WERC ENVIRONMENTAL DESIGN CONTEST

2026

Task 5: Request for Proposals:

Enhanced Evaporation of Produced Water

Task developed by: Basin Disposal, Inc., Chevron, Coterra Energy, HF Sinclair, and NGL Water Solutions.

Task Sponsored by: Platinum Sponsor Chevron and
Silver Sponsor NGL Water Solutions

Introduction

Your team is tasked with exploring innovative approaches to significantly increase PW evaporation rates using technologies that are both environmentally responsible and cost-effective.

In some oil-producing regions such as the Permian Basin, along with the oil, extremely large amounts of water are pumped from the ground. This water, known as produced water (PW), must be managed properly. In the future, it is hoped that regulatory agencies will permit treatment and beneficial re-use of PW. Until then, PW operators must rely on various method of disposing of it, such as injecting it into Class II Salt Water Disposal wells (SWDs) – which is costly – or evaporating it, which has proven technically challenging so far.

Natural evaporation through exposure to sunlight cannot keep pace with the high volumes of PW generated in the Permian Basin, and currently, efforts intended to accelerate natural evaporation have yet to demonstrate feasibility, effectiveness, and environmental sustainability.

Problem Statement

Your team is invited to research, evaluate, and design an innovative enhanced evaporation process for managing produced water. The primary goal is to cost-effectively maximize evaporation, thereby reducing the volume of PW requiring disposal.

The proposed solution may use continuous or batch treatments and should be suitable for implementation in the Permian Basin near Carlsbad, NM. The bench-scale design should scale up to accommodate a continuous PW flow of 500,000 bbl/day (21 million gallons/day), and, if needed, provide up to 1 MM bbl of PW as a buffer for fracking operations in the event of operational shutdowns.

You are encouraged to explore innovative and practical approaches that go beyond the typical impoundment pond for storing this volume of PW. In addition, your approach should comply with all environmental regulations and, where possible, go beyond them by incorporating additional environmentally responsible measures. At the same time, it should minimize costs for PW operators by reducing energy consumption, material costs, labor costs, maintenance, waste, SWD disposal. etc.

Background

PW is a byproduct of 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 (primarily through gravity or hydrocylones), the oil is sent to market, and the remaining brine is termed "produced water."

PW has historically been classified as industrial wastewater due to its high salinity, typically about four times that of seawater, and the presence of trace hydrocarbons and other constituents that vary by basin. PW disposal is challenging because of its complex composition and the large volumes generated.

In the Permian Basin (one of the most prolific and water-rich O/G basins in the US), approximately four barrels (bbl) of water are produced for every bbl of oil, with some isolated basins producing 12 bbl of PW per bbl of oil [1]. To put this in a daily perspective, in 2024 approximately 20 million barrels per day (MMbbl/d) of PW were pumped from the Permian Basin, and volumes continue to rise [2]. In contrast, other oil and gas basins such as the Appalachian Basin produce significantly less water—only about 0.33 MMbbl/d—highlighting the unique scale of the water management challenge in the Permian. Note that 1 bbl equals 42 gallons and MM is used in the O/G industry to represent "million."

Salt Water Disposal Wells

In the early days of O/G production, to dispose of the large amounts of water recovered during oil extraction, PW was routinely injected into separate geologic formations via EPA Class II Salt Water Disposal (SWD) wells. The prevailing philosophy was that this ancient water, once deeply buried, was simply being returned to the subsurface from where it originated.

Initially, the wells' capacity seemed limitless. However, emerging research has unexpectedly indicated a correlation between deep saltwater injection and induced seismicity in certain instances in the Permian Basin. In response, both operators and regulators have taken steps to address these concerns. Operators continue to inject PW into SWDs, but now do so under stricter regulatory oversight, supported by an increased monitoring of well conditions in the SWDs and a heightened awareness of the need to track injection volumes. Once a well reaches its permitted capacity, it is decommissioned. These evolving constraints present increasing challenges for O/G operators who are committed to managing PW safely and responsibly – while also managing ever-growing volumes of PW.

New limits placed on SWD injection present challenges for PW operators, but with challenge comes opportunity. One recently implemented approach to managing PW is recycling for use in hydraulic fracturing operations. In the early days of fracking, fresh groundwater was the default water source, but the industry has made notable strides in conserving groundwater by reusing PW from its own operations. Although recycling adds approximately $0.25 per barrel – mainly due to treatment and handling requirements compared to using fresh water – it has significantly advanced industry sustainability. However, demand for fracturing water does not keep pace with the high volumes of PW generated in the Permian Basin.

