Weldon Spring Disposal Cell Performance: The First Ten Years - 11333

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ABSTRACT

The Weldon Spring Site is the site of a former uranium processing facility and TNT production plant, located in St. Charles, Missouri. The Weldon Spring Site was remediated under the Comprehensive Environmental Response, Compensation, and Liability Act. Construction of an engineered disposal cell on the Weldon Spring Chemical Plant property began in 1997, and disposal activities were completed in 2001.

This paper discusses the design and construction aspects of the disposal cell along with the performance of the first 10 years, including annual inspections, aerial surveys, leachate collection and monitoring, and groundwater monitoring.

INTRODUCTION

Design and Construction

Construction of an engineered disposal cell on the Weldon Spring, Missouri, Site Chemical Plant property began in 1997. Approximately 1.13 million cubic meters of waste materials, including building debris, asbestos-containing materials, treated raffinate sludge, contaminated soils, drums, process equipment, and the Quarry bulk wastes, were disposed of in the cell. To form a structurally stable material, raffinate sludge was mixed with Portland cement and fly ash in the engineered and constructed on-site chemical stabilization/solidification (CSS) plant to create grout that was pumped to the disposal cell. Disposal activities were completed in 2001.

The disposal cell is located on the northeastern portion of the Chemical Plant property, and the outer perimeter protection system encompasses an area of approximately 17 ha. The 5-sided cell has 4:1 side slopes over the clean-fill dike, and cover slopes of approximately 13:1 over the waste. The maximum width of the cell footprint, including the rock-covered apron, is approximately 457 m, and the maximum height above grade is approximately 28 m. The cell contains approximately 1.13 million cubic meters of contaminated waste, with a total activity of 243 TBq (6570 Ci). The waste column has a maximum thickness of 19 m, and the waste footprint, including the lower interior dike slopes, is approximately 10 ha.

Six primary systems were incorporated into the cell design: the cover, the waste, a surrounding clean-fill dike, a geochemical barrier, a basal liner system, and a leachate collection and removal system (LCRS).

The cell cover system is approximately 2.6 m thick; the upper 1 m of the top slope consists of limestone riprap with an average diameter of 20 cm; the riprap is 61 cm thick on the side slopes. The riprap layer protects the cover from erosion and restricts penetration of the cover by plant roots and burrowing animals. This riprap layer overlies a sequence of aggregate bedding and drainage layers. Beneath these layers is a high-density polyethylene (HDPE) liner with an attached layer of bentonite. The principal radon/infiltration barrier consists of a 0.9-m-thick layer of compacted low-permeability clayey soil beneath the HDPE liner.

Three drainage bays were created at the cell bottom sloping toward two low points on the north side of the cell floor to facilitate leachate flow. The west bay includes a monolith of debris cemented with grout containing raffinate sludges.

The cell bottom liner incorporates two HDPE layers separated by a synthetic drainage layer consisting of geotextile and geonet. The upper HDPE liner system is covered with drainage aggregate and a layer of peat mixed with low-radioactivity soil that will adsorb some leachate contaminants. The lower HDPE liner system was placed on a bentonite mat-covered 0.9-meter-thick layer of compacted clay. The mat and clay layer provide an additional low-permeability liner and geochemical barrier that will adsorb uranium and other constituents in leachate that potentially could leak through the HDPE liner system. The cell foundation complies with a siting requirement included in the Missouri regulations for the equivalent of a 9.1-m (30-ft) thickness of clay with a permeability of 10^{-7} cm/s under the contained waste.

Specific performance and design criteria for the cell include:

- Seismic resistance: sustain a Maximum Credible Earthquake defined as:
  - Peak Ground Acceleration = 0.26 g (gravitation constant)
  - Period of the Design Ground Motion = 0.3 s
  - Duration of the Design Ground Motion = 24 to 30 s
  - Horizontal Seismic Acceleration Coefficient (long term) = 0.17
  - Horizontal Seismic Acceleration Coefficient (short term) = 0.13
- Sustain a Probable Maximum Precipitation (PMP) event defined as 97.5 cm in 24 hours.

Annual Inspections

Annual inspections of the disposal cell began in 2003 as part of the long-term surveillance and maintenance (LTS&M) program. The disposal cell is inspected in accordance with the LTS&M Plan and the annual inspection checklist. The cell is inspected by walking 10 transects over the cell and around the cell perimeter. Handheld Global Positioning System (GPS) equipment is used to navigate the 10 transects.

