Making Produced Water More Productive

Alternative Uses and Reuse of Produced Water

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Dr. Jeri Sullivan Graham
Los Alamos National Laboratory
Jeri.sullivangraham@state.nm.us
ejs@lanl.gov
505-695-4875

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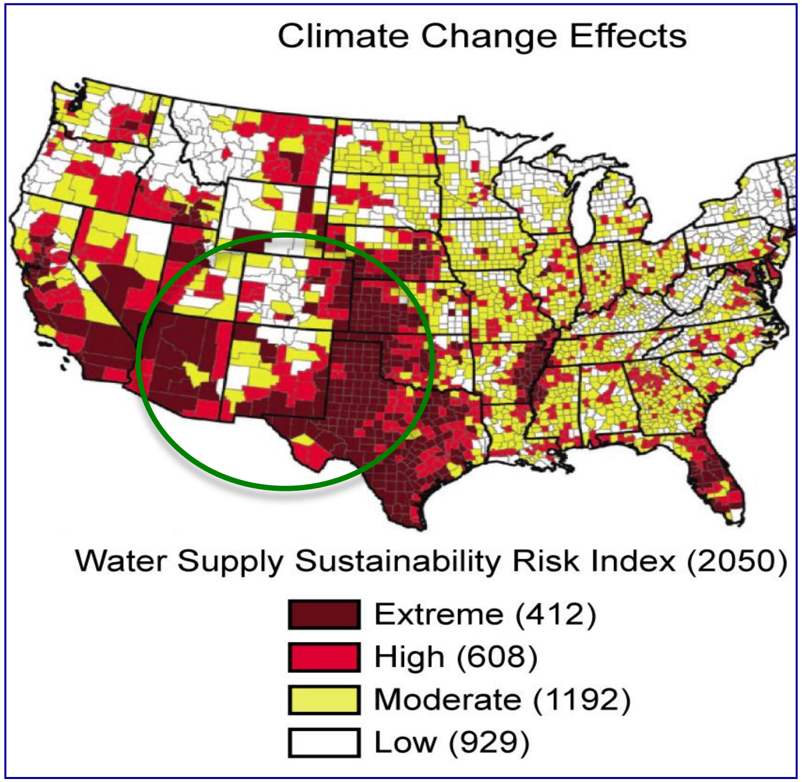
Energy, Minerals and Natural Resources Department

Southwest & Southern Rocky Mountain Region

- The region is delicately balanced in terms of water supplies and demands
- Impacts of climate change and energy production are acute
- Important water-energy challenges:
  - Climate impacts
  - Disruptive events: fire, floods, infrastructure failure
  - Fully allocated water rights
  - Growing/shifting population
  - Rapid and extensive energy development
  - Uncertainties in water for power production



Key Aspects to Implementing PW Use

- **Availability**-right place, right time, right volume
- **Treatment**-Metals, TSS, scale-forming minerals, biologics, organic compounds
- **Liability, Risk Perception and Use Acceptance**
  - Who owns the water? Who owns the minerals? What if something undesirable happens?
  - Industrial Uses-e.g., mining, oil and gas production
  - Other Human Uses-irrigation, industry, drinking
  - Biofuel production and coproducts (animal feed, pharmaceuticals)
- **Safe Use and the Environment**
  - Handling salty water and waste from treatment (concentrate)
  - Operations-spills, corrosion in wells and pipelines, storage
  - Non-impingement on fresh water resources
  - Long-term sustainability of the resource-planned obsolescence?
  - Hydrologic Studies and regional/basin data
- **Policies-**water rights or rights of capture, inter-basin transfers
- **Regulations promoting or inhibiting use (RCRA, state, EPA, etc.)**
- **Market Analysis**
  - Which customer will buy the water? At what price? …and Scarcity perceptions
- **Infrastructure Investment**
- **Costs**
  - Access (pumping from subsurface)
  - Transport
  - Treatment and waste disposal (solids, liquid concentrate)
- **Financing-Public or Private?**
- **Partnerships** with Industry and Localities
  - Build-Own-Operate-Transfer (BOOT), Design-Build-Finance-Transfer (DBFT) and other structures

