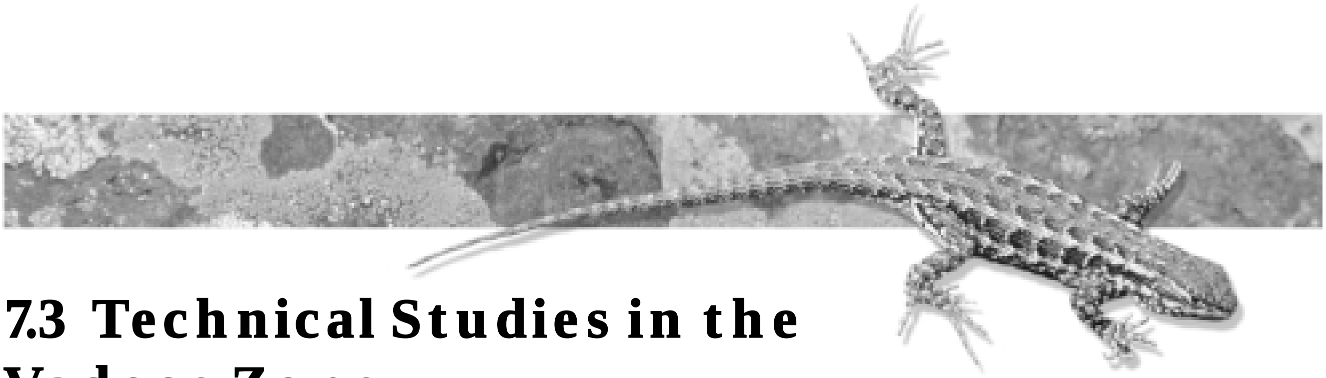

7.3 Technical Studies in the Vadose Zone

D. G. Horton

This section summarizes the activities and results of technical studies done at the Hanford Site in fiscal year 2001 to better understand the vadose zone and vadose zone contamination. These studies were designed to help develop new, innovative methods for cleanup and monitoring at the Hanford Site. These studies include the demonstration and testing of several geophysical methods to monitor and characterize the soil column (Sections 7.3.1 and 7.3.2), the use of chemical parameters to distinguish various sources of subsurface waste and subsurface moisture to understand transport processes in the vadose zone (Sections 7.3.4 and 7.3.5), infiltration experiments at a clastic dike site to determine the hydrologic properties of clastic dikes (Section 7.3.3), and development of a model to predict the migration of subsurface contaminants based on measured infiltration rates (Section 7.3.6).

7.3.1 High-Resolution Seismic Methods for Subsurface Characterization

E. J. Freeman

High-resolution seismic characterization experiments were conducted at the Hanford Site in May 2001. The objective was to create an image of the sedimentary units at selected sites with sufficient resolution to identify distinct sediment layers from the ground surface to the water table. It was hoped that the continuous images of the sediment layers in the vadose zone could be used to identify field scale sediment-layer differences with some degree of confidence. Field-scale sediment-layer differences are important in modeling fluid flow and contaminant transport in the vadose zone. This section presents a brief summary of the experiments and their results. Freeman and Bachrach (2001)[(a)] give a full discussion of the experimental methods and the results.

Four sites were selected to test the high-resolution seismic method: the Sisson-Lu experimental site in the 200-East Area, the proposed disposal site for immobilized low-activity waste in the 200-East Area, an excavated area south of Waste Management Area S-SX in the 200-West Area, and a clastic dike location south of the 200-East Area on Army Loop Road (Figure 7.3.1).

The Sisson-Lu experimental site, located southwest of the Plutonium-Uranium Extraction Plant, was chosen because there is a large quantity of neutron probe moisture data available from several wells completed to 18.6 meters (60 feet) depth at the site. The high-resolution seismic survey completed at this site showed changes in the sediment layering to a depth of ~50 meters (~165 feet). Comparing the existing neutron probe data with the new seismic data showed that the best reflectors are the tops of the low moisture zones, which correspond to coarse-grained units. In addition, the data suggest that not all sedimentary layers are continuous along the 14-meter- (45-foot-) long survey line. Finally, the data also show the orientation of what are interpreted to be elongate deposits (possibly a buried channel).

The immobilized low-activity waste site is located west of the Sisson-Lu site. This site was chosen because it is the location of the proposed repository for future

(a) Letter report from E. Freeman and R. Bachrach (Pacific Northwest National Laboratory, Richland, Washington) to F. M. Mann (CH2M HILL Hanford Group, Inc., Richland, Washington), *Application of High Resolution Shallow Seismic Methods for Subsurface Characterization at the Hanford Site*, dated September 25, 2001.

