2021 Summary Report of Operational, Programmatic, and Technical Accomplishments

January 2022

New Mexico Produced Water Research Consortium
New Mexico State University
Las Cruces, New Mexico

1. Consortium Overview

In passing the 2019 Produced Water Act, the New Mexico legislature established a framework for the ownership, management, and reuse of produced water inside and outside of the oil and gas sector moving forward. Through this act, statutory control, and regulatory authority for the reuse of produced water outside the oil and gas industry was designated to the NM Environment Department (NMED), while reuse of produced water within the oil and gas sector remains under the jurisdiction of the Oil Conservation Division (OCD) of the NM Energy Minerals and Natural Resources Department.

Through the 2019 Produced Water Act, New Mexico is acknowledging the potential for treated produced water reuse to enhance freshwater sustainability and the use of treated produced water to support and spur additional economic development opportunities, while ensuring protection of the environment and public health and safety. To help support that goal, NMED entered into a Memorandum of Understanding with New Mexico State University (NMSU) in September 2019 to create the **New Mexico Produced Water Research Consortium** (Consortium).

The role of the Consortium is to establish and coordinate a focused research and development program in collaboration with state and federal environmental and natural resource agencies, academia, industry, and non-governmental organizations (NGOs) to:

1) fill scientific and technical knowledge gaps necessary to establish regulations and policies for fit-for-purpose treatment and reuse of produced water; and
2) accelerate technology and process research, development, and implementation for environmentally sound, safe, and cost-effective reuse of produced water for industrial, construction, agricultural, rangeland, livestock, municipal, aquifer storage, surface water, and/or other applications.

The goal of the Consortium is to help facilitate collaboration among industry, the public, NGOs, and technology vendors, to support the reuse of oil and gas produced water outside the oil and gas sector for uses that are technically, environmentally, and economically sound and that are safe to the public and socially responsible.

2. Consortium 2021 Operational Accomplishments

Operation Management Summary

To better coordinate Consortium Operations, the consortium hired an Operations manager to oversee improvement of Consortium information delivery to members and the public. The Operations manager was assigned responsibility for web portal updates, to facilitate the transition of technical documents onto the public side of our web portal, maintain document control schedules, and enable better use of the web portal as a public information outlet, and to provide timely information on Consortium announcements, press releases, and sign-ups for webinars, podcasts, etc. This effort was in support of both program and research management and oversight by Consortium management.

Process Management Summary

The Consortium improved our operations and management strategies in 2021 through the following activities:

- Reworking of the Consortium Web site to enhance public and Consortium membership access to all Consortium data and information;
- Publishing our first technical Request for Proposals;
- Updating the Management and Operations Plan for 2021;
- Based on member feedback, improving the 2021 Membership Agreement;
- Based on 2020 technical efforts, modifying the 2021 Program Plan and Schedule;
- Based on NMED review, updating the Consortium draft Research Plan; and
- Finalizing and implementing a Consortium Education and Outreach Program Plan.

All of the documents noted above were provided to the TSC and the GAB for review and approval. All the organizational and operational management documents have been developed to provide a consistent and technically sound operational process and management approach that support the following objectives:

- Conduct fair and efficient Consortium operations;
- Establish fair and objective selection of technologies for testing and evaluation;
- Conduct fair and thorough technology evaluations of cost, performance, and public health and safety risks;
- Encourage stakeholder involvement; and
- Provide Consortium information and technical data and reports to the public in a timely, consistent, and easily understood manner.

After review and approval by the Consortium TSC and GAB, all completed documents were placed on the Consortium website for public access.

3. General 2021 Program Accomplishments

Summary of Consortium Participation

The Consortium was intentionally organized with an interest in open membership of a broad spectrum of stakeholders including industry, associations, academia, municipalities, and NGOs at a nominal annual cost. This was to give any interested group the opportunity to provide input and follow progress on the research and development program and to review individual project results throughout the year.

As shown in the table below, the Consortium was able to continue to expand participation in 2021. Currently the Consortium includes almost 200 organizational representatives participating in the Consortium from over 60 different groups, companies, organizations, and government agencies. By the end of 2021, over 275 different individuals were on the Consortium list serve.

Consortium Participation by Year

Year	Participants	Total Interested Parties
2019	100	120
2020	130	170
2021	190	275

Consortium Funding, Research, and Cooperative Agreements

A metric of Consortium success is the number and quality of sponsorships, partnerships, and cooperative agreements with companies, organizations and associations, and state and federal agencies. Notable new efforts and a summary of ongoing efforts with existing partners in 2021 are presented below.

Consortium Sponsorships. In 2021, the Consortium received a major 3-yr funding sponsorship from Chevron to go along with previous 3-year sponsorships in 2019 and 2020 from NGL and Exxon Mobile, respectively.

Consortium Research Partnerships. In 2020, the Consortium entered into a major partnership with the US EPA on their Water Reuse Action Plan (WRAP). As part of that partnership, the Consortium agreed to lead work with the Groundwater Protection Council (GWPC) and the WateReuse Association on various aspects of the potential reuse of treated produced water. In 2021, the Consortium continues to work directly with the EPA, GWPC, and WateReuse on produced water goals, technical activities, research, and coordination of presentations at national water reuse workshops.

In 2021,the Consortium also entered into several major research partnerships with the following agencies and groups:

- EPA Region 6, Region 8, and EPA's Office of Research and Development (ORD) on a Regional Applied Research Effort (RARE) for produced water. As part of this partnership, the Consortium agreed to provide raw and treated produced water samples from across New Mexico to the US EPA to conduct human cell-line risk evaluations. EPA will provide evaluation results to the Consortium to use in establishing risk and toxicology testing methodologies for produced water treatment and reuse.

