A Case Study on Exempting an Evaporative Disposal System from Air Permitting

Company Overview

Background

- Founded in 2012, Energy Water Solutions (EWS) is a water technology company privately-backed by Auxano Ventures and BioUrja Group
- Committed to a sustainable approach to produced and flowback water management
- Developed proprietary and patented **VOX™** water evaporation technology
- Business model based on four pillars:
  1. Reducing costs for our customers
  2. Translating **Environment, Social and Governance (ESG)** principles into concrete action
  3. Maintaining an outstanding **health, safety and environmental (HSE)** culture
  4. Achieving utmost reliability in everything
- Headquartered in Houston, TX

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Houston, TX
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How We Create Value

- Reducing produced and flowback water handling and disposal costs (transportation + injection) through onsite water evaporation
- Expanding the water management capabilities of our customers at the wellhead
- Providing services in a seamless and reliable manner
- Helping our customers to achieve ESG goals by taking trucks off the road and reducing associated emissions and traffic, returning water to the water cycle via evaporation, and a breakthrough low-emissions technology in the operation of the **VOX™** units

Our Safety and Service Focus

- Safe, reliable, knowledgeable, and experienced field operations team
- Strict compliance with state regulations and customer HSE standards and practices
- 8+ years of company oilfield work completed safely
- Zero fatalities, lost time incidents and recordable incidents
- Decommissioning: when it's time to redeploy we do so in a safe and responsible manner, leaving nothing behind

The Water Challenge and the **VOX™** Solution

Challenge

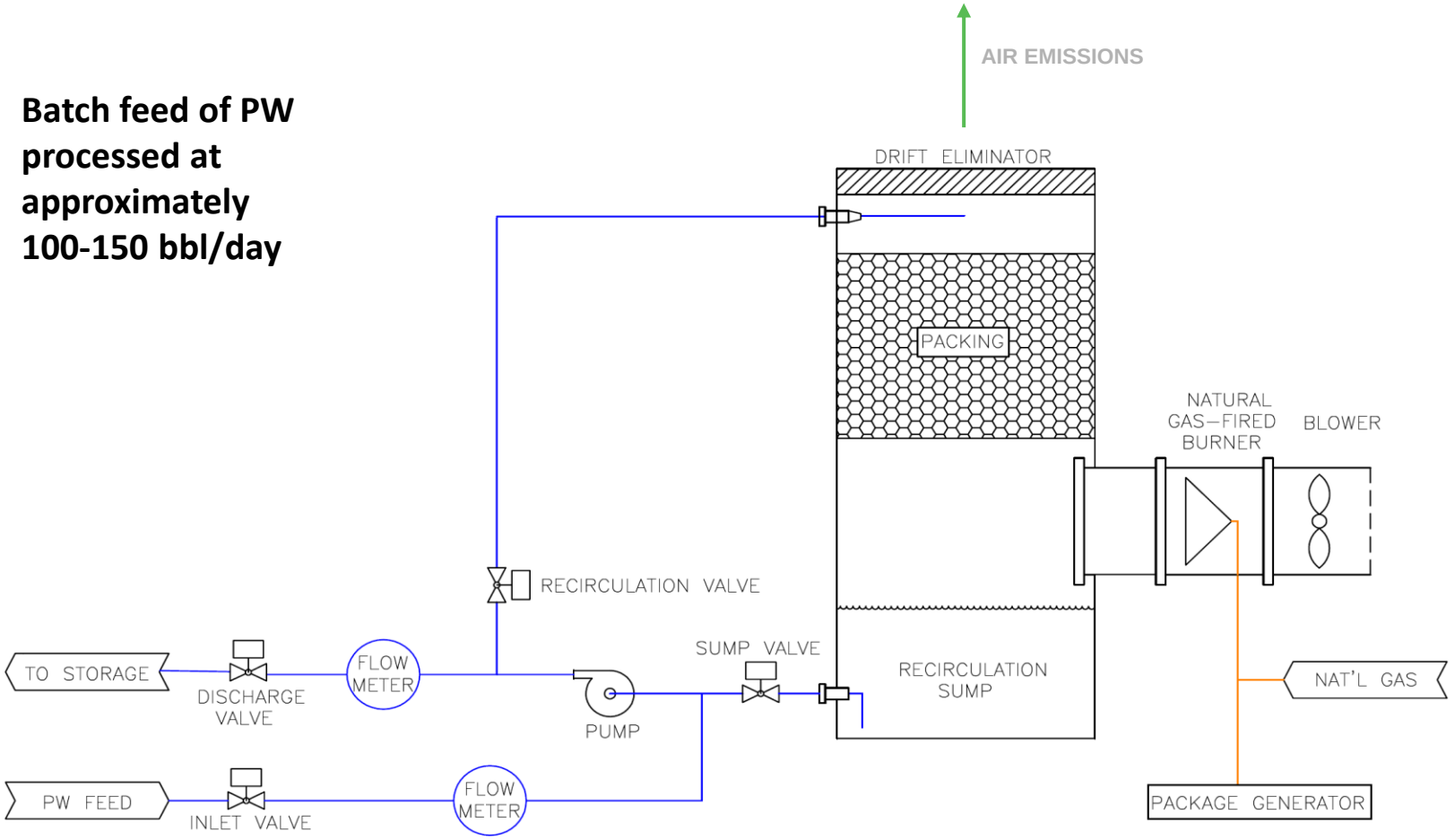
- Water handling is one of the biggest **environmental** and **cost** challenges faced by the oil and gas industry
- The ongoing development of the U.S.'s unconventional resources has led to:
  - increased water use for hydraulic fracturing and
  - growing amounts of produced water
- Most operators truck water volumes from the well pad to injection sites leading to several issues:
  - High truck transportation and injection costs due to large and/or remote volumes
  - Decreasing availability of disposal options due to capacity constraints, regulatory concerns and seismic potential
  - Elevated transportation-related emissions
  - Road safety issues as a result of high truck and other traffic
  - Roadway degradation
  - Potential environmental impacts associated with spills either in transport or at injection sites
- Customers, regulators, investors and the general public increasingly demand adherence to high ESG standards including:
  - Responsible stewardship of water resources
  - Reduction of emissions

