - NMSU, Utah State, Texas A&M, Colorado State, UC Davis

Parameter	Units	NM Regulatory Value	BoR Recommended Ag Values
pH			6.5-8.0
Temperature	°C		25-30
Turbidity	NTU		30 max
Total dissolved solids (TDS not damage or impair animal, plant ,or aquatic life)	mg/L	5000	500-?*
Chlorides	mg/L		<100
Sulfates	mg/L		
Alkalinity	mg/L		<500*
Nitrates	mg/L		10-45
Total Metals	mg/L	~ <10	~<25
Aluminum	mg/L	5.0	5.0 long-term. 20.0 short-term
Arsenic	mg/L	0.1	0.1 - 2.0
Beryllium	mg/L		0.1 - 0.5
Boron	mg/L	0.75	0.75 - 5.0
Cadmium	mg/L	0.010	0.01 - 0.05
Chromium	mg/L	0.100	0.10 - 1.0
Cobalt	mg/L	0.050	0.05 - 5.0
Copper	mg/L	0.200	0.20 - 5.0
Fluoride	mg/L		1.0 - 15.0
Iron	mg/L		5.0 - 20.0
Lead	mg/L	5.0	5.0 - 10.0
Lithium	mg/L		2.5
Manganese	mg/L		0.20 - 10.0
Molybdenum, dissolved	mg/L	1.0	0.01 - 0.05
Nickel	mg/L		0.20 - 2.0
Selenium	mg/L	0.050	0.02
Vanadium, dissolved	mg/L	0.100	0.1 - 1.0
Zinc	mg/L	2.0	2.0 - 10.0
Naturally Occurring Radioactive Material	pCi/L	~ <30 *	
Adjusted gross alpha	pCi/L	15*	
Radium 226+228	pCi/L	30*	
Total Oils and Grease	mg/L		35*
Ammonium (NH_4^+)	mg/L		10-40*

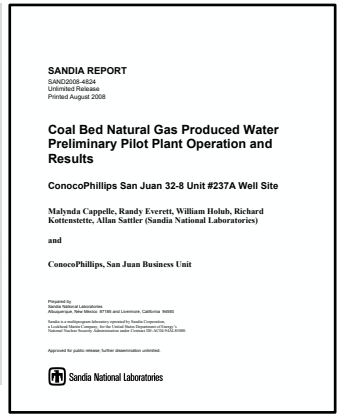
* Federal guidelines or common state guidelines based on wildlife and health issues

Pilot Treated Produced Water Reuse in Rangeland Restoration

- Conoco Phillips/Sandia/NMSU Ag Research Center 2004-2008
  - BLM research permit with OCD
  - Treated 25,000 ppm TDS produced water with pre-treatment and RO - then blended with produced water to get 2,000 ppm -12,000 ppm
  - 6 tons/ac CO2 sequestration
  - Sprinkler and water cannon irrigation on several acres
  - 3-4 acre-inches per year to supplement rainfall
  - 6,000 ppm TDS blended PW had best growth
- Based on SAR ag water quality requirements and common western soil adapted grasses


NRCE

Water in the Desert:
Engineering/Legal/Logistical Study to Implement the Conversion of Oil and Gas Produced Water to Useable Water in Lea and Eddy Counties, New Mexico


SANDIA REPORT
SAND2008-4824
Unlimited Release
Printed August 2008

Coal Bed Natural Gas Produced Water Preliminary Pilot Plant Operation and Results

ConocoPhillips San Juan 32-8 Unit #237A Well Site

Malynda Cappelle, Randy Everett, William Holub, Richard Kottenstette, Allan Sattler (Sandia National Laboratories)

