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Re-Injection Accelerates Groundwater Clean Up at Fernald
Fluor Fernald, Inc.

By

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INTRODUCTION

A successful one year long, field scale demonstration of the use of groundwater re-injection at Fernald was recently completed bringing DOE one step closer to achieving an accelerated site remediation (DOE 2000). The demonstration marks the end of a several year effort to evaluate whether:

- re-injection could be conducted efficiently at Fernald, and
- if the approved aquifer remedy at Fernald would benefit by incorporating re-injection.

Evaluation of re-injection technology involved not only technical considerations, but also participation and cooperation of regulators and stakeholders. The demonstration was considered to be unique in that it was integrated into the design of the current approved aquifer remedy and utilized the existing remediation infrastructure. Information collected during the demonstration indicated that re-injection wells could be operated efficiently at Fernald and that the current approved groundwater remedy should be modified to include the use of re-injection.

BACKGROUND

The 1050-acre DOE site at Fernald, Ohio lies over the Great Miami Aquifer (a sole source aquifer), which is one of the largest sources of drinking water in the nation. For over 35 years until 1989, the Fernald site processed uranium metal for U.S. Defense Programs. Approximately 136 acres of the site were utilized directly in the production process. Approximately 220 acres of the underlying Great Miami Aquifer were contaminated with uranium above a concentration of 20 parts per-billion (ppb). Figure 1 is a map that outlines the site and the underlying 20 ppb uranium plume. Reducing the level of uranium in the groundwater to the proposed U.S. Environmental Protection Agency (U.S. EPA) health-protective concentration limit of 20 ppb is a primary goal of the Fernald environmental Management Project (FEMP), managed since 1992 by Fluor Fernald.

The Record of Decision (ROD) for Fernald's Operable Unit 5 calls requires restoration of the aquifer by 2023 using "pump-and-treat" technology. The ROD presents a 28 well extraction system, which operates at a maximum rate of 4000 gallons per minute (gpm). In the OU5 ROD the DOE agreed to continue evaluating innovative technologies which might enhance the approved aquifer remedy. Re-Injection of treated groundwater was considered to be one such innovative technology, however, the technology was unproven at Fernald. The challenge was therefore how to proceed with designing and implementing the approved pump-and-treat aquifer remedy and simultaneously evaluating the use of groundwater re-injection as a means of improving the remedy. The evaluation of re-injection technology at Fernald was sponsored by the DOE Office of Science and Technology Subsurface Contaminants Focus Area, at the request of Fernald.

WORK DESCRIPTION

The use of Re-Injection technology at Fernald was evaluated following the strategy outlined in Figure 2. To begin the evaluation several different modeling scenarios were conducted by modifying the approved design for the pump-and-treat remedy to include strategically positioned re-injection wells. The modeling predicted that re-injection would provide the following benefits:

- Shorten the remedy by approximately 7 years
- Produce faster pore-volume turnover, helping to reduce stagnation and accelerating the rate at which uranium would be flushed to extraction wells
- Minimize the cumulative drawdown effect of numerous extraction wells
- Help to provide a hydraulic barrier to continuing migration of the plume.

As a result of the favorable modeling outcomes it was decided to conduct a small, single-well re-injection test to determine what physical and chemical challenges would need to be overcome for a successful re-injection operation. A short term (72-hour) small scale (injection through a single well at a rate of 300 gpm) was all that could be conducted because the infrastructure needed for a larger and longer test did not exist. The test was conducted in October of 1995. During the test groundwater with a uranium concentration of less than 20 ppb was pumped from one region of the aquifer and re-injected into the aquifer utilizing an existing extraction well. At an elapsed time of 600 minutes, the water level in the well being used for injection began to rise very rapidly indicating that the well was plugging. The planned 72-hour test was subsequently stopped short. A plot of the water level rise in the injection well versus time indicated a biological growth pattern where an abundant food supply was available (Pyne 1995). It was concluded that mixing reduced water with oxygenated water during the test resulted in the precipitation of ferric oxy-hydroxide within the re-injection well. The oxidizing reaction created an environment in which Gallionella iron bacteria obtained energy and thrived from the oxidation of ferrous iron to ferric iron. The conclusion was that only water with similar pH, Eh, and iron content should be mixed, in order to limit the growth of ion bacteria (DOE 1995).

