# Efforts to Improve Efficiency of Extraction Well Operation at the Fernald Preserve, Harrison, Ohio - 16177

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## ABSTRACT

The Fernald Preserve, a former uranium processing facility that produced high-purity uranium metal products during the Cold War, is located in southwest Ohio. The facility became a US Department of Energy Office of Legacy Management (LM) site in November 2006, following completion of the Comprehensive Environmental Response, Compensation, and Liability Act environmental remediation and site restoration (with the exception of groundwater). When the site was turned over to LM, approximately 76.5 ha of the Great Miami Aquifer remained contaminated with uranium above the final remediation level of 30 µg/L.

Here, uranium contamination is being removed from groundwater in the Great Miami Aquifer through a pump-and-treat operation, which is predicted to continue until 2033. Twenty extraction wells pump about 30 million liters per day. Operation of the system is impacted by iron in the groundwater that promotes iron fouling of the well pumps, motors, and screens.

The design of the well field evolved over 21 years and reflected a conservative system that could respond to a wide range of pumping conditions. For instance, some of the extraction wells were sized with pumps and motors that would allow the well to pump up to 1890 L/min (500 gpm) if warranted. The added flexibility, though, came at the cost of operational efficiency.

We describe the efforts that have been taken by LM since the Fernald site was transferred to LM to mitigate the operational impacts from the iron fouling aquifer conditions and improve the efficiency of the well-field operation. Variable-frequency drives were installed at six wells to replace flow control valves. Several wells with oversized pumps and motors were changed from 24-hour per day operation to 8-hour per day operation to allow the pumps to operate closer to their design flow rates. Pumps and motors were “right-sized” at many wells to improve pumping efficiency. The process used to rehabilitate (or clean) well screens was improved, and a process was developed to clean pumps without having to pull them from the well. To reduce pressure drops, improvements were also made to the configuration of the discharge piping. A new control system was installed for each well to allow local control and local tracking of energy used. The amount of energy used daily compared to number of gallons pumped provides a method to assess pump performance and determine when action is necessary to restore well pump efficiency.

Additionally, the metrics being employed to help quantify well-field efficiency improvements are described, and the benefits achieved by proactively managing the pump-and-treat operation are presented.

## INTRODUCTION

The Fernald Preserve is located in southwest Ohio on the site of the former Feed Materials Production Center, a uranium processing facility that produced high-purity uranium metal products as the first step in America's nuclear weapons production cycle. The Fernald Preserve became a US Department of Energy Office of Legacy Management (LM) site in November 2006, following completion of the Comprehensive Environmental Response, Compensation, and Liability Act environmental remediation and site restoration (with the exception of groundwater). When the site was turned over to LM, approximately 76.5 ha of the Great Miami Aquifer remained contaminated with uranium above the final remediation level of 30 µg/L.

At the Fernald site, legacy uranium contamination is being removed from groundwater in the Great Miami Aquifer through a pump-and-treat operation, expected to continue until 2033. Twenty extraction wells pump about 30 million liters per day. Operation of the system is impacted by the oxidation of iron compounds by bacteria in the groundwater that causes biofouling of the well pumps, motors, and screens.

The design of the well field evolved over 21 years and reflected a conservative system that could respond to a wide range of pumping conditions. For instance, some of the extraction wells were sized with pumps and motors that would allow the well to pump up to 31.5 L/s (500 gpm) if warranted. The added flexibility, though, came at the cost of operational efficiency.

The Fernald site is the largest consumer of electricity in the 90-site LM program because of the energy-intensive operation of the groundwater extraction wells. Fernald has the largest active groundwater remedy in LM, with a target of pumping 353 L/s (5590 gpm) continuously. Increasing the efficiency of the wells and using less energy is a high priority for Fernald personnel.

## PROCESS AND RESULTS

Efforts to increase the efficiency of the extraction well operation at the Fernald site focused on several major issues. The first issue to be investigated was of the clogging of the pipes and pumps by a heavy red-brown material. Most of the extraction wells are screened across the water table because that is generally where the highest uranium concentration is found. The pumped water contains high concentrations of iron, manganese, and carbonate, which precipitate out of solution and clog the well screens, the pumps, and the discharge pipes. The precipitate appears to be held together by filamentous bacteria. When well screens become clogged with the precipitate, the specific capacity (gpm/foot drawdown) decreases. More energy is needed to lift the water column from lower in the well to the surface. As the pump bowls and impellers become clogged with the precipitate, more energy is required to rotate the impellers to maintain the desired flow rate from the well. Cleaning the precipitated material to prevent plugging of the screens and pumps is the highest priority for maintaining flow rates and reducing energy usage.

