WATER IN OIL

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Are thermal technologies what the Permian Basin needs?

In part one of a series on brine concentration approaches, WiO looks at the feasibility of widespread deployment of thermal technologies to address Permian Basin produced water challenges.

The notion of deploying thermal technologies to manage produced water in US shale plays has gained traction in recent years. Historically deemed much too expensive for produced water, several circumstances have led technology providers to take another look at bringing thermal technologies to unconventional basins where water volumes have grown exponentially over the past decade.

In the Permian Basin, produced water disposal through reinjection into saltwater disposal wells (SWDs) has been the norm (*see chart 1*) due to both the existence of approximately 8,000 active SWDs in the region and the low cost of reinjection, which falls in the range of $0.05-1.65/bbl depending on location, transportation distance and whether the SWD is producer-owned or third party-operated. However, the industry is now facing disposal constraints due to regulatory responses to environmental and operational concerns, which threatens to limit new capacity and drive disposal fees higher.

"At some point, disposal capacity is going to reach a plateau. In that scenario, you'll have to look at thermal technology as an alternative means," Devesh Mittal, Aquatech's energy services vice-president and general manager, told *WiO*.

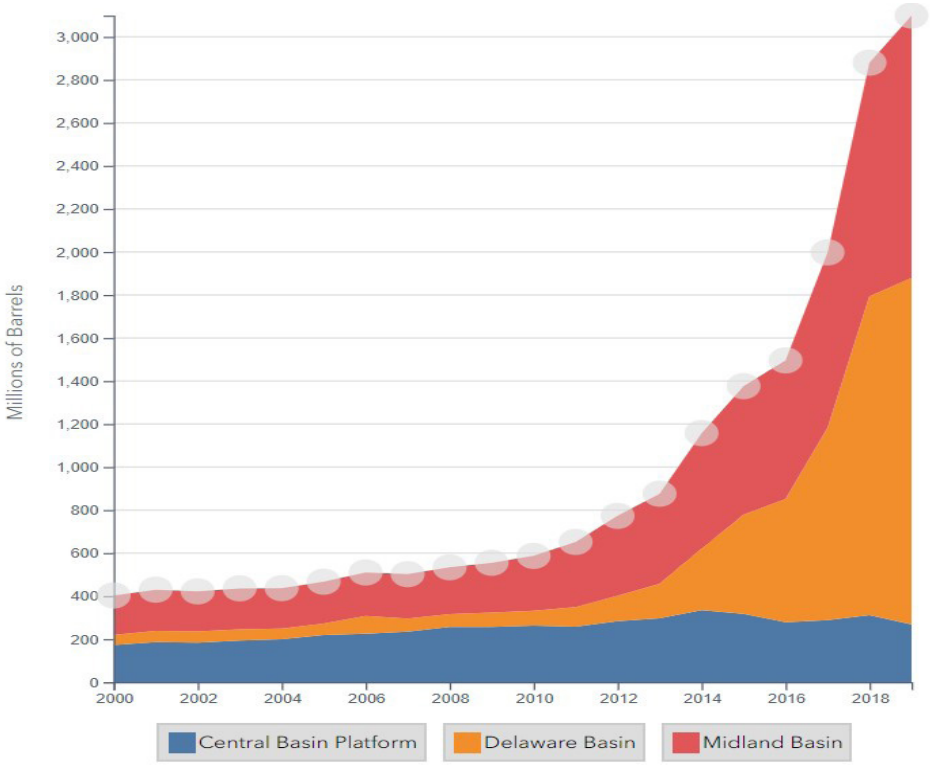
Thermal technologies could benefit both operators and commercial SWD operators if the price is right. Producers' disposal costs would fall as water volumes shrink, and SWDs would not reach capacity as quickly.

But disposal constraints are not the only impetus for considering thermal technology deployment in the Permian Basin or other plays in the US' Mid-Continent and Western regions. Drought and economic development are contributing to rising water stress, a challenge which could be partially addressed by reusing water recovered from thermal treatment processes in applications outside the oilfield. Producers, regulators, technology providers and academic researchers are all looking at how to make this possible, including ways to bridge the cost gap for thermal technologies.

Several well-established thermal technologies have been used to treat produced water (*see table*), but in an industry that has struggled through two severe downturns in the past five years and in which players are looking to trim costs everywhere they can, these approaches have remained largely unappealing. However, as disposal constraints and water stress intensify, some technology providers have identified opportunities to innovate system designs and business strategies to bring costs within shale operators' comfort zones.

