Agricultural Reuse of Treated Produced Water

Katie Lewis and Jaroy Moore

Texas A&M AgriLife Research – Lubbock

Bill Weathersby

Energy Water Solutions

Purpose of Project

Use locally produced oilfield-generated produced water for agricultural beneficial reuse purposes.

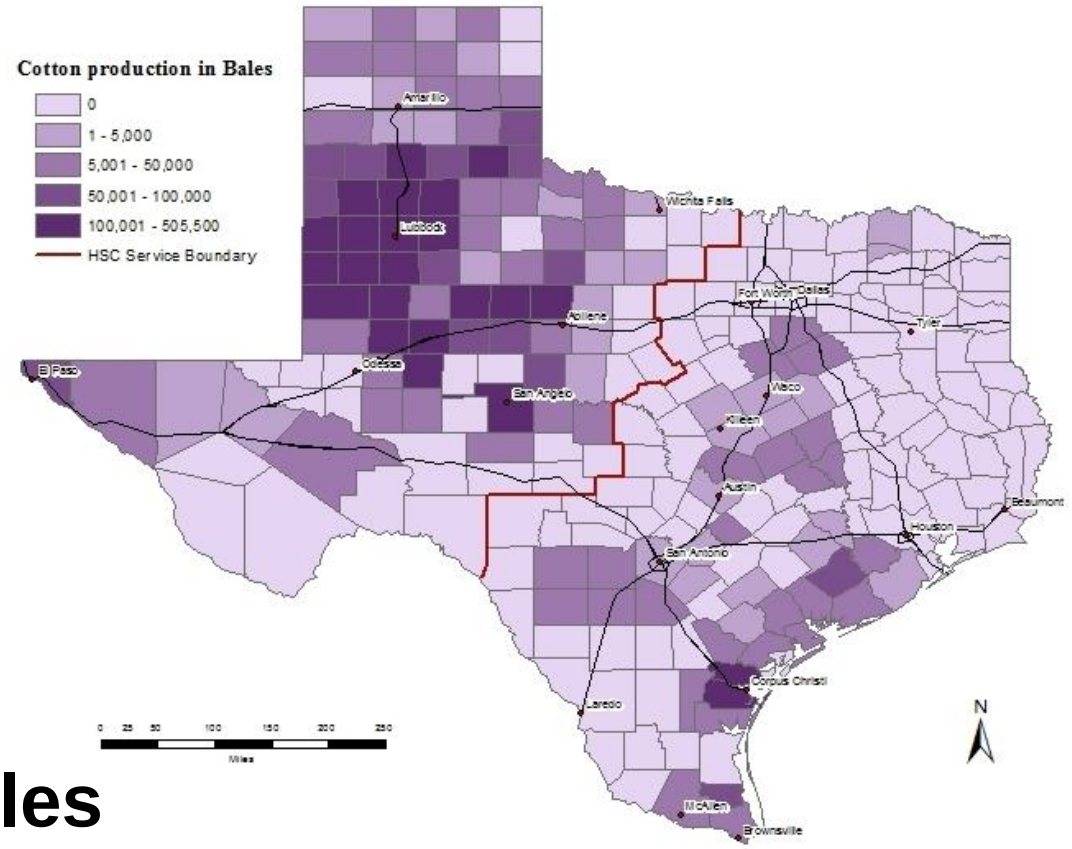
Objectives

1. Evaluate cotton growth and yield response to irrigating with treated produced water blended with groundwater (1:4 ratio).

2. Determine the effect of treated produced water on soil chemical properties by measuring soil elemental concentrations and pH and electrical conductivity (EC) at varying soil depths.

Why Cotton?