PW Storage – Impoundment Ponds and New Alternatives

Fracking operations are intermittent. Therefore, PW is often stored until it is needed for reuse. The most common storage is large open-air impoundments, also called ponds, pits, or lagoons, that each can hold over a million bbl of water. These ponds balance fluctuations in supply and demand, equalize variable pipeline flow rates, and provide a buffer for scheduling fracking operations.

While relatively inexpensive to construct, lagoons come with significant regulatory and operational challenges. Regulations require impermeable liners with integrated leak-detection systems that must be monitored daily. In New Mexico, if a leak is detected, operators must notify the Oil Conservation Division (OCD) within 24 hours, remove all fluids within 48 hours, and promptly begin liner repair and soil remediation. Pumping one MMbbl of PW within this time frame poses major logistical hurdles, making impoundment pond management and liner maintenance challenging for PW operators. Additional requirements for soil remediation, liner repair or replacement, and related actions are outlined by the NM State Records Center and Archives [3]. These remediation efforts are costly and can result in facility shut downs until all issues are resolved.

Another challenge of open-air impoundment pits is that large bodies of water are attractive to wildlife, and the PW they hold poses environmental and safety risks to birds and other animals. Although operators continue to test various deterrents, none have proven fully effective.

For these reasons, reliance on impoundment ponds alone is becoming increasingly challenging. PW operators are seeking new approaches that reduce risk, improve reliability, and better align with environmental and regulatory expectations. Although you may find the impoundment model to be the best solution for your design, your team is also encouraged to propose alternatives that could serve as safer and more practical solutions to managing high volumes of PW.

Beneficial Reuse

Looking to the future, there is hope that large volumes of PW can be treated for beneficial reuse, such as agricultural irrigation. This would allow this newly extracted, anciently stored water to supplement water supplies in arid, water-scarce regions. The O/G industry, along with researchers in academia, continues to develop more effective and efficient PW treatment technologies, but the greatest barrier to widespread reuse remains the lack of clear regulatory approval pathways. Until regulatory frameworks for beneficial reuse are established, enhanced evaporation may offer the most environmentally sustainable alternative for managing excess PW.

Enhanced Evaporation

Cost is always a key factor in developing new engineering solutions. While SWD injection and impoundment ponds remain relatively economical options for managing excess PW, they cannot keep up with peak flow volumes. A commonly considered alternative is natural solar evaporation (using open, shallow ponds exposed to sunlight), but even in the sunny and arid southwestern U.S., where evaporation rates in PW ponds average 0.25" water per day (Table 1), it cannot keep pace with PW production in the Permian Basin.

As a result, the O/G industry is actively pursuing enhanced evaporation technologies to better manage large volumes of PW. These technologies reduce water volume by improving evaporation efficiency, thereby accelerating the natural process of solar evaporation.

Although effective means of quickly evaporating water are well-developed, such as thermal -and membrane-based systems, they are highly energy- and capital-intensive. Their implementation would require careful planning to ensure that the added energy demands can be managed efficiently and cost-effectively.

TABLE 1. AVERAGE EVAPORATION RATES FOR PW IN THE PERMIAN BASIN

Month	Inches Precip.	Average High Temp	Average Low Temp	Average % Humidity	Evap Rate (in/day)	Evap Rate (in/month)	Net Evap (in/month)	Bbl of Evap/Acre
Jan.	0.47	58	28	57	0.14	4.34	3.87	2,502
Feb.	0.54	63	32	51	0.23	6.44	5.9	3,814
Mar	0.51	70	38	40	0.16	4.96	4.45	2,877
Apr	0.64	78	46	37	0.29	8.7	8.06	5,211
May	1.17	87	56	40	0.23	7.13	5.96	3,853
Jun	1.53	94	64	43	0.35	10.5	8.97	5,799
Jul	2.01	95	68	49	0.4	12.4	10.39	6,717
Aug	1.83	93	67	54	0.5	15.5	13.67	8,838
Sep	2.11	87	59	58	0.35	10.5	8.39	5,424
Oct	1.16	78	48	54	0.275	8.525	7.365	4,761
Nov	0.81	67	36	53	0.15	4.5	3.69	2,386
Dec	0.63	58	28	55	0.18	5.58	4.95	3,200
							Annual bbl of Evap/Acre	55,382

Enhanced evaporation presents some operational challenges:

- Once evaporation exceeds approximately 50%, substantial amounts of solid residues begin to accumulate. This requires a comprehensive plan for removal and disposal of the solids.
- Because solids removal may damage the liners, regularly scheduled inspections and provisions for repairs must be considered. (See Spill Rule 19.15.29 [4] and [5])
- Evaporation of brine slows significantly as salinity increases, and it effectively stops when the solution reaches the saline saturation point.