The second issue to be resolved was to ensure that the pumps/motors in each well were the optimal size. The wells were all designed to be pumped continuously for the duration of the remedy. In order to simplify operation and maintenance, pumps and motors were limited to two sizes, one for the 30 cm (12 inch) diameter wells and one for the 41 cm (16 inch) diameter wells. As changes were made to the remedy and flow rates required from each well varied, the pumps originally installed in the wells were not always operating at their design points. Oversized and undersized pumps and motors use more energy to pump the desired flow rate from the well than properly sized pumps and motors.

The third area for improvement was that of control equipment and instrumentation for the wells. The first four wells were installed offsite at the leading edge of the plume in 1993 and were locally controlled with flow control valves to maintain the desired flow rates. Two additional wells were installed offsite in 1998 that also used flow control valves to maintain desired flow rates. Later wells installed onsite were equipped with variable-frequency drives (VFDs) to control flow rates and had simple programmable control stations that allowed remote control of the well from the site's wastewater treatment plant. Recent projects involved installing VFDs at the 6 offsite wells and installing new programmable logic controllers (PLCs) at all 20 wells. The PLCs provide increased control of the well pump and motor in different conditions and a way to track energy used by each well.

The last optimization project undertaken was to remove unneeded check and air release valves and to increase pump discharge headers to 15 cm (6 inch), where possible. Unneeded valves and pipe reducers increase resistance to flow and add to the energy required to pump water from a well to the discharge point.

## Reducing Pipe and Pump Clogging

A paper presented at the Waste Management 2009 Conference discussed methods developed to clean pumps in the well without using a crane to pull and replace them (W.A. Hertel, C. Glassmeyer, and J. Powell, "Fernald Preserve Aquifer Restoration Extraction Well and Pump Maintenance Improvements – 9427"). The cleaning process began in 2009 and is still being used with a chemical that contains a mixture of glycolic and hydrochloric acids. The twenty wells have been treated a total of 204 times with mixed results. The cleaning process consisted of adding 19–38 L (5–10 gal) of the acid mixture to the pump discharge pipe and allowing the mixture to sit in the pump for 1–3 hours. The pump was then cycled on and off manually or from the control station for about 24 hours.

Some pumps respond well to the chemicals, and flow rate improvements over 6.3 L/s (100 gpm) have been seen. Other pumps do not respond as well but experience definite improvements in maximum achievable flow rates. Some wells, however, do not respond to the acid mixture and show little to no improvement. The most unusual wells show significant improvement after some treatments and no improvement after other treatments. The consultant who initially recommended the acid mix being used is going to be retained again this year to see if he has suggestions for the pumps that are not responding to the current chemical mix.

The same mixture of glycolic and hydrochloric acids has been used for the past 7 years for cleaning well screens during the annual well rehabilitation campaign. For the first 5 years it was used for days 1 and 3 of the well rehab, and a 208 L (55-gallon) drum of hydrochloric acid was added on the second day of rehab. For the past 2 years a surfactant was used on alternate days with the mixture of glycolic and hydrochloric acid. The purpose of the surfactant was to remove the small particles that were loosened by the acid. Eliminating the use of hydrochloric acid provided a significant safety improvement to the rehabilitation process.

Well rehabs are usually performed during the summer, and 4 to 6 wells are rehabbed each year. Each rehab costs $12,000–$20,000, so it is important that wells are rehabbed as effectively as possible to minimize the number of wells that require rehab each year.

The initial performance test of wells immediately after the first rehabs using the surfactant showed significant improvement in specific capacity. Unfortunately, the performance test performed 3 months after rehab indicated that the specific capacity for two of the wells had returned to the levels measured before rehab. Figure 1 shows the specific capacity for Well 21 and how it has been affected by rehabs over the past 8 years. Discussions with our well maintenance subcontractor and the consultant are leading us to believe that different methods of rehab may need to be tried with some of the wells. The theory is that the iron bacteria colonies adapt to the acid-based treatment method and it then becomes less effective. Other methods of well rehab are being investigated.