- Non-food crop
- Texas' most valuable crop



2014 Yield

- U.S.: 15.8 million bales
- Texas: 6.2 million bales
  - 86% of Texas cotton produced in West Texas

Cotton Production

- **Cotton is considered a drought and salt tolerant crop**
  - **Requires 510 – 610 mm water (20” – 24”) for maximum yield**
  - **~50% of cotton in Texas High Plains is irrigated**

- **Threat to maintaining production**

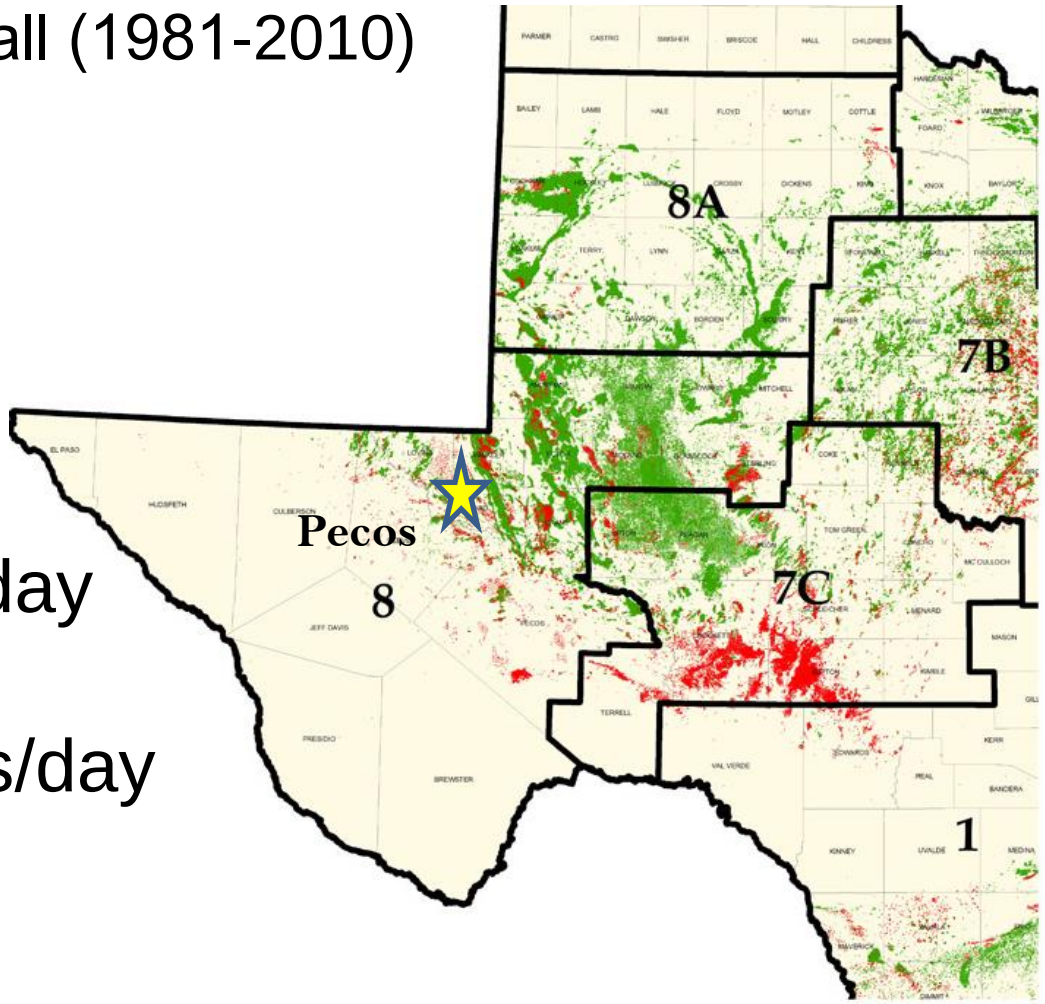
WATER QUANTITY and QUALITY

Project Details

- **Location**
  - Texas A&M AgriLife Research Station, Pecos, TX
  - 12.1” average rainfall (1981-2010)

Permian Basin Oil Production

<u>2008</u>
710,480 barrels/day
<u>2015</u>
1,339,412 barrels/day



Project Details

- **Produced water**
  - Anadarko provided locally produced oilfield-generated produced water
  - Transported the water to the test site for treatment and land-application

- **Treatment of produced water**
  - Energy Water Solutions (the Woodlands, TX)
  - Developed a process train for the treatment of produced water from both oil and gas production fields

Public Policy Initiatives

Improved Legislation & Permitting

- Wellington Water Works
  - Colorado Water Court Approval 2007

- HB and Senate Bill in Colorado enabling ground discharge
  - Over 7.5 M Barrels of recycled water released in aquifer

