

**Groundwater Remediation at the Fernald Preserve, Cincinnati, Ohio:
Overview and Status - 10318**

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ABSTRACT

This paper summarizes and provides the status of the groundwater remediation under way at the Fernald Preserve near Cincinnati, Ohio, and the efforts being taken to manage and protect human health and the environment through effective and efficient long-term-surveillance and maintenance.

The Fernald Preserve became a U.S. 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 189 acres of the Great Miami Aquifer remained contaminated with uranium above the final remediation level of 30 micrograms per liter.

Pump-and-treat technology is being used to remediate the aquifer. Twenty-three extraction wells are operating at a combined target pumping rate of 4,775 gallons per minute. Groundwater modeling predictions indicate that pump-and-treat operations will continue until 2023. Certifying the modules and removing the remediation infrastructure after pump-and-treat operations are complete will likely require a minimum of 3 additional years.

SITE BACKGROUND

The Fernald Preserve is a 1,050-acre site, approximately 18 miles northwest of Cincinnati, Ohio. The preserve overlies the Great Miami Aquifer (GMA), which the U.S. Environmental Protection Agency (EPA) has designated as a sole source aquifer.

In 1951, the U.S. Atomic Energy Commission—predecessor agency to the U.S. Department of Energy (DOE)—began building the Feed Materials Production Center outside the small farming community of Fernald, Ohio. The facility's mission was to produce "feed materials" in the form of purified uranium compounds and metal for use by other government facilities involved in producing nuclear weapons for national defense.

The feed materials facility operated from 1952 to 1989, produced more than 500 million pounds of uranium metal products, and contaminated the soil, surface water, sediment, and groundwater on and around the site. In 1991, the site's mission was formally changed from uranium production to environmental remediation and restoration under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The cleanup project was divided into Operable Units. Operable Unit 5 focused on environmental media and biological receptors, including groundwater, impacted by site activities.

With the exception of the GMA, physical completion of the CERCLA remediation was declared on October 29, 2006, and the site was officially transferred to DOE's Office of Legacy Management (LM). By then, all contaminated soils had been excavated and certified to meet final remediation levels (FRLs) (with the exception of certain areas associated with utility corridors and groundwater infrastructure left in place to remediate the aquifer); the on-site disposal facility was complete; all required groundwater infrastructure was installed, operational, and secured; and restoration activities were completed within all excavated areas.

NATURE AND EXTENT OF GMA CONTAMINATION

An evaluation of the nature and extent of contamination in the GMA is documented in the *Remedial Investigation Report for Operable Unit 5* [1]. The report concludes that of the GMA's 50 constituents of concern, uranium is the principal one. When the site was turned over to LM in 2006, approximately 189 acres of the GMA remained above the uranium FRL of 30 micrograms per liter ($\mu\text{g/L}$).

The primary sources of contamination that contributed to the present geometry of the uranium plume include (1) the former waste pits that were present in the Waste Storage Area; (2) the former inactive fly ash pile that was present in the South Field; (3) former production activities; and (4) the previously uncontrolled surface water runoff from the former production area, which had direct access to the aquifer through former drainage features. Figure 1 shows the extent of the uranium plume ($30 \mu\text{g/L}$ or higher) as of the second half of 2008.

GROUNDWATER REMEDY

The *Final Record of Decision for Remedial Actions at Operable Unit 5* (ROD) [2] defines a pump-and-treat groundwater remedy for Fernald and establishes FRLs for the 50 constituents of concern. The extraction system is divided into three modules: (1) the South Plume, (2) the South Field, and (3) the Waste Storage Area.

Pumping in the GMA began in 1993 from four recovery wells installed at the southernmost tip of the uranium plume. The objective was to capture the leading edge of the uranium plume and prevent it from mixing with off-site industrial plumes known to be present downgradient of the Fernald plume. From 1998 to 2004, re-injection was used to enhance the remedy. Re-injection, however, was discontinued based on groundwater modeling and the unfavorable results of a cost/benefit analysis.

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The restoration strategy focuses primarily on the removal of uranium, but it is also designed to:

- Limit the further expansion of the plume.
- Remove all targeted contaminants to concentrations below FRLs.
- Prevent undesirable draw-down impacts beyond the Fernald property.
- Prevent contamination in downgradient industrial plumes from being pulled into the Fernald plume.

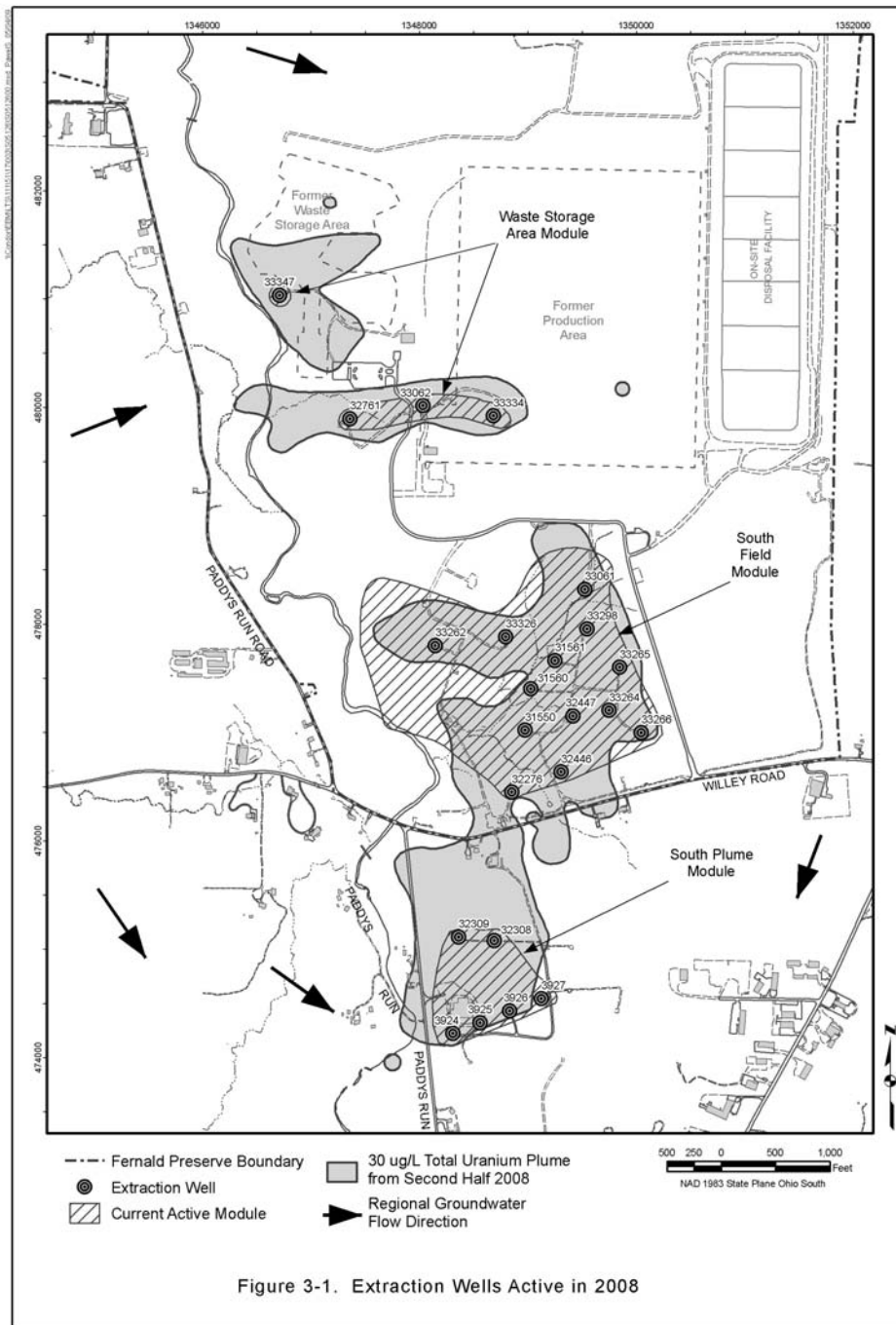


Fig. 1. Plume map from second half of 2008, showing the location of active extraction wells.

The well field currently consists of 23 extraction wells with design target pumping rates from 100 to 300 gallons per minute (gpm) each. Figure 1 shows the location of the extraction wells. The total well field design target pumping rate is 4,775 gpm, or approximately 6.9 million gallons per day. Since pumping began in 1993, over 26 billion gallons of water have been pumped from the GMA, over 9,000 pounds of uranium have been removed from the GMA, and approximately 9.78 billion gallons of groundwater have been treated.

Uranium is removed from the groundwater extracted from the GMA as necessary to achieve discharge limits specified in the ROD. Discharge limits are set at 600 pounds of uranium per year and an average discharge concentration of 30 µg/L per month.