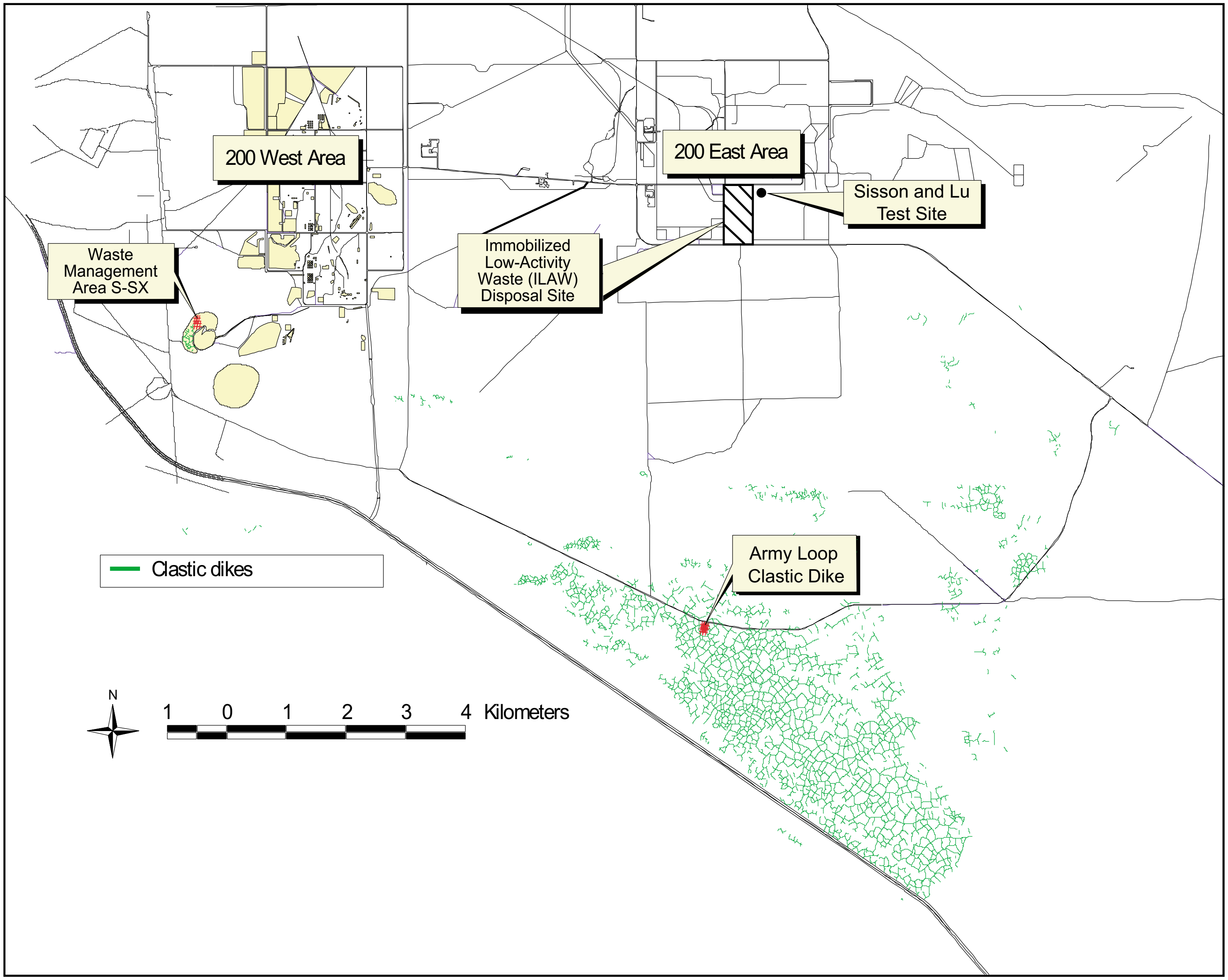

Figure 7.3.1. Location Map of Sites Selected for High-Resolution Seismic Characterization

vitrified waste. The objective of the seismic method was to survey to a depth of ~100 meters (~330 feet). The results of the survey clearly showed the water table at a depth of 90 to 95 meters (295 to 312 feet). This is a significant improvement compared to the depth achieved previously with ground penetrating radar surveys. Additionally, comparison of the seismic profile with the geologist's log from a groundwater well located ~10 meters (~33 feet) north of one of the survey lines showed good agreement between the geologist's observations and the seismic survey results.

In addition to the large-scale features such as lithologic contacts and the water table, small-scale features were identified in the survey profiles. Potential channels or depressions and fault or slump structures were interpreted from discontinuous and offset seismic reflections.

The excavated area south of the S-SX tank farms was selected because the upper 5 meters (16 feet) of sediment had been removed, permitting the potential for deeper signal penetration. There was an attempt to specifically identify a gravel layer previously thought to exist at a depth of ~20 meters (~65 feet) beneath the site. That gravel layer was not positively identified, but a gravel unit at a depth of 45 meters (148 feet) was recognized. In addition, the gravel layer appeared to be laterally continuous along the entire 30-meter (98-foot) profile. Other lithologic contacts could be identified on the seismic profile that corresponded to lithology changes in the geologist's log.

The clastic dike site was located ~100 meters (328 feet) south of Army Loop Road and 1.6 kilometers (1 mile) east of Goose Egg Hill. (Clastic dikes are vertical, sedimentary features that crosscut horizontal bedding. See Section 7.3.3 for more on clastic dikes.) The site was selected because of the prominent profile of the dikes in ground penetrating radar surveys previously conducted. The objective was to determine whether the dike would be detected by the seismic survey. The clastic dikes consisted of laminated sand and silt, with the laminations oriented subparallel to the dike. The sediment surrounding the dike was dominantly sand. The dike was detected by the seismic survey but the image was not as pronounced as the image previously obtained from ground penetrating radar.

