Alternative Site Technology Deployment- Monitoring System For The U-3ax/bl Disposal Unit at the Nevada Test Site

Jason M. Dixon, Daniel G. Levitt, and Stuart E. Rawlinson
Bechtel Nevada, POB 98521, M/S NLV081, Las Vegas, NV 89193

36th Annual Engineering Geology and Geotechnical Engineering Symposium: Soil and Water Issues for the Arid West

ABSTRACT

In December 2000, a performance monitoring facility was constructed adjacent to the U-3ax/bl mixed waste disposal unit at the Nevada Test Site (NTS). Recent studies conducted in the arid southwestern United States suggest that a vegetated monolayer evapotranspiration (ET) closure cover may be more effective at isolating waste than traditional Resource Conservation and Recovery Act (RCRA) multi-layered designs. The monitoring system deployed next to the U-3ax/bl disposal unit consists of eight drainage lysimeters with three surface treatments: two are left bare; two are revegetated with native species; two are being allowed to revegetate with invader species; and two are reserved for future studies. Soil used in each lysimeter is native alluvium taken from the same location as the soil used for the cover material on U-3ax/bl. The lysimeters were constructed so that any drainage to the bottom can be collected and measured. To provide a detailed evaluation of the cover performance, an array of 16 sensors was installed in each lysimeter to measure soil water content, soil water potential, and soil temperature. Revegetation of the U-3ax/bl closure cover establishes a stable plant community that maximizes water loss through transpiration while at the same time, reduces water and wind erosion and ultimately restores the disposal unit to its surrounding Great Basin Desert environment.

INTRODUCTION

Long-term stewardship of landfills at the NTS has required evaluation of environmental factors associated with the arid climate of the southwestern United States. In December of 2000, U-3ax/bl was closed as a historic mixed waste disposal unit at the Area 3 Radioactive Waste Management Site (RWMS). Closure of U-3ax/bl is unique in that it was one of the first mixed waste disposal units to receive regulatory approval for closure using the monolayer-ET cover. This closure cover is a significant departure from the traditional RCRA subtitle C and D multi-layered systems. This paper describes the design and deployment of a monitoring facility using drainage lysimeters and the latest monitoring and data acquisition technology for demonstration of cover performance.

A drainage lysimeter facility was deployed immediately adjacent to U-3ax/bl to: (1) demonstrate performance and provide post-closure monitoring of the cover deployed on U-3ax/bl, and (2) evaluate the effectiveness of various surface treatments for a monolayer-ET cover to minimize liquid migration and erosion, accommodate subsidence, and maximize overall long-term integrity of the cover. Recent studies (Dwyer, 2001; Levitt et al., 1999) indicate that a monolayer-ET cover effectively accomplishes these desired results. Furthermore, a monolayer-ET cover is simple to construct and maintain and is therefore more cost-efficient. Design and construction of the performance monitoring facility at Area 3 was supported through the Department of Energy's (DOE) Accelerated Site Technology Deployment (ASTD) program, administered under the Technology Development (TD) program.

SITE DESCRIPTION

The Area 3 RWMS is located in Yucca Flat, within the northeast quadrant of the NTS at an elevation of 4,020 ft (1,225 m). Yucca Flat is a hydraulically closed basin with a physiography typical of a Basin and Range setting. Figure 1 shows the location of the Area 3 RWMS relative to various surrounding geographic features. The site is situated on approximately 1,000 ft (300 m) of dry alluvium. The water table occurs in the underlying volcanic tuff units approximately 1,614 ft (492 m) below the site (Shott et al., 1997).

SYSTEM DESIGN

Although the design of the lysimeter facility is simple, it will provide years of reliable water balance data that will allow scientists to assess the performance of an existing monolayer-ET cover. The facility will also provide a means to evaluate the various near-surface cover treatments such as mulching and application of various vegetation species. Each drainage lysimeter is constructed of 10 ft (305 cm) diameter 3x1 corrugated metal pipe (CMP), which provides a cost-effective yet sturdy sidewall that minimizes the potential for development of a preferential pathway down the wall. Figure 2 shows a cross-section of the lysimeter and monitoring design. Each CMP is only slightly exposed at the surface (< 1 in) to minimize wind barrier effects on the surface energy balance, and to prevent localized runon. To further minimize the potential for run-on, the facility is slightly elevated (≈ 1 ft) and constructed within a pre-existing berm. Native soil from excavated construction of the facility was used as backfill inside the lysimeters. This soil is the same type of soil that was used to construct the operational and final cover for U-3ax/bl. The soil was placed in the lysimeter in 6 in (15 cm) lifts and compacted to 85 percent of the maximum proctor density to a total depth of 8 ft (2.4 m). This method and depth of backfilling resembles the placement of fill for the U-3ax/bl cover. Based on previous studies by Bechtel Nevada (1998), a cover thickness of 8 ft (2.4 m) is sufficient to minimize long-term migration of liquids through the cover, and prevent biointrusion and penetration of plant roots into the waste zone.