  Additionally, through this RARE effort, EPA has provided contacts with ORD on new Whole Effluent Toxicity (WET) testing approaches being developed by EPA that will be utilized by the Consortium to establish state-of-the science WET testing capabilities.

- The US Department of Energy (DOE) and Sandia National Laboratories (Sandia) to support research and development on the socio-economic and environmental cost/benefit of the treatment and reuse of produced water for various fit-for-purpose applications in the Permian Basin in New Mexico. The DOE and Sandia provided funding for development of a system dynamics model of produced water reuse. The Consortium provided technical information on produced water quality and quantity, treatment costs, potential applications to consider, and coordinated model design with New Mexico stakeholders.

- The GWPC to establish a framework using their WaterStar data format for the design and implementation of a produced water data portal for New Mexico. The Consortium worked with several state agencies and research groups to identify all the available data on both quantity and quality of produced water generated in New Mexico, and GWPC funded the manpower to put the data into a graphical user interface.

- The Bureau of Reclamation's Brackish Groundwater National Desalination Research Facility (BGNDRF) in Alamogordo, NM to facilitate bench -scale testing of produced water treatment technologies. The Consortium funded development of a produced water holding and testing area at BGNDRF and a cooperative testing and evaluation support effort with BGNDRF.

- Agreement in December 2021 with several other states with produced water research efforts to establish a coordinating council around funding for multi-state research efforts. The states participating include Colorado, Texas, Arizona, Oklahoma, and Wyoming. The NM Consortium will help coordinate group meetings throughout 2022.

Consortium Cooperative Agreements. In 2021, the Consortium established cooperative agreements for produced water pilot testing support with a number of companies including Kanalis Resources, NGL, Solaris, Black Buck, Crystal Clear Water, Hilcorp, Occidental Petroleum, and Cimarex. These agreements included coordinating and/or providing raw or treated produced water for testing, providing sites for testing, or providing other resources during technology testing.

4. Consortium 2021 Research Program Priorities and Schedule

The Consortium's 2021 research and development efforts were established to provide a follow-on and expansion of the 2020 technical accomplishments and to help accelerate program progress. This included:

- The establishment of several task committees within the Working Group structure to allow more detailed evaluations of the technical research and development efforts for the Consortium;
- Create technical reports, papers, and models to summarize the efforts and results of research, analysis, and demonstration efforts during 2021; and
- Based on a review of the 2019 NMED produced water public engagement meeting comments, the 2018 NM Desal Association report on treated produced water reuse, and the 2020 EPA report on produced water issues, establish a robust public education and outreach program across New Mexico and the region.

The following tasks were identified to pursue for 2021, including:

1. Develop and Submit a Research and Development Request for Proposals (RFP)

- Coordinate with NM WRRI to create an RFP format and evaluation approach.
- Phase 1 - Advertise RFP in early 2021 to include research options for produced water Treatment/Cost Benefit Analysis/Scenario Planning/Data Portal and GIS Applications.
- Establish Consortium RFP review committee and use committee to rank and select projects.
- Phase 2 - Begin testing with approved test plans and Independent Consortium Project Evaluation Teams, 4-6 projects starting in mid 2021.
- Phase 3 – Consortium to establish a cost and performance report template and Consortium Project Evaluation Teams to prepare draft evaluation reports as testing is completed and data is collected.

2. Produced Water Interim Constituent Analysis Requirements

- Identify Produced Water Analysis requirements for treatment testing projects for 2021.
- Include consideration of additional NORM, semi-volatile organic compounds, TPH, BTEX, etc. analysis to support pre-treatment and treatment analysis requirements.
- Include analysis efforts to address potential unknown chemicals in raw and treated produced water, with a focus on treated produced water analysis.

- Coordinate with NMED so efforts support future regulatory and policy guidance on treated produced water analysis and reuse.

3. Produced Water Data Portal Development and Roll-Out

- Integrate NM Petroleum Recovery Research Center (PRRC) at NM Tech, NM OCD, NMSU, and USDA produced water quantity and quality data into a GWPC WaterStar format to create a user friendly and GIS-based produced water data portal for Tier 1 and 2 (public access) information as proposed by the 2020 Task Committee.
- Collect produced water data from producers and integrate into the Data Portal – establish Non-Disclosure Agreement (NDA) and Need To Know (NTK) process approach for higher tier data.
- Provide portal operational capabilities for public and other users to assess in mid- 2021
- Pursue opportunities to fund Tier 2-4 development efforts in 2022, with Tier 4 data retrieval being the most limited, allowing access only to regulatory entities who will not compromise Confidential Business Interest (CBI) protection agreements.

4. Assess Risk and Toxicology Evaluation Tools and Identify Optimum Approach

- Phase 1 – Identify quantitative risk assessment and toxicology testing approaches compatible with and appropriate for treated produced water potentially toxic constituents.
- Establish ecological and human impact testing and analysis tools and facilities needed for New Mexico to address WET testing, Genomic/cellular impacts, and fate and transport modeling and analysis.
- Phase 2 **–** Take treated produced water from 2021 treatment studies and beta-test approaches in laboratory and field-scale testing (such as greenhouses) to assess and measure ecological and human health and safety toxicity and risk potential for various final produced water treatment levels.
- Evaluate ability to use this approach to quantify the relative-risk of treated produced water reuse to reuse of treated municipal and industrial waste waters for fit-for-purpose applications.