The seismic profiles obtained in 2001 showed the capability of the method to image distinct lithologies throughout the entire vadose zone. The seismic technique did well in identifying individual sedimentary layers and structural features, interpreted to be faults and ancient stream channels. Such features may influence variability of fluid and contaminant flow in the vadose zone. The seismic profiles correlated well to geologist's logs and neutron probe logs at sites where they were available. The seismic method was much cheaper than drilling boreholes and provided good quality, continuous three-dimensional pictures of the subsurface.

7.3.2 Vadose Zone Transport Field Studies

G. W. Gee and A. L. Ward

Studies began at the Hanford Site to evaluate the processes controlling the transport of fluids in the vadose zone and to develop a reliable database for testing vadose zone transport models. These models are needed to evaluate contaminant migration through the vadose zone to underlying groundwater at the Hanford Site. Details of the work accomplished in fiscal year 2001 can be found in PNNL-13679. This section summarizes the work completed to date.

A study site, known as the Sisson-Lu site in the 200-East Area (see Figure 7.3.1), was selected because it had previously been characterized extensively using several geophysical monitoring techniques. Building on the characterization efforts of the past 20 years, instruments were installed at the site to use eight characterization methods: advanced tensiometers, neutron probe, electrical resistance tomography, high-resolution resistivity, cross-borehole radar, and cross-borehole seismic surveys. Sediment coring was used to obtain samples for analyzing chemical and isotopic tracers.

Laboratory-scale experiments suggest that fluid properties may influence transport behavior through the Hanford Site vadose zone. Yet, the importance of these influences to field-scale transport is largely unknown, thereby limiting the accuracy of contaminant-transport predictions. To assess the importance of these interactions in field-scale solute transport, tank leaks were simulated by performing a series of injections with dilute fluids in late spring and early summer of 2000 and with hypersaline fluids (excessively saline solutions such as those found in single-shell tanks) during the spring of 2001. In both tests, a suite of isotopic and ionic tracers was included in the injected fluids. A summary of the 2000 test results can be found in PNNL-13487.

The tests in fiscal year 2001, which were designed partly to evaluate the effects of fluid properties and transport processes, involved the injection of

19,000 liters (5,020 gallons) of hypersaline fluid over the course of 5 weeks. This was followed by 11,400 liters (3,010 gallons) of solute-free water applied in a 2-week period. The eight characterization methods were used to monitor the infiltration and re-distribution of the liquid over the course of 3 months.

Results show that the subsurface distributions of both the dilute and hypersaline fluids are controlled by interactions between small-scale horizontal stratification and fluid properties. The centers of mass for the two plumes were similar in the lateral and transverse directions, but were significantly different in depth. The hypersaline plume had traveled 2.6 times deeper than the dilute plume.

Concentration profiles of tracers in the liquid were generally asymmetric with a large mass occurring at a depth of 5 to 7 meters (16 to 23 feet), and a smaller mass at a depth of 10 to 12 meters (33 to 39 feet). Also, there was a preferred flow path to the southeast. The locations of the mass peaks were coincident with the general depths of finer-textured layers which occur at ~6 meters (~20 feet) and at ~12 meters (~39 feet) depths. The fine sand sediment in these layers controlled the migration of the water and caused a substantial increase in horizontal spreading. The moisture plume was confined to a depth of 13 meters (43 feet) in the fiscal year 2000 test but was detected at depths of 16 meters (52 feet) in the southwestern part of the monitoring site in 2001. Thus, the plume had penetrated below the lower, 12-meter (39-foot) fine-grained, confining layer.

These observations emphasize the need to consider local-scale textural discontinuities in conceptual models of field-scale transport at the Hanford Site because they appear to cause lateral spreading of vadose-zone plumes. Lateral spreading of contaminant plumes has been noted in the vadose zone at Hanford Site tank farms and other waste sites. Work in 2001 has led to the development of a scaling method that can be coupled with inverse-flow modeling to estimate parameters for heterogeneous soil at the field scale. Application of this technique to estimate the hydraulic parameters from the Vadose Zone Transport Study field experiments has begun with a two-dimensional simulation. Pacific Northwest National Laboratory's computer code called Subsurface Transport Over Multiple Phases (PNNL-12030; PNNL-12034) was combined with the universal inverse modeling code, UCODE (Poeter and Hill 1998), to estimate unsaturated hydraulic parameters. The prediction of water-content distributions using laboratory-measured parameter values resulted in poor model fits. However, using field-scale values from the new scaling technique resulted in significantly better model fits for both water content and pressure head.

The techniques being developed in the Vadose Zone Field Transport Study are critical to the development of long-term, field-scale transport predictions describing the subsurface distribution of fluids and contaminants.

7.3.3 Hydrogeologic Influence of Clastic Dikes on Vadose Zone Transport

C. J. Murray, D. G. Horton, A. L. Ward, and G. W. Gee

A 3-year study of clastic dikes and their influence on vertical movement of moisture and contaminants in the vadose zone began in fiscal year 2000 and continued in 2001. The study is funded by DOE's Environmental Management Science Program. The goal is to describe the geometric and hydrologic properties of clastic dikes and extrapolate those properties to the vadose zone beneath waste storage and disposal facilities. Results of the work accomplished in 2000 were summarized in PNNL-13487. This section summarizes the work accomplished in 2001.

