Task 5. Request for Proposals: 2025

Maximizing Value Captured from Produced Water

Task proposed by Chevron and NGL Water Solutions

Task developed by Chevron, NGL Water Solutions, the New Mexico Produced Water Research Consortium, Coterra Energy, and APATEQ PWT-S.A.

Task Summary

You are invited to recover constituents from a Permian Basin pre-treated brine concentrate and process them into a sellable form to offset the overall costs of treating produced water for reuse. Consider producing entirely new products or new applications of products that will ensure long-term revenue streams, reduce the volume of produced water needing to be disposed, and help the oil and gas industry move toward a Net Zero economy.

Background

Produced water (PW) is a byproduct of oil and gas (O/G) production. When oil is pumped from the ground, every barrel comes to the surface mixed with several barrels of saline water, along with other constituents that were trapped in the rock formations millions of years ago. Once brought to the surface, the oil and water are separated, the oil is sent to market, and the remaining brine is termed "produced water." For additional PW-related terms, see the Appendix, p. 6.

Although PW has historically been considered industrial wastewater, this is changing as the O/G industry seeks ways to use it beneficially. It is a challenging undertaking because PW has a salinity approximately four times that of ocean water. It also contains small amounts of oil and various other components that depend on its basin of origin.

<u>Economic Solutions for Treating Produced Water</u>

The western United States, particularly the drylands of the Southwest, is experiencing severe drought. With the region serving over 60 million people and groundwater levels at a historical low, the need for water is urgent [1]. One water supply that New Mexico has in abundance is PW. About 19 million bbl per day (MMbbl/d) of PW were produced across the Permian Basin in 2023 and volumes continue to rise [2]. These large volumes of PW provide opportunity for enhancing regional water supplies and mitigating drought issues. Such large water volumes are not found in all O/G basins. For reference, another prolific O/G basin in Appalachia yields PW at only 0.33 MMbbl/d.

The most cost-effective means of addressing the large volumes of water in the Permian Basin are 1) to recycle it for O/G activities or 2) to inject it into geologic formations via EPA Class II Saltwater Disposal Wells (SWDs). These two alternatives may be the most cost-effective on the short term, but they have their own challenges. For example, SWDs are limited in their capacity. When an SWD reaches its capacity, it is decommissioned to further injection. This results in challenges for O/G operators who deal with high volumes of PW.

The O/G industry can support drought-challenged areas by treating PW for beneficial reuse, such as for non-edible agriculture, industry, habitats, or recreation. Such treatment would help mitigate drought conditions by providing additional water to support quality of life while preserving fresh water sources for higher-standard uses such as drinking water. At the same time, beneficial reuse of PW will significantly decrease the amount of PW being disposed into SWDs.

The limiting factor for treating PW for reuse has historically been the cost of treatment due to the complex and energy-intensive treatment train required to remove the salts, organics, and other constituents. Although recent technological developments are bringing down costs, PW treatment has been ranging from \$1.00-\$3.00/bbl to treat for unrestricted beneficial use—up to six times the cost of treating surface waters for potable use (about $0.48/bbl) [3].

One attractive option to offset the costs of treating PW is to identify constituents in the water that can be recovered, processed, and sold. Sometimes called "brine mining," this is an area of active research that may include extracting constituents in their elemental form or using them as feedstock for new compounds [4]. This will not only improve the economic feasibility of treating PW for beneficial reuse, but it also has the potential of significantly reducing the volume of liquids and solids being disposed in SWDs—goals that are paramount in the O/G industry.

Efforts to recover valuable constituents will contribute to a circular economy by making use of valuable constituents rather than injecting them downhole. In addition, extracting constituents from PW may reduce the environmental impact of current mining methods for those same constituents.

Pre-treated Concentrated Brine from the Permian Basin

To solve this design challenge, teams will work with Permian Basin brine concentrate provided by the New Mexico Produced Water Research Consortium (NMPWRC). The concentrate will be the effluent (often termed "reject") from a PW desalination treatment train. Before being used at the contest, this brine will be pretreated to remove organics and bacteria, thereby allowing it to be shelf-stable for the contest. The brine will have low TSS, low organics, and high (>200,000 ppm) TDS. In January 2025, the NMPWRC will collect the brine concentrate, ship a portion of it to each registered team, and reserve a portion for the April 2025 bench-scale demonstrations.

