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UCRL-AR-128638

Post-Closure Plan for the Pit 6 Landfill Operable Unit Lawrence Livermore National Laboratory Site 300

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May 18, 1998

***Weiss Associates, Emeryville, California**

Environmental Protection Department
Environmental Restoration Division

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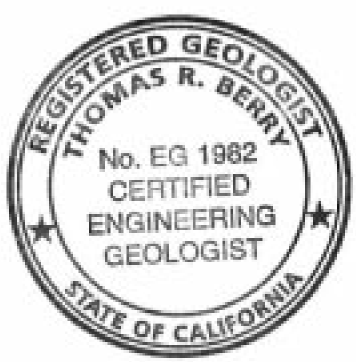
Certification

I certify that the work presented in this report was performed under my supervision. To the best of my knowledge, the data contained herein are true and accurate, and the work was performed in accordance with professional standards.



4/11/98

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Acronyms and Abbreviations

For the convenience of the reader, a reference list defining acronyms and abbreviations used throughout this document is presented after the tables.

1. Introduction

This document constitutes the Post-Closure Plan which proposes programs for post-closure monitoring and maintenance for the Pit 6 Landfill located at Lawrence Livermore National Laboratory (LLNL) Site 300. Site 300 experimental test facility, located in the Altamont Hills near Tracy, California, is owned by the U.S. Department of Energy (DOE) and operated by the Regents of the University of California.

Data obtained during environmental investigations indicate that chlorinated solvents have been released to the subsurface from buried debris in the Pit 6 Landfill. Site investigation and characterization activities and results for the Pit 6 Operable Unit (OU) are discussed in detail in the Site-Wide Remedial Investigation (SWRI) Chapter 12 (Webster-Scholten, 1994).

Possible remediation measures for the Pit 6 Landfill OU were evaluated in the Feasibility Study (Devany et al., 1994) which was later redesignated as an Engineering Evaluation/Cost Analysis (EE/CA), and an addendum to the EE/CA (Berry, 1996).

Closure/post-closure of the Pit 6 Landfill is being conducted as a non-time-critical removal action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as part of the overall remediation of Site 300.

The removal action for the Pit 6 OU was approved by the U.S. Environmental Protection Agency (EPA), California Department of Toxic Substances Control (DTSC), and Regional Water Quality Control Board (RWQCB)-Central Valley Region in May 1997 to address ground water contamination. An Action Memorandum authorizing implementation of the removal action was signed by the DOE in June 1997 (Berry, 1997). The removal action, consisting of construction of a landfill cap and associated drainage system for closure of the Pit 6 Landfill, was implemented in the summer of 1997. The final status of the Pit 6 OU including the landfill and cleanup standards for the volatile organic compound (VOC) plume will be addressed in the Site 300 Site-Wide Record of Decision (ROD), currently scheduled for submittal in 2000.

This document is submitted to meet applicable State requirements under California Code of Regulations Title 22 (22 CCR) Articles 1, 6 through 8, and 14 and 23 CCR Article 5, Sections 2550.0 through 2550.12 and Article 8, Section 2580 for post-closure ground water monitoring and landfill cap inspection and maintenance, as well as providing contingencies for addressing existing ground water contamination. These regulations were established as Applicable or Relevant and Appropriate Requirements (ARARs) for the Pit 6 Landfill removal action in the EE/CA and Action Memorandum.

Under CERCLA, onsite actions must comply only with the substantive portions of a given ARAR and need not comply with administrative requirements. Monitoring and associated reporting (CERCLA five-year review, reporting of detection monitoring results, etc.) are considered substantive requirements under CERCLA. However, additional permitting and reporting associated with other ARARs are considered administrative and redundant to requirements under CERCLA.

This document includes:

- Background information on site location and description (Section 2.1).

- A summary of site closure activities to date including installation of the Pit 6 Landfill cap and drainage control system (Section 2.2),
- A description of closure documentation and notification procedures (Section 3).
- A description of post-closure care and use of the Pit 6 Landfill area (Section 4).
- Proposed procedures for post-closure inspection and maintenance of the Pit 6 Landfill cap and associated drainage (Section 5).
- Proposed water quality protection standards including constituents of concern, concentration limits, point of compliance, and the compliance period (Section 6).
- Proposed Detection Monitoring Program to provide early detection of any future releases of contaminants (Section 6).
- Proposed Corrective Action Monitoring Program for the existing VOC plume (Section 6).
- Contingency plans for the detection of releases from buried waste and corrective actions (Section 7).

2. Site Background

2.1. Site Location and Description

LLNL Site 300 is located in the sparsely populated Altamont Hills about 12 miles southeast of the LLNL Livermore Site, in Livermore, California and about 8.5 miles southwest of Tracy, California (Fig. 1). The Pit 6 Landfill is located immediately north of Corral Hollow Road in the southwest portion of Site 300 (Fig. 2). The Carnegie State Vehicular Recreation Area (SVRA), used for off-road motorcycles, is located across Corral Hollow Road to the south. Residential facilities for rangers who maintain the SVRA are located about 1,000 feet (ft) southeast of the Pit 6 Landfill on the north side of Corral Hollow Road (Fig. 3).

The landfill is located on a relatively flat terrace about 40 ft above Corral Hollow Road (Fig. 3). Between 1964 and 1973, an estimated volume of 1,911 cubic yards (yd^3) of waste from LLNL and Lawrence Berkeley National Laboratory was buried in three solid waste trenches and six smaller animal pits. Consistent with disposal practices at the time, the trenches and pits were unlined. Waste was covered with native soil immediately after placement and the area was regraded when use of the landfill was discontinued.

LLNL subsequently built and operated a rifle range on top of the landfill to train security personnel. The rifle range was demolished immediately prior to construction of the landfill cap in June 1997. A new rifle range will be constructed on top of the landfill cap and put into service in December 1997.

2.1.1. Physical Characteristics

2.1.1.1. Topography and Climate

The topography of Site 300 consists of a series of steep hills and canyons generally oriented northwest to southeast. Elevation ranges from about 500 ft above Mean Sea Level (MSL) in the southeast corner to about 1,750 ft above MSL in the northwest. The Pit 6 Landfill is located close to the southern boundary on a gently sloping terrace with an average elevation of about 710 ft above MSL. Precipitation runoff flows to the south along drainage divides to the west and east of the area towards Corral Hollow Creek, an intermittent stream that flows to the east.

The climate of Site 300 is characterized by mild winters with little rain and hot, dry summers. Sunshine is abundant throughout the year. Based on continuous meteorological data (1930 - 1995) for Site 300 (Hydrosphere Data Products, 1996), the average annual rainfall is 13.97 inches (in.) with an annual rainfall ranging from a low of 6.40 in. to a high of 32.37 in. in 1976 and 1983, respectively. The mean annual temperatures, based on daily records, ranges from 41 degrees Fahrenheit (˚F) in 1946 to 76˚F in 1958. The lowest temperature of record was 18˚F recorded on January 5, 1961 and December 9, 1972 and the highest was 115˚F on September 3, 1950.

The Probable Maximum Precipitation (PMP) for the site was calculated for the Title II landfill cap design (Golder Associates, Inc., 1996) using Hydrometeorological Report No. 49, "Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages," by the U.S. National Oceanic and Atmospheric Administration, and Hydrometeorological Report No. 36, "Interim Report, Probable Maximum Precipitation in California," by the U.S. Weather Bureau. Based on the methods described in these reports, the PMP for 1, 3, 6, and 24 hours was calculated. The highest PMP estimated for the Site 300 facility area was the 24-hour PMP of 12.62 in.

During winter, cyclonic westerly storms affect the region and are accompanied by rainy periods with winds from the north and northwest. Summers are consistently hot and dry with winds from the west and west-southwest. During the spring and fall, wind directions are more variable.

2.1.1.2. Geology

Geologic characterization of the Pit 6 Landfill area involved integrating data from surface geologic maps, drill cores, trench and test pits, surface and borehole geophysics, and aerial photographic interpretation. Stratigraphic units identified beneath the Pit 6 OU include:

- Quaternary alluvium (Qal) and terrace deposits (Qt) - unconsolidated clay, silt, sand and gravel beds. The disposal trenches for the Pit 6 Landfill were constructed in the terrace deposits.
- Lower Blue Sandstone Member of the Miocene Neroly Formation ($Tnbs_1$) - poorly consolidated volcaniclastic sandstone with interbedded claystone, siltstone, and minor conglomerates.
- Miocene Cierbo Formation (Tmss) - silty sandstone to sandstone with interbedded claystone and siltstone.
- Eocene Tesla Formation (Tts) - fine-grained sandstone and claystone with localized pebble and coal beds.