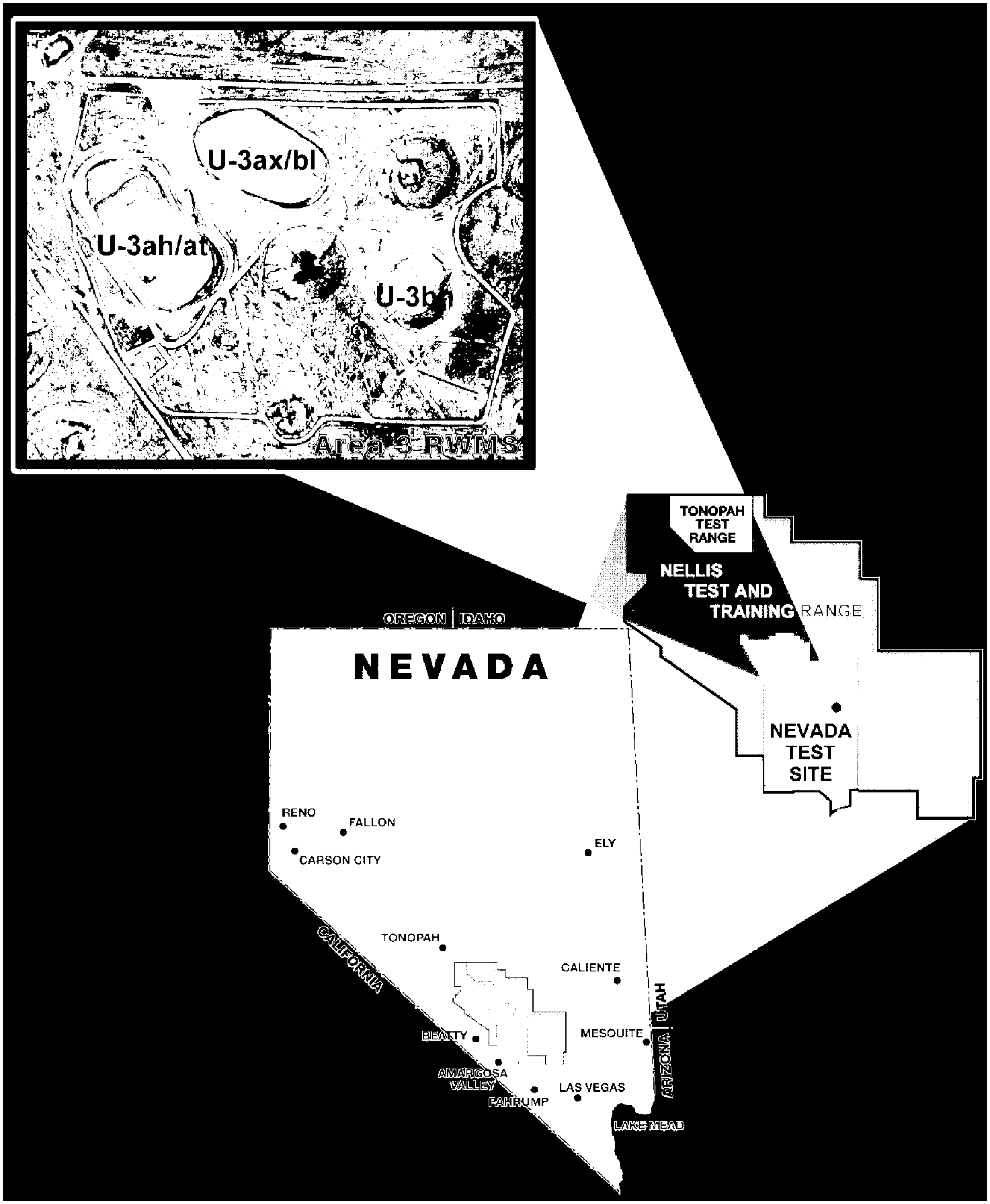

Figure 1 Location of U-3ax/bl within the Area 3 RWMS, the Nevada Test Site, and Nevada.

