Status and Performance of the On-Site Disposal Facility Fernald Preserve, Cincinnati, Ohio – 11137

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ABSTRACT

The On-Site Disposal Facility (OSDF) was constructed at the Fernald, Ohio, Site for disposal of wastes generated during site cleanup. The 36 ha OSDF comprises eight individual cells; the facility was closed in October 2006 with the capping of the eighth cell. The Fernald Site became a U.S. Department of Energy Office of Legacy Management Site in November 2006.

The OSDF has a composite cover system and a double liner system containing cell-specific leachate collection systems (LCSs) and leak detection systems (LDSs). Groundwater is monitored beneath the facility at two levels via a network of monitoring wells.

This paper presents the status and performance of the facility using results from cap inspections, monitoring pre- and post-closure LCS and LDS flow volumes, and monitoring leak detection constituent concentrations from the LCS, LDS, and monitoring wells. The paper also presents the activities being undertaken to manage and protect human health and the environment through effective and efficient long term-surveillance and maintenance of the OSDF. A discussion of the complexity of monitoring a disposal facility constructed on a footprint that was remediated to risk-based cleanup levels is also provided.

FERNALD SITE BACKGROUND

The 425 ha Fernald Preserve is located approximately 29 km 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, a predecessor agency of 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 purified uranium compounds and metal for use by other government facilities involved in the production of nuclear weapons for the nation's defense.

The feed materials facility operated from 1952 to 1989 and produced more than 226.8 million kilograms (500 million pounds) of uranium metal products. Site operations resulted in contamination of soil, surface water, sediment, and groundwater on and beneath the site. In 1991 the uranium production mission formally ended, and the site's mission changed 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 (OU5) focused on environmental media and biological receptors impacted by site activities, including groundwater.

With the exception of contamination that remained in the GMA, physical completion of the CERLCA remediation was declared on October 29, 2006, and the site was officially transferred into DOE's Office of Legacy Management (LM). Upon transfer to LM, all contaminated soil 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 (OSDF) was completed; all required groundwater infrastructure was installed, operational, and secured; and restoration activities were completed within all excavated areas.

ON-SITE DISPOSAL FACILITY

DOE worked with site stakeholders to develop a balanced approach to site waste disposal. The approach called for encapsulating the less-contaminated wastes on site and shipping the more highly contaminated wastes via train and truck to permitted disposal facilities in Utah and Texas. Because the GMA underlies the site, DOE requested a waiver of Ohio solid waste landfill siting criteria; the waiver was obtained prior to the construction of the OSDF.

Prior to construction of the facility, soil underlying the OSDF footprint was remediated to the cleanup criteria established under CERCLA. Residual contamination above background but below cleanup standards in the facility area has complicated the leak detection monitoring program for the facility.

Waste acceptance criteria that were protective of the GMA were developed and approved by EPA and Ohio EPA (OEPA) prior to design and construction of the facility. A waste acceptance organization was formed by the contractor to ensure that the waste acceptance criteria were met throughout the construction/filling of the facility. This organization, with oversight by EPA and OEPA, was active during the entire filling of the OSDF. A strict construction quality assurance and quality control program was also developed and implemented throughout the construction, filling, and capping of the facility. This program was also subject to oversight of EPA and Ohio EPA.

The facility was constructed, filled, and capped cell by cell from 1997 to 2006; final capping was completed in October 2006.

Facility Description

The OSDF occupies approximately 36 ha in the northeast area of the Fernald Preserve (Fig. 1). It has a capacity of 2.26 million cubic meters and a maximum height of approximately 20 m. The facility consists of eight individual cells with a multilayer composite cover system nearly 3 m thick. Fig. 2 depicts the individual components of the cover. The purpose of the cover is to keep water, plant roots, and burrowing animals out of the facility.

Fig. 1. Aerial View of the Fernald Site (outlined in red) June 2010 with OSDF Outlined in Blue.