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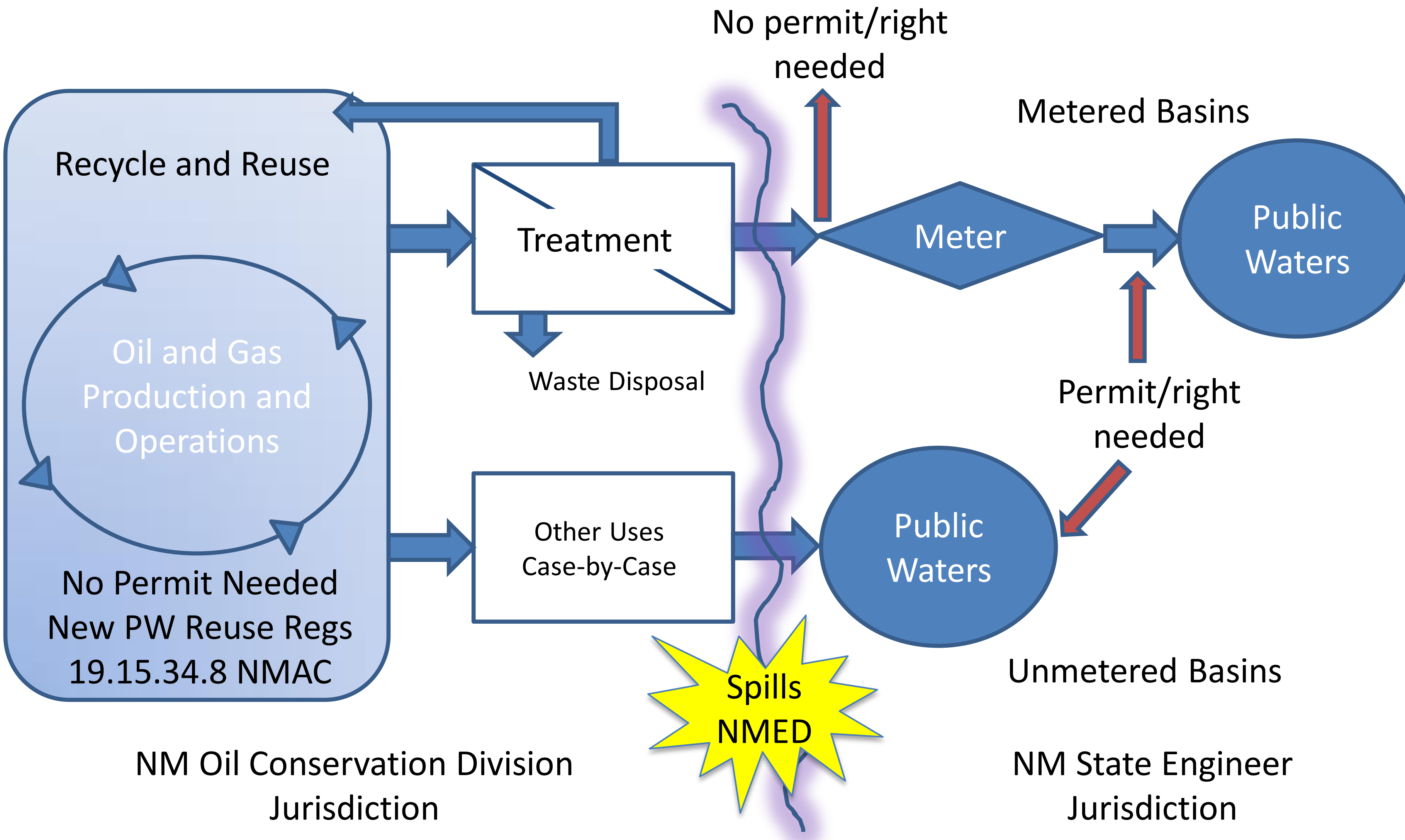
New Mexico Produced Water Regulatory Framework for Reuse-*a fuzzy dividing line…..*



Alternative uses for Produced Water

- Reuse in oil and gas production
  - Hydraulic fracturing
  - Steamflooding (California)
- Irrigation (after treatment or dilution)
  - Rangeland rehabilitation
  - Non-food (cotton) crops
- Algal biofuel production
- Potash mining (proposed)

