Water Treatment for Hydraulic Fracturing Operations

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Cetco

Scope of Presentation – Water Treatment for HF Operations

In this presentation, the major technologies that are likely to dominate recycling of HF flow back fluids are discussed.

These are:

- **Coagulation / Flocculation & Electrocoagulation**
- **MVC – Mechanical Vapor Compression**
- **Ceramic Membranes and other Media**
- **Biotreatment**
- **+ oxidation, biological control, scale control**

Scope of Presentation – Water Treatment for HF Operations

There are three aspects of hydraulic fracture flow back that are driving the industry to select these technologies.

These are:

- **High volumes of water**
- **Three stages of field development**
- **High concentration of organic and inorganic TSS**

Water Volumes in Unconventional are a Game Changer

Conventional HF in the US: 1 MM wells

Conventional HF outside the US: 1.5 MM wells

This suggests that there is a huge body of experience in managing, handling, treating, and recycling HF flow back fluids.

But the volumes of water involved in Unconventional are a Game Changer:

- Unconventional HF: 120,000 bbl (20 ML)/job
- Conventional HF: 2,000 bbl (320 kL)/job

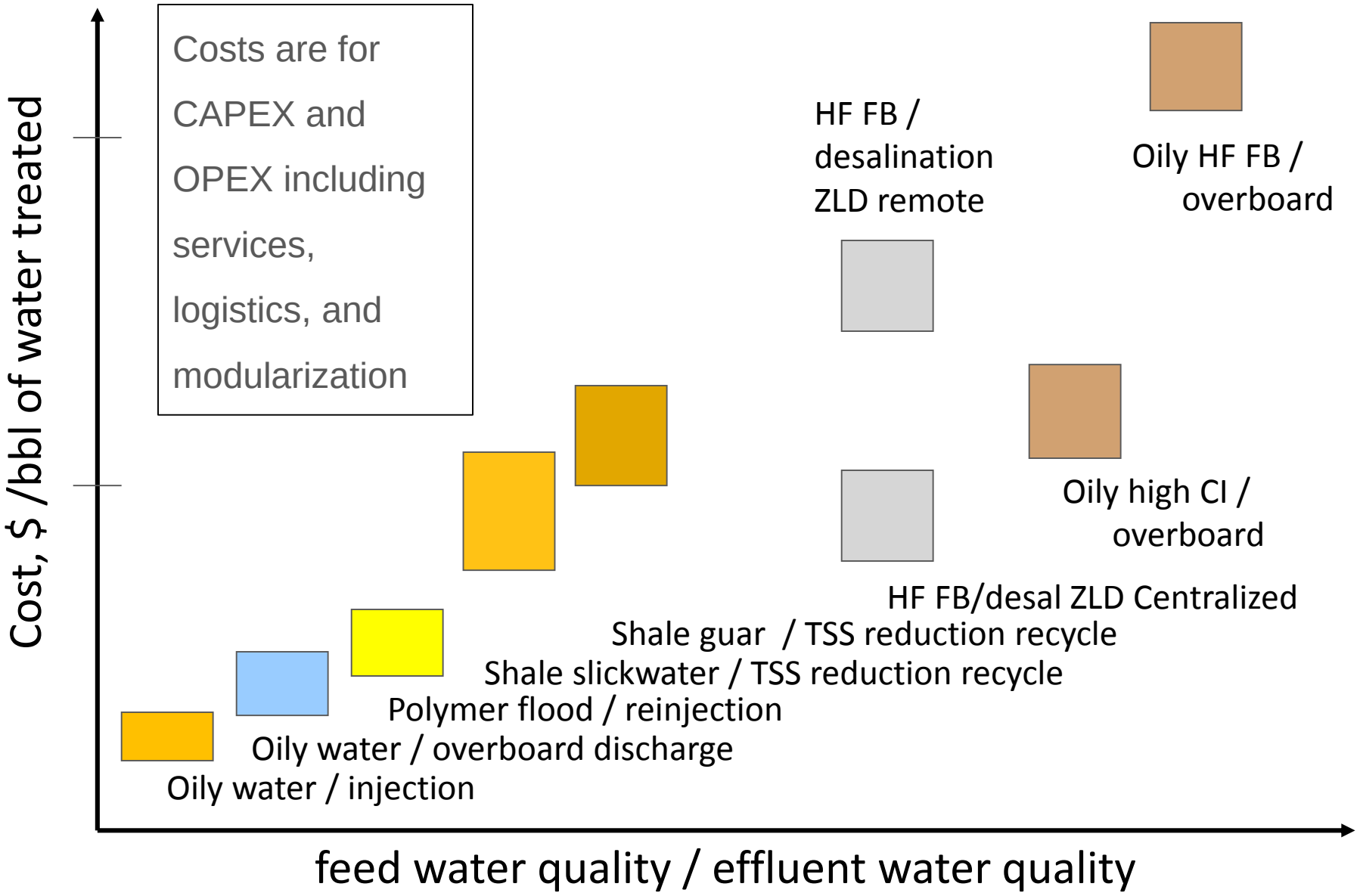
Conventional Offshore HF Flow Back – as a possible analog?