A second single well short-term, single well injection test was conducted in the spring of 1996. A different extraction well was used than was used in the first test so that treated water could be injected. As a result of being treated for uranium the water was also oxidized and any ferrous iron present in the water was converted to ferric iron prior to being injected into the aquifer. Injection took place for five days. Physical plugging of the injection well did not take place during the second test. Injection resulted in some iron bacteria growth within the well though. Even though injection caused bacterial growth in the well, physical plugging of the well screen in the well did not occur during the test, and no evidence of the beginning of physical plugging was found. Bacterial sampling conducted in the well following the test indicated that iron bacterium was present (DOE

1996). The conclusion reached from the two single well tests was that iron bacterial growth conditions, which are natural for the Great Miami Aquifer, couldn't be eliminated, but they could be controlled so that the onset of physical plugging would be prolonged or reduced. With an aggressive bacterial control program, it appeared that it would be possible to operate re-injection wells efficiently.

Following the small, short-term tests all that remained to prove the technology at Fernald was conducting a longer-term (one-year long) field scale test. A major concern with the field scale use of re-injection at Fernald was how much, and how often the re-injection wells would be inoperative due to plugging and the resulting costs that would be needed to keep the wells operating. Another unknown was whether re-injection would actually work as modeled both in terms of hydraulic control of the uranium plume and remediation of the uranium within the plume. However, the problem with obtaining long term field-scale information was the lack of required infrastructure. Rather than fund and conduct a field-scale demonstration separate from the approved groundwater remedy, only to have wasted infrastructure following the demonstration that might not be able to be used in the remedy, the decision was made to incorporate the field-scale demonstration into the ongoing aquifer remedial design effort. This cost conscience measure would allow for the immediate incorporation of re-injection technology into the aquifer remedy, should the field scale demonstration show that re-injection was viable at Fernald. If not viable, the remedy strategy would revert back to the approved ROD remedy and other efforts to shorten the time frame would be pursued.

With approval from the regulators and stakeholders and support from the Office of Science and Technology's Subsurface Contaminants Focus Area, a one-year field scale re-injection demonstration began in September of 1998. Treated groundwater was re-injected back into the aquifer through five strategically placed wells at the combined rate of 1,000 gpm. Figure 1 shows the location of the 5 re-injection wells. The water being injected was treated via an expansion of the site's Advanced Wastewater Treatment (AWWT) facility, also shown in Figure 1. This facility began operation back in 1995 treating storm water and site wastewater, with a design capacity of 1,100 gallons per minute. Ion exchange reduces uranium concentration in the treated water too less than 20 ppb. To support groundwater treatment needs the treatment capacity of the AWWT was expanded by 1800 gpm in 1998.

During the re-injection demonstration, extraction was also taking place through sixteen pumping wells as part of the approved remedy. Four of these wells had been operating since August of 1993, the other wells had only begun operating approximately a month prior to the start of the re-injection demonstration. Evaluation of the effectiveness of re-injection was approached in part as to how well the re-injection and extraction wells operated together to achieve remediation objectives. The specific objectives of the demonstration were as follows:

- Determine if a re-injection rate of 200 gpm per well could be sustained at the field scale for a time period of one year.

- Determine the operational and maintenance costs required for maintaining re-injection rates of 200 gpm per well at the field scale.

- Determine if the extraction and re-injection wells would work together as modeled to maintain capture of the 20 ppb uranium plume.

- Determine if actual hydraulic patterns and profiles would indicate increased flushing in the aquifer and minimized pumping-related drawdown as predicted by the groundwater model.

RESULTS

The target re-injection rate during the demonstration was 1000 gpm (200 gpm per well). Over the course of the one-year demonstration this equates to approximately 526 million gallons of treated groundwater. Actual operation of the five wells during the demonstration resulted in the re-injection of approximately 455 million gallons of treated groundwater, 86.5 percent of the target volume. The 86.5% uptime is considered very good for the first year of operation.

One of the objectives for conducting the demonstration was to obtain one year's worth of information on the cost to operate the re-injection wells. Of concern was the possibility that the wells would experience frequent and sever plugging, leading to excessive maintenance costs. Prior to the demonstration re-injection had only been accomplished in one well at Fernald for a short (5-day) time period. The first year of operation though went better than expected concerning plugging in the five re-injection wells. Of 20 planned treatments (quarterly treatments for plugging in each of the five re-injection wells) only six treatments were required, which only involved two of the wells. A cost analysis based on data collected during the demonstration was conducted. The cost analysis assumed that the groundwater re-injection would be successful in reducing the time needed for the active remediation of the aquifer by 7 years. The results indicated that by shortening the aquifer remedy by 7 years, the aquifer remediation project could realize a potential (net present value) cost savings of approximately $14.3 million.