Figure 2 illustrates the percentage of water treated compared to the monthly average uranium discharge concentration over time. As Figure 2 shows, since 2005, the percentage of treatment needed to achieve discharge limits has been decreasing. Very soon, treatment will no longer be required.

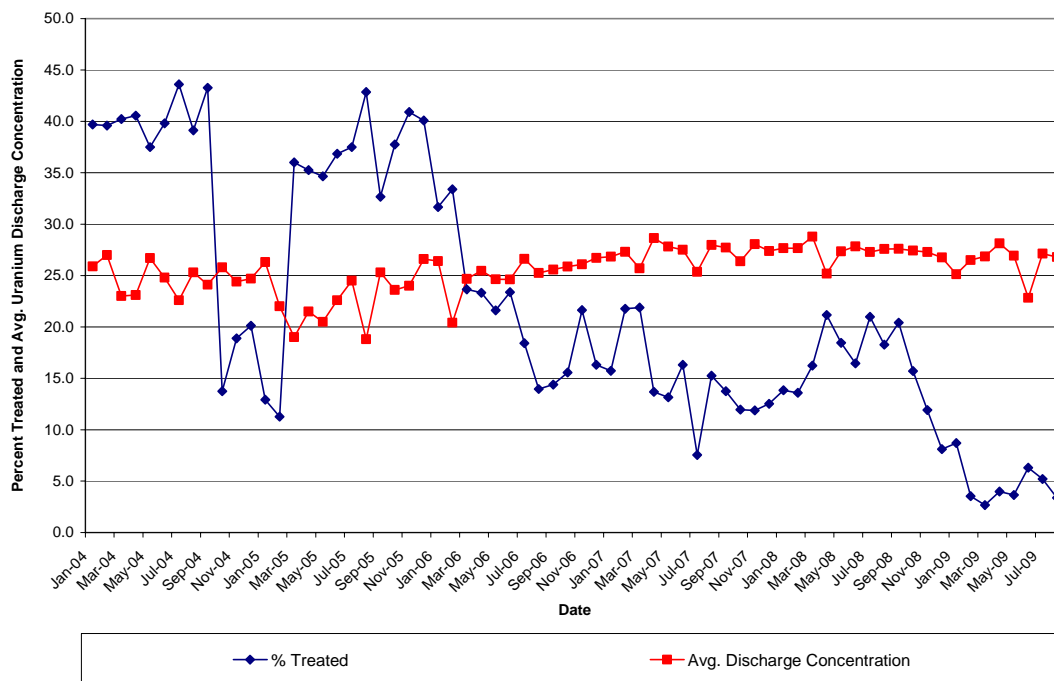


Fig. 2. Percentage of water treated compared to the monthly average discharge concentration over time.

In the near future, DOE will request that EPA and the Ohio Environmental Protection Agency approve the shutdown and decommissioning of the water treatment facility. This request will include a continued commitment to maintain aggressive pumping rates in order to maximize mass removal from the aquifer and shorten remediation times.

MANAGING THE REMEDY

LM is responsible for completing the groundwater remedy at Fernald. One of LM's main goals is to protect human health and the environment through effective and efficient long-term surveillance and maintenance. This is being accomplished at the Fernald Preserve by:

- Following the approved *Fernald Groundwater Certification Plan* [3].
- Proactively managing pump-and-treat uncertainty.
- Maintaining aggressive operations.
- Involving stakeholders.

GROUNDWATER CERTIFICATION PLAN

The *Fernald Groundwater Certification Plan* [3] defines a method for verifying the completion of the groundwater remedy. Preferably, pump-and-treat technology will make it possible to meet the remediation goals defined in the ROD, and the cleanup will be certified complete. However, the plan also covers other potential contingencies and exit scenarios.

The plan defines a six-stage groundwater cleanup certification process:

- **Stage 1—Pump-and-treat operations:** Pump-and-treat operations will continue in each module until groundwater FRL constituent concentrations have been achieved. Groundwater modeling predicts that pump-and-treat operations will be complete in the South Plume module first, followed by the South Field module and then the Waste Storage Area module. All modules are currently in Stage 1 of the process.
- **Stage 2—Post-pump-and-treat operations/hydraulic equilibrium state:** Groundwater levels and uranium concentrations will be routinely measured to document that steady-state water levels and concentrations have been achieved following the completion of pump-and-treat operations.
- **Stage 3—Certification/attainment monitoring:** For 3 years, water level and water quality monitoring will be conducted quarterly in all available wells located in the aquifer restoration footprint to document that FRLs continue to be maintained.
- **Stage 4—Declaration of transition monitoring:** A certification report, documenting that the FRLs have been successfully reached and maintained, will be prepared and issued.
- **Stage 5—Demobilization:** Groundwater remedy infrastructure (including water treatment facilities, valve houses, and underground piping) will be demolished and disposed of. Well abandonment, soil excavation, certification, and closeout reporting for each module will be completed.

- **Stage 6—Long-term monitoring:** Long-term monitoring will be conducted for a minimum of 5 years to document the impact (if any) that residual uranium contamination in the vadose zone has on constituent concentrations in the certified-clean aquifer. The concern is that in the future, water levels could rise and dissolve uranium that is fixed in the vadose zone beneath former source areas.

A phased approach is being implemented for each stage of the process. Remediation of the off-property portions of the uranium plume are targeted to be completed first because the ROD has made doing so a priority.

Groundwater modeling predictions reported in the *Waste Storage Area Phase II Design Report* [4] indicate that pump-and-treat operations will proceed in the South Plume module until 2015, in the South Field module until 2022, and in the Waste Storage Area module until 2023. Certifying the cleanup of the modules and removing the remediation infrastructure will require a minimum of 3 additional years. As a result, the aquifer remedy will be completed no earlier than 2026.

PROACTIVELY MANAGING PUMP-AND-TREAT UNCERTAINTY

Managing the groundwater remedy effectively and efficiently requires that uncertainties and risks be properly identified and factored into the remedy. Two large risks associated with any pump-and-treat operation are overly optimistic modeling predictions and the rebounding of FRL constituent concentrations after pump-and-treat operations end.

Modeling Predictions

During a pump-and-treat remediation, groundwater contaminant concentrations decrease over time. To evaluate progress, a regression line can be fitted to the plotted concentrations. If the slope of the regression line reaches zero at an average contaminant concentration value that is at or below the groundwater FRL, there is no problem, but if the slope of the regression line reaches zero at an average contaminant concentration that is above the groundwater FRL, then pump-and-treat objectives will not be achieved.

Pump-and-treat modeling predictions are often overly optimistic. Representing aquifer complexities such as heterogeneity, isotropy, and geochemical conditions in a groundwater model is problematic. Comparing model predictions to actual concentration trends measured in the field provides a method for assessing how realistic modeling predictions are.

General Methods for Remedial Operation Performance Evaluations [5] provides guidelines for establishing a timeframe for achieving pump-and-treat objectives using measured concentration data. The guidelines recognize the asymptotic nature of concentration decline curves associated with pump-and-treat operations and suggest that this uncertainty be addressed by using a 95 percent upper concentration limit (UCL) of the measured uranium concentration data to establish a conservative estimate to complement the estimate made using the actual concentration data.

At Fernald, the modeled well concentration trends are also used to determine how model-predicted concentrations compare to the actual and conservative concentration trends. An example is shown in Figure 3. The measured data indicate that the uranium groundwater FRL will be reached in this well around 2011. The trend of the 95 percent UCL indicates that the uranium groundwater FRL will not be reached until approximately 2020. This indicates that the pump-and-treat portion of the aquifer remedy will be completed at this location between 2011 and 2020. The model-predicted concentration trend shows that the actual data trend matches the groundwater model's prediction more closely than it does the conservative data trend of the UCL. So, this well appears to be on target to achieve its pump-and-treat objective early in the 2011-to-2020 timeframe. Presenting concentration trend data in this format provides insight into whether groundwater modeling predictions adequately reflect conditions observed in the field.

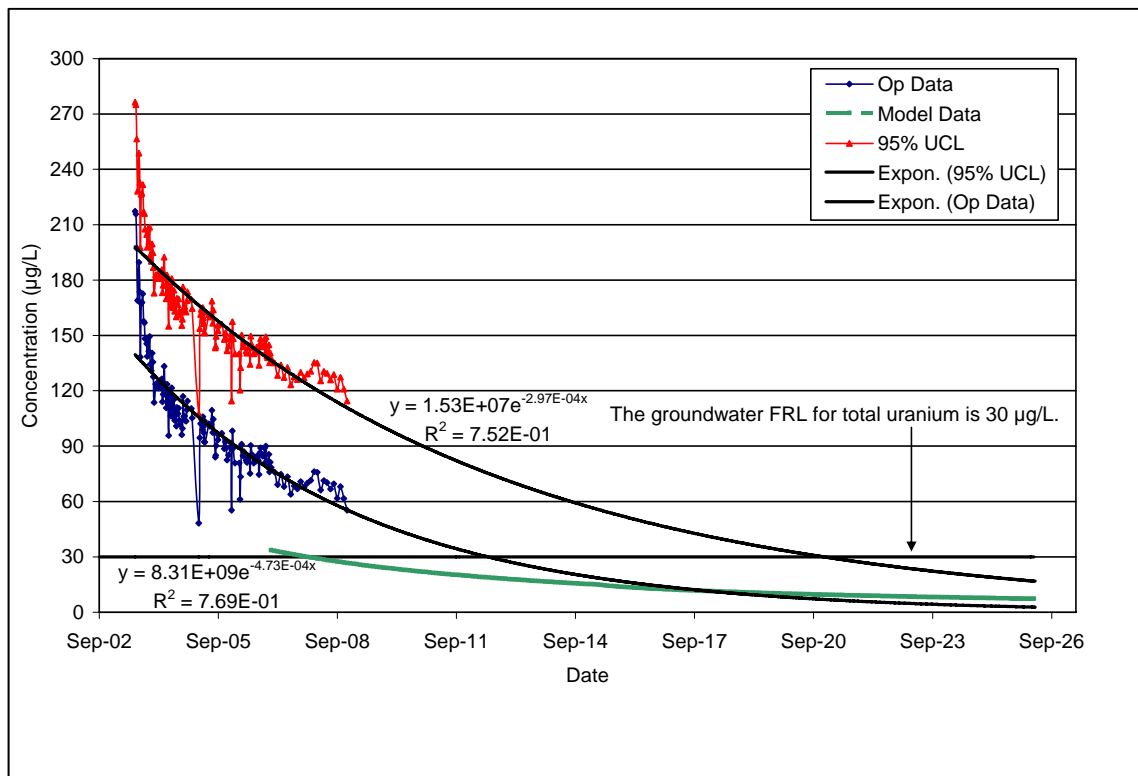


Fig. 3. Uranium concentration decline curves for Well 30.

Data at Fernald indicate that the uranium concentration decline curves for the extraction wells are becoming more asymptotic each year. To date, though, the model-predicted concentration curve more closely resembles the concentration data being measured in the extraction wells than the curve defined by the 95 percent UCL, suggesting that the model-predicted cleanup estimates resemble what is being observed in the field.

By the end of 2008, the pump-and-treat remedy had removed approximately 9,126 pounds of uranium from the GMA. Groundwater modeling predictions indicate that

a total of 13,890 pounds will have been removed upon completion of the remedy. Data regression calculations on the uranium concentration data set indicate a total of 13,273 pounds, and the 95 percent UCL of the uranium concentration data set indicates another 23,553 pounds. The estimated percentage of completion at the end of 2008 was 69 percent based on the measured uranium concentration data, 66 percent based on the model predictions, and 39 percent based on the 95 percent UCL of the measured uranium concentrations.

Rebounding of Contaminant Concentrations

Once pump-and-treat operations stop, water levels commonly rebound. The associated contaminant concentrations also tend to rebound because of the heterogeneity of the aquifer materials, because de-stressing the aquifer causes geological changes, and because rising water levels re-saturate portions of the upper aquifer where contamination is sorbed to aquifer material.

Uranium contamination is known to be bound to aquifer sediments in the unsaturated portion of the GMA beneath former contamination source areas. This contamination will remain bound unless water levels in the aquifer are allowed to rise, saturate the contaminated sediments, and enable the bound contamination to dissolve into the groundwater. Annual well field shutdowns began at Fernald in 2007 so that water levels each year are allowed to rise as much as possible and saturate some of the aquifer material that is not normally saturated. To achieve the highest water level possible, the well field shutdowns coincide with seasonal high water levels in the aquifer.

The annual shutdowns provide insight into what effects rebounding might have, and help mitigate rebounding's eventual impact on completing the pump-and-treat objectives.

Figure 4 illustrates the water level changes that have been monitored during each of the three shutdown exercises conducted since 2007. The maximum measured water level rises in 2007, 2008, and 2009 were 2.6 feet, 2.5 feet, and 3.1 feet, respectively. Uranium concentration data collected in the monitoring wells revealed mixed results. In some wells, uranium concentrations during the shutdowns increased; in others, uranium concentrations decreased.

MAINTAINING AGGRESSIVE OPERATIONS

DOE is committed to maintaining design-established pumping rates at Fernald in order to maximize mass removal from the aquifer and shorten remediation times. The ROD and subsequent *Explanation of Significant Differences for Operable Unit 5* [6] stipulate compliance with a monthly flow-weighted average total uranium concentration of 30 µg/L at the Great Miami River. The ROD stipulated, in addition to the concentration limitation, that the total mass discharged during a year may not exceed 600 pounds.

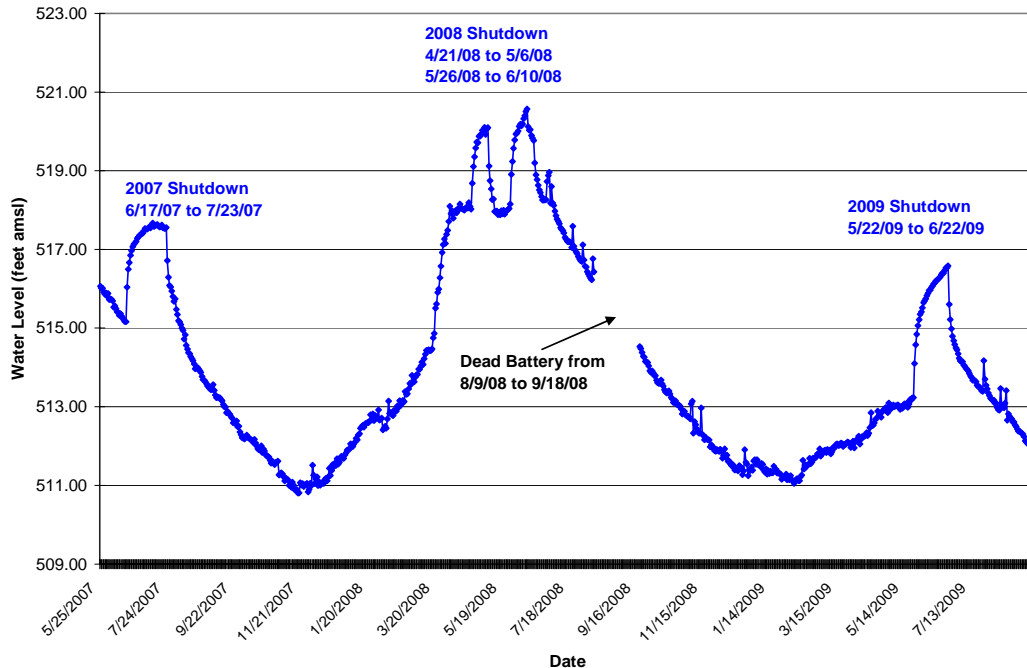


Fig. 4. Rebound-exercise water levels.

The groundwater remedy is based on the groundwater modeling design, presented in the *Waste Storage Area Phase II Design Report* [4], which establishes a target pumping rate of 4,775 gpm. Since the site's transition to LM in 2006, LM has increased actual groundwater extraction rates from 78 percent of the target in 2006 to 97 percent in 2007, 99 percent in 2008, and 105 percent in 2009 (through September), while maintaining compliance with uranium discharge limits. LM has done so by more aggressively testing and maintaining well field performance [7]. Crucially, each well's performance is rigorously tested each quarter, which provides the data necessary to promptly maintain the well pumps, motors, and screens. Moreover, LM cleans the pumps and well screens using refined methods and chemicals that reduce clogging in the pumps and screens.

STAKEHOLDER INVOLVEMENT

An important and often overlooked aspect of effectively managing a groundwater remediation is stakeholder involvement. At Fernald, there are several ways that stakeholders can stay involved: Site environmental reports are issued annually, and public meetings are held routinely to keep stakeholders informed of progress being made toward remediating the aquifer. Additionally, at the Fernald Preserve Visitors Center, information and displays regarding the groundwater remediation are provided and the staff is available to answer questions regarding the groundwater remediation. Approximately 12,000 visitors used the Center during its first 15 months of operation (Summer 2008 to Fall 2009). Tours of the water treatment facility are also available and detailed explanations of the groundwater remediation efforts and associated infrastructure are provided by Aquifer Restoration Project technical personnel upon request.

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