Welcome to Bear Creek Services

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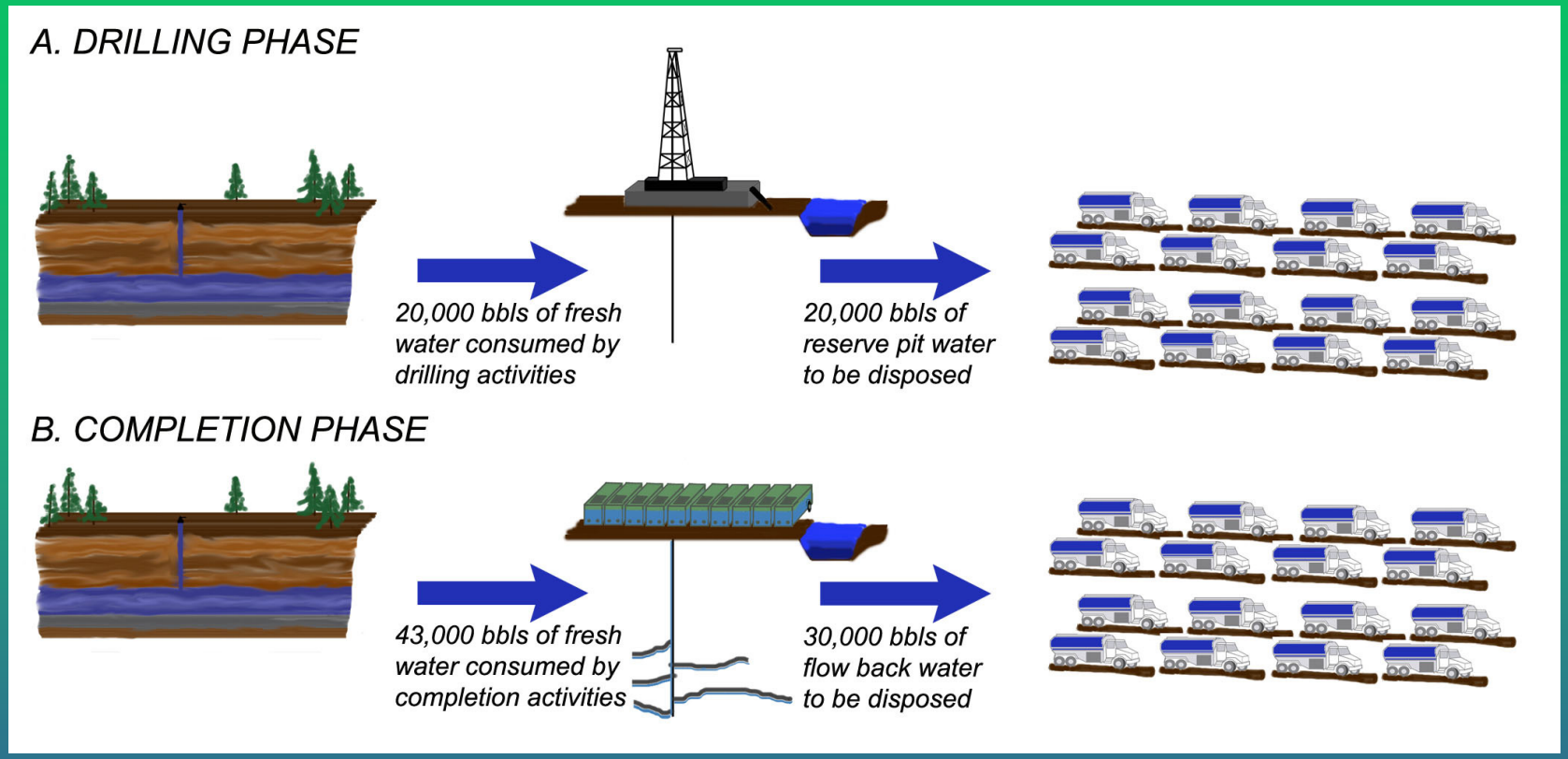
Water Reclamation Technology 2010

Three primary types of E&P wastewater

The chemistry, volume, rate, and logistical timing of each type of fluid is unique to EACH well

- Drilling Fluids
  - Water-based mud
  - Rig Supply water
- Completion Fluids
  - Stimulation fluid (upstream frac water)
  - Flow back (downstream frac wastewater)
  - Work-over fluid
- Production Fluids
  - Geological saltwater produced with the hydrocarbons

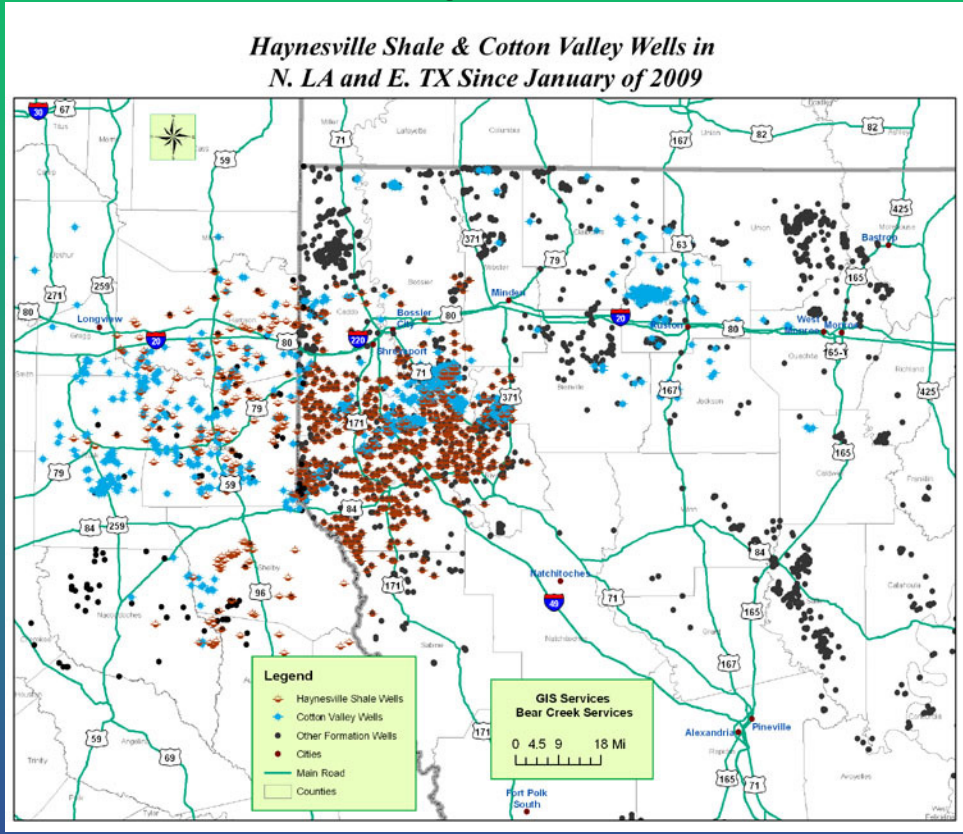


***completion fluid estimates based on vertical well frac, comparable water requirements for EACH stage of horizontal shale wells*