Compact, simple, reliable systems for stranded water

Most systems involve pre-treatment and some form of media

	Vendor 1	Vendor 2	Vendor 3	Vendor 4
System	Weirbox + Filters + Media + AC	Weirbox (w/ coalescer pad) + Filters + Media + AC	Surge tank + CINC Centrifuge + Media + AC	Separator (w/ plates and coalescer pad) + Media + AC
Form	Granules	Cloth	12 x 20 granules	Granules
Regenerable?	No	No	Backwash/rinse	No
Design criteria	2 BPM	5 gpm / ft^2	13.5 gpm / ft^2	2 gpm / ft^2
Flow direction	Radial O→ I	Radial O→ I	Down	Up

Ranking of Produced Water Treatment Challenges



Shale HF Flow Back Fluid Characterization

As far as water treatment is concerned, there are only two types of flow back fluid:

1) Slickwater fluids

- **moderate TSS: 500 – 1,000 mg/L**
- **well understood**

2) Polysaccharides (guar, HEC, xanthan)

- **very high TSS: 2,000 – 8,000 mg/L**
- **high fouling tendency**

Nothing else needs be considered due in part to variability of flow back fluids.

Analog Water Treatment Industries

Beef Rendering Plan (002-83)			
Contaminant	Raw (mg/l)	Treated	% Removal
BOD	5,700	590	89.6%
TSS	4,540	260	94.3%
FOG	3,050	150	95.1%

