



Boron Removal From Produced Water

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Abstract: Boron is an ongoing issue in the recycle of produced water and some brine waters because it causes premature gelling of frac fluids used for “gel” frac operations. Boron causes polysaccharides (guar, etc.) to cross link when placing the proppant. If boron is present in source water, the fluid can gel and cause operational problems.

While there are several options available for boron removal, boron selective ion exchange resins are preferred because they achieve removal to <5 ppm B, can be regenerated for reuse and can produce reasonable volumes of water. This paper will present data on field experience with boron removal from produced water and provide information on treatment costs.

Waters Associated with Hydraulic Fracturing

Shale Frac Flowback

The portion of injected frac fluids that return to surface before production.

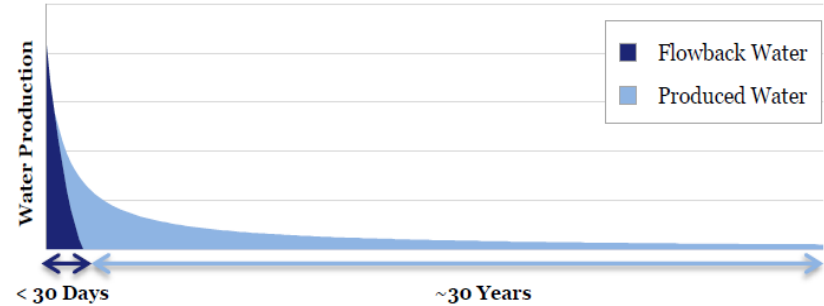
- Typically 10-20% returns quickly in 7-14 days with a rapid decline in quality & quantity

Shale Produced Water

Typically refers to water produced from the shale wells longer term.

- Significantly lower flow rates than flow back, and more consistent quality.

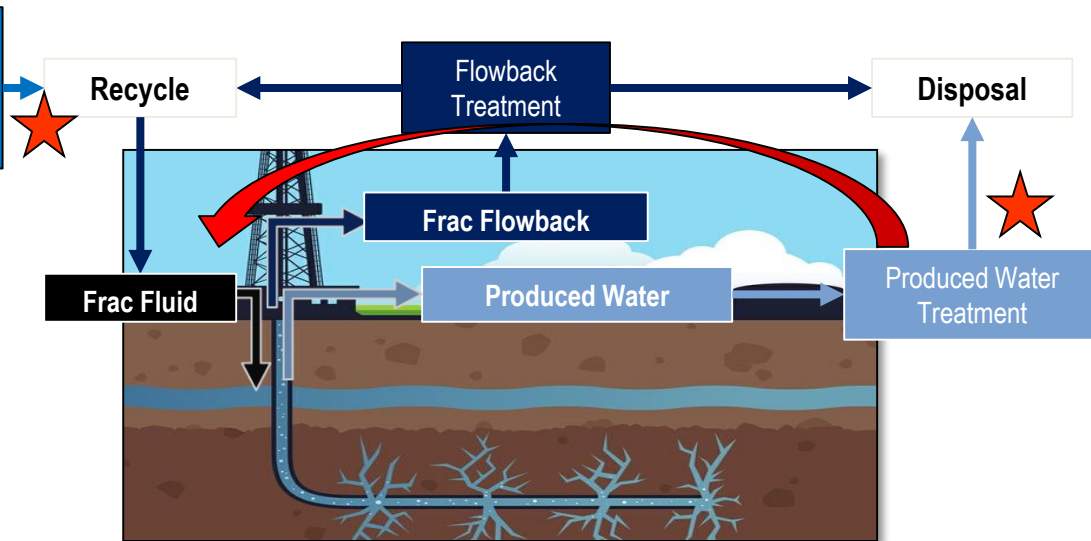
Illustrative Water Use in the Lifecycle of the Shale Well