Clastic dikes are common sedimentary structures in the vadose zone at the Hanford Site (BHI-01103). The dikes are vertical to subvertical structures that are often contorted and irregular. They crosscut the normal subhorizontal sand and silt beds of the Hanford formation. Previous investigators have proposed that the dikes may provide a preferential path for contaminated water leaking from waste tanks to move through the thick unsaturated zone to the unconfined aquifer. However, there is insufficient evidence to determine if that speculation is accurate. One of the goals of this study is to provide information that can be used to evaluate that speculation.

The main focus of the project in 2001 was to study a site near Army Loop Road (see Figure 7.3.1 for the location of the clastic dike site at Army Loop Road). Ground-penetrating radar surveys, air photos, and field mapping were used to select a site to trench across a clastic dike. In June 2001, a clastic dike at the Army Loop Road site was trenched with a backhoe to a depth of ~3.5 meters (~11 feet) (Figure 7.3.2). The exposed clastic dike was in a sand-dominated portion of the Hanford formation. The dike excavated at the Army Loop Road site was 2 meters (6.5 feet) thick.

Instruments to measure air-permeability were used to measure the permeability of the dike and the host sediment. The results indicated the median air permeability of the dike was about one order of magnitude lower than the permeability in the matrix. The overall variability of permeability in the dike-matrix system was approximately four orders of magnitude. This was an important observation, because some methods used to scale permeability data from the point-source scale to the field scale assume that variability in the system is low. This means it would be questionable to apply those scaling methods to a clastic dike system.

Figure 7.3.2. Photograph of the Clastic Dike Exposed in the Army Loop Road Excavation. Each grid shown in the front of the lowest exposed face is 2 meters (6.5 feet) wide by 1 meter (3.28 feet) high. Blue tent in the background covers the infiltration test site.

The continuity of the vertical bands within the dike was measured. A line was laid out across the dike on the floor of the excavation. Each vertical band that crossed the line was then traced up and down the excavation to see if it was continuous. In most cases, the bands could be traced for ~1.6 meters (~5.25 feet) before they pinched out or were obstructed by a cross-cutting band. The range of continuity observed was from 0.2 to 7.7 meters (0.6 to 25 feet), with all but one band having an apparent continuity of <~2.5 meters (<~8.2 feet). This degree of continuity will affect transport through the clastic dike and will be used to construct models of the properties within the dike.

A large-scale infiltration experiment was conducted at the Army Loop Road site. A drip irrigation system was used to apply specific amounts of fluid. Three applications of water were applied to the clastic dike and surrounding matrix, and the progress of the infiltrating water was monitored for each application rate. Water content, matric potential (i.e., a measure of the amount of water in unsaturated material), and electrical conductivity were measured throughout the tests.

Once steady state was achieved with the third (and lowest) application rate, the irrigation supply tank was switched to a solution of potassium bromide and the tracer dye known as Brilliant Blue FCF. The presence of the potassium bromide made it easier to detect the wetting front in the subsurface. Solution application was continued until the potassium bromide moved below ~0.5 meter. Further movement of the water was monitored with a neutron probe and cross-borehole radar instruments in boreholes that extended to a depth of ~7 meters (~23 feet).

The excavation began after the application of the tracer in the infiltration area. After construction of the main excavation area was complete, an additional face was excavated at the edge of the infiltration area so that the distribution of the dye could be examined. The upper portion of Figure 7.3.3 shows a composite color photographic image of the dye in the sediment, and the lower portion of the figure is a map of the moisture distribution in the face of the excavation. The photographic image shows the heterogeneous distribution of the blue dye. The dike is in the center-right area of the image, from 3 to 5 meters (10 to 16 feet), and tended to transmit less dye. However, some of the deepest penetrations of the dye occurred in restricted bands within the dike.

The map of the moisture distribution (bottom part of Figure 7.3.3) was made using time domain reflectometry probe measurements. Although the moisture map captures the main features seen in the photographic image, the important heterogeneity in the distribution of dye and moisture is not captured in the map. Figure 7.3.4 shows the moisture distribution and indicates that much greater levels of moisture are stored in the clastic dike.