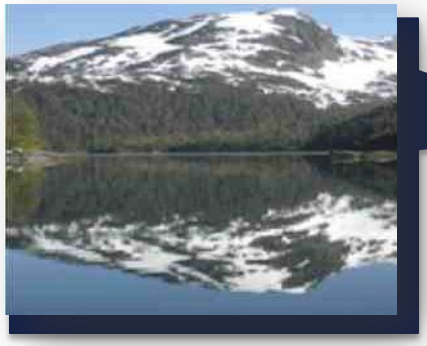
- United States Patents for design and processes
  - ***6,348,154***- Methods to remove heavy metals from water
  - ***8,097,163***– Purification of oil field water for beneficial use
  - ***12/421,462*** – Beneficial use of produced water (pending)

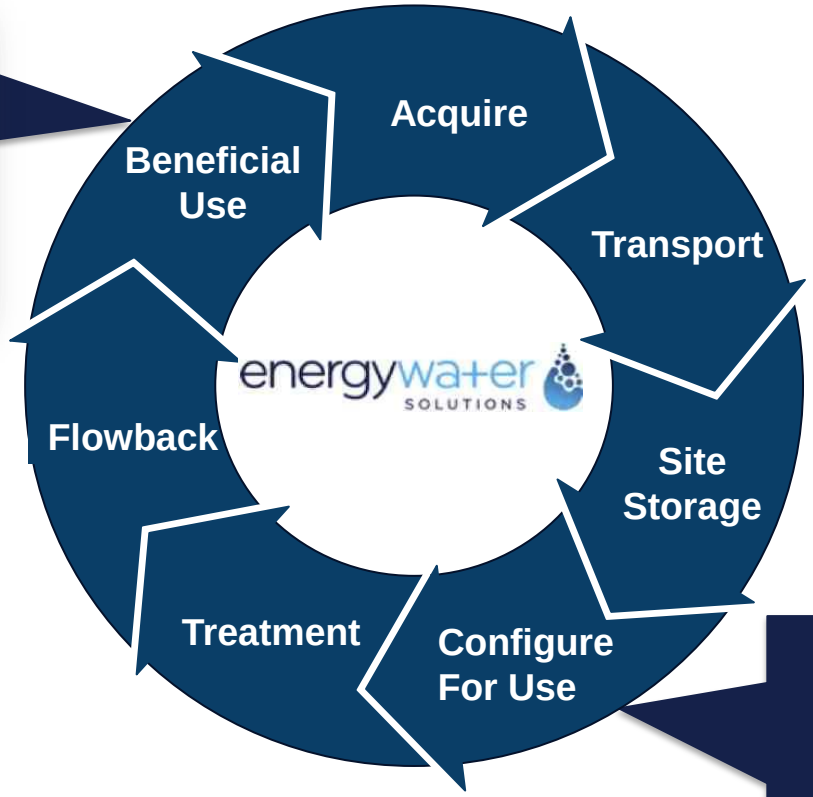
- Texas Railroad Commission mobile permit
  - Five additional bills proposed in Texas in 2013 Sessio
    - SWD tariff, recycling mandate, discharge of fresh…

energywater SOLUTIONS

Mobilizing Recycling

planning *for lowered costs*





- Movable in field
- Central field depot
- Optimum placement
- Close to wells
- Limit trucking
- Lower risk & opex

Consistent water quality via plant control systems

Modular units scale:
1,250 to over 50,000 BPD

energywa+er SOLUTIONS

EWS Optimized Process

Patented Technology

Modular On Site Energy Water Solution

Fresh Water and Products

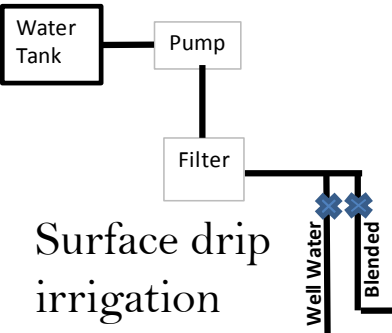
US Patent Protection

8,097,163 - Purification of oilfield Water for beneficial use (1-5)

6,348,154 - Methods to remove heavy metals from water - rare earth minerals harvesting (4)