Enhanced Evaporation Research and Trials

The basic principles of enhanced evaporation are

1. Increasing the energy in the system to accelerate the phase change from liquid to vapor, and
2. Increasing the water's surface area to expose more water molecules to the air.

Despite its apparent simplicity, enhanced evaporation of PW has been an area of research for many years and has proven challenging. Some approaches target increasing energy input (#1), others focus on increasing water surface area (#2), and some combine both strategies. The complex composition of PW – salts, hydrocarbons, and metals – can complicate the evaporation process. For example, as brine becomes more saline, the rate of evaporation decreases sharply and essentially comes to a halt once the solution reaches its saturation limit. Oil and other contaminants can also inhibit evaporation. Their presence often requires pre-treatment prior to evaporation, and this adds complexity and cost. However, recovering the oil during this step may help offset these additional expenses.

Several enhanced evaporation strategies are listed below to support the development of your team's original solution. These are provided for context only—your team is expected to propose a distinct and innovative approach. Note that for each strategy, engineers have noted significant challenges.

1. ***Increasing the water's surface area by:***
    a. ***Spraying, bubbling, or trickling the water over long distances.*** This process is often combined with heating the water, so it can be an application of both #1 and #2.
    Challenges: the droplets created can carry salts, hydrocarbons, and metals into the air, creating airborne pollutants. When air velocities drop, these constituents are deposited on the ground, compromising local vegetation.

    b. ***Utilizing evaporation mats, wicking materials, or membranes.***
    Challenges: frequent fouling on the wicking materials as the water evaporates and leaves behind salts and minerals. The wicking materials are also susceptible to damage during harsh weather, and their efficiency can diminish over time.

2. ***Increasing the energy within the system through:***
    a. ***Heating the water, often through flash or mechanical vapor recompression.*** This uses heat or a vacuum to boil off the water and condense the steam.
    Challenges: it is a high-energy process that is costly to maintain, pretreatment is needed to remove oil and grease, and it requires frequent maintenance because of rapid scaling/fouling of the system.

    b. ***Mechanical means such as fans or wind-producing mechanisms.*** These increase the mass-transfer rate at the boundary between the air and the water, replacing the humid air with drier air. Note that this process can often increase the water's surface area, so it can be an application of both #1 and #2, above. In particular, some convection-based designs blow air over multiple shallow pans of PW.
    Challenges: Power needed to run the fans is difficult to scale to the large impoundment areas, the fans can disperse PW droplets into the air, posing risks of air and land contamination. Finally, exposure to harsh saline environments makes the fans susceptible to corrosion.

Note that constantly fluctuating flow rates, as we frequently see in O/G operations, can greatly affect your system's evaporation performance due to 1) fluctuating pond surface area, 2) shifting salt and mineral concentrations, and 3) disruption of temperature gradients within the water. Additionally, your assumptions about residence time and rate variability will drastically affect performance of your system.

Providing PW for Fracking

This design challenge is two-fold:

1) Enhancing evaporation to manage the excess PW produced by O/G operations – often hundreds of thousands of bbl/day at highly variable rates.
2) Supplying water for intermittent fracking operations.

Teams are encouraged to explore innovative solutions that address both objectives. Innovative designs that depart from conventional solutions are welcome, provided they meet all safety and regulatory requirements.

To ensure continuous operations, your design should incorporate a plan to supply at least two days' worth of PW (1 MM bbl) when needed for fracking. This reserve, whether achieved through storage or another innovative approach, will maintain operations, even in the event of scheduled maintenance, system malfunctions, or unplanned upstream disruptions. Regardless of your team's approach, the system must accommodate new influxes of PW at any time and at varying rates.

