Zero Liquid Discharge for Water Remediation

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AQUEN

FOSSIL WATER
Clear Solutions for Water

Zero Liquid Discharge

- *Strategy*
- *Technology Selection*
- *Case Studies*
- *Recommendations*

Project Portfolio: Design-Build-Operate-Transfer Contracts in Water, Wastewater and Waste

- ***Montney A:*** *water strategy for 10,000 m^3/day water supply licensing, permitting, intake, pipeline, infield water management, storage ponds, pumping systems*
- ***Montney B:*** *10,000 m^3/day intake design-build-commission, pump station d-b-o, pipeline hydraulic design and specifications*
- ***Montney C:*** *5,000 m^3/day water loading station for flowback and produced water storage and reuse*
- ***Cordova A:*** *10,000 m^3/day intake, license and approvals*
- ***Montney D:*** *3,500 m^3/day d-b-o intake, pipeline, pumping station, Section 8 approvals*
- ***Bakken A:*** *2,000 m^3/day full service terminal design*
- ***Permian A:*** *350 usgpm drilling mud dewatering and recycling trailers design-build*
- ***Montney E:*** *19 m^3/minute flowback filtration and recycling system design-build-operate at frac site*
- ***Deep Basin A:*** *750 m^3/day: water injection modules design-build-commission*
- ***Montney F:*** *750 m^3/day produced water treatment and injection facility design-build-commission*
- ***SAGD A:*** *500 m^3/day drinking water plant design-build-commission*
- ***SAGD B:*** *750 m^3/day water and wastewater plant*
- ***Montney G:*** *water management strategy for 1 million m^3/year including sour flowback reuse*
- ***Deep Basin B:*** *water licensing and intake approvals for 2 million m^3/year frac water supply (current)*
- ***Deep Basin C:*** *design-build-install-commission 10,000 m^3/day intake structure for frac water supply (current)*
- ***Montney H*** *conceptual design water reuse systems for Tupper West Development*
- ***Montney I:*** *conceptual design water reuse hub for Sunrise West Development*
- ***Montney J:*** *conceptual design water reuse hub for Dawson Development*
- ***Montney K:*** *conceptual design water reuse hub for Bernadet Development*
- ***Montney L:*** *design-build-commission 10,000 m3/day pump stations and 400kW natural gas-fired generator sets*
- ***Deadwood A:*** *design-build-operate 875 m3/day water conditioning and deep-well injection system*

ZLD Strategy

- *Design*
  - *Flows and loadings: peak, buffer, upset*
  - *Technology selection*
  - *Measurement and controls: field surrogate vs laboratory*
- *Execution*
  - *Mobile*
  - *Modular*
  - *Fixed*

Technology Selection

- *Segregation*
- *Gravity separation (physical): tank, pond, c-Ring, API, heater treater, clarifier*
- *Enhanced Gravity (mechanical): hydrocyclone, centrifuge, flotation, weighted (ballasted) flocculation*
- *Size exclusion: screening, cake filtration, media filter, cross-flow membrane, absorptive filtration*
- *Evaporation/Distillation: desorption (air stripping), evaporation/condensation, stream stripping (distillation)*
- *Crystallization: evaporator, eutectic freezing*
- *Deionization: ion exchange, electrodialysis, electro-deionization, reverse osmosis, nano-filtration*
- *Chemical Treatment: lime, acidification, oxidation, coagulation/flocculation*
- *Biological treatment: aerobic digestion, anaerobic digestion*
- *Residuals: solidification, stabilization, encapsulation*

Technology Selection Special Cases

- *Flotation: sparged, dissolved air, induced gas, micro-bubble, venturi*
- *Membranes: low-pressure, high-pressure, ceramic*
- *Evaporators: mechanical vapour recompression, thermal, drum dryer, falling film evaporator*

Hierarchy of Process Selection

- *Chemical Consumption*
- *Energy Consumption*
- *Physical Footprint*
- *Process Robustness*
- *Process Reliability*