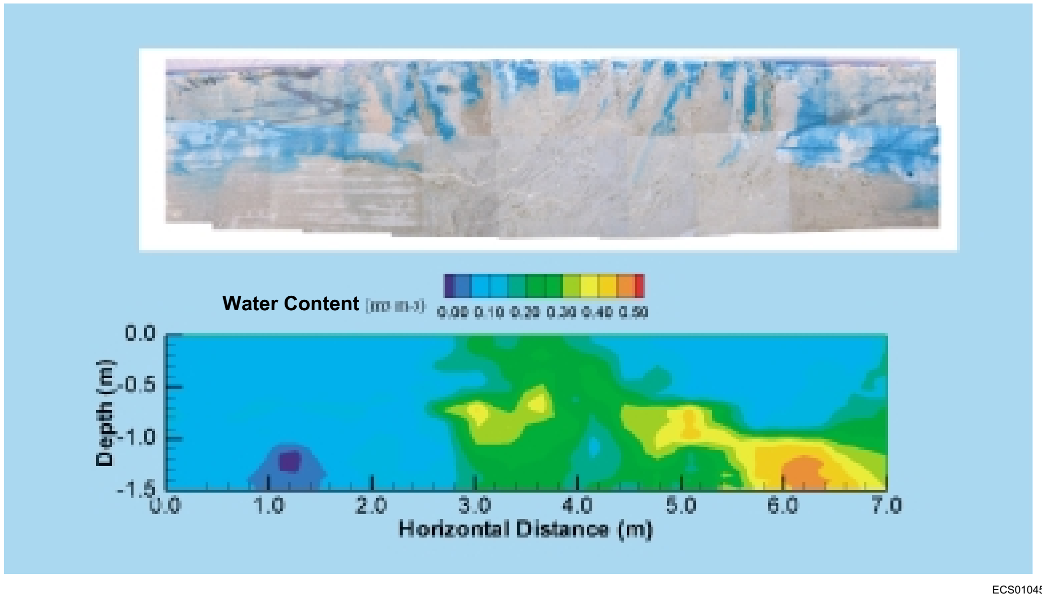

Figure 7.3.3. Dye Infiltration Experiment at the Clastic Dike in the Army Loop Road Trench. The upper image is a photo of the exposure showing the distribution of the blue dye. The lower image is a computer generated map of moisture distribution in the dike and adjacent sediment. The dike is between about 3 and 5 meters (10 and 16 feet).

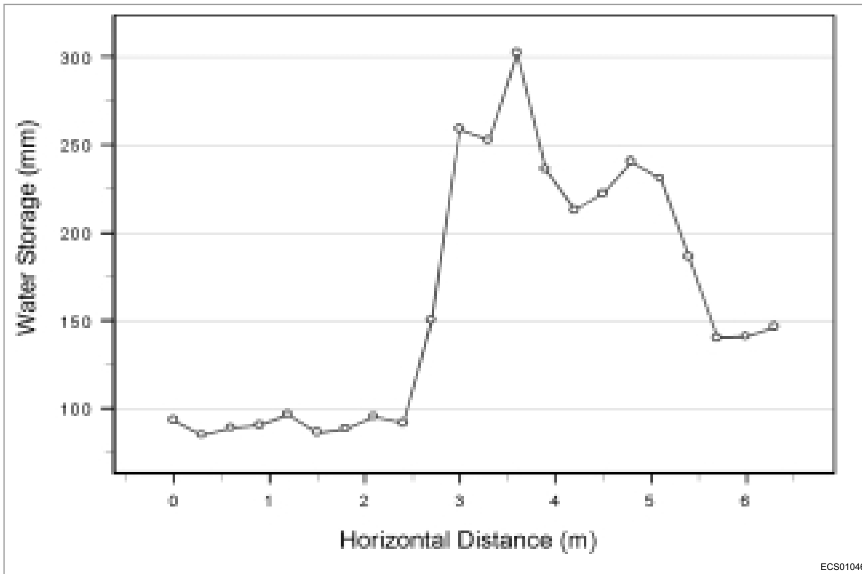

Figure 7.3.4. Moisture Distribution within the Clastic Dike in the Army Loop Road Exposure. The dike is between 3 and 5 meters (10 and 16 feet).

One important feature noted in the excavation and infiltration experiment was a clastic sill that extends from one side of the dike. (A sill is similar to a dike except that a sill is parallel to the enclosing geologic beds instead of cross-cutting the geologic beds.) This sill was detected prior to the excavation, when the access boreholes for the infiltration tests were being installed. Moisture data recorded prior to any infiltration activities at the site indicated the presence of a high-moisture zone at a depth of ~1.5 meters (~5 feet) that was present only on the western side of the dike, but not on the eastern side.

Based on previous experience, it was suspected that the feature was a clastic sill. The sill exerted a major influence on the movement of moisture during the experiment. On the side of the dike with no sill, the moisture appears to have migrated uniformly through the sediment. On the side of the dike with the sill, however, moisture penetrated below the sill relatively late during the experiments. Exposing the sill during the excavation showed that moisture had migrated several meters laterally within the sill, carrying moisture well outside of the infiltration zone. This suggested that sills are important controls on vadose zone transport. The results also indicated that even though the air permeability and saturated hydraulic conductivity within the dike and sill were very low, clastic dikes may still be fast transport paths under unsaturated conditions in the vadose zone.

The results of this study indicated that conceptual and numeric models of fluid and contaminant transport through the vadose zone should consider clastic dikes and clastic sills in the subsurface capable of influencing flow.

7.3.4 Isotopic Fingerprinting of Radionuclide Sources at Single-Shell Tanks

J. C. Evans, P. E. Dresel, and O. T. Farmer

Researchers from Lawrence Berkeley National Laboratory and Pacific Northwest National Laboratory analyzed stable and long-lived isotopes in drill core samples from the S-SX tank farm, 200-West Area, in 2001. The purpose of the work was to show whether isotopic and chemical ratios could differentiate among leak events. This section summarizes the results of that effort. The full text of the experimental methods and results can be found in Evans et al. 2001.[b]

Sediment core samples were obtained from borehole 3082, the slant borehole at tank SX-108 (see Section 7.1.2 for more information about the borehole at SX-108). Concentrations of trace metals, common anions, and selected radionuclides were measured from samples of the core in an attempt to differentiate among several possible contaminant sources. The chosen constituents were the isotopic systems of cesium, iodine, and molybdenum and the relatively mobile constituents chloride, nitrate, sulfate, and technetium-99.