Water level and uranium concentration data collected during the demonstration indicated that the re-injection wells and extraction wells would work together as modeled to capture the 20-ppb uranium plume. Hydraulic patterns and profiles measured during the demonstration indicated that increased flushing in the aquifer and minimized pumping related drawdown was achieved. Figure 3 compares the predicted and measured water table profile for the re-injection demonstration area. The location of the profile is shown in Figure 1. The comparison shows that the shape of the predicted and actual profile is very similar, but that the measured water table was higher than the predicted water level.

CONCLUSIONS AND DISCUSSIONS

Incorporation of re-injection technology into the aquifer remediation at Fernald supports a nationwide DOE effort to accelerate the remediation and closure of DOE sites. At Fernald, the DOE is currently targeting a ten-year aquifer remediation, rather than a twenty-eight year cleanup as originally defined in the OU5 ROD. As mentioned earlier, incorporation of groundwater re-injection into the aquifer remedy is expected to shorten the aquifer remediation by seven years. The predicted achievement of a 10-year clean up of the aquifer is also based on:

- Other operable units completing their accelerated clean-up objectives so that surface access is available for aquifer remediation wells. The accelerated removal of source terms will allow recovery wells to be located closer to the center of uranium plumes

- A prediction that most of the uranium present in the aquifer will not become fixed to the aquifer sediments and can be readily pumped out of the aquifer.

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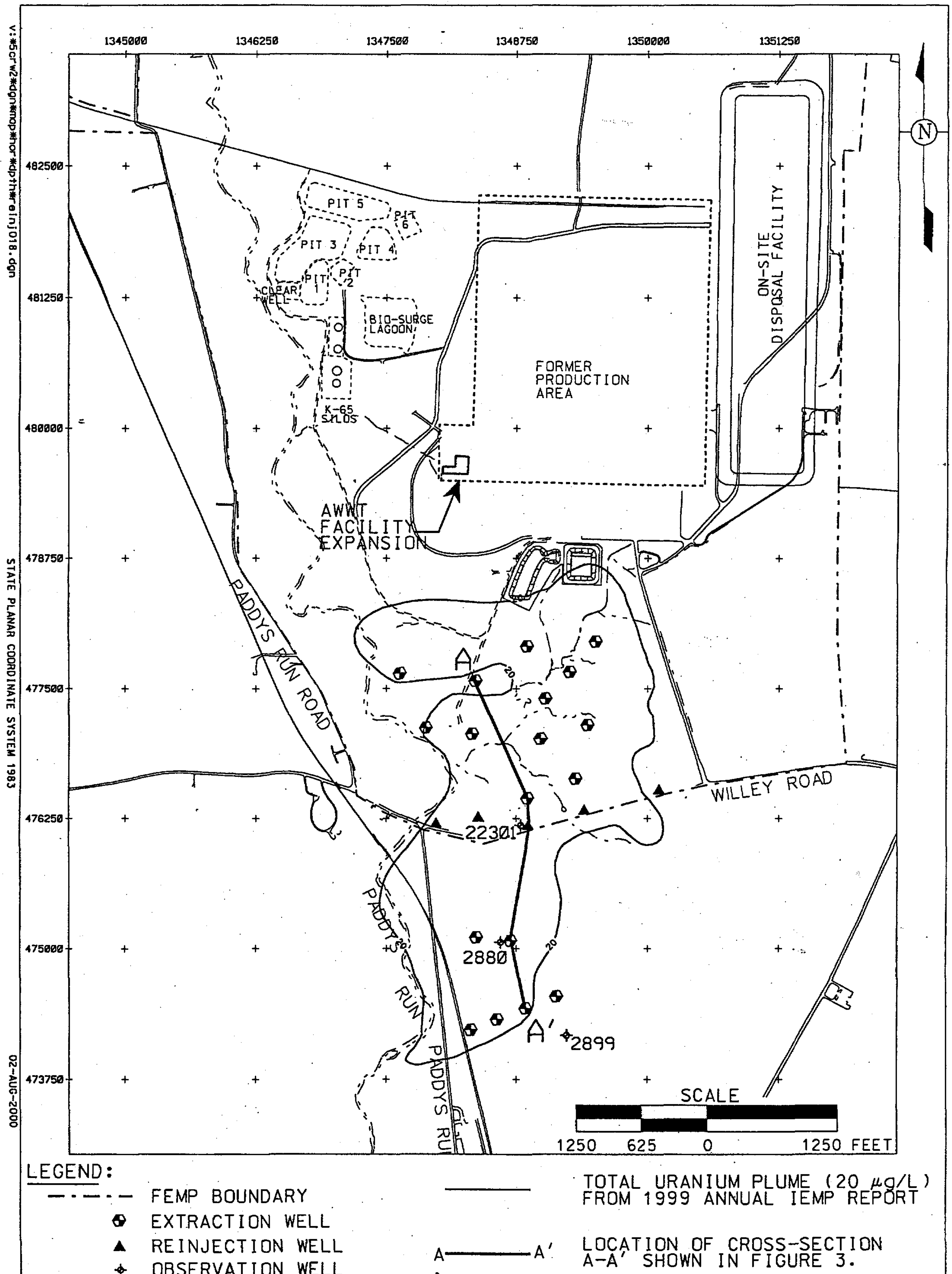