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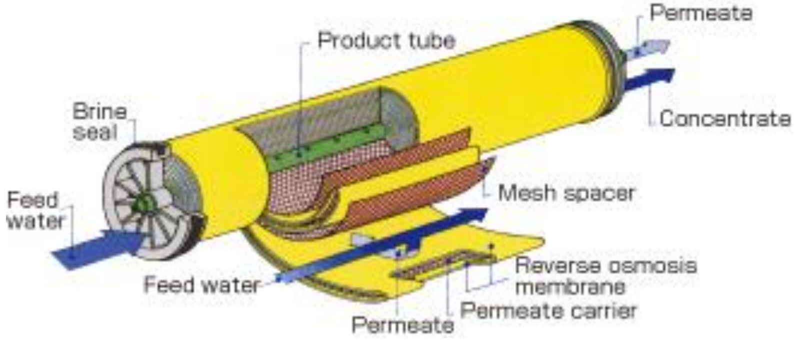
Reuse Criteria for HF

- Critical treatments for reuse in hydraulic fracturing
  - Solids/TSS
  - Free and colloidal oil
  - Microbes
  - Iron and floc formers
  - Ion balance (divalents; mineral scale inhibition)
  - Boron (cross link disruption)
- Less critical: pH, salinity. Salinity can be as high as ~200,000 mg/L TDS

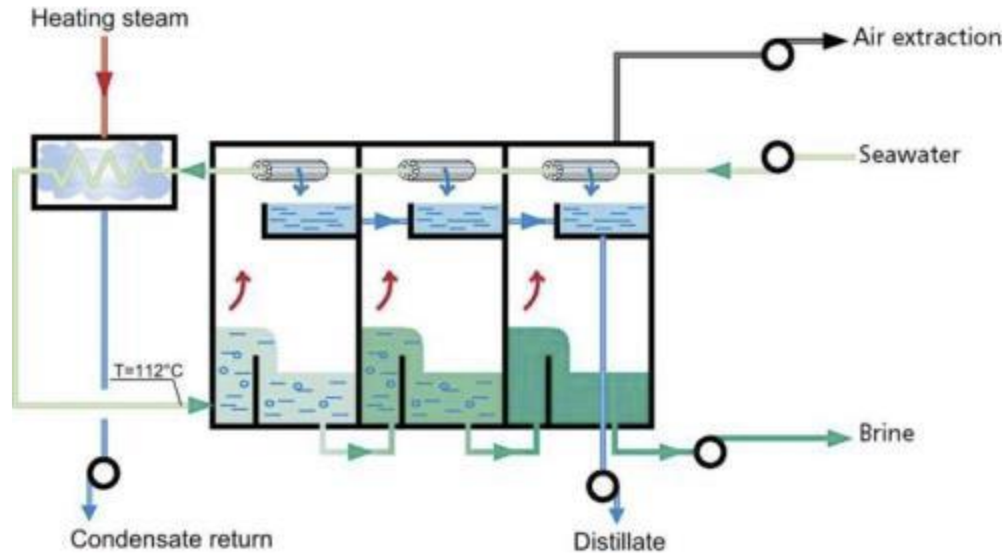
Many treatment options

- Membrane methods
  - Reverse Osmosis
  - Nanofiltration
  - Common in US
  - Usually for seawater



We can recover about 50% of the input water; the rest is concentrated waste that must be disposed at a cost!

More Options



- Thermal methods
  - Multistage Flash Distillation
  - Multiple Effect Distillation
  - Solar Thermal
  - Most Common in the Mideast (in combo with power gen)
  - Now being used for produced water

A solar receiver in a field in Firebaugh, Calif. It is part of a project developed by WaterFX to cleanse water at a lower cost than traditional desalinization.
Peter DaSilva for The New York Times

Solar Distillation
Parabolic trough with heat transfer fluid
(Solar FX-image from New York Times)

More Options

- Hybrid Membrane/Thermal methods
  - Membrane Distillation
  - Low-Temperature Distillation (LTDis)
- Electrocoagulation, Capacitive Deionization
  - Uses for specific constituents, lower salinities