PERMIAN BASIN DISPOSAL VOLUMES

Source: B3 Insight



Details of selected thermal technologies				
Technology	**Tech type**	**Description**	**Strengths**	**Weaknesses**
Direct contact evaporation	Established	Evaporation processes in which the heating or cooling medium is in direct contact with the feedwater to be treated. Can be used in single- or multi-stage configurations.	• Can be powered by waste heat, such as flare gas or turbine/engine heat • Proven solution	• Requires thermal energy • Water recovery not always an option
Mechanical vapor compression (MVC) evaporator	Established	Evaporator system that utilizes heat generated from mechanically compressed vapor, rather than boiler-produced steam, to evaporate water.	• Low-TDS product • Successful track record • Minimal/No pretreatment	• High energy usage • Requires availability of low-cost steam • Large quantities of cooling water required
Membrane distillation	Emerging	Vapor is induced through a membrane that allows for the transmission of vapour but not liquid by the resulting temperature differential between the heated feedwater and a cooler or vacuum chamber.	• Can be coupled with other TDS technologies • Can treat difficult wastewater streams • Lower relative energy consumption	• Requires significant cooling water • Lower yield compared to other desalination technologies • Other volatile substances can be transmitted through the membrane
Thermal crystallizer	Established	Class of forced circulation evaporators that use a flash evaporation chamber to further concentrate feedwater to the point of crystal formation.	• Low-TDS product	• High capital and operating costs
Vertical tube falling film brine concentrator	Established	Class of thermal technologies that use heat-exchange surfaces or low-pressure separation chambers to concentrate feedwater.	• Low-TDS product	• High capital and operating costs

FLEXIBILITY BY DESIGN: Massachusetts-based Heartland Water Technology and Oklahoma's HyQ Technologies – which both presented their technologies in a PWS webinar earlier this month – have developed highly portable, modular systems that can adapt to changing client needs relatively quickly.

Heartland has been evaporating challenging wastewaters, including produced water, for 15 years. The company's LM-HT Produced Water Concentrator is a 3,000 bbl/d direct contact evaporator, which means there is no heat exchanger, allowing the equipment to avoid the scaling and corrosion issues typically associated with conventional thermal technologies.

"If you lose control of the water chemistry, solids tend to come out of solution and scale up heat transfer surfaces and plug channels. They can also be extraordinarily corrosive," Heartland CEO Earl Jones explained to *WiO*. "Heartland's process allows us to virtually eliminate scale and corrosion. We never have to worry about materials of construction."

He added that the company's direct contact design is proven and simple to operate, resulting in less system downtime and lower capital and operating cost.

HyQ, on the other hand, has developed 5,000-bbl/d and 10,000-bbl/d thermal crystallizers and is now finalizing the design of an 800-bbl/d mobile unit. Last month, CEO Jared Boehs told WiO that HyQ's technology can concentrate brine and achieve zero-liquid discharge (ZLD). In a 2019 pilot in Oklahoma, the company demonstrated that it could feed produced water directly from a pipeline into its crystallizer and generate distillate with total dissolved solids (TDS) levels below 100 mg/L for reuse applications.

Heartland, whose commercial projects have focused on the Marcellus Shale, can also achieve ZLD with its direct contact evaporator without having to add a crystallizer unit. This gives Heartland the flexibility to produce a heavy brine, slurry or ZLD by simply changing an operating setting, allowing customers to tailor their residual to site-specific needs.

"Generally speaking, the solution that probably works best in the Permian is a brine concentration solution, given the numerous disposal wells already in place. If I can shrink the produced water volume 50-70% and have a pumpable liquid to put downhole, then that's a good, economic solution," Jones told *WiO*.

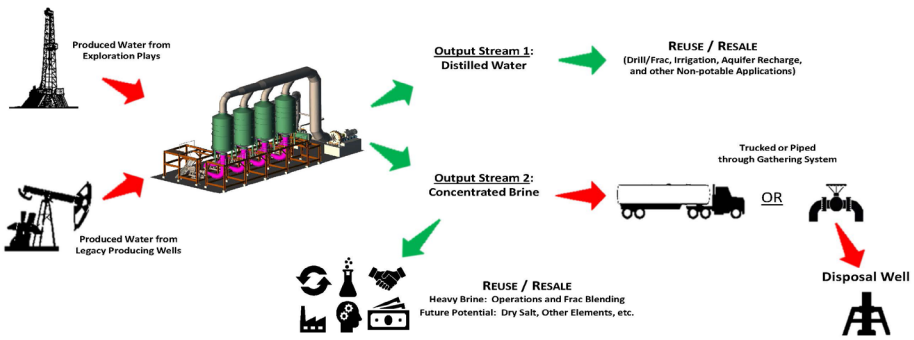
Both Heartland and HyQ can set up their systems at well pads – saving operators transportation costs – or at producer-owned or commercial SWD facilities – helping to optimize disposal operations (*see chart 2*).