The analytical results for cesium-137 and technetium-99 concentrations versus depth showed two concentration peaks for each radionuclide with the more mobile technetium-99 the deeper of the two. The cesium data, however, were inconclusive with respect to separating different leak events for the two peaks because the sample preparation method dissolved large amounts of natural cesium from the sediment and because of large measurement error.

The measured distribution of total molybdenum and molybdenum-100 showed three peaks in concentration at depths of 20.7, 27.5, and 35.4 meters (68, 90, and 116 feet). The molybdenum data indicated three leak events for molybdenum-bearing waste.

Molybdenum and chromium should have the same geochemical properties; thus, hexavalent molybdenum may be a surrogate for hexavalent chromium. The distributions of both of these elements again suggested three separate leak events with the bulk of the molybdenum slightly retarded with respect to the chromium.

Iodine-129 is considered a very hazardous substance (drinking water standard = 1 pCi/L [0.037 Bq/L]) and highly mobile in the natural environment. Very little iodine-129 is expected in tank waste because it was largely partitioned into the vapor phase during operations. However, residual fission-derived iodine disposed to tanks is probably in the tank liquids and available for release during leaks. Stable iodine (iodine-127) should also be present as a reducing agent during chemical processing or as a chemical impurity. Thus, the isotopic ratio of iodine isotopes is likely to vary and can be used as a fingerprint for individual

(b) Evans, J. C., P. E. Dresel, and O. T. Farmer (Pacific Northwest National Laboratory, Richland, Washington), "ICP/MS Isotopic Determination of Nuclear Waste Sources Associated With Hanford Tank Leaks." Submitted March 27, 2001, to *Journal of Environmental Radioactivity*.

waste streams. The distribution of iodine isotopes with depth in samples from borehole C3082 showed that iodine in the sample came from two different leak events.

Several non-isotopic species are known to migrate almost unretarded through the vadose zone. These species include chloride, nitrate, sulfate, and technetium. The distributions of chloride, nitrate, and technetium with depth in borehole C3082 showed two peaks for each constituent.

In conclusion, isotopes of iodine and molybdenum can be used to distinguish different leak events from waste tanks. Cesium isotopes were not successful in discerning different leaks. Ratios of several different unretarded species also can be used to discern different leaks. The separate leaks may be from different tanks or from more than one leak from a single tank. Comparison of isotopic and species ratios of vadose zone sediment can help to determine sources of vadose zone and groundwater contamination.

7.3.5 Water Movement Through the Vadose Zone as Inferred from Isotopic and Chemical Measurements of Borehole Samples

J. C. Evans, P. E. Dresel, and O. T. Farmer

To evaluate contaminant transport through the vadose zone to groundwater requires an understanding of how and where water moves in the vadose zone. An isotopic and chemical study of porewater from cores obtained during drilling of RCRA well 299-W22-48, at the S-SX single-shell tank farms in 200-West Area, was done in fiscal year 2001 to investigate this issue. This section summarizes the report of this work, which is found in RPP-7884.[c]

Stable isotopes of hydrogen and oxygen can help indicate the origin of water in the vadose zone near waste sites. A shift in isotope composition to heavier values indicates that the water was partially evaporated before it entered the ground. (Evaporation preferentially removes the lighter isotopes of oxygen and hydrogen so that the remaining water is "heavier.") Heavier porewater can indicate waste is from single-shell tanks or waste disposal cribs.

Well 299-W22-48 was drilled immediately east of Waste Management Area S-SX in 1999 (see Figure 6.2.21). The borehole was drilled in a previously disturbed area in the vicinity of past-practice disposal facilities. Thirty-two samples were collected from the drill core. Porewater was extracted from the samples, and the water content and abundances of the stable isotopes of oxygen and hydrogen were measured at Lawrence Berkeley National Laboratory.

The oxygen and hydrogen isotope composition of groundwater at the Hanford Site suggests that the source for water in the unconfined aquifer is natural precipitation that has not undergone evaporation processes. The composition of the vadose zone porewater, however, indicates that these waters have undergone significant evaporation.

The oxygen isotope composition versus depth for porewater samples is shown in Figure 7.3.5. The oxygen isotope composition of the shallowest sample is much heavier than local precipitation or Hanford Site process water from the Columbia River, two potential sources of surface water. The shift in the isotope composition to heavier values signifies that the waters have been strongly evaporated. This is typical of near-surface soil waters, especially in arid and semiarid environments. At a depth of 2 meters (6.5 feet), the oxygen isotope composition of the porewater reflects that of precipitation and Columbia River water. Beneath 2 meters (6.5 feet), most porewater is shifted to heavier compositions. There are two porewater samples from the deeper part of the core that do not show the effects of evaporation. The deeper sample, from 71.8 meters (236 feet), is from the saturated zone and has the composition of groundwater in the unconfined aquifer. The other sample, at 44.7 meters (147 feet), is from an extremely moist zone. Isotopic analyses for uranium-236 and fission-derived isotopes of molybdenum show no evidence of nuclear production associated with the moist sediment sample.