As a guide for initial design planning, Table 1 lists typical constituents in Permian Basin PW concentrate. Brine provided at the contest will have similar constituent concentrations. Once the PW is collected for the contest, the NMPWRC will report to each team the concentrations for constituents listed in Table 1.

Table 1. Typical constituents in Permian Basin Clean Brine Concentrate.

Constituent	Feed (ppm)
TDS	252,000
TPH*	<5
Cl	144,600
Na	76,324
Ca	9,108
Sr	2,696
Mg	1,502
K	1,294
NH_3	TBD
SO_4	540

Constituent	Feed (ppm)
HCO_3	240
Li	64
Si	34
Ba	13.2
PO_4	7.4
Fe	2
Mn	0.72
Al	0.28
Zn	0.08
Pb	1

*TPH: Total Petroleum Hydrocarbons

Maximizing Value of the Treated PW Concentrate Stream

Your primary goal is to consider the full economics of the problem by determining the best balance between three issues:

1) recovering constituents from the concentrated brine to make a useful product;
2) identifying an existing market or proposing a new market for the product that will generate reliable revenue;
3) reducing the volume of liquids and solids to be disposed after you have recovered valuable constituents.

Teams should also factor into their analysis the possibility that their process may be more cost effective when scaled to higher production volumes than specified in this task. If this is the case, cost-recovery calculations for processing up to 150K bbl/day of concentrate may be included in the technical report.

Treating and Disposing of Produced Water

For PW, "treatment" usually refers to desalination. Pre-treatment and post-treatment refer to removing oils, VOCs, suspended solids, etc. Every PW application has its own unique treatment train (pretreatment, treatment, and post-treatment) requirements.

To gauge the success of your product in reducing waste streams, consider that, based on the salinities in the Permian Basin, current treatments require approximately 50,000 bbl of PW to produce 25,000 bbl of desalinated water, leaving 25,000 bbl of concentrated brine as the residual effluent stream. Your team will be removing constituents from this residual stream, but will not be expected to treat produced water for reuse.

After removing the constituents needed to produce your product, your team will be left with your own residual stream that, in your full-scale operation, you should plan to inject into an SWD. These residuals should be in liquid form because the disposal of solid waste from PW is difficult and expensive. Further, to minimize down-hole pressures, regulations limit TDS to 250,000 ppm for SWD injection. Teams are cautioned to ensure that any chemicals they may add while producing their valuable product will not elevate the TDS levels of their residual effluent.

Consider the cost of SWD injection to be $1.00/bbl (conversely, reducing disposal volumes will save $1.00/bbl). Assume that the processing facility will be sufficiently close to an SWD site that there will be no transportation costs related to delivering remaining brine to an SWD.

Problem Statement

Your team will design a process to produce a useful product from Permian Basin pre-treated brine concentrate. Base the constituent recovery on a 25,000 bbl/day stream of brine concentrate. Your solution should be optimized to obtain the greatest market value for your product while reducing the volume of the reject brine, thereby reducing disposal costs of the liquids remaining after constituent recovery.

Teams are encouraged to be innovative in their solutions and consider new applications and/or creating new markets for their proposed products. Solutions should be logistically feasible, provide a long-term offset of PW treatment costs, and include a plan for post-treatment and/or disposal of the reject concentrate stream after the product has been produced.

Design Considerations

Your proposed design should provide specific details and outcomes as follows.

- Base your analysis on a 50,000 bbl/day treatment facility having a 25,000 bbl/day reject concentrate stream.
- Produce a usable and marketable product from the constituents recovered from the provided concentrated brine. Select the constituents to optimize a long-term, stable income from the sale of the product while minimizing the costs associated with disposal of the remaining concentrate.
- Include a Process Flow Diagram (PFD) for the selected treatment process. The PFD must include mass and energy balances (input and output streams, reactants, reaction rates, etc.). Take extra care to ensure that all processes and waste streams are included. This is a major element of judging (see Team Manual for PFD examples).
- Propose a plan for waste-stream management after product generation. If post-treatment prior to injection into an SWD is needed to ensure safety and/or regulatory compliance, include this in your PFD and process analyses as theoretical considerations. A bench-scale demonstration of waste stream post-treatment is not required.