Another way in which companies

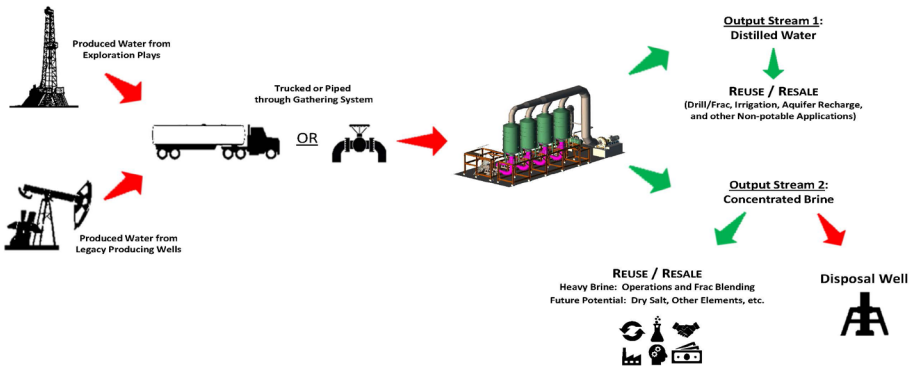
UNIT PLACEMENT SCENARIOS

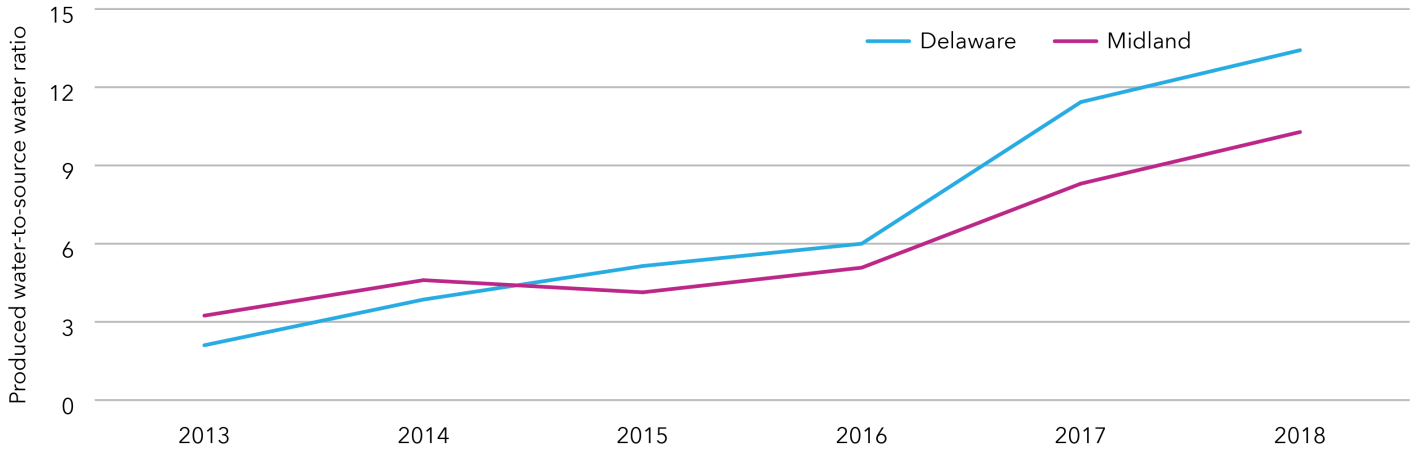
Source: HyQ Technologies

SCENARIO 1: Wellsite & Centralized Production Operations



SCENARIO 2: SWD / Midstream Integration





PERMIAN BASIN PRODUCED WATER-TO-SOURCE WATER RATIO

Source: FracFocus, New Mexico Oil Conservation Division, Texas Railroad Commission

can realize lower costs and appeal to producers is by using flare gas as the thermal energy source for their systems. Heartland estimates that the total cost of its systems would add up to around $0.70-0.90/bbl if using flare gas, while, HyQ estimates that in the Permian Basin and most of the Mid-Continent region it can achieve an average cost of $1.05/bbl if using flare gas, compared to $1.70/bbl when using electricity from a power line.

In Q3 2019, Permian producers flared as much as 750 mcf/d of natural gas, prompting extreme concern from regulators and environmental groups. The ability to put the excess gas to use in an environmentally friendly way while addressing the produced water challenge is a clear win-win for the industry.