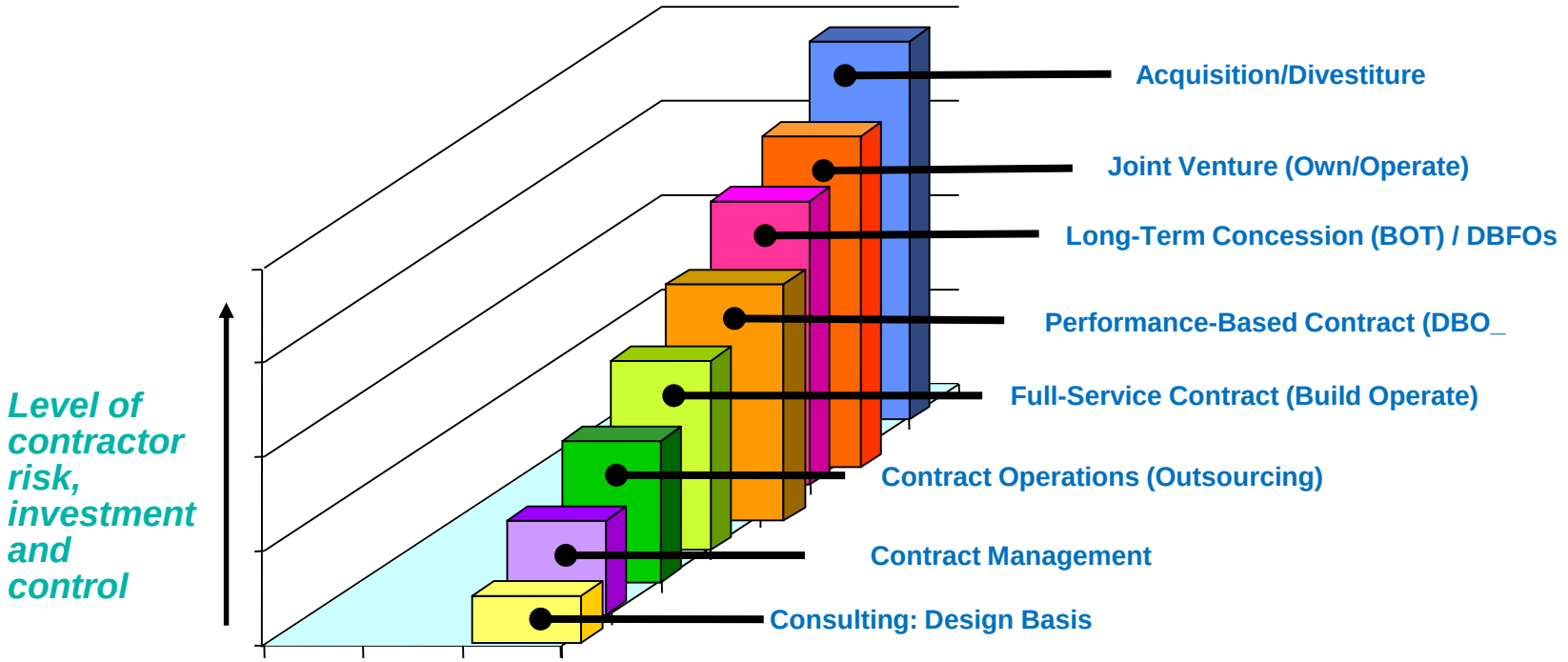
Challenges

- *Process Design Criteria: Max-min-median vs upsets*
- *Treat vs divert*
- *Process control measurements*
- *Automation vs operator intervention*
- *Process acceptance*

Execution Strategy

- *Mobile*
- *Modular*
- *Fixed*

Project Delivery Continuum



Case Studies

- *Canbriam Water ReUse Hub*
- *Stormwater Effluent Pond: Treat, Blend, Release, Inject*

Mobile Case Study

- *Problem: disposal of excess flowback and produced water combined with shortage of fresh water*
- *Solution: high-rate filtration and blending (19 m^3/minute)*

Modular Case Study

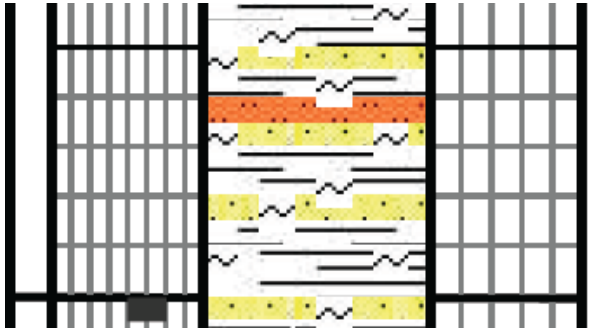
- *Problem: treat and release 100,000 m3 of high-TDS stormwater and treated effluent*
- *Solution: mobile media filter, bag filter and RO system*
- *Post-script: brine-making RO reject and injection*