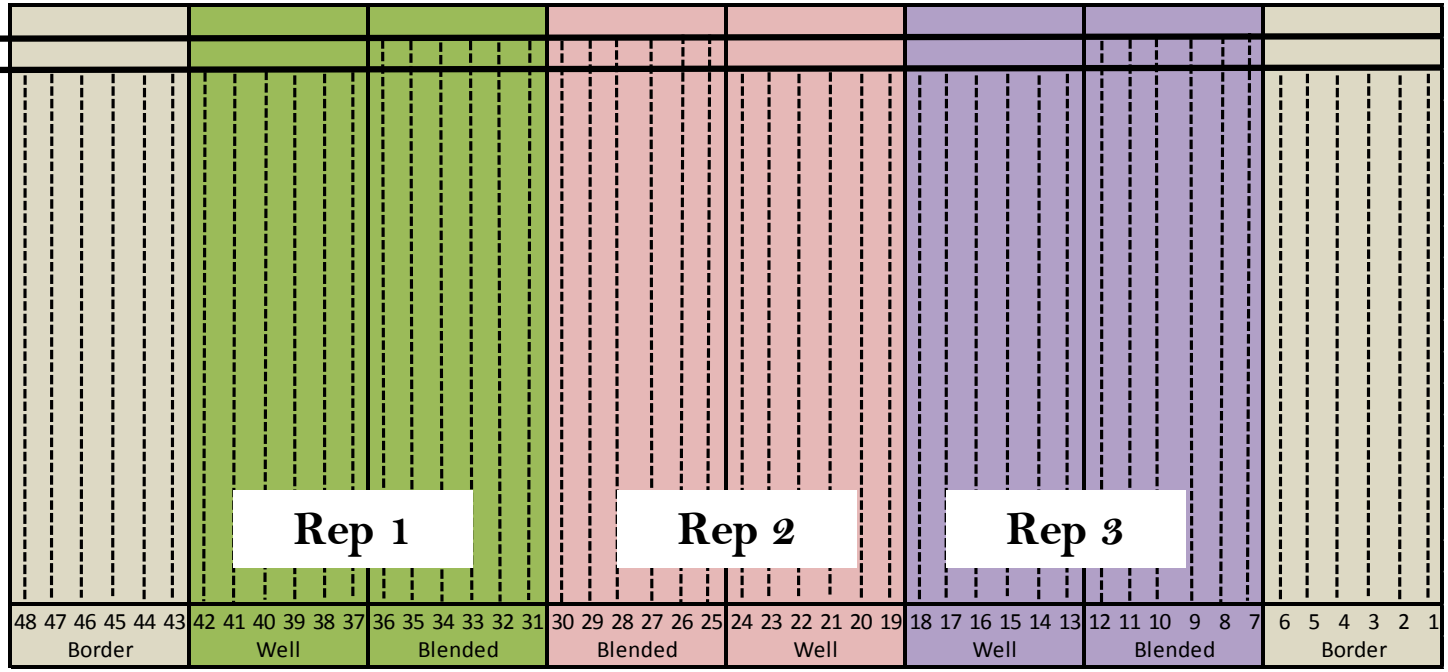
energywater SOLUTIONS

Project Details



Irrigation Treatments (3 reps)

1. 100% groundwater (GW)
2. Blended water (4:1 ratio, GW:treated produced)



Irrigation volumes (June 6th to September 4th)

Groundwater: 13.9 acre-inches

Blended water: 10.7 acre-inches

Project Details

- **Cotton variety: DP 1359**
  - Planted on 2 June 2015
  - Harvested on 24 November 2015
    - Lint yield
    - Fiber quality

- **Soil and Water Monitoring:**
  - Soil samples collected at depth prior to initiating research and after the final irrigation event
    - 0-15 cm, 15-30 cm, and 30-60 cm
  - Water samples (groundwater, treated produced, and blended) were collected every four weeks