"The major producers are concerned not just about the economics, but also their social and environmental responsibility," Jones said. If they don't look to strong environmental solutions they may lose the opportunity to harvest these long-lived shale plays, not because it's not economical, but because folks are unhappy with their environmental performance."

ECONOMIES OF SCALE: With several thermal evaporative technologies in its portfolio, Aquatech is one of the most experienced players using this approach in the oil & gas space. Like HyQ and Heartland, Aquatech has developed a mobile evaporator system called MoVAP. That system was first deployed in the Marcellus Shale in 2012 but is now operating in other industries where there is a need to reduce brine volumes. While MoVAP is a great solution for well pad and hub facility applications. However, due to the Permian Basin's high produced water volumes, centralized facilities comprising high-capacity systems will also likely be deployed in this market, Mittal told *WiO*.

Instead, Aquatech is interested in bringing a large-scale facility to the Permian where produced water-to-source water ratios are very high (*see chart 3*) and total produced water volumes are expected to continue rising as drilling activity recovers. Mittal said the company would consider installing a system like the 300,000-bbl/d facility it has in Oman to support steamflood enhanced oil recovery activities at Occidental Petroleum's Mukhaizna asset. That project comprises falling film evaporators and a mechanical vapor compression (MVC) unit. Large systems like that could capitalize on economies of scale, particularly when it comes to operating costs, as labor in the Permian is quite expensive.

Manish Backliwal, Aquatech's director of business development, told *WiO* that falling film and/or forced circulation crystallizers can be employed in the Permian Basin depending on produced water chemistry and flows, and that MVC or steam can be used to drive the thermal system.

Although Aquatech is also working on emerging thermal technologies, Mittal believes those would be more appropriate for smaller-scale operations, while time-tested technologies should be deployed for large developments to minimize project risk.

"It's not that we don't have technologies in the development stage as well, but as a company, we feel that it would be prudent to use those on smaller-scale applications in the beginning," Mittal said. "I think it requires some time to understand the requirements of methodologies and the scaling, corrosion and fouling potential of newer technology designs such as membrane distillation."

SOMETHING FROM NOTHING: One way to improve the economy of evaporative treatment operations is to monetize various produced water constituents and co-products generated from the treatment process, such as rare earth elements (REEs), sodium chloride and lithium. However, this approach is commercially viable only under very specific circumstances and in certain locations, and success is largely dependent on revenues from water handling services.

Companies interested in this approach should ensure that a local market exists for the products generated from the treatment process. For example, in the northeast, the salts produced through crystallization can be used to de-ice roads during the winter and chlorides can be used in various industries. It is also important to ensure a consistent supply-demand match to avoid creating a solid waste disposal problem.

Eureka Resources is probably the best-known example of a company that has built a multi-product extraction and sales strategy on the back of its pro-

duced water management business. The company now transforms what has historically been considered a waste by the oil & gas industry into a feedstock for the production of valuable commodities: oil, methanol, sodium chloride, calcium chloride and lithium.

"The more things you can take out of the produced water and purify to industry standards for reuse and revenue generation, the lower your cost is to treat a barrel of water through advanced treatment," Eureka Resources COO Kevin Thimmesch told *WiO*. "If you can extract enough minerals to offset the costs of treatment, then you're in the game."

Eureka has three Marcellus Shale locations – a brine and calcium chloride receiving and storage facility; another with a distillation unit and methanol column; and one with a 5,000 bbl/d crystallizer, as well as a membrane bioreactor and reverse osmosis unit to treat distillate before discharging it to the Susquehanna River (*see chart 4*). The company's most valuable co-product is sodium chloride, of which it produces around 15,000 tons per year (tpy). Eureka began producing lithium in 2019 and is continuing to commercialize its lithium extraction process. Thimmesch said that at full production, Eureka will produce around 350 tpy of lithium for the renewable energy market.