Solution

- The **VOX™** technology:
  - vaporizes wastewater at the pad site using high temperature air
  - produces a heavy brine for disposal, leaving TDS, NORM and other compounds within the concentrated brine
  - is carefully calibrated to the specific needs of the pad to ensure no solids are produced
- Cost Reductions - The result is an immediate reduction in wastewater transportation and disposal costs through onsite water evaporation
- EWS helps customers to achieve their ESG goals by:
  - Taking trucks off the road and thereby reducing associated emissions and traffic
  - Returning water to the water cycle via evaporation
  - Breakthrough low-emissions technology in the operations of the **VOX™** units

Process Description

Batch feed of PW processed at approximately 100-150 bbl/day



Permitting

Request for Determination (RFD)

- Managed by EWS
- Includes:
  - Project summary and scope ✓ ✓
  - Site layout drawings ✓
  - Process description ✓
  - Water analysis from the planned location of installation ✓ ✓
  - Emissions summary for the VOX™ units ✓
  - Total site emissions inclusive of VOX™ units ✓
  - Other supporting documentation ✓ ✓
- Only involves Bureau of Air Quality
- Approval time is ~1 month

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- Managed by the Customer
- Includes:
  - Project summary and scope ✓ ✓
  - Site layout drawings ✓
  - Approved RFD ✓
  - Updated radiation protection action plan ✓
  - Demonstration that Ra-226 and Ra-228 in air effluent meets the Applicable or Relevant and Appropriate Requirements criteria ✓
  - Other supporting documentation ✓ ✓
- Involves Bureaus of Oil & Gas, Air Quality and Radiation Protection
- Approval time is ~1 month

✓ **EWS Responsibility**

✓ **Customer/Operator Responsibility**

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Emissions? What Emissions?