During the inspection, the inspectors separate into two groups and walk five transects each. The inspectors look for depressions, shifts of cell plane vertices, and other indications of settlement. A few small, shallow depressions have been noted during the annual inspections. It appears that the depressions range up to approximately 5 to 8 cm deep. These slight depressions are not unexpected for a disposal cell of this type and are not a cause of concern. They will continue to be monitored. Other items for inspection were vegetation, wet areas, apron drains, guardrail, and the stairs. No vegetation has been observed growing on the disposal cell since a few plants were observed during the first inspection. No wet areas have been observed, and the apron drains, guardrail, and stairs are still in good condition.

Five designated areas of the cell are located and observed annually for any signs of rock degradation A GPS unit was used during the 2003 inspection to map the five areas chosen for rock degradation review. A square is also painted around the areas. The inspectors use photographs from the past years' inspections and compare the photograph to the rock degradation area during the inspection to observe if any rock degradation or changes have occurred. Photographs from each year are also compared. No rock degradation has been observed in these areas thus far.

It has been observed in the past 2 years that much of the rock is darker than in previous years and was thought to be due to weathering. The darkened rock is not an issue that could compromise the disposal cell, just an observation of a changed condition.

Results of these inspections show that the disposal cell is functioning as designed

Aerial Surveys

Aerial surveys are required by the LTS&M Plan to be performed in conjunction with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 5-year reviews. The survey is required to be conducted with a vertical resolution no less precise than 15 cm and map and survey data to be produced with the cell surface represented by 30-cm contour intervals. The data are reviewed for indications of possible settlement. The first survey was performed in 2003 as a baseline, and subsequent surveys were performed in 2005 and 2010, in conjunction with the CERLCA 5-year reviews.

A comparison on the baseline topography from 2003 to the 2010 topography indicates general uniform settlement in the cell no more than 61 cm (Fig. 1.). The side slopes are stable and show no evidence of bulging or slumping.

