MWH

BUILDING A BETTER WORLD

Rocky Mountain EHS Peer Group Meeting

January 20, 2011

Management and Treatment of Produced Water

Lynn A. Haas
Client Service Manger
1300 Old Plank Rd
Mayfield, PA 18433
Office: 570-282-5667
Cell: 570-561-7635
lynn.a.haas@mwhglobal.com

Overview of Presentation

- Produced Water “101”
  - Chemical characterization of produced waters
  - Levels of treatment (management)
  - Applicable technologies and expected performance
- Benefits of produced water treatment
  - Resource management, waste minimization
  - Facilities management
  - Environmental risk

MWH

What is produced water?

- Frac Flowback — water injected to hydrofracture the formation, that comes back up quickly (1 to 2 weeks)
  - Clean water is usually trucked in
  - Sand and chemical additives to optimize frac'ing process and long-term production from well
- Produced water — groundwater that is "produced" with oil and gas over the life of the well
  - Usually high concentration of total dissolved solids (TDS), primarily salts which are highly soluble
  - Dissolved and phase-separable organics

MWH

Water Quality Characterization

Frac Flowback and Produced Water			
(All in mg/L)	Wind River, WY	Rifle, CO	Vernal, UT
TDS	6,500	14,000	49,000
Chloride	2,000	8,500	28,500
TSS	150	330	150
O&G	120	30	
TPH GRO	78	350	55
TPH DRO	14	150	100
Benzene	17	15	11
Toluene	28	25	14
Ethylbenzene	1	1.1	0.5
Xylene	2.1	20	6
Methanol	225	100 to 500	

MWH

Management of Produced Water

- Historically
  - Injected in disposal wells
  - Evaporated in ponds
  - Trucked to offsite (toll) treatment facility
  - Water/wastewater is an operations cost

- Increasing focus on reuse or treatment to discharge requirements
  - Potential to minimize cost and impacts
  - May even be an additional source of revenue

MWH

Conveyance Considerations

- Trucking
- Pipelines
  - Direct from wells to water management facility or from satellite offloads to water management
    - Safety, carbon footprint reduction, better control of volumes moved, avoids constraints on truck traffic
  - Materials of construction, distance, gravity, pressures, pump stations

MWH

Loading/Offloading Considerations

- Offloading stations
  - Containment, security, efficiency

Treatment Headworks - Surge Control and Equalization

- Need to offload trucks quickly
- Surging and frequent start/stops causes significant problems for oil recovery and downstream treatment equipment
- Invest in upfront tanks to handle surge and provide adequate blending to attenuate variations in water quality (8 to 12 hrs DT min; prefer 24 hrs)
- Feed process equipment at constant rate (steps)
- Improves operation and reduces need to oversize treatment equipment