5. Socio-Economic, Environment, Ecological Cost-Benefit Analysis (CBA)

- Phase 1 - Identify CBA approach compatible with Environment Society Governance (ESG) approaches to provide quantitative modeling and analysis for weighing different benefits and costs of treated produced water reuse including economic development opportunities.
- Select or establish a modeling and analysis team to conduct CBA evaluation of fit-for-purpose reuse of treated produced water.
- Phase 2 -Establish evaluation review team to analyze test problem based on information from testing projects.
- Identify pros/cons and changes or improvements needed based on user input.

6. Scenario Analysis Economic Development Planning

- Phase 1 - With input from federal, state, county, and community agencies evaluate scenario analysis needs for NM.
- Phase 2 - based on industry and regulatory agency input, conduct a scenario analysis to assess the likelihood of treated produced water availability for reuse and industrial/other development over the next 25-30 years.

7. Produced Water Education and Public Outreach

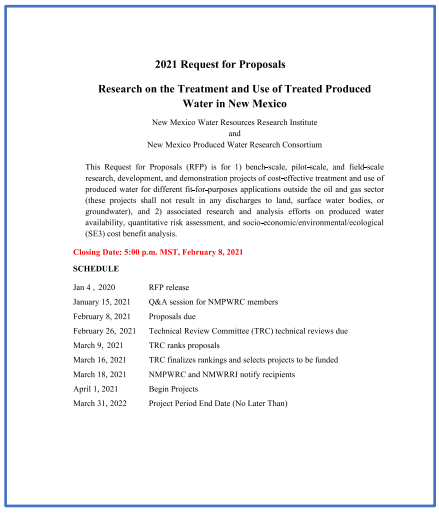
- Phase 1 – Establish a public education and outreach program to provide the public with information on treated produced water reuse benefits and challenges.
- Utilize the Consortium website and data portal to allow public access to appropriate data and information on environmental issues or challenges of treated produced water reuse for various applications.
- Conduct public meetings in SE and NW New Mexico.

5. Consortium 2021 Research and Technical Accomplishments

The following research and technical accomplishments are highlighted relative to each of the seven major research priorities identified above in Section 4 for 2021.

1. Development and Implementation of a Research RFP

This effort was coordinated by Consortium management and was done in cooperation with the NM Water Resources Research Institute (WRRI) at NMSU. WRRI has over 50 years of experience in developing and funding water treatment related research that has been approved by both federal and state water management agencies, and for this reason, the Consortium entered into a cooperative agreement in 2020 with WRRI to support the solicitation, selection, and management of research, testing, and evaluation of innovative produced water treatment technologies.



2021 Request for Proposals

Research on the Treatment and Use of Treated Produced Water in New Mexico

New Mexico Water Resources Research Institute
and
New Mexico Produced Water Research Consortium

This Request for Proposals (RFP) is for 1) bench-scale, pilot-scale, and field-scale research, development, and demonstration projects of cost-effective treatment and use of produced water for different fit-for-purposes applications outside the oil and gas sector (these projects shall not result in any discharges to land, surface water bodies, or groundwater), and 2) associated research and analysis efforts on produced water availability, quantitative risk assessment, and socio-economic/environmental/ecological (SE3) cost benefit analysis.

Closing Date: 5:00 p.m. MST, February 8, 2021

SCHEDULE

Jan 4 , 2020	RFP release
January 15, 2021	Q&A session for NMPWRC members
February 8, 2021	Proposals due
February 26, 2021	Technical Review Committee (TRC) technical reviews due
March 9, 2021	TRC ranks proposals
March 16, 2021	TRC finalizes rankings and selects projects to be funded
March 18, 2021	NMPWRC and NMWRRI notify recipients
April 1, 2021	Begin Projects
March 31, 2022	Project Period End Date (No Later Than)

The cooperative approach was formalized in the Consortium's **Research Selection and Management Plan** and was used to develop the Consortium's **2021 Request for Proposals (RFP) Document** that was released on January 4, 2021. The RFP included calls for four categories of proposals covering treatment, pre-treatment, sampling, and analytical analysis, produced water data mining efforts, and socio-economic analysis. The Consortium received 27 proposals covering all these categories for both Consortium funded and self-funded projects. The Consortium research selection and management process enables WRRI to work with the Consortium to conduct unbiased technical evaluation of the proposals.

The Consortium used technical volunteers from across the Consortium membership to establish a diverse review committee of 18 members. Each proposal was evaluated by at least 6 members using an evaluation matrix developed by WRRI and Consortium management. The test scores were combined independently by WRRI to rank proposals into three categories, high priority and scores, intermediate priority and scores, below average or non-compliant proposals.

In a final meeting, each proposal was individually discussed by the review team, starting at the bottom, and working up. The lower and below average proposals were quickly dropped, and most discussion was around the medium to high-ranked proposals. In this case, the whole team was looking for fatal flaws that might have been missed, or additional insight into the proposer if available. This led to final selection on March 10, 2021 of the technologies, vendors, and project funding requirements identified in the table below. The selections spanned most of the RFP categories and included technologies or projects that were either self-funded or were asking for Consortium matching funds.

Proposal Team	Technology Description	Location Identified	Funding Amount
Eureka Resources	PW thermal treatment and mineral recovery	Ship PW to PA for full-scale treatment	Consortium - $0 Vendor - $146K
zNano Membranes	Polymeric-based ceramic membrane for pretreatment of PW	Brackish GW National Desalination Research Facility (BGNDRF)	Consortium - $15K Vendor - $75K
Crystal Clearwater Resources	PW low-temperature distillation	Permian Basin midstream (Solaris)	Consortium - $70K Vendor - $136K
Katz Water Technologies	PW thermal treatment	BGNDRF	Consortium - $58K Vendor - $59K
Marah Water Services	PW Electro-coagulation/cavitation	Permian Basin Midstream or BGNDRF	Consortium - $0 Vendor Self-funded
Hydrozonix	Ozone PW pre-treatment	Permian Basin operator	Consortium - $15K Vendor self-funded
Geosyntec	ESG Stakeholder Analysis Tool	Permian Basin stakeholders	Consortium - $57K
NMSU College of Engineering	Risk, Toxicology, Chemical Testing and Analysis Lab Updates	NMSU	Consortium - $75K
NMSU WRRI	System Dynamics modeling of treated produced water impact on State/regional Water Plans	NMSU/WRRI	Consortium - $65K State of NM - $59K

Additionally, three self-funded projects submitted official proposals to be evaluated by the Consortium. These are highlighted in the table below. Not highlighted are several projects that started discussions with the Consortium in 2021 for projects that could start in 2022.