Another change to the pumps has been to have the internal surfaces of all new pumps coated with an epoxy paint to make it slicker so the iron bacteria cannot attach to the cast iron pump bowls easily. This has been a recent change, and its effectiveness cannot yet be evaluated. The use of stainless steel pump bowls was investigated and rejected due to the high cost of of stainless steel pumps. It remains a possible option for the future if the epoxy coated pumps do not last significantly longer than cast iron.

## Right-Sizing Pumps and Motors

The Fernald Preserve well field was installed in six separate projects beginning in 1993 and ending in 2006. Different design engineering firms were used for the projects. To prevent each design firm from using a different type of equipment in each project, a standard design was established. All of the 30 cm (12 inch) diameter wells had seven-stage Byron Jackson 8MQ pumps with 22 kW (30 hp) Byron Jackson motors. The design point for the 8MQ pumps was 18.9 L/s (300 gpm). All of the 41 cm (16 inch) diameter wells had five-stage Byron Jackson 10MQ pumps with 30 kW (40 hp) Byron Jackson motors. The design point for the 10MQ pumps was 31.5 L/s (500 gpm).

The design flow rate for all the wells was 6.3, 12.6, or 18.9 L/s (100, 200, or 300 gpm). The design flow rates were based on the results of modelling data for removing uranium from the aquifer. The design flow rates were agreed to by all involved regulatory agencies and are enforceable by the regulators. In order to ensure the design flow rates are achieved, the operational setpoints for the wells are set 10% higher than the design flow rates to account for downtime for maintenance.

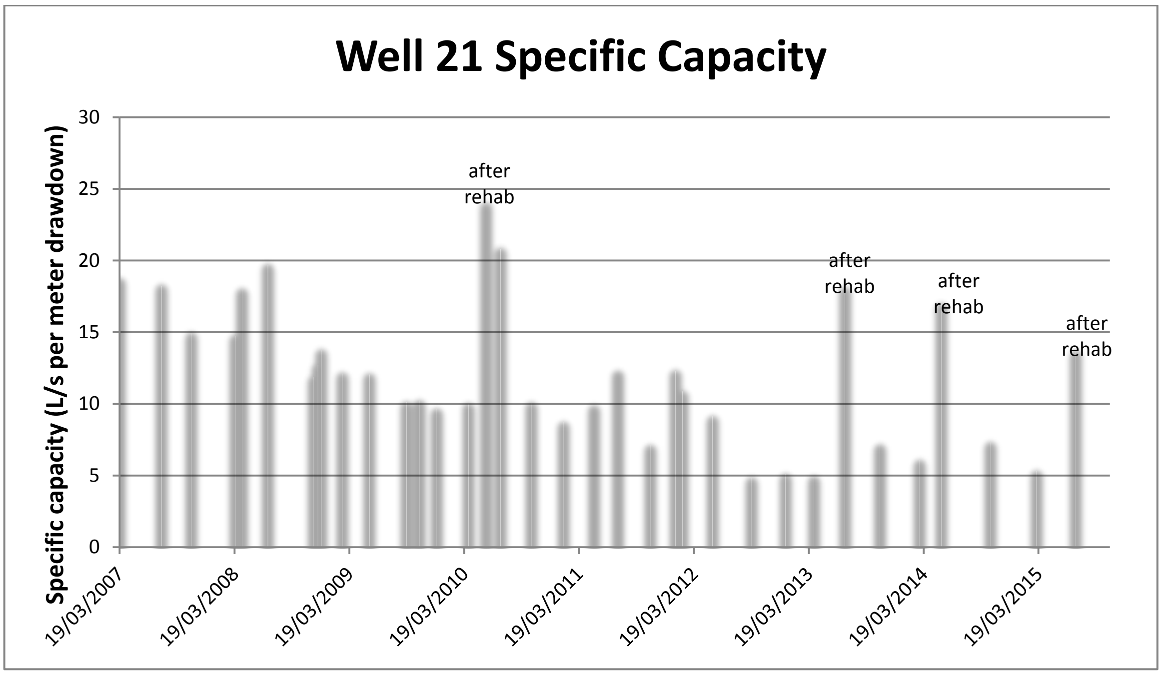

Figure 1. Well 21 Specific Capacity

Because of the plugging of wells screens and clogging of pumps, the well pumps do not operate at their design points very long. It has become standard practice to install a well with a design point about 12.6 L/s (200) gpm higher than the well setpoint to allow the pump to continue operating for the longest time possible.