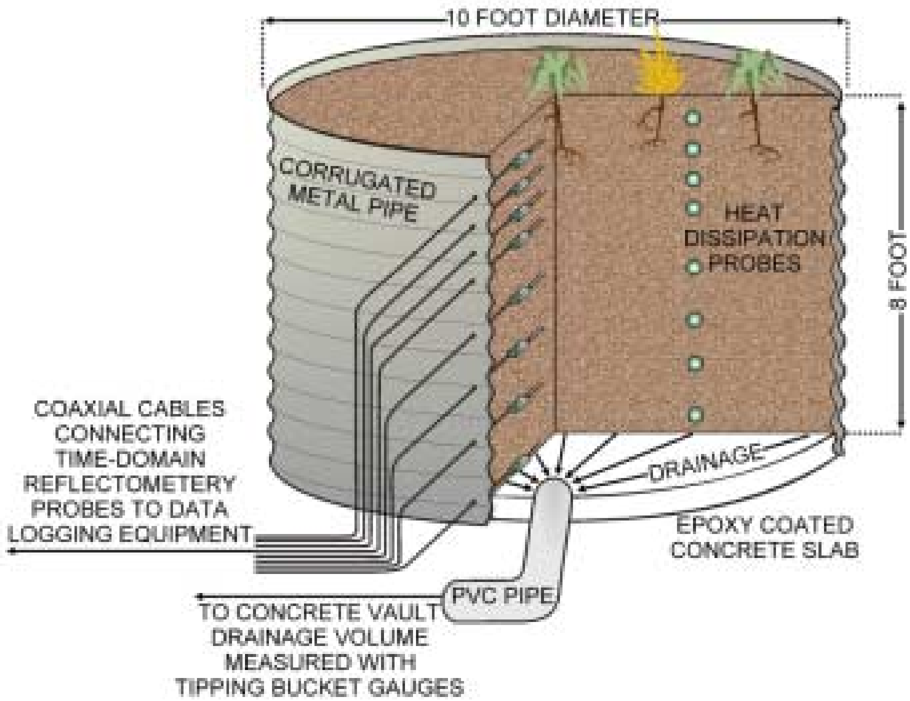

Figure 2 Schematic cross-section of a typical lysimeter configuration at Area 3.

Within each lysimeter, prior to backfilling, a sloped concrete slab was constructed to provide a sealed bottom barrier. The concrete mix design included polyethylene reinforcing fibers and was poured with welded wire mesh in place to minimize temperature and shrinkage cracking. The concrete was allowed adequate curing time, then was treated with high strength epoxy adhesive, to create an impermeable bottom layer. Any drainage that accumulates at the bottom of the lysimeters is directed to a central drain where it will exit the CMP through a media retention nozzle into a 2 in (5.2 cm) polyvinyl chloride (PVC) pipe. The stainless steel media retention nozzles consist of 2.4 in (6 cm) (outside diameter) standard wound wedge wire screen [0.016 in (0.41 mm) slots] with a 2.5 in (6.4 cm) effective screen length. A thin layer of sand, acting as filter pack, was placed around the slotted area to prevent clogging.

SURFACE TREATMENTS

A key component in the performance of the monolayer-ET cover is vegetation. With the addition of native vegetation, the system can remove moisture from the cover before it enters the waste zone and reduce erosion (runoff and wind). The selection of plants for the cover was based on characteristics that maximize transpiration while minimizing infiltration and biointrusion to the waste layer (Winkel et al., 1995).

Three surface treatments are being evaluated at the ASTD lysimeter facility: two are bare (no vegetation), two are revegetated with native species, and two are being allowed to revegetate with invader species. By using multiple surface treatments, the effects of forcing revegetation can be compared with natural invasive revegetation. In addition, the magnitude of moisture withdrawal, or transpiration, can be closely evaluated by comparing the vegetated surfaces to the bare surfaces.