Challenge #1 and #2: Algae and Shelf

Challenge #3: Fluid Compatibility

Table 1 – Sample Parameters

Item	pH	ECe	Na^+	Ca^{++}	Mg^+	K^+	Cl^-
Red River Water	6.42	469	100,440	11,800	3038	3460	160,000
	SO_4	NO_3-N	NO_3	S.G.			
	4000	238	1034	1.19			



Cambro-Ordovician Deadwood

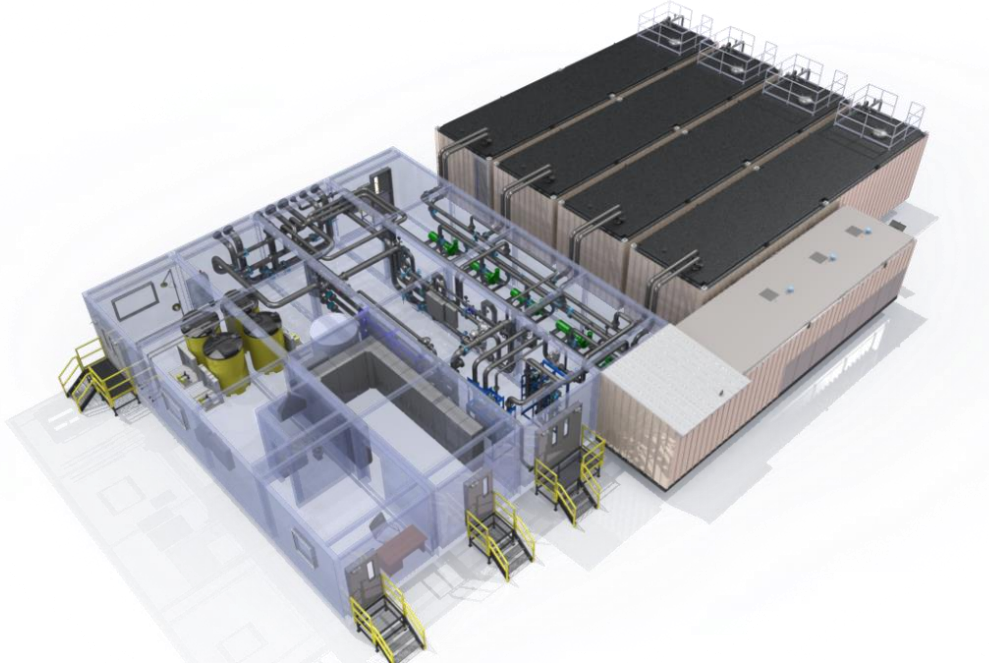
SANDSTONE: abrpt SS aggregates peppered with dk grn glauc, non calc, mL-fU, sb rnd, ply srtd, plus SILTSTONE/SHALE: minty grn-brick rd-purp, glauc, sli dolc, vfg, waxy; plus loose sand, clr frstd cU-cL, rnd, well srtd.

Challenge #4: Fluid Compatibility

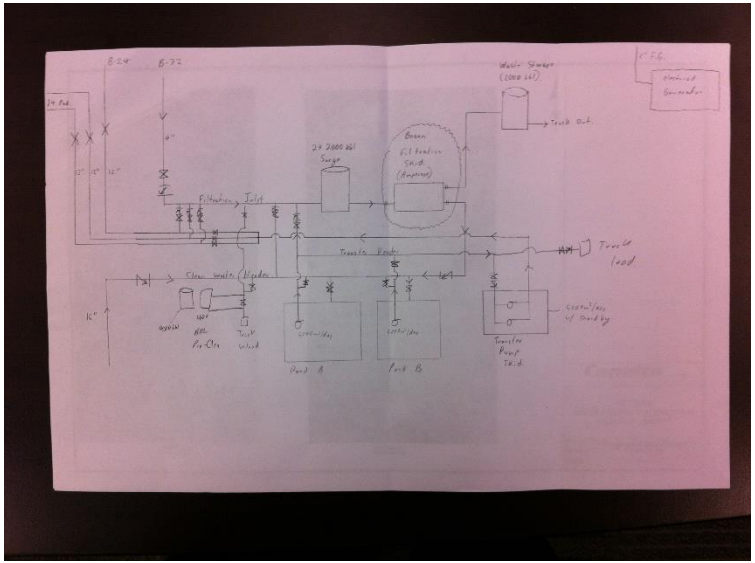
Challenge #5 Temperature

Fixed Facility Case Study

- *Problem: treat 1,250 m3/day of >50,000 mg/L produced water for reuse*
- *Solution: plug-and-play modular plant with aeration, clarification, filtration and blending*