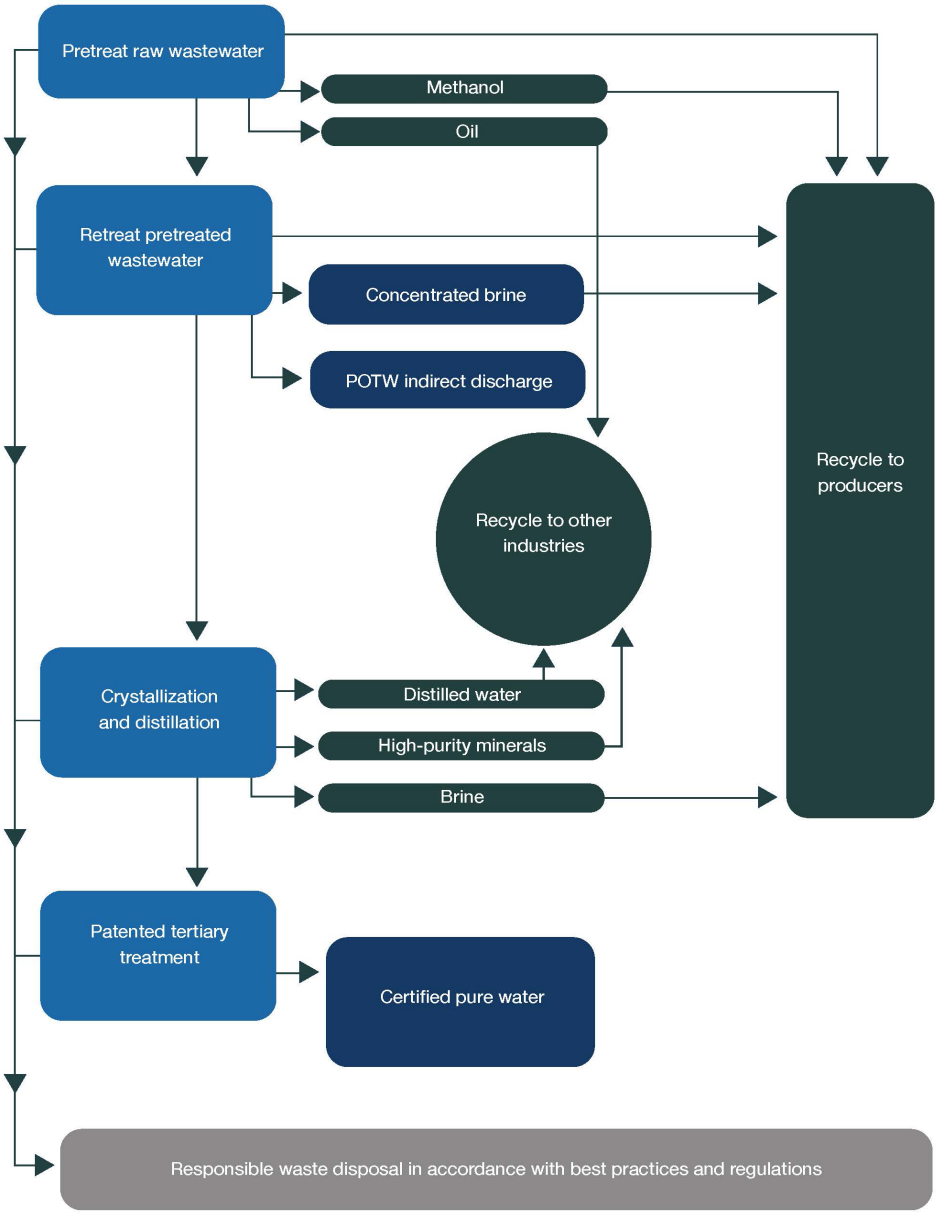
Antelope Water Management, which acquired Canadian vacuum membrane distillation company KMX Technologies earlier this year, has also expressed interest in lithium and REE extraction to further align its business with the energy transition and counterbalance the costs of treating industrial waste streams including produced water. Antelope has joined the New Mexico Produced Water Research Consortium to further explore related opportunities to deploy KMX's proprietary technology in the basin.

Like Antelope, Eureka has also joined the consortium with an interest in expanding its business model beyond the Marcellus Shale. The company sees potential to generate revenue in the arid Permian Basin by selling not only extracted products, but also clean water generated through its treatment process.

Though there is much hype around the potential for lithium extraction from Permian Basin produced water, interested parties should be cautious. US lithium carbonate and hydroxide prices are at their lowest points since 2015, and some research suggests that the region's produced water may not be ideal for lithium mining due to the potential for other water constituents to reduce recovery efficiencies and because lithium may not even be present in economical amounts.

PROCESSES AT EUREKA RESOURCES' FACILITIES

Source: Eureka Resources



WAIT-AND-SEE MOMENT: Given the havoc wrought on the shale sector by 2020's pandemic-induced oil price crash, the deployment of thermal technologies in the Permian Basin is likely to remain minimal in the near term, with more of a focus on continued piloting and strategizing. Mittal told *WiO* that it is hard to predict when this approach will really take root, but that people are definitely engaging in the conversation.

Jones feels similarly. He told *WiO* that for the next six months or so, players interested in this area will be focused on ensuring that potential clients understand the economic benefits of their thermal-based solutions and preparing for oil activity to rebound.

"I suspect that we're still a ways away from broader market adoption," he said, adding that it is encouraging to technology providers that the industry appears to be recovering more rapidly than had been anticipated.