Protection of the GMA and the overlying perched groundwater system includes the following measures for each of the eight cells (refer to Fig. 2 for a cross section of the liner system):

- Leachate collection system (LCS)
- Leak Detection System (LDS)
- Multilayer composite liner system
- Multilayer composite cap system

The LCS consists of a gravel layer installed beneath the waste to collect rainwater that came into contact with the waste during cell construction and additional moisture that is draining from the waste following capping. The LDS is located beneath both the LCS and the primary geosynthetic liner system and provides a mechanism for collecting and monitoring leakage through the primary liner layer of the OSDF prior to any releases to the environment. Both systems drain to the west and extend beyond the synthetic liner systems into valve houses, where leachate becomes accessible for monitoring.

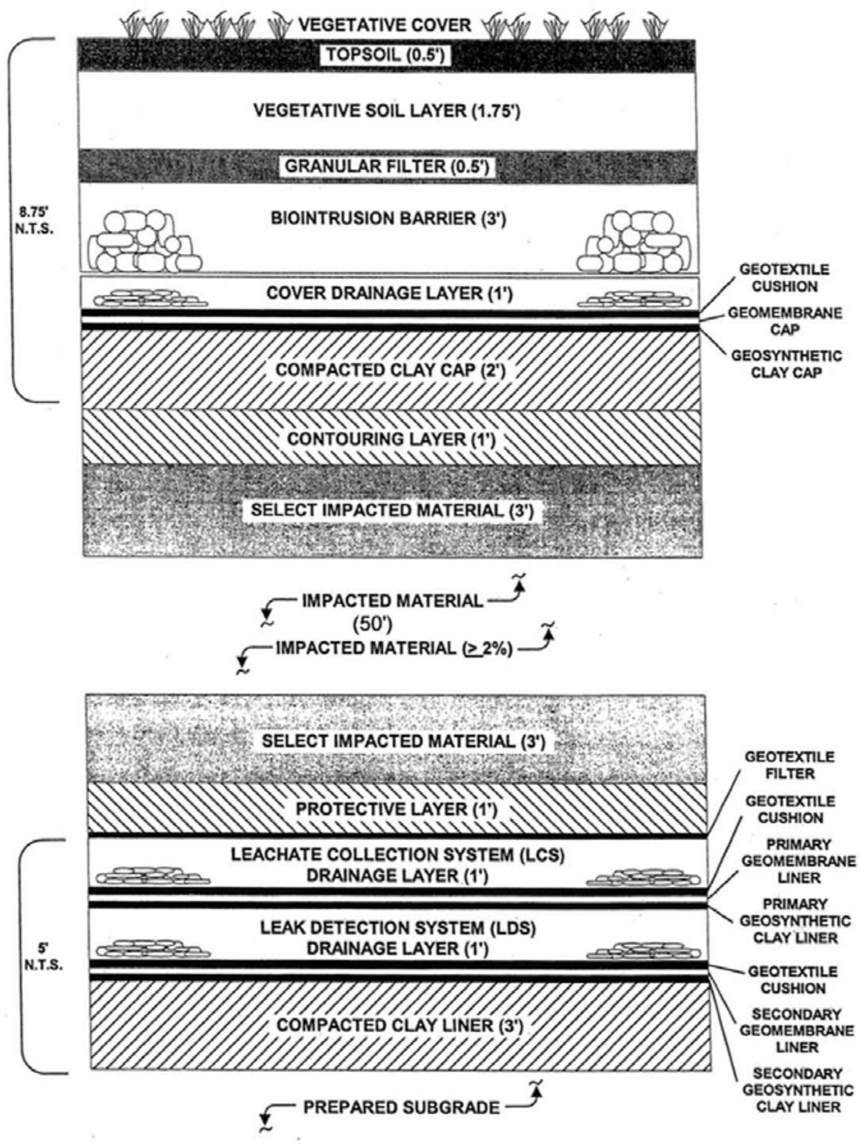

Fig. 2. OSDF Cover and Liner Components.

The base of each cell liner also slopes toward the centerline of the cell, and the centerline of the base is sloped toward the west. Leachate moving along the top of a liner would first travel toward the centerline and then west along the centerline to be drained from the cell via piping at the liner penetration box, which is the lowest elevation point of the cell.