Figure 4 shows a south-north cross section of the subsurface underlying the Pit 6 OU. Alluvial terrace deposits are essentially flatlying and extend from ground surface to about 30 ft below ground surface (bgs) to the $Tnbs_1$ bedrock contact. The $Tnbs_1$ sandstone dips 5 to 20 degrees south, reflecting the dip of the south limb of the Patterson Anticline. Abrupt changes in the dip of bedrock occur across the Carnegie Fault Zone, a northwest-southeast trending fault zone that transects the Pit 6 Landfill area (Fig. 4). South of the Carnegie fault zone, bedrock units are oriented nearly vertical and are locally overturned by up to 30 degrees.

An active (Holocene) fault strand is located approximately 150 ft south of the Pit 6 Landfill. South of this fault, Quaternary alluvial deposits associated with Corral Hollow Creek are underlain by the Cierbo and Tesla Formations which are also vertical and locally overturned.

A bedrock trough extends eastward from the southeast corner of the Pit 6 Landfill and is coincident with an increased thickness of Qt gravel channel deposits. The trough may influence the migration of trichloroethylene (TCE)-contaminated ground water as discussed in Section 2.1.3.1.

2.1.1.3. Hydrogeology

Two hydrogeologic units have been defined in the Pit 6 OU: the Qt-Tmss (Quaternary terrace deposits-Cierbo Formation) and Qal-Tts (Quaternary alluvium-Tesla Formation) hydrogeologic units. The hydrogeologic units are hydraulically separated by faulting and lithologic discontinuities.

As shown in Figure 5, the Qt-Tmss hydrogeologic unit is restricted to the area north of Corral Hollow Road. This hydrogeologic unit consists of the following stratigraphic units:

- Quaternary terrace deposits (Qt).
- Lower Blue Sandstone member of the Miocene Neroly Formation ($Tnbs_1$).
- Cierbo Formation (Tmss).

These stratigraphic units are hydraulically connected due to extensive bedrock fracturing within the Carnegie Fault Zone. Saturation in the Qt unit is laterally discontinuous and consists of, at most, a few feet of saturated silty gravel overlying an irregular bedrock contact. Water in the Qt unit communicates directly with the underlying $Tnbs_1$ and Tmss bedrock units. This water-bearing zone extends to a depth of at least 245 ft. Hydraulic conditions range from unconfined to confined.

North of the Carnegie Fault Zone, ground water in the Qt-Tmss hydrogeologic unit has historically flowed primarily downdip in a southward direction, at an estimated average rate of 30 feet per year (ft/yr). In the fault zone, ground water flows to the southeast. This distinct change in flow regime and the results of cross-fault hydraulic test data indicate that the northern limit of the Carnegie Fault Zone impedes north-south ground water flow in the bedrock units. This barrier may result from either offset of the beds or low permeability gouge in the fault plane. Ground water flow in the Qt unit is probably not appreciably affected by the faulting.

During the summer of 1996, water elevations in wells north of the Carnegie Fault Zone dropped over 10 ft, several feet below water elevations in wells within the fault zone. Current water level elevations (Fig. 6) suggest that the flow regimes north of and within the fault zone are behaving relatively independently and the northern limit of the fault acts as a hydraulic barrier below the Qt/bedrock contact. Flow currently appears to be toward the southeast throughout the immediate vicinity of the Pit 6 Landfill. However, when ground water rises into the Qt, as has been the case prior to 1996, the potentiometric surface is continuous across the fault zone (Fig. 7). Under these historical conditions, shallow ground water north of the fault zone flows generally south. Upon entering the fault zone, flow is to the southeast.

During the second quarter of 1997, depth to ground water in the vicinity of trenches 1, 2, 3 and animal pits 1-6 in the Pit 6 Landfill ranged from 27 to 76 ft bgs. The estimated depth to the base of the waste buried in these trenches and pits ranges from 11 to 16 ft bgs; the vertical distance from the base of the buried waste to ground water is 15 to 60 ft.

The Qal-Tts hydrogeologic unit is restricted to the area south of Corral Hollow Road and the southern half of the Carnegie SVRA Residence Area (Fig. 5). This hydrogeologic unit consists of Quaternary alluvium (Qal) and the Tesla Formation (Tts) stratigraphic units. Ground water elevations in the Qal-Tts hydrogeologic unit beneath the Corral Hollow Creek floodplain are typically 25 to 30 ft lower than in the Qt-Tmss hydrogeologic unit. Shallow ground water is ephemeral and present locally in the Qal unit of the Corral Hollow floodplain. Following heavy precipitation, ground water in the Qal probably flows eastward in the same direction as surface flow. The direction of underlying flow in the Tesla Formation is undetermined.

2.1.1.4. Surface Water

The natural, but rarely occurring, surface water in the Pit 6 OU area typically is the result of either surface runoff from precipitation or from spring discharge. As a result of the semiarid nature of Site 300, natural surface runoff is rarely observed, and only occurs briefly during severe [>0.3 inches/hour (in./hr] or prolonged (>2 hour) storm intervals (Bryn et al., 1990). During severe storms, surface water may flow along one of several north-south ravines and into Corral Hollow Creek.

Three springs, Springs 7, 8, and 15, are located in the immediate vicinity of the Pit 6 Landfill as shown in Figure 3. These springs occur along the mapped traces of the Carnegie Fault and associated Holocene fault strand.

Spring 8 is a perennial spring located about 550 ft southwest and hydraulically crossgradient of Pit 6. Ground water emanating from the Qt and $Tnbs_1$ stratigraphic units flows from Spring 8 at approximately 1 gallon per minute (gpm). The maximum water depth measured in this spring is about 1.5 in. with a standing water surface area of approximately 80 square feet (sq. ft).

Springs 7 and 15 are intermittent springs located approximately 510 to 550 ft southeast and downgradient of the Pit 6 Landfill. When flowing, ground water from the Qt unit flows into Spring 7 at a rate of approximately 2 gpm. Spring 7, which is the closest to Pit 6, has been dry since the summer of 1992. Ground water flows from the Qt and Tmss stratigraphic units into Spring 15 at a rate of about 1 gpm during the wet season (winter). Spring 15 has been dry since late 1991. Both springs cease flowing during the dry season.

2.1.1.5. Water-Supply Wells

Four offsite water-supply wells are located in the vicinity of the Pit 6 Landfill: two active wells, CARNRW1 and CARNRW2, and two inactive wells, CARNRW3 and CARNRW4 (Fig. 3).

These wells are located in the Carnegie SVRA operated by the State of California Department of Parks and Recreation.

Wells CARNRW1, 2, and 3 are located approximately 1,500 ft east of the Pit 6 Landfill in the SVRA Residence Area. Well CARNRW1 supplies ground water for filling the Residence Pond, and is not chlorinated or used as potable water (Caldera, 1991). Ground water from CARNRW2 is used for irrigating trees, watering motorcycle tracks, washing vehicles, and occasional fire fighting. The water is chlorinated but is rarely used as drinking water because of its poor natural water quality, which results in a sulfurous odor and bad taste (Webster-Scholten, 1994). Well CARNRW3 has not been used for consumption since the pump was pulled in 1982. Park rangers do not plan to use the well again because of its very poor natural water quality.

Well CARNRW4 is located 450 ft south-southwest of the Pit 6 Landfill near the Carnegie SVRA Headquarters Building. This well is not currently used and probably has never been used because of low production and recharge (Webster-Scholten, 1994).

2.1.2. Inventory of Buried Waste

Between 1964 and 1973, waste from LLNL Livermore Site and Lawrence Berkeley National Laboratory was buried in three solid waste trenches and six smaller animal pits shown in Figure 8. Records indicate that the solid waste (estimated volume of 1,762 yd^3) in the trenches primarily consists of shop and laboratory materials contaminated with residues of uranium, thorium, and beryllium; capacitors; empty drums and tanks; a degreaser; compressed gas cylinders; pallets; and mercury-filled lamps and ignition tubes. The animal pits contain animal carcasses and waste from biomedical experiments (estimated volume of 149 yd^3). Records indicate that some animal carcasses retained quantities at the milli- to microcurie level of mostly short-lived radionuclides at the time of burial. Table 1 provides an inventory of disposed waste, and Table 2 lists radionuclides and their respective half-lives. Although records do not specify disposal of VOCs, vapor, soil, and ground water data indicate that VOCs were released near the southeast corner of the landfill and therefore were likely to be in some of the buried waste. The trenches and animal pits were unlined, and the waste was covered with native soil immediately after placement.

The only known instance of buried radioactive material (i.e., above background levels) in Pit 6, other than residues and the animal pit waste, was three shipments containing depleted uranium 238 (D-38). At the direction of LLNL management, this waste was exhumed in 1971 and shipped offsite along with some waste containing mercury. Two subsequent radiation surveys detected no residual radioactivity.