	SWRO	SWRO	LTDis
Year	2015	2030 (projection)	2015
Cost of water $/m^3$	0.4–0.7	0.3–0.4	0.25–0.35
Construction $/m^3$	1,000–1,700	500–1,000	500–700
Power use (kWh/m^3)	2.1–2.6	1.3–1.7	0.8–1.3
Recovery ratio (%)	50–55	55–65	80
Plant uptime (%)	70–80		>95
Source: D&WR, February March 2015 p.23			

Oil and Gas producers are reducing fresh water consumption

- Treatment goal: 100% PW reuse; retain cross-link gel efficiency

	FW Job	PW w/ EC	PW w/o Treatment
Water Cost	$250,000	$0	$0
Water Treatment	$0	$65,000	$22,500
Water Transport	$75,000	$285,000	$285,000
Pumping Cost	$1,300,000	$1,500,000	$1,500,000
Total Cost	$1,625,000	$1,850,000	$1,807,500

Information courtesy of Kent Adams, VP, Bopco LP

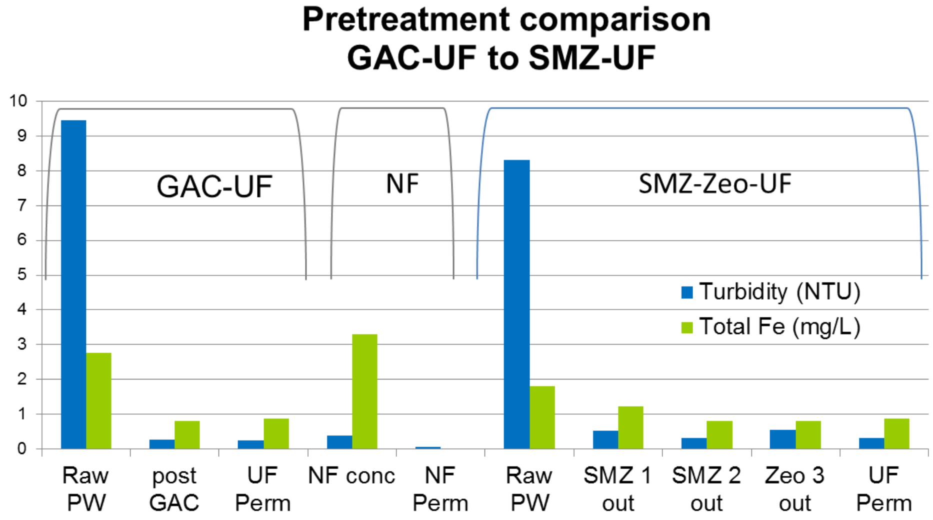
PW Treatment for Steam Generation and Aquifer Recharge

- California's San Ardo field
- Treatment to assure discharge water quality standards and Once Through Steam Generator quality requirements
- Goals: reduce Total Dissolved Solids and Boron while maintaining 75% recovery.
- Methods: oil removal/sorption, softening, filtration, and Reverse Osmosis.
- Results: Reuse of water in oilfield and recharge to groundwater via basins. 50,000 bbls per day of treated water for discharge.
- http://www.veoliawaterstna.com/news-resources/case-studies/opus_technology_aquifer.htm

Produced Water Treatment for use in Rangeland Rehabilitation, Bloomfield NM

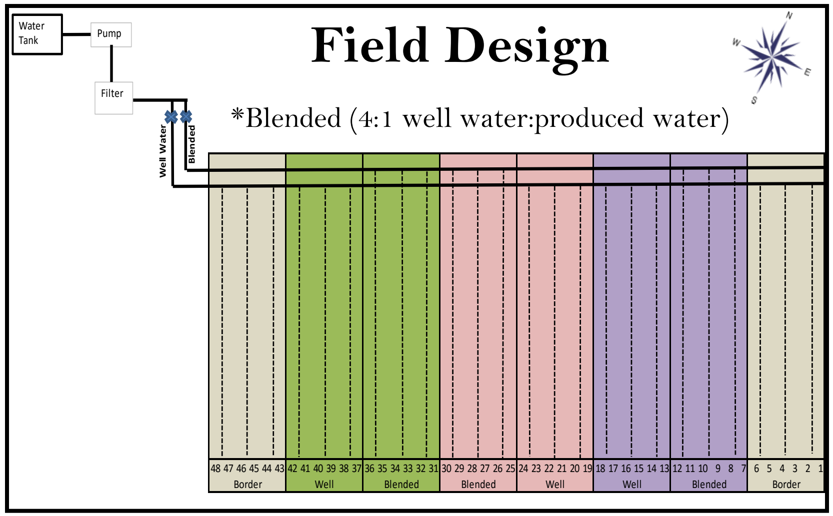
- Coal bed methane produced water was treated with multiple steps for organic, coal fine, and salt removal
- Water was discharged to comparative rangeland plots to evaluate most appropriate quality for vegetation rehabilitation
- Collaborative effort between Conoco Phillips, small businesses, LANL, SNL, Bureau of Land Management, and State of NM