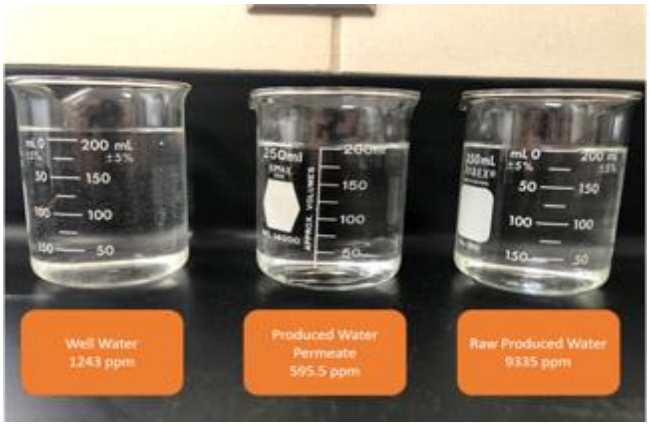
Proposal Team	Technology Description	Location Identified
Kanalis Resources	Bench-scale study of reverse osmosis treatment of 10,000 ppm TDS produced water from the San Juan Basin for land and ag applications	Bench scale study at BGNDRF, with green house studies at NMSU
Hilcorp	Membrane distillation of 40,000 ppm TDS produced water from the San Juan Basin for land applications	Pilot-scale study on San Juan Basin for small remote sites
Bechtel	Pilot-scale thermal distillation technology of 100,000 ppm TDS produced water from the Permian Basin	Small pilot-scale study in Houston

The Consortium worked with these companies to coordinate testing and development. A few of the projects were completed in 2021 and others are underway. The projects have been authorized to be completed by March 2022. Final reports of completed projects are expected to be completed by March 2022.

Since the testing and evaluation of produced water treatment technologies is an important aspect of the Consortium, some summary results of the completed projects are presented below that should provide some insight on the current technical status of produced water treatment and general trends in the final quality of treated produced water. Comprehensive final technical reports and results from the pilot projects will be made publicly available when completed and approved by the Consortium. They will be made available on the Consortium website.

Kanalis Resources Summary Results. Kanalis Resources started initial bench-scale testing at BGNDRF in April 2021 using an existing reverse osmosis (RO) system on site. The Kanalis raw produced water is very high-quality with very little organics and a salinity of about 10,000 ppm TDS. The produced water is from the Entrada sandstone formation and is located about a mile from the Ojo Encino Chapter House in the checkerboard area of the Navajo Reservation, and about 30 miles southwest of Cuba, NM.

With a 10-micron filter for pre-treatment, the raw produced water was treated with a standard RO system in a single pass configuration as shown on the right. The treated water quality shown below, was approximately 300-600 ppm TDS, with almost all constituents meeting drinking water standards. The permeate yield was approximately 40% and could feasibly be increased to approximately 70% with a common dual-pass RO system.



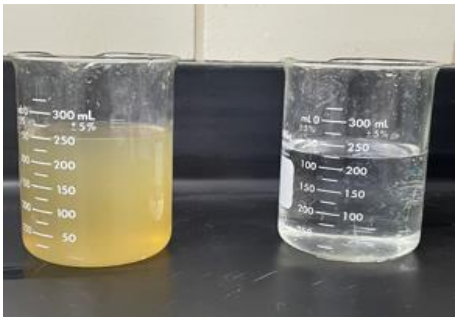
The green house studies of the use of the treated produced water for growing both range grasses and alfalfa as potential forge crops, showed improved growth and yields as water salinity increased from 300 ppm TDS to 6,000 ppm TDS brackish water.

The data suggest that treatment of produced water or blending of treated produced water could provide a water quality that could significantly improve rangeland remediation and restoration opportunities. The final cost effectiveness of the approach is currently being evaluated, and a final technical report is expected by March 2022.

Z-Nano Summary Results. Z-nano started initial bench-scale pre-treatment testing of produced water using a low-cost ceramic-coated polymer ultrafiltration membrane. The testing was conducted at BGNDRF from early June through late July 2021. The raw produced water was provided by Consortium member and sponsor, NGL, from the Permian Basin with a salinity of about 100,000 ppm TDS and about 100-200 ppm organics. The goal of the testing was to assess the performance of the ceramic-coated membranes of different spacing thicknesses to meet the Produced Water Society suggested produced water pre-treatment standards of pH of 6-8, NTU of <25, and organics of <30 ppm at flow rates of 1.5 to 3 gal/min per 40-inch-long membrane.

The goal of the proposed pre-treatment standard is to provide a consistent treated produced water quality such that pretreated produced waters can be co-mingled and mixed without concerns for scaling, precipitation, etc. Z-nano was attempting to meet that goal without any chemical pretreatment with a novel ultrafiltration membrane that is durable like a ceramic membrane but low cost like a polymer membrane. This could be a major operational and cost benefit to producers and midstream companies and facilitate produced water recycling and reuse. The Z-nano membrane was tested in a CrossTek bench-scale skid as shown in the picture on the right.