Iterative Design Process Focused on Emissions

VOX4 Stack Test

- VOX4 Prototype installed August 2019 on a pilot basis in Tioga County (North Central Region)
- Submitted and received approval for stack test protocol from PADEP Air Quality Source Testing to quantify total particulate matter (PM) emitted from the evaporator
- Stack test conducted In November 2019
  - Total PM Concentration = 0.0022 grain/dscf
  - Total PM Emission rate = 0.28 ton/year
- Stack test approved by Source Testing in March 2020; allows for use of RFD process

Emissions Summary (1 Unit)			
Pollutant	Emissions (lbs/hr)	Emissions (tpy)[1]	Calculation Method
PM	0.0639	0.28	Stack test
PM 10	0.0096	0.042	Cooling Tower Equivalent
PM 2.5	0.0096	0.042	Cooling Tower Equivalent
SOx	0.0011	0.005	AP 42, Table 1.4-2
CO	0.1604	0.702	AP 42, Table 1.4-1
NOx	0.1909	0.836	AP 42, Table 1.4-1
Total VOCs[2]	0.0744	0.326	Mass Balance
Total HAPs[2]	0.0129	0.057	Mass Balance

1: Based on 8760 hours operation/year
2: Dependent upon water chemistry; assumed 100% emitted during evaporation

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Applicable or Relevant and Appropriate Requirements

Table 2 of Appendix B to 10 CFR Part 20

Atomic No.	Radionuclide	Class	Table 1 Occupational Values: Col. 1 Oral Ingestion ALI (µCi)	Table 1 Occupational Values: Col. 2 Inhalation ALI (µCi)	Table 1 Occupational Values: Col. 3 Inhalation DAC (µCi/ml)	Table 2 Effluent Concentrations: Col. 1 Air (µCi/ml)	Table 2 Effluent Concentrations: Col. 2 Water (µCi/ml)	Table 3 Releases to Sewers: Monthly Average Concentration (µCi/ml)
88	Radium-226	W, all compounds	2E+0 Bone surf (5E+0)	6E-1	3E-10	9E-13	-	-
			-	-	-	-	6E-8	6E-7
8	Radium-228	W, all compounds	2E+0 Bone surf (4E+0)	1E+0	5E-10	2E-12	-	-
			-	-	-	-	6E-8	6E-7

Facilities may demonstrate that the annual average effluent concentrations in air meet the ARAR criteria outlined above with the screening modeling tool AERSCREEN.

Demonstration of ARAR using AERSCREEN

- **Representative influent and effluent water samples collected.**
- **Radionuclides analyzed: Ra-226 and 228 (pCi/L in water).**
- **Mass balance to estimate release rate from evaporator (Ci/sec).**
- **Annual average emission rate determined using estimated release rate (Ci/sec) and 1-hour maximum concentration as determined by AERSCREEN (ug/m^3).**
- **1-hour max was determined from pad boundary to nearest receptor.**
- **Annual avg. = 1-hour max multiplied by a factor from EPA-454R-92-019 Screening Procedures, page 4-16.**

Calculations	Units	Ra-226	Ra-228
Emission Rate	Ci/s	2.53E-11	1.256E-11
Max Concentration Annual Avg	pCi/L	8.86E-05	4.40E-05
Equivalent Evaporator Count		4	4
Adjusted Max Concentration Annual Avg, Based on Evaporator Count	pCi/L	3.55E-04	1.76E-04
ARAR Standard	pCi/L	9.00E-04	2.00E-02
Is the maximum concentration within 10 km lower than the ARAR Standard?		YES	YES

SE TECHNOLOGIES Responsive Reliable Results

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AERSCREEN Source Data Inputs

- **Coordinates**
- **Emission rate**
- **Exit T, Velocity, stack diameter**
- **Release height**
- **Property boundary**
- **Receptor locations**
- **Maximum radius distance to model**