2.1.3. Existing Contamination

Investigations have been conducted to identify the nature and extent of contamination in the Pit 6 OU. Data indicate that the chlorinated solvent TCE and trace concentrations of other VOCs were released to the subsurface from buried debris in the Pit 6 Landfill. Soil and water samples confirm that no significant concentrations of metals, high explosive (HE) compounds, radionuclides, or other chemicals have been released from Pit 6 other than some evidence of a minor past release of tritium (^3H). A list of constituents of concern for the Pit 6 OU is presented in Section 6.

2.1.3.1. Ground Water

Ground water samples have been routinely collected in the Pit 6 OU area since 1984. Ground water samples have been analyzed for VOCs, aromatic hydrocarbons, HE compounds, metals, polychlorinated biphenyls (PCBs), pesticides, phenols, and radionuclides. These data indicate that TCE is the primary chemical of concern in ground water beneath the Pit 6 OU. The historical maximum TCE concentration detected in ground water is 250 micrograms per liter (µg/L). Other VOCs, including tetrachloroethylene (PCE), 1,1,1-trichloroethane (1,1,1-TCA), 1,2-dichloroethylene (1,2-DCE), 1,2-dichloroethane (1,2-DCA), and methylene chloride have been detected at lesser concentrations. No VOCs have been detected in the active water-supply well, CARNRW1, used by the Carnegie SVRA. Trihalomethanes (THMs) were detected in the Carnegie SVRA water-supply well CARNRW2; however, this was due to sampling downstream from the chlorination unit for this well. The sampling point has been moved upstream of the chlorination unit, subsequently no THMs have been detected in CARNRW2 well water above the detection limit of 0.2 µg/L.

Ground water data indicate that a ground water TCE plume extends to the southeast from Pit 6 (Fig. 9). The shape of the TCE plume is controlled by the irregular contact between the Qt unit and the Tertiary bedrock, and is coincident with an increased thickness of Qt gravel discussed in Section 2.1.1.2. TCE distribution in ground water is restricted to the uppermost section (Qt and $Tnbs_1$) of the Qt-Tmss hydrogeologic unit. No VOCs have been detected in ground water samples from the Qal-Tts hydrogeologic unit south of the fault zone.

VOC concentrations in ground water have naturally attenuated by almost two orders of magnitude over the past few years, and are below or close to Maximum Contaminant Levels (MCLs) in all wells. As of second quarter 1997, TCE was the only VOC detected in Pit 6 OU monitor wells other than *cis*-1,2-DCE which was detected in one well (K6-01S). VOC concentrations detected in ground water have decreased from a historical maximum concentration of 250 µg/L during the fourth quarter of 1988 to a maximum total VOC concentration in the second quarter of 1997 of 15 µg/L (Fig. 10), all of which was TCE. Currently the TCE plume extends about 500 ft east of the southern corner of Pit 6. Only two onsite wells, EP6-09 and K6-19, have concentrations above the 5 µg/L MCL for TCE. Available data suggest that VOC concentrations are naturally declining. This reduction in concentrations can be attributed to one or more mechanisms including dilution, dispersion, irreversible sorption to solid media, evapotranspiration, biodegradation, and/or chemical degradation. Should the overall declining trend continue, VOC concentrations in most wells could be below MCLs within a few years.

Activities of tritium are above background in monitor well BC6-12 suggesting a possible localized release. Tritium was first analyzed for in BC6-12 in 1994 when an activity of 555 picocuries per liter (pCi/L) was detected. Tritium activity detected in BC6-12 as of June 1997 was 1,390 pCi/L whereas activities in surrounding wells have typically been below a detection limit of 100 pCi/L. These data suggest a minor and localized release of tritium has occurred, possibly due to infiltration of rain through areas of subsidence in the landfill (before capping). Detected activities are an order of magnitude below the State MCL of 20,000 pCi/L. There is no Federal MCL for tritium. Tritium sampling will be conducted quarterly in well BC6-12 and surrounding wells to further evaluate this possible release. No evidence of anthropogenic releases of other radioactive contaminants has been detected in soil or ground water samples collected during environmental investigations.

There has been no evidence of metals, HE compounds, PCBs, or pesticides released to ground water.

2.1.3.2. Soil and Rock

Soil and rock samples collected from the Pit 6 OU were analyzed for VOCs, aromatic hydrocarbons, PCBs, metals, and HE compounds. These analytic data have identified TCE as the primary chemical of potential concern in soil and rock. The maximum VOC concentration (0.45 milligrams per kilograms [mg/kg] of TCE) detected in soil in the Pit 6 OU was detected in a sample collected from near the eastern end of Trench 3. TCE has not been detected in soil at depths greater than 16.2 ft.

2.1.3.3. Surface Water

Surface water samples collected from Spring 7 contained a maximum TCE concentration of 110 µg/L in 1988. Other VOCs, including 1,2-DCE were detected at concentrations up to 45 µg/L. No PCBs, benzene, toluene, ethylbenzene and total xylenes (BTEX), HE compounds, or tritium have been detected in Spring 7. Spring 7 has been dry since the summer of 1992. The one surface water sample collected from Spring 15 yielded a TCE concentration of 1.2 µg/L in 1991; no other contaminants were detected. Because the spring has since gone dry, no subsequent samples have been collected. VOCs, PCBs, BTEX, HE compounds, and radionuclides have not been detected in surface water samples collected from Spring 8 or the Cargnegie SVRA Residence Pond.

2.1.4. Summary of the Baseline Risk Assessment

A baseline risk assessment was conducted as part of the SWRI (Webster-Scholten, 1994) to evaluate risks to public health and the environment associated with environmental contamination at Site 300 if no action were taken.

The SWRI baseline risk assessment calculated an individual excess lifetime cancer risk of:

- 5×10^{-6} for onsite workers potentially inhaling VOCs volatilizing from subsurface soil to air in the rifle range area.
- 4×10^{-5} for onsite workers from potentially inhaling VOCs volatilizing from surface water at Spring 7 (when present).
- 3×10^{-6} for offsite residents from inhaling VOCs volatilizing from the surface of the SVRA residence pond if VOCs reach the water-supply wells that are used to fill the pond.

The excess lifetime cancer risks calculated for all other exposure scenarios for the Pit 6 OU were below 10^{-6} with a Hazard Indices of less than 1. The 10^{-4} to 10^{-6} risk range is a target within which risk should be managed as part of a cleanup action.

The inhalation risks for Spring 7 and the SVRA residence pond do not currently have an exposure pathway because Spring 7 has been dry since 1992 and VOCs have not migrated to the water-supply wells used to supply the residence pond. These risks will be addressed by institutional controls including monitoring as discussed in Section 7.2. The inhalation risk from VOCs in soil is addressed by the landfill cap which is designed to prevent VOCs from volatilizing from subsurface soil to air.

2.2. Site Closure

Closure/post-closure of the Pit 6 Landfill is being conducted as a non-time-critical removal action under CERCLA as part of the overall remediation of Site 300.

The main component of this removal action consists of engineering and constructing an impermeable landfill cap and associated drainage control to prevent infiltration of surface water into the pits or trenches that could mobilize contaminants (Fig. 11). Reduced ground water recharge in the area of the VOC plume will further reduce the potential for offsite migration of VOCs. Other components of the removal action include ground water monitoring and administrative controls.

Construction of the Pit 6 Landfill cap and drainage control system began in June 1997 and was completed in September 1997. The landfill cap extends laterally beyond the perimeter of the Pit 6 burial trenches and animal pits, over an area of about 2.4 acres (Fig. 12). The landfill cap and associated drainage diversion system was designed to:

- Minimize infiltration of surface water into the buried waste and generation of leachate.
- Protect the landfill cap from storm water run-off and run-on.
- Prevent localized collapse into void spaces in the buried waste.
- Minimize potential damage from vegetation or burrowing animals, and allow for easy low-cost maintenance.
- Prevent escape of subsurface VOC vapors to the surface to mitigate inhalation risk to onsite workers.
- Accommodate post-closure use of the area as a rifle range.