Each cell is monitored below the liner penetration box with a horizontal till well (HTW), which represents the first monitoring point for a release from a cell. HTWs provide monitoring of the perched groundwater quality beneath the point where the LCS and LDS pipes exit the liner system. The GMA is monitored from both an upgradient and a downgradient monitoring well for each cell.

Given the attention to quality assurance/quality control during the installation of the OSDF liner system, it is doubtful that a breach in the liner would have gone unnoticed during construction, but it is possible that a breach could develop. Such a breach would provide a potential pathway for leachate migration, but adequate hydraulic head is needed to drive leachate through the breach and clay liner into the underlying horizon.

Cap Inspections and Performance

Facility cap inspections are conducted quarterly to ensure cap integrity is maintained. The inspection team typically includes representatives from OEPA, S.M. Stoller Corporation, and LM. During OSDF construction, a cell cap was included in the quarterly inspection once it was seeded and vegetation was becoming established. Issues identified during inspections typically include small erosion rills, rocks that surface as topsoil settles, animal burrows and digging, small areas that require reseeding, and the presence of woody vegetation, thistle, or other noxious species.

The issues are addressed as follows:

- Erosion rills are repaired if they exceed 8 cm wide by 15 cm deep.
- Rocks that surface are removed, especially if they will interfere with mowing activities or may be a source location for erosion.
- Animal burrows and holes are filled in and reseeded, if necessary.
- Areas that require reseeding are seeded and covered with jute matting to help prevent erosion of the seed.
- Woody vegetation is removed, and herbicide is applied to the noxious weeds.

Following each inspection, a report is submitted to LM documenting the inspection and any findings. These reports are available to the public on the Fernald Preserve website (http://www.lm.doe.gov/fernald/Sites.aspx). Copies of the reports are also sent to EPA and OEPA as a follow-up to the inspection, providing information gathered by all involved and stating how findings will be handled. Through 2010, cell cap inspections show no visual signs that the integrity of the cap has been compromised in any way.

A more quantitative indicator of cap performance is the comparison of precipitation volume on the facility to leachate generation from the facility. The volume of precipitation that fell on the OSDF in 2009 was approximately 208 million liters (55.0 million gallons). The facility's multilayer cap is designed to inhibit rainwater from permeating the OSDF. The volume of collected leachate in 2009 (775,800 L [204,937 gallons]) represents approximately 0.4 percent of the precipitation that fell on the OSDF during the year, indicating that the cap is performing as designed to reduce infiltration. Another indicator that the cap is performing as designed is the ongoing downward trend of the quantity of leachate being generated by the facility. This is discussed in more detail below.

Liner Performance

Cell-specific apparent liner hydraulic efficiencies are calculated using the following equation:

$$\text{Hydraulic efficiency} = [1 - (\text{Volume}_{LDS}/\text{Volume}_{LCS})] \times 100 \qquad \text{(Eq.1)}$$

Apparent liner hydraulic efficiency is a measure of how a cell's liner is performing. The above equation considers *all* the LDS volume to be leakage through the primary liner, which is a conservative measure. In the *Report on the 1995 Workshop on Geosynthetic Clay Liners* [1], several sources of flow from leak detection layers are identified. These sources include:

- Top liner leakage
- Construction water and compression water
- Consolidation water
- Water from groundwater infiltration.

Monthly apparent liner efficiencies were consistently greater than 95 percent for Cells 1 through 8 during 2009. As shown in Table I, monthly apparent liner efficiencies for all cells generally improved from January 2009 to December 2009. Monthly liner efficiencies (in percentages) are provided for Cells 1 through 8 in the 2009 Site Environmental Report for the Fernald Preserve [2].

Table I. Apparent Liner Efficiency (%), January 2009 Compared to December 2009.

