INTEGRATED SUSTAINABILITY

WATER | WASTE | ENERGY

Flowback Reuse to Decrease Source Water Requirements for Hydraulic Fracturing Operations

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Should We Reuse Flowback Water?

YES!!!!!!

Maybe…

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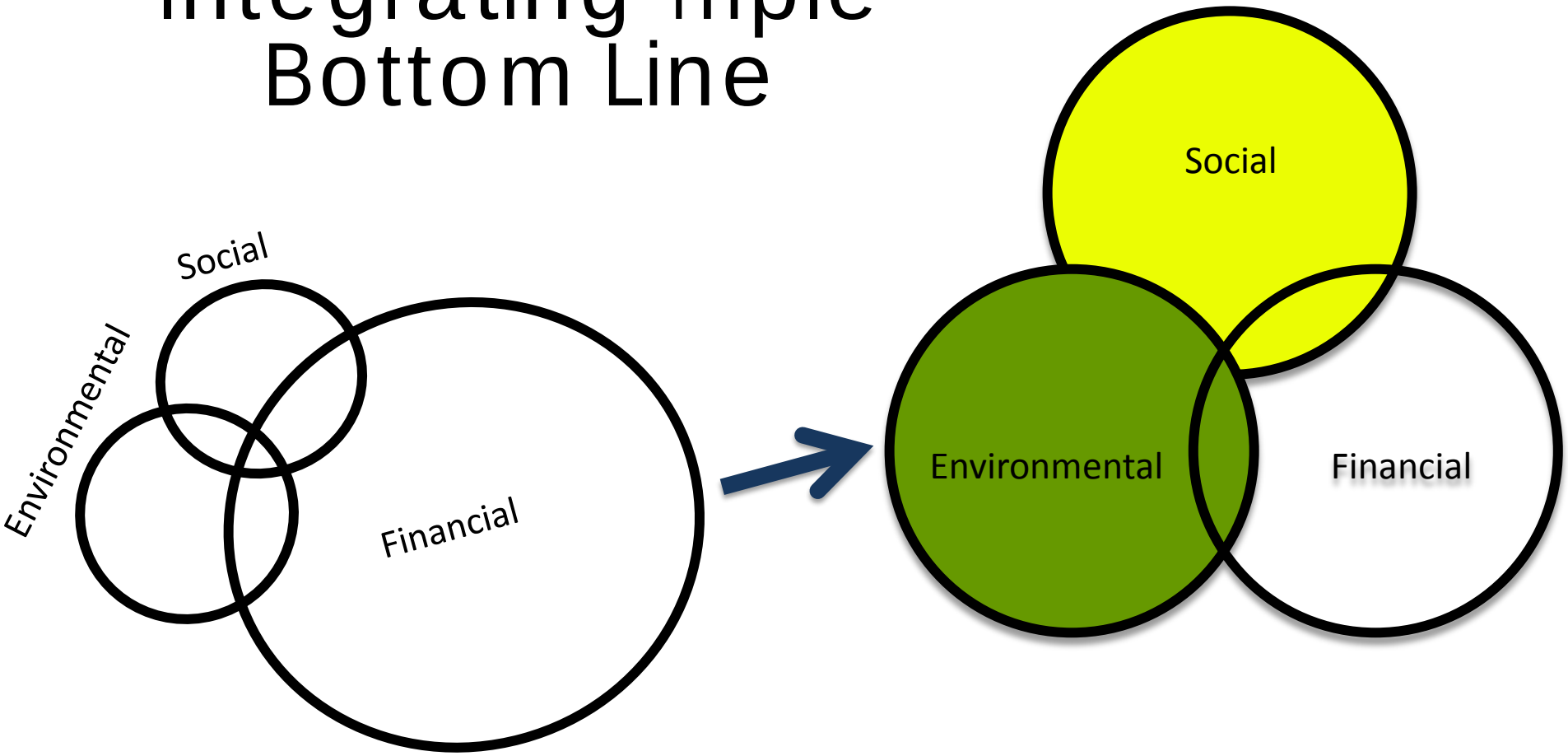
Shifting Decision Making

Integrating Triple Bottom Line



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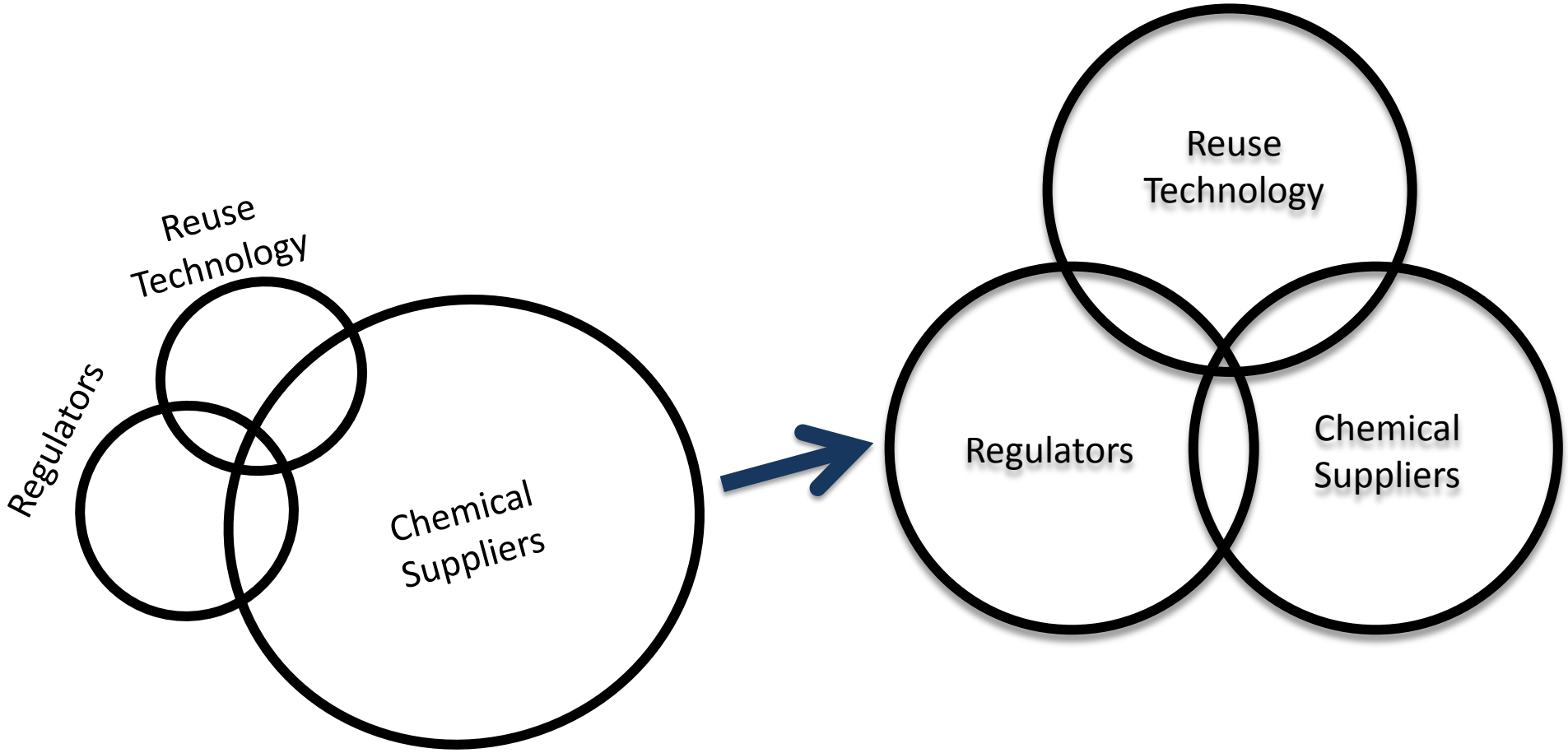
Collaboration Between Stakeholders



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Key Definitions

- Produced Water
  - Any water that flows from a well as a result of oil and gas operation
- Flowback
  - After a well is stimulated injection fluid will flow back during well testing
- Proppant
  - Solids added to frac solution to hold fractures open
- Scaling Tendency
  - Driving force for precipitation
- TSS
  - Total Suspended Solids
- TDS
  - Total Dissolved Solids
- NORM
  - Naturally Occurring Radioactive Material

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Why Reuse?

- Reduces source water demand
- Decreases produced water disposal
- ?Reduces production costs?
- Reduces water movement requirements
- Required/soon to be required by regulators

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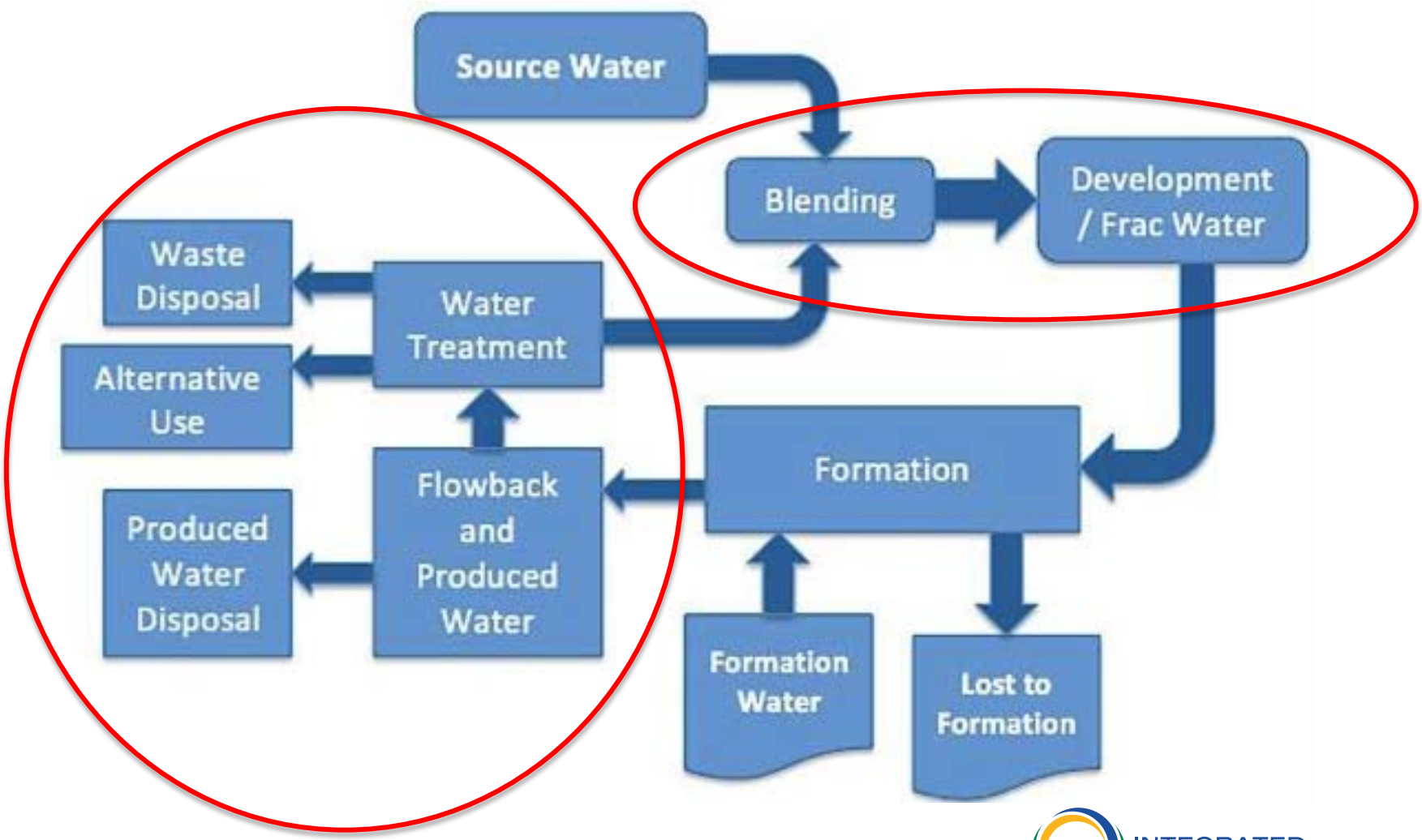
Water Flow
(MiSWACO, 2011)



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Hydraulic Fracturing Water Requirements

	Units	Cross Linked	Linear Gels	Slickwater
Temperature	°C	15-40	15-40	3-40
pH		6-8	6-8	5-8
Chloride	ppm	<30 000	<50 000	<90 000
Hardness	ppm (as $CaCO_3$)	n/a	n/a	<15 000
TSS	ppm (µm)	50 (<100)	50 (<100)	50 (<100)
TDS	ppm	n/a	n/a	n/a
Iron	ppm	<25	<25	n/a
Water Use		Low →		High
Proppant		High ←		Low

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Constituents of Concern in Hydraulic Fracturing Water

- TDS
- pH
- TSS
- Multivalent Cations
  beryllium, magnesium, calcium, strontium, barium, iron, aluminum
- Scale Forming Anions
  carbonate, bicarbonate, sulfate
- NORM
- H_2S
- Chemical Flowback

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Hydraulic Fracturing Water Microbiological Concerns

- Aerobic Heterotrophic Bacteria
- Slime Forming Bacteria
- Nitrifying/Denitrifying Bacteria
- Iron Related Bacteria
- Acid Producing Bacteria
- Sulphate Reducing Bacteria

$$CH_4 + SO_4^{2-} \xrightarrow{Bacteria} HCO_3^- + HS^- + H_2O$$

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Source Water Chemistry

Same Formation

	Units	Ground	Ground	Ground	Surface	Surface	Runoff
Ca	ppm	2 963	417	131	2.4	2.6	68
Mg	ppm	1 238	86	39	0.6	1.5	45
Sr	ppm	154	29	25	0.2	0.2	0.5
Ba	ppm	1.6	139	128	0.1	0.1	0.1
Fe	ppm	167	28	0.1	1.7	1.7	0.1
SO_4^{2-}	ppm	1 510	46	10	59	64	406
HCO_3^- /CO_3^{2-}	ppm	122	113	1 055	148	157	80
H_2S	ppm	ND	ND	ND	ND	ND	ND
pH		6	6.9	7.6	8.1	8.1	8.6
TSS	ppm				58	44	

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Produced Water Chemistry

Same Well

Same Pad

	Units	Flowback	Produced	Flowback	Flowback	Produced	Produced	Produced
Ca	ppm	4 089	11 793	400	342	790	304	0.3
Mg	ppm	961	3 053	24	32	249	23	0
Sr	ppm	88	250	652	127	360	86	0
Ba	ppm	1	0.5	251	643	98	40	0.1
Fe	ppm	13	7	19		43	6	1.7
SO_4^{2-}	ppm	1 443	969	9	7	4.4	3	1.4
HCO_3^- /CO_3^{2-}	ppm	682	164	975	1 360	191	157	6 528
H_2S	ppm	67%	ND		ND	ND	ND	ND
pH		6.9	6.3		7.6	5.8	6.1	6.8
TSS	ppm	378			633	16	1	8

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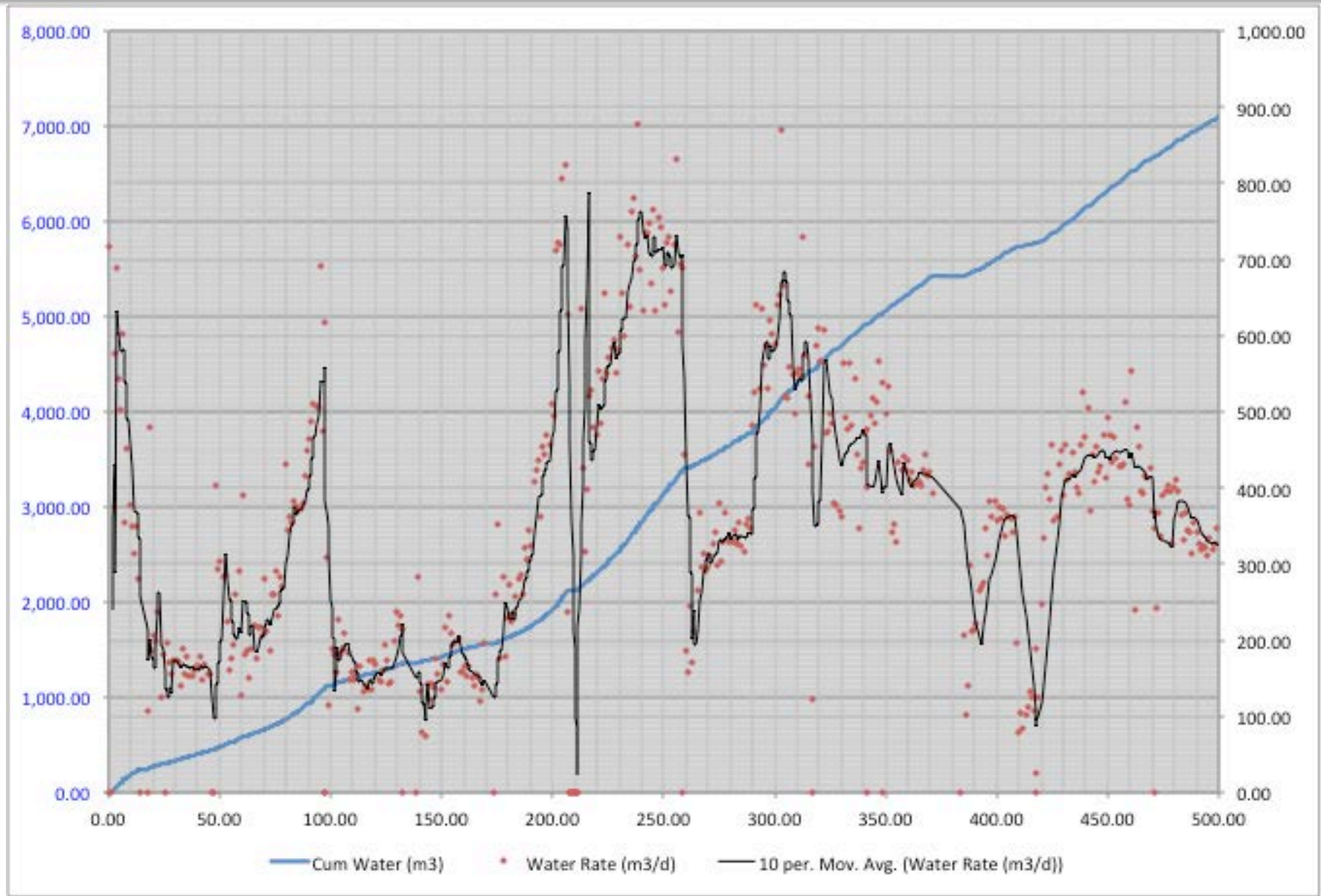
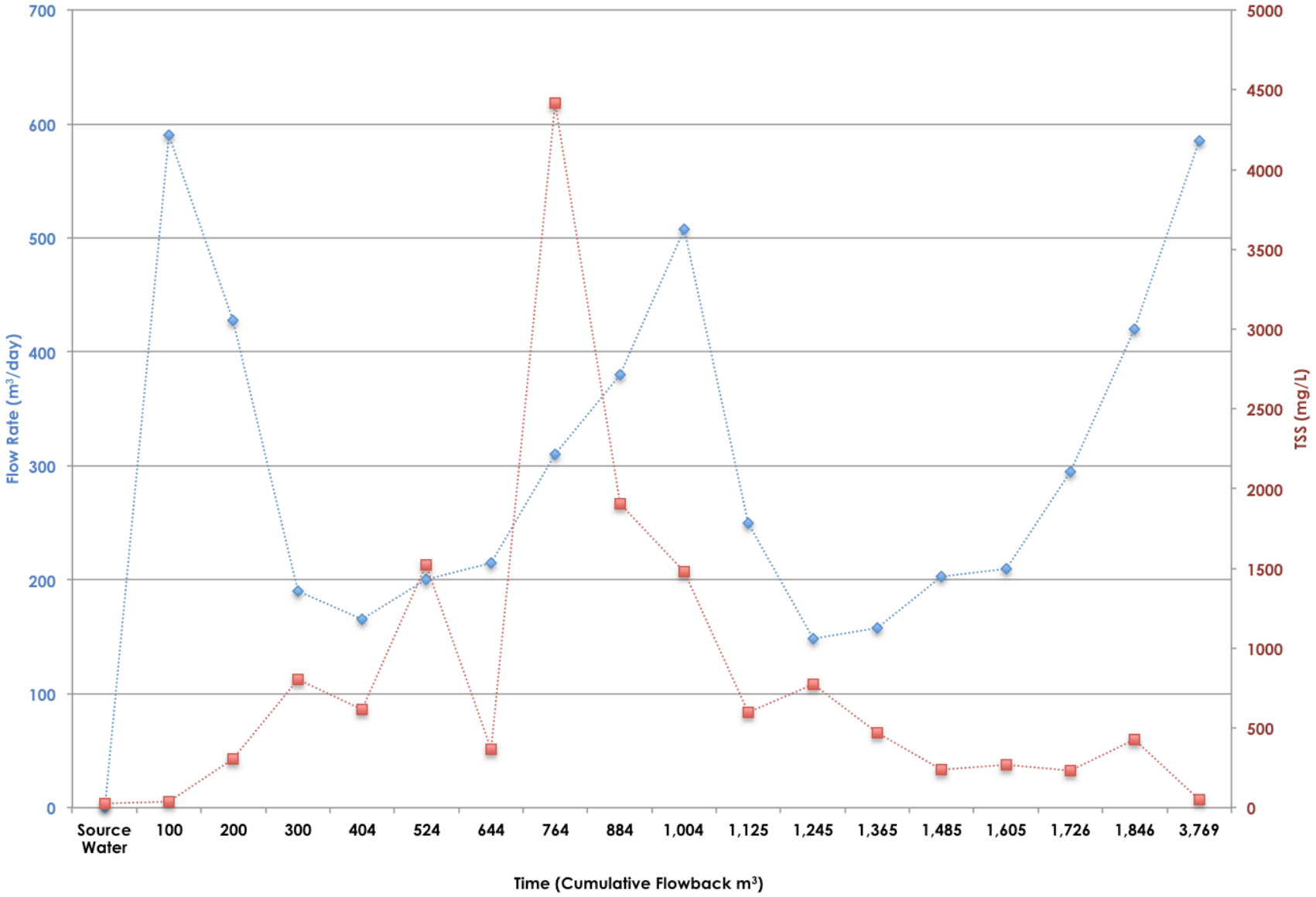
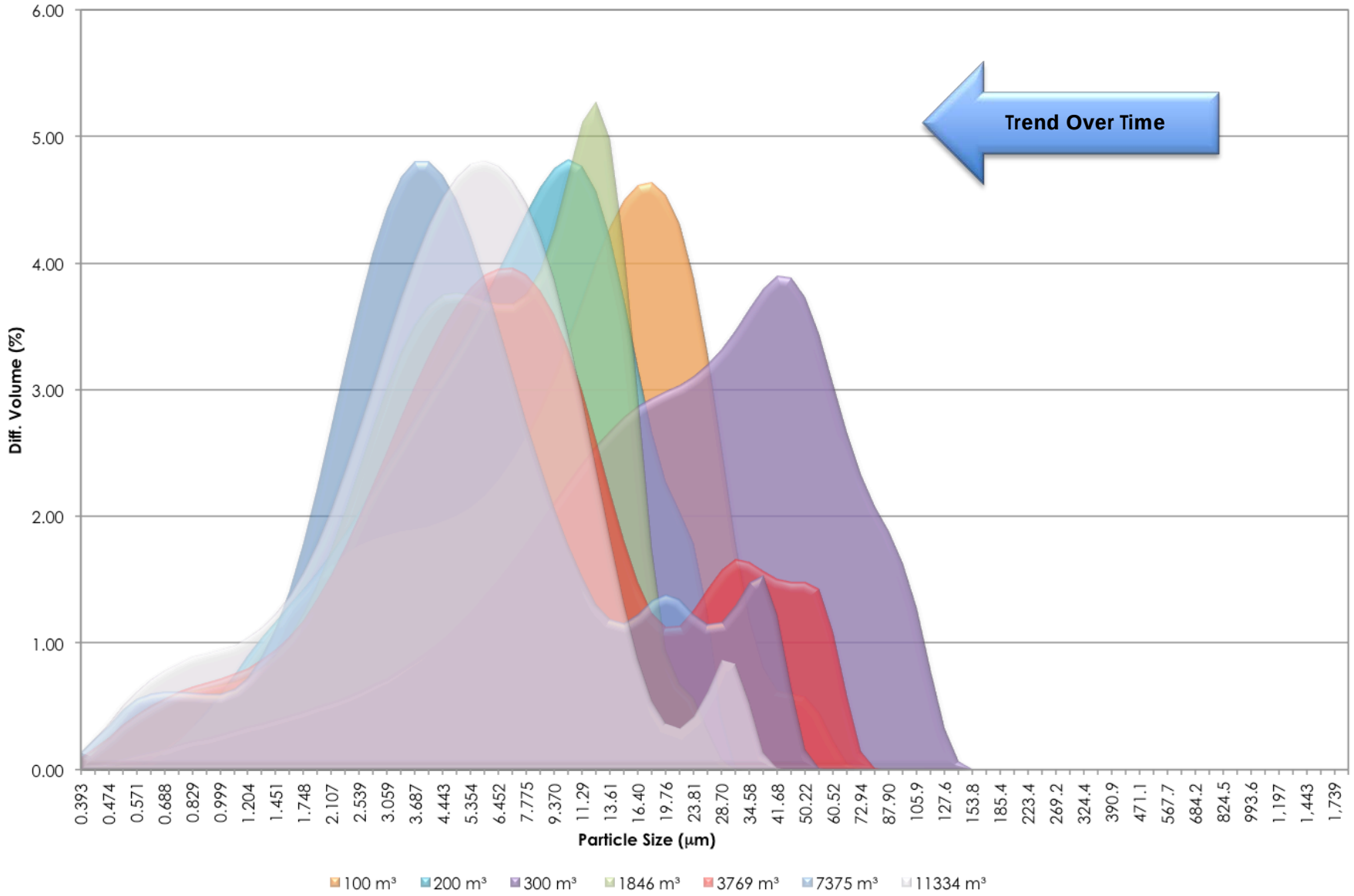
Produced Water Variability
Flow



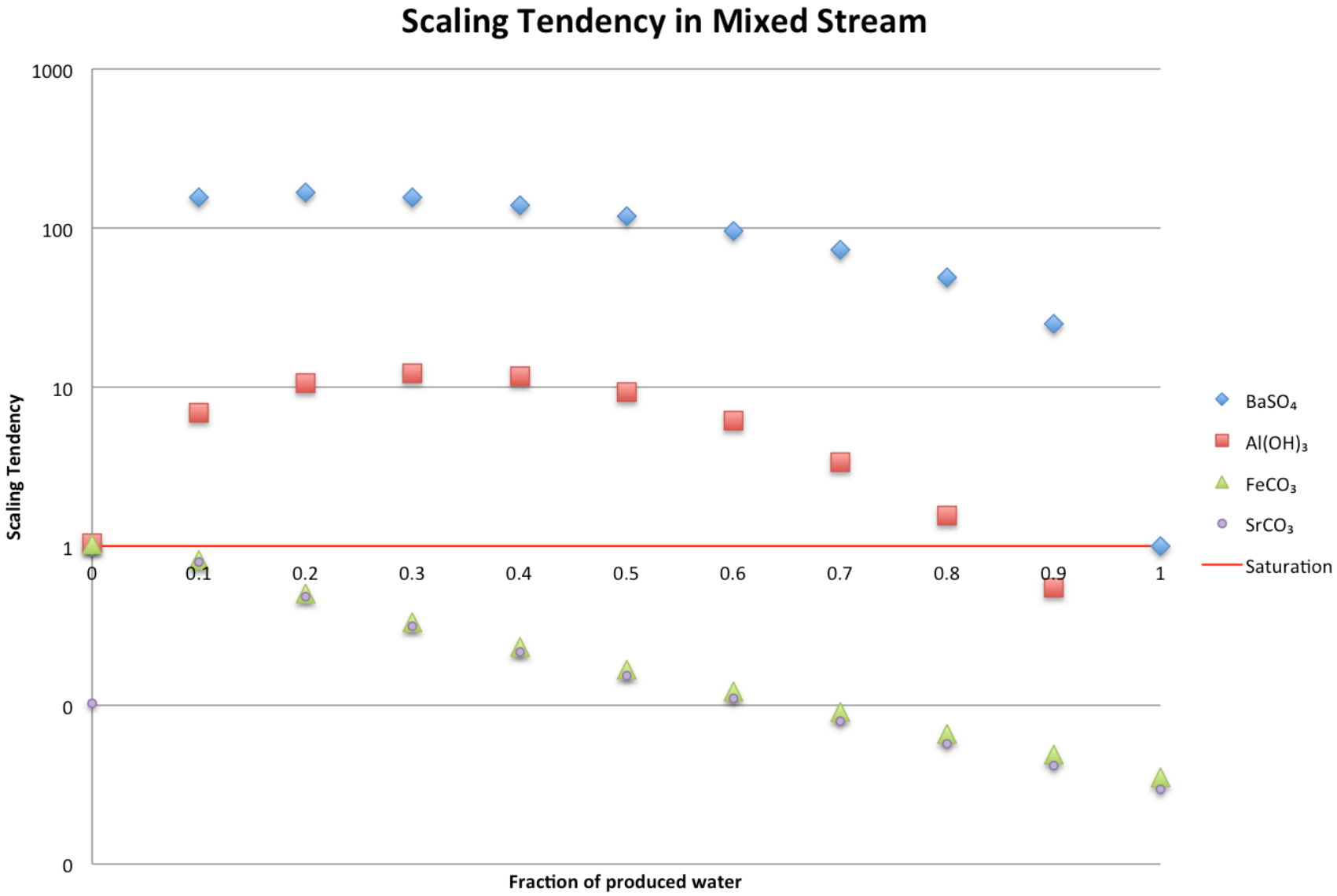
Produced Water Variability
Solids Concentration



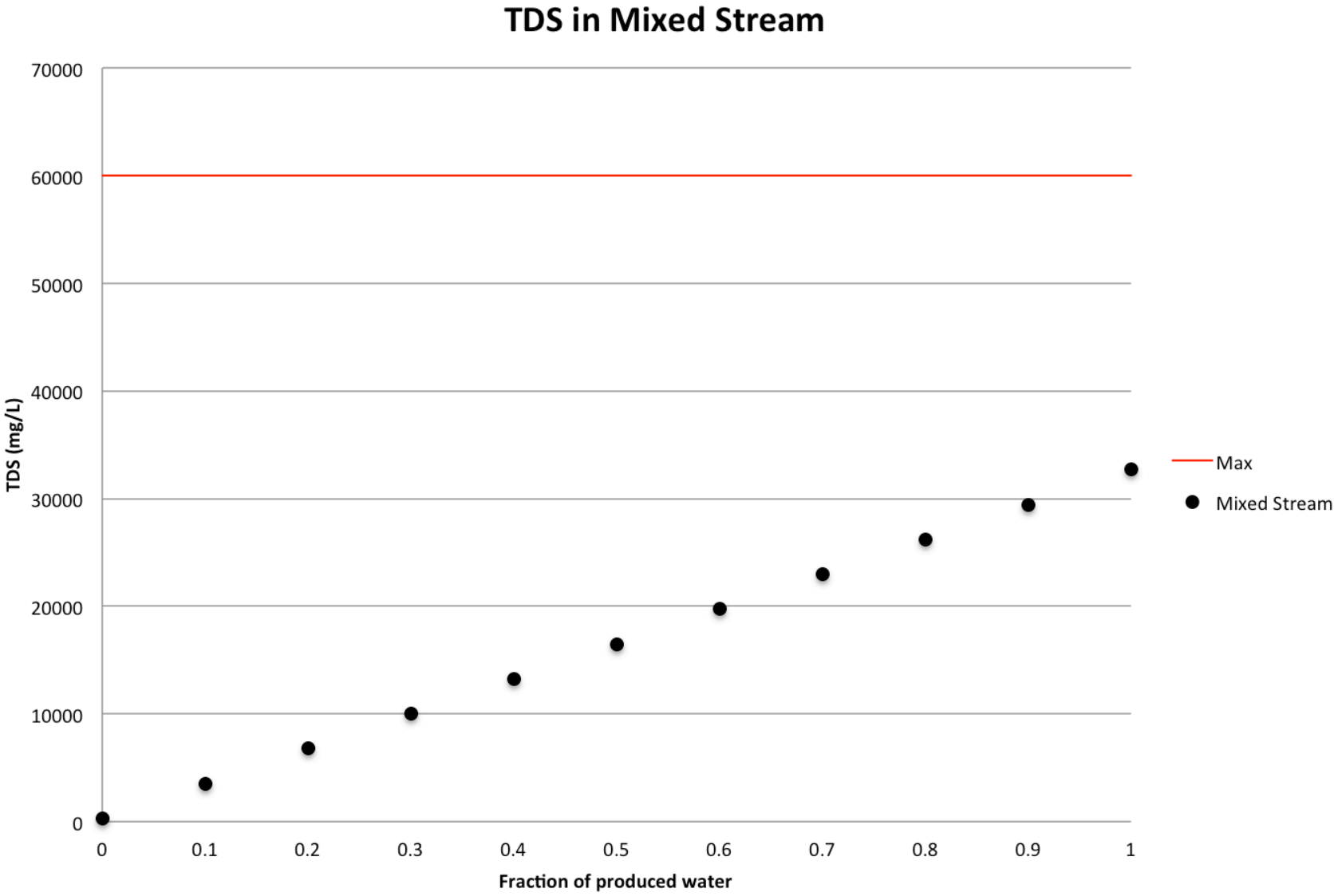
Produced Water Variability
Solids Size Distribution



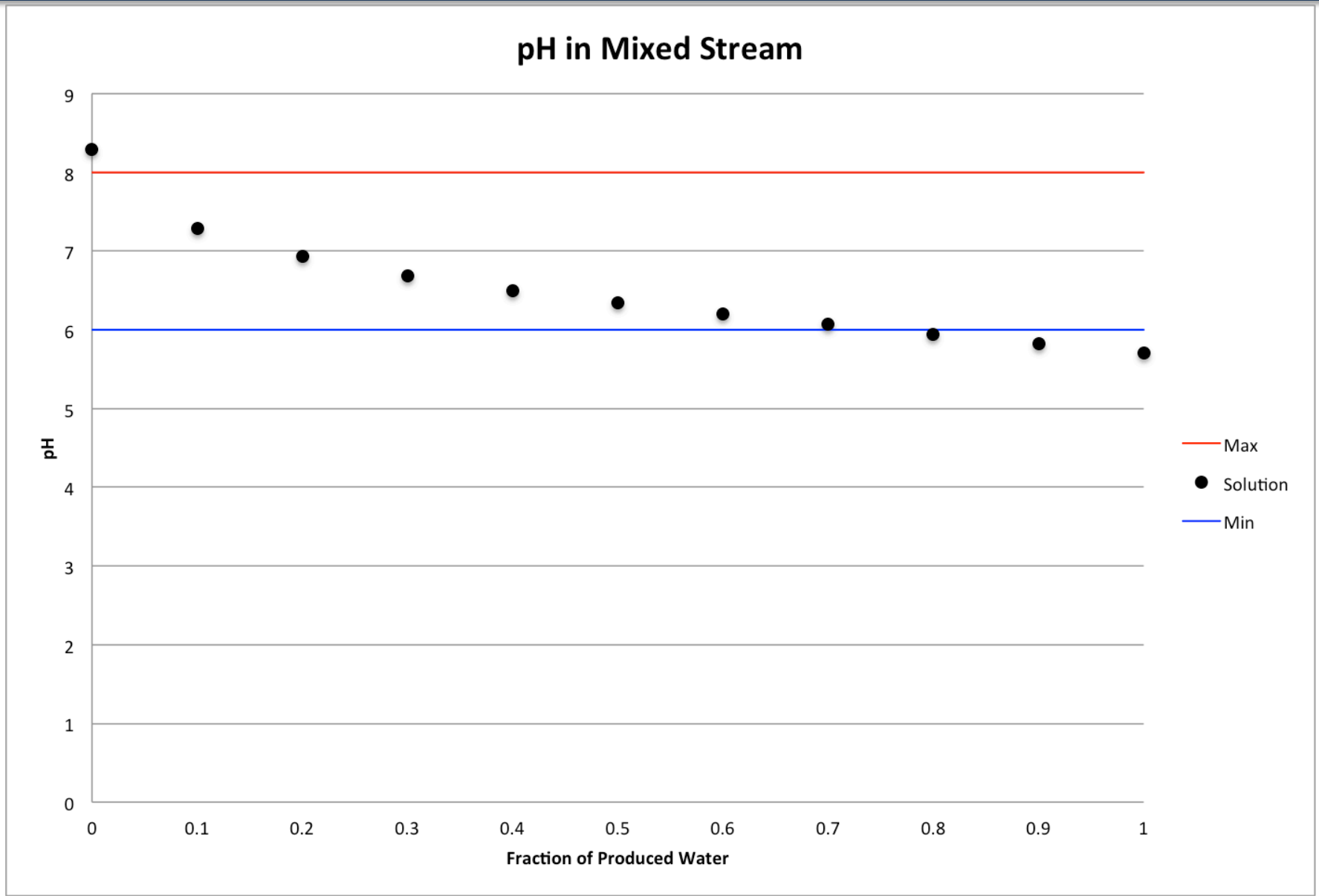
Chemical Modeling
Scaling Tendency



Chemical Modeling
TDS



Chemical Modeling
pH



Treatment Concerns

- H_2S
  - Chlorine Dioxide

$$8ClO_2 + 5H_2S + 4H_2O \rightarrow 5SO_4^{2-} + 8Cl^- + 8H^+$$

  - Scavengers

$$R(Scavenger) + H_2S \rightarrow R + SO_4^{2-} + H_2O$$

- Lime/Soda Softening
  - Increases pH
  - Increases carbonate

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Summary

- Reuse is site specific (economics)
- Extent/type of treatment is dependent on:
  - Produced water quality
  - Source water quality
  - Blending ratio
  - Fracturing fluid
  - Proppant used

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