The Z-nano membranes have been used successfully in offshore produced water treatment applications where the oil content is significantly higher than in inland applications, where oil and water separators are common. We were hoping to see very good results with the system for applications in inland areas with lower oil content. Overall, the test results showed very encouraging results with high TSS and organics removed. The treated and waste water were recombined at the end of the testing and disposed in a produced water injection and disposal facility in the Permian Basin.



<u>Crystal Clearwater Resources Summary Results</u>. Crystal Clearwater Resources started initial pilot-scale testing of the thermal treatment of high TDS produced water (130,00 - 170,000 ppm) at a Cimarex site south of Carlsbad on the NM/TX state line. The produced water for this pilot project and came via pipeline from about 1/4 mile away. The process is a novel cascading thermal evaporation technology that minimizes scaling and provides a high- quality distillate. During operation, the pilot operations were conducted in a secondary containment berm or about 80 feet by 80 feet. The pilot plant shown on the right treated approximately 500 bbls per day of produced water with a clean water recovery of about 40%.

The recovery was a little lower than expected because the waste heat provided by the compressor station like the one shown on the right provided about only about 80% of the 5 mmbtu/hr required for optimum performance. The distillate quality was approximately 300-500 ppm TDS with some VOC and ammonia carryover that might need to be removed in post-treatment for any future potential final applications. The distillate and concentrate were recombined and returned to the source site via pipeline and discharged into a saltwater disposal well.

The testing was conducted in cooperation with Consortium partner Solaris, and Cimarex, which is not a Consortium partner. Both organizations provided significant contributions to make this project successful. Cimarex testing started in early November 2021 and operations with Solaris and the Consortium started in early December 2021. Overall, the system operated for

approximately a month with minimal operational challenges. No significant pre-treatment was used.

To date, we are seeing from the technologies tested to date that the maturity of the technologies selected by the Technical Review Committee are relatively high and to date have generally performed well. The high quality of the treated produced waters obtained suggest that technologies generally are available to treat produced water to levels approximately equivalent to surface water and ground water resources in the Southwestern U.S.

2. Produced Water Interim Constituent Analysis Requirements

After a significant review of produced water quality in the western US in 2020, NMSU undertook a more detailed analysis of produced water from the Permian Basin under current operational conditions in 2021. The results of that study include three general findings:

- Based on analysis of over 300 potential constituents, produced waters in NM contain approximately 100 major constituents, most are either 1) minerals from chemical leaching from geologic formations (salts, metals, minerals), 2) organics such as oils or petroleum related compounds from interaction with the oil in the formations, and 3) turbidity and other compounds from drilling and fracking;
- Produced water from unconventional production is generally higher in TDS, NORM, and synthetic organic compounds, than conventional produced water;
- Produced waters are similar in constituent quantities to other waste waters such as municipal or agricultural waste water which often have approximately 60-70 constituents.

The information collected has been reviewed by Consortium technical participants and was submitted for technical publication. When finally published the report will be made available on the Consortium web site.

Based on the data collected and the analysis, the Consortium Task Committee proposed a list of constituents to assess and measure to support tiered a range of needs including preliminary assessment, treatment process control, or regulatory compliance. The list included consideration of sampling and analysis costs to meet these tiers of analysis. The results were provided to NMED for consideration for future regulatory and policy guidance on treated produced water analysis requirements for treatment and reuse.

The Task Committee also considered identification of potential unknown chemicals in raw and treated produced water. It was agreed that the focus moving forward should be on analysis of treated produced water. It was also determined that NMSU has an analytical instrument capable of identifying over 400,000 compounds based on a mass analysis accuracy to four decimal points. This information was used to establish in the 2022 Consortium budget, funding for personnel to use this instrument to analyze produced water from the 2021 and 2022 produced water treatment studies.

3. Produced Water Data Portal Development and Roll-Out

In 2020, the Consortium established a working group to help define the functions needed in a Produced Water Data Portal to allow easier public and produced water user access to high fidelity water quality and quantity location data in a GIS format. This was to be able to facilitate the identification and evaluation of produced water treatment and reuse options and associated infrastructure needs.

Priorities identified included a data portal that allows collection and use of meta data, is easily accessible through a web-based interface, is updated frequently, provides reliable information, and provides different tiers of user access - from general use for the public to detailed use by major data users and data mining applications, and provides data on proprietary chemical data that is anonymized but available to NM public health agencies for access on a need-to-know basis.

In fall 2020, the Consortium signed a Memorandum of Agreement with the GWPC, the NM PRRC, and NMSU to initiate collaboration on a New Mexico produced water data portal. The effort was to combine the NMSU GIS work with the currently-available NM produced water quantity and quality data from OCD and PRRC, and integrate it with the GWPC's new Water Star initiative to create a "New Mexico Produced Water Data Portal," which could become a standard produced water database format for other states. The data portal would focus initially on produced water being disposed of through deep well injection, often called salt water disposal wells (SWDs). This is the excess produced water currently available for treatment and reuse. In the future, information in the portal could be expanded to include produced water treatment facilities and treated produced water available for reuse.

The task committee worked through 2021 with GWPC and the other New Mexico participants to create a data portal that meets the Tier 1 requirements for public access. The alpha version was released in mid 2021 for the tsk committee to review and comment. In October 2021, the portal was made available to the NM Water Data Initiative, and the site is up and operating at http://nm.waterstar.org. The portal includes a FAQ section, data description, User's Guide on how to use the data base, as well as all the data. The GWPC will provide a Quick Start User Guide Video in early 2022.

