Produced Water Pilot Projects: Summary of Proposed Operations Name of Company: New Mexico Institute of Mining and Technology

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Type of Project: Lab ○ Bench Scale ○ Pilot Project ◉ Field scale ○

Funding: Consortia Funding ☐ Private Funding ☐ Other ☐

Company Description: (Experience, types of technology, primary work of company, etc)

This pilot project is a business initiative from three different entiities: NM Institute of Mining and Technology, Process Equipment and Service Company, Inc. (PESCO), and Hilcorp Energy Company. The direct contact membrane distillation technology proposed for the project was developed by the petroleum Recovery Research Center (PRRC) of the New Mexico Institute of Mining and Technology (NMIMT) LOCATED IN Socorro, New Mexico. Process Equipment & Service Company (PESCO) a leading manufacturer of oil and gas process equipment located in Farmington, New Mexico, has created a mobile membrane distillation treatment until that will house the technology. Hilcorp Energy Company, an oil and gas produced with over 12,000 operated wells located in Aztec, New Mexico, is providing two well sites that produce water for the testing site.

Website: https://www.nmt.edu/research/organizations/prrc.php

Executive Summary: general purpose and benefits of the proposed technology process.

The technology proposed for this project is a desalination process using pre-treatment (DCMD), without post-treatment polishing. DCMD is a thermal-driven technology to remediate PW by using novel polyvinylidene fluoride (PVDF) hollow fiber membranes that were developed at the Petroleum Recovery Research Center at the New Mexico Institute of Mining and Technology. The relatively low TDS water in the San Juan Basin would allow this DCMD technology to demonstrate high water recovery and low-energy consumption, making the DCMD process cost-effective and energy-efficient for commercial-scale application in the petroleum industry, including operations in portions of the Permian Basin. Re-filtration of concentrated waste water will allow demonstration of the system on water that approaches saturation (150,000 to 250,000 TDS) at the same site. This will effectively demonstrate a system that can create a potential industrial source of fresh water (which is less than 10,000 ppm TDS) while reducing salt water disposal volumes by a factor of 2-5 times, once proven. The hollow fibers are bundled and installed in a series of membrane modules which are installed in the filtration treatment unit. Much of the produced water (PW) in the San Juan Basin is relatively clean, with total dissolved solids (TDS) ranges from Medium TDS (40,000 – 100,000 mg/L) to Low TDS (<40,000 mg/L). None of the wells involved in this project will have any hydraulic fracturing chemicals as they were drilled in the years 1994 and 2013, respectively; thus, all of the PW constituents to be treated are naturally-occurring minerals from the geologic strata. This test is entirely closed-loop, and all water, both cleaned, and concentrated, will be mixed back together into the same tanks from which the water originated for disposal per the existing, approved disposal process.

Goals of the Project: what are the goals of the project to accomplish—days operational, stability, quality and quantity of distillate, barrels of distillate produced, etc.

The Project seeks to test the treatment technology with the ultimate goals of (1) treating the PW to the water quality standards that would permit the treated PW to have potential fit-for-purpose reuses, such as: providing water for Hydrogen projects; air pollution, carbon footprint, and freshwater use reductions from less-frequent truck transport; and (2) commercialize the treatment technology to reduce the volume of produced water disposed of in SWDs and increase water resources for other applications. This proposed nine-month project will be led by the principal investigator (PI), Dr. Robert Balch from the NMIMT. In the San Juan Basin, large quantities of PW are produced from individual well sites that often very