2.2.1. Landfill Cap

As presented in Figure 13, the landfill cap consists of four engineered layers as listed below from top to bottom:

- A 2-ft-thick topsoil and vegetative cover to allow runoff while inhibiting erosion. The thickness of the vegetative layer was optimized to maximize evapotranspiration, thereby minimizing infiltration of precipitation. The vegetative cover consists of a mix of Bromus hordeceous, Zorro fescue, Hydron rose clover, and Poa scabrella.
- A geocomposite drainage layer to drain water that may infiltrate into the topsoil. This drainage layer, in conjunction with the underlying high-density polyethylene (HDPE) liner, will deter animals from burrowing through the landfill cap.
- A combined HDPE and geosynthetic clay liner consisting of:
  - a 60-mil textured HDPE liner to reduce the potential for slippage between the liner and overlying drainage layer, and
  - a geosynthetic, low-permeability ($\leq 10^{-7}$ centimeters per second [cm/sec]) clay liner system consisting of 0.25 in. of bentonite matting.
- A minimum 2-ft-thick compacted foundation layer consisting of fine-grain silty sand with slightly varying silt, clay, and gravel content. This layer was placed over the existing

ground surface after all plant material was stripped and the site graded. Two layers of geogrid structural reinforcement were installed in the lower portion of the foundation layer to prevent collapse into void spaces. Three layers of geogrid were installed in the vicinity of the new rifle range structure. The geogrid layers will provide additional structural support to protect onsite workers from safety hazards associated with potential void space collapse. The combined soil and synthetic layers will mitigate migration of VOCs that may flux from the subsurface in the immediate vicinity of the rifle range.

In conjunction with the construction of the rifle range, above-grade markers will be installed along the perimeter of the landfill cap to provide additional survey elevation control of the cap. The outdoor rifle range that was removed to allow construction of the cap, will be replaced and put into service in December 1997 (Fig. 3). This rifle range will be used by the LLNL Security Forces for small firearms training. A landfill cap maintenance program will be initiated to ensure the future integrity of the cap as discussed in Section 5.

2.2.2. Surface Water Drainage Control System

The surface water run-off and run-on control system consists of lined surface water channels, down drain pipes, and corrugated metal culverts. Water that reaches the geocomposite drainage layer drains to the cap perimeter where it empties into perforated drain pipes. This water is discharged to concrete-lined channels on the east, west, and south sides of the landfill. A large, rip-rap lined drainage channel is located on the north side of the landfill to divert surface runoff from the north from reaching the landfill cap. Water collected in the channel drains to a natural drainage divide to the west of the landfill cap which drains to Corral Hollow Creek. This system has the capacity for a 24-hour PMP storm event. A leachate capture system was not included because installation would have required excavation and/or significant disturbance of the buried waste. In addition, the landfill cap was designed to prevent the creation of leachate.

2.2.3. Monitoring

Ground water in the vicinity of the Pit 6 OU will be monitored to:

- Provide early detection of any future releases of contaminants to ground water from the buried waste, as described in the Detection Monitoring Program.
- Provide data to (1) evaluate the natural attenuation of the VOC plume, (2) assess the effectiveness of the corrective action (3) monitor tritium in ground water or (4) trigger re-evaluation of the need for implementing contingency actions, as described in the Corrective Action Monitoring Program.

Both monitoring programs are discussed in detail in Section 6.

Monitoring of surface water bodies that could be affected by a release from the Pit 6 Landfill will be conducted by sampling Springs 7 and 15 (when water is present) as discussed in Section 6.2. Storm water runoff is collected and diverted away from the Pit 6 Landfill by surface and subsurface drainage systems. Storm water runoff therefore does not infiltrate into the Pit 6 Landfill and would not be affected by a release from the landfill. In addition, storm water runoff from the natural drainage divide is monitored as part of the LLNL Operations and Regulatory Affairs Division Site-Wide Storm Water Monitoring Program (Order 94-131). Storm water runoff monitoring therefore is not included as part of the Post-Closure Plan surface water monitoring program.

A vadose zone monitoring program will not be implemented at the Pit 6 OU due to potentially unacceptable risks to human health and landfill liner integrity posed by installing a vadose zone monitoring system, as discussed in Section 6.3.

3. Documentation and Notification of Closure

In December 1996, the Title II Design for Pit 6 Landfill Closure (Golder Associates, Inc., 1996) was submitted to and accepted by the EPA, DTSC, and RWQCB as the landfill closure plan to ostensibly meet requirements under 22 CCR 66264.112 and 23 CCR Chapter 15.

This Post-Closure Plan is submitted in lieu of a Report of Waste Discharge meeting the substantive requirements of 23 CCR 2590, as agreed to by the U.S. EPA, DTSC, and RWQCB. As prescribed by CERCLA Section 121(e)(1), Code of Federal Regulations Title 40 (40 CFR), 300.400(e), and the Site 300 Federal Facilities Agreement (FFA), the administrative permitting requirements for onsite remediation activities are waived. Therefore, Federal, State, or local permits are not required for closure/post-closure activities for the Pit 6 Landfill or for the schedule and permit requirements for final closure under 22 CCR 66264.113 are not applicable.

3.1. Certification of Closure (22 CCR 66264.115)

In December 1997, DOE/LLNL submitted to the EPA, DTSC, and RWQCB a Construction Quality Assurance (CQA) report certifying that the Pit 6 Landfill has been closed in accordance with approved closure plan (Title II design) specifications (Golder Construction Services, Inc., 1997). The CQA report documents the construction quality assurance activities that occurred during the landfill cap construction. The CQA report included quality assurance testing results, as-built drawings, and other quality assurance documentation necessary to verify that the Pit 6 Landfill Closure was performed in accordance with CQA requirements and design specifications.

The CQA report was submitted with the signed approval of representatives of LLNL, the DOE, and the independent, California-registered engineer who performed the construction quality assurance during landfill cap construction.

3.2. Survey Plat (22 CCR 66264.116)

After completing construction of the landfill cap, a new rifle range was constructed on top of the cap in December 1997. A survey plat of the landfill cap and the overlying rifle range will be prepared and certified by a professional land surveyor licensed in California. Within 60 days of completing rifle range construction (approximately 150 days after the completion of the landfill cap), DOE/LLNL will submit this survey plat to the EPA, DTSC, and RWQCB. The survey plat will include a prominently displayed note stating the owner's or operator's obligation to restrict disturbance of the hazardous waste disposal unit.

3.3. Post-Closure Notices (22 CCR 66264.119)

LLNL Site 300 is owned by the DOE and operated by the Regents of the University of California. The DOE and the University have jurisdiction over land use on this DOE-owned property. In addition, the closure activities at the Pit 6 OU were performed as an onsite CERCLA removal action. Therefore, the administrative requirements of 22 CCR 66264.119(b) regarding notification to the local zoning authority, notice to the deed, and certification of the notice do not apply.

However, DOE/LLNL submitted to the DTSC, U.S. EPA, and RWQCB a record of the type, location and quantity of hazardous wastes disposed of within each pit/trench of the Pit 6 Landfill, to the best of DOE/LLNL's knowledge, as part of the SWRI (Webster-Scholten, 1994) and in Section 2.1.2 of this document.

In addition, Section 28 of the Site 300 FFA requires that the DOE retains liability notwithstanding any change in ownership or possession of the Site. The FFA requires that the DOE: (1) gives written notice of the property condition to the recipient of the property interest, and (2) notifies the U.S. EPA, DTSC, and RWQCB of any property transfer and provisions made for any additional remedial actions, if required. The DOE is also required to take appropriate actions to ensure that all environmental investigation activities and removal/remedial actions undertaken as part of the FFA will not be impeded or impaired by any property transaction.

3.4. Post-Closure Plan (22 CCR 66264.118)

Submittal of this Post-Closure Plan is in accordance with the substantive requirements of 22 CCR Chapter 14, Section 66264.118. As required, this plan includes a description of activities that will be carried out after closure of the Pit 6 Landfill including monitoring and maintenance activities and the frequencies at which they will be performed to ensure the integrity of the landfill cap and the function of the monitoring systems (Sections 5 and 6).

4. Post-Closure Care and Use of Property (22 CCR 66264.117 and 27 CCR 20950 and 21090)

Research operations for the DOE at Site 300 are expected to continue indefinitely. No other plans for the Site 300 property exist or are anticipated. The Pit 6 Landfill site is located within the secured borders of Site 300. A rifle range used for training of LLNL security personnel has been constructed on top of the landfill. Post-closure use of the area will not be allowed to disturb the integrity of the final cap or any components of the monitoring system unless approved by the DTSC and RWQCB.

4.1. Post-Closure Plan; Amendment of Plan (22 CCR 66264.118 and 23 CCR 2550.6)

Post-closure monitoring and maintenance will be conducted throughout the post-closure period by LLNL personnel in accordance with this post-closure plan. Details of the monitoring and maintenance plan are discussed in Sections 5 and 6.

4.1.1. Length of the Post-Closure Care Period

There are two components of post-closure care:

- Cap maintenance and ground water monitoring for detection of future releases from the Pit 6 Landfill.
- Corrective action monitoring of the existing VOC plume.

4.1.1.1. Duration of cap maintenance and future release detection monitoring

The Detection Monitoring Program, as well as the need for cap inspections and maintenance, will be evaluated at least every five years in conjunction with the CERCLA Five Year Review currently scheduled for submittal in 2002. The DOE plans to operate Site 300 indefinitely. As specified in 23 CCR 2580 and 27 CCR 20950, the post-closure maintenance and monitoring period shall extend as long as the waste buried in the Pit 6 Landfill poses a threat to water quality.