Innovative PW supply: An ideal enhanced evaporation system would match PW production rates, eliminating the need for storage, and allowing PW to be delivered to fracking operations on a just-in-time basis. If your team pursues this path, you must also provide a contingency plan to ensure fracking water availability in the event of operational delays in your system.

Temporary storage: Alternatively, your team may implement temporary storage as a buffer for operational disruptions. Storage solutions may be entirely innovative or an adaptation of the traditional impoundment pond.

For reference, a typical pond in Carlsbad, NM is 700' x 700' x 20'. The 20' depth includes *freeboard*, a 2-3 foot buffer above the expected water level to prevent overflow from waves or flooding [6, 7]. This data is provided only to illustrate scale; your design may depart from this significantly in size, configuration, and concept.

Additional Treatments

Optional to this task is the opportunity to remove oil from the PW. This may be done at any point in your process. Oil recovery may improve evaporation efficiency (and for some evaporation technologies, its removal is essential) while providing a valuable byproduct. The sale of recovered oil could also help offset operational costs.

For the bench-scale demonstration, the oil content – represented by TrueSyn 200i, a standard component used in PW synthetic solutions (see Table A-1) – will be 200 ppm. If your team chooses to include an oil-recovery process, aim for a target oil concentration <30 ppm remaining in the PW after treatment.

Other Environmental Considerations

Ensure that your solution will not introduce environmental risks to wildlife or the surrounding environment. A common obstacle for many technologies currently being tested is the inadvertent deposition of chlorides on nearby soils due to wind drift [4]. Such incidents can lead to the shutdown of an enhanced evaporation prototype trial.

Naturally occurring radioactive material (NORM) is also a concern in evaporated solids. It should be carefully considered in managing residuals after evaporation, including wind drift, pond cleanup, and disposal.

Design Requirements

Your proposed design should answer the Problem Statement given on page 1 and provide specific details and outcomes as follows:

- Review the literature for previous enhanced evaporation efforts and develop your own innovative solution, based on the synthetic PW chemistry shown in Table A-1. Consider the potential success of either continuous or batch treatments.
- Develop a solution capable of managing PW in the Permian Basin near Carlsbad, NM at a flow rate of 500,000 bbl/day, while providing a two-day buffer of 1 MMbbl of PW for fracking operations.
- Include a Process Flow Diagram (PFD) for the selected evaporation process. The PFD must include mass and energy balances (input and output rates, including waste streams, reactants, reaction rates, etc., as applicable).
- Report your system's expected full-scale evaporation rates, extrapolated from your bench-scale prototype, and compare this with the inflow rate of 500,000 bbl/day.
- Report the residence time needed for evaporation of a given volume of PW and discuss how variations in input flow rates will affect your system's performance.
- Identify and address the fate of any waste products generated by the PW treatment technology. Particularly consider salt drift, removing and disposing of solids, etc.
- Present a Techno-Economic Analysis (a.k.a. Techno-Economic Assessment) for implementing your full-scale enhanced evaporation system based on a means of providing a 1 MMbbl buffer of PW and an incoming PW flow rate of 500,000 bbl/day.

  Include your estimate of capital costs (CAPEX) and operational costs (OPEX) for a full-scale solution and appropriate graphical representation of your cost data.

  Report all costs for a full-scale operation. Costs must include all waste-stream disposal. Ideally, your team's solution will reduce the cost of PW disposal in SWDs which is currently $0.70/bbl.
  - Capital expenses typically include, but are not limited to, equipment, pipes, pumps, etc. Do not include costs of buildings and appurtenances to the treatment process.
  - Operating expenses (OPEX) should be calculated as cost/bbl of PW evaporated annually, including, but not limited to, materials needed, including consumables (chemicals, sacrificial components, liner repair, etc.) In addition to other operating costs your team identifies, include these operating costs: staff labor rate of $70/hour; solids disposal costs ($50/ton). Energy requirements (cost/bbl and Kwh/bbl): research an industrial natural gas rate and state in $/MM BTU; use an electricity rate of $0.09/kWh.
  - Visualization tools: Use tools such as sensitivity analyses, graphs, and other visuals to illustrate how key parameters impact system performance and economics.
- Reflect on alternative designs and situations in which those designs might be more viable than your chosen design, recalling that an optimal solution depends on outside factors–the "best" design may be dependent on region and may change over time.
- Include a public involvement plan, as applicable (see Team Manual).
- To qualify for the P2 (Pollution Prevention) Award, document success in improving energy efficiency, pollution prevention, and/or waste minimization, as it applies to your project. Place this in a separate "Pollution Prevention" section of the report.
- Address any intangible benefits of the selected treatment process.
- Address safety aspects of handling the raw produced water, volatiles, and any final products. Safety issues for both the full-scale design and the bench-scale demonstration should be addressed in both the written report and the Experimental Safety Plan (ESP)

