Task 5 Overview:
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

The full task problem statement will be published in early August, when our SMEs finalize the document.

Background

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. Current enhanced evaporation efforts intended to accelerate natural evaporation have yet to demonstrate feasibility, effectiveness, or environmental sustainability. Your team is tasked with exploring innovative approaches to significantly increase PW evaporation rates using technologies that are both environmentally responsible and cost-effective.

Problem Statement

Your team is invited to research, evaluate, and design an 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 implement either 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 rate of 500,000 bbl/day (21 million gallons/day). *Our SMEs are currently discussing the parameters for storage, but are considering that teams include a 2-day storage capacity to allow for operational shutdowns or disruptions.*

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 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, was 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 ability to monitor well conditions in the SWDs and a heightened awareness of the need to track of 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 it for 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 the industry sustainability. However, demand for fracturing water does not keep pace with the 500,000+ bbl/day of PW generated in the Permian Basin.

PW Storage

Because fracking operations must be carefully scheduled, recycled PW is often stored until needed. To manage large fluctuations in demand, PW is typically held in large open-air impoundments—often exceeding capacities of one million barrels—commonly called ponds, pits, or lagoons. These temporary storage sites help manage operational swings in production, but the system is far from straightforward. In most cases, the volume of water entering these lagoons greatly exceeds what is reused for fracking, and hundreds of thousands of bbl of PW are added to the ponds every day.

These open-air ponds have served to equalize flow rates, and flow rates vary even in dedicated pipelines. This flow rate variability will drastically affect evaporation performance. Note that storage considerations must include assumptions about residence time.

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 timeframe 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].

Daily liner monitoring and the potential need for emergency pumping, liner repair/replacement, and soil remediation are costly and can result in facility shut downs.

Another challenge of open-air impoundment pits is that large bodies of water are attractive to wildlife. When these ponds contain PW, they pose environmental and safety risks to birds and other animals. Although operators continue to test various deterrents, none have proven fully effective. Therefore, your team's alternative solutions to impoundment lagoons for increasing backup storage could prove beneficial to PW operators.

Beneficial Reuse

Looking ahead, there is hope that these 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 largest 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 are insufficient for managing 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 address the challenge of managing large volumes of PW. Enhanced evaporation refers to a collection of technologies designed to accelerate the natural rate of water evaporation. By increasing evaporation efficiency, these technologies reduce the volume of PW that must be stored or disposed of.

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 thus be cost-effective.

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 also be considered. (See Spill Rule 19.15.29 [4] and [5])

Note that some enhanced evaporation systems allow for (and some require) pre-treatment to remove residual oil prior to evaporating the water. In such cases, recovering additional oil can help offset treatment costs, offering both environmental and economic benefits.

Temporary Water Storage

The ideal enhanced evaporation system would keep up with PW production without needing any storage capacity. However, this is extremely unlikely, and in the real-world, operations require contingency planning. Temporary storage becomes helpful during scheduled maintenance, system malfunctions, or unplanned upstream disruptions. Therefore, to ensure continuous and safe operations, your design should incorporate backup storage with capacity for at least two days' worth of PW.

As discussed previously, impoundment ponds present some potential environmental and operational challenges, including liner failures, wildlife hazards, and costly remediation. In light of these concerns, your team is encouraged to propose innovative alternatives to traditional open-air ponds for temporary PW storage. However, after evaluating alternatives, you may determine that open-air pits remain the most suitable solution. If so, you may incorporate impoundment ponds into your enhanced evaporation design.

Enhanced Evaporation Research and Trials

The basic principles of enhanced evaporation are

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

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 water surface area (#1), others focus on increasing energy input (#2), and some combine both strategies. The complex composition of PW – salts, hydrocarbons, and metals – can complicate the evaporation process. For example, evaporation of brine slows significantly as salinity increases, and it effectively stops when the solution reaches the saline saturation point. Oil and other contaminants can also inhibit evaporation. Their presence often requires pre-treatment prior to evaporation. This adds complexity and cost, but 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 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 and 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.

Incorporating Innovative Storage Solutions

Various enhanced evaporation systems have been proposed, but none have proven viable for the large-scale implementation required in million-bbl ponds. Although your system may not use open-air ponds for storage, to add perspective on the scale of storage, it is useful to reference the dimensions and considerations of a full-scale pond. In Carlsbad, NM, and impoundment pit is typically 700' wide x 700' long x 20' deep. The depth includes a safety margin, termed freeboard, that protects against overflow caused by wave splashing or flooding [6]. Freeboard requirements vary by regional regulations, but generally, the pit height is 2-3 feet above the expected water level [7].

Given the challenges of PW storage and enhanced evaporation, teams are encouraged to explore non-traditional storage solutions that support both water storage and evaporation. Innovative designs that depart from conventional pond configurations are welcome, provided they meet all safety and regulatory standards and that residence times are accounted for in the mass balance.

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 while providing a valuable byproduct, and its sale could help offset operational costs of your processes.

For the bench-scale demonstration, the oil content – represented by TrueSyn 200i, a standard component used in PW synthetic solutions [8] (see Table A-1) – will be 200 ppm. If your team chooses to include an oil recovery process, aim for a target oil concentration <30ppm 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, metals, and other substances on nearby soils due to wind drift [4]. Such incidents can lead to the immediate 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 Considerations

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 based on the capacity to store one-million-bbl of PW in the Permian Basin near Carlsbad, NM with 500,000 bbl/day PW input flow rate. Innovative means of short-term PW storage are encouraged that may reduce the size of the typical impoundment pit or eliminate it altogether.
- 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 expected full-scale evaporation rates, scaled up from your bench-scale prototype results, and evaluate how this will scale with inflow rates of 500,000 bbl/day.
- Report the residence time needed for evaporation of a given volume of PW and reflect upon how input flow rate variabilities will affect performance of your system.
- 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 million bbl buffer of PW that flows into the storage area at a rate of 500,000 bbl/day PW.

  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 that 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: Sensitivity analyses, etc.
- 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 the capacity to store 1 million bbl of PW, in case of operational shutdowns. 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

At the contest, bench-scale demonstrations can run from Monday at 10 am to Tuesday at 2 pm. 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 in your 30% Project Review.

Before treatment: Submit one 100 mL bottle of the PW solution in your bench-scale impoundment.

After treatment: Submit three 100 mL bottles of the PW remaining in your impoundment. Two for measuring TDS and the remaining two for measuring oil content. Sample-collection vials at the contest will be provided by WERC.

<u>Contest Analytical Testing Techniques</u>

- **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.
  - For cases in which TDS is not appropriate, other means of measuring evaporation will be arranged with the team (such as volume of fluid reduces, 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 at NMSU's laboratories.

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 sets forth the details for demonstrating and testing your system during the contest in Las Cruces. Include the following project-specific details:

1. A Process Flow Diagram (PFD) illustrating proposed mass and energy balances (input and output rates, including waste streams, reactants, reaction rates, etc., as applicable), residence times, etc.
2. The basic needs for your bench-scale demonstration setup, including the need for an indoor or outdoor bench-scale demonstration area (such as exposure to sunlight), electrical access, wind shielding, water sources, requested demonstration duration, etc.
3. Draft plans to include a 3-D view, drawn to-scale, with dimensions labeled. 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 bench-scale parameters and options for making special requests.
4. Testing and Verification Plan. Outline your proposed testing protocols to verify evaporation rates including a clearly defined control setup for baseline comparison and how you plan to collect and record evaporation rates and other performance criteria to evaluate your system's effectiveness.

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.

Technical Report Requirements

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. The report will be evaluated for quality of writing, logic, organization, clarity, reason, and coherence. Standards for publications in technical journals apply.

In addition to the listed requirements, your report must address in detail the items highlighted in the Problem Statement, Design Considerations, Evaluation Criteria, and the 2026 Team Manual.

Evaluation Criteria

Each team is advised to read the 2026 Team Manual for a comprehensive understanding of the contest evaluation criteria. As described in this manual, your response to this Task consists of four parts and will be scored based on the rubrics in the Team Manual:

- a written report,
- a formal oral presentation,
- a demonstration of your technology using a bench-scale representation, and
- a poster that conveys the essence of your work in a concise fashion using a mix of text and graphics.

For a copy of the Team Manual, Public Involvement Plan, and other important resources, visit the WERC website: https://iee.nmsu.edu/outreach/events/international-environmental-design-contest/guidelines/

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

- The volume evaporated by your prototype.
- Potential for real-life implementation, including effectiveness, cost, expected reliability, and maintainability. Judges will weigh the cost/benefit of your solution against those for other teams.
- Ideally, the cost of your solution should be economically attractive, as compared with disposal.
- 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).

Awards

Each year, the WERC Environmental Design Contest and its sponsors award more than $30,000 in cash prizes. See the Team Manual for more information.

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

Early Fall	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

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

[4] Title 19, Chapter 15, Part 29. Natural Resources and Wildlife; Oil and Gas; Releases. New Mexico Public Records and Archives. 2018. https://www.srca.nm.gov/parts/title19/19.015.0029.html

[5] Procedures for Implementation of the Spill Rule (19.15.29 NMAC). September 6, 2019. Grisham, Propst, and Leahy. OCDInternalPolicy-SpillRuleClarifications.pdf

[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.*
***Sourcing Option: RB Products may be able to ship small amounts to you.* charge for shipping only. Contact micah@rbproductsinc.com
****Sourcing Option: Powder Technologies Inc. offers 4 kg for $80. Contact: levi@powdertechnologyinc.com*
***** 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 2, below.

1. Use a wide-mouth, semi-transparent polyethylene or polypropylene container.
2. Mix [salt into] the water phase (salt + water).
3. Add dust and clay solid phase (dust and clay) to the water phase.
4. Add the oil phase to the water phase and mix.
5. Top off with DI water to make 1.0 L.
6. Mix thoroughly
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.

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.

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 oil has an affinity for plastics, its exposure to plastic surfaces should be minimized, though using a plastic bucket is unavoidable. Limiting contact with additional plastic containers, utensils, etc., helps reduce oil loss due to adsorption.

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 (if yours is coarse, crush it), adding it gradually to hot water, and mixing with each addition. Alternatively, WERC's laboratory technicians use room-temperature water and, after completing Step 6 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 (200ppm) 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. These solids represent what remains in PW by the time it reaches a storage area, such as an impoundment. They are introduced into PW during shale fracking, when 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.