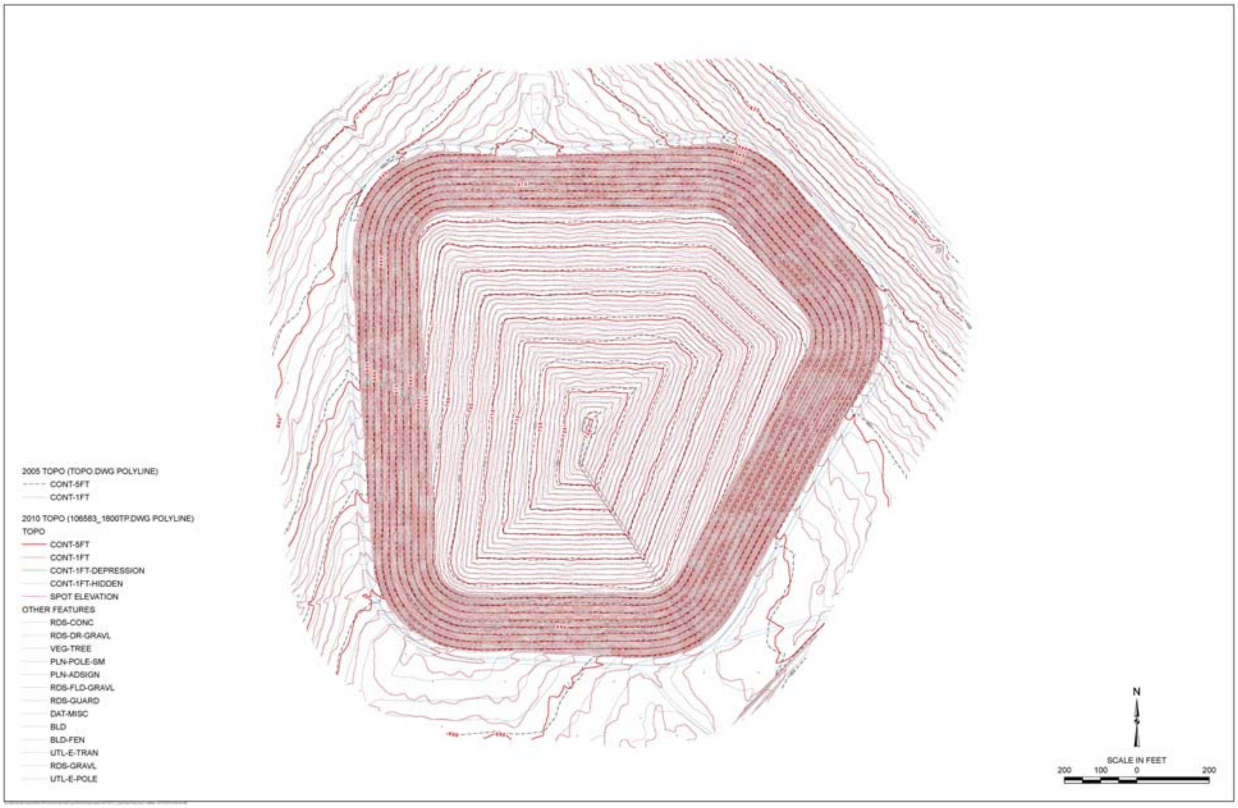

Fig. 1. Topography comparison for Weldon Spring disposal cell.

Leachate Collection and Removal System

The Leachate Collection and Removal System (LCRS) collects leachate generated from the Weldon Spring Site disposal cell. The LCRS was designed and constructed with primary and secondary liners that have collected construction water and precipitation that was accumulated during the construction period. This system includes primary, secondary, and external containment leachate flows that are independently monitored before discharging into the common storage sump. The operational capacity of the common storage sump is approximately 42,400 L. The LCRS receives minor flow volumes of pretreated monitoring well purge water that are also discharged to the sump and pretreated and disposed of with the leachate. The accumulated leachate is periodically pumped, pretreated, and finally transferred off site to the Metropolitan St. Louis Sewer District Bissell Point Treatment Plant for final treatment and discharge.

Leachate from the cell is collected in a primary collection system under the cell consisting of 10-cm-diameter perforated HDPE pipes placed in the drainage material on top of the primary liner. The pipes convey leachate by gravity to a sump located north of the disposal cell. The primary collection system pipes converge into the sump. The sump consists of a 61-m-long, 107-cm-diameter HDPE pipe for storage and a 152-cm-diameter HDPE manhole for access. A zone of drain gravel in an annulus enclosed by an 80-mil (2-mm)-thick HDPE geomembrane liner was placed around the leachate piping between the cell liner and the sump and also around the sump itself to provide secondary containment. Within the cell, the primary collection pipes are configured to overflow into the drain gravel if they become clogged or if water levels exceed 30 cm, to be conveyed inside the annulus to the secondary containment around the sump. A monitoring well was installed adjacent to the sump manhole to detect leakage from the sump or overflow of the primary collection pipes into the secondary containment system.

A secondary collection system consists of an HDPE geonet placed between layers of geotextile (high-tensile strength filter fabric), which is placed between the primary and secondary bottom liners. This system collects leakage through the primary liner. Fluids flow through the secondary collection system to two gravel-filled sumps, one for each basin, located along the north edge of the cell. The fluids are then conveyed by HDPE pipe through the gravel-filled annulus to the HDPE sump north of the cell. Flows in secondary collection system pipes are monitored individually within the sump. One of the functions of the secondary system is to monitor the flow rate to determine if there is any significant leak.

Instrumentation sensors installed in the LCRS sump are used to monitor the combined (primary and secondary) leachate volume. The east and west secondary leachate collection system flow is discretely monitored prior to being combined with the primary leachate through a system of volumetrically calibrated containers. These containers are equipped with level switches and discharge valves. The container fills with secondary leachate to a predetermined level, and a valve is actuated that dumps the contents. The number of discharges is recorded electronically and displayed at the LCRS monitoring cabinet. The secondary flow rates are calculated from these data. The primary leachate production is calculated by subtracting all other contributing flows from the total leachate production. The LCRS monitoring cabinet was installed in the LCRS Support Building and displays the combined sump level and the discrete secondary collection system number of discharges. These data are also remotely uploaded into the System Operation and Analysis at Remote Sites (SOARS). SOARS allows for acquiring daily data and observing data without accessing the LCRS. SOARS has greatly aided in the daily monitoring of the LCRS.