Food Processing: high organic TSS

High loading of dissolved and suspended biodegradable contaminants

Anaerobic + aerobic activated sludge

Ref.: **Powell Water Systems Inc.**

Analog Water Treatment Industries

Pulp and Paper: high loading of polysaccharides

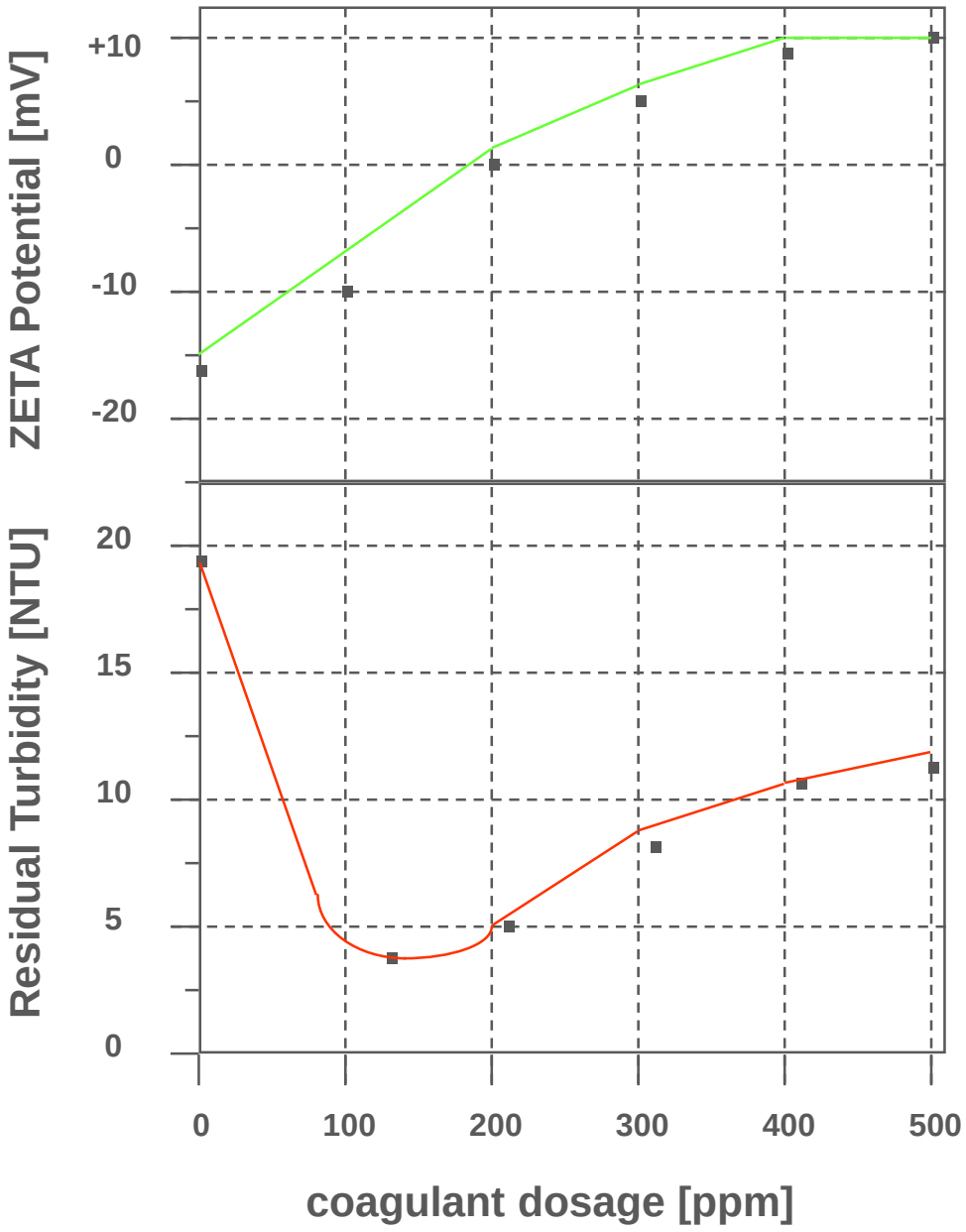
COD = 1,000 to 5,600 mg/L

Lower COD: Chemical oxidation + coagulation: 50 % COD removal

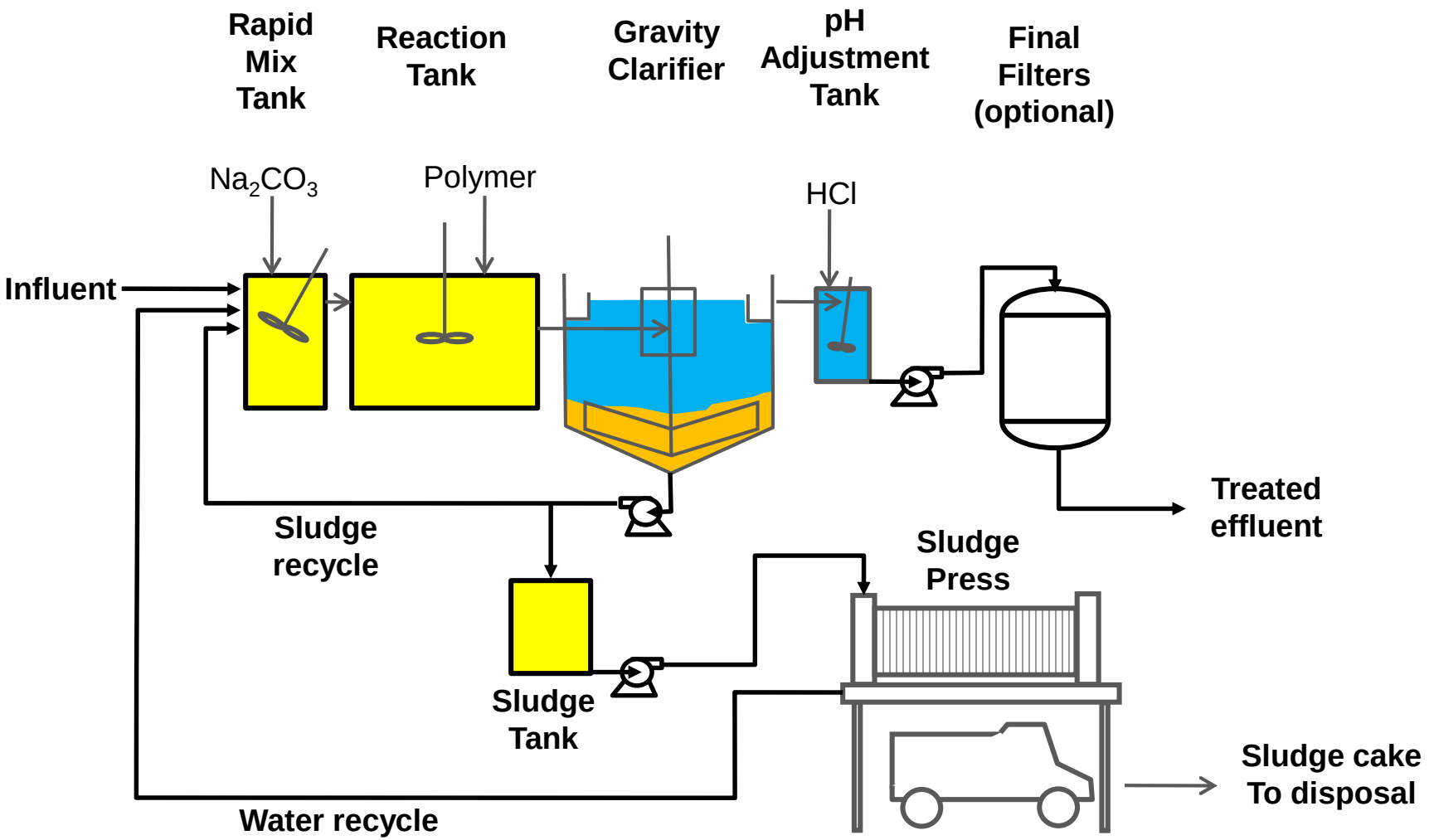
Higher COD: Chemical oxidation + anaerobic / aerobic activated sludge: 90 % COD removal