The pattern of the shallow, 0.5-meter- (1.6-feet-) deep, strongly evaporated sample underlain by the 2-meter (6.5-foot) sample that is the same as

(c) RPP-7884. Draft. "Transport Mechanisms Inferred by Isotope Geochemistry." In *Field Investigative Report for Waste Management Area S-SX*, Appendix D.6. J. C. Evans, P. E. Dresel, and O. T. Farmer, CH2M HILL Hanford Group, Inc., Richland, Washington.

unevaporated groundwater, precipitation, or Columbia River water is similar to patterns observed in other studies of shallow, unsaturated soil. The unevaporated sample from 2 meters (6.5 feet) implies that the soil column at well 299-W22-48 experienced anomalously high infiltration that allowed unevaporated water to reach that depth. The oxygen isotopic composition allows the possibility that process water was spilled on the surface at this site; there is anecdotal information suggesting that there once was an infiltration pond for disposing of clean process water in the vicinity.

Data for the water from the moist sediment zone are of great interest in deciphering subsurface water movement. The data show that the water is not from direct, vertical infiltration because the isotopic composition of porewater above and below the moist zone is different than that of the water from the moist zone. The most likely source for the porewater in this zone is the 216-S-3 crib located ~50 meters (~165 feet) northwest of the borehole, though some contribution from the S-SX tank farms is possible.

In summary, the stable isotopic composition of porewater collected from sediment in Waste Management Area S-SX was used to distinguish water from liquid disposal sources from natural infiltration.

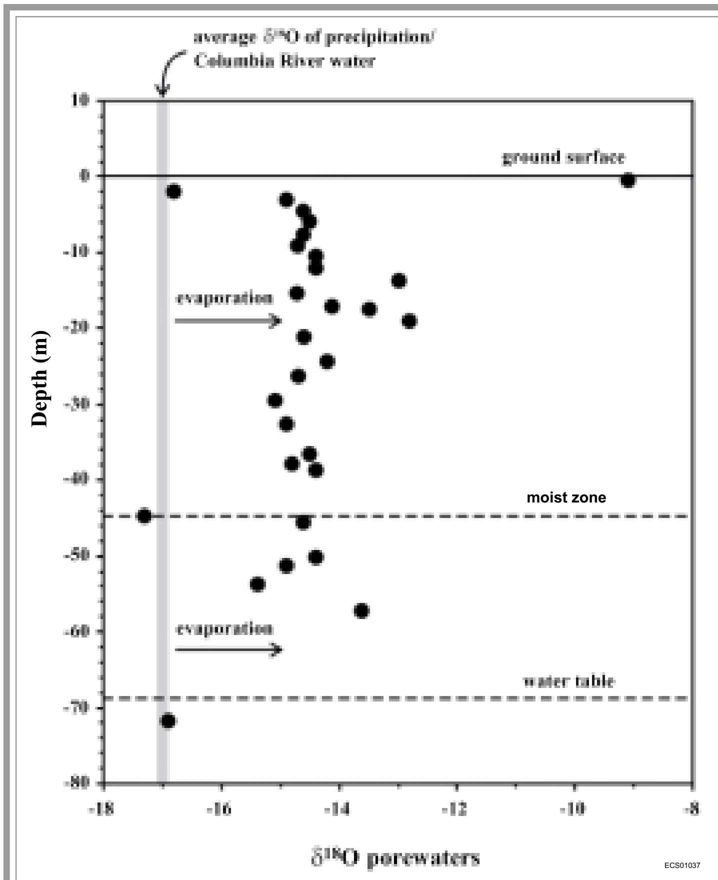

Figure 7.3.5. Oxygen Isotope Composition versus Depth for Samples of Porewater from Well 299-W22-48. The approximate depths of the moist zone above the Plio-Pleistocene caliche layer and the groundwater table are also shown.

7.3.6 Predicting Deep Drainage Using Soil Hydraulic Properties and Soil Texture Data

G. W. Gee and A. L. Ward

Movement of contaminants from leaking tanks is accelerated by infiltration of precipitation. Tank farms and other waste sites at Hanford are generally covered with gravel and kept free of vegetation. These factors eased operation of the tanks and prevented uptake of contaminants by plants or animals, but enhanced infiltration of precipitation.

This study used data collected from previous studies to calibrate a simple water balance model that predicts infiltration. The previous studies included Gee et al. 1992, PNNL-13033, Tyler et al. 1999, PNL-6488, PNL-6403, and Gee and Bauder 1986.

Independent drainage data was collected to test the model. The independent data were from a 7-meter- (23-foot-) deep basin lysimeter, a device for measuring infiltration, at the Hanford Site's Solid Waste Landfill where data have been collected since 1996. At each site, texture of the surface soil (grain size distribution) was determined using wet sieving and hydrometer analysis (Gee and Bauder 1986).

Deep infiltration at waste burial sites at the Hanford Site is best analyzed by assessing the complete water balance of the surface soil. Infiltration is an integral component of the water balance and in its simplest form is equal to precipitation minus the sum of storage change plus evapotranspiration plus run-off/run-on.

Water balance of surface soil is controlled by three main variables: climate, soil, and vegetation. The assessment of net infiltration at the waste sites involved the interaction of these three factors. The Tank Farm Water Balance Model is based on the climate, soil, and vegetation applicable to the tank farms and the fact that most waste sites have highly permeable surfaces and are on relatively level ground (little or no run-off or run-on). The model also assumes that winter precipitation dominates the net infiltration process and that annual water storage changes are negligible.

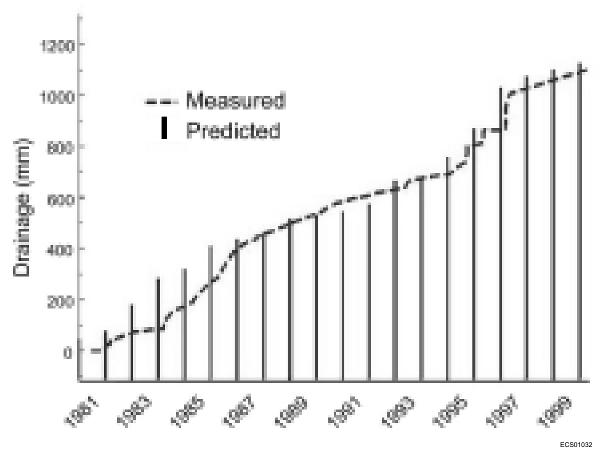

Figure 7.3.6. Twenty-Year Record of Measured and Predicted Drainage from Buried Waste Test Facility Lysimeter

The performance of the water balance model is shown in Figure 7.3.6, where the model is applied to the lysimeter data from the Buried Waste Test Facility. The agreement between modeled and observed infiltration is good. However, the model was not independent of the lysimeter data, because the infiltration for the first 15 years from the lysimeter was used in fitting the evaporation factor in the model. However, the model then was applied to independent data from the Solid Waste Landfill lysimeter (HNF-7173). Table 7.3.1 shows measured annual infiltration compared to that predicted by the water balance model for a 4-year period. The annual infiltration is predicted within 4 millimeters (0.16 inch) for all 4 years. (The calendar year 1997 winter precipitation exceeds the 1997 annual precipitation because the winter precipitation was calculated from November 1996 to March 1997.)

Uncertainty in the infiltration is dependent on uncertainties in the surface soil texture. Variations in the percentage of fine-grained materials by several percentage points can alter the infiltration estimate by 10 to 20 millimeters (0.4 to 0.8 inch) per year or more. For example, an increase of fine-grained material from 1% to 7% reduces the predicted infiltration by a factor of nearly 3, from 80 to 28 millimeters (3.1 to 1.1 inches) per year.

Infiltration predictions were developed for several tank farms, where texture data were available for surface sediment. Table 7.3.2 shows the predicted annual infiltration from the Tank Farm Water Balance Model, based on

Table 7.3.1. Measured Drainage at the Hanford Solid Waste Landfill Compared to that Predicted by the Tank Farm Water Balance Model

Year	Annual Precipitation (mm)[(a)]	Winter Precipitation (mm)[(a)]	Measured Drainage (mm)[(a)]	Predicted Drainage (mm)[(a)]
1997	162	224	162	158
1998	164	107	41	42
1999	95	86	22	21
2000	205	88	19	23

(a) To convert to inches, multiply by 0.03937.

Table 7.3.2. Predicted Drainage Rates from the Tank Farm Water Balance Model Related to Percent Fines in Surface Sediment and Percentage of Annual Precipitation Based on a 20-Year Record

Site/Soil	Percent Fines[(a)]	Drainage (mm/yr)	Percent Precipitation
AP tank farm	1	80	43
S tank farm	3	56	30
U tank farm	7	28	15
Coarse gravel	0	98	53
Solid Waste Landfill Site	3	56	32
Silt loam	60	0	0

(a) Percent fines = Percent of soil particles <2 mm in spherical diameter.

surface texture and the past 20-year climate record. Infiltration estimates from the texture data suggest that over a 20-year period, the average infiltration rate ranged from 15% to over 50% of the annual average precipitation (28 to 80 millimeters per year [0.8 to 3.1 inches per year]).

Data available from lysimeter studies at the Hanford Site have shown that winter precipitation and surface textures are the dominant controls to waste site drainage (Gee et al. 1992; PNNL-13033). The calibration data set for the Tank Farm Water Balance Model contains a 20-year precipitation record and infiltration from lysimeters with surfaces ranging from clean gravels to fine silt loams. Combining these data into a water balance model has led to a simple expression for predicting infiltration at tank farms and other waste sites that have bare surfaces. The model does not account for thermal effects on evaporation due to radioisotope heated tank waste, i.e., warmer subsurface temperatures could increase the evaporation rates from tank farms thus decreasing infiltration. For this reason, the values reported here may overestimate the actual infiltration fluxes. There have been no direct measurements of infiltration at Hanford Site tank farms and only one set of measurements for other waste burial grounds (the Solid Waste Landfill), so full verification of the model remains to be completed as additional data are collected.