The surface revegetated with native species was prepared identically to U-3ax/bl. The surface was tilled and planted with a mix of seeds from native species. The percentage of each species used in the seed mix is based on the relative contribution of a particular species to the total perennial plant cover typical of adjacent native plant communities, the size of the seed, rooting characteristics (i.e. shallow rooted species), and experience with the species at the NTS (DOE/NV, 2000). To initiate germination and emergence, seedlings were protected by applying grain straw mulch followed by scheduled irrigations during the winter and spring. The frequency of irrigation is based on the amount of rainfall received to date and climate conditions at the time of implementation. The straw mulch also provides organic matter to the nutrient-poor soil. Continued irrigation during the late spring and early summer will aid the establishment of plants and their survival during the typically hot and dry summer. This method of native revegetation has been successful in previous applications on and near the NTS (Hall and Anderson, 1999).

PERFORMANCE MONITORING

A meteorology tower located within 400 ft (122 m) of the performance monitoring facility has been operational since July 1995. Measurements at the tower include air temperature, wind speed and direction, relative humidity, barometric pressure, net radiation, and solar radiation. Soil temperature and soil heat flux are measured in the ground below the tower, whereas precipitation is measured in a stand-alone rain gauge near the tower. Meteorology data provide the necessary components to approximate evapotranspiration based on the surface energy balance.

The objective of monitoring the performance of the U-3ax/bl closure cover is to observe migration of water as a result of infiltration events, and the subsequent redistribution and storage of moisture. Temperature profiles are also measured to evaluate hydraulic responses in the system due to thermal gradients in the lysimeter soil. Sensors that measure water content, water potential, and temperature are installed at eight depths within each lysimeter. Water content is measured using time domain reflectometry (TDR), whereas water potential and temperature are measured using heat dissipation (HD) probes. Probes near the surface were installed in a dense configuration [≈ 3 in (7.6 cm)] to capture the rapid and pronounced changes in water potential as a function of soil moisture and time. Such changes result from quickly progressing soil wetting and ensuing drying typically seen in arid climates. Placement of HD and TDR probes is shown in Figure 2.

In recent years, HD probes have become an increasingly reliable tool for measuring extremely dry soil. These probes have a large measurement range, from near-saturation to a dryness of thousands of bars. Heat dissipation probes are also used to measure soil temperature using the thermocouple junction located within the probe (Bechtel Nevada, 1999).

So that a complete water balance of the system can be determined, any drainage from the lysimeters that accumulates at the bottom, flows to the underground monitoring vault where it can be measured with tipping bucket flow meters. Using data collected from the meteorology tower, along with measurements taken directly from the lysimeters, estimates of storage with time provide a detailed water balance and allow scientists to track wetting fronts and calibrate flow models for long-term performance evaluation. These data also provide insight into the optimal surface treatment for the monolayer- ET system.

Although unsaturated hydraulic properties of the soil are measured directly, side-by-side measurements of pressure head (from HD probes) and moisture content (from TDR) may provide an alternative means of determining soil properties used for unsaturated flow modeling. Furthermore, measurement of all water balance components provide information on trends in hydrologic parameters that may influence the movement of water and potential contaminants.

DATA COLLECTION

Monitoring at the ASTD lysimeter facility requires data collection to verify the performance of the cover placed on U-3ax/bl and to demonstrate the effectiveness of various components that make the monolayer ET cover most suitable in arid or semi-arid conditions. All monitoring data from the ASTD lysimeter facility, including drainage measured externally from the lysimeters, are electronically collected and recorded with data loggers mounted inside the underground monitoring vault (see Figure 3). A direct communication link was installed between the vault and the nearby meteorology tower, where all aforementioned atmospheric and soil conditions are also electronically collected and stored. Using a modem link in the tower, all meteorology and lysimeter data is accessed remotely and downloaded for processing and analyses.

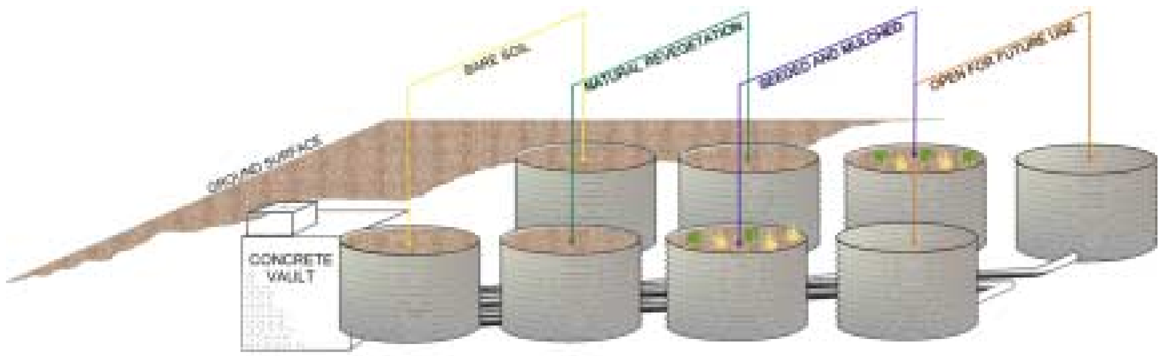

Figure 3 Drainage lysimeters and underground monitoring vault.

