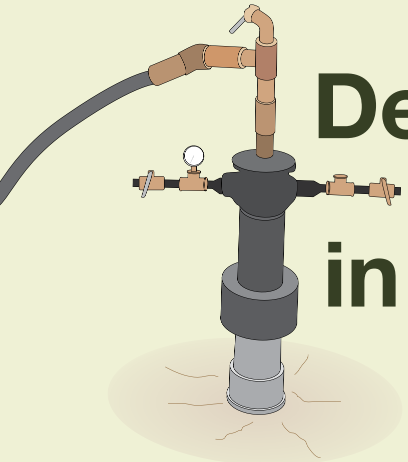

Deep-Well Injection of Desalination Concentrate in El Paso, Texas

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On August 8, 2007, El Paso Water Utilities (EPWU) officially opened the Kay Bailey Hutchison Desalination Plant in El Paso, Texas. The plant is supplied by 32 production wells that pump brackish groundwater from the Hueco Bolson. Two unique aspects of the plant are its large capacity (27.5 million gallons per day [mgd]) and the use of three deep injection wells located about 22 miles from the plant for the disposal of up to 3 mgd of concentrate—the byproduct of the reverse osmosis process. The focus of this article is on the injection wells: how EPWU selected this disposal option, the investigations and tests that were completed for well design and regulatory approval, and the initial testing and operation of the wells.

The investigations and analyses that culminated in the construction and operation of the three injection wells began in 2001. Initially, three methods of concentrate disposal were considered: passive evaporation, enhanced evaporation, and deep-well injection. Passive evaporation for 3 mgd of concentrate would have required a 700-acre double-lined pond. Enhanced evaporation would have required a smaller pond and mechanical sprayers to increase the evaporation rate. An economic analysis of the three alternatives showed that deep-well injection would be significantly less expensive than either evaporation alternative if a suitable site could be located. Thus, a detailed investigation of the deep-well disposal option was performed from 2002 to 2004, consisting of geologic investigations, test drilling, geophysical studies, preliminary modeling, and finally the construction and testing of a pilot well.

Initial Investigations

After considering several potential sites, the initial geologic investigation focused on results of an earlier test-drilling effort in the New Mexico portion of Fort Bliss to locate a potential geothermal resource. Data obtained from that effort suggested that the Silurian Fusselman formation (fractured dolomite) might be a suitable injection reservoir. Attention concentrated on a portion of Fort Bliss property near the Texas-New Mexico state line.

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Four test holes were drilled in this area in 2003. The test holes encountered a sequence of alluvial and lacustrine sediments above a thick sequence of Paleozoic shale and limestone. Below this, the top of the Fusselman formation was encountered at depths ranging from 2,300 to 2,900 feet. At the end of the drilling program, falling head slug tests were completed in two of the test holes. Test results from the hole that fully penetrated the Fusselman formation provided preliminary data on the hydraulic conductivity of the formation, and suggested that it was a suitable candidate for injection.

The geophysical investigation consisted of supplementing existing gravity measurements in the area with a dense network of gravity measurements taken in the immediate vicinity of the test holes. The combined gravity dataset was interpreted with respect to formation depths obtained from the test-hole drilling program. The resulting subsurface geologic model provided the basic framework on which a preliminary numerical flow model of the area was constructed.

The objective of the numerical flow model was to investigate the potential range of relative hydraulic conductivity conditions in the various rock units. In addition, the role of faults in the area as conduits or barriers to flow was evaluated. The results provided estimates of the potential build-up of groundwater levels and areas of concentrate migration under a wide range of geologic and operational scenarios.

These findings led to the construction of a pilot well in the summer of 2004. The well was completed to Class I injection well standards and to a depth of 3,770 feet, with 9-inch diameter open-hole completion in the injection zone (below 2,300 feet). Testing consisted of two pumping tests (step-drawdown and 47-hour constant rate) and an injection test. The produced water from the pumping tests was stored and used for the subsequent injection test. Results of these tests, including the estimated location of faults, were consistent with the slug test results and the subsurface geologic model.