Make up Waters for Frac Fluids

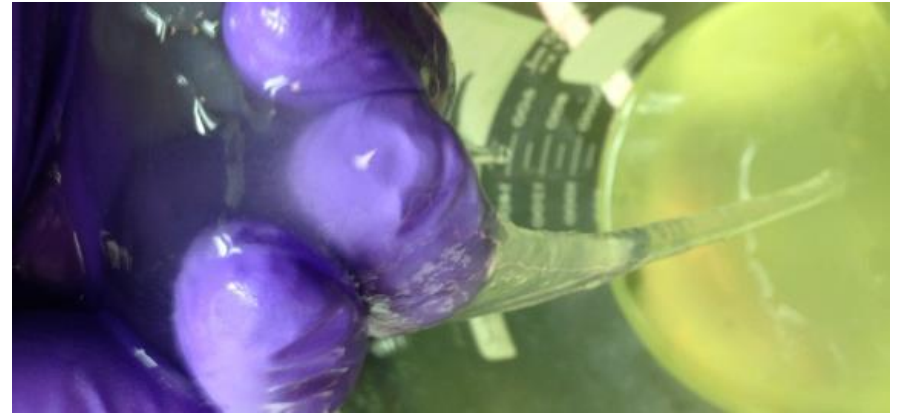
- fresh water
- brackish water
- produced waters

★ **Targets**



Why Recycle Produced Water?

- Reduce fresh water use
- Drought – More expensive
- Reduce truck traffic
- Isotonic salt background
- Reduce chemical use
- Earth quakes
- Disposal well shut-downs
- Sustainable & Green



Considerations

Cost

Practicality

For gel frags – Boron

Snot Balls – Guar solution
plus boron

Treatment Options

- Precipitation/Coagulation and filtration
- RO can remove B to the desired limits
- Solubility of B is too high to work

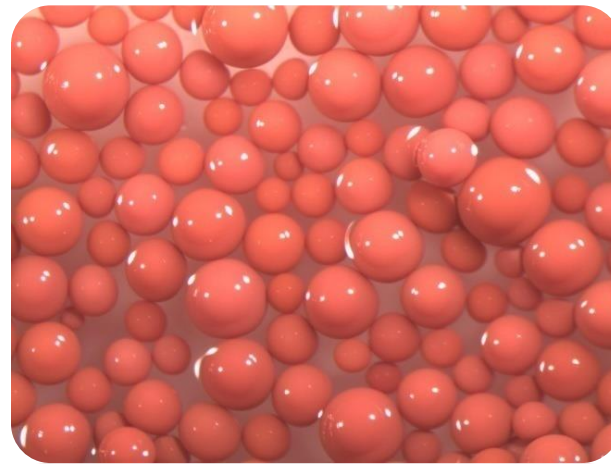
- RO produces a lot of waste water if TDS is low
- RO makes large volumes of salt concentrate when TDS is high (30,000 ppm)
Waste brine can be 30 to 50% of the feed water

Best Option is Boron Selective Ion Exchange Resins

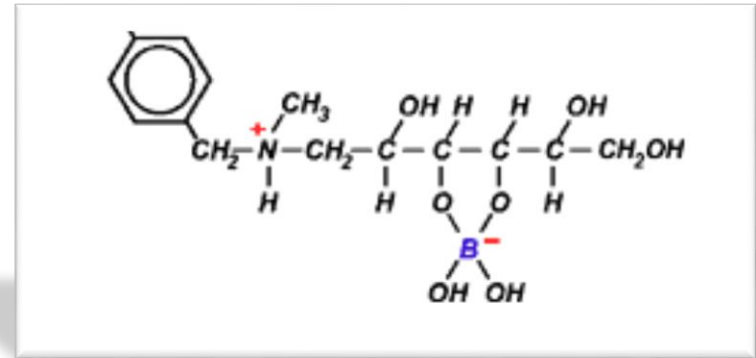
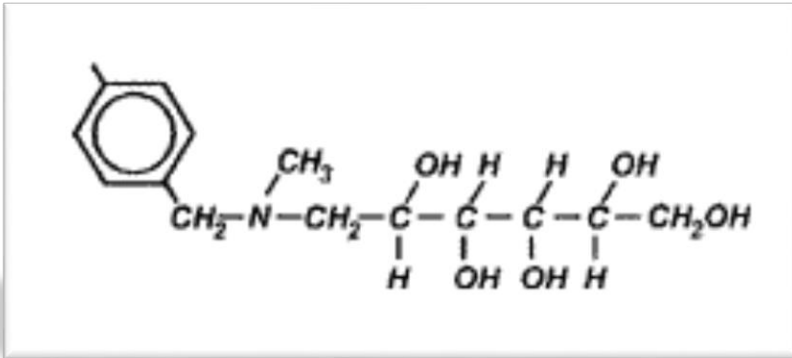