RESULTS

Water samples collected on 6 June 2015

Parameters	Units	Water Source		
		Groundwater	Treated Produced	Blended
Sodium (Na)	ppm	999	42	766
Calcium (Ca)	ppm	167	4	127
Magnesium (Mg)	ppm	50	1	40
Carbonate (CO_3)	ppm	< 1	< 1	< 1
Bicarbonate (HCO_3)	ppm	122	37	122
Chloride (Cl)	ppm	1900	20	1450
Conductivity	µS/cm	4950	150	3800
pH		7.6	7.8	7.4
Phosphorus (P)	ppm	< 0.01	< 0.01	< 0.01
Potassium (K)	ppm	18	5	14
Nitrate (NO_3)	ppm	5	6	4
Sulfate (SO_4)	ppm	1204	31	1362
Boron (B)	ppm	0.5	4.1	0.8
TDS	ppm	3218	98	2470
SAR		17.4	4.9	15.2

Soil Characteristics

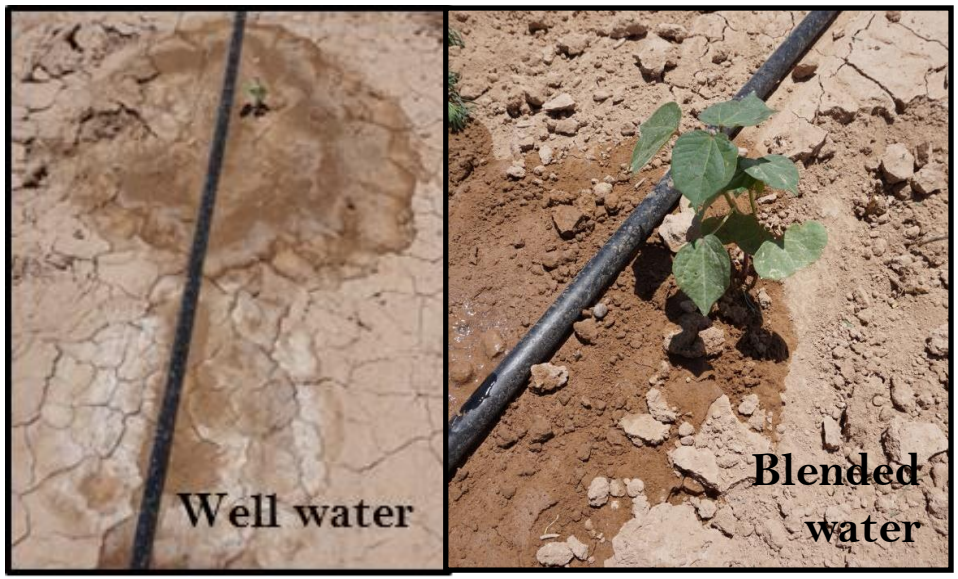
Hoban silty clay loam

pH	Conductivity	NO_3-N	P	K	Ca	Mg	S	Na	SAR*
--	mmhos/cm				ppm				--
8.7	1.8	22.1	30	450	17634	516	482	1373	16.7

17% $CaCO_3$ and 31% gypsum (NRCS)