MWH

Levels of Treatment

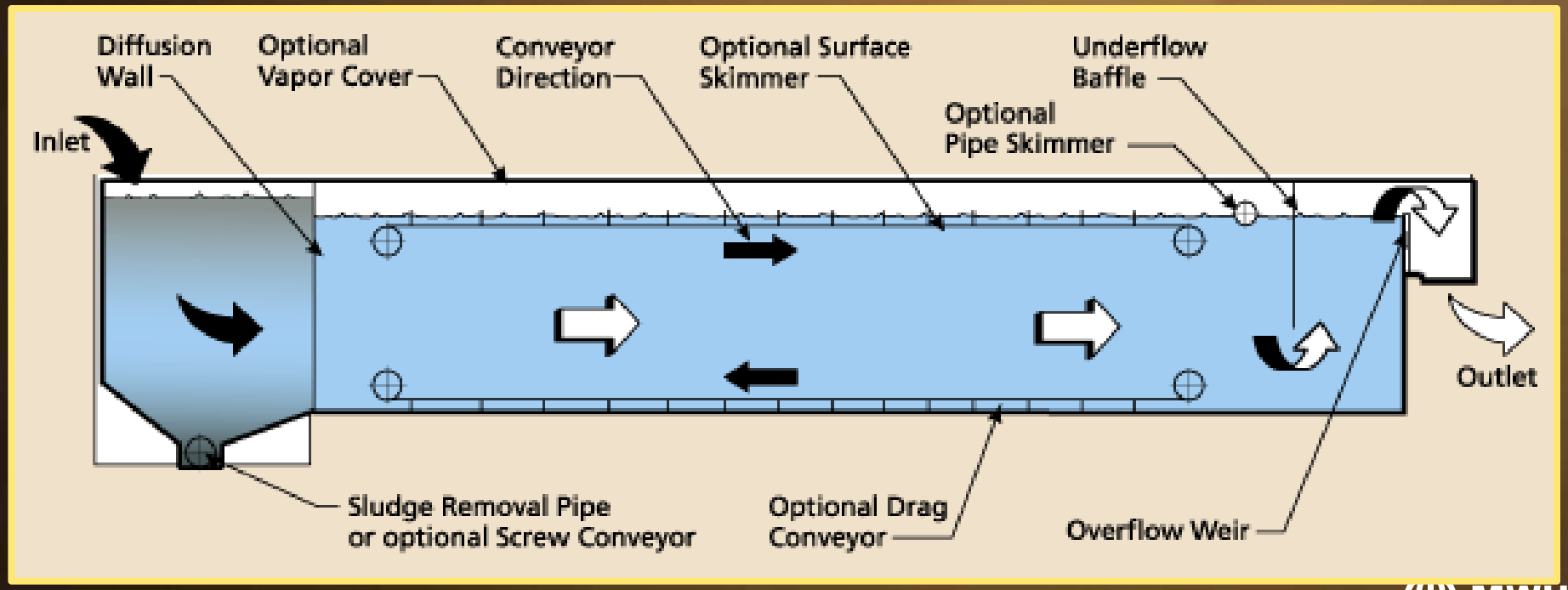
- Level 1: Free phase hydrocarbon recovery
- Level 2: Remove emulsified oil and suspended solids
- Level 3: Remove dissolved organics
- Level 4: Remove dissolved solids to meet stringent surface discharge standards or industrial re-use standards