Month	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	Cell 7	Cell 8
January 2009	100	100	100	99.19	97.24	98.15	96.80	98.11
December 2009	100	100	100	99.50	98.68	99.27	99.15	99.19

Leachate Collection System Flow Volumes and Rates

Leachate volumes have been measured since waste placement began. Leachate flows were very high prior to capping due to infiltrating rainfall. Fig. 3 is a graph showing monthly leachate volume for the facility since just prior to cap completion in September 2006 through August 2010. Note the large monthly flows prior to cap completion (>3 million liters [800,000 gallons] and >1.5 million liters [400,000 gallons] in September and October 2006, respectively) and much lower flows since cap completion in October 2006. Also note the general downward trend since capping, which is a good indicator that the cap is performing as designed. Leachate volume measured in 2009 indicates that 775,800 L (204,937 gallons) of leachate were collected. The total volume measured in 2009 represents an 18 percent decrease from the total volume measured in 2008 (944,200 L [249,421 gallons]).

LCS flow-monitoring measurements for individual cells are trended to provide an indication of changes in system performance. Semilog plots indicate that leachate volumes from all cells continue to decline over time, but the decline curves are flattening. In 2009 the overall monthly facility leachate flow declined by 6,606 L (1,745 gallons) or approximately 8.6 percent (77,230 L [20,403 gallons] for January 2009 versus 70,630 L [18,658 gallons] for December 2009).