Bench Scale Demonstration

Bench-scale demonstrations will serve to illustrate the design considerations listed above. The bench-scale unit shall demonstrate a process that can be scaled up to 500,000 bbl/day throughput, with the ability to supply 1 MM bbl of PW for fracking operations. It will include a synthetic solution of produced water of chemistry given in Table A-1. The constituents of the synthetic solution are typical for a sample of produced water from the Delaware Shale play (“play” - see Appendix), with the addition of extra organics (simulated by TrueSyn 200i). If planning to recover some of this oil, consider <30ppm to be the target value for the oil remaining in the PW after treatment

Your team will demonstrate the functionality and effectiveness of your enhanced evaporation system during the bench-scale demonstrations scheduled for Tuesday, April 14, 2026. Your bench-scale prototype can run from Monday 10 am to Tuesday 2 pm, and the final results will be evaluated on Tuesday, April 14. If your team wishes to operate overnight, this must be approved in the ESP.

At the contest, each team will be provided with up to 18 liters (5-gallon container) of synthetic solution to work with during the bench-scale demonstration. Submit your team’s request for synthetic solution volumes in your 30% Project Review.

Before the contest:

- Your team will submit the 30% Project Review and build and test the bench-scale prototype using a synthetic solution that you mix for home-lab testing.
- WERC can ship TrueSyn 200 I, Fine Arizona Test Dust, and AquaGel bentonite clay after your team has registered for the contest. Email werc@nmsu.edu to request these materials.

At the contest your team will provide: A working bench-scale prototype that demonstrates your team’s full-scale enhanced evaporation system. Teams will provide all materials and supplies needed to demonstrate the system, except the synthetic solution.

At the contest WERC will provide: Basic booth setup, as described in the Team Manual, synthetic PW (See Table A-1), sample-collection bottles, and any other items requested by your team in the 30% Project Review. For example, if there are materials or chemicals that would be difficult/unsafe to transport to the contest, your team may request that WERC provide these. (See 30% Project Review, below.)

Bench-scale testing*:* Due to contest constraints, all teams at the contest have a maximum of 30 hours to demonstrate their solution. Your team will be demonstrating your solution outdoors, unless otherwise requested.

Before evaporation: Submit two 100 mL bottles of the PW solution from your bench-scale impoundment – one for measuring TDS and the remaining one for measuring oil content.

After treatment: Submit three 100 mL bottles of the PW remaining in your impoundment. Two for measuring TDS and the remaining one for measuring oil content.

Contest Analytical Testing Techniques

- **Amount of Evaporation*:** As appropriate to your team’s solution, evaluation of evaporation rates could include pre- and post- bench scale demonstration measurements of
    - Total dissolved solids.
    - Alternate means of measuring evaporation (such as water levels, volume of solids produced, salinity, density, etc., as guided by your team’s prototype).
- **Oil content:** as determined gravimetrically by hexane extractable material (HEM) and/or by total petroleum hydrocarbon analysis (TPH), as available in NMSU laboratories. Watch FAQs for updates.

* Note that water recovery and loss may be assessed indirectly through water-quality measurements. Because measuring evaporation loss can be challenging, WERC recommends using multiple methods to provide cross-checks.

30% Project Review

An important part of preparing your bench-scale demonstration will be your completion of the 30% Project Review. Due in late January, or a date requested by your team, it outlines the general design and functionality of your enhanced evaporation system and outlines the details for demonstrating and testing your system during the contest in Las Cruces. The 2026 Team Manual gives general guidelines for the 30% review. Pay particular attention to the Process Flow Diagram (PFD) that serves as a robust outline of all processes and balanced inputs, and outputs involved in your treatment system.