A screen capture showing the location of produced water available for disposal by quarter-township across New Mexico is shown below. By selecting a specific quarter-township, the database will provide data on current and historical disposal in that zone by month, the average quality, and the specific water quality available. It also provides location of major roads and infrastructure to identify potential treatment locations and sites. Icons at the top of the page allow easy navigation through the available data and information.

New Mexico Produced Water Data Portal

WaterSTAR
An RBDMS Product

GROUNDWATER PROTECTION COUNCIL

NM STATE — NM Produced Water Research Consortium

[FAQ/Fact Sheet]

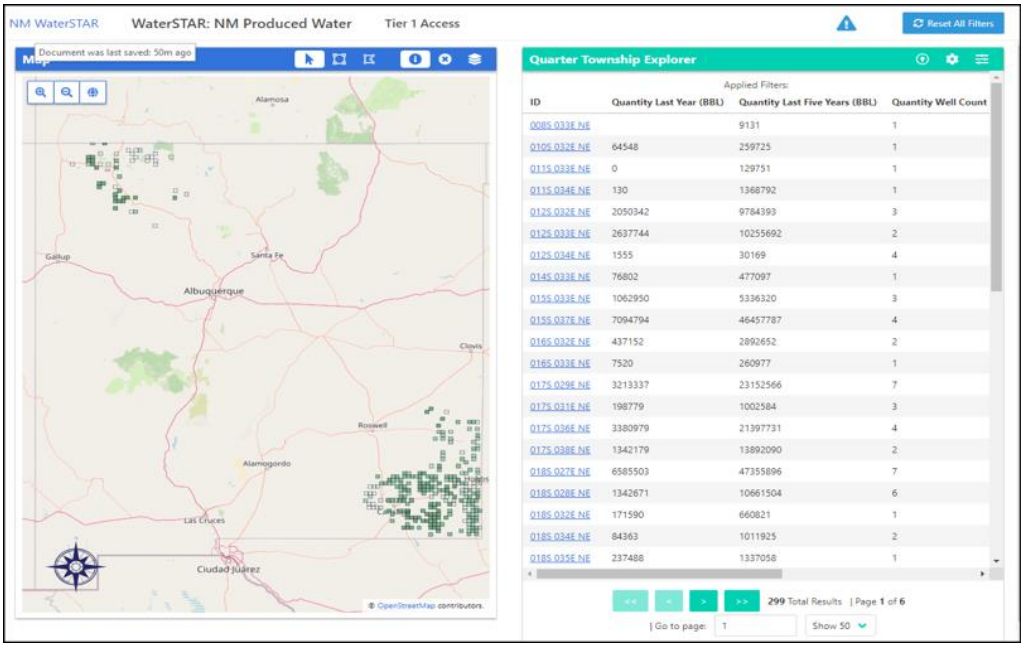
[Dataset Description]

[User's Guide Documentation]

Quick Start User Guide Video (x minutes) – Coming Soon

[New Mexico Produced Water Data Portal]

The produced water quality data collected from producers over the past few decades is included in the Data Portal, but significantly more water quality data needs to be collected annually for multiple years to make the data base more up to date with the unconventional wells and disposal wells that are coming online. This will be a major priority in 2022 and beyond.



While the Tier 1 data portal has been an important first step, the Consortium will continue to work with the GWPC and other states to expand funding to expand the framework to address Tier 2-4 capabilities and create similar produced water portals in other states in support of the EPA WRAP produced water program.

4. Assess Risk and Toxicology Evaluation Tools and Identify Optimum Approach

In the 2020 NMSU case studies on the use of treated produced water outside the oil and gas sector, it was observed that many states utilize qualitative risk and toxicology assessments to assess public and environmental health and safety. In many cases, values for produced water

constituent bioaccumulation and toxicity in soils, flora and fauna, surface water and associated biota, and ground water resources vary widely based on assumptions or averaged values based on soil type, species, animal, or plant estimates.

Therefore, the Consortium established a broader task committee to investigate ways to establish a quantitative risk assessment approach using more direct toxicology measurements and risk calculations. This required more direct coordination with recent research ongoing around the country at the US EPA on improved WET testing approaches (such as micro-toxicity testing and new species (zebra fish) WET testing), human cell-line risk analysis, and additionally at efforts at several universities and in Canada. Several major efforts were undertaken to address these challenges. These included:

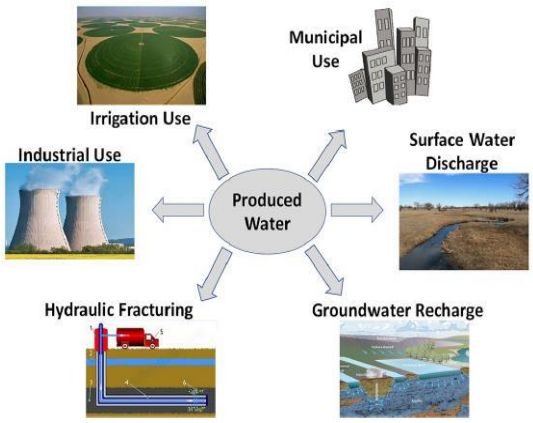
1. Development of a series of Conceptual Environmental Impact Models for various potential applications of treated produced water including land applications for things such as agriculture, rangeland restoration, land remediation, and road construction; surface water applications such as river or stream flow augmentation; and industrial applications. These Conceptual Models included potential receptor uptake or accumulation that needed to be specifically evaluated for constituent fate and transport for each application. This includes analyzing potential transport in various media and the overall air, soil, flora and fauna receptor uptake and accumulation over time, ground water and surface water mixing and concentration impacts over time and associated potential human risk and impacts over time.
2. To facilitate moving in this direction, the Consortium task committee reached out to collaborate with the EPA's Cincinnati Laboratory, ORD, and Regions 6 and 8 as part of their Regional Applied Research Effort on produced water. In support of that effort, the Consortium provided EPA with both raw and treated produced water for cell-line toxicity and other testing in July 2021. That data should be available in early 2022 to provide insight on the general improvement in human risk by treating produced water.
3. In 2021 as part of the RFP, the Consortium RFP review and selection committee chose to fund an effort at NMSU to expand their capabilities to conduct micro-tox, WET testing, and green house testing of treated produced water to provide members quicker access to scoping study data on the impact of treated produced water.
4. Additionally, through our industry task committee members, we were able to identify more sophisticated analysis approaches to toxicity and risk analysis for different conceptual fit-for-purpose produced water treatment and reuse cases and associated fate and transport modeling.
5. Finally, results from bench-scale produced water pre-treatment and treatment studies and a small-scale produced water treatment study of high TDS produced water showed that produced water could be consistently treated to about 200-500 ppm TDS in the finished water, with some low levels of organics, metals, and ammonia remaining in the treated water. The data from this testing suggest that produced water can be treated to relatively