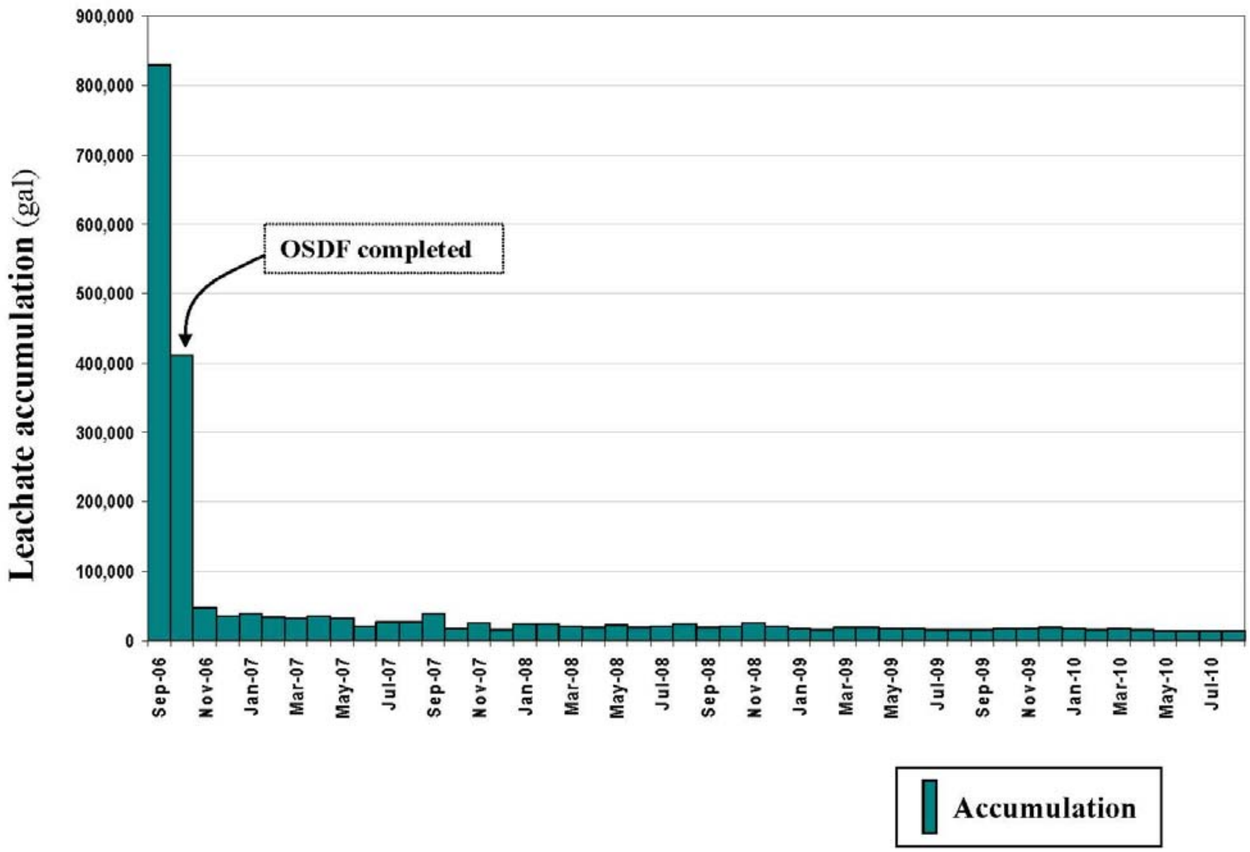

Fig. 3. Leachate Collection System Accumulation Volumes.

Leak Detection System Flow Volumes and Rates

Quantitative measurements of the volumes accumulating in and pumped from the LDS tanks are collected. These data are used to determine both accumulation rates and accumulation volumes for each cell's LDS.

Trend analyses of the LDS flow-monitoring measurements are conducted for all cells to provide an indication of changes in system performance. Monthly accumulation volumes are monitored and recorded. Trend graphs indicate that overall LDS flows (with the exception of Cell 1) have declined. Since approximately 2005, flow in the Cell 1 LDS has ranged from approximately 0 to 38 L (0 to 10 gallons) per month.

The *On-site Disposal Facility Final Design Calculation Package* [3] defines an initial response leakage rate for individual cells of 187 liters per hectare per day (Lphd) (20 gallons per acre per day [gpad]). The 2009 maximum LDS accumulation rates and the percent of the initial response leakage rate for each cell are as follows:

Table II. 2009 Maximum Accumulation Rates—Leak Detection System.

Cell	LDS Maximum Accumulation Rate Lphd (gpad)	Percent of Initial Response Leakage Rate
1	0.37 (0.04)	0.2
2	0.00 (0.00)	0.0
3	0.00 (0.00)	0.0
4	2.38 (0.25)	1.3
5	4.49 (0.48)	2.4
6	2.15 (0.23)	1.1
7	2.71 (0.29)	1.5
8	1.59 (0.17)	0.9

These LDS accumulation rates indicate that the liner systems for the cells are performing well within the specifications outlined in the approved OSDF design. The initial response leakage rate of 187 Lphd (20 gpad) is a design criterion for commencing an investigation into the possibility that a leak from the facility has occurred. Because all of the cells are closed and capped, it is expected that LDS accumulation rates will continue to diminish over time. LM will continue to track the accumulation rates closely to verify that the primary liner systems are performing as designed.

Leak Detection Monitoring

Ohio Solid and Hazardous Waste regulations require that groundwater quality be monitored to determine if a leak is occurring from a disposal facility. Monitoring for a leak from the OSDF using only water quality data is challenging in that:

- The low-permeability clay beneath the facility does not readily transmit water, and
- The presence of preexisting or background contamination and post-construction water quality changes (below FRLs) beneath the OSDF are still taking place, and these changes complicate the interpretation of data.

DOE has developed a strategy to meet the regulatory requirements, given the unique challenges presented by residual soil contamination beneath the OSDF. The key to a plausible potential leak determination is the presence of adequate hydraulic head in the LDS (i.e., action leakage rate) coupled with observed water quality changes in the LDS and HTW.

DOE evaluates the water quality of the HTW or GMA horizon in relation to the hydraulic head in the cells' LDS. A water quality change in an HTW or GMA well accompanied by a corresponding action leakage flow rate in the LDS would be an indication that a leak may have occurred.

Action Leakage Rate

The action leakage rate is the monitoring criterion used to assess the presence of hydraulic head in the cell of the facility. The action leakage rate is the maximum design flow rate that the LDS can remove without the fluid head on the bottom liner exceeding 30 cm (1 ft) (40 CFR 264.302).

Stated another way, it is the flow rate that corresponds to a hydraulic head within the facility capable of driving fluid through a liner breach. The OSDF has an action leakage rate of 1,870 Lphd (200 gpad) [3].

To be conservative, DOE uses an initial response leakage rate of 1/10 of the action leakage rate (i.e., 187 Lphd [20 gpad]). Should the initial response leakage rate of 187 Lphd (20 gpad) ever be measured in the LDS, DOE will begin the process of determining why the flow is increasing so that actions can be taken long before the action leakage rate is reached. The highest LDS maximum accumulation rate in 2009 was 4.49 Lphd (0.48 gpad) in Cell 5; less than 3 percent of the initial response leakage rate of 187 Lphd (20 gpad).

Residual Soil Contamination Beneath the Facility

In the immediate vicinity of the OSDF, contaminant concentrations are present above background levels in surface and subsurface soil, the perched groundwater in the glacial till, and the GMA. The nature and extent of contamination in these media were documented in the OU5 Remedial Investigation Report [4]. Additional characterization of the perched groundwater in the glacial till in the OSDF footprint has been documented in the OSDF Pre-Design Report [5]. FRLs for soil were established in the OU5 Record of Decision [6], and residual contamination below the soil FRLs interferes with the interpretation of water quality data.

Contaminant concentrations in surface and subsurface soil within the OSDF footprint exceeded the soil FRLs, but certification reports [7–10] show that contaminant levels are now below FRLs. For example, the background value for uranium is 4.56 mg/kg [11], the FRL is 82 mg/kg [6], and the mean values for the 17 certification units that correspond to the locations of the HTWs range from 5.96 to 57.2 mg/kg (Table III).

DOE has been monitoring selected constituents in the HTWs, and some of the constituent concentration trends have been increasing. Because residual contamination below the FRLs is present in the area of the HTWs, and installation of the facility changed recharge/infiltration conditions in the area, it is not unexpected that contaminant concentrations in perched groundwater would increase. The OU5 leaching coefficients for contaminated soil [12] can be used to calculate the range of expected groundwater uranium concentrations in below-FRL soil (Table III), and uranium values in the HTWs [13] fall near or below the concentrations predicted using the lower value for the leaching coefficient. The maximum detected uranium concentration in perched groundwater (0.021 mg/L) prior to OSDF construction [5] is slightly lower than the maximum HTW value detected (0.029 mg/L in Cell 3). However, this is expected, as the soil was disturbed during construction, and particle surfaces exposed to the atmosphere during construction may leach more readily than less-reactive surfaces in undisturbed soil. Based on the K_l value of 185 in Table III, the uranium concentration in the Cell 3 HTW could reach a maximum value near 0.2 mg/L without uranium contribution from the OSDF.

Table III. Mean uranium value[a] for certification units at or near the horizontal till wells, expected groundwater uranium concentrations based on the reported range for uranium leach coefficients (K_l) in low-leachability soil[b], maximum HTW concentration[c], and observed perched-water concentration prior to OSDF construction[d].

Certification Unit	Uranium (mg/kg)	Cell	Uranium (mg/L)			
			K_l = 185	K_l =2700	HTW-max	Pre-const
P19	38.1	1	0.206	0.014	0.012	0.020
P18	38.9	1, 2, and 3	0.210	0.014	0.029	0.010
P18-11	18.6	3	0.101	0.007	0.029	0.003
P17-33	11.7	3 and 4	0.063	0.004	0.029	0.013
P17-31	25	4	0.135	0.009	0.008	0.013
A1P2-S2SP-01	24.3	5	0.131	0.009	0.021	0.005
A1P2-S2SP-02	32.5	5	0.176	0.012	0.021	0.005
A1P2-S2SB-04	10.9	6	0.059	0.004	0.024	0.007
A1P2-S2NI-02	21.5	6	0.116	0.008	0.024	0.007
A1P2-S2SB-02	6.64	6	0.036	0.002	0.024	0.007
A1P2-S2NI-07	8.64	6 and 7	0.047	0.003	0.024	0.007
A1P2-S2SB-01	5.96	7	0.032	0.002	0.004	0.021
A1P2-S2SP-04	17.7	7	0.096	0.007	0.004	0.021
A1P2-S2NI-08	57.2	7 and 8	0.309	0.021	0.006	0.021
A1P4-C1	28.8	8	0.156	0.011	0.006	0.019
A1P4-C2	14.7	8	0.079	0.005	0.006	0.019
A1P4-C3	16.6	8	0.090	0.006	0.006	0.019

[a] Data obtained from certification reports [7–10].
[b] Leach coefficients obtained from Table 2.2 of the OU5 K_l study [12].
[c] HTW maximum concentrations taken from 2007 Site Environmental Report [13].
[d] Perched groundwater results taken from OSDF pre-construction study [5].

Water Quality Monitoring

Three water quality data interpretation techniques are used to assess changing water quality conditions in HTW and GMA wells and to compare conditions in the HTW and GMA wells to conditions inside the facility in the LCS and LDS.

- Concentrations are trended over time for constituents that have not reached steady-state conditions.
- Control charts are prepared for constituents that are stable.
- Bivariate plots are prepared for each cell to illustrate how the water quality signature of the LCS, LDS, and HTW of a cell compare.

Water Quality Monitoring Results for 2009

A total of 120 concentration trend plots were constructed for the 15 constituents monitored quarterly in the LCS, LDS, and HTW of each cell in 2009. Fifty increasing constituent concentration trends were identified in HTWs and/or downgradient GMA wells of Cells 1 through 8.

Eighty-four control charts were constructed for constituents that met the criteria for use of a control chart (i.e., normal or lognormal distribution, steady-state, no serial correlation). All but two displayed "in-control" situations. The two exclusions were iron in the HTW of Cell 4 and arsenic in the HTW of Cell 5.

Bivariate plots for each cell show that the chemical signatures of the uranium-sodium concentrations in the LCS, LDS, and HTW of each cell in the OSDF plot in distinct fields, indicating that mixing between the monitoring horizons is nonexistent or too insignificant to detect (Fig. 4). For example, if there was significant leakage from the LCS to the LDS, the LDS points would trend toward the LCS field. The same observation would hold for leakage from the LDS to the HTW. However, as noted above, there is no hydraulic drive to push fluid through the primary and secondary liners if there were a breach in the liners. Based on the LCS/LDS volumes and bivariate plots, the probability is very low to insignificant that leakage is occurring through the liners and the increasing concentration trends noted in the HTW are attributed to fluctuating residual contaminant concentrations beneath the facility.

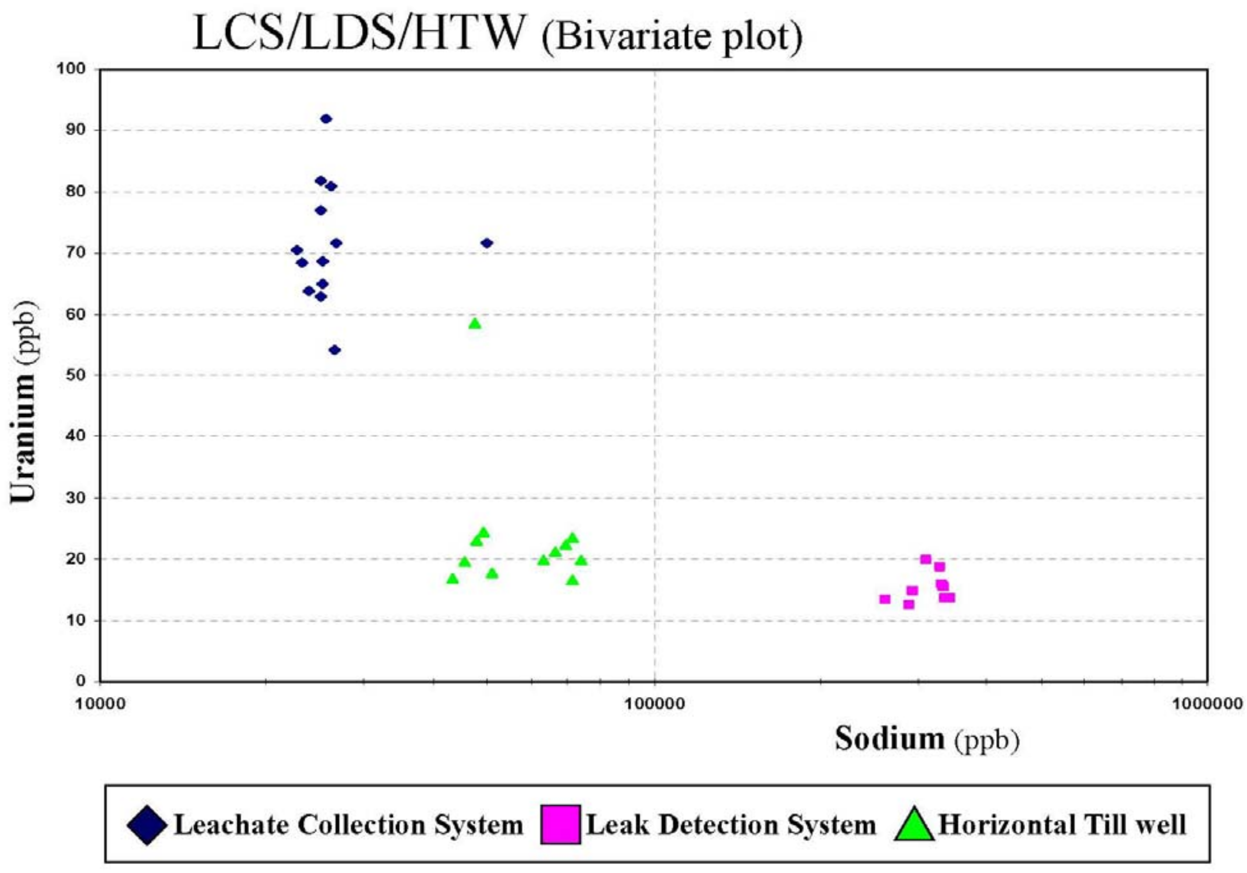

Fig. 4. Typical Uranium – Sodium Bivariate Plot.

CONCLUSIONS

Because the OSDF is essentially a potential source area located above a horizon of high background concentrations of contaminants, it is difficult to distinguish (on water quality data alone) if changing water quality conditions beneath the facility are resulting from a leak from the facility or from changing background conditions that are independent of a leak from the facility. LM will continue to assess changing water quality conditions beneath the OSDF through an ongoing program of monitoring and assessments.

Performance/Findings

- Based on LCS and LDS flow data, engineered drainage features within the OSDF continue to perform as designed, indicating that there is no leakage from the disposal facility.
- The highest LDS maximum accumulation rate recorded in 2009 was 4.49 Lphd (0.48 gpad) in Cell 5; less than 3 percent of the initial response leakage rate of 187 Lphd (20 gpad).
- LCS volumes continue to diminish with time. Total facility leachate in 2009 was 18 percent less than in 2008 (approximately 776,000 L [205,000 gallons] compared to 944,500 L [249,500 gallons]).
- LDS accumulation rates indicate that the liner systems are performing well within the specification outlined in the approved facility design.
- By December 2009, monthly liner efficiencies were consistently greater than 98 percent for Cells 1 through 8.
- Eighty-four Shewart-CUSUM control charts were prepared in 2009. All but two display concentrations that are in control. The two exclusions are iron in the HTW of Cell 4 and arsenic in the HTW of Cell 5.
- Fifty increasing concentration trends were identified in the HTW and/or downgradient GMA wells of Cells 1 through 8 in 2009. Based on bivariate plots for uranium-sodium in the LCS, LDS, HTW, and GMA wells of each cell, the increasing concentration trends are attributed to fluctuating background concentrations. LM will continue to investigate all of these trends through monitoring and assessments.
- In 2009, quarterly physical inspections of the OSDF revealed no visual signs that the integrity of the OSDF cap had been compromised in any way.

Acknowledgements

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