The monitoring sensors and cups that are used to record flow rate data have been monitored continuously since the cell was completed in 2001. Data analysis has shown a consistent flow decrease in both the primary and secondary monthly average flow rates. The combined monthly flow rate of both the primary and secondary leachate was reduced by 70 percent from 2002 to 2009. This documented flow decrease relates well to the estimated flow rate reductions projected during the initial engineering design. Fig. 2. shows the daily averages of the primary leachate production from October 2001 through October 2010.

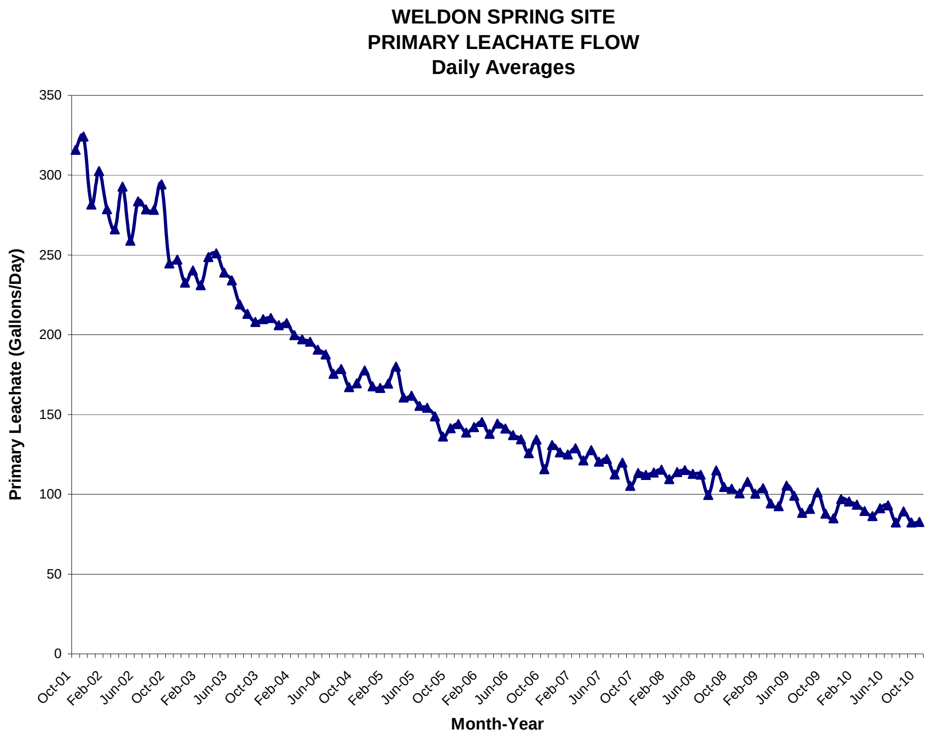

Fig. 2. Daily average flow rate for primary leachate at Weldon Spring Site, 2001-2010.

The water chemistry of the leachate has also been closely monitored since the cell has been sealed. Most monitored parameters have remained fairly consistent from 2002 to 2009. The most significant change has been a decrease in the concentrations of iron and manganese. These changes occurred slowly as the flow rate and volumes of leachate were reduced. This reduction may be due to these elements precipitating out in the liner and pipes prior to entering the collection sump. Concentrations of uranium, other metals, and other radiological constituents have remained stable.

Total uranium concentration in untreated leachate has diminished from 193 pCi/L (283 µg/L) in April 2001 to as low as 13.5 pCi/L (9.2 µg/L) in March 2005, indicating that the geochemical barrier is continuing to perform to reduce the uranium concentration. Fig. 3. shows uranium concentration from 2002 through October 2010 and how the concentration is trending with time. The uranium concentration has been varied slightly over the past 5 years.