FIGURE 1. LOCATION MAP

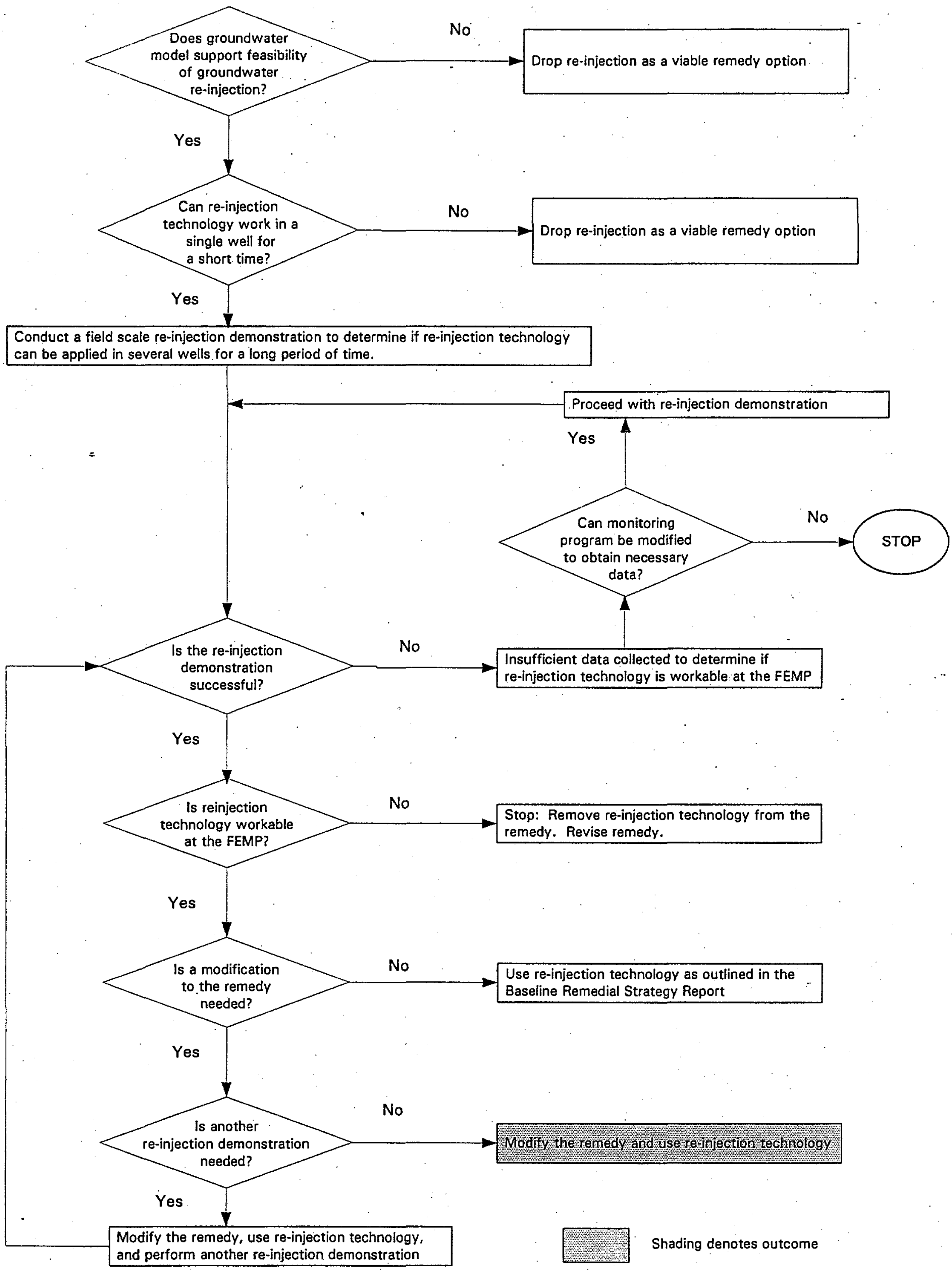

Figure 2 Re-injection Technology Evaluation Flowchart

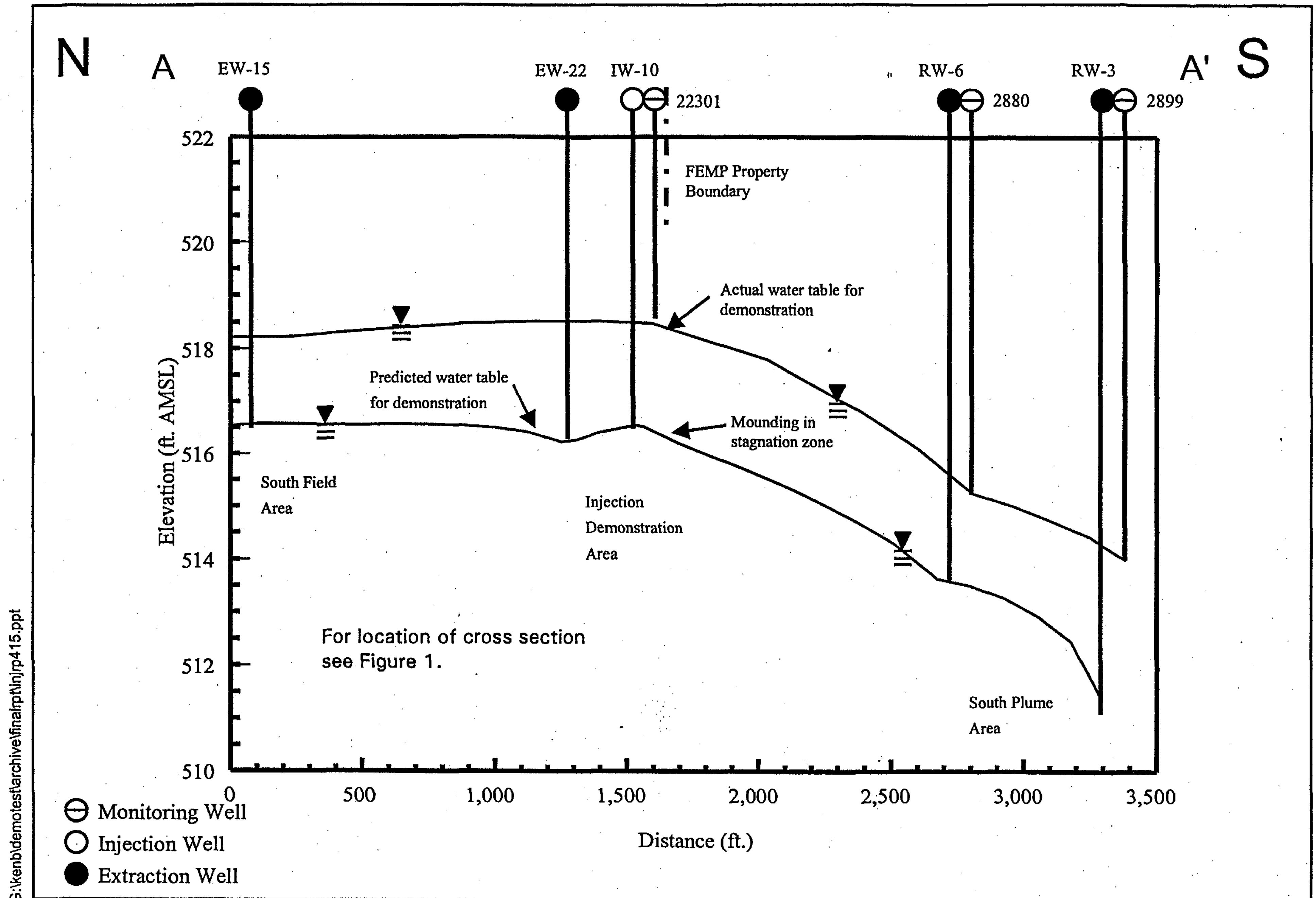

Figure 3. Measured Water Table Elevation Profile for Demonstration Time Period