Major Technology Categories

- Adsorption/Exchange
- Chemical/Catalytic Conversion
- Chemical Oxidation
- Concentration/Volume Reduction
- Membrane Processes
- Physical Separation
- Thermal/Catalytic Destruction
- Biological Oxidation/Reduction/Conversion (presented at end)
- Miscellaneous

Comprehensive State-of-the-Art Technology List

(Considered Feasible based on Full-Scale or Reliable Pilot-Scale Application)

- Adsorption/Exchange
  - Activated Alumina
  - Activated Carbon
  - Ion Exchange
  - Macroreticular Resins
  - Bentonite
  - Natural Polymeric
  - Chitosan/Algal
  - Solvent Extraction
- Chemical/Catalytic Conversion
  - Catalytic Dechlorination
  - Hydrolysis
  - Photolysis
  - Reductive Degradation
  - Ozonation/chlorination
  - Fenton's Agent
- Concentration/Volume Reduction
  - Evaporation/Crystallization
  - Freeze Crystallization
  - Steam Stripping
  - Vacuum Distillation
  - Pervaporation
- Membrane Process
  - Electrodialysis
  - Reverse Osmosis
  - Nano Filtration
  - Ultrafiltration

Five Evaluation Categories (see Attachment 8 for subdivision of Evaluation Categories)

1. Technical Feasibility
2. Cost-Effectiveness
3. Operational Reliability
4. Environmental Issues
5. Aesthetic Considerations

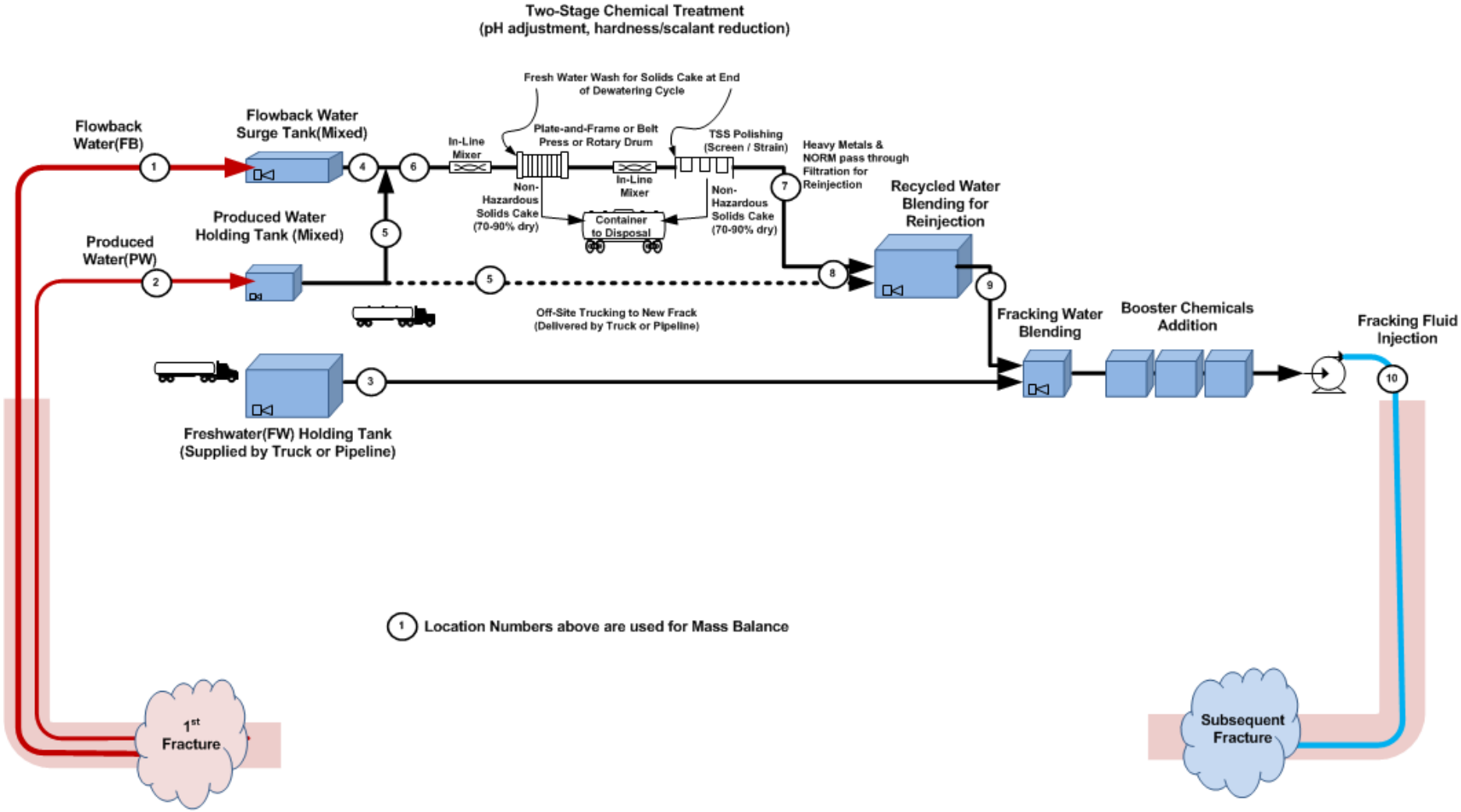
Preliminary Screening of Water Treatment Technology Options

Technology	Target Treatment	Advantages	Disadvantages	Selection Results
Total Suspended Solids Removal, Including Precipitated Heavy Metals (including Radioactivity) and Free Oils				
pH Adjustment	Maintain pH; necessary for other treatments and/or discharge.	Improves certain chemical reactions; allows standard materials of construction. Can use organic rather than inorganic acid to minimize TDS input.	Adds salt (TDS), annual operating expense.	Selected for further evaluation. Opportunity for combined use of recycled wastestreams for pH control.
Coagulation / Precipitation of heavy metals with inorganic precipitation	Removal of heavy metals non-soluble hydroxide of co-precipitate in an inorganic sludge. May not be necessary for reuse of flowback.	Renders heavy metals into an insoluble form for gravity separation and concentration into a disposal sludge.	Will probably require pH adjustment and chemical addition. Can produce substantial quantities of solids for disposal. Care must be taken to maintain solids as a non-hazardous waste. Requires sludge handling system for dewatering. Chelating agents can inhibit specific constituent precipitation, if desired.	Selected for further evaluation.
Coagulation / Precipitation of heavy metals with high-affinity coagulant	Very efficient for low concentrations of heavy metals without substantial solids production. Tri-mercaptan / carbamates have been very successful.	Low sludge production, low heavy metals concentration in treated effluent. Minimal solids production and handling. Filter may be used instead of clarifiers.	Chemical precipitant is expensive. Chemical handling is sensitive and control is necessary to prevent accidental effluent aquatic toxicity.	Selected for further evaluation.
Ion Exchange Resins	Selective removal of salts and/or metals if recovery issues are prevalent.	Can effectively remove acid/base and metal ions.	Would require extensive pretreatment for oil, TSS and possibly TDS, Adds considerable TDS to system. Regenerant is liquid and can be hazardous.	Rejected for further evaluation.

RED SHADING INDICATES "REJECTED TECHNOLOGY" NOT DEEMED APPROPRIATE FOR FURTHER EVALUATION

ENVIRON

Concept: Zero Water Discharge Water Lifecycle

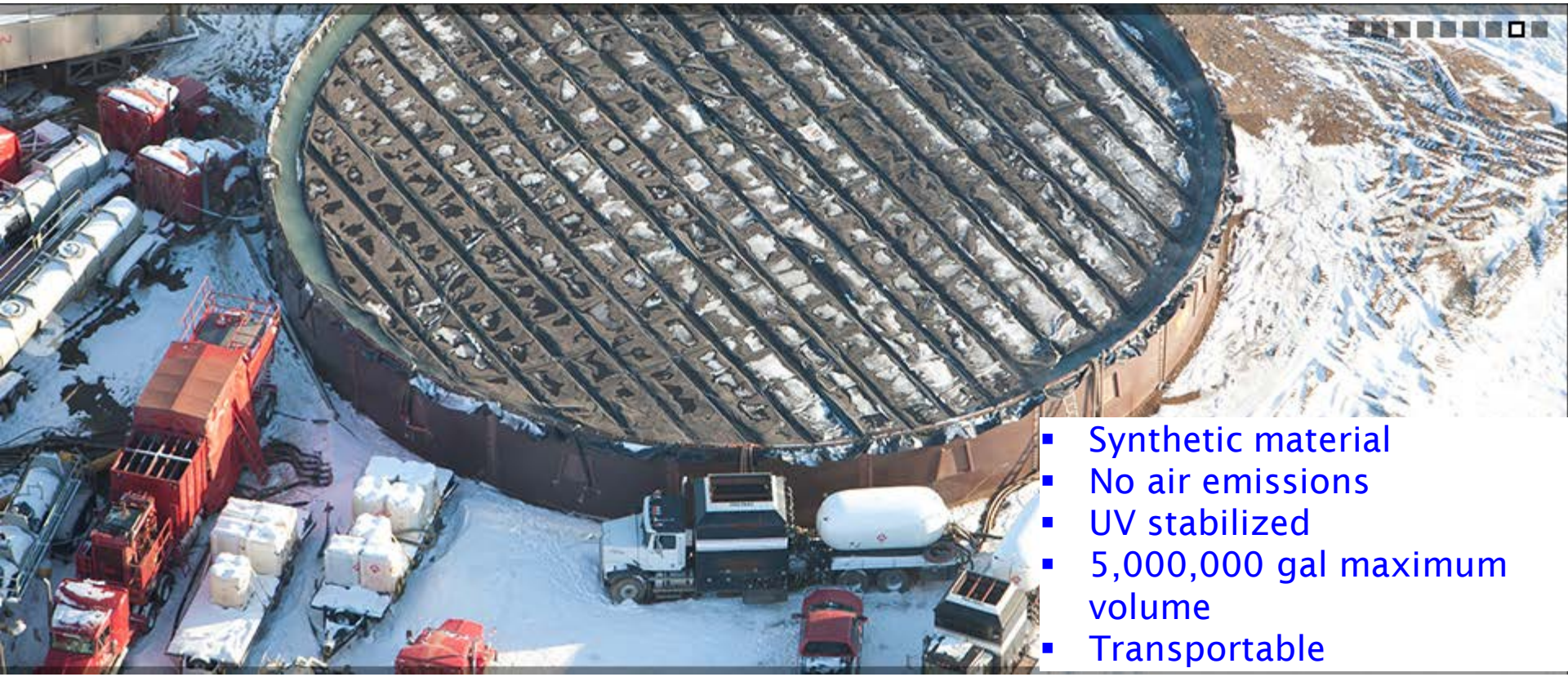


ENVIRON

Bladders

- Synthetic material
- No air emissions
- UV stabilized
- 200,000 gal maximum volume
- Transportable

Swimming Pools-B: Circular



- Synthetic material
- No air emissions
- UV stabilized
- 5,000,000 gal maximum volume
- Transportable

Plate & Frame Filter Press Illustrations

Trailer-mounted
Conveyor for cake discharge to container for hauling to disposal

Positive displacement, air diaphragm pumps for pumping sludges.

Synopsis of Zero Water Discharge Concept

- Designed to Eliminate Exposure to the Environment: air, surface water, groundwater and solids residues
- Emphasizes Staged / Selective Treatment of Flowback Water to Minimize Chemicals in Reuse Cycle
- Optimizes Water Flow / Storage Management for Salt Blending
- Minimizes Chemical Treatment on Blended Recycle Stream
- Flexible for Near-Future Issues
  - Modularly expandable
  - Range of chemical additives, if required

Goals & Benefits

- Goals
  - 100% Performance and Reliability
  - Environmentally Sound
  - Cost-Effective
  - Flexibility For Emerging and Near-Future Anticipated Issues
- Benefits
  - Substantially Lower Operational Costs (trucking, chemicals, process management)
  - Less Sulfide
  - Less Trucking
  - True EHS Consequence: Less Harmful
  - Operator-Friendly Manageable Industrial Wastewater Process
  - More Reliable, Predictable, Economical Process and Environmentally-Sensitive Program That Results in a Much Improved Gas Completion

Path Forward:
Laboratory & Field Confirmations

Confirmation of Approach and Realistic Economics

- Task 1. Bench-Scale Laboratory Screening Investigation
  - Round 1
  - Round 2
- Task 2. Small-Scale Field Confirmation
- Task 3. Full-Scale Field Performance