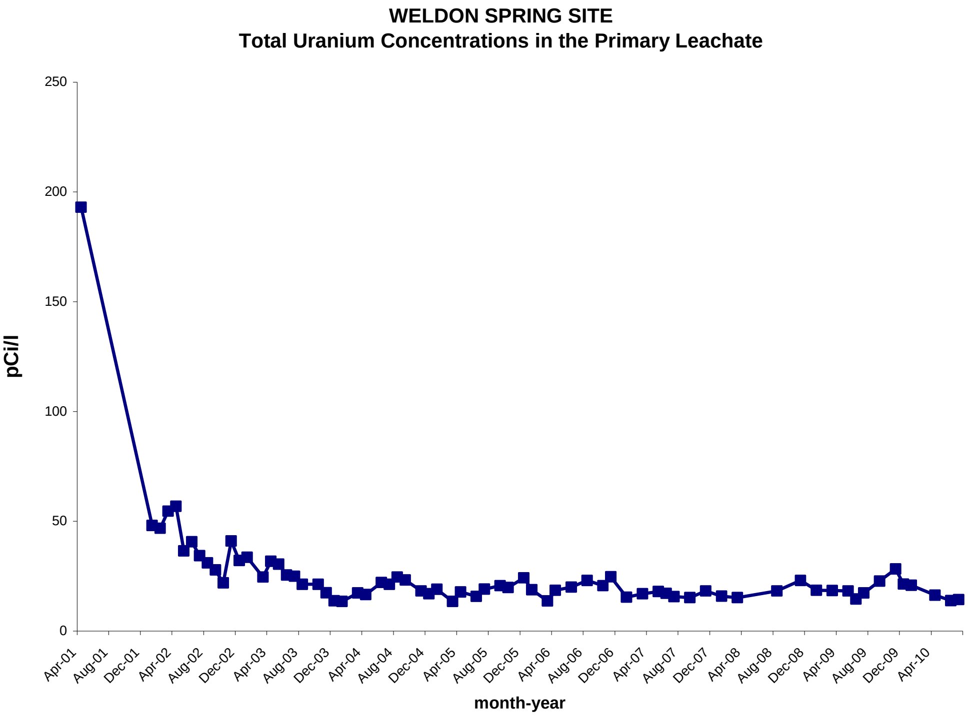

Fig. 3. Uranium concentrations in leachate at the Weldon Spring site, 2002–2010.

The value for the Action Leakage Rate (ALR) was set at 935 L per hectare per day (LPHD) (100 gallons per acre per day) for the entire cell floor of 9.7 ha. The average daily ALR recorded from 2002 through 2009 has ranged from 30 to 148 L/day for the entire cell footprint of 9.7 ha, or 3 to 13.7 LPHD. These flow rates are significantly less the ALR and show that the integrity of the primary liner is stable and intact.

The Sump External Containment System (SECS) was designed to provide an alternate leachate route for certain exceptional situations (e.g., severe obstruction of the primary leachate pipes) and to prevent formation of a hydraulic head exceeding 30 cm over the primary cell liner. The flow rates have been closely monitored over the years because the west secondary production is much less than the east secondary production. It was suspected that a leak in the secondary LCRS (west branch) HDPE pipe had created a connection between the secondary LCRS (west branch) and the Sump External Containment. However, the analysis of the SECS water does not support this supposition, since the uranium and other leachate analytical results do not match the primary leachate water characteristics. The majority of the SECS water is believed to be from infiltration of ground water. Also the SECS water is dependent on precipitation, which increases during the spring and summer and decreases in fall and winter.

Groundwater Monitoring

Five groundwater monitoring wells, one spring, and disposal cell leachate are sampled as part of the detection monitoring program for the disposal cell. This monitoring is performed to meet the substantive requirements of 40 CFR 264, Subpart F; 10 *Code of State Regulations* (CSR) 25-7.264(2)(F); and 10 CSR 80-3.010(8). These federal and state hazardous- or solidwaste regulations were identified as applicable or relevant and appropriate requirements for the disposal cell. Semiannual detection monitoring began in mid-1998, after cell construction had begun and waste placement activities were initiated. Groundwater and surface water samples are analyzed for the list of analytes in Table 1. Leachate was analyzed for a longer list of analytes.

Table 1. Disposal Cell Detection Monitoring—Analyte List.

Radiological	Inorganic Ions	Metals	Nitroaromatic Compounds	Other	General Indicator Parameters
Radium-226 Radium-228 Thorium-228 Thorium-230 Thorium-232	Chloride (L) Fluoride (L) Nitrate (L) Sulfate (L)	Arsenic Barium Chromium Cobalt (L) Iron (L) Lead Manganese Nickel Selenium Thallium Uranium	1,3,5-TNB 1,3-DNB 2,4,6-TNT 2,4-DNT 2,6-DNT NB	PCBs PAHs	pH Temperature Specific Conductance COD (L) TDS (L) TOC (L) Turbidity (L)

L = monitoring in leachate only; PCBs = polychlorinated biphenyls; PAHs = polycyclic aromatic hydrocarbons; COD = chemical oxygen demand; TDS = total dissolved solids; TOC = total organic carbon