FUTURE STUDIES

Although the ASTD facility consists of eight lysimeters, only six lysimeters with three surface treatments are currently being used for performance and demonstration of the monolayer-ET closure cover. The two remaining lysimeters are instrumented identically to the other six, and will likely be used to study one or a combination of the following possible scenarios:

- Simulate climate change conditions i.e. two to three times normal current precipitation.
- Evaluate breakthrough drainage i.e. the amount of precipitation it would take to produce drainage under bare and vegetated surface treatments and/or under various atmospheric conditions (winter vs. summer).
- Investigate the performance (transpiration, rooting depth and density) of various plant species under wetter than normal climate conditions.
- Evaluate the effects that additional coarse material near or at the surface would have on infiltration, evapotranspiration, erosion and ultimately, cover performance.
- Artificially enhance colonization by various plants, small mammals, ants, reptiles, etc, to study the effects that roots and burrows would have on the modification of cover design. Such investigations could be performed through observations of root activity by installing mini-rhizotrons.
- Potentially examine processes that influence the transport of contaminants in unsaturated or nearly saturated soil conditions.

CONCLUSIONS

The ASTD lysimeter monitoring facility provides a means to evaluate cover performance by studying the effects of near-surface cover treatments, and the effects of various other components within the system. Final closure of U-3ax/bl and deployment of the ASTD drainage lysimeter facility is paving the way for future monolayer-ET closure covers at the NTS and other arid or semi-arid DOE sites. As an added benefit, the monolayer-ET cover costs significantly less to construct and maintain than a multi-layer RCRA subtitle C cover typically used for hazardous waste landfills. A monitoring approach has been implemented considering the processes acting on the cover over time. Hydrologic and atmospheric monitoring is expected to provide information about processes that influence the water balance and overall performance of disposal covers in arid environments.

REFERENCES

Bechtel Nevada, 1998. "Technical Studies to Support U-3ax/bl Closure." Letter report to U.S. Department of Energy/Nevada Operations Office, Las Vegas, Nevada. July 1998.

Bechtel Nevada, 1999. "Area 3 Crater Infiltration Study, 1999 Status Report." U.S. Department of Energy/Nevada Operations Office, Las Vegas, Nevada. September 1999.

DOE, see U.S. Department of Energy, Nevada Operations Office

Dwyer, S.F, 2001. "Finding a Better Cover." Civil Engineering. January 2001.

Hall, D.B. and D.C. Anderson, 1999. "Reclaiming Disturbed Land Using Supplemental Irrigation in the Great Basin/Mojave Desert Transition Region After Contaminated Soil Reclamation: the Double Tracks Projects." USDA Forest Service Proceedings RMRS-P-11, 1999.

Levitt, D.G., M.J. Sully, B.L. Dozier and C.F. Lohrstorfer, 1999. "Determining the Performance of an Arid Zone Radioactive Waste Site Through Site Characterization, Modeling and Monitoring." Proceedings of the Waste Management '99 Conference, Tucson, Arizona.

Shott, G.J., V. Yucel, M.J. Sully, L.E. Barker, S.E. Rawlinson and B.A. Moore, 1997. "Performance Assessment/Composite Analysis for the Area 3 Radioactive Waste Management Site at the Nevada Test Site, Nye County, Nevada, Revision 2.0." Bechtel Nevada. DOE/NV-491.

U.S. Department of Energy, Nevada Operations Office, 2000. "Closure Plan for Corrective Action Unit 110: Area 3 RWMS U-3ax/bl Disposal Unit, Nevada Test Site, Nevada." Environmental Restoration Division, DOE/NV—647. August 2000.

Winkel, V.K., J.P. Angerer, D.B. Hall, W.M. Fariss, 1995. "Plant and Animal Characteristics Affecting the Design of Protective Covers, Integrated Closure Program, Final Report." EG&G Energy Measurements. February 1995.