Additional AERSCREEN Modeling Inputs

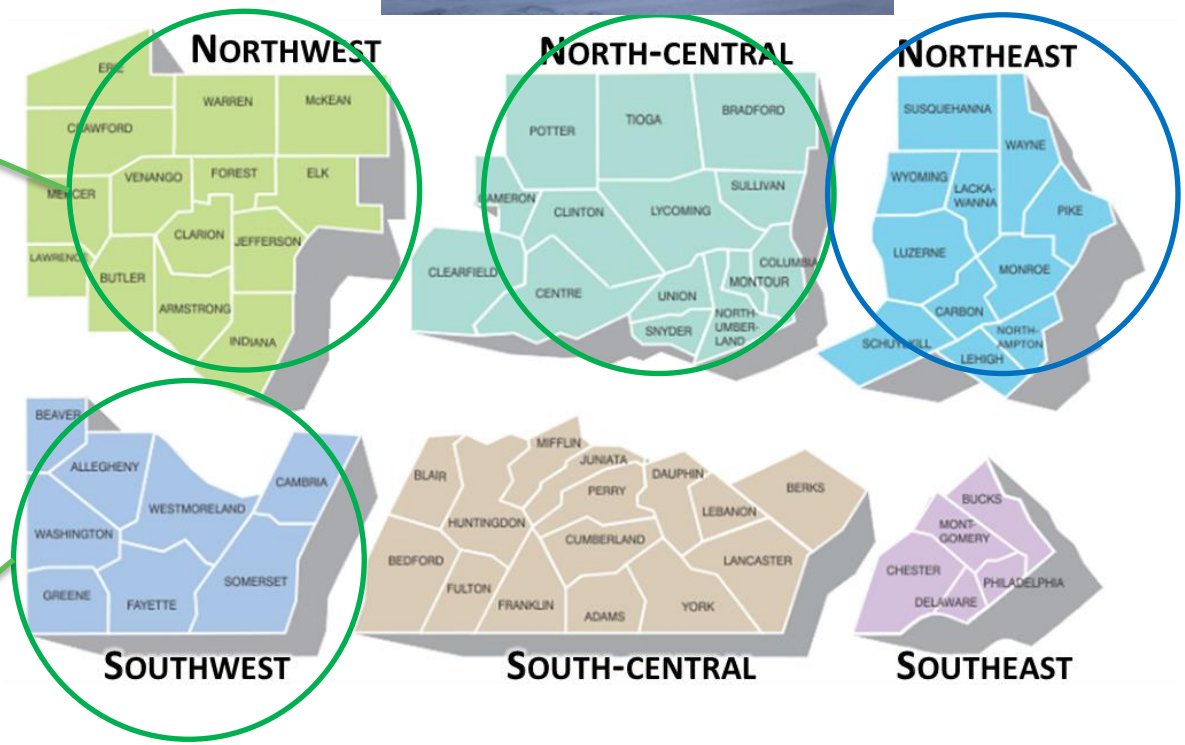
The DEP recommends that the following additional programs be used, and their outputs input into AERCREEN, instead of using default values:

Building Downwash. BPIPPRM file – Building Profile Input Program-Prime. Input UTM, structure dimension size into program. Only needed if there are surrounding influencing structures. Lakes AERSCREEN View Program runs BPIPPRM program.

Land Surface Characteristics. AERSURFACE – Used for generating surface characteristics – actual versus default terrain parameters. The Land Surface Data is used as input into the program. AERSURFACE is stand-alone from Lakes, part of AERMOD software package.

Terrain Height. AERMAP – Used for terrain data inputs. Calculates how terrain is laid out at source and receptors. Lakes includes AERMAP with AERSCREEN view.