- Ensure that the TDS of your residual (waste) stream will be no higher than 250,000 ppm to comply with SWD injection regulations.
- Assume that constituent recovery and disposal of any remaining brine will be accomplished within the PW treatment facility, thus eliminating the need for considering transportation logistics or costs on either end of your process.
- Present a Techno-Economic Assessment and Analysis (TEA) to construct a full-scale process to produce a usable product that will scale with an influent rate of 25,000 bbl/day of brine concentrate. This will include your estimate of costs for a full-scale solution. Include appropriate graphical representation of your cost data.
    - All costs must be demonstrated, including the cost of managing and disposing of the residual streams, staffing, and any post-treatment needed after product generation.
    - CAPEX (Capital costs) typically include, but are not limited to, equipment, pipes, pumps, etc. Do not include costs of buildings and appurtenances to the treatment process.
    - OPEX (Operating costs) should be calculated as cost to produce your product on an annual basis, based on a rate of 25,000 bbl/day of influent brine concentrate. Include these costs:
        - Materials needed, including consumables (chemicals, sacrificial components, etc.)
        - Staff labor rate ($70/hour); solids disposal costs ($50/ton); energy requirements (cost/bbl and Kwh/bbl): use an electricity rate of $0.10/kWh and research an industrial natural gas rate and state in $/MM BTU.
        - Additional operating costs that your team identifies.
        - If higher production rates (up to 150,000 bbl/day) would improve earnings from constituent recovery, include this analysis in your TEA, along with 25,000 bbl/day estimates).
    - Address the cost offset for treating PW that will result from the sale of your recovered constituent. Compare this with the current cost of $1-3/bbl for treating PW and the disposal rate of $1.00/bbl for SWD injection.
    - Visualization tools: Sensitivity analyses, etc.
    - Teams are advised to create a multi-disciplinary team by inviting a business major to help draw up economic plans for full-scale implementation of your designs.
- Include a public involvement plan that addresses public perception and potential public contributions in utilizing PW in your chosen product and its application (see Team Manual).
- Address any intangible or indirect benefits of the selected treatment process, such as improving the environmental impact of mining and/or producing your selected product.
- Address safety aspects of handling the raw clean brine concentrate, residual streams, and final products. Safety issues for the full-scale design should be addressed in the written report. Safety issues for the bench-scale demonstration should be addressed in both the written report and the Experimental Safety Plan (ESP).

Bench Scale Demonstration

The bench-scale unit should demonstrate a process that will produce a useful, marketable product from pre-treated brine concentrate obtained from the Permian Basin. The bench-scale design should be scalable to a plant that produces 25,000 bbl/day of concentrated brine.

Chemistry of the brine will be similar to that shown in Table 1. In January 2025, the NMPWRC will report constituent values for the brine to be used at the contest. Teams should consider the corrosive nature of the clean brine concentrate and ensure that materials used in the bench-scale apparatus will maintain their integrity when exposed to fluids of chemistry shown in Table 1.

At the contest, each team will be provided with up to 18 liters (5-gallon container) of clean brine concentrate to work with during the bench-scale demonstration. <u>You are not required to use the entire amount of the solution during the demonstration.</u> Teams requiring more or less PW concentrate should indicate this in their ESP by February 26, 2025.

After treatment, your team shall submit 125-mL samples for analysis: one sample of influent (brine concentrate). two samples of your waste stream, and additional samples of your final product, as warranted by your ESP. Collection of samples will be witnessed by a WERC staff member.

<u>PW EHS Protocols</u>

Untreated PW is considered a hazardous material, but it is not a hazardous waste. It can be toxic and/or corrosive. Teams should consult their institution's Environmental Health and Safety (EHS) protocols for handling and disposing of the brine concentrate. At the contest, teams will follow all handling and disposal protocols outlined by the NMPWRC and the New Mexico Environment Department (NMED).