Coal fines accumulating in the modified zeolite filtration medium.



Cotton Production Using Produced Water

Katie Lewis, Dustin Kelley, and Jaroy Moore
Texas A&M AgriLife Research



Pecos Soil Characteristics

Hoban silty clay loam

(17% $CaCO_3$ and 31% gypsum)

Variety: DP 1359
Planted: 2 June 2015

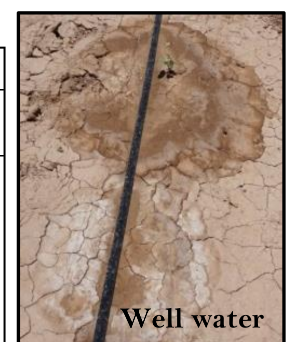
Irrigation Source	Lint Yield (kg/ha)
Well	658
Blended	637
P-value	0.834

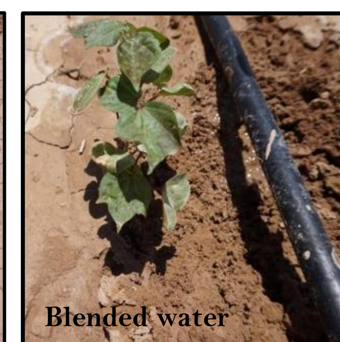
Prior to Study Initiation

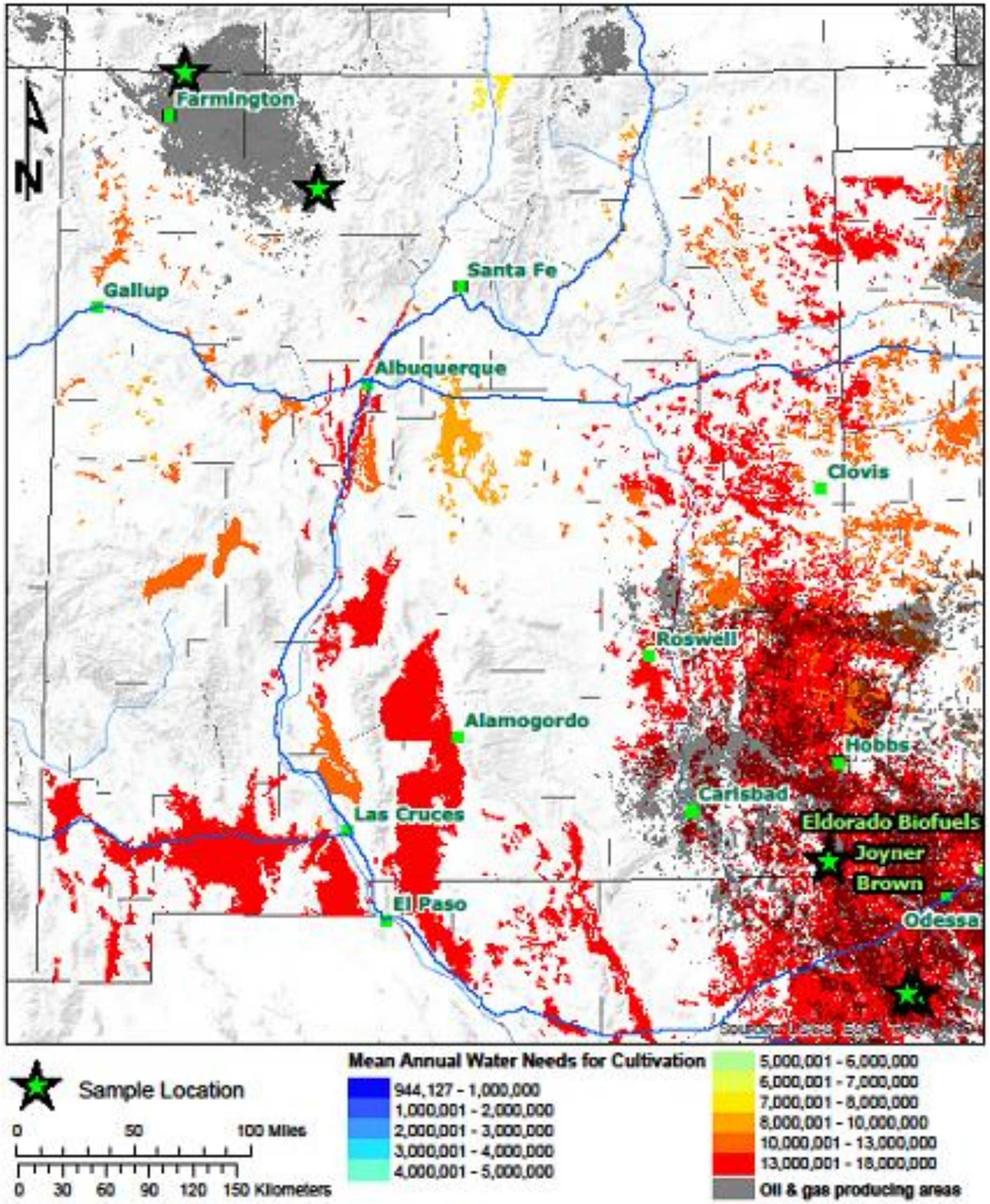
pH	EC	NO_3-N	P	K	Ca	Mg	S	Na	SAR
--	dS/m	mg/kg							--
8.7	1.8	22.1	30.0	450	17634	516	482	1373	16.7

Soil samples collected 7 Sept 2015

Irrigation Source	Depth cm	pH --	EC dS/m	NO_3-N	P	K	Ca	Mg	S	Na	B	Cl	SAR --
				mg/kg									
Blended	0-15	9.0	1.5	9	35	531	14915	575	654	1230	1.6	1018	13.8
	15-30	9.1	1.2	12	26	474	16896	513	476	1347	1.2	896	17.6
	30-60	8.8	1.7	19	19	425	24243	485	528	1349	1.2	1256	15.3