4.1.1.2. Duration of corrective action monitoring

The duration of monitoring the existing VOC plume is dependent on the rate VOCs decline to cleanup criteria. For the past several years, the plume has been naturally attenuating and may reach cleanup standards without having to implement active remedial measures. The Site-Wide ROD will establish cleanup standards and prescribe additional measures to meet these standard, if necessary. The Corrective Action Monitoring Program presented in this document will be in effect at least until the issuance of the Site-Wide ROD at which time it may be continued, revised, or discontinued depending on VOC concentrations in ground water. The Corrective Action Monitoring Program will be evaluated at least every five years in conjunction with the CERCLA Five Year Review. The Corrective Action Monitoring Program will be discontinued when COC concentrations have been reduced to meet cleanup standards established in the Site-Wide ROD.

4.1.2. Post-Closure Contact [22 CCR 66264.118(B)(3)]

Because Site 300 will continue as an active facility indefinitely, a copy of the approved post-closure plan and all revisions will be kept in the office of the Site 300 Manager. The following person and alternate can be contacted about the closed facility at Site 300 during the post-closure care period:

Division Leader
Operations and Regulatory Affairs Division
Environmental Protection Department
Lawrence Livermore National Laboratory
P.O. Box 808, L-633
Livermore, California 94551
Telephone: (510) 423-6577

Site 300 Manager
Lawrence Livermore National Laboratory
P.O. Box 808, L-871
Livermore, California 94551
Telephone: (510) 423-1396

4.1.3. Amendments to the Post-Closure Plan [22 CCR 66264.118(d)]

DOE/LLNL will amend the post-closure plan whenever operating plan changes occur during the post-closure care period. Requests for modifications to the post-closure plan will be made at least 60 days prior to any proposed changes in facility design or operations or within 60 days after any unforeseen changes occur that affect this plan.

4.2. Cost Estimates and Financial Assurance (22 CCR 66264.144 and 66264.145)

Because Site 300 is a U.S. Government facility, pursuant to 22 CCR 66264.140(c), it is exempt from the financial and liability requirements outlined in 22 CCR Chapter 14, Article 8 66264.140, 23 CCR 2580(f) and 2550.0(b), and 27 CCR 20950(f). Therefore, cost estimates and financial assurance for post-closure care are not included.

Site 300 experimental test facility is a portion of the LLNL Federal research facility owned by the DOE and operated under contract by the Regents of the University of California. Site 300 is currently on the CERCLA National Priority List and ground water and soil cleanup activities are administered under a FFA. The DOE is an agency of the Federal government and the United States Congress authorizes funding to meet the mission requirements as well as the financial obligations of the laboratory.

4.3. Security (22 CCR 66264.14)

The entire perimeter of Site 300, including the vicinity of the Pit 6 Landfill, is enclosed by a 4-ft-high, barbed-wire fence. Warning signs are placed around the perimeter of Site 300 on the barbed wire fence indicating that the site is U.S. government property, an explosives test facility, and that trespassing is forbidden by law.

The outdoor firing range, located on the Pit 6 Landfill cap, is used by the LLNL Security Forces for small firearms training. The small firearms firing range is typically open from 7 a.m. to 3 p.m. Monday through Friday, except in January, February, July, and August when it is open from 7 a.m. to 10 p.m. to allow for night-fire practices. A gate located off Corral Hollow Road at the entrance to firing range is used to control access to the firing range. The gate remains open during firing range operating hours and is locked at all other times. An electric eye posted at the gate triggers a bell in Building 899B (Fig. 3) when a vehicle or person passes through the gate. A member of the small firearms training staff and/or Building Coordinator is stationed at Building 899B, when the gate is open. All LLNL personnel and visitors to the firing range are required to check in and out with the training staff or Building Coordinator at Building 899B and provide information regarding the purpose of their visit. As a precautionary measure, a red warning flag is flown, which is visible from the gate during times when firearms practice is actively occurring at the firing range.

The entrance gate is locked at all times during hours when the firing range is closed. When the firing range is closed, access to the area must be coordinated through Site 300 security at the main entrance badge office.

In addition, 24-hr surveillance is maintained at Site 300 seven days a week, through a combination of the following:

- 24-hr security patrol of the facility.
- Controlled access to the facility, which is open only to authorized visitors.
- Closed-circuit television monitoring by security personnel of portions of Site 300.

All visitors must report to the main entry gate on Corral Hollow Road, fill out personal information sheets, and receive badges before entering Site 300. Badges must be presented to protective force officers, who are stationed at the main entry gate to the facility, as well as at designated locations within Site 300 where there are police posts for access control.

5. Post-Closure Inspection and Maintenance

A program will be implemented to inspect and maintain the Pit 6 Landfill cap, associated drainage controls, and the monitoring network. Detailed visual inspections will be made annually and after each major storm of the final cap, drainage and diversion channels, ground water monitoring system, signs, etc., as detailed in the inspection checklist provided in Table 3. Any deficiencies noted will be corrected. Those individuals responsible for conducting the inspections at the facility will have copies of the schedule and the inspection checklist.

If inspections reveal the need for maintenance, repairs will be scheduled. Personnel performing the maintenance, or their supervisor, will date and sign the inspection checklist and record the nature of the repairs. The checklists will be reviewed to ensure the inspection and remedial action schedules are being followed. All completed forms will be accumulated and retained for three years. Reporting of inspection and maintenance activities to the regulatory agencies will occur on an annual basis and in the event that significant repairs to the landfill cap or runoff and drainage system are required, as discussed in Section 6.4.

5.1. Inspection and Maintenance of the Final Cap [22 CCR 66264.310(b)(1) and 27 CCR 20950(e) and 21090(c)(1)]

Throughout the post-closure period, the structural integrity and effectiveness of the final cap for the Pit 6 Landfill will be maintained. The landfill cap will be inspected annually under the supervision of a registered civil engineer or a certified engineering geologist including:

- A site walk to visually inspect the cap for excessive erosion, animal burrowing or other penetrative damage, and differential settlement or other earth movement.
- An elevation survey by a licensed surveyor using existing surveyed permanent markers as reference points to check for differential settlement.

Corrective actions will be implemented, as necessary, to correct the effects of settling, subsidence, erosion, biological penetrative damage or other events that could affect the integrity and effectiveness of the cap. Slight damage to the final cap by settlement or erosion will be repaired by adding more topsoil and reseeding the new area and/or other appropriate erosion control measures to return the landfill cap to specified grade and vegetative cover. More severe damage, such as gullying or subsidence that exposes layers beneath the final cap layer, will be repaired using the same procedures and material in the same thicknesses as specified in the approved cap design.

It is possible that some vegetative biointrusion could occur but will not penetrate beyond the topsoil layer due to the geocomposite drainage layer and underlying HDPE liner. Appropriate measures will be taken to eradicate burrowing animals and repair the final cap. Large plants that could penetrate the HDPE layer (such as trees or bushes) will be removed from the cap before any damage can occur. Any bare spots on the cap will be fertilized and reseeded as needed.

The LLNL Safeguards and Security Department (SSD) is responsible for maintenance of the small firearms firing range at the Pit 6 Landfill. The Building 899 Coordinator is responsible for the inspection and coordination of maintenance activities for the firing range. SSD and the Building Coordinator will be made aware of the landfill cap maintenance requirements so that firing range maintenance activities will be performed in compliance with these requirements and will not compromise the integrity of the landfill cap. SSD will notify the Operations and Regulatory Affairs Division prior to initiating any ground-disturbing maintenance activities at the firing range.

5.2. Inspection and Maintenance of the Ground Water Monitoring System [22 CCR 66264.310(b)(3) and 27 CCR 20950(c)(3)]

To maintain the integrity of the ground water monitor system, the monitor wells will be examined and maintained at least annually and in conjunction with well sampling. A logbook will be kept in a sealed zip-lock bag inside each wellhead stovepipe or vault to document activities performed and observations made each time the monitor well is used or examined. During routine sampling of the monitor wells, any changes in turbidity of sampled ground water or well yield, anomalous depth-to-water measurements, or any other unusual observation will be documented. If a well exhibits significantly increased turbidity or reduced yield for unknown reasons, it will be redeveloped using a surge block and bailer or pump to remove fine material. A downhole camera may be used when encrustation of the screen or casing failure is likely. In situations where such problems are confirmed and no less extreme remedy is deemed sufficient, the well will be destroyed. This will be accomplished using conventional well destruction technology. A new monitor well will be installed at an equivalent hydrogeologic position in the flow system. The borehole will be drilled and the well completed using standard LLNL procedures.