<u>Teams will bring to the contest</u>

Teams will bring a functioning apparatus that will fulfill the requirements of the task, with all piping properly tethered. All experimental conditions and equipment must be documented in the ESP for review.

<u>WERC will provide at the contest</u>

At the contest, each team will be provided with:

1) a kiddie wading pool and/or tarps as secondary containment in case of spills,
2) Up to 18 liters of concentrated brine to work with during the bench-scale demonstration, and
3) 125-mL sample bottles for influent, waste stream, and product collection.

<u>Contest Analytical Testing Techniques</u>

At the contest, each team's bench-scale demonstration will be analyzed by:

- Composition and/or functionality of the product produced, as determined by the team's ESP.
- Waste stream reduction (volume)
- TDS of the team's reject brine (to be less than 250,000 ppm)
- Additional analyses may be warranted by the team's ESP and may include pH, turbidity, TSS, etc.

Evaluation Criteria

Each team is advised to read "Evaluation Criteria" and "Contest Scoring" in the 2025 Team Manual for a comprehensive understanding of the contest evaluation criteria. For a copy of the Team Manual, Public Involvement Plan, and other important resources, visit the WERC website: <u>Guidelines | werc.nmsu.edu</u>

In addition to evaluation criteria that applies to every task, Judges will evaluate your team's response to the problem statement, with consideration of the Design Considerations listed above.

Experimental Safety Plan (ESP) and Required Short Course.

See team manual for details. Due dates are listed below.

Dates, Deadlines, FAQs (*dates subject to change—watch website FAQs*)

- Today: Email us to let us know you are interested in this task. We will contact you with breaking news.
- October 15, 2024 - December 31, 2024 – Early Bird Registration (discount applies).
- December 1, 2024 - February 20, 2025: Mandatory On-demand Course: Preparing the Experimental Safety Plan. See website and Team Manual for information.
- February 17 - 26, 2025: Experimental Safety Plan (ESP) due. Include requests for volume of brine concentrate and ancillary equipment needed at the contest.
- March 7, 2025: Final date to register a team.
- March 31, 2025: Technical Report due
- Weekly: Check FAQs weekly for updates:
  - Task-specific FAQs: 2025 Tasks/Task FAQs
  - General FAQs: 2025 General FAQs
- All dates or task requirements are subject to change. Check FAQs for updates online.

References

[1] Williams, A.P., Cook, B.I., & Smerdon, J.E. 2022. Rapid Intensification of the Emerging Southwestern North American Megadrought in 2020-2021. Nature Climate Change. 12(3), 232-234. https://doi.org/10.1038/s41558- 022- 01290 -z.

[2] Bennett, K. Permian Embraces Produced Water Recycling. August 2023. Permian Embraces Produced Water Recycling

[3] Data and Information used by WaterSense. 2022. EPA.Gov - WaterSense Data (Accessed 7/5/2024)

[4] Murray, Kyle E. 2023. Pathway for Recovering Critical Minerals and other Elements of Interest from Produced Water. Ground Water Protection Council. August 2023. Gross Values of Elements in Produced Water for Potential Resource Recovery (gwpc.org).

Appendix: Produced Water Terms

Brine used at the contest - Pretreated produced water concentrate resulting from a desalination treatment process. It will have low TSS, low organics, and high TDS (>200,000 ppm).

Brine – any solution with a concentration of over 35,000 ppm TDS (USGS definition).
PW and PW concentrates are usually brines.

Clean Brine – A clean brine is a high-salt concentration PW with oils, greases, suspended solids, iron, and bacteria removed. It has been pH adjusted. It has NOT been desalinated. The term "clean brine" must be associated with produced water. (Produced Water Society definition)

Distillate - desalinated water or desalinated brine, using a thermal process.

Permeate - desalinated water from an RO process

Desalination concentrate - the highly saline reject concentrate that comes out of a desalination (RO or distillation) process.