In summer 2012, some operations personnel suggested operating the wells that have design setpoints of 6.3 L/s (100 gpm) at 18.9 L/s (300 gpm) for 8 hours per day instead of 6.3 L/s for 24 hours per day. The basis for the suggestion was that the optimal design point for the pumps in those 4 wells was 18.9 L/s. According to the pump curve, the most efficient point of operation for the pump was the design point. Operating the pump at its setpoint should result in less energy use. The concept of operating the pumps for 8 hours per day instead of 24 hours per day was called “pulse pumping.” The geologist in charge of modeling well pumping at the Fernald Preserve modeled pulse pumping the four wells with 6.3 L/s design flow rates and determined that capture of the plume could be maintained while pulse pumping. Pulse pumping began in September 2012 after concurrence was received from Ohio and US EPAs.

Pulse pumping was performed manually by operators starting the pumps in the morning and stopping them each day before they went home. The pumps could only be pulse pumped during the day since the site is only staffed during the day. The main drawback to pulse pumping was that it increased the pressure in the well discharge header because the four wells were pumping at 18.9 L/s (300 gpm) each instead of 6.3 L/s (100 gpm). The increase of 50.5 L/s during the day caused some of the other wells to work harder to meet their setpoints.

After a new control system was installed at the wells in 2014, wells could be pulse pumped at different times during the day to reduce energy use at all of the wells.