Include the following project-specific details:

1. Submit a complete Process Flow Diagram (PFD). The PFD serves as a robust outline of all processes in your treatment system, showing balanced inputs and outputs.
2. Submit a draft for your bench-scale demonstration setup. The draft should be a 3-D view, drawn to-scale, with dimensions labeled.
    a. Consider that the contest is held at a banquet facility, without typical lab resources (e.g., no fume hoods, ovens, etc.). WERC typically provides your team with an 8’ folding table with access to 120V power. See the Team Manual for more booth parameters.
    b. Drawings that WERC cannot easily interpret will be returned to the team for revisions – help us understand your plans so we can support you!
3. Request the volume of synthetic PW needed to run your bench-scale demonstration.
4. Testing and Verification Plan*. Outline your proposed testing protocols to verify evaporation rates, including: a clearly defined control setup for baseline comparison, how evaporation rates and other performance criteria will be collected and recorded to evaluate your system’s effectiveness, and the duration of the testing.

Experimental Safety Plan (ESP) and Required Short Course

See team manual for details. Due date is listed below.

Technical Report Requirements

Refer to the Team Manual. The written report must address in detail the items highlighted in the Problem Statement, Design Requirements, Evaluation Criteria, and the 2026 Team Manual. The written report should demonstrate your team’s insight into the full scope of the issue and include all aspects of the problem and your proposed solution. It will be evaluated for quality of writing, logic, organization, clarity, reason, and coherence. Standards for publications in technical journals apply. The report must include 3 independent audits.

Evaluation Criteria

Each year, the WERC Environmental Design Contest and its sponsors award more than $30,000 in cash prizes. Awards include task-specific prizes as well as overall contest awards. See the Team Manual for details.

Read the 2026 Team Manual, as a team, 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: https://werc.nmsu.edu/team-info/guidelines.html

Your team’s response to this task includes five components (see Rubrics in the Team Manual):

- Written report,
- Formal oral presentation,
- Bench-scale prototype demonstration,
- Poster concisely conveying the essence of your work through text and graphics,
- Flash Pitch: a separately judged 3-minute investor pitch for your project

Judges' evaluation of your entry will include consideration of the following points specific to this task.

- The volume evaporated by your prototype.
- The capacity to provide PW for fracking operations.
- Potential for real-life implementation, including effectiveness, expected reliability, and maintainability.
- The cost effectiveness of your solution as compared with disposal, and the cost/benefit of your solution compared with that for other teams.
- Thoroughness and quality of the economic analysis.
- Originality and innovation represented by the proposed technology.
- Other specific evaluation criteria that may be provided at a later date (watch the FAQs).

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

Today	Email us to reserve a spot for your team and get on the email list for this task. Registration is limited.
Weekly	Check FAQs weekly for updates: • Task-specific FAQs: 2026 Tasks/Task FAQs • General FAQs: 2026 General FAQs
November 1, 2025 - December 31, 2025	Early Bird Registration (discount applies)
December 1, 2025 – January 30, 2026	30% Project Review Due (or as arranged with WERC).
December 1, 2025 – February 16,2026	Mandatory On-demand Course: Preparing the Experimental Safety Plan. See website and Team Manual for information.
February 17, 2026	Final date to register a team w/o permission.
March 9 -13, 2026	Experimental Safety Plan (ESP) due to Juanita Miller. Include requests for chemicals, materials, etc.
April 2, 2026	Technical Report due
April 12 – 15, 2026	Contest in Las Cruces

Contacts:

ESP and Safety Officer: Juanita Miller, miljgh@nmsu.edu
All other questions and concerns: Ginger Scarbrough, werc@nmsu.edu

References

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[3] Title 19, Chapter 15, Part 17. Natural Resources and Wildlife; Oil and Gas; Pits, CLOSED-LOOP SYSTEMS, BELOW-GRADE TANKS AND SUMPS. https://www.srca.nm.gov/parts/title19/19.015.0017.html

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[6] Freeboard. Federal Emergency Management Agency (FEMA). 2020. https://www.fema.gov/about/glossary/freeboard

[7] BLM regulation: Produced Water. U.S. Dept. of the Interior, Bureau of Land Management. 2023. https://www.blm.gov/sites/default/files/docs/2023-05/BLM%20OFWMS%20March%202023_0.pdf

[8] Produced Water, Volumes I and 2, John M. Walsh, Petro Water Technology, 2019.

Appendix I – Synthetic Solution

The constituents of the synthetic solution are typical for a sample of produced water from the Delaware Shale play. In the O/G industry, a "play" refers to O/G reservoirs that have similar characteristics such as source rock, reservoir rock, and the way they trap the oil.