DAF + chemical precipitation: 60 % COD removal

Ref.: **Pokhrel, Treatment of Pulp and Paper Wastewater – A Review**


ZETA Potential [mV]
+10
0
-10
-20
Residual Turbidity [NTU]
20
15
10
5
0
0
100
200
300
400
500
coagulant dosage [ppm]

Primary Treatment Flow Diagram – Example



Ref.: Shell report

Stage of Field Development:

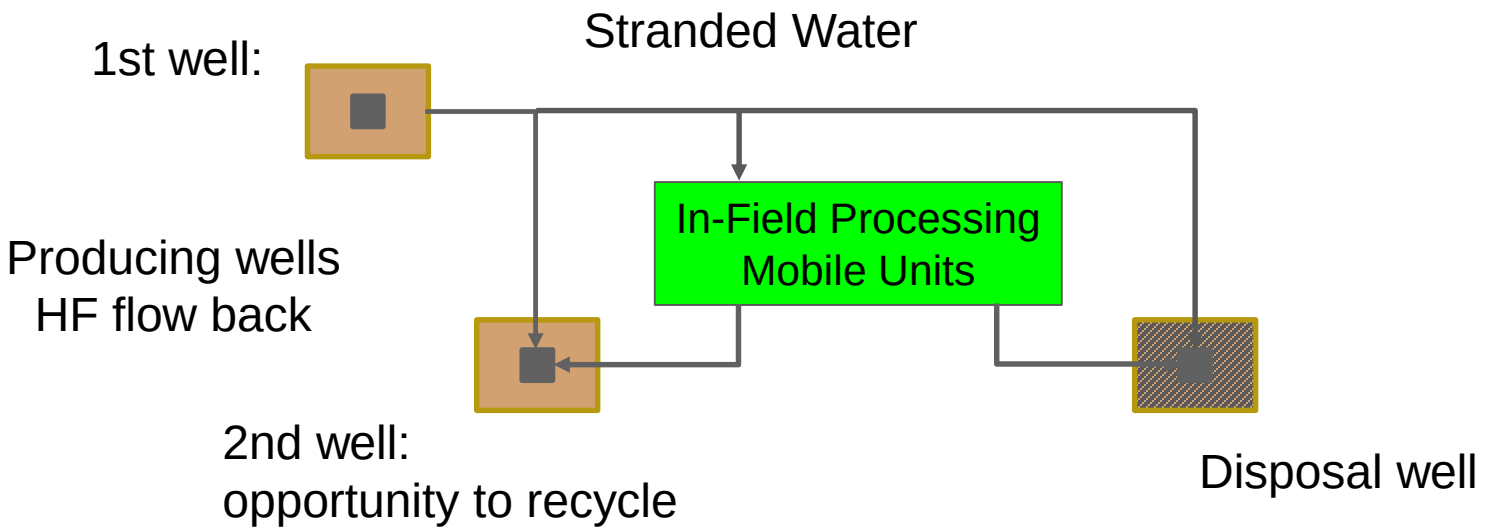
Three Stages of Field Development:
(defined in terms of type of water treating equipment)

1) Remote and isolated well development –
mobile water treating systems

2) Well clusters with some in-field drilling and completions –
modular water treating systems

3) Extensive in-field development with infrastructure –
networked conveyance systems
centralized water treating plants

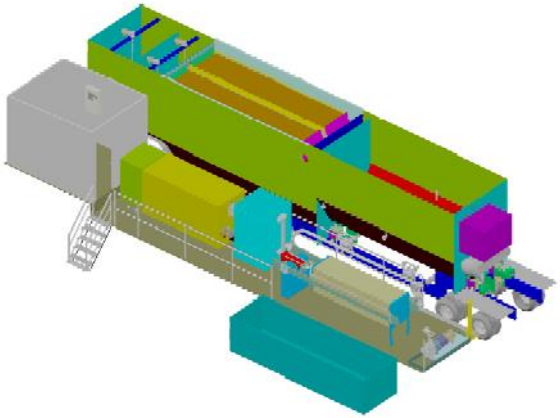
Initial stage of field development:
a few isolated well pads
no water infrastructure



isolated and remote water treatment:
reduce or eliminate need for disposal
provide fracturing fluids for next well (recycling)

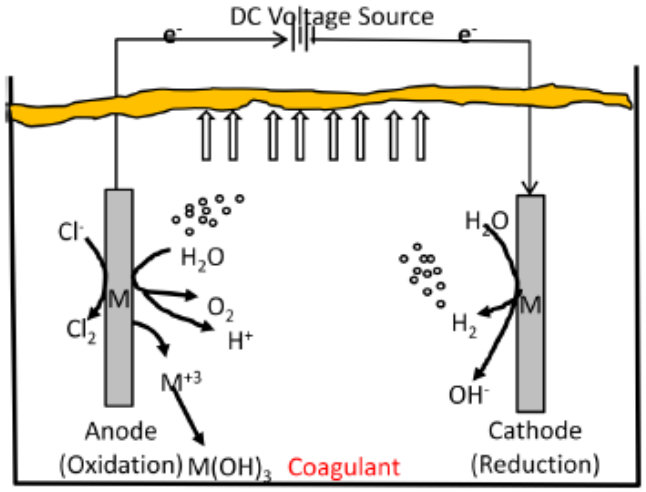
Distance from well to treatment < 2 miles

Mobile Technology



Fountain Quail / Aqua-Pure ROVER Mobile Clarifier – TSS (solids and organics) are chemically precipitated. Solids settle fconveyed to filter press, ultimately to cuttings box. 90 % removal of TSS. Capacity is 10 kBWPD (7 BPM).

GE Mobile Evaporation – Truck-mounted MVR with horizontal shell in tube Hex. Capacity 1 BWPM.



Mobile Electrocoagulation units: Halliburton, Cetco – reduced chemical consumption, 90% removal of TSS.

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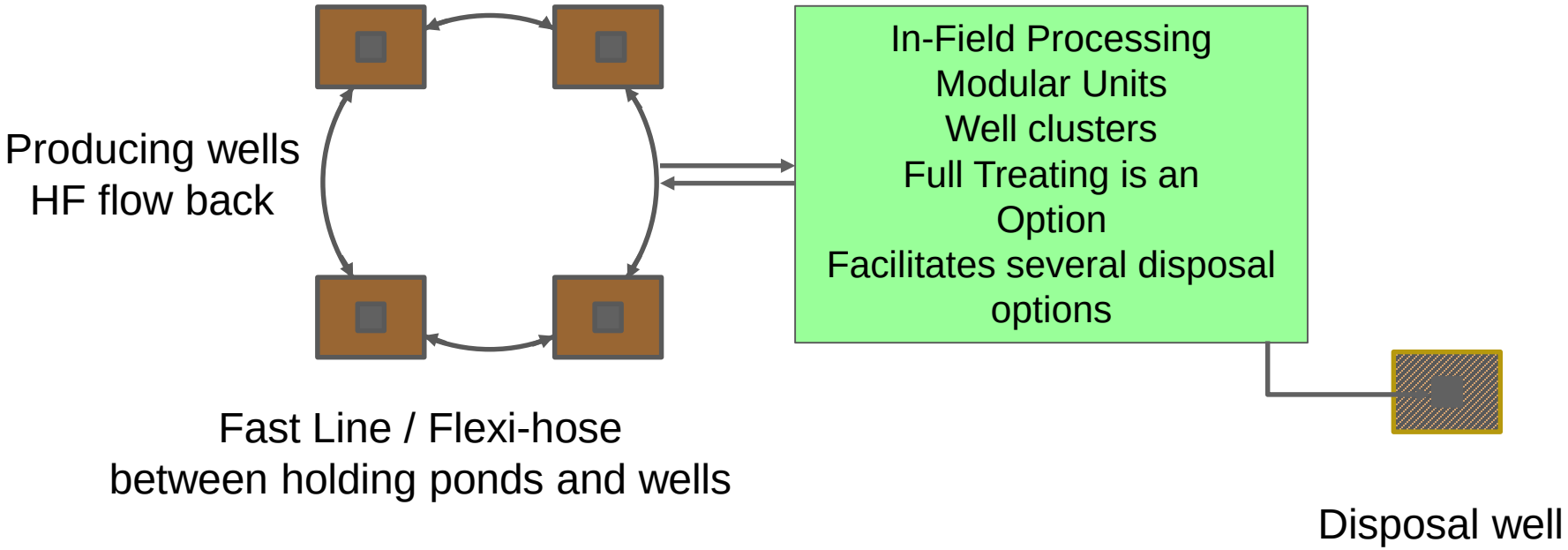
Some in-field development:

well clusters

modular water treating units

no water infrastructure



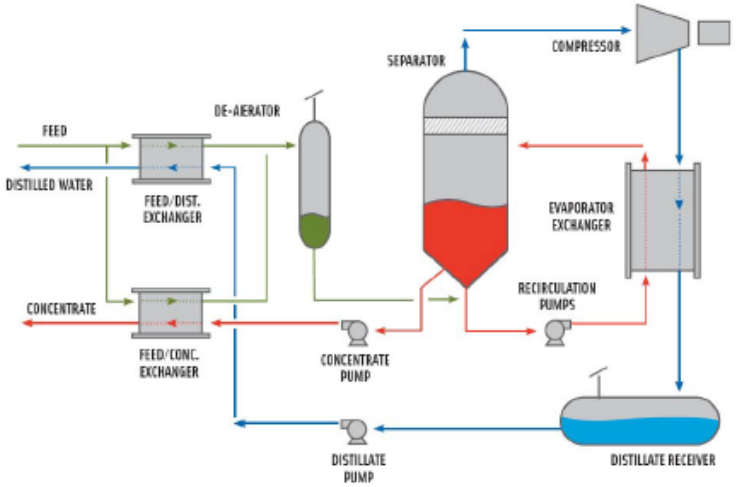
modular water treatment:
larger than mobile, requires set-up
reduce or eliminate need for disposal
provide fracturing fluids for next well (recycling)

Distance from well to treatment < few miles

Semi – Centralized / Modular Treatment Facilities

Barnett Shale: Semi – Permanent evaporation facilities using Fountain Quail NOMAD MVR evaporation technology. Capacity ~ 20 kBWPD.

Marcellus Eureka Resources Facility: Semi – Permanent facilities NOMAD.



Comparison of Thermal Desalination Techniques

		MED	TCD (MED-TVC)	MVC	RO	MSF
Plant depreciation	10 % per annum	0.90	0.60	0.80	0.48	0.69
Electricity	0.022 US$/kWh	0.022	0.022	0.308	0.088	0.088
Sea water	0.028 US$/m3	0.196	0.084	0.056	0.084	0.235
Steam	3.616 US$/tonne	0.58	0.58	-	-	0.58
Chemicals		0.024	0.024	0.016	0.03	0.015
O & M	3 % of investment /year	0.27	0.18	0.24	0.144	0.2
Total cost USD / m^3		**2.0**	**1.5**	**1.4**	**0.8**	**1.8**
Total cost if steam is free		**1.4**	**0.9**	**1.4**	**0.8**	**1.2**

Centralized Processing

CWT / POTW

Full Treating is an Option

Lower treatment cost
Higher gathering cost

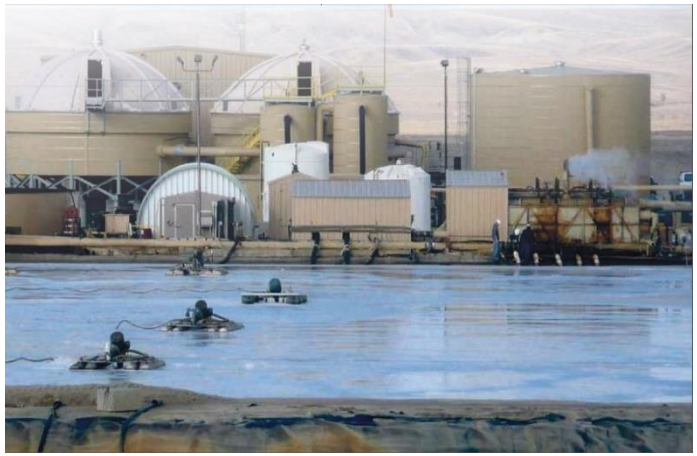
Requires a network

Facilitates fill re-cycle

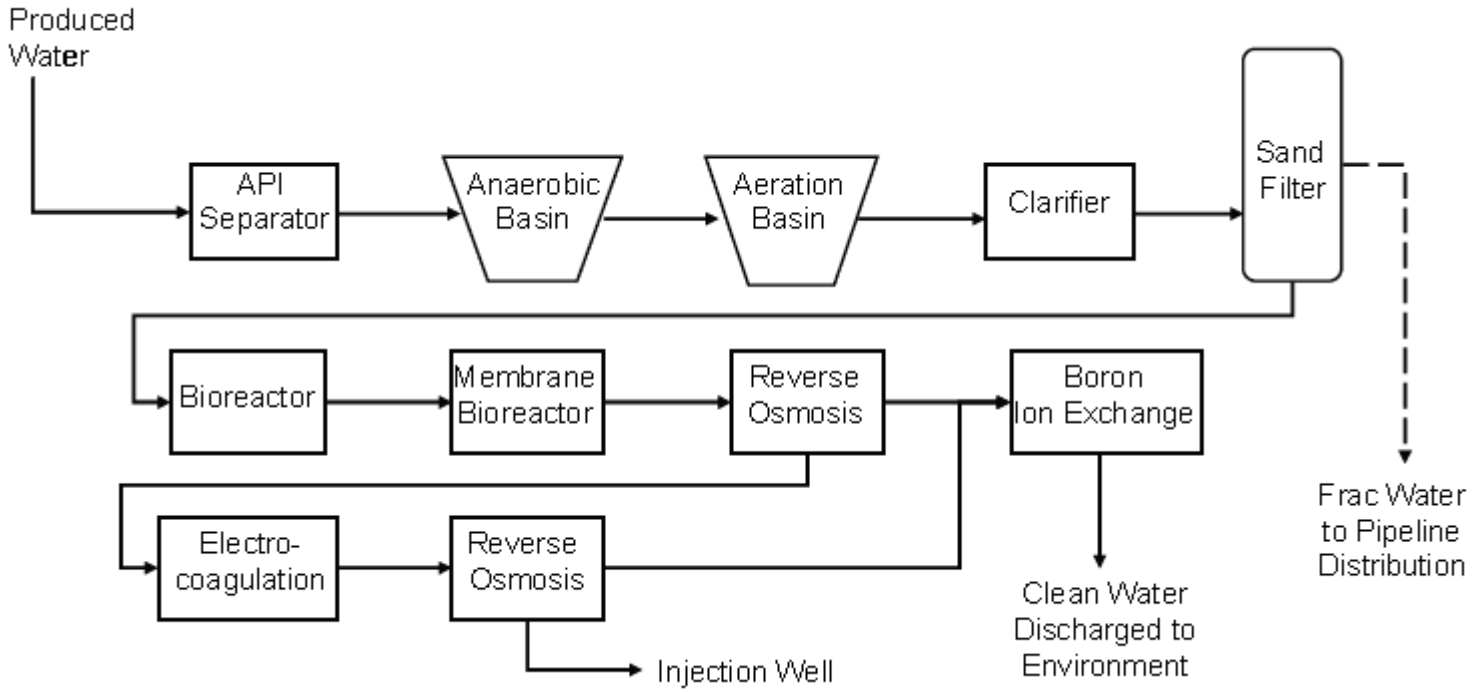
Networked Water
a few large scale treatment sites

Centralized
Distance to treatment facility
> 20 miles

Pinedale



Pinedale – Further Refinement



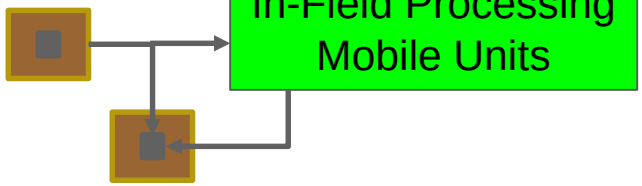
Parameter	Typical Plant Feed Range	WYPDES Discharge Limits WY0054224	Results March 2010
O&G, mg/l	50–2,400	10	Non-Detect
TDS, mg/l	8,000–15,000	500	41
Chloride, mg/l	3,600–6,750	230	18
Sulfate, mg/l	10–100	3,000	Non-Detect
Conductivity, µS/cm	8,000–20,000	7,500	78
pH	6.5–8.5	6.5–9	7.34

Note the additional treatment steps employed for RO reject (brine). This greatly reduces the volume of reject from the facility. Overall recovery is 84 to 90 % of feed.

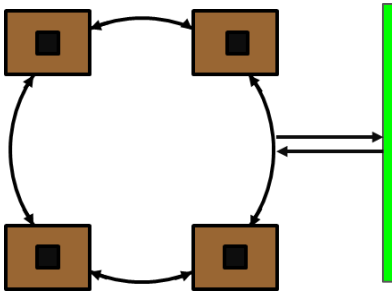
Also note the use of Electrocoagulation.