Well	0-15	8.9	2.2	36	35	528	15054	596	835	1751	1.6	1637	17.5
	15-30	9.0	2.1	18	26	471	16352	514	503	1496	1.1	979	17.3
	30-60	8.8	1.8	26	16	409	25706	485	504	1487	1.2	1609	16.9


Well water


Blended water



Farmington
Gallup
Santa Fe
Albuquerque
Clovis
Roswell
Alamogordo
Hobbs
Carlsbad
Las Cruces
El Paso
Eldorado Biofuels
Joyner
Brown
Odessa
N
Sample Location
0
50
100 Miles
0
30
60
90
120
150 Kilometers
Mean Annual Water Needs for Cultivation
944,127 - 1,000,000
1,000,001 - 2,000,000
2,000,001 - 3,000,000
3,000,001 - 4,000,000
4,000,001 - 5,000,000
5,000,001 - 6,000,000
6,000,001 - 7,000,000
7,000,001 - 8,000,000
8,000,001 - 10,000,000
10,000,001 - 13,000,000
13,000,001 - 18,000,000
Oil & gas producing areas

Produced Water Treatment Process, Jal, NM

Inflow → Oil/water separator → Sand/ carbon filter → Raw product tank

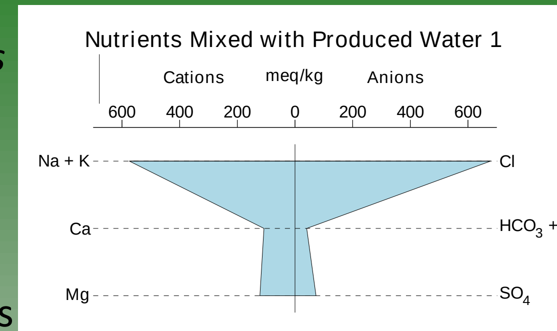
pH adjustment tank → Polyfloc tank → Stack scrubber/ ozone → Finish Product Tank