MWH

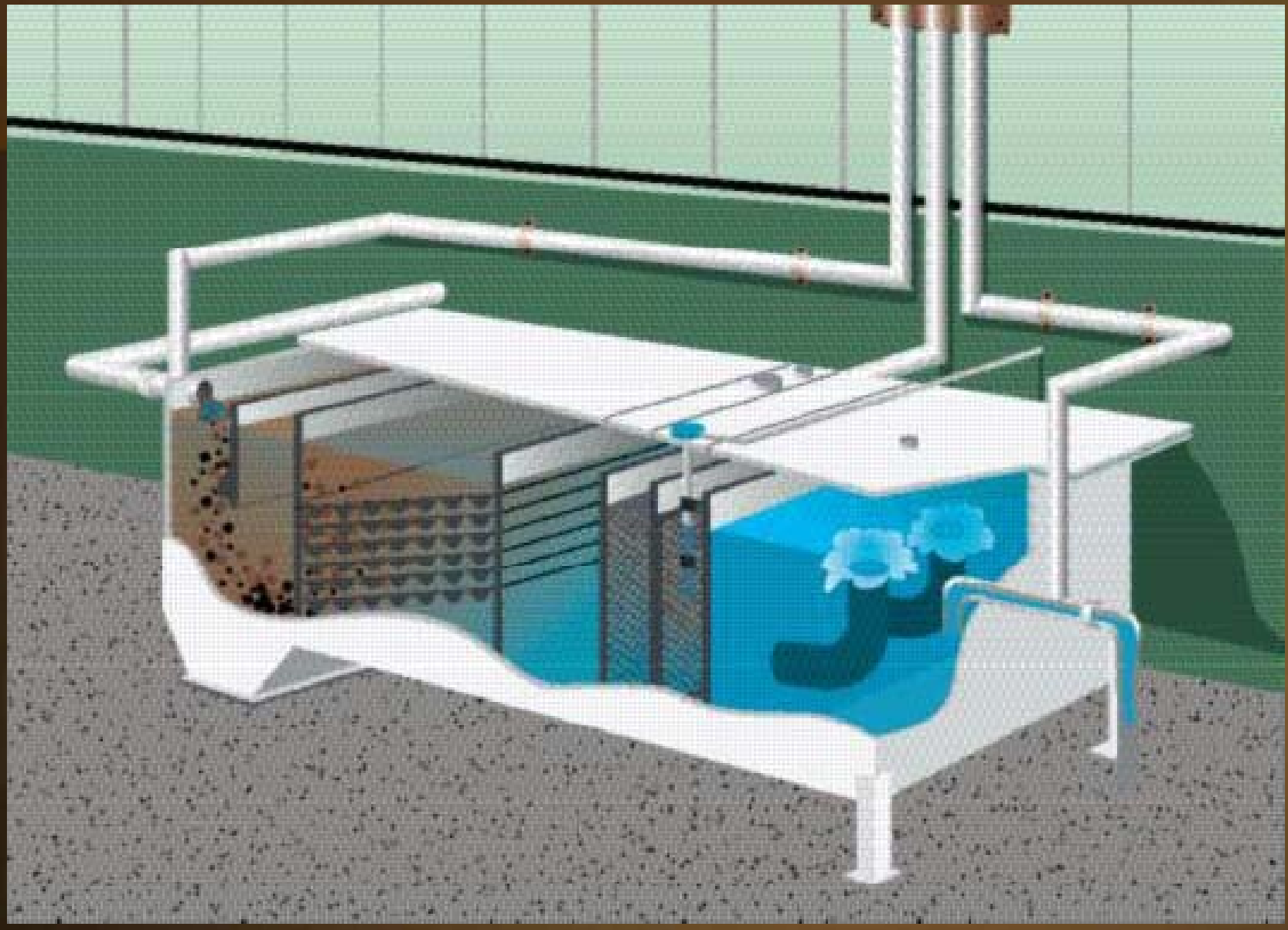
Oil/Condensate Recovery

- Gun barrels vs API or CPI separators
  - 100 to 500 mg/l O&G in water as gun barrel effluent
  - Gun barrel tanks can make three cuts – condensate, oil, and water
  - Better removal of TPH DRO than GRO
  - VOCs are removed with oil/condensate
- Short circuiting
- Paraffin and solids management

MWH


Diffusion Wall
Optional Vapor Cover
Conveyor Direction
Optional Surface Skimmer
Underflow Baffle
Optional Pipe Skimmer
Inlet
Outlet
Sludge Removal Pipe or optional Screw Conveyor
Optional Drag Conveyor
Overflow Weir

MWH



MWH

Level 2 - Oil and Solids Removal

- Typically need <10 mg/l O&G and <25 mg/l TSS for surface discharge
- Some states require “no sheen” on ponds
- Target < 10 mg/l O&G ahead of bioreactor
- Target < 1 mg/l O&G ahead of RO membranes
- Typically need two step treatment

MWH

Potential Treatment Trains for O&G and Solids Removal

HC Recovery	First Cut Solids and O&G Removal	Solids Removal	O&G Removal	Final Polish
Gun Barrel	DAF	Bag Filter	Walnut Shell	Mycelx
API		Sand Filter	Organoclay	Ceramic UF
CPI		Self-cleaning		

MWH

Oil and Solids Removal

- Centrifuges
- Hydrocyclones
- Flotation (DAF, IGF)
  - Coagulant and polymer flocculant aided
- Typically meet 30 mg/l O&G

MWH

Oil and Solids Removal

- Media filters (nutshell, organoclay, GAC, mycelx, sand filters)
- Bag filters, cartridge filters (double lined, resin bonded)
- Self-cleaning screen filters
- Ultrafiltration (ceramic membranes)
- Typically meet <3 mg/l O&G

MWH

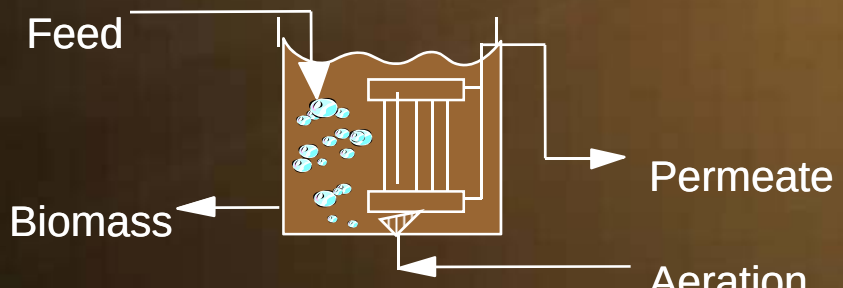
Basic Observations

- Solids are generally quite small…5 to 10um range
- Coagulation and flocculation are needed for effective, practical and economical filtering
- Need to remove solids before O&G polishing units to improve their effectiveness and keep cost down
- O&G varies from site to site; some need emulsion breakers some don't
  - Amount of free vs emulsified vs dissolved oil
  - Basic compounds making up the O&G