It was anticipated during development of the detection monitoring program that the list of signature parameters may be modified, as necessary, based on future changes in leachate and/or groundwater concentrations. Barium, iron, manganese, and uranium were identified as "signature parameters" for the disposal cell detection monitoring program. Based on data collected from 2000 through 2002, all four of these parameters had been detected at concentrations at least an order of magnitude higher in the leachate than in the underlying groundwater or Burgermeister Spring (with the exception of uranium), which enhances the reliability of any conclusions that are drawn based on fluctuations in concentrations of groundwater constituents. It was determined that increasing trends of these four parameters in the groundwater would be considered a signature of cell leachate that has migrated to the underlying aquifer.

The detection monitoring program is evaluated in every 5 years in conjunction with the CERCLA 5-year review. In 2006, a comparison of the annual averages for each signature parameter in the leachate and disposal cell wells or Burgermeister Spring indicated that the concentrations of iron and manganese in the leachate had decreased to levels that no longer exceed those detected in the groundwater by an order of magnitude. Although the levels of uranium in the leachate had decreased over time, the levels were still an order of magnitude greater than those detected in groundwater. Barium concentrations in the leachate had remained stable in the leachate and continued to be greater in the leachate than in the groundwater.

Under the present monitoring program, barium and uranium data from each monitoring event are compared to the baseline tolerance limits (BTLs) to trace general changes in groundwater quality and determine whether statistically significant evidence of contamination due to cell leakage exists. Tolerance limits for signature parameters have been calculated using the data set from 1997 through 2002, using 95 percent confidence limits.

The data from the remainder of the parameters are reviewed to evaluate the general groundwater quality in the vicinity of the disposal cell and to determine if there are changes in the groundwater system. Data are compared to the three most recent years of data to determine if statistically significant changes in concentrations are present. A measured concentration is considered statistically significant if it is greater than the arithmetic mean plus three times the standard deviation for a given location.

Wells with data showing statistically significant increases or decreases are resampled to confirm the exceedance. If the results of the resampling confirm the exceedance, historical leachate analytical data and volumes are evaluated to assess the integrity of the disposal cell. If the leachate data do not indicate that the exceedance could be the result of leakage from the cell, an assessment of the analytical data and review of sitewide monitoring data is performed. If the exceeding parameter is a contaminant of concern for the operable unit addressing groundwater at the chemical plant, this information is evaluated under the monitoring program for that operable unit.

The monitoring results for the signature parameters have indicated that there is no evidence of leakage into the groundwater beneath the disposal cell. A comparison of current and historical data indicates that the general groundwater quality in the detection monitoring wells and springs has remained consistent.

The leachate is sampled semiannually, and the data are used for comparison with corresponding concentrations in wells if elevated levels of constituents are identified in the groundwater. In general, the composition of the leachate has remained stable over the past 10 years, with the exception of iron, manganese, and uranium. Concentrations of these three constituents have shown a general decline.

Groundwater flow rate and direction are evaluated annually. The groundwater flow direction is determined by constructing a potentiometric surface map of the shallow aquifer using the monitoring wells at the Chemical Plant. The configuration of the potentiometric surface has remained relatively unchanged since the construction of the disposal cell, although the groundwater elevations have decreased by almost a meter. The groundwater flow direction is generally to the north. A groundwater divide is present along the southern boundary of the site.

The average groundwater flow rate (average linear velocity) is calculated using the equation $v = -Ki/n_e$. The average hydraulic conductivity (K) using data from the cell monitoring wells is 7×10^{-3} cm/s. An effective porosity (n_e) of 0.10 was selected to estimate the maximum groundwater flow rate in this area. The hydraulic gradient (i) in the disposal cell area is 0.011 m/m and is based on data from monitoring wells 2032 and 2055, located 640 m apart. The average flow rate is 67 cm/day, which is the average flow rate calculated since 2005.

CONCLUSIONS

The data and information obtained from the first 10 years demonstrate that the cell is functioning as designed. Physical inspections show general settlement of the cell and minimal degradation of the cell cover. Leachate generation has significantly decreased, as predicted during the initial design. The groundwater detection monitoring program confirms no evidence of leakage from the cell. The selected remedies protect human health and the environment, comply with federal and state requirements, and are cost-effective.