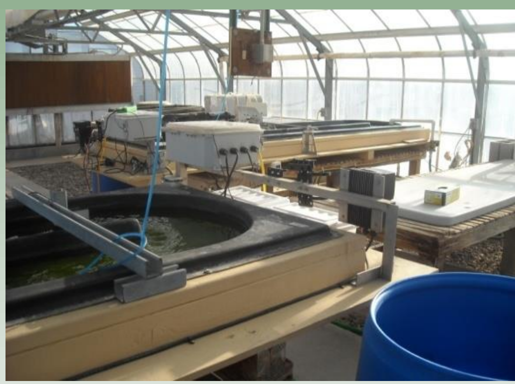
- **Sampling event on October 4, 2011 at the Jal, NM Facility.**
- **Sampling points include raw inflow water from an oil well, post oil/water separation, post sand/carbon filtration, post flocculation and post ozone treatment.**

Growing algae in Produced Water

Lab Scale-LANL

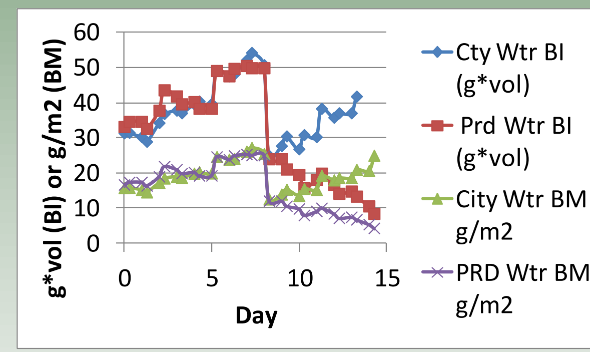
N. Salina 1776; *Scenedesmus+Tetracystis*
Salinity 10,000-30,000 mg/L
Testing various salinity ranges (10,000-30,000 mg/L); Cu:Zn ratios; HCO_3^- concentrations (200-1,000 mg/L)
Modeling used to optimize media recipes





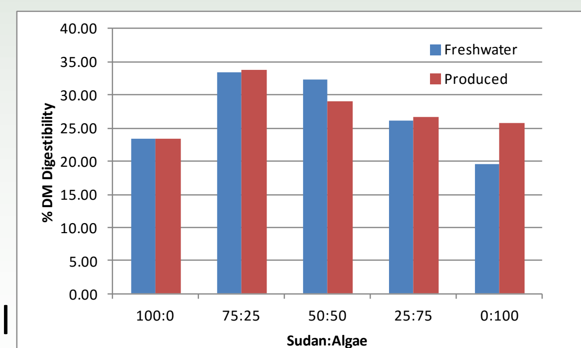
Pilot Scale-Texas Agrilife Pecos

N. Salina 1776;
salinity 19,000-28,000 mg/L
OD=0.6-0.8; AFDW=0.35 g/L;
BI=8-50 g/L
Exhibited low tolerance to higher salinity range



Field Scale-Eldorado Biofuels

Scenedesmus+Tetracystis (Jalgae™);
Salinity 11,000-13,000 mg/L
Growing consistently in treated PW
Low concentration commercial fertilizer sources of N, P, K
HCO_3^- concentrations ~700-900 mg/L
Diluent fresh water from local stock well
Quality is similar to FW samples



Contact for more information–

Jeri Sullivan Graham, Ph.D
Los Alamos National Laboratory
ejs@lanl.gov; 505-695-4875 c
New Mexico Energy, Minerals and Natural Resources Department
Jeri.sullivangraham@state.nm.us

photo courtesy of Chip MacLaughlin (chip.maclaughlin@laredopetro.com) accessed 07/25/2014.

Katie L. Lewis
Texas A&M AgriLife Research – Lubbock
katie.lewis@ag.tamu.edu
361-815-3836