MWH

Level 3 Treatment for Dissolved Organics

- Membrane bioreactors (MBRs)
- Reduce space requirement
  - UF membrane instead of clarifier
- Eliminate need for filtration step if tight TSS and BOD/COD limits or going to RO for desalination
- Achieve higher quality effluent



Physical-chemical Treatments

- Air stripping
  - Transfer contaminant from water to air
  - May be viable for low contaminant concentrations
- Adsorption (activated carbon)
  - Transfer contaminant from water to “solid”
- Oxidation
  - UV/ozone/peroxide “destroys” hydrocarbon contaminants
  - Will not “destroy” inorganic components

MWH

Physical Chemical vs Biological

Physical-Chemical	Biological
Pros	*Pros*
Easy to pilot test	Can handle a wide arrange of constituents
Industry has a preference for physical-chemical systems	Has “components” of oxidation, stripping, biodegradation, adsorption, precipitation, entrapment
May be operationally less complex	Addresses membrane biofouling and methanol issues
Cons	*Cons*
Generally more labor intensive to maintain filtering component	Sensitive to upsets
Difficult to optimize chemical conditioning as influent quality changes	Generally larger equipment and land space
Need several process units to remove all problem constituents	Large quantity of sludge to manage

MWH

Level 4 Treatment TDS Reduction

- Partial flow treatment to low TDS levels and blending with pretreated water may be suitable to meet reuse or discharge standards
- Membranes are generally less expensive than evaporators…TDS levels control this decision
- TDS > 50,000 mg/l is not conventionally practical to treat with membranes (30,000 mg/l preferred)
- Greater TDS needs to blend or use evaporators

MWH

Salinity Removal Technologies

Technology	Maximum Feed TDS mg/l	Energy kWh/100 barrel-treated
Capacitive Deionization	5,000	20
Electrodialysis Reversal (EDR)	7,000	60
Electrodialysis (ED)	42,000	-
Reverse Osmosis	50,000	15-30
VSEP	35,000	15-30
Dewvaporation	100,000 to 150,000	150-400
Membrane Distillation	250,000	600-700
Evaporator/Concentrator	100,000	400
Crystallizer	250,000 to 350,000	1000-1300

MWH

Going the Membrane Treatment Route

- Water recovery and membrane run time/longevity are key factors
  - Significant pretreatment is required to control scaling and fouling
  - Need effective cleaning regiment
- Need plan for reject management (20 to 25% of influent)
- Need to assess and understand fouling potential
  - Rigorous testing program
  - Membrane autopsy

MWH


Ionics RO

Membrane Fouling

- Reversible fouling
  - Particulate, scale, or slime
  - Temperature, pH adjustment, surfactants
- Inorganic
  - Calcium, barium, iron, silica
  - Low pH, temperature
- Organic
  - Dissolved organic carbon
  - High pH, temperature
- Biofouling
  - Slime
  - Biocide/high pH, temperature
- Irreversible fouling

MWH

Going the Evaporation/Distillation Route

- Energy costs are significant
- Waste heat from compressors can reduce cost with some systems
- Additional condensate recovery
- Can be used to further concentrate RO reject

MWH

Evaporators/Concentrators

- Some systems recover water; some just evaporate it
- Still generate a reject 10 to 40% of influent
- Pretreatment needed for free phase hydrocarbon and gross solids removal
- High capital cost due to exotic materials of construction
- Controlling scale deposits is critical

MWH

Residuals Management

- Evaporation or RO reject streams
- Hydrocarbon laden solids
  - Potential to process for additional hydrocarbon recovery
- Spent bag and cartridge filter disposal
- Sludges need dewatering and disposal
- Radionuclides in sludges, spent filters, scale can lead to designation as low-level rad waste

MWH

Facilities – Advantages of Produced Water Management/Treatment

- Recovery of crude/condensate as a salable product
- Treat to the appropriate level for onsite reuse
  - A “Level 1 or Level 2” treated effluent may be suitable for reuse as frac fluid make-up
  - A “Level 3” treated effluent may be suitable for reuse or low tech, low cost final treatment/disposal (solar evaporation or land application)
  - A “Level 4” treated effluent may be suitable for high quality industrial reuse (boiler feed), surface water discharge, or other beneficial reuse

MWH

Facilities – Advantages of Produced Water Management/Treatment

- Logistics advantages
  - Reduced need for fresh water (in) and wastewater disposal (out)
    - Potential to minimize wastewater volume to meet deep disposal conditions
    - Reduce dependence on outside resources
  - Centralized treatment facility may be designed with sufficient capacity to be a regional resource
  - Find an end user for treated water (or minimize disposal volume) if water balance is a net positive

MWH

Facilities – Advantages of Produced Water Management/Treatment

- Economic advantages
  - Long-term water/wastewater costs in operations will be reduced after one-time capital investment in treatment facility
  - Treatment design dependent on cost/benefit analysis – don't overtreat or undertreat
  - Revenue potential
    - Toll treatment for others
    - Sell high quality treated effluent

MWH

Environmental/Regulatory – Advantages of Produced Water Management/Treatment

- Treatment vs. deep disposal wells
  - Injection is generally the most economical disposal solution, minimizing offsite haul costs and potential for environmental exposure, but
  - Is becoming more difficult to permit, and
  - Requires favorable geology (isolated aquifer of relatively poor quality, capable of accepting flow at reasonable pump discharge pressure), or haul to offsite disposal well site
- Treatment/reuse can minimize the deep disposal waste stream

MWH

Environmental/Regulatory – Advantages of Produced Water Management/Treatment

- Treatment/reuse vs Evaporation ponds
  - Evaporation pond issues include:
    - Potential VOC air emissions – pre-treat to remove VOCs or install VOC control cover on pond
    - Ground water protection (liner and leak detection)
    - Surface water protection (stormwater and SPCC Plan)
    - Wildlife protection
    - Long-term waste disposal - contaminant accumulation in pond sludge could lead to classification as low-level radioactive, hazardous, or mixed waste when sludge disposal is required
  - Treatment/reuse can minimize evaporation pond capacity

MWH

Regulated releases

- Air emissions
  - Colorado Regulation Number 7
    - Oil/water separators in Petroleum Processing and Refining must have emissions controls (floating cover or vapor recovery)
    - VOCs cannot be disposed by evaporation unless RACT is utilized
    - Condensate tanks in Oil & Gas operations must have 95% efficient air pollution control equipment
  - Utah “Notice of Intent”
    - Calculate and report emissions of criteria and hazardous air pollutants
    - If emissions could exceed limits, then treatment/control will be required as a permit condition
  - Wyoming “Notice of Installation”, similar to Utah

MWH

Regulated releases

- Treated Water Discharge Alternatives
  - NPDES surface water permitted discharge
    - Discharge requirements set for discrete reaches of receiving streams
    - Stream quality or designated use dictate discharge requirements
      - Aquatic life, human health, potable supply
  - POTW pretreatment standards
      - *May* be less stringent than NPDES – no “pass-through” and no “toxic” compounds
      - Pretreatment permit conditions are established by the POTW
      - POTW may charge for use (industrial waste surcharge)

MWH

Regulated Releases

- Land application
  - Generally applicable to wastewater with naturally biodegradable constituents (degradable organics or nutrients)
  - If produced water is high TDS (inorganics) it will likely require TDS treatment before land application will be permissible
- Deep well injection
  - Permit application based on expected constituents and concentrations
  - Confined aquifer, poor quality, isolated from any potential “usable” groundwater

MWH

Public Relations – Advantages of Produced Water Management/Treatment

- Corporate Responsibility and Sustainability
  - Demonstrate that environmental protection is part of corporate values system
    - Environmental resources will be responsibly protected during drilling and production operations
  - Stewardship of a common environmental resource
    - Pollution prevention/waste minimization principles (reduce, reuse, recycle) benefits all users of the common resource
    - Carbon footprint, greenhouse gas emissions, water footprint

MWH

THANK YOU!

MWH