Regulatory Approval

Results of the studies and the pilot well test were used in 2004 and 2005 to prepare an application to the Texas Commission on Environmental Quality (TCEQ) for a Class V Authorization to inject concentrate into the Fusselman and Montoya formations. The key features of the application were that: 1) the proposed injection wells were in a remote location, with no other production or injection wells in the area; 2) the expected concentrate had a lower total dissolved solids concentration than the formation water, which is about 8,000 milligrams per liter (mg/l); and 3) the injection would be by gravity (no pumping). The application acknowledged the limitations of a single short-term test and the uncertainty of the faults as barriers or conduits to flow. Authorization was obtained on July 13, 2005.

Geochemical Investigations

The potential for mineral precipitation in the well and formation was studied from late 2005 to early 2007. Based on geochemical modeling, calcite, barite, and silica in the concentrate would be supersaturated and thus tend to precipitate, but the significance of precipitation would depend on the kinetics of the reaction. Results of jar tests using pilot-plant concentrate and crushed formation samples suggested that precipitation reactions would be slow (several days).

It was tentatively concluded that well-bore precipitation would likely not be an issue, but precipitation in the injection reservoir might be, depending on the rate of movement of the injected fluid away from the well bore and the size of the fractures. Mitigation strategies, such as the need to lower the pH of the concentrate prior to injection, were identified, and a plan for initial operation was developed to further test the potential for mineral precipitation during initial operation.

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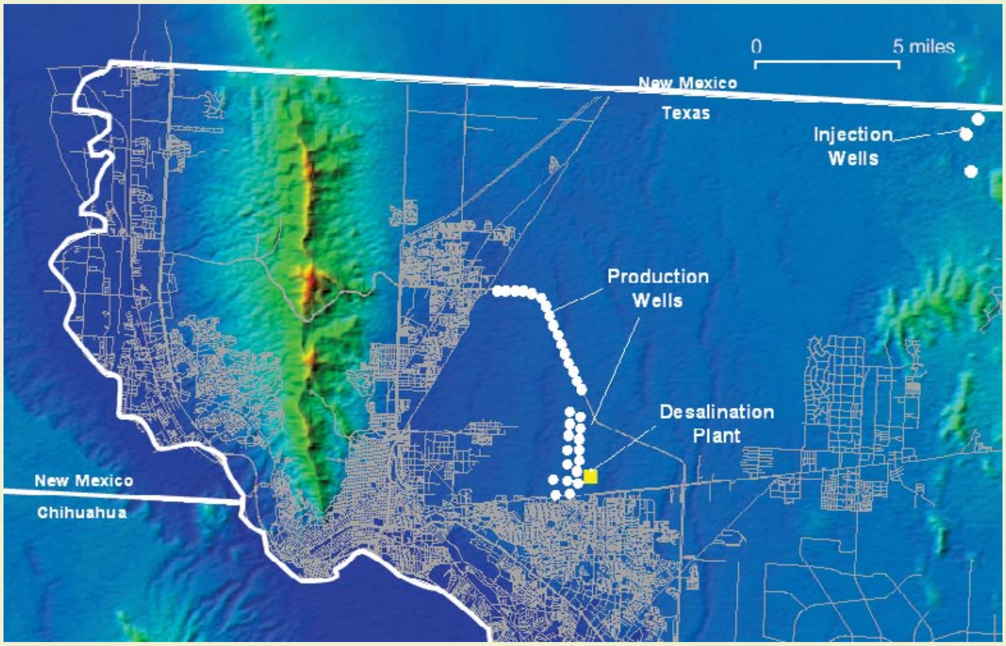

Location of injection wells relative to production wells and the desalination plant in El Paso.