and

ConocoPhillips, San Juan Business Unit

Sandia National Laboratories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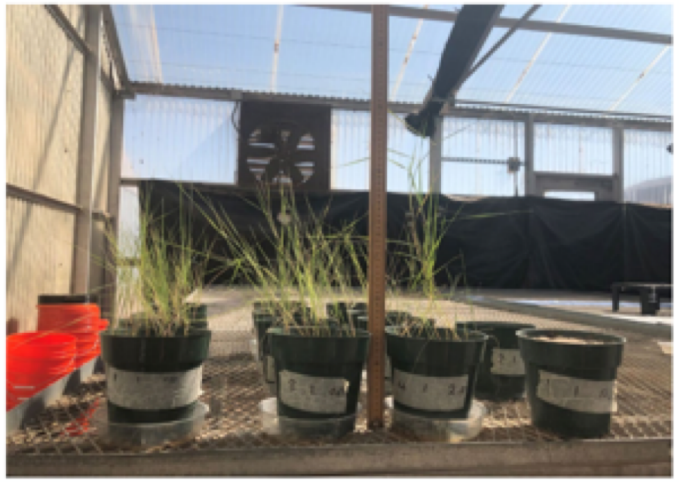
Common Green House Ag Studies with Produced Water

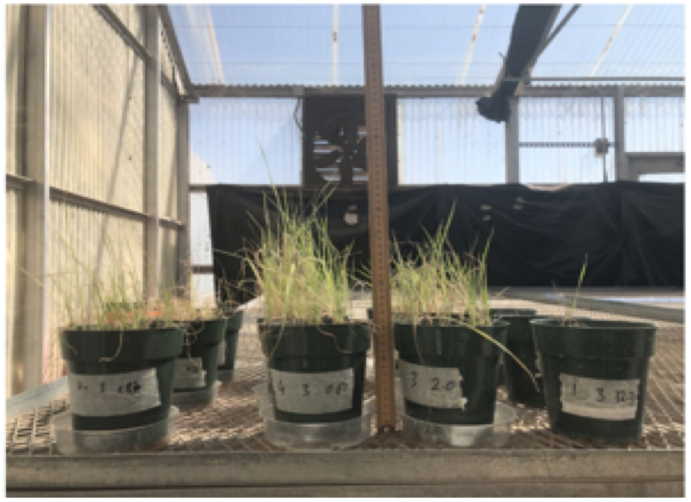
- Treated vs diluted water results can be significant
- Constituent ratios and soils are important
- Always identify waters – e.g.
  - Diluted PW (1400 ppm)
  - Tap water (400 ppm)
  - Treated PW(250 ppm)
  - Raw PW (8500 ppm)
- Coordinate with ag agencies (NRCS etc.)

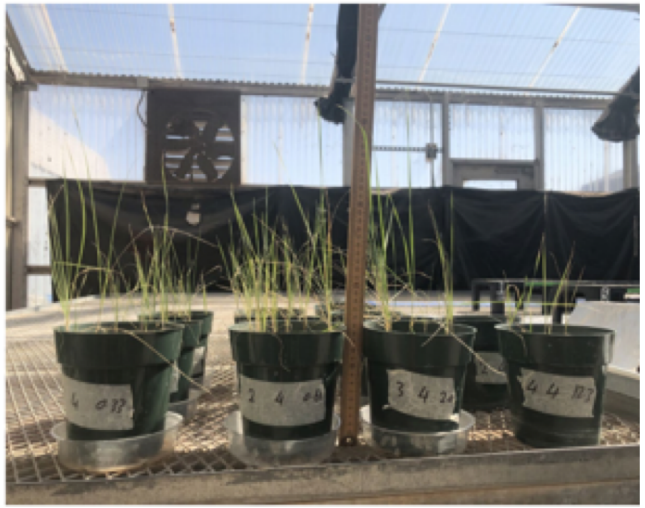
Western Wheat grass



Alfalfa

Meadow Brome grass





Russian Wildrye

Closing Comments – EPA Permitting, Collaboration

- 40CFR 261.4 (b)(5) – Produced water exempted as a hazardous waste
  - 40CFR 270.65 – RDD Permit only for 'hazardous waste' therefore not applicable to PW
- 40CFR 122 – NPDES permits for irrigation applications vary by WOTUS
  - 122.46 (c) –allows for short research spans i.e. pilot-scale projects
- Science-based irrigation standards from western ag research centers – NMSU, CSU, TAMU, UC Davis, Utah State, etc. are being used
- Permian Basin should have consistent agricultural and wildlife water quality standards and regulations – TX, NM, BOR, CO are close
- Produced water can be treated to meet current science-based irrigation standards, and studies have shown ecological and fresh water sustainability benefits of doing so in the west.

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