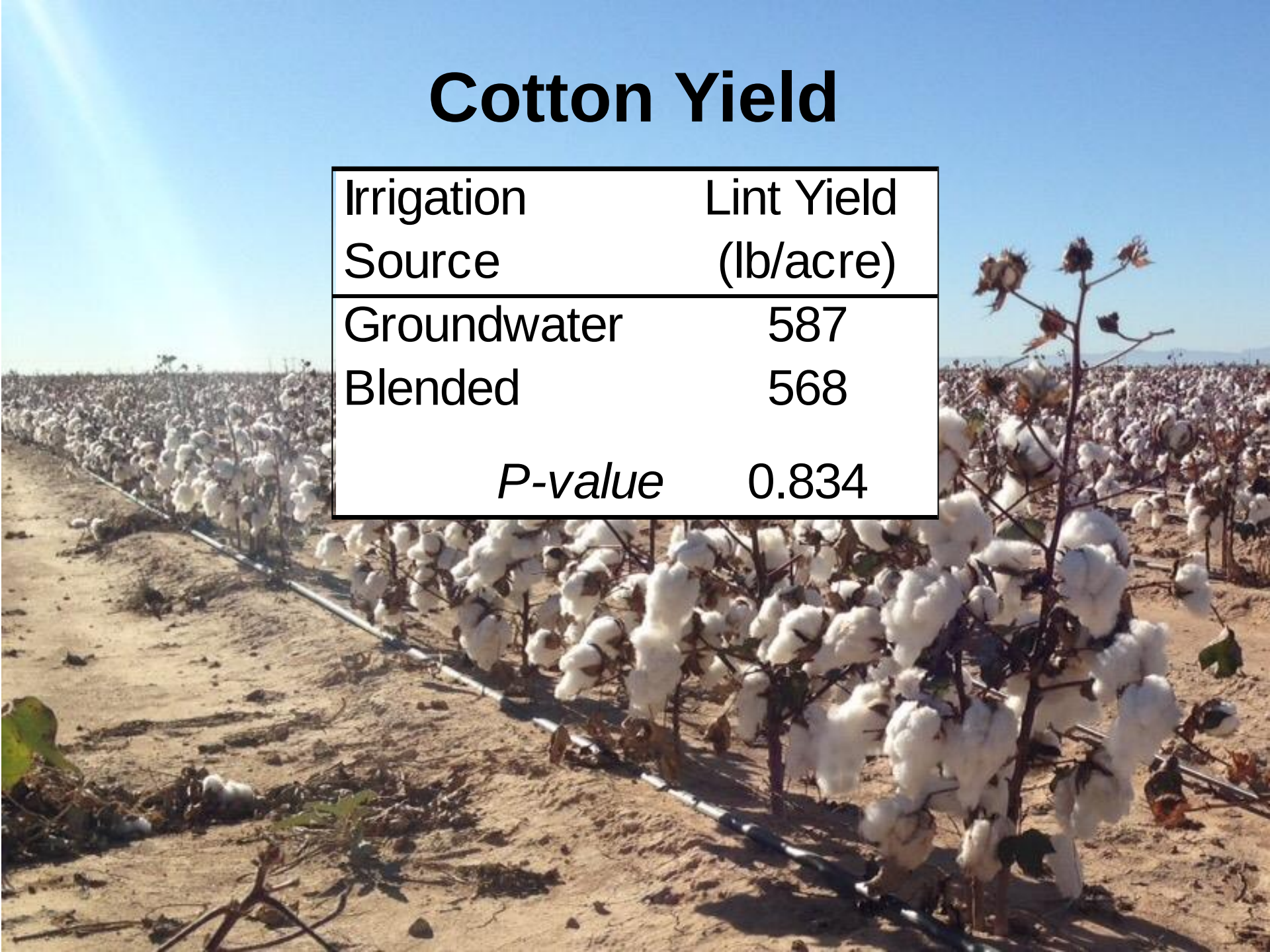
Soil Characteristics (post harvest)

Irrigation Source	Sample Depth	pH --	Conductivity mmhos/cm	NO_3-N	P	K	Ca	Mg ppm	S	Na	B	Cl	SAR* --
	0-6"	9.0	1.5	9	35	531	14915	575	654	1230	1.6	1018	13.8
Blended	6-12"	9.1	1.2	12	26	474	16896	513	476	1347	1.2	896	17.6
	12-24"	8.8	1.7	19	19	425	24243	485	528	1349	1.2	1256	15.3
	0-6"	8.9	2.2	36	35	528	15054	596	835	1751	1.6	1637	17.5
Groundwater	6-12"	9.0	2.1	18	26	471	16352	514	503	1496	1.1	979	17.3
	12-24"	8.8	1.8	26	16	409	25706	485	504	1487	1.2	1609	16.9