The Progression of Stages in HF Water Treatment

Increasing distance between well and water treatment



In-Field Processing
Mobile Units



In-Field Development
Modular Units
Well clusters
Full Treating is an Option

Centralized Processing

CWT / POTW

Full Treating is an Option

Lower treatment cost
Higher gathering cost

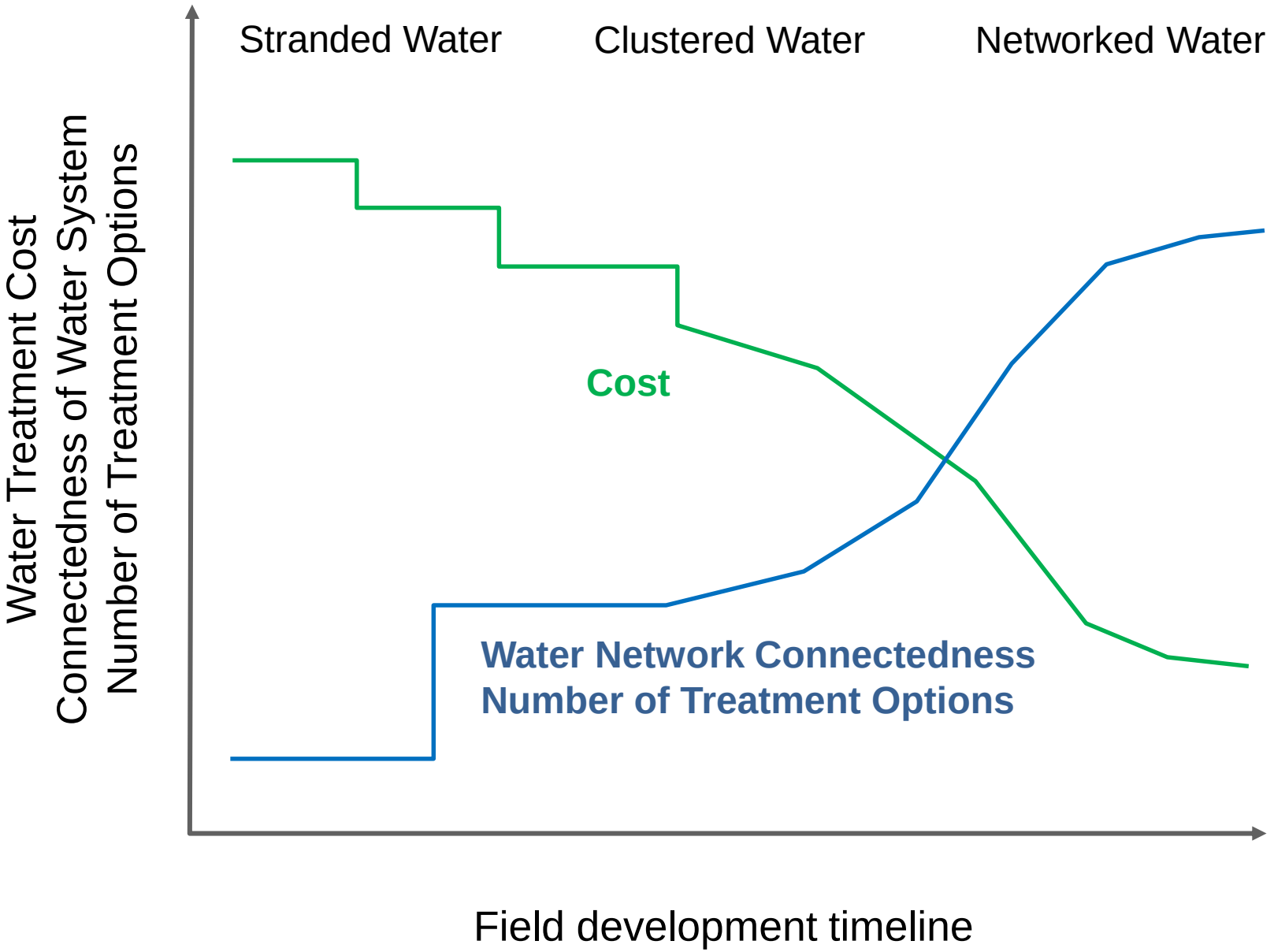
Requires a network

Facilitates fill re-cycle

In-Field	Near-Field	Centralized
Dist < 2 miles	2 < Dist < 20 miles	20 miles < Dist
Stranded Water	**Clustered Water**	**Networked Water**
Mobile Units	**Modular Units**	**Centralized Treatment**

Increasing distance between well and water treatment

Cost versus Stage of Field Development:



Conclusions

The dominant technologies for HF flow back water treatment for recycling will be:

1) MVR for desalination – modular & centralized

3) Coagulation / Flocculation, EC and ceramic membranes for mobile and modular TSS removal

3) Biotreatment for centralized TSS removal

Other specialized technologies will be applied for breaking the polymer (oxidation), biological control (ozone, on-site chlorine generation) and for scale control (mostly chemicals)

The End

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