Water pre-treatment strategy

- Remove particulates, sand, dirt, oily solids
- Free phase and dispersed oil
- Water Soluble Oil (WSO) - BTEX, Gasoline Range Organics (GRO), Diesel Range Organics (DRO), Total Petroleum Hydrocarbons (TPH)
- If desired, other components like Hardness (Ca/Mg/Sr/Ba) and boron can also be removed

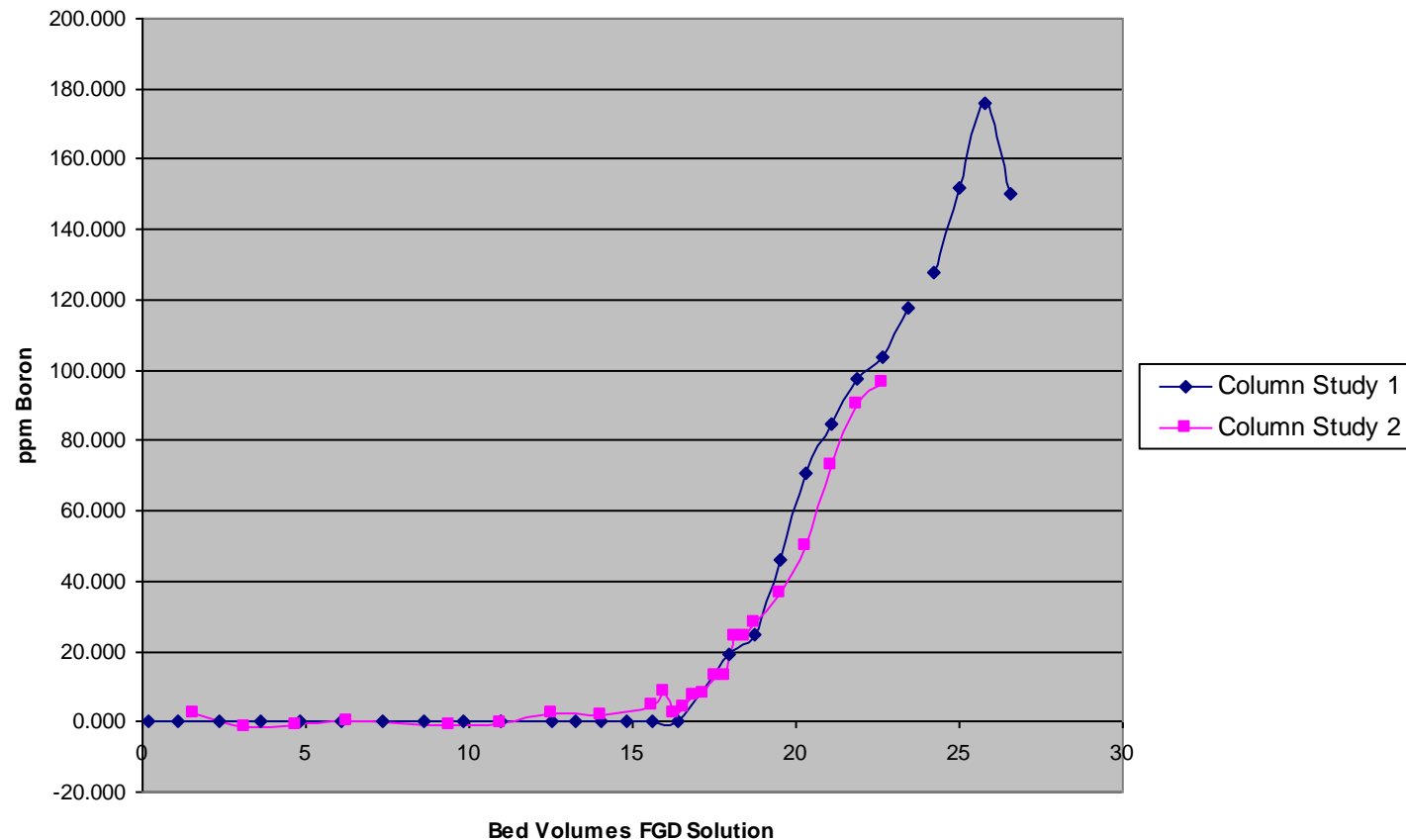


Boron Selective Ion Exchange Resin



BSR-1 Boron Removal Column Study 1

- Experience with “worse water” Flue Gas Desulfurization (FGD) waste water
- BSR is regenerated with acid, producing a concentrated boron waste for disposal
- Depending on boron concentration in feed water, waste can be 1-2% of feed water



Boron Removal

- Boron causes gel frac additives to gel/crosslink – must be removed
- Treatment Options –
 - RO but will remove all ions...but lots of waste
 - Boron Selective IX resins...small, concentrated waste

*You want your gel to gel when you want it to gel,
but you don't want it to gel when you don't want it to
gel...*

Boron Selective ion exchange resin for Boron Removal from Produced Water



Lab Validation Testing

- Feed water
 - 55.9 ppm B
- Treated water
 - 0.0065 ppm B
 - 99.9% removal



Conducted multiple tests from multiple plays in the US with the same result – boron removed

DW&PS Product Applications

LOCATION	FEED B (ppm)	TREATED B (ppm)
CO	20.6	0.9
JK	21.3	0.9
GW	33.4	0.4
OK	63.7	0.1
Eagle Ford	55.9	0.06