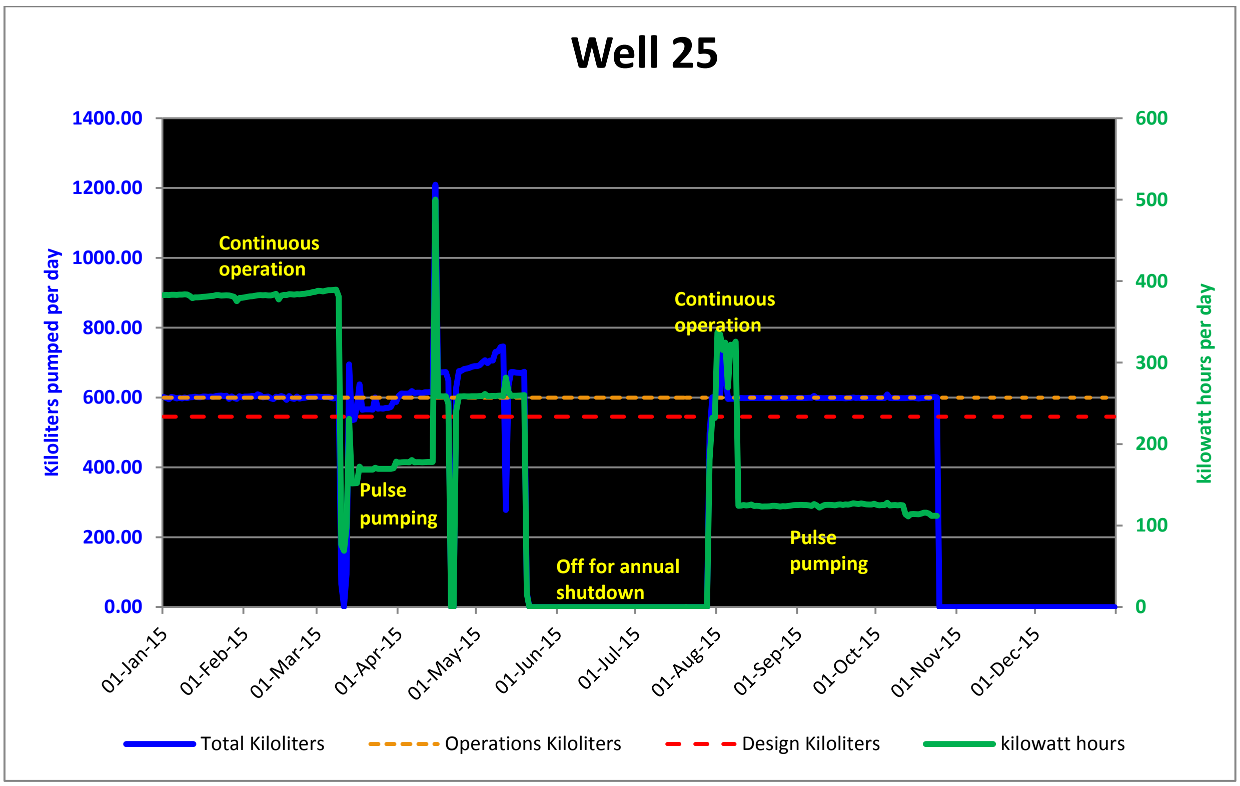


Figure 2. Kiloliters per day Pumped by Well 25 During 2015

Figure 2 shows the daily output and energy usage of Well 25 during 2015. For the first 2 months, the pump was operated continuously and used an average of 380 kilowatt hours per day (kWhr/day). In March it was switched back to pulse pumping, and the energy use was reduced to about 180 kWhr/day. A new pump was installed in July. During continuous operation, it used about 350 kWhr/day and only about 140 kWhr/day when it was switched to pulse pumping in late August. All of the pulse pumping wells show similar reductions in energy use.

In summer 2014, a new operating design for the well pumping rates was approved by Ohio and US EPAs. Flow rates for eight wells were increased, and three wells that were outside the plume were shut down. The design change was implemented to decrease the time required to clean up the aquifer to the safe drinking water limit. The goal is to operate all pumps at 10% over the design point for each well and reduce energy use as much as possible. Pumps and motors were moved from wells where they were over- or undersized to wells where the pump design point is closest to the well design flow rate. While this seems like an obvious concept, it resulted in more complicated planning for well maintenance and required having more spare pumps and motors available. Instead of only two sizes of pumps and motors, there are now seven sizes of pumps and four sizes of motors in use.

## Control Equipment and Instrumentation

The first four wells installed at the Fernald Preserve were installed offsite at the leading edge of the contamination plume. They were installed in 1993, and the flow rate from the wells was controlled by flow control valves. Two additional wells were installed in that area in 1998 that also were controlled by flow control valves. All of the wells installed onsite had VFDs to control the flow rate and were designed to be controlled by the computerized control system at the site’s wastewater treatment facility. Flow control valves are an inefficient way of controlling flow because the motor operates at 100% speed all the time. The flow control valve closes and opens as needed to maintain the desired flow rate. A VFD is a more efficient way of controlling flow rates because the motor only operates at the speed needed to maintain the desired flow rate.

A project was implemented in fall 2011 to install a VFD at Well 4. Fernald Preserve operations personnel installed the VFD with some assistance from a subcontractor electrician. The same type of VFD was installed as was in use at all the onsite wells. Figure 3 shows how the number of gallons pumped per kilowatt hour used increased after the installation of the VFD. The blue line shows the average L/kWh for the periods before and after installation of the VFD.

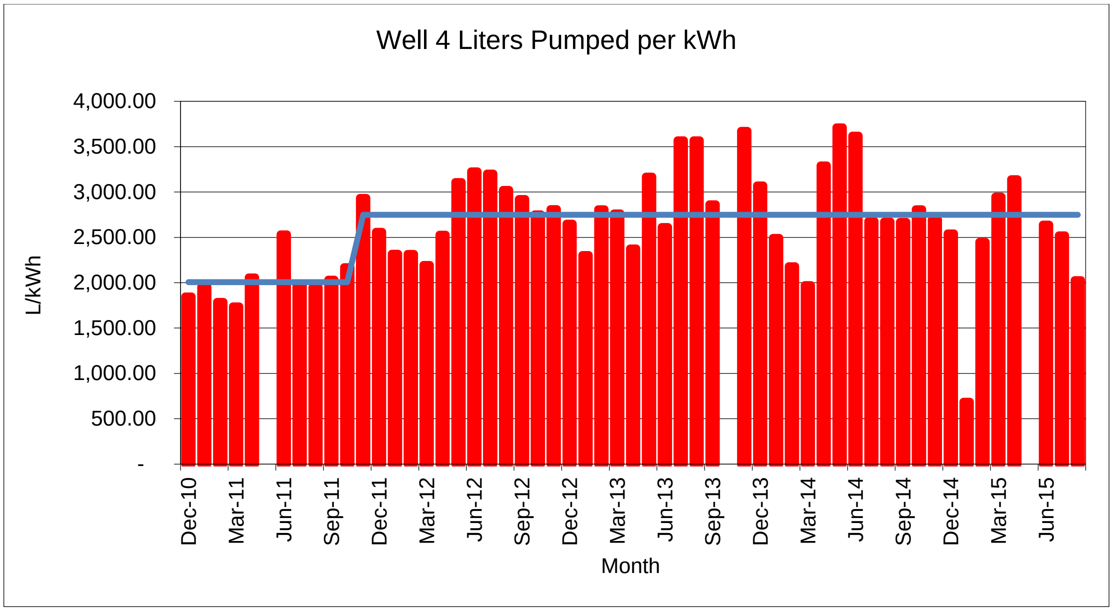


Figure 3. Number of Liters Pumped per Kilowatt Hour at Fernald Site Well 4

VFDs were installed in the five remaining wells with flow control valves in 2013. The number of gallons pumped per kilowatt hour used has also improved for each of these wells. The amount of improvement varies by well.