***amount of flow back per well varies greatly between formations, ranging from 10% to 80% water returned during flow back*

Well Count in N. LA / E. TX January 2009 – January 2010

- Haynesville Shale Wells (Jan 2009 to present)
  - 921 (NLA) + 187 (ETX) =1108
  - 1108 wells x 8MM gpw = 8,864,000,000 (8.9 billion gallons)
- Cotton Valley Wells (Jan 2009 to present)
  - 1175(NLA) + 405 (ETX) = 1580
  - 1580 wells x 2MM gpw = 3,161,000,000 (3.16 billion gallons)
- Projected to drill ***thousands*** of Haynesville wells in 2010



Well count and map compliments of Dr. Xingwen Chen, Director of GIS, Bear Creek Services

Once fresh water becomes E&P waste, the vast majority permanently leaves the fresh water cycle, especially when deep (disposal) well injected

Federal, State, and Local regulators are actively developing restrictions regarding fluid transportation, use, and disposal options

Disposal options vary by region but typically include:

- Land farming (limited to water-based drilling fluid, allowed in some states)
- Annular injection (limited water-based drilling fluid, allowed in some states)
- Private disposal wells (mostly used for production water)
- Commercial disposal wells (used for pit, flowback, and production water)
- Recycle, Reclaim, Reuse (limited use for pit water, flow back, and production water)

With further restrictions on land-farming and waste transportation eminent, the current disposal infrastructure will soon be insufficient to handle the waste volumes being generated

What's the water hype about?

- The major public issues are about
  - The source of the water (drinking water aquifers and municipal drinking water)
  - The perceived environmental / ecological threats to drinking water due to unsafe transportation and handling
  - The 'mystery' of what's in completion fluid (often proprietary and under-regulated compared to other industries)
  - Political agendas

Water resources in other shale plays are even more sensitive!

http://www.energyindustryphotos.com/shale_gas_map_shale_basins.htm

So why is it difficult to put water treatment technologies into the oilfield?

Upstream Issues With E&P Water

- Volumes, Consumption Rates, and Density
  - Millions of gallons per day of demand in short cyclic periods in decentralized leases
  - Freshwater Aquifer insufficient and overuse is irresponsible
  - Surface water usage logistics (access, regulations, water quality, and transportation)
- Rights, Rules, and Regulations
  - Navigable waterways
  - State local permit requirements vary, too many regulatory agencies involved in different aspects of water resource management
  - Privately owned water use rights
- Ground water contamination concerns
  - Storage of water containing frac chemicals (completion fluids)
  - Public hype about hydraulic fracturing into the ground water
  - Disclosure of proprietary chemistry

Downstream Issues with E&P Water

- Current disposal options are insufficient
  - Private and Commercial Injection wells combined can not keep up with rates of waste production
  - Insufficient wastewater storage options
- Regulations limit waste treatment/reuse options
  - N.O.W. regulations limit final disposition of wastewater
  - Regulations were not written in anticipation of the water-related issues
  - Lack of regulatory permit options for recycling and reclamation
  - Lack of incentives that encourage responsible reuse

Criteria for an ideal water recycling technology

- Ideal wastewater reclamation processes should strive to meet the following criteria:
  - Reduce the amount of fresh water being removed from the fresh water cycle
  - Maximize the amount of water being reused within the industry
  - Decrease E&P costs (fits into current cost paradigm)
  - Do not create a “new” waste streams containing undesirable by-products or co-products
  - Accommodate the diverse chemistry (heterogeneity) of various wastewaters with minimal pre-treatments
  - Primarily consume a waste energy source and have a minimal carbon footprint, i.e. does not trade water recycling for a bigger carbon footprint
  - Minimally disrupt current operational practices
  - Minimize the volume and distance of water to be transported
  - Reduce the potential risks of environmental damage

– *Many good prospect technologies, but no silver bullets*

The non-insurmountable barriers to water technology transfer into E&P

- Portability vs. Scalability
  - Centralized facilities or mobile units
  - J-I-T Production or long-term storage
- Versatility vs. Effectiveness
  - Design for heterogeneous water
  - Create high quality fluid from a particular waste stream
- Lack of proactive regulatory guidelines
  - Need additional education, proposed rule changes, industry associations
- COST
  - If Nat Gas stays below $6.50, recycling and reclamation can not create a new (net) cost for operators. It can however, replace an existing cost. If it saves operators money, it will be rapidly accepted
- Support and service
  - Water resource management consulting (acquisition to divestiture)
  - Oilfield experienced personnel that also understand water technologies

Water Reuse Opportunity 1

- **Water-based drilling waste (pit water) recycled for use as completion fluid**
  - High TSS, Low TDS fluid with some HC's
  - 20,000 to 30,000 bbls per well (10-20% of frac fluid needs)
  - Flocculation
  - Filtration
  - Chemical precipitation
  - Gravity separation

- Matters of Concern:
  - Drilling Eng. Vs Comp. Eng
  - Need to remove incompatible solutes (scale tendency)
  - Need to remove suspended solids (0.5-5 micron)

- Some Advantages
  - Water is already on-location
  - Eliminates transportation of up to 20% of frac fluid
  - Reduces cost of water disposal
  - Reduces burden on disposal wells
  - Reduces trucking impact

Water Reuse Opportunity 2

- **Flowback from one well recycled for use as completion fluid for another well**
  - High TSS, High TDS fluid with some HC's
  - TDS increases with time
  - 20,000 to 80,000 bbls per well (10-50% of frac fluid needs)
  - Flocculation
  - Filtration
  - Chemical precipitation
  - Evaporation

- Matters of Concern:
  - Rate: 1 – 5 bpm flow back
  - Need to remove incompatible solutes (scale tendency)
  - Need to remove suspended solids (proppant et.al.)
  - Need to remove polymers, friction reducers, and gels
  - Water composition changes significantly over time
  - Must transport water for reuse or store in large ponds (potential env concerns)

- Some Advantages
  - Reduces cost of water disposal
  - Reduces burden on disposal wells
  - Reduces trucking impact
  - Reduces need for fresh water

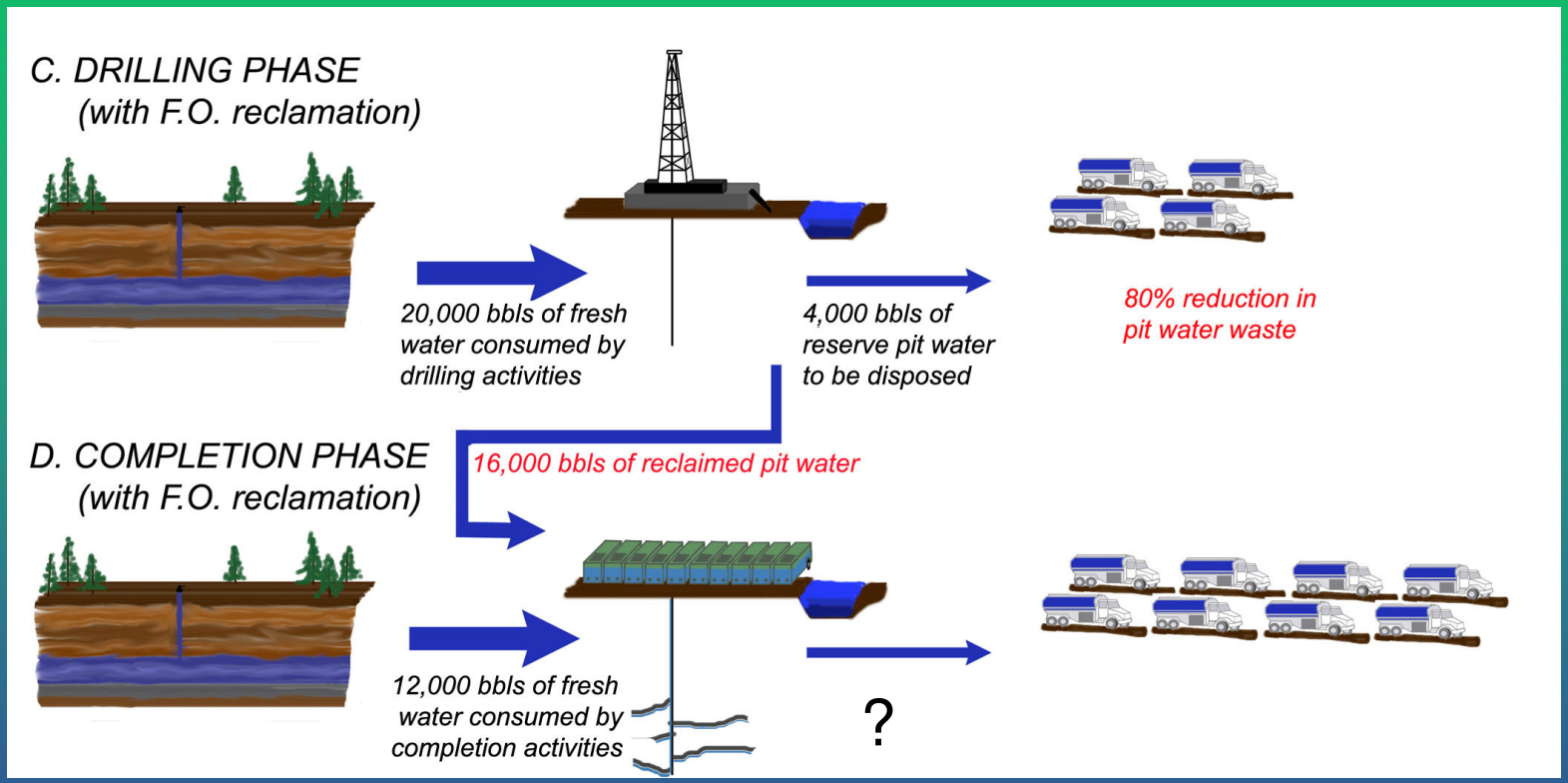
Water Reuse Opportunity 3

- **Production water from one well recycled for use as drilling or completion fluid for another well**
  - Low TSS, High TDS fluid with some HC's
  - Fairly consistent make-up
  - 10 to 400 bbls/well/day
  - Flocculation
  - Filtration
  - Chemical precipitation
  - Evaporation

- Matters of Concern:
  - Rate – insufficient quantities for most operators
  - Need to remove incompatible solutes (scale tendency)
  - Need to remove additives (soaps, foamers, etc)
  - Not cost effective to transport unsaturated solutions (<26%)
  - Must transport water for reuse and store in tanks

- Some Advantages
  - Eliminates cost of water disposal
  - Reduces need for fresh water
  - Reduces cost of clay stabilizers
  - Reduces trucking impact

The Bear Creek Green Machine Recycles Reserve Pit waste into completion fluid

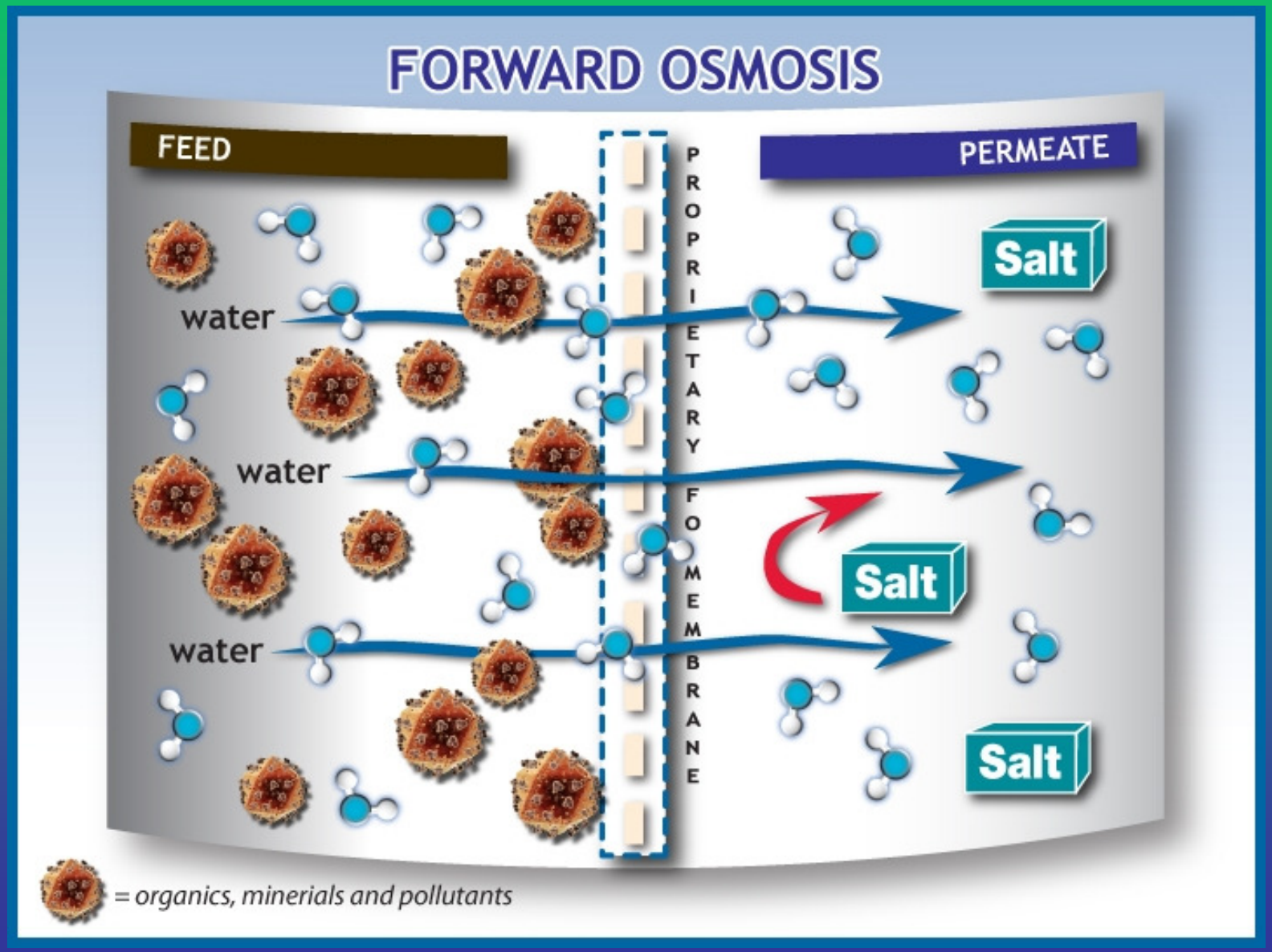


Bear Creek is developing companion technologies for flow back and production water through strategic partnership and R&D

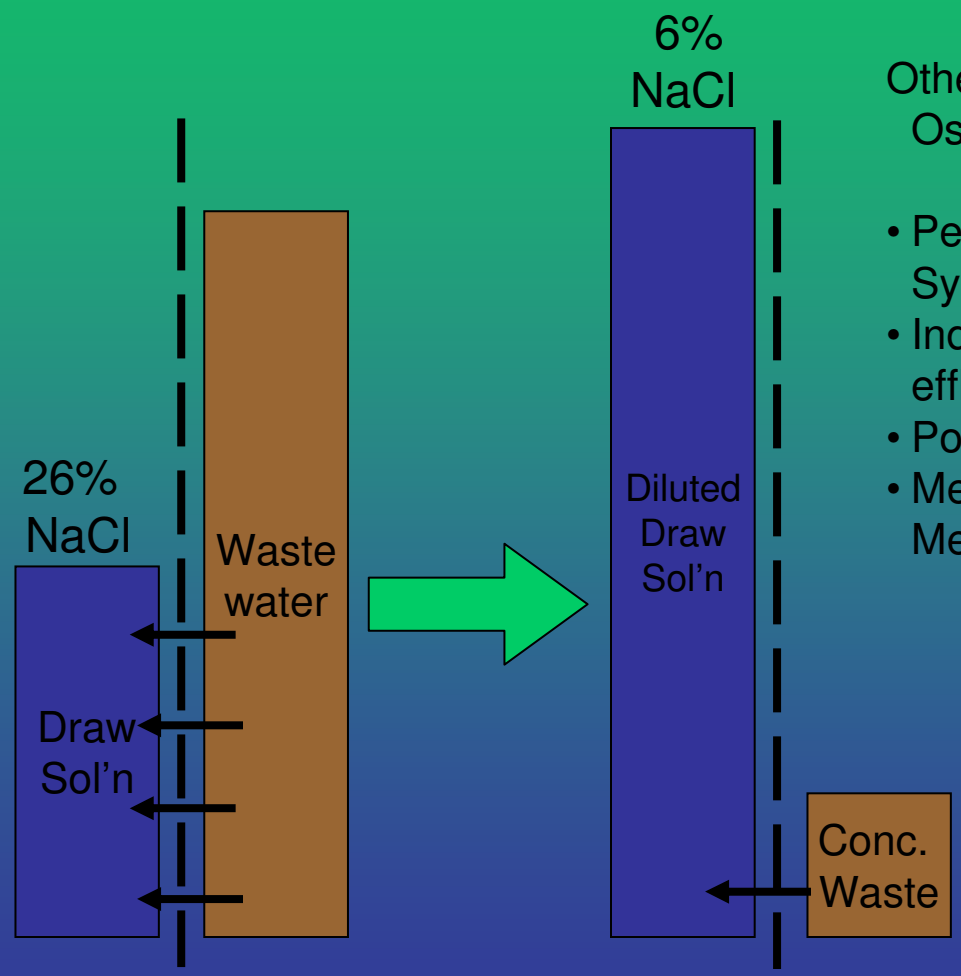
Why is ‘Bear Creek’s Green Machine’ Different?

- Primary reclamation process is driven by alternative energy (osmotic gradient-drive)
- Entire system is low pressure and safe to operate
- Selective filtration (forward osmosis membrane technology) rejects unwanted solutes and solids from the waste stream without complicated pre-treatments or fouling
- Economically competitive with conventional disposal

What is Forward Osmosis?



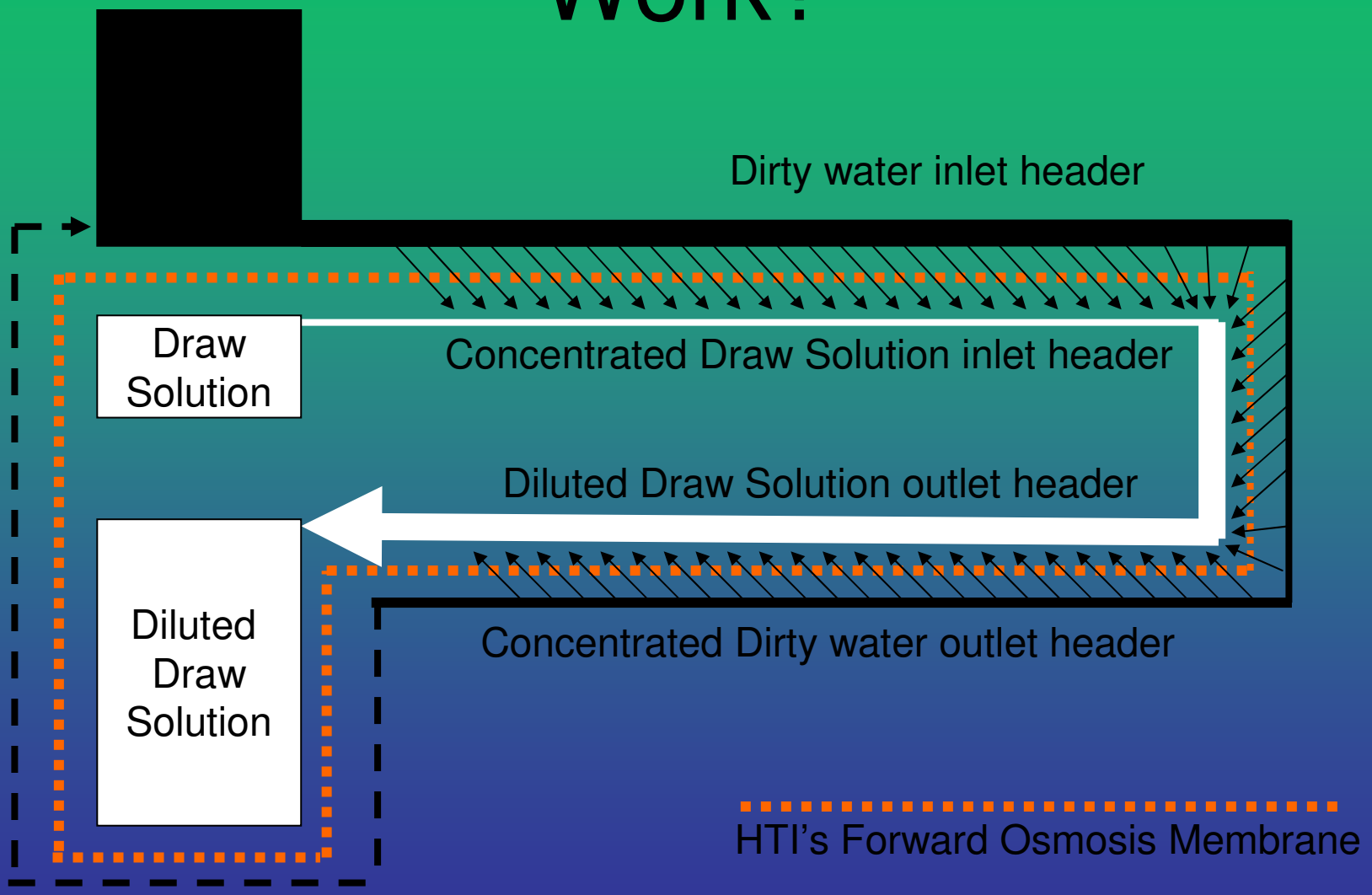
The basic FO premise: Dilute the draw solution, Concentrate the wastewater



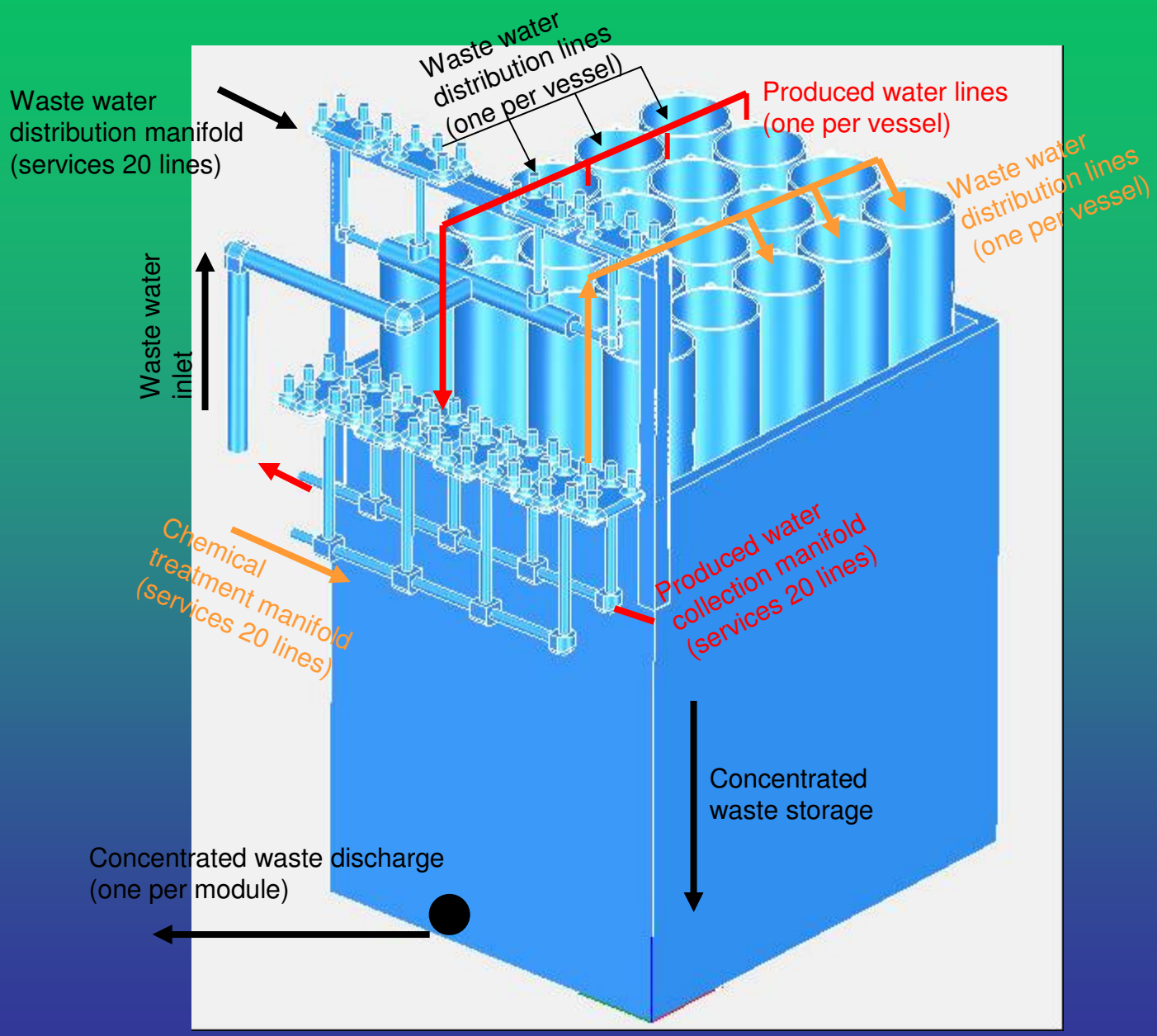
Other Uses of Forward Osmosis:

- Personal Hydration Systems
- Industrial wastewater effluents
- Power generation
- Membrane Bioreactor Media

How does the Green Machine Work?



Module with 20 treatment vessels, Flow Diagram



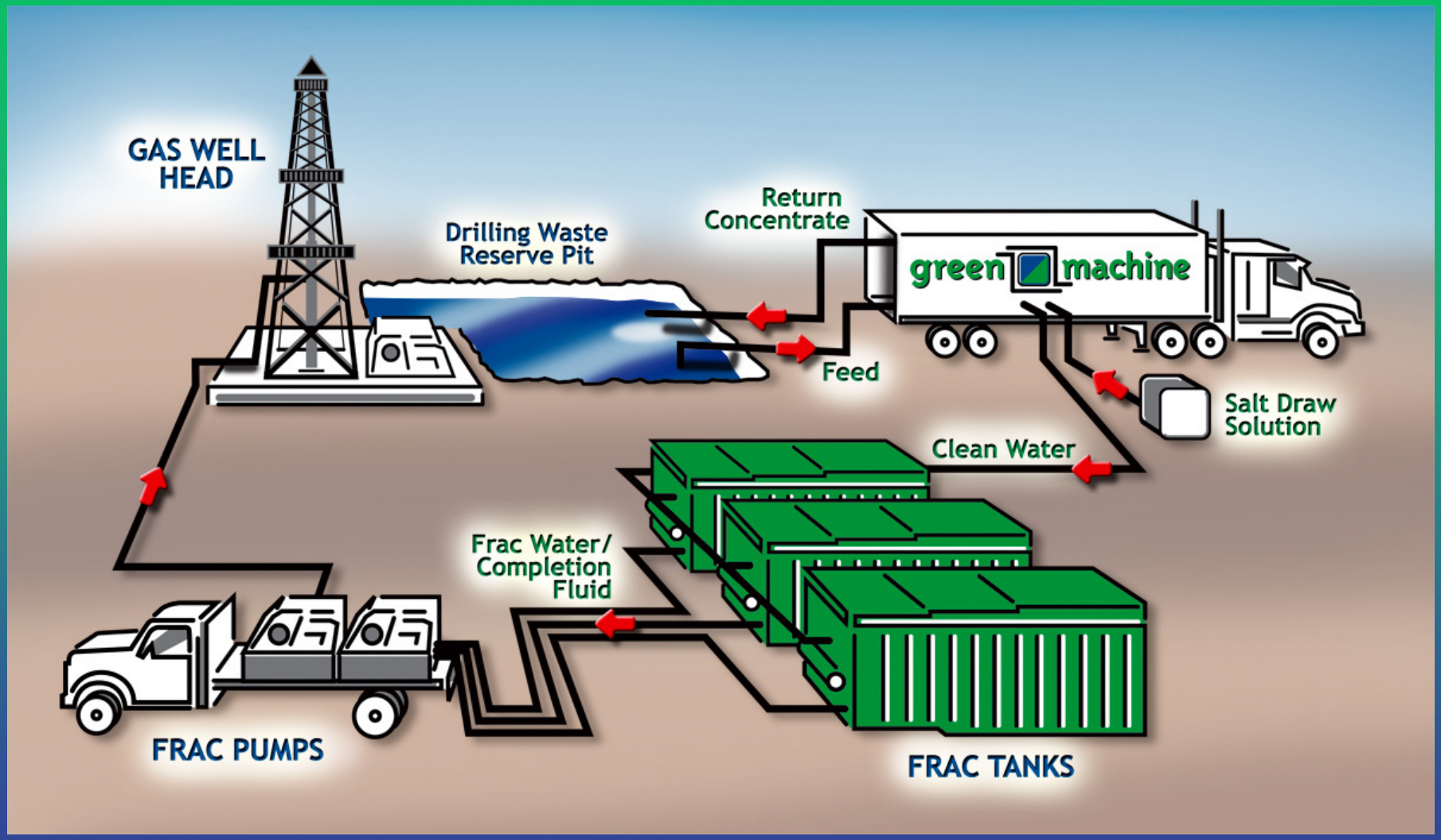
Produced water return lines

Waste water supply lines

Waste water in FO vessels

Full Scale Green Machine Trailer, Layout Diagram

(14 Modules and all accessories on one trailer)
2.0 – 4.00 bpm production w/ 25 Kw Generator, up to 3 small centrifugal pumps

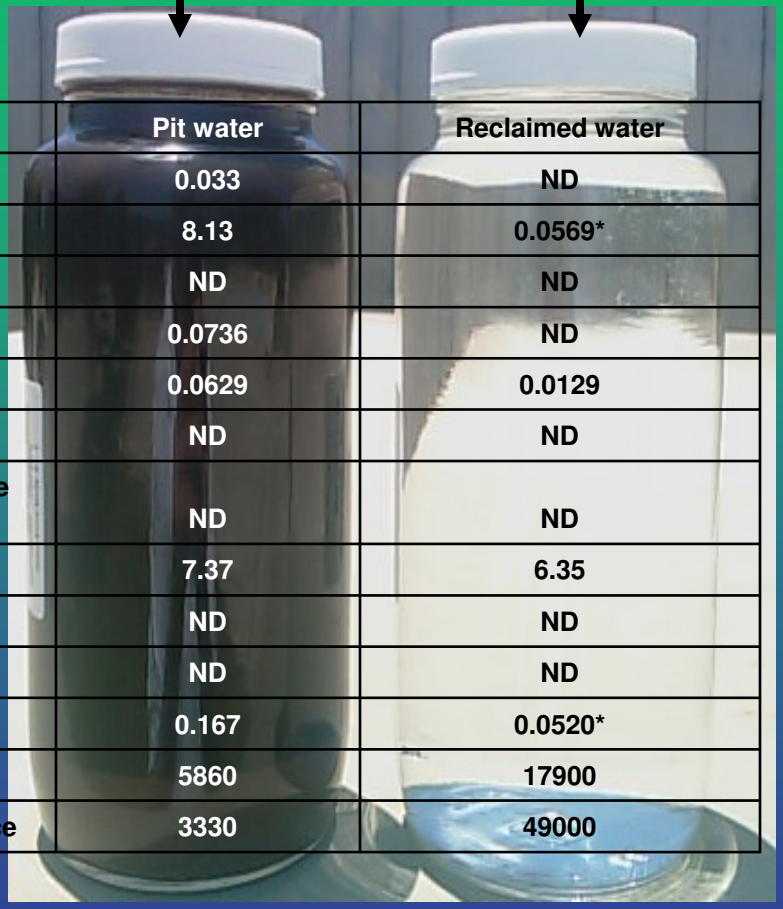

GAS WELL HEAD
Drilling Waste Reserve Pit
Return Concentrate
green machine
Feed
Salt Draw Solution
Clean Water
Frac Water/ Completion Fluid
FRAC PUMPS
FRAC TANKS

BARCO PUMP

FM 514

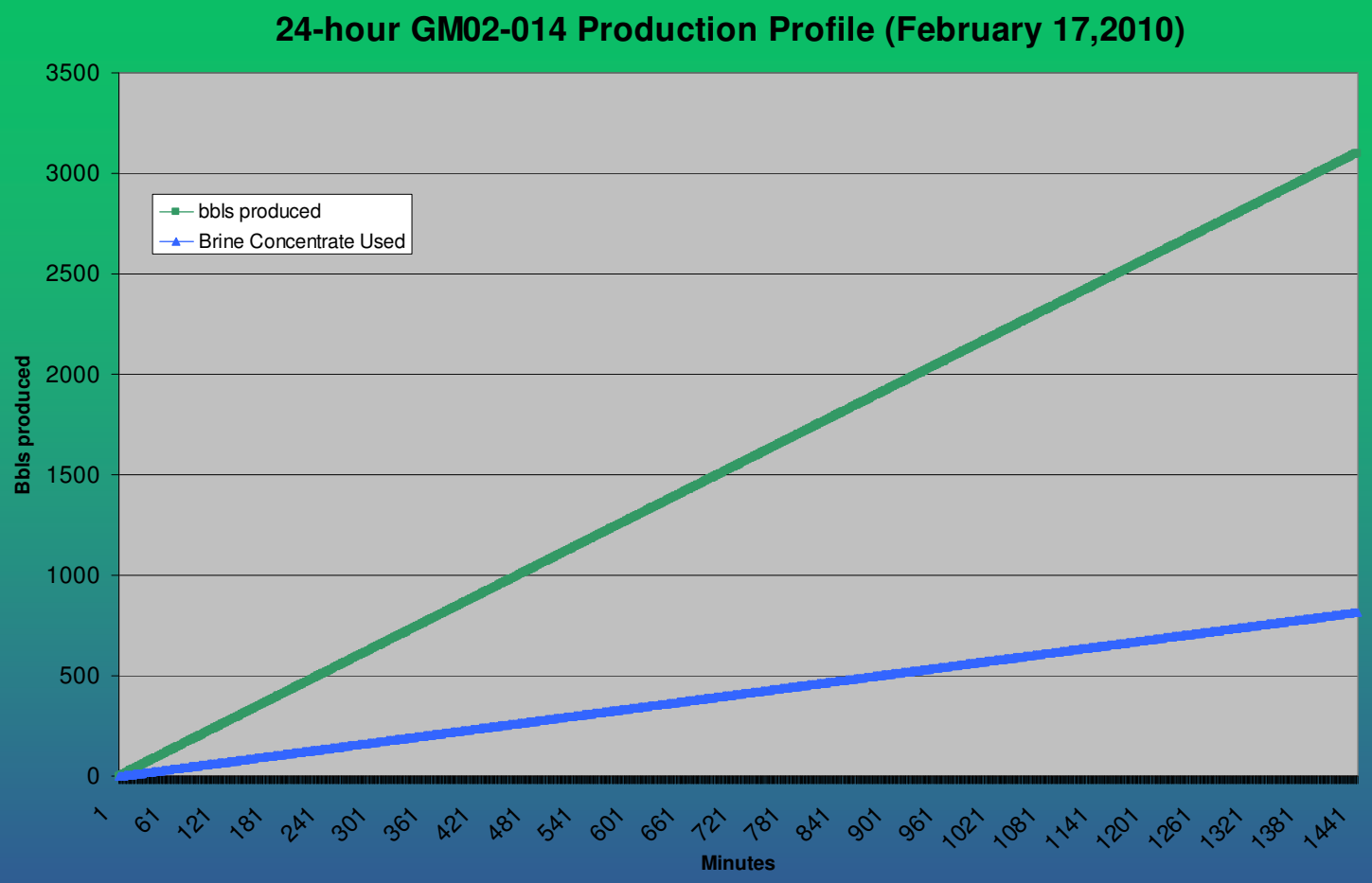
Pit water Before

Reclaimed water After



	Pit water	Reclaimed water
Arsenic	0.033	ND
Barium	8.13	0.0569*
Cadmium	ND	ND
Chromium	0.0736	ND
Lead	0.0629	0.0129
Mercury	ND	ND
n-Hexane Extractable Material	ND	ND
pH	7.37	6.35
Selenium	ND	ND
Silver	ND	ND
Zinc	0.167	0.0520*
Chloride	5860	17900
Specific Conductance	3330	49000

*analytes were also present in small quantities in the concentrated draw solution (data not show, but available upon request)



Green Machine Output varies with # of units, temperature, and concentration of produced fluids:
Ranges from 2 – 4 bpm for a full size unit

Why is it “GREEN”?

- Utilizes very little carbon-based energy (entire unit can run on a 25 KW generator and which uses less than 25 gallons of fuel per day)
- Harnesses the potential energy in the completion fluid to drive the filtration process
- Reclaims E&P waste water for re-use (reduces drawn-down on fresh water resources)
- Reduces the carbon footprint and road damage associated with trucking-related expenses

How does it compare to other technologies?

- Truly Green (small carbon footprint & alternative energy-driven)
- Portable, Scalable, Modular (easy set up, take down, and can be ‘right-sized’ for the job)
- Economical (comparable to conventional disposal costs)
- Conducive to combinations of treatment media (course, affinity, phase, chemo)
- Highest water quality (rejects 100% of virus, bacteria, solids, >98% of undesirable solutes including iron, calcium, metals, barium, etc)
- Safe (entire unit runs on less than 10 psi, has no moving parts other than the self-contained pumps, and uses little electricity)

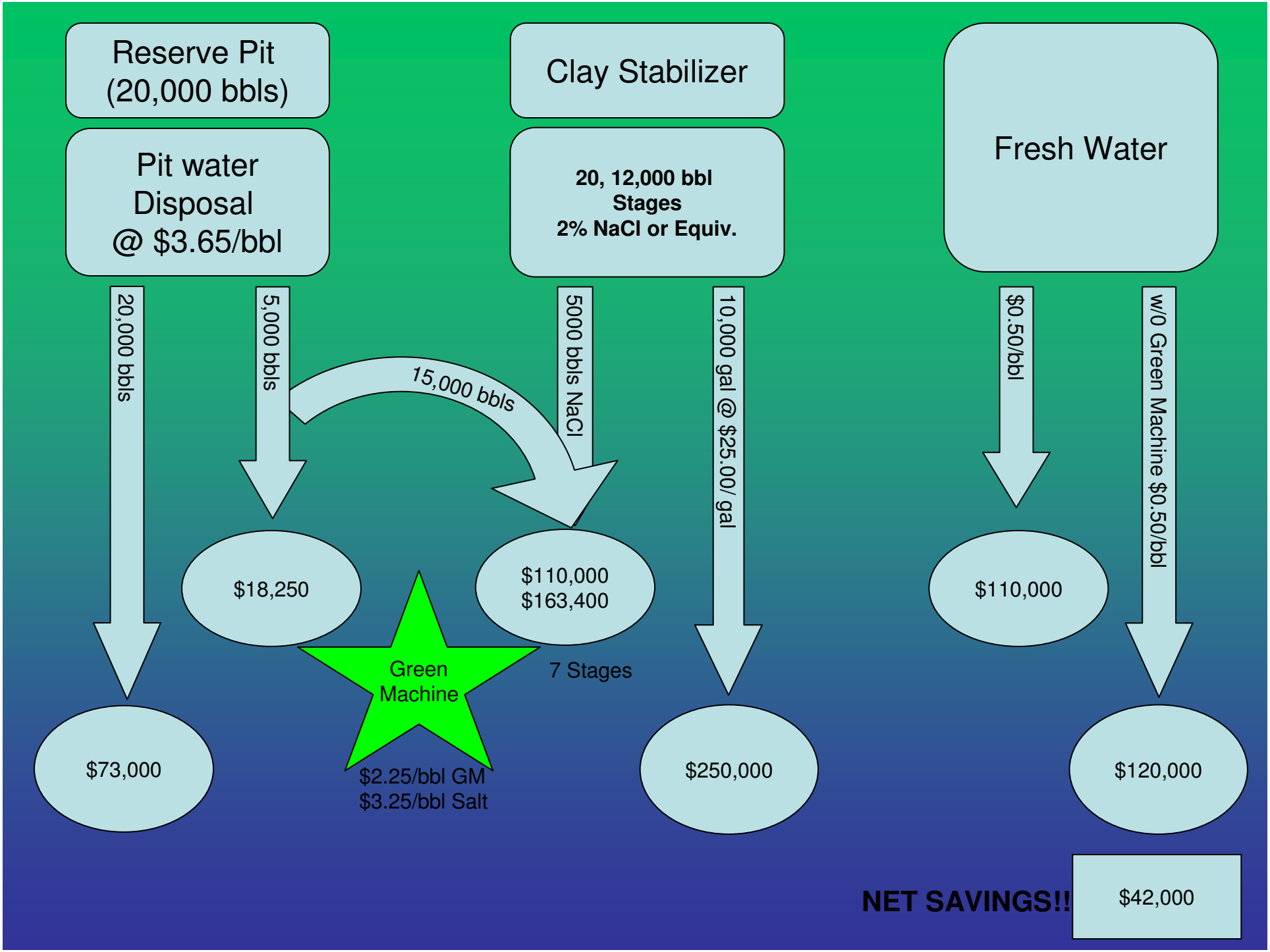
Limitations and Considerations

- Current commercial unit does not produce fresh water (makes a brine designed for completion or workover fluid)
- Works most effectively on low TDS waste water (<3% TDS, 30,000 ppm)
- Timing of the reclamation job falls between drilling and completion (ideally just before completion to minimize fluid storage costs)
- Local regulations vary

How does it add value?

- Can reduce freshwater cost
- Can reduce disposal cost
- Can reduce trucking costs
- Can reduce completion fluid costs (biocides, etc)
- Can reduce materials cost (surface casing)

- Reduces freshwater drawdown
- Reduces transportation of wastewater
- Reduced potential environmental impact
- Significantly reduced carbon footprint


Reserve Pit
(20,000 bbls)
Pit water
Disposal
@ $3.65/bbl
Clay Stabilizer
20, 12,000 bbl
Stages
2% NaCl or Equiv.
Fresh Water
20,000 bbls
5,000 bbls
15,000 bbls
5000 bbls NaCl
10,000 gal @ $25.00/ gal
$0.50/bbl
w/0 Green Machine $0.50/bbl
$18,250
$110,000
$163,400
7 Stages
$110,000
Green
Machine
$2.25/bbl GM
$3.25/bbl Salt
$73,000
$250,000
$120,000
NET SAVINGS!!
$42,000

COST BREAKDOWN
Disposal and Brine In

- **20,000 bbl reserve pit haul off**
- **Average disposal cost/bbl-$1.50/bbl**
- **Total disposal cost $30,000**
- **Trucks to haul-160**
- **Average transit time-4 hours @ $70/hr or $2.15/bbl**
- **Total transit cost-$45,000**
- **Total transit and disposal cost for 20,000 bbls**

$55,400

- **5000 bbls of 26% brine**
- **Cost per bbl-$6.50**
- **Total brine cost-$32,500**
- **Trucks to haul-50**
- **Average transit time-4 hours @ $70/hr or $2. 80/bbl**
- **Total transit cost-$14,000**

$46,500

Total cost for disposal and brine in-$101,900

GREEN MACHINE COST

- $5.50 per bbl (20,000 bbl) = $110,000****
- Residual in pit (5,000 bbl) @ 3.65 = $18,250
- Clay Stabilizer (6500 gallons) @ $25 = $163,000
- Fresh Water (220,000 bbls) @ $.50 = $110,000

  $401,250

Additional cost savings:

- Biocide and Scale inhibitor in frac water
- Trucking permits / road damage

- ****Note this is estimated cost, actual price can vary by location and job.

CONVENTIONAL COST

- Pit Closure (20,000 bbl) @ 3.65 = $73,000
- Clay Stabilizer (10,080 gallons) @ $25 = $252,000
- Fresh Water (240,000 bbls) @ $.50 = $120,000

$445,000

Additional cost:

- Biocide and Scale inhibitor in frac water
- Trucking permits / road damage

- ****Note this is estimated cost, actual price can vary by location and job.

GREEN MACHINE CARBON EMISSION SAVINGS (PER PIT)

- 150 Truck Loads to Remove Pit
- 120 Miles Round Trip @ 4 MPG
- 30 Gallons of fuel burned per truck
- 30 Gallons X 150 truck loads=4500 Gallons
- 4500 Gallons = 45.511 tons of CO_2
- 22.2 pounds/gallon

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  - Mr. Ron Scott
  - Team Bear Creek