Case Study: Canbriam Water ReUse Facility



Week 1

Week 40

Current Case Study: Under Development

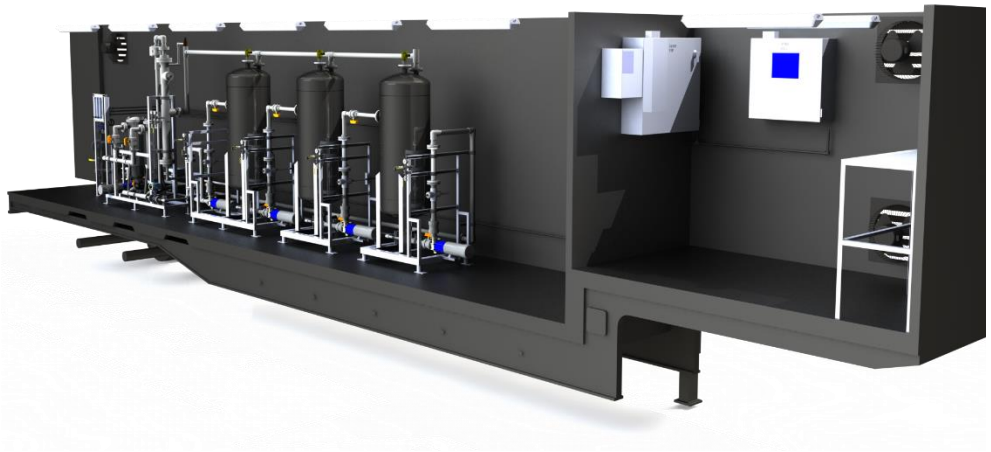
- *Problem: design a system to concentrate methylated compounds from mine runoff, encapsulate contaminants and discharge clean water to environment*
- *Solution: ultrafiltration, product-staged reverse osmosis, mechanical vapour recompression (evaporation), drum crystallizer*

Case Study: Sour Water ReUse

Beverly Hills

Horn River

Case Study: Sour Water ReUse



Sour Water ReUse Technology Options

Technology	Description	CAPEX	OPEX
Modular Stripper (Fossil Water)	5-stage process (1) inlet separator (2) natural gas mixer (3) flash vessel (4) polisher (5) off-gas to recovery or flare		
Conventional Stripper: ie. Debolt	5-stage process: (1) inlet separator (2) degassing tower (3) stripping tower (4) polisher (5) off-gas to incinerator		
Oxidation (hydrogen-peroxide) Permian	5-stage process. (1) oxidant addition (2) reactor (3) filtration (5 µm) (4) residual scavenger (5) elemental sulfur disposal		
Oxidation (chlorine-dioxide) ie. Permian	5-stage process. (1) oxidant addition (2) reactor (3) filtration (5 µm) (4) residual scavenger (5) elemental sulfur disposal		
Oxidation (ozone) Permian	4-stage process (1) hydrodynamic cavitation (2) ozonation (3) acoustic cavitation (4) electrochemical oxidation		
Scavenger-based Permian	4-stage process (1) gas scrubber (2) scavenger (3) tank scrubber (4) sweet water disposal/recycle		

Recommendations for ZLD

- *Develop Process Flow Diagram at outset of project with SME's: this drives more focused development of criteria*
- *Pay attention to physical conditions that create upset conditions*
- *Utilize process selection hierarchy to select technology*
- *Select technology integration model best-suited to application (mobile, modular, fixed)*
- *Select project execution model that achieves program objectives (traditional agreement, performance-based contract)*

For more information:

Calgary design-build-operate www.fossilwater.com

Salt Lake City original equipment manufacturer (OEM) www.aquenusa.com

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