5.3. Inspection and Maintenance of the Runoff and Drainage System [22 CCR 66264.310(b)(4) and 27 CCR 20950(c)(4)]

All drainage layer drain pipes, and surface water drainage channels and outfalls will be inspected annually and after each major storm for erosion and accumulated debris. Repairs will be made with similar materials used in the original construction, as specified in the approved Title II design (serving as the closure plan). Drainage channels and culverts will be cleared of blockage and repaired as necessary to maintain the drainage system design capacity.

5.4. Inspection and Maintenance of Benchmarks [22 CCR 66264.310(b)(5) and 27 CCR 20950(d) and 21090(c)(5)]

Benchmarks placed at Site 300 are surveyed using Mt. Diablo, a U.S. Geological Survey marker located near the West Observation Post (the Elk Monument), and a third benchmark located approximately 5 miles southwest of the Elk Monument. Benchmarks at the site are primarily 3-in.-diameter stainless steel discs set in concrete, although there are a few brass discs set in concrete and others consisting of railroad spikes driven into Corral Hollow Road. All of the Site 300 benchmarks were resurveyed in 1984 to within 0.01 ft. Following completion of the Pit 6 Landfill cap and construction of the rifle range, survey points will be installed at the four corners of the landfill cap using locally established benchmarks. Benchmarks are inspected primarily during use; if the survey crew finds a benchmark shifted out of position during the course of any job, they will resurvey its position and reestablish the benchmark. Benchmarks around the Pit 6 Landfill will be inspected at least annually.

Protective stovepipes with cement pads or below-grade vaults are installed around all monitor wells. Following monitor well installation, the LLNL Survey Team surveys the cement pad or edge of vault to the nearest 0.01 ft. A metal well identification (ID) tag (shiner) is attached to the survey location by the Survey Team with the well ID stamped on the tag. These monitor well benchmarks are inspected routinely as part of the monitor well inspection and maintenance routine.

6. Post-Closure Monitoring

Post-closure monitoring of the Pit 6 Landfill will be conducted to meet the applicable requirements of 23 CCR, Division 3, Chapter 3, Article 5 and 22 CCR, Division 4.5, Chapter 14, Article 6. This will include the following elements:

- Establishing water quality protection standards including constituents of concern (COCs), concentration limits for COCs, a point of compliance and monitoring points (wells), and the compliance period for which monitoring will be conducted (Section 6.1.3).
- Establishing general water quality monitoring and system requirements including details of monitor well construction, and sampling and analysis procedures (Section 6.1.4).
- Implementing a Detection Monitoring Program for ground water to detect future releases of contaminants to ground water from buried waste in the Pit 6 Landfill (Section 6.1.5).
- Describing the circumstances under which an Evaluation Monitoring Program would be implemented (Section 6.1.6).
- Implementing a Corrective Action Monitoring Program for ground water to evaluate the natural attenuation of the VOC plume and the effectiveness of the corrective action (landfill cap) (Section 6.1.7).
- Implementing a Surface Water Monitoring Program to monitor surface water bodies that could be affected by a release from the landfill (Section 6.2).
- Establishing record keeping and reporting requirements for the monitoring programs (Section 6.4).

6.1. Ground Water Monitoring

6.1.1. Applicability of Ground Water Monitoring Requirements (23 CCR 2550.0 and 22 CCR 66264.90)

The Pit 6 Landfill, as a waste management unit at which waste was discharged in or on land for disposal, meets the definition of a "landfill" under 23 CCR 2601. As such, the Pit 6 Landfill is subject to the ground water monitoring requirements established in 23 CCR 2550.1 (Required Programs) and 2550.7 (General Water Quality Monitoring and System Requirements). The monitoring programs proposed for Pit 6 are designed to meet these requirements and are discussed in Sections 6.1.2 through 6.4.

6.1.2. Required Programs and the Water Quality Monitoring Program (23 CCR 2550.1 through 2550.10 and 22 CCR 66264.91)

The following sections establish the Water Quality Protection Standards and monitoring programs proposed for the Pit 6 Landfill in accordance with 23 CCR 2550.7, 2550.8, 2550.9, and 2550.10. The Detection Monitoring Program is designed to provide early detection of any future releases of contaminants to ground water from the buried waste in the Pit 6 Landfill. The Corrective Action Monitoring Program is designed to: (1) continue evaluating natural attenuation of the VOC plume, (2) monitor tritium in ground water, (3) evaluate the effectiveness of the corrective action, and (4) trigger re-evaluation of the need for implementing contingency actions.

The Detection Monitoring Program and Corrective Action Monitoring Program for ground water are discussed in Sections 6.1.5 and 6.1.7, respectively. Evaluation monitoring is not proposed at this time as there is no significant or physical evidence which indicates there have been releases from the Pit 6 Landfill in addition to that evaluated and described in the SWRI (Webster-Scholten, 1994), the EE/CA for the Pit 6 OU (Devany et al., 1994), and the EE/CA Addendum (Berry, 1996). As discussed in Section 2.1.3.1, tritium has been detected in one well (BC6-12) at activities that may suggest a localized release. As tritium has only been detected in one well and the detected activities in this well are an order of magnitude below the State MCL for tritium, ground water sampling and evaluation for tritium will be conducted as part of the Corrective Action Monitoring Program. Section 6.1.6 describes events which could trigger evaluation monitoring.

6.1.3. Water Quality Protection Standards (23 CCR 2550.2 and 22 CCR 66264.92)

The water quality protection standard for the Pit 6 Landfill consists of COCs, concentration limits for those COCs, points of compliance, and monitoring points as described in the following sections. These water quality protection standards apply during the compliance period discussed in Section 6.1.3.4.

6.1.3.1. Constituents of Concern (23 CCR 2550.3 and 22 CCR 66264.93)

COCs, as defined by CCR Chapter 15, are waste constituents, reaction products, and hazardous constituents that are reasonably expected to be in or derived from waste buried in the Pit 6 Landfill.

We have identified 24 COCs. These are listed in Table 4. The list of COCs is based on one or more of the following criteria:

- Records specifically identify the COC as being disposed of in the Pit 6 Landfill or potentially associated with the buried waste (Section 6.1.3.1.1).
- The COC has been detected above background concentrations in soil, ground water and/or surface water in the immediate vicinity of the Pit 6 Landfill, indicating a previous release (Section 6.1.3.1.2).
- The COC is a contaminant or breakdown product that can reasonably be expected to be associated with the type of waste disposed of in the Pit 6 Landfill (Section 6.1.3.1.3).

Analytic data for COCs in ground water in Detection Monitoring Program wells to date are contained in Appendix A. Of the 15 COCs detected at least once in ground water, only TCE has been detected above the MCL (5 μg/l) in ground water in the past two years. TCE and tritium are the only COCs detected in ground water above background concentrations as of second quarter 1997. Ground water will be monitored for all COCs in the Detection Monitoring Program wells as discussed in Section 6.1.5. For the Corrective Action Monitoring Program wells, ground water will be analyzed for halogenated VOCs in all wells and for tritium at selected wells (Section 6.1.7).

6.1.3.1.1. COCs Identified in Disposal Records or Potentially Associated with Buried Waste

A Waste Material Logbook, as well as reports, memos, and interviews of personnel, documented waste disposed of in the Pit 6 Landfill. These records were used to identify potential COCs associated with the buried waste.

Some COCs were specifically identified in the records as being associated with the buried waste. Additional COCs were mentioned in the records as being authorized to be disposed of in the landfill however, confirmation of their disposal (i.e., specific shipment numbers and quantities) is not recorded. Included in this category are a number of primarily short-lived radioactive isotopes which were used in experiments performed on animals buried in the six animal pits located along the northern part of the Pit 6 Landfill (Table 2). Records also indicate that three shipments of depleted uranium, as well as equipment containing or contaminated with mercury, were buried in one or more of the three solid waste trenches but were exhumed and shipped offsite in 1971 (Decker, 1971). These shipments were buried for up to 23 months prior to exhumation. Ventilation equipment and ducting containing residues of beryllium, thorium, and uranium were also disposed of in the solid waste trenches (Kvam, 1971). Other COCs are inferred to have the potential to be present based on information in the waste disposal records. For example, more than 2,000 capacitors were placed in the three solid waste trenches. Anecdotal information suggests that the capacitors were drained of PCB oil prior to shipment to Site 300, however the assumption was made that these capacitors may still have contained some residual PCB dielectric fluid.

The constituents identified in the disposal records as being disposed of or potentially associated with waste in the Pit 6 Landfill have been listed as COCs. The exception to this are isotopes which have radiologic half-lives of sufficiently short duration as to eliminate the possibility of these constituents to still be present in the waste.

Thirty-five radioactive isotopes were listed in the records as being associated with biomedical experimental waste or residue associated with waste disposed of in the Pit 6 Landfill. As part of the COC selection process we re-evaluated original records related to waste disposal at the Pit 6 Landfill. While not specifically mentioned in the Pit 6 Landfill waste inventory logbook, records related to disposal procedures suggest that seven radionuclides in addition to those listed in the SWRI may have been disposed of with the biomedical waste in the animal pits. To be conservative, we included these radionuclides in our decay analysis to determine if any of these (or their daughter products) should be considered COCs. These additional radionuclides are: gold-195 (^{195}Au), iodine-125 (^{125}I), niobium-95 (^{95}Nb), strontium-89 (^{89}Sr), tellurium-132 (^{132}Te), thallium-204 (^{204}Tl), and yttrium-91 (^{91}Y). Records suggest that, if these radionuclides were disposed of at the Pit 6 Landfill, quantities would be similar to other radionuclides known to be associated with the waste.

Also, materials with residues of natural thorium (^{232}Th) were mentioned as being authorized for disposal in the larger trenches. Again, while not specifically mentioned in the waste inventory logbook, we evaluated thorium as part of the COC selection process.

In order to evaluate which isotopes are potentially still present at sufficient levels to warrant monitoring, decay calculations were performed to estimate residual radioactivity in the Pit 6 Landfill. The equation for radioactive decay is expressed as

$$A(t) = A(t_0)e^{-\lambda(t-t_0)} \qquad \text{(Eq. 6-1)}$$

where $A(t)$ is the activity at time t, $A(t_0)$ is the activity at the reference (or "zero") time t_0 and (λ) is the isotope's decay constant. The decay constant is related to the half-life by

$$\lambda = \frac{\ln 2}{t_{1/2}} \qquad \text{(Eq. 6-2)}$$

where $t_{1/2}$ is the isotope's half-life. For the purpose of determining the source term, the following assumptions were made for all isotopes except ^{3}H, ^{232}Th, and uranium-238 (^{238}U):

- The initial activity at the reference time for each isotope was 1 curie (1 Ci). As all of the historical data indicated maximum activities by isotope were in the millicurie range, this assumption should be conservative by at least a factor of ten. Many isotope activities are recorded as being in the millicurie and microcurie range.
- The reference time was assumed to be 1972 or 25 years ago. This is also a conservative estimate, as most material was placed in the site during the late 1960s.
- Current calculated residual activities of 10 microcuries (μCi) or less are discounted as being of negligible risk (i.e., those isotopes that have decayed to 10^{-5} of their conservatively estimated original amount). This is also a very conservative estimate and is protective of the environment. Ten μCi is comparable to the natural background radiation in a cubic meter of soil. Calculated residual activities are presented in Table 2.

These assumption were not made for ^{232}Th and ^{238}U that were disposed of as residues on glove boxes and other waste. Initial activities of these isotopes are unknown. Therefore, we conservatively assumed these isotopes are COCs. The assumptions were also not made for ^{3}H as this isotope was detected in ground water and therefore is classified as a COC.

Based on this evaluation, only nine isotopes have a radiologic half-life which would indicate the potential for these isotopes to still be present at activities above background. These include antimony-125 (^{125}Sb), cesium-137 (^{137}Cs), cobalt-60 (^{60}Co), sodium-22 (^{22}Na), strontium-90 (^{90}Sr), thallium-204 (^{204}Tl), ^{232}Th, ^{3}H, and ^{238}U (Table 2) (Hall, interdepartmental memo, 1997).

6.1.3.1.2. COCs Detected in Ground Water

Volatile Organic Compounds

Although not specifically identified as contaminants disposed of in the Pit 6 Landfill, several chlorinated VOCs, including TCE, PCE, 1,2-DCE, 1,1,1-TCA, methylene chloride, and chloroform have been detected in soil and/or ground water samples indicating a release to the subsurface. In addition, benzene, toluene, ethylbenzene, and total xylenes have been detected in ground water. Therefore, these contaminants have been listed as COCs.

Acetone and Freon 113 have also been detected in ground water samples. Of the 224 analyses conducted for acetone in 28 wells, acetone was detected in one sample each from four wells in October of 1990. Acetone has not been detected in samples from any wells before or since that time. Acetone is known to be a common laboratory contaminant. The concentrations at which acetone was detected in these wells (5.4 to 11 μg/L) are significantly less than the 10X multiple of the blank result (50 μg/L by the 10x Rule) (EPA, 1991). There is no Federal or State MCL for acetone. The detection of acetone in one sample each from four wells during the same time period does not appear to indicate a release of acetone, therefore acetone will not be considered a COC.

A total of 703 samples from 29 wells were analyzed for Freon 113 from 1984 through 1997. Freon 113 has been detected in one sample in each of five wells. Like acetone, Freon 113 is a common laboratory contaminant. The concentrations at which Freon 113 was detected in samples from these wells (0.9 to 4.7 μg/L) are less than the 10X multiple of the blank result (5 μg/L by the 10x Rule) (EPA, 1991). There is no Federal or State MCL for Freon 113. The detection of Freon 113 in a single sample from each of five wells does not appear to indicate a release of acetone from the Pit 6 Landfill, therefore Freon 113 will not be considered a COC. Freon 113 is included in the EPA Method 601 analyses that will be conducted as part of the monitoring programs discussed in Sections 6.1.5 and 6.1.7.

Metals

A number of metals, including antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc have been detected in ground water from wells in the vicinity of the Pit 6 Landfill. Trace amounts of metals occur naturally in ground water and concentrations may vary depending on natural geochemical processes and the mineralogy of source materials (Goldschmidt, 1954). Based on a comparison with background values established in the SWRI (Webster-Scholten, 1994), of the 15 metals that have been detected in ground water in the vicinity of Pit 6, 13 metals were determined to be: (1) within the range of background values established for those metals at Site 300, (2) within the range of background values established for metals regionally, and/or (3) present at highest concentrations in wells hydraulically upgradient of the Pit 6 Landfill.

Antimony (Sb) and silver (Ag) were detected in ground water samples from downgradient wells above background levels. Sb was detected in one sample from one well in 1984 and has not been detected in samples from any wells since 1984. Ag was detected once in ground water samples from four wells but has not been detected in any wells in the last five years.

Beryllium and mercury were specifically listed in the waste disposal records as being associated with the buried waste, and therefore will be included as COCs. All other metals detected in ground water fall within the range of background concentrations for these metals or show limited frequency of detection (Ag and Sb) and will not be considered as COCs.

Other Compounds

Phenolics and phthalates have also been detected in ground water samples in the vicinity of the Pit 6 Landfill. Phenolics have been detected in samples from seven wells at concentrations ranging from 0.001 to 0.09 µg/L. Two of the wells (K6-03 and -04) in which phenolics were detected are located hydraulically upgradient of Pit 6. There is no State or Federal MCL for phenolics. As phenolics were detected in upgradient wells, there does not appear to have been a release of phenolics from the Pit 6 Landfill. Therefore, phenolics will not be considered as COCs. However, since analysis for phenolics has not been conducted since 1995, quarterly monitoring for phenolics will be conducted in detection monitoring wells for a period of one year. If phenolics are not detected during this monitoring period, this analysis will be discontinued.

Two phthalate compounds, bis (2-ethylhexyl) phthalate and butylbenzylphthalate, were detected in one sample each from two wells in 1984. One of the two wells in which these compounds were detected is located upgradient from the Pit 6 Landfill. Analysis for phthalates continued until 1987 during which time no phthalate compounds were detected in any of the eight wells sampled. Phthalate compounds are known to be common laboratory contaminants. The concentrations at which the two phthalate compounds were detected in samples from these wells (44 to 78 µg/L) are less than the 10X multiple of the blank result (100 µg/L by the 10x Rule) (EPA, 1991). The highest concentrations of both phthalate compounds were detected in the upgradient well and were detected only once each in two wells and do not appear to indicate a release of phthalate compounds from the Pit 6 Landfill. These phthalate compounds will therefore not be considered as COCs. However, because these compounds have not been analyzed for since 1987, we propose to conduct quarterly monitoring for phthalates in detection monitoring wells for a period of one year. If phthalate compounds are not detected during this monitoring period, this analysis will be discontinued.

6.1.3.1.3. Potential COC Breakdown/Decay Products

Several studies suggest that some VOCs may undergo chemical degradation in ground water systems under certain conditions (Mabey and Mill, 1978; Barrio-Lage et al., 1986; Roberts et al. 1986; Vogel et al., 1987; Jeffers et al., 1989; Wolfe and Macaladay, 1992). VOCs detected in ground water in the vicinity of the Pit 6 Landfill include TCE, PCE 1,2-DCE, 1,1,1-TCA, chloroform and methylene chloride. Analytical data suggests that limited chemical degradation of VOCs to other compounds (degradation products) is occurring in the vicinity of Pit 6. For example, an overall increase in the parent-to-degradation product ratio over time (TCE versus *cis*-1,2-DCE) has been observed in only two wells. No vinyl chloride, the end product of the degradation of PCE, TCE, 1,2-DCE, and 1,1,1-TCA, has ever been detected in Pit 6 ground water. TCE, PCE, 1,2-DCE, and 1,1,1-TCA are most likely primarily original contaminants. All of these VOCs are analyzed for as part of a standard EPA Method 601 analysis which will be conducted on Pit 6 ground water samples.

Similarly, several radionuclides reported as associated with waste buried in Pit 6 Landfill are known to decay to a variety of daughter products. As indicated in Table 2, three of these radionuclides, cerium-144 (^{144}Ce), molybdenum-99 (^{99}Mo), and tungsten-187 (^{187}W) degrade to unstable daughter products [neodymium-144 (^{144}Nd), technetium-99 (^{99}Tc), and rhenium-187 (^{187}Re), respectively] whose radiologic half-life would indicate the potential for these isotopes to still be present. Residual radioactivity for these daughter products was calculated using the radioactive decay equations 6-1 and 6-2 to determine if these isotopes were still present at sufficient levels to warrant monitoring. The residual radioactivity for these isotopes are listed in Table 2. Given the low initial activity levels and low residual radioactivity of these daughter products, none of these longer-lived daughter products appear to be of concern and therefore are not listed as COCs.

Both ^{232}Th and ^{238}U have a number of daughter products which are long-lived and may be detected if ^{232}Th and ^{238}U are released to ground water. However, the presence of these radionuclides will be somewhat difficult to interpret through ground water monitoring as they are both naturally occurring and as a result will likely be found in ground water. If analysis for total uranium or gross alpha/beta indicate a release of either isotope, further analysis for potential daughter products will be considered.

6.1.3.2. Concentration Limits (23 CCR 2550.4 and 22 CCR 66264.94)

For each COC, concentration limits have been established where sufficient data exist for that COC to establish a background concentration. Concentration limits for 13 of these COCs are presented in Table 5. Six COCs have not been previously monitored with sufficient frequency to determine concentration limits. Therefore, concentration limits for these COCs are listed as To Be Determined (TBD) and at least one year of quarterly monitoring results will be needed to develop background concentrations to be used as concentration limits. Concentration limits will be used in the Detection Monitoring Program to detect evidence of future releases of contaminants to ground water from buried waste in the Pit 6 landfill. When cleanup levels are set, DOE will comply with 23 CCR 2550.4.

Table 2 indicates which isotopes have potential to still be present. Because these isotopes are either alpha or beta emitters, background gross alpha and beta activities will be used as a surrogate for all radioisotopes other than uranium and tritium.

A discussion of the methods used to determine concentration limits for the COCs is presented in Appendix B.

6.1.3.3. Point of Compliance and Monitoring Points (23 CCR 2550.5 and 22 CCR 66264.95)

The proposed point of compliance for which the water quality protection standards apply is a vertical surface located at the hydraulically downgradient limit of the Pit 6 Landfill that extends through the uppermost aquifer underlying the landfill. Detection monitoring points for this point of compliance consist of six monitor wells located approximately 50 to 100 ft downgradient of the landfill (Fig. 14). The closest existing monitor wells to the landfill are proposed as the detection monitoring points due to safety concerns associated with drilling in close proximity to buried wastes. Data from these detection monitoring wells will be used to detect any future releases of COCs to ground water from the Pit 6 Landfill as discussed in Section 6.1.5.

The corrective action monitoring points consists of 24 downgradient monitor wells (Fig. 14). Data from the corrective action monitoring wells will be used to evaluate natural attenuation of the VOC plume and the effectiveness of the corrective action as discussed in Section 6.1.7.

6.1.3.4. Compliance Period (23 CCR 2550.6 and 22 CCR 66264.96)

The compliance period is defined, for the purposes of detection monitoring, as the post-closure maintenance period. This is defined in Chapter 15 as the period after closure during which the waste could have an adverse effect on the quality of waters of the state.

As specified in the Action Memorandum for the Pit 6 Landfill OU Removal Action (Berry, 1997), corrective action monitoring will continue at least until contaminant concentrations reach cleanup standards to be specified in the Site-Wide ROD.

The Detection Monitoring Program and Corrective Action Monitoring Program will be evaluated every five years in conjunction with the CERCLA Five Year Review, or more frequently as necessary.

6.1.4. General Water Quality Monitoring and System Requirements (23 CCR 2550.7 and 22 CCR 66264.97)

6.1.4.1. Monitor Well Locations and Purpose

The monitoring program serves to: (1) to provide early detection of future releases from the waste buried in the Pit 6 landfill (detection monitoring), and (2) to monitor the existing ground water contamination (corrective action monitoring). Figure 14 shows the monitor wells in the vicinity of the Pit 6 Landfill and indicates which purpose they serve. Table 6 shows well construction details including depth, screened interval, and other completion information. Graphic well log summaries are included in Appendix C.

6.1.4.2. Well Construction [23 CCR 2550.7(e)(2) and 22 CCR 66264.97 (e)(2)]

LLNL well drilling and installation procedures are consistent with those prescribed in the *Resource Conservation and Recovery Act Ground Water Monitoring Technical Enforcement Guidance Document* (U.S. EPA, 1986) and the LLNL *Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs),* (Dibley and Depue, 1997). Monitor wells that require replacement during the post-closure period will be constructed using materials and techniques specified in LLNL SOP 1.4 (Dibley and Depue, 1997) for monitor well installation. Well construction procedures are described below.

Hollow stem augering is used in shallow boreholes and unconsolidated deposits. Air rotary, air mist or mud rotary drilling are used in deeper boreholes and consolidated materials. Continuous wireline coring is used to collect rock core with minimal disturbance. These methods prevent introduction of drilling fluids into the formation which might compromise sample integrity.

Drilling continues until the water-bearing zone of interest is encountered. Prior to casing emplacement, a bentonite plug is placed at the base of the borehole. Screened and blank polyvinyl chloride (PVC) casing is used to construct the well. Current LLNL SOPs (Dibley and Depue, 1997) require that the filter pack consist of #3 Monterey-type sand covered with a minimum of 1-ft layer of finer-grained #0 concrete sand. A bentonite seal is placed over the filter pack to prevent infiltration of cement grout into the filter pack. Cement grout is then placed from the top of the bentonite seal to the surface to seal the annular space to the surface. Additional grout is used to create a pad for emplacement of a locked steel well-head protector to provide stability and security. A survey marker is placed on the concrete well-head pad and surveyed relative to an appropriate benchmark. This survey marker is used as a reference for future water level measurements.

Mud rotary drilling techniques are used where cross-contamination or mixing of separate aquifer zones are of concern. The mud cake which develops on the borehole wall prevents the introduction and mixing of water from separate aquifers during drilling. If a well is completed in a deeper water-bearing zone, the annular space of the section of the borehole which penetrates a shallower aquifer is grouted to prevent potential migration of contaminants in ground water from the shallower to deeper aquifer.

Information on the construction of the existing ground water monitor wells for post-closure monitoring of the landfill and corrective action monitoring of the VOC plume is summarized in Table 6. Graphic well log summaries for monitor wells in the vicinity of the Pit 6 Landfill are presented in Appendix C.

Following well installation, the well will be developed to enhance well efficiency and subsequent water sample quality by removing materials introduced into the ground water, water-bearing formation, sand pack, and well screen during drilling and well installation. Well development procedures are detailed in LLNL SOP 1.5 (Dibley and DePue, 1997).

6.1.4.3 . Ground Water Elevation Measurement Procedures and Analysis [23 CCR 2550.7(e)(15) and 22 CCR 66264.97(e)(15)]

Elevations of the potentiometric surface will be recorded each time a monitor well is sampled or at least once a quarter. Water levels are measured using a calibrated electric sounder with an accuracy of 0.01 ft. Specific procedures for water level measurements are detailed in LLNL SOP 3.1 (Dibley and DePue, 1997). This information will be used to: (1) construct contour maps, (2) evaluate hydraulic gradients, and (3) calculate flow rates within the regional aquifer. Data will be reported quarterly to the regulatory agencies.

6.1.4.4 . Sampling and Analysis Procedures [23 CCR 2550.7(e)(4) and 22 CCR 66264.97(e)(4)]

Monitor wells will be sampled according to LLNL SOPs (Dibley and Depue, 1997) governing ground water monitor well sampling. The relevant SOPs for ground water sampling are as follows:

- SOP-2.1—Presample Purging of Wells. DOE/LLNL has recently received approval to implement low-volume sampling techniques for certain wells to reduce purge water generation and provide more representative sampling. Low-volume sampling techniques are discussed in this SOP.

- SOP-2.2—Field Measurements on Surface and Ground Waters.
- SOP-2.3—Sