Key Considerations for Frac Flowback/Produced Water Reuse and Treatment

NJWEA Annual Conference





May 9 – 13, 2011
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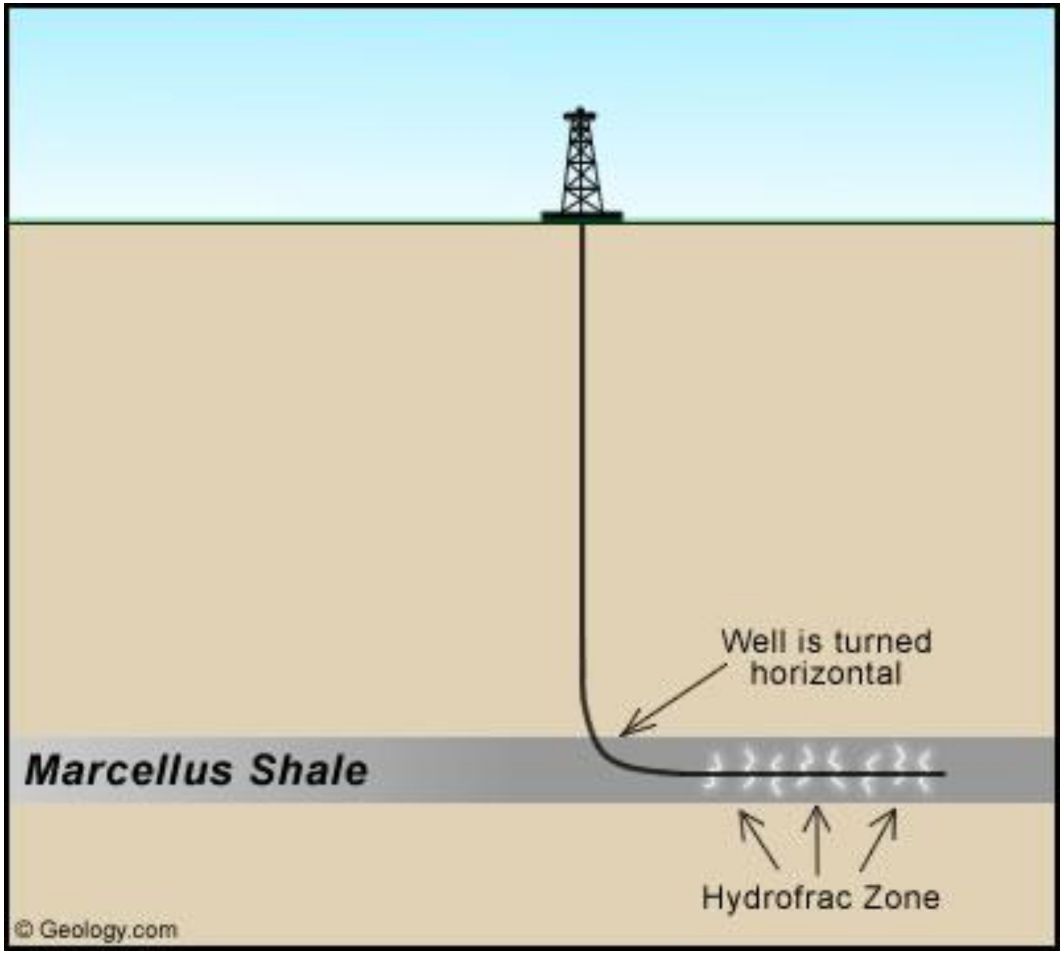
Today's Agenda

- Hydraulic Fracturing Process
- Flow and Water Chemistry
- Treatment Alternatives

Hydraulic Fracturing

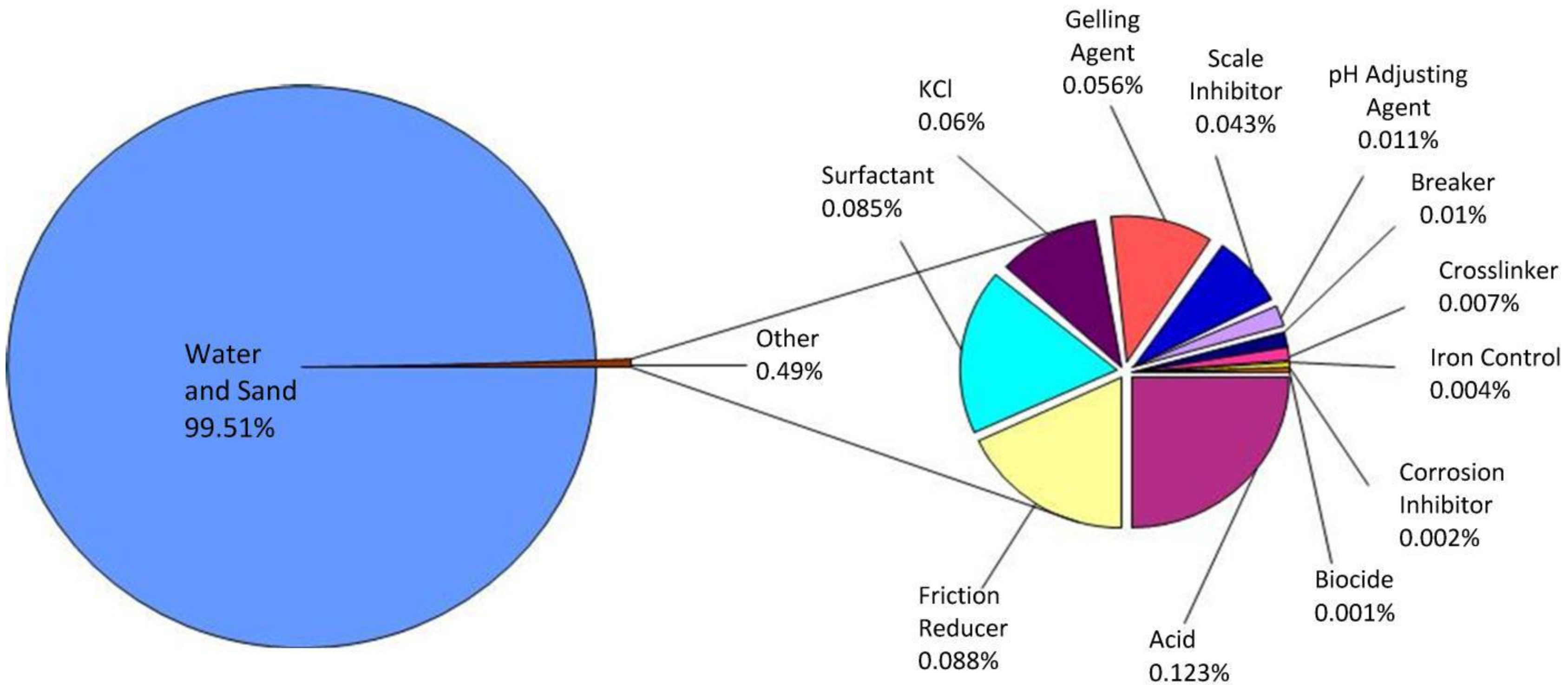
- Frac Method: Typically slick water frac
- Wells: 4 to 8 wells per pad
- Frac Water Volume: 4 to 6 million gallons per well
- Flowback: 15 - 35% Frac “flowback” water recovery requiring collection, handling, and disposal / treatment



Source: ALL Consulting. *Handbook on Coal Bed Methane Produced Water: Management and Beneficial Use Alternatives*, July 2003.

Composition of a Fracturing Fluid

- Fracturing solution consists of sand and water
- Additives include biocides, corrosion inhibitors, O_2 scavengers, friction reducers, surfactants, etc.



Frac Flowback Water Quality
(mg/L)

Parameter	Feed Water	Flowback
pH	8.5	4.5 to 6.5
Calcium	22	22,200
Magnesium	6	1,940
Sodium	57	32,300
Iron	4	539
Barium	0.22	228
Strontium	0.45	4,030
Manganese	1	4
Sulfate	5	32
Chloride	20	121,000
Methanol	Neglible	2,280
TOC	Neglible	5,690
TSS	Neglible	1,211

Wide Variation in Frac Flowback Chemistry (mg/L)

Parameter	Frac 1	Frac 2	Frac 3	Frac 4
Barium	7.75	2,300	3,310	4,300
Calcium	683	5,140	14,100	31,300
Iron	211	11.2	52.5	134.1
Magnesium	31.2	438	938	1,630
Manganese	16.2	1.9	5.17	7.0
Strontium	4.96	1,390	6,830	2,000
TDS	6,220	69,640	175,268	248,428
TSS	490	48	416	330
COD	1,814	567	600	2,272

Ref: ProChemTech International, Inc.

Flowback Water Management Issues

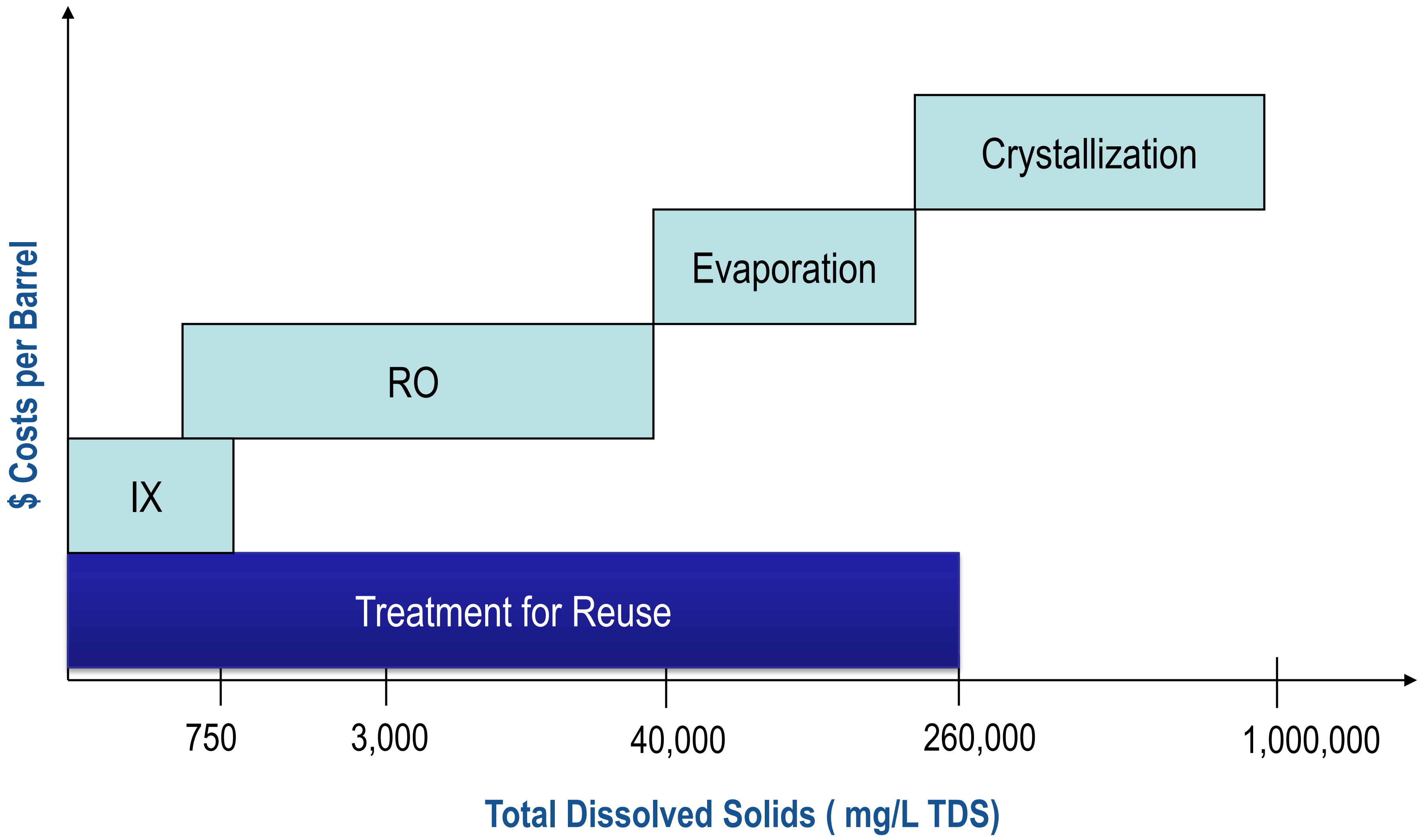
- Limited disposal capacity
- Long haul distances
- Limited freshwater supplies for fracturing
- Water volumes and chemistry presents treatment challenges
- Increased regulatory scrutiny

Flowback Water Management Solutions

- Treatment for Reuse
  - Oil/Grease
  - Hardness
  - Bacteria
- Treat for Discharge
  - Same as Reuse, Plus:
  - TDS

Treatment for Reuse

Range of Applicability vs. Cost



Treatment for Reuse Objectives

- Remove petroleum hydrocarbons
- Remove friction reducers and other polymer additives
- Remove inorganic scale forming compounds
- Kill bacteria
- Cost-effective

Re-use Technologies

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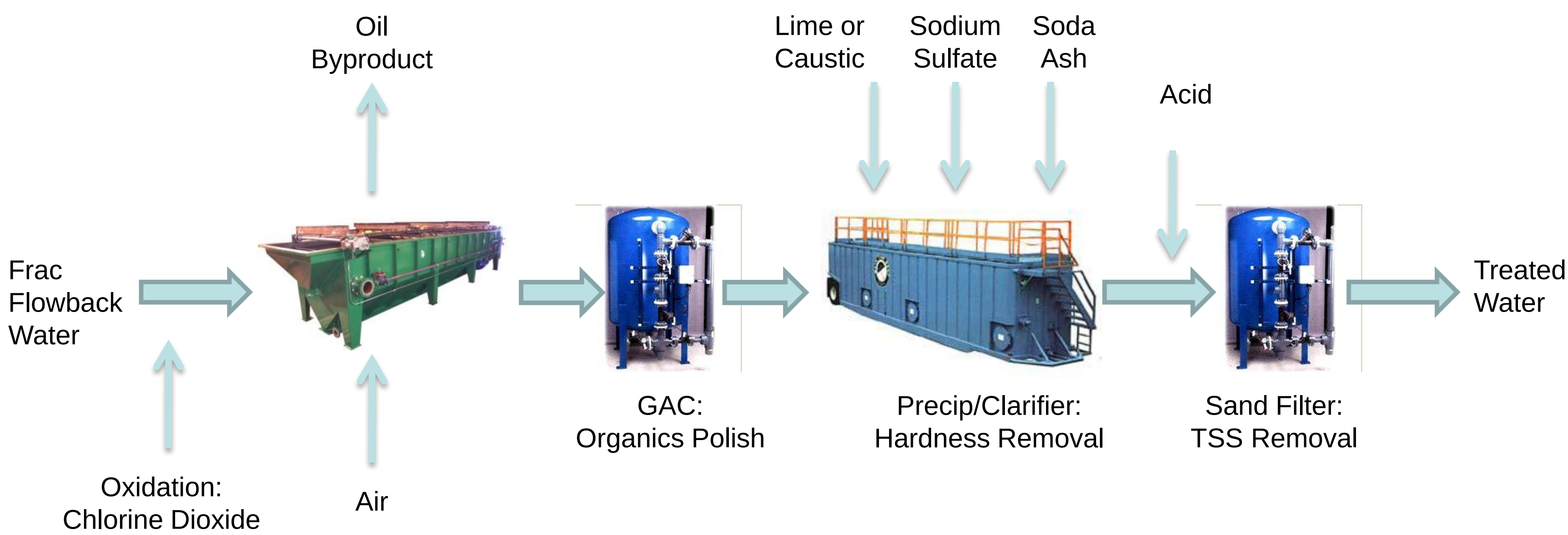
Organic Removal

- API Separators
- Dissolved Air Flotation
- Chemical Oxidation
- Biological Processes
- Activated Carbon
- Walnut Shell Filters
- Organo-Clay Adsorbants
- Air Stripper (VOC)

Inorganic Removal

- Chemical Precipitation
- Lime/Soda Softening
- Clarifiers
- Settling Ponds
- Ion Exchange
- Multi-Media Sand Filtration
- Greensand Filters
- Cartridge Filtration

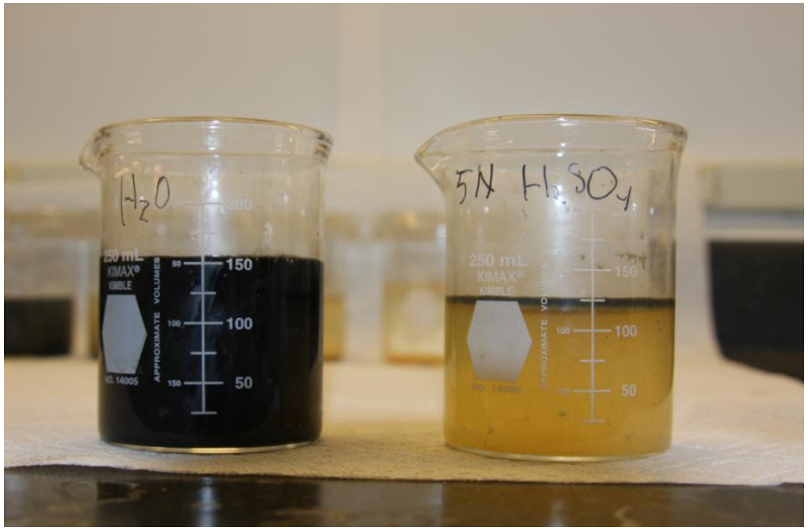
Example of Reuse Treatment Solution



Step 1. Chlorine Dioxide Oxidation

Oxidation/Disinfection

- Chlorine dioxide is strong oxidant that provides selective chemical oxidation
- Breaks oil/grease emulsions
- Destroys friction reducers and other chemical additives
- Kills Bacteria
- Oxidizes reduced compounds, such as Fe, Mn, Sulfide, ammonia, etc.
- More efficient than bleach



Ref: Sabre Technologies

Step 2. Dissolved Air Flotation
Hydrocarbon Removal

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- Fine bubble diffusion floats oil/grease and TSS to top
- Skimmer potentially recovers saleable oil
- Covered designs also available for VOC emission control
- Skid-mounted design

Ref: Pan America Environmental Website

Step 3. Granular Activated Carbon
Organics Polish

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- Liquid phase activated carbon removes most hydrocarbons and other organics
- Spent carbon is disposed of in approved facility
- Simple design and operation
- Skid-mounted design
- Periodically backwashed to remove TSS.

Step 4. Chemical Precipitation/Clarification
Metals/Hardness Removal

- Chemical precipitation system removes inorganic scale-forming compounds (barium, strontium, metals, hardness, etc.)
- Custom design mobile frac tank design includes multiple mix tanks and built-in clarifier
- Sludge is removed and dewatered in separate system prior to off-site disposal
- High pH operation (9.5 to 11)
- Elevated pH prevents bacteria from growing

Ref: Rain-for-Rent Website

Step 5. Multi-Media Sand Filtration
TSS Polish

- Conventional sand filter removes TSS before reuse
- Acid or carbon dioxide addition ahead of filter to reduce pH and eliminate calcium carbonate scaling
- Periodically backwashed with filtered water. BW returned to front of system.

Summary of Reuse Treatment System

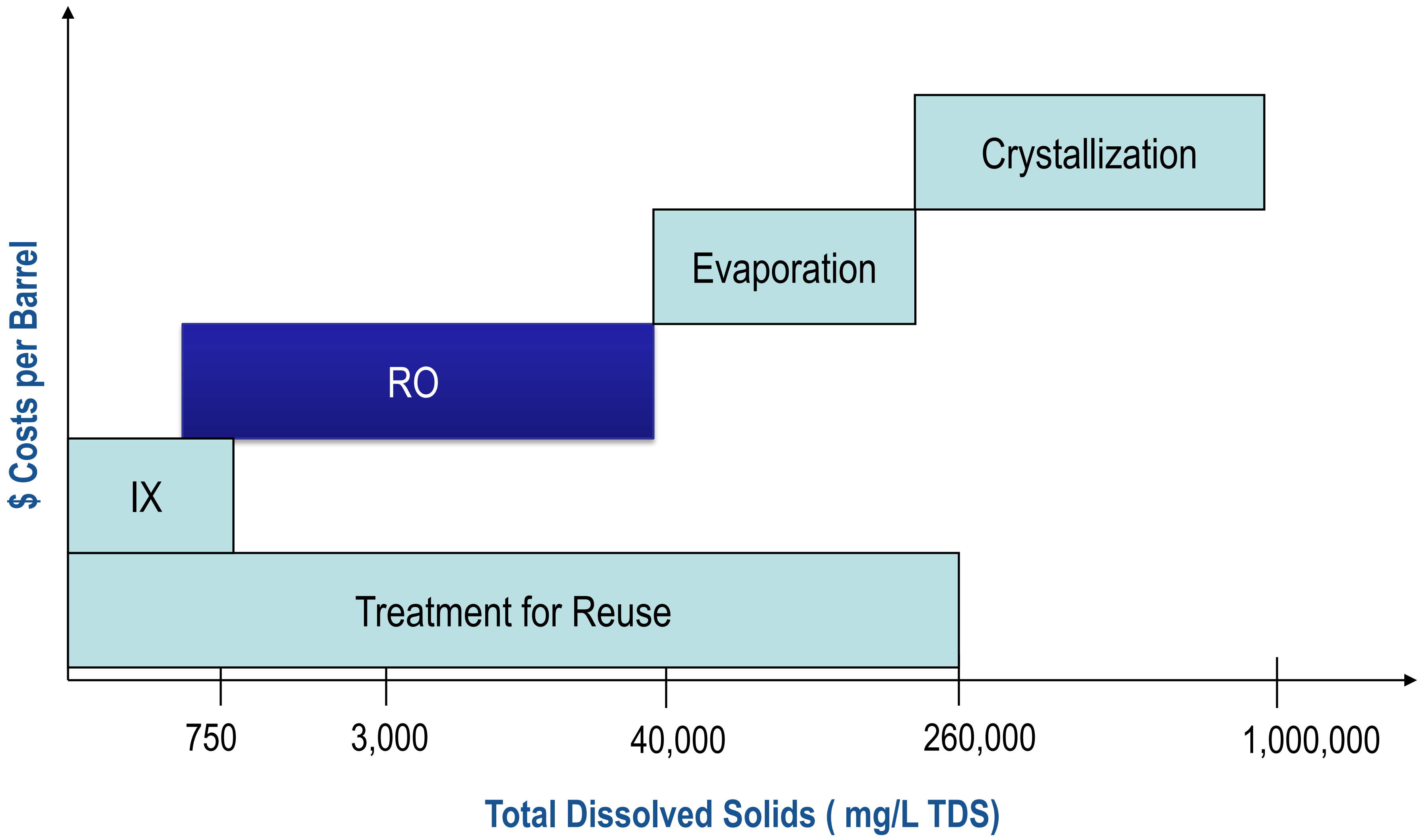
- Treatment systems are available to remove organic and scale-forming compounds, allowing reuse without TDS removal
- Treatment reduces fresh water makeup requirements and off-site disposal costs
- Multiple design options are available
- Bench and pilot-scale testing recommended to select best treatment options and minimize cost

Removal of TDS

Viable TDS Removal Alternatives

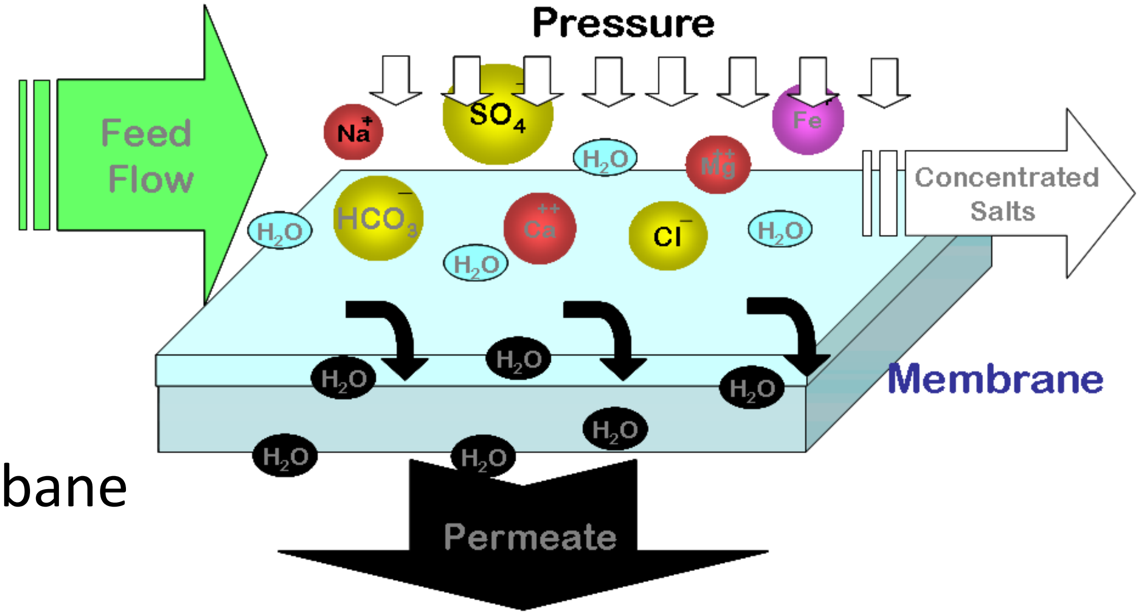
- Membrane Treatment
  - Reverse Osmosis
  - Nanofiltration
- Evaporation
  - Thermal Evaporators
  - Crystallization

Range of Applicability vs. Cost



Reverse Osmosis

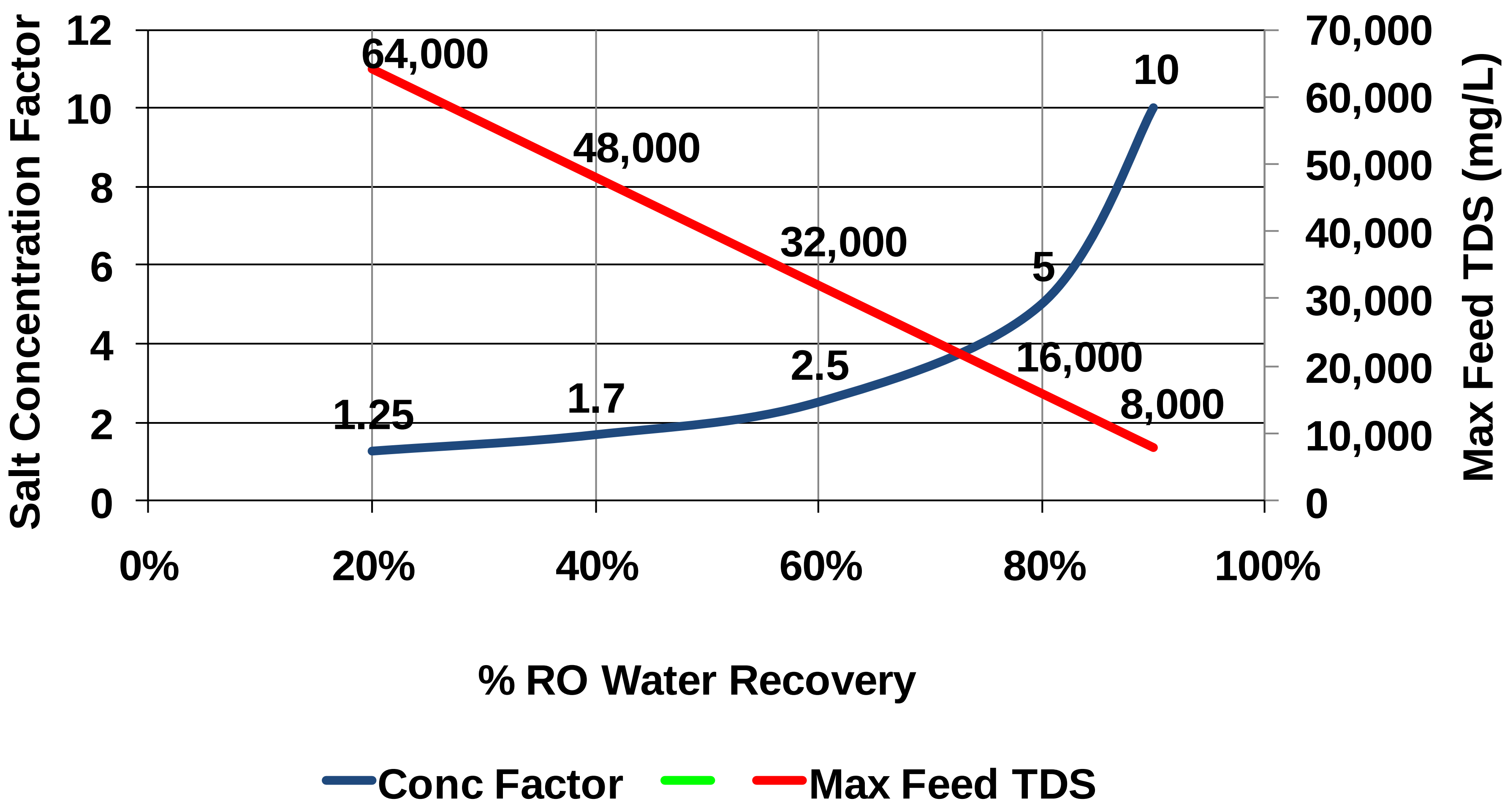
- Membrane separation technology that removes dissolved solids (TDS) from water
- Membrane is semi-impermeable - allowing only water to pass; 99%+ of all ionized species are rejected
- Non-selective treatment process
- Degree of <u>all</u> ion rejection is dictated by size and charge
- NF is a loose RO membane



Reverse Osmosis (cont)

- Maximum concentrate TDS is approx. 80,000 mg/L
- Energy costs are $1/10^{th}$ to $1/15^{th}$ the cost of mechanical evaporation
- Skid-mounted, compact design
- Operating pressures up to 1200 psig
- Multiple membranes and manufacturers available

Salt Concentration vs. Recovery



Historical Problems with RO Treatment for Produced Water

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Limited success due to inadequate pretreatment, resulting in fouling and scaling from:

- Calcium Hardness
- Iron
- Barium and Strontium
- Silica
- Microbiological Growth
- Organics
- Silt and Suspended Solids

Key to Success: Efficient Pretreatment

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Pretreatment Steps:

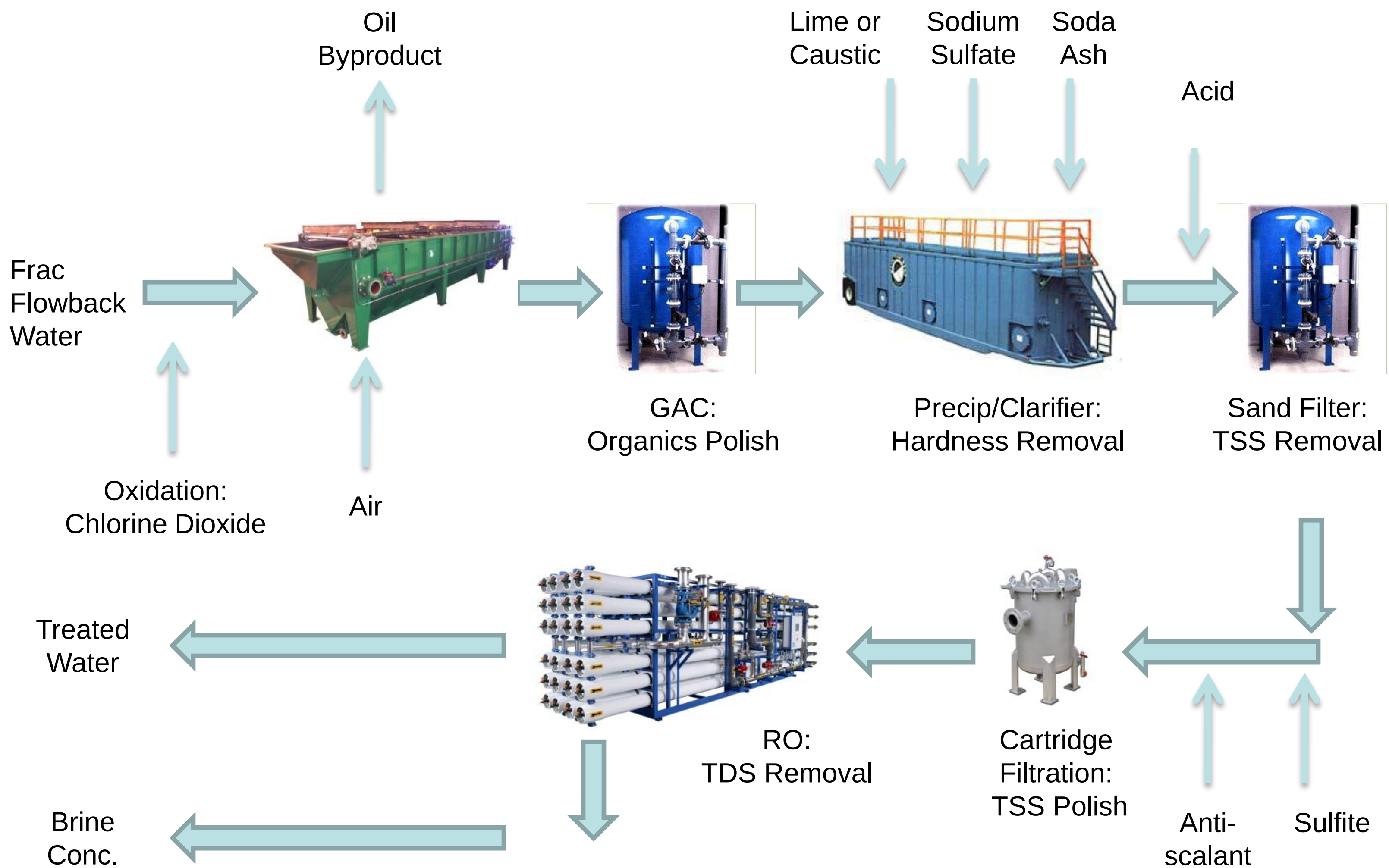
- Organics removal (oil/grease, polymers, etc.)
- Efficient hardness and metals removal
- Particulate removal
- Bacteria control

Result: Better pretreatment leads to less membrane fouling, higher water recovery and a lower cost of brine disposal

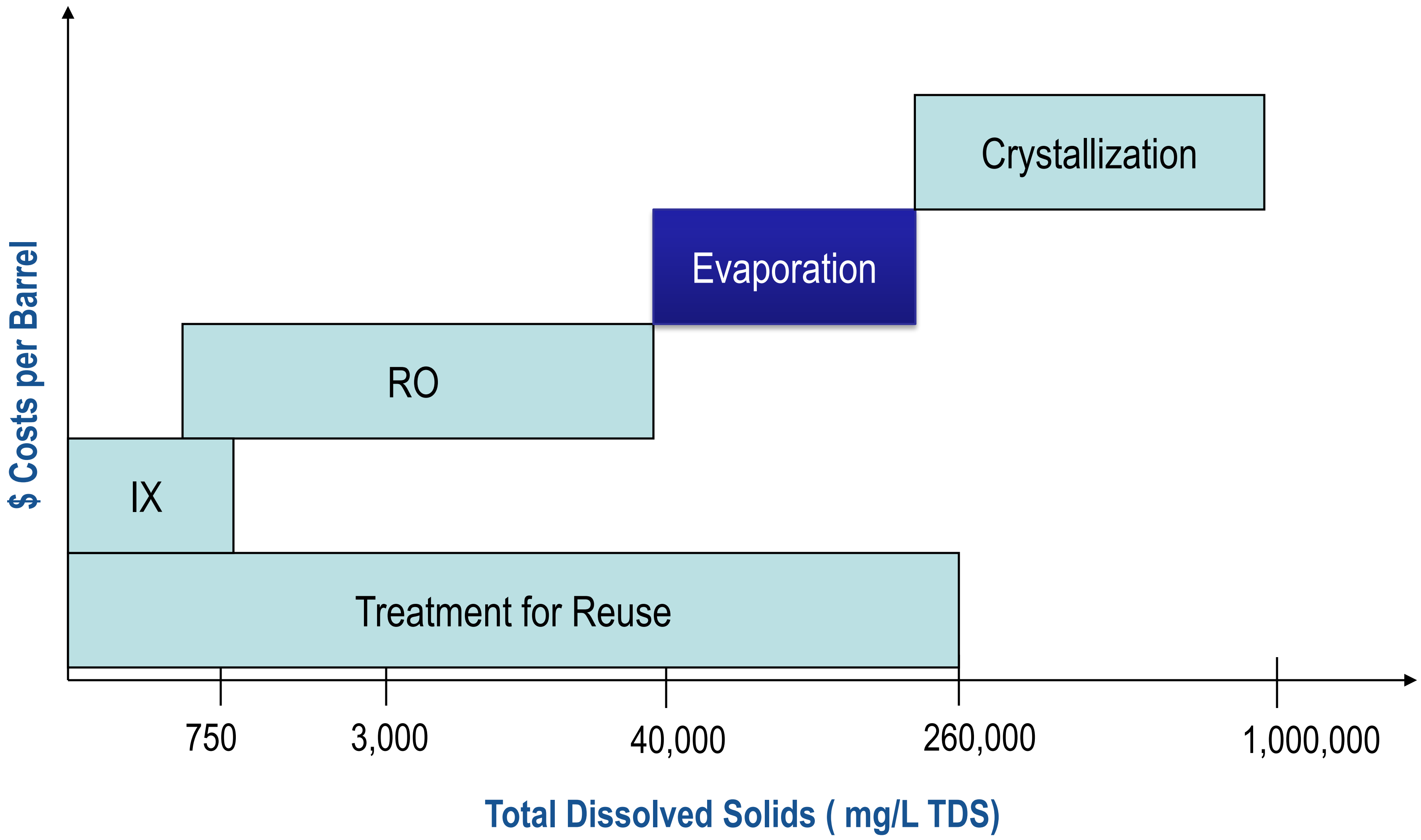
Scale Forming Salts

Salt	Saturation Concentration (mg/L)
Calcium Carbonate ($CaCO_3$)	8
Calcium Fluoride (CaF_2)	29
Calcium Orthophosphate ($CaHPO_4$)	68
Calcium Sulfate ($CaSO_4$)	680
Strontium Sulfate ($SrSO_4$)	146
Barium Sulfate ($BaSO_4$)	3
Silica, amorphous (SiO_2)	120

Example Treatment Solution for TDS Removal



Range of Applicability vs. Cost



Evaporation

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- Ideal TDS Range of Feed Water is 40,000 to 120,000 mg/L
- Produces high quality distillate and liquid brine concentrate
- Brine concentrate requires further treatment or disposal (max TDS concentration is approx. 260,000 mg/L)
- Evaporation systems more energy intensive than RO
- Most evaporation systems cannot handle any solids

Types of Evaporation Systems

- Forced Circulation
- Falling Film
- Rising Film
- Agitated Thin Film
- Plate and Frame

Selection Considerations

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- Chemical Composition of Feed Stream
- Scaling/Fouling Potential
- Foaming Potential
- Materials of Construction
  - Based on Corrosion Potential of Feed Stream

Economization

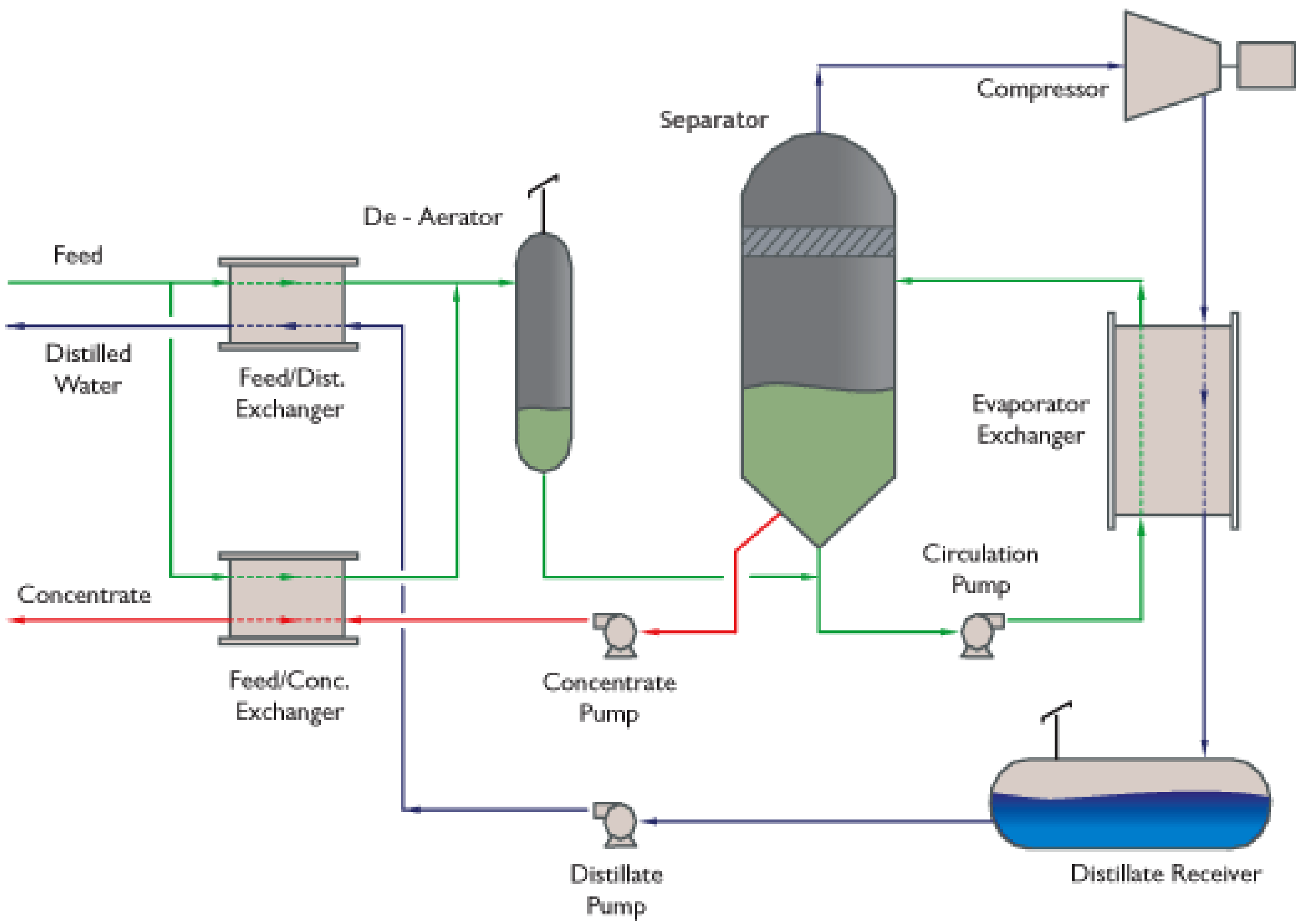
- Multiple Effects
  - Vapor From Each Effect is used in the Next/Previous Effect Depending on Set-up to Reduce Steam Use
- Vacuum
  - Reduces Boiling Point
  - Maximizes Efficiency When Used in Concert With Multiple Effects
- Mechanical Vapor Recompression
  - Recompresses the Vapor to Reduce Steam Use
  - Usually Uses Just One Effect

Pretreatment Equipment and Controls

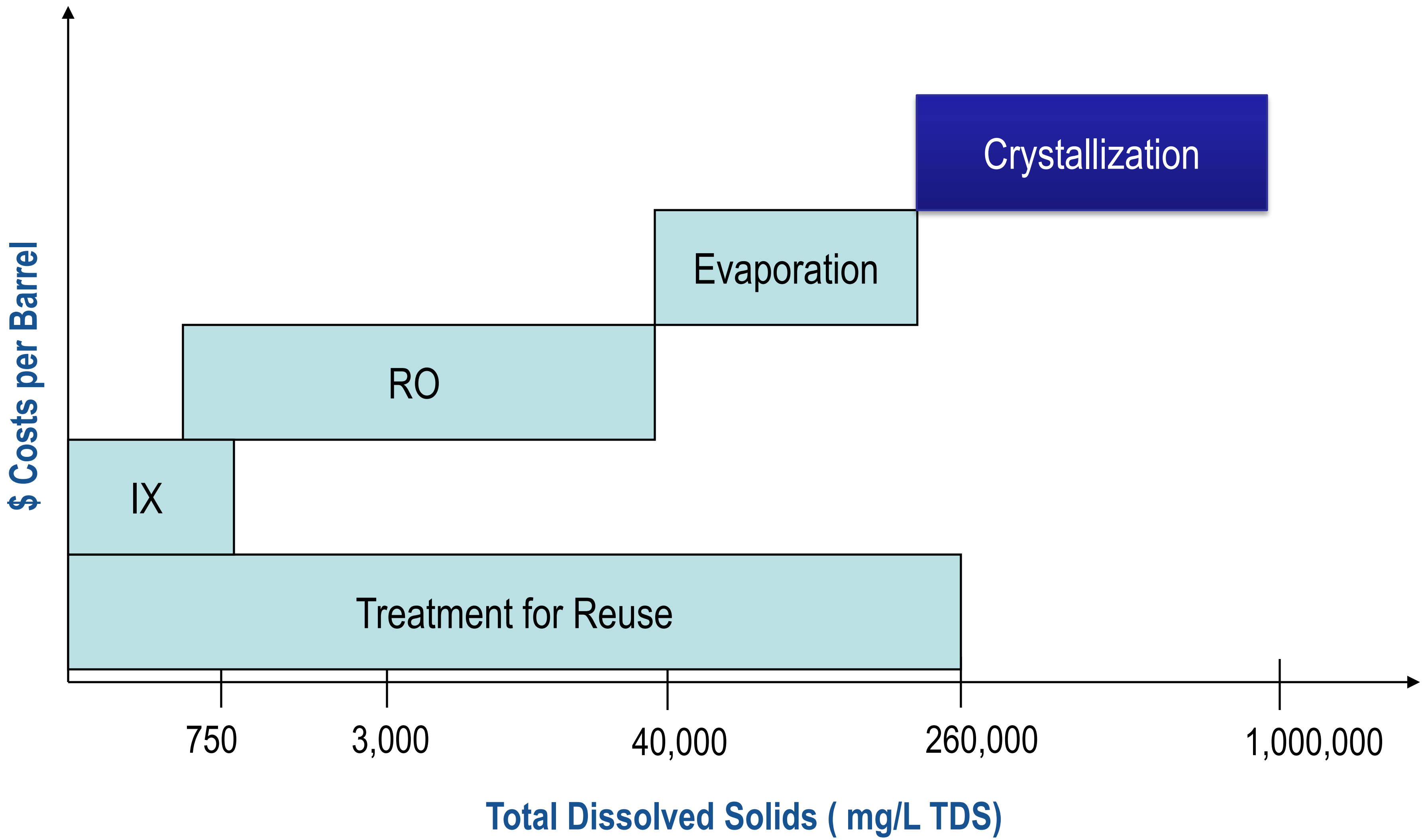
- Particulate Removal via Filtration
- pH Control
- Scale Prevention
- Organic Removal
- Defoamer Addition
- Preheating via Heat Exchangers

MVR Evaporator

Most Economical for this Application



Range of Applicability vs. Cost



Brine Concentrate Treatment Options

- Crystallizer
- Drum Dryer
- Spray Dryer
- Haul to Disposal Well

Crystallizer

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- Complex system designed to produced purified salt products
- Very large systems requiring central location
- Multiple Types of Crystallizers available
- For Marcellus flowback water, two products can be produced with proper pretreatment:
  - Sodium Chloride dry salt
  - Calcium Chloride liquid

Drum Dryer

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- Capable of converting mixed salt liquids into dry solids
- Typically steam driven systems operating at atm or under vacuum
- Relatively compact footprint
- Multiple types of dryers available
- Results in dry product

Ref: Buflovak website

Spray Dryers

- Hot air produced from burning natural gas used to evaporate liquid sprayed in top of tall cylindrical vessel
- Dries solids quickly in a single pass
- Baghouse is used to collect salts and vent off gas
- Very tall systems require central treatment location
- In general, very effective for mixed salt streams

Ref: Swenson Technology Website

Evaporation Summary

- Most economical for high TDS/low volume sources
- Pretreatment necessary to keep heat transfer surfaces clean
- Variety of manufacturers and designs available
- Most efficient design is Mechanical Vapor Recompression
- Evaporators are generally very large; some skid mounted units available
- Produced brine stream requires further treatment

Questions and Answers

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