Cotton Yield

Irrigation Source	Lint Yield (lb/acre)
Groundwater	587
Blended	568
P-value	0.834



Summary

Irrigating with treated produced water blended with groundwater

- Did not reduce cotton yield or lint quality
- Reduced soil salinity parameters

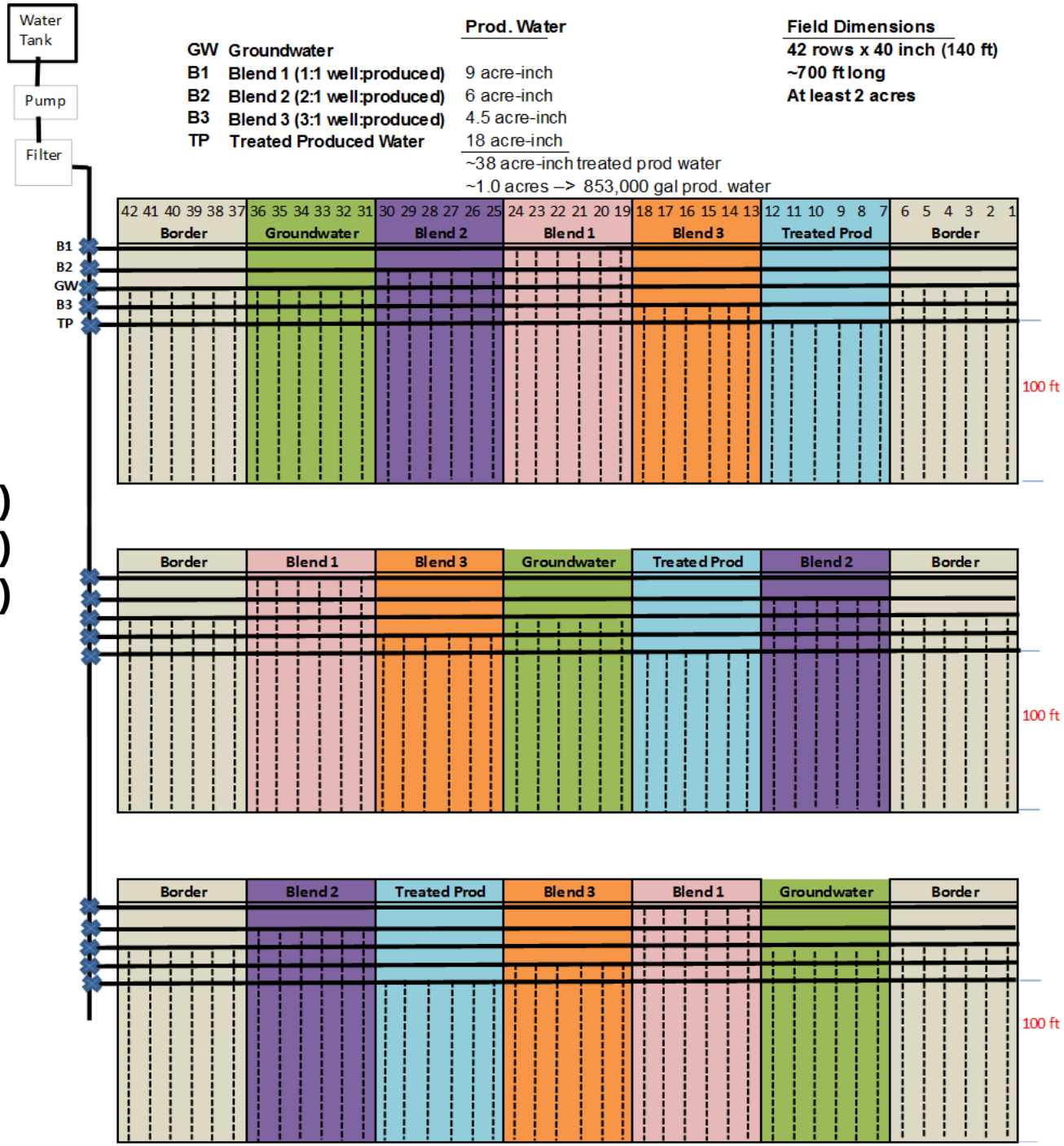
Future Research

- Identify and quantify boron in treated water
  - Fate in soil?
  - Plant uptake?
- Blending greater volumes of desalinated produced water with less well water may:
  - Improve soil chemical and physical properties
    - As result of decreasing salt load
  - Conserve fresh water sources
  - Enhance the longevity of agricultural production
- However, other ratios of blended water (and possibly other crops) must be examined…

Future Research

Treatments

1. Groundwater (100%)
2. Blend 1 (1:1 GW:TPW)
3. Blend 2 (2:1 GW:TPW)
4. Blend 3 (3:1 GW:TPW)
5. TPW (100%)




Katie L. Lewis, Ph.D.
Texas A&M AgriLife Research – Lubbock
katie.lewis@ag.tamu.edu
361-815-3836
TEXAS A&M
AGRILIFE
RESEARCH
energywater
SOLUTIONS
Anadarko