High removal of boron allows post blending of treated and untreated water

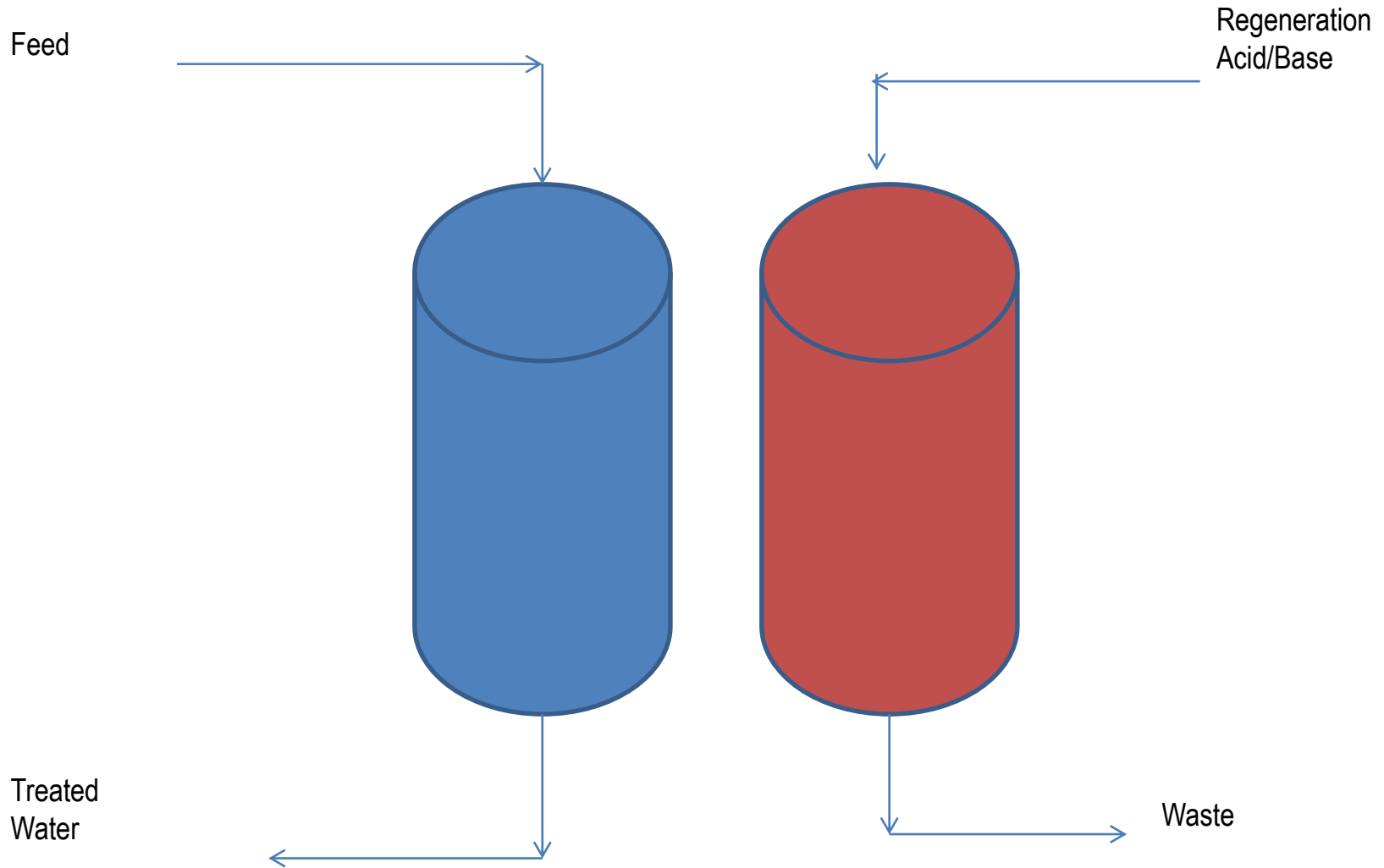


DW&PS Product Applications

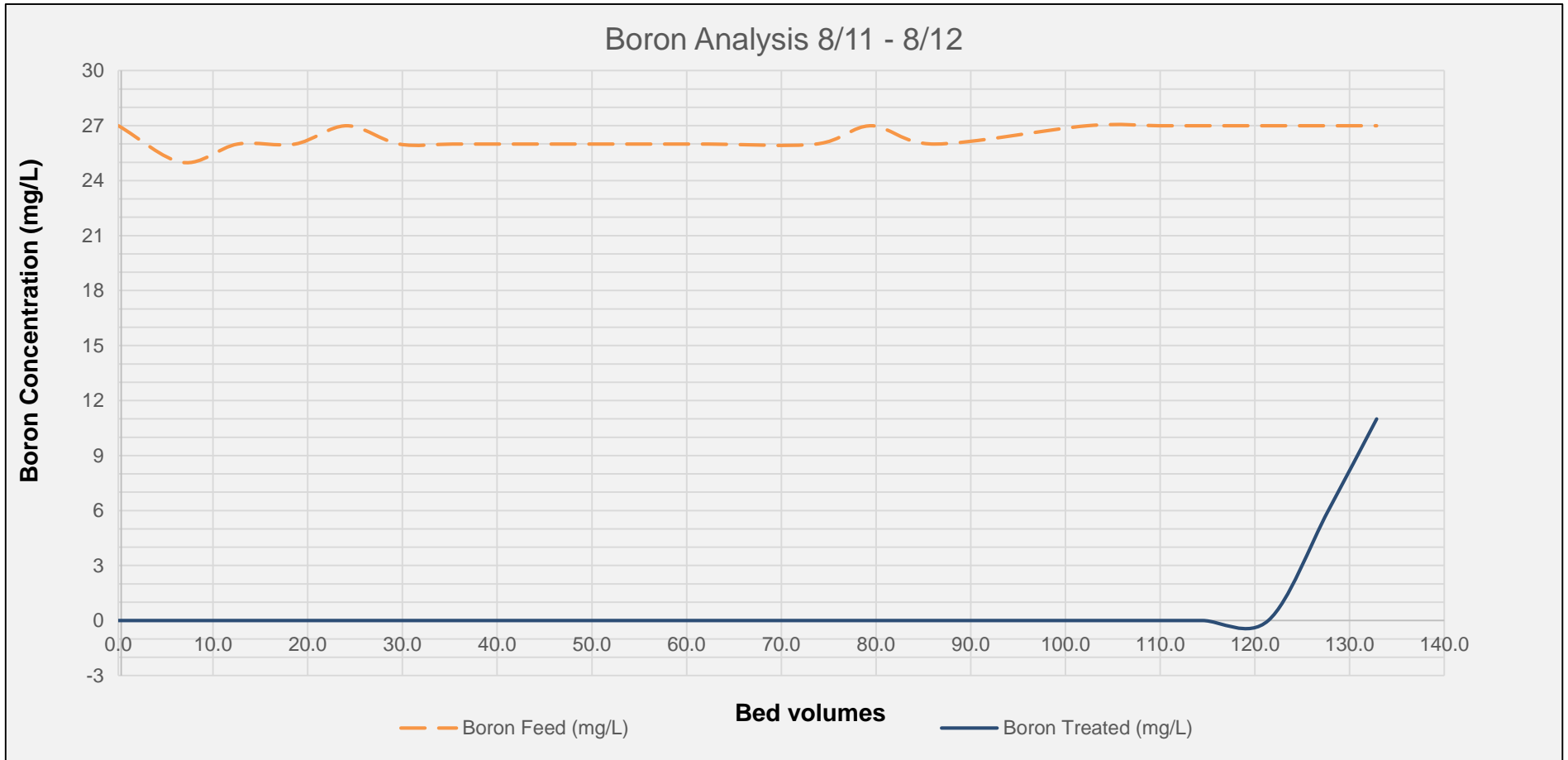
Shop photo of equipment used at a recent field pilot for boron removal from produced water



System Layout



Testing data



1 BV of waste is <1% of feed water

Ongoing Monitoring of Media Life

High Sierra Anticline Disposal Facility Boulder, WY

Dow Boron Selective Resin has been in service for 3 years

RESIN PROPERTIES	NEW RESIN SALES SPEC	VESSEL A	VESSEL B	VESSEL C
WRC, %	51 - 59	58.0	57.8	57.9
TEC, meq/mL	0.70	0.81	0.90	0.76
SSC, meq/mL	--	0.00	0.00	0.00
WBC, meq/mL	--	0.81	0.90	0.76
TEC as rec'd, meq/mL	--	0.83	0.82	0.79
Organics, g C/ft ³	--	45	138	76

3 year old resin looks like new resin



Economics of Treatment

Assumptions –

25 ppm B reduced to <5 ppm B

10,000 bpd – 292 gpm – 3.5 MM bpy

Pretreatment to remove particulate and suspended oil

			Amortized	
Equipment	\$ 500,000	15 yr life	\$33,333/yr	1.0 ¢/brl
Resin Cost	\$ 303,000	5 yr life	\$60,000/yr	1.7 ¢/brl
Chemical Cost	\$ 115,000	Annual	\$115,000/yr	3.3 ¢/brl
Total Cost				6.0 ¢/brl

Conclusions

- Proven Technology
- Boron Selective ion exchange resins can remove boron from produced water
 - Cost effective



Acknowledgements

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