high levels and often comparable drinking water quality with additional post-treatment as needed. This is consistent with treated produced water results from California, Wyoming, Colorado, and Pennsylvania. The treatment data collected suggest that some fit-for-purpose applications of treated produced water could be possible.

Originally, the intent of the task committee in 2021 was to integrate these efforts and data and apply to a few select potential applications and assess the general effectiveness of current treatment approaches to protect public and ecological health and safety. Unfortunately, the lack of enough treated produced water from the treatment studies, the delay in upgrading the NMSU WET testing capabilities and the changing landscape of WET testing, and the COVID delays in EPA's ability to conduct the human cell line toxicity assessment, and the need for more detailed risk analytical modeling has delayed some of the final results of major analysis efforts of this task committee until 2022.

5. Socio-Economic, Environment, Ecological Cost-Benefit Analysis

An emerging challenge to oil and gas operators is the need to be able to address in a holistic and qualitative manner issues around environmental and social justice issues associated with oil and gas operations, often called ESG impacts. Also of importance is a concern of accurately calculating the cost/benefit and pubic and ecological risks of fit-for-purpose reuse of treated produced water. Of importance to regional economic development agencies is what fit-for-purpose reuse applications of treated produced water are most beneficial to their community and have the least public and environmental risks.



To assess these issues quantitatively, Consortium management proposed an ESG project on produced water treatment and reuse to a team led by Sandia National Laboratories that included economists from UNM and modelers from NM Tech to develop a socio-economic and public risk model for the Permian Basin. The project was proposed to DOE Fossil Energy and was funded by DOE in January 2021 to focus on the Permian Basin. The goal of the modeling tool and the problem it is expected to address are presented in the highlighted description .

Tool for Assessing the Economic, Societal and Environmental Tradeoffs in Oil & Gas Produced Water Management and Reuse

Goal: Develop an integrated model for assessing the economic, societal and environmental tradeoffs associated with alternative produced water management and fit-for-purpose treatment and reuse.

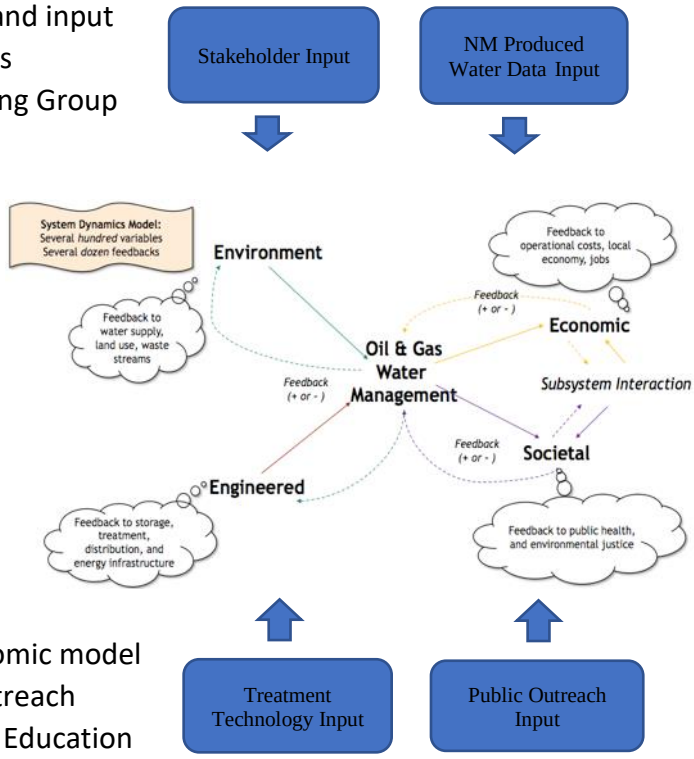
Problem: While many oil producers are considering qualitative Environmental, Social, and Governance (ESG) strategies to assess the general cost and benefits of the reuse of produced water, there is no comprehensive tool for **quantitatively** assessing the full costs and benefits of alternative produced water management and reuse strategies

The Consortium intends to expand the tool for use in other basins in New Mexico and has also had discussions with the Sandia team to expand the information in this tool for use in other states.

The modeling team used a system-dynamics (a stocks and flows modeling approach) that utilizes integrated feedback for subsequent time steps to provide a dynamic assessment for various fit-for-purpose applications that calculate impacts on operational, capital and avoided disposal costs for various applications, potential economic benefits of water use, and finally estimates of potential health and safety risk impacts.