remote and are not interconnected with a PW pipeline system; because there are no major centralized PW treatment sites in the San Juan Basin, treatment is only cost-effective if the treatment unit can be moved from well site to well site depending on need. The treatment unit design is focused on smaller units which are skid-mounted. At this size, the DCMD Units are designed to treat 5,000 gallons per day of PW that contains up to 200,000 mg/L TDS. The DCMD Units are mobile, skid-mounted, and enclosed in a weatherproof container measuring approximately 8' wide x 20' long x 8' tall. The skid is easily transportable so that it can be readily moved from well site to well site to treat PW at two existing oil and gas well sites operated by Hilcorp in the San Juan Basin, designated for this project. During the project test, all treated water and residuals will be returned to the PW tank at the well site for storage and disposal in accordance with current PW requirements; the project has been designed and will be managed to ensure that there is no planned or accidental discharge or release of produced water outside of a permitted Oil Conservation Commission (OCD) facility and the system will operate inside existing berms at each site. Data collection during pilot testing will be in accordance with the NM PW Consortium's most current guidance documents

Site Identification:

Physical Location(s) where *all parts* of the project are to be conducted: address, T-R-Section, Lat/long, site description.

Site 1: NE/SW of Section 28, T26N-R9W, N.M.P.M., San Juan County, NM
Site 2: NW/NE of Section 22, T30N-R11W, N.M.P.M., San Juan County, NM

Land status of location(s) for *all parts* of project: private, federal, BLM, Tribal, USFS, other.

Site 1 is located on BLM surface. Site 2 is located on fee surface owned by Hilcorp San Juan, LP.

Were any parts of the project conducted or sourced within the exterior boundaries of a Native American Indian Reservation?

No

Were all landowners noticed? (You may be asked to provide documentation of Notice)

Yes, we have met with the BLM and they support our pilot project (see October 27, 2022 email from Sarah Scott, BLM Farmington Field Office, with copies provided to John Roderick and Adrienne Sandoval). Hilcorp will submit a Sundry outlining the new equipment to the temporarily added to the wellsite and wait to begin project operations until we receive an approval Sundry from the BLM

Proposed Schedule: date(s) of proposed testing, duration of testing.

We are still running tests on the treatment unit in the manufacturing space at PESCO. We hope to mobilize sometime in early 2023 and plan to test the treatment technology for approximately nine months.

Technology Performance Objectives: Treatment target goals: treated water recovery in bbls/day, daily operational target (hrs/day), treated produced water recovery target % of raw water feed, quality target, initial TDS and target TDS after treatment, source water data, basin, formation, and other pertinent data.

The PW treatment process will generate two resulting product streams. One will be a stream of treated produced water. It is expected that the resulting data from the project will demonstrate that the contaminants from the source PW that remain in the treated water stream will be reduced to below NMOCD and NMED water quality standards. Thus, in theory, the treated PW could qualify for various fit-for-purpose applications, and in the future as the regulatory environment evolves, potential other re-use applications. The other waste stream will be a smaller volume of concentrated brine to be

disposed of downhole at salt water disposal wells already used by the operator.
The expected ratio of treated water to concentrated brine will depend on the salinity of the source PW, but it is expected that this ratio will be in the range of 5:1 to 20:1 (treated water to concentrated brine), thereby greatly reducing the volume of water to be hauled to an off-site disposal well. This reduction of the overall PW waste stream that requires SWD disposal is a key component for calculating the money saved versus current practice. If the results show a significant cost savings, then it will pave the way for Hilcorp to work with the Consortium and the State of New Mexico regulatory agencies to pursue alternate use options, eliminating most of the current PW hauling and disposal. Once proven to be a cost effective treatment, this treatment technology could be applied across the San Juan Basin and beyond, reducing operating costs, extending the economic lives of wells, significantly reducing the volume of water truck traffic on lease roads and highways, reducing risk of seismic activity from SWD wells, and resulting in a substantial influx of potentially usable clean water across the State of New Mexico.

Treatment System Design and Process: brief description of the general technology to be used, how the process will flow and the expected results.

The process flow of the Treatment Unit begins with the inflow of the contaminated water source (feed solution) through pre-treatment filters into an internal surge tank. (Note: Since samples from the two test wells indicated there are minimal issues with suspended solids or entrained hydrocarbons that would affect the primary membrane filter media, only a basic level of filtration of the inlet water will be required. If, however, it is determined to be a problem upon testing, additional pre-treatment equipment can be added at that time). After the PW enters the internal surge tank, it is circulated by pump through a feed solution cycle loop where it flows through the filter modules, coming in direct contact with the hollow fiber membranes. Vapor from the hot feed solution side migrates, via the DCMD process, across the highly-porous and hydrophobic membrane barriers over to a permeate water circulation loop. As permeate water builds in the treated water surge tank, it is routed to a treated water storage tank and then on for testing to verify it met treatment objectives. During the DCMD process, the concentration of TDS in the feed solution loop will build. When it reaches a pre-determined set point of maximum concentration for subsequent SWD disposal, the concentrate will be moved to a concentrate holding tank. At this point, the cycle starts again. The TDS concentration of the contaminated water source directly affects the ratio of treated water to concentrate produced by the MD Unit. Spill prevention and countermeasures include MD Unit self-contained instrumentation monitoring flows and temperatures with auto-shutdown capability including internal catch pan leak detection. Also, the unit and associated piping and equipment will be placed inside a lined, bermed containment area to catch any leaks that may occur from piping or the MD Unit, preventing a concentrate or PW water leak to the soil.

Disposal of the treated produced water, soil, plant material, etc:

The project will be completely closed loop; after the produced water has been treated, it will be returned to the holding tank and hauled to a permitted salt water disposal facility per the normal disposal process. No water will be released or discharged on site.

Other Attachments or information:

Membrane distillation offers the capability to treat high salinity PW with theoretically 100% of salt rejection. In a typical direct contact membrane distillation (DCMD) process, the hot feed and cold permeate solution are separated through a hydrophobic microporous membrane, which prevents the salt permeation but allows water vapor transport through the membrane pores. The vapor transport is driven by the temperature-induced vapor pressure difference across the two sides of the hydrophobic membrane.
As the DCMD process is not purely thermally driven, membrane distillation can be operated at a much lower temperature than the other conventional thermal distillation processes, leading to lower specific energy consumption. Aside from the energy advantage, DCMD shows a considerably lower fouling potential than the pressure-driven based membrane process, such as reverse osmosis and nanofiltration. Because there is no trans-membrane pressure applied on the membrane surface, the accumulation of foulants on the membrane surface are significantly eliminated.
In recent years, New Mexico Tech has successfully developed a novel Janus hollow fiber membrane that significantly enhances the efficiency of this process. It has been proven from bench-scale experiments that the Janus hollow fiber membrane exhibits simultaneously enhanced water flux and energy efficiency compared to the other conventional PVDF membranes.

In this project, a pilot-scale Janus hollow fiber membrane-based DCMD system will be constructed for testing with actual oilfield produced water in the San Juan Basin. The initial test units will be designed to treat 5,000 gallons per day of water that contains up to 200,000 mg/L of total dissolved solids. The MD Units designed by PESCO are skid-mounted units which are easily transported from well site to well site.

The treatment technology used for this project is direct contact membrane distillation (DCMD). DCMD is a thermal-driven technology by using a porous hydrophobic membrane to remediate PW that was developed by the Petroleum Recovery Research Center at the New Mexico Institute of Mining and Technology (NMIMT). Hollow fiber membrane (HFM) offers a compact, cost-effective solution for filtering large volumes of impaired water utilizing minimal space and energy. NMIMT has successfully fabricated different types of HFMs for oilfield produced water management

Other Research Support: The research on the novel hollow fiber membranes has been financially supported by the Department of Energy (DOE) through the Research Partnership to Secure Energy for America (RPSEA) (award number 12123-16). The Janus-HFM used in this proposed DCMD process was also supported for a laboratory-scale study from the Bureau of Reclamation (BOR) (agreement number R17AC00143). Most recently, two new projects were selected by the BOR for both laboratory-scale and pilot-scale demonstrations of innovative hollow fiber membranes-based DCMD process for high-salinity produced water treatment.