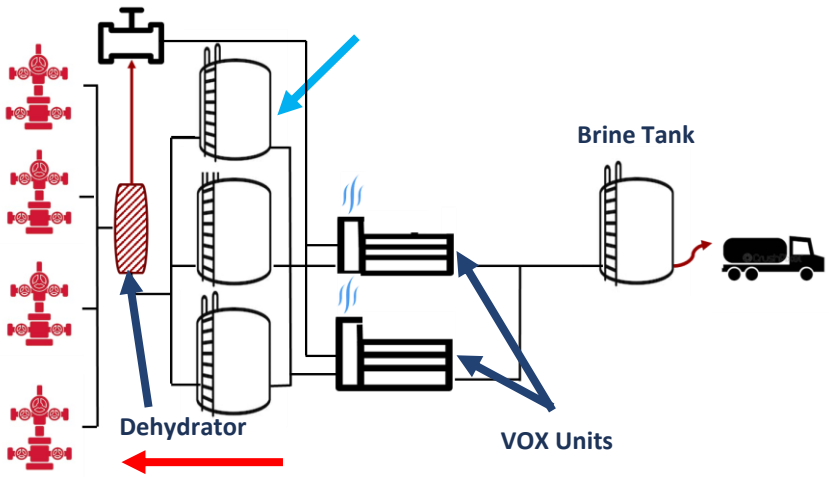
Permitted Regions



Seamless Pad Integration with Small Footprint

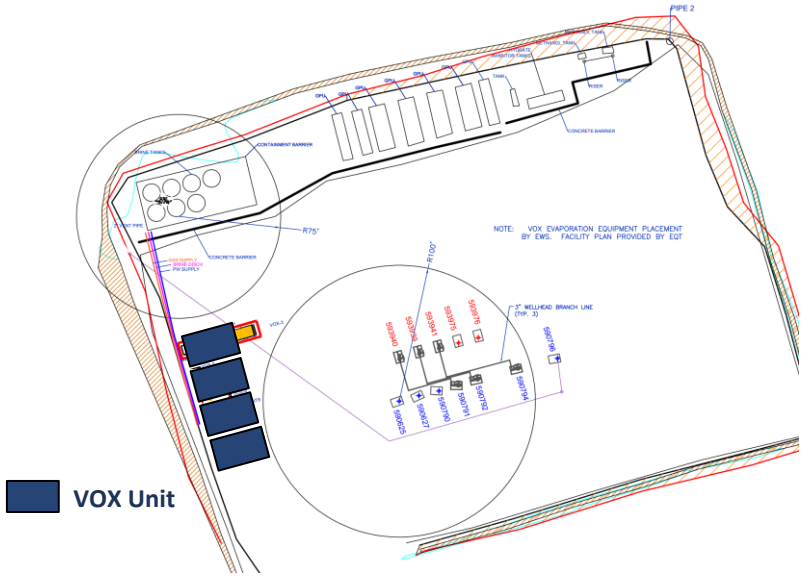
Pad Integration: Generic Flow Diagram

3 connection points: wastewater to VOX, brine discharge, & wellhead gas connection



Site Plan Design

Compact footprint allows for multiple units possible



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Mobilization, Installation and Operations

Summary

- EWS takes complete responsibility for the successful, safe, and reliable operation of the **VOX™** units
  - Comprehensive team with all disciplines required to deliver a full-service approach
  - EWS provides upfront permitting, engineering, operations support and maintenance with minimal interference to operator
- Installs at the wellhead with one day installation and commissioning
- Compact footprint (6.5'x 11.5'), lightweight design allows for easy transportation and minimal impact to well site
- No external utilities required, wellhead gas only
- Safety shutdowns with unit instrumentation
  - Instrumented for remote operations and control
  - Continuous data gathering enables reliable operation

Energy Water Solutions Responsibilities

- Energy Water Solutions handles the following:
  - Obtain any regulatory approvals in cooperation with producer's staff
  - Performance/quality check prior to the unit being shipped
    - Including 24-hr factory acceptance test, all on-site operational requirements, and start-up/shutdown
  - Plan, manage and execute all aspects of transportation, installation, containment, commissioning and start-up
  - Secondary containment for **VOX™** units on customer's site
- Complete on-site operational support and maintenance

Customer Responsibilities

- Site or customer specific HSE instructions/guidance/permits
  - Customer permits (e.g. in PA OG 71/71a)
  - Policies/procedures for safe and responsible operations
  - Equipment siting criteria (e.g., spacing/setbacks)
  - Operations, HSE emergency, Police, Fire and EMS contacts
- Site modifications to support evaporation which may include:
  - Produced water and brine connection lines, gas service to **VOX™** and produced water/brine storage
- Removal of concentrated brine via truck or pipeline
- Producer maintains waste ownership of the produced/flowback water

Conclusions

- Evaporation is a simple process, but it is not well defined from a permitting standpoint
- Many of the bureaus within DEP do not speak to each other on a regular basis; External coordination is required
- Holding preapplication meetings with the regional bureaus allows the reviewers to ask questions and provide feedback ahead of application
- Modeling using AERSCREEN has been successful in determining compliance with ARARs for Ra-226 and Ra-228
- Focusing on emissions and staying under plan approval limits allows for more streamlined approval process
- More focus needs to be put on other emissions outside of PM; NOx is a limiting factor when using AP42 tables