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Well Construction and Testing

The second and third injection wells were constructed in late 2006 and early 2007, and completed to Class I standards. The wells are 3,720 feet and 4,030 feet deep, and include 8.5-inch-diameter open-hole completions in the injection zone (below 2,900 feet). During test pumping of each of the wells, drawdown data were collected in the two non-pumping wells to provide estimates of aquifer transmissivity; these data were used to update the subsurface geologic model. Based on the results of the testing program, it was concluded that any two of the wells could be used to inject 3 mgd of concentrate. Initial operational plans, therefore, included developing a rotational schedule to operate two wells over an 8-hour period. Thus, each well would be operational for 16 hours and at rest for 8 hours.

At the completion of testing, each well was video-logged to assess the nature and size of the fractures in the injection zone. Numerous fractures over the entire thickness of the injection zone were observed, many of which were nearly an inch wide. The number and size of the fractures, coupled with the open-hole completion, reduced concerns regarding the potential for mineral precipitation.

As part of the overall project, surface facilities (tanks, pipes, valves, communications systems) were constructed at each injection well site. The sites are remote with no commercial power readily available; an evaluation determined that their modest power requirements (about 7.5 kilowatt-hours per day) could best be met by a solar power system with propane generator backup.

Testing of the wells began in May 2007 and initially involved injecting fresh Hueco Bolson groundwater in order to develop baseline well-performance data without concern of mineral precipitation. At the beginning of plant operations, the concentrate was diluted, but dilution was gradually reduced and finally eliminated, with no observable change in well performance related to injection rate and groundwater level buildup. During these tests, the concentrate received no pH adjustment. Although the tests were short-term and the initial operation has been only a few months, it appears that mineral precipitation is not significant with respect to well performance. Monitoring efforts during operation include continuous recording of injection rate and depth to groundwater in each well and monthly water quality analyses of the injected concentrate.

Costs

Overall desalination construction costs were about $91 million. Of that, concentrate disposal was about $19 million, including construction of the pipeline, surface facilities, and wells. Annual operating costs for the entire project are projected to be $4.8 million, of which $200,000 is expected for concentrate disposal. Assuming 80 percent operation at capacity, produced water costs are expected to be about $534 per acre-foot, of which $49 per acre-foot is related to concentrate disposal.

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by regulatory constraints, available space, environmental impacts, or other limitations, the cost of the disposal increases dramatically as technology is added to treat the waste stream.

Some technologies, such as Turbomisters, Wind Aided Intensified Evaporation (WAIV), and Solar Bees augment evaporation and reduce land area requirements, but the water is not recovered and costs for energy, equipment, and maintenance are higher. Even more advanced are Zero Liquid Discharge (ZLD) technologies which use both thermal and nonthermal processes to recover more of the water, leaving a solid waste for disposal.

Research is being conducted on intermediate chemical treatment (lime precipitation and ion exchange) to allow for further membrane treatment and water recovery with seawater RO or vibratory shear enhanced processing (V-SEP). Beyond the membrane alternatives are the most expensive thermal evaporation and crystallization processes.

The ZLD alternative is used least, as it has the greatest energy and operating costs. Yet these alternatives allow for the best option for recovering lost water resources and have the greatest potential for innovative treatment solutions. A significant amount of research is being conducted in this area in Arizona, El Paso, and other regions facing similar water shortage and disposal challenges.

Looking Ahead

As communities struggle to find new economically viable and sustainable sources of fresh water, they will face the inevitable question, “How do we remove the salt?” The answer will rely on technologies such as reverse osmosis. RO can remove impurities from the water and, as history has proved, will continue to become more efficient. Recent advances in large-diameter technologies and membrane chemistry will lower capital costs for facilities, leading to improved water quality at lower cost. A complete answer must also address the concentrated waste streams generated by the process, especially for inland facilities. Significant opportunities exist for research and development of innovative and cost-effective approaches to treatment and waste handling.

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