In 1998, programmable control stations were installed at each of the wells to allow the pumps to be controlled locally or remotely from the wastewater treatment facility. The programmable control stations were programmed using a laptop computer that used Windows 97. The control stations and programming computer were both obsolete by 2013. A project was initiated in late 2013 to replace all the control stations with PLCs. The objectives for the new PLCs were to update hardware and software and to include control mode for well cleaning and pulse pumping and the ability to track energy used by each well.

A control mode for pulse pumping was created that allowed the pump to be started and stopped any time of day automatically. Currently, three wells are being pulse pumped at 18.9 L/s (300 gpm) at different times of day. Since only one of the pulse pumping wells operates at a time, the pressure in the discharge header has been reduced and energy used throughout the well field has been reduced.

The control mode for well cleaning allows the operator to select the motor output percentage. With the old control system, the operator could only set the desired flow rate and not the motor speed. For pump cleaning the objective was to simply spin the pump slowly to mix the acid inside the pump and not pump the acid up the discharge pipe. Without the ability to control motor speed, the only way to mix acid was to turn the motor on for about 5–10 seconds and off 4 times an hour for 24 hours. The new control system allows the operators to control the motor speed to slowly mix the acid through the pump for any desired duration.

Energy used by the motor is tracked by the new PLC by recording the kWh used each day. The daily kWh usage is tracked in a spreadsheet with daily gallons pumped. When the number of kWh begins trending up, it means that the motor is working harder to pump the same amount of water. That is being used as an indicator that the pump is becoming clogged. The pump can then be treated with the acid mixture to try to clean it before the pump can no longer achieve its setpoint.

### Data Collection and Tracking

The amount of data collected for every well has increased significantly in the past several years. The new control system allows the tracking of kWh of power consumption so that the number of gallons pumped per kWh used can be trended. This information is being used to treat pumps before they become totally clogged.

Data collected during pump treatments includes number of gallons of acid added, wait time before pump is started, motor rpm during cycling, pressure and maximum flow rate before treatment, pressure and maximum flow rate after treatment, and pH and color of spent acid solution pumped from the well. These data are being used to try to identify why some treatments result in significant improvement to maximum flow rate and others result in no improvement. The number of times each pump has been treated is tracked to see if cleanings become less effective the more each pump is cleaned.

Other data being tracked about each well are the date, type, and size of pump and motor installed in each well. These data are used to ensure that an adequate number of spare pumps and motors of every size are available and to budget for future pump and motor purchases.

## CONCLUSIONS

Efforts to improve the operation of the extraction wells at the Fernald Preserve have been successful and cover all aspects of the wells and their associated equipment. The rehabilitation process for the wells has been changed, and the results are being studied to see where additional improvement can be made. A process for cleaning pumps in situ has been developed, and data gathered from that process is also being reviewed for potential improvements.

Pumps and motors have been installed in wells where they can operate at their optimal efficiency points. Pumps that are oversized are only being pumped for 8 hours per day instead of 24 hours to allow them to operate more efficiently. Consequently, pumping efficiency has increased, measured by volume pumped per kilowatt hour of electricity used.

New instrumentation was installed at all the wells to allow the tracking of energy use and better control of the motor for pulse pumping and in situ pump cleaning. The energy use data has allowed in situ pump cleaning to be performed when energy use increases, but before the pumps become totally plugged. The improved control of the motor has allowed different methods of mixing acid through the pump without the need for an operator to be at the well starting and stopping it.

Because the extraction wells are predicted to remain in operation for 10–20 more years, the process of improving operation of the extraction wells will continue for the duration of the groundwater remedy at the Fernald Preserve. The methods currently being used will continue as long as they are effective. Other methods will be investigated and implemented if they show potential for improving operation and equipment life.