TABLE A-1. THE BENCH-SCALE APPARATUS SHALL TREAT WATER OF THE FOLLOWING CHEMISTRY[8]

Water phase	**Amount per liter of synthetic solution**
Tap water	750 mL
Sea Salt*	120 g
Oil phase	**Amount per liter of synthetic solution**
TrueSyn 200 I*	200 mg
Solid phase	**Amount per liter of synthetic solution**
Fine Arizona Test Dust (Medium Grade)**	50 mg
Sodium Bentonite Drilling Clay (AquaGel by Baroid Industrial Drilling)**	50 mg

**At the contest, WERC will source sea salt from a local store (Sprouts store brand). It dissolves fairly easily.*
*** Contact WERC–we will gladly ship these items to you. They ordinarily come in industrial quantities.*

Sample Preparation

To prepare samples for preliminary testing at your campus, follow these steps to make 1 liter of synthetic produced water using the chemistry from Table A-1, above.

1. Use a wide-mouth, semi-transparent polyethylene or polypropylene container.
2. Add salt to the water phase.
3. Add the solid-phase materials (dust and clay) to the water phase.
4. Add the oil phase to the water + solid phase and mix.
5. Top off with DI water to make 1.0 L and mix.
6. Let sit overnight, then blend with a high-speed drill or homogenizer*.
7. Just before use, use a homogenizer/mixer to generate small droplets of the oil phase.

*Letting the solution sit overnight allows the salt and clay/dust to dissolve prior to mixing. The next day, blend for 5 minutes in a 5-gallon bucket using a high-speed drill or homogenizer fitted with a paint-mixing paddle. A kitchen blender is not recommended because a considerable amount of oil may be lost due to adhesion to the blender's inner surfaces.

We recommend mixing the solution in a 5-gallon bucket and retrieving it for use directly from that container. Measuring, mixing, and pouring from a single container minimizes oil loss due to adhesion on the walls of multiple containers. Since the organic oil has an affinity for plastics, its exposure to plastic surfaces should be minimized, though using a plastic bucket may be unavoidable. Limiting contact with additional plastic containers, utensils, etc., helps reduce oil loss due to adsorption.

Mixing the Synthetic Solution: Maintaining Emulsion Integrity
It is very important that the oil be mixed quite vigorously before treatment to ensure that the oil phase is homogenously distributed through the mixture. Out in the field, the oil in PW is present as finely dispersed micron-size droplets that form a stable emulsion. They do not readily separate from the water even after several days in the battery tanks.

Sea Salt: Dissolving Strategies
In previous WERC PW design challenges, some teams have had difficulty dissolving their sea salt. Here are a few tips that may help. Since your team will be using large amounts of salt during bench-scale testing, WERC recommends off-the-shelf sea salt available in grocery stores, rather than costly laboratory-grade options. We have had success with Sprouts fine sea salt. For testing in your home lab, you may need to try different brands, as teams have reported that some dissolve more readily than others.

Teams have had more success using finer-grained salt (crush it, if yours is coarse), adding it gradually to hot water, and mixing with each addition. Alternatively, WERC's laboratory technicians use room-temperature water and, after completing Step 5 above, let the solution sit overnight prior to the final 5-minute mixing.

Appendix II–Synthetic Solution FAQs

PW goes through several processing steps before reaching storage areas (such as impoundments). Production streams from oil-producing shale wells first flow into battery tanks or hydrocyclones, where the oil and water are separated. Battery tanks function as gravity-based separators. The recovered oil is collected, while the remaining water – typically containing 70 to 150 ppm of oil – is sent for disposal in UIC Class II injection wells (SWDs) or impoundment ponds.

TrueSyn 200i is used in the synthetic solution as a surrogate for actual oilfield oil. The concentration used in this design challenge (200 ppm) is just above the typical range for oil recovered during separation. WERC selected this higher oil-phase concentration to enable teams to clearly demonstrate the impact of organics in their systems.

Teams have asked about the small amounts of solids (AZ test dust and sodium bentonite drilling clay) included the synthetic solution. During shale fracking, immense quantities of ultra-fine solid particles are generated and carried to the surface along with the PW. While larger particles easily settle out due to gravity, the finer particles remain suspended in the water for extended periods. The solids listed in Table A-1 are representative of the volumes and sizes of particles that remain suspended in PW during storage.