The Consortium's roles were to:

- Support the effort by providing access and input to the model from regional stakeholders (coordinated by the Applications Working Group);
- Provide access to the produced water data portal data (coordinated through the Data Portal Task Committee);
- Provide desalination and produced water treatment technology cost and performance data through Dr. Pei Xu's produced water treatment decision support tool (coordinated through the Treatment Working Group); and
- Coordinate outreach of the socio-economic model at Consortium public education and outreach events (coordinated through the Public Education and Outreach Committee) in October and November 2021.



The Consortium supported the Sandia-led team in demonstration of the tool to DOE in both September and December 2021. In 2022 the Consortium is planning to work with the team to help in QA/QC of the data using several specific examples and in helping to integrate a more detailed and robust environmental risk model based on expected research results on risk and toxicology modeling and analysis efforts in 2022.

6. Scenario Analysis Economic Development Planning

This effort was not pursued this year in an effort to focus on the integration of existing produced water quality and quantity data into a web-based format and the completion of a

socio-economic model of the Permian Basin. With these completed in 2021, we can now utilize the graphic user interface (GUI)-based produced water information and the GUI-based socio-economic model to focus scenario analysis efforts in areas of most importance for potential use and applications. Additionally, there were concerns about COVID impacts on production development, resource needs, and potential bans on drilling and fracking on public lands that could have made the analysis outdated.

Our expectation is that some level of scenario analysis will be initiated in 2022 by the Consortium in order to estimate expected trends in produced water availability and location. This will likely be impacted by new reductions in produced water disposal permits in several regions to reduce seismicity issues and challenges.

7. Produced Water Reuse Public Education and Outreach

It was identified early in 2020 that public education and outreach is needed for better inform on not only the potential issues and challenges of fit-for-purpose treatment and reuse of produced water, but also the potential advantages of creating new water supplies and opportunities for economic development. It was determined that the Consortium needed to be more proactive as a resource for providing general information to the public on 1) emerging produced water issues, 2) potential treated produced water use opportunities, 3) how to use the Produced Water Data Portal, as well as 4) additional information on the risk and health and safety issues surrounding the potential use of treated produced water.

To accomplish this, the Consortium established a Public Education and Outreach Task Committee to look at the best way to keep both the Consortium members and the public aware of Consortium efforts and activities , as well as help educate the public on the basics of produced water and the emerging issues, challenges, and opportunities regarding the treatment and potential reuse of treated produced water. Based on discussions within the Task Committee, they recommended several education and outreach steps that were developed into a **Communication, Outreach, and Education Plan** for the Consortium in late 2020.

The plan highlighted the efforts needed for successful public involvement and education through a combination of activities and approaches that included:

- Use of web-based communications and document management to provide easy access to Consortium members and the public of Consortium research efforts, outreach activities, produced water facts, and program information;
- Internal communication processes and approaches to assist Consortium Members in tracking Consortium progress, activities, meetings, schedules, technical and scientific research opportunities, research activities, and summary research reports;
- External communication of Consortium operations, activities, highlights, research, and reports for public review; and

- Outreach to the public through public education workshops to improve public understanding of the implication of research results in terms of expected impacts to public and environmental health and safety for various fit-for-purpose reuse of treated produced water.

In 2021, the Public Education and Outreach Committee met regularly to implement the major elements of the Education and Outreach Plan. The Consortium planned to begin public meetings in the first quarter of 2021, but COVID restrictions delayed the originally planned outreach meetings from the late spring and summer of 2021 to the fall of 2021. Even with this 6-month delay, one of the scheduled fall outreach programs scheduled in Hobbs at the New Mexico Junior College in mid-November was still postponed by the hosting venue until early 2022 at the earliest.

Three major accomplishments occurred in 2021 by the Public Education and Outreach committee. They include:

- Support to hire an Operations Manager for the Consortium to support the public education and outreach efforts of the Task Committee. The Committee worked closely with the Operations Manager to establish an improved web site for better public access to Consortium documents, fact sheets of general information on many issues related to oil and gas development, produced water, treatment, and public education and outreach workshop materials and presentation materials;
- Coordination of meetings with elected and public officials during the summer of 2021 to discuss public education needs in local communities and successful outreach efforts and formats that work best in those communities, and
- Coordination with regional community colleges across New Mexico to help support public education and outreach workshops on produced water treatment and reuse on their campuses, and to help in communication of the workshops in the local news media.

While all these activities were important, the ability to support three different workshops in the fall of 2021 during COVID restrictions is probably one of the more impressive accomplishments of the Consortium in 2021.

The Consortium was able to work with industry members to provide two back-to-back technical workshops on Consortium efforts on produced water reuse at the NM Oil and Gas Association (NMOGA) Annual meeting in Santa Fe in early October 2021. In early November, the Consortium held a workshop in Farmington at San Juan College School of Energy with five

break-out sessions and held a similar workshop at the NMSU- Carlsbad campus in mid- November. The NMOGA workshop had about 75 participants, the Farmington workshop had about 20 participants, and the Carlsbad workshop had about 25 participants as shown on the right.

The survey from each of the workshops showed a high level of satisfaction with the workshop format, and many respondents requested even longer break-out sessions and longer workshops to get even more detailed information.

The Consortium will continue in 2022 to upgrade the web site and create additional fact sheets as needed and will continue to expand public education and outreach workshops across New Mexico. Workshops have tentatively been scheduled for Hobbs at NMJC early in 2022, Espanola at Northern NM Community College in late spring 2022 to address oil and gas issues in the Jicarilla area, a session in Albuquerque at Central NM Community College in the summer of 2022, and follow up meetings in Farmington at San Juan College and Carlsbad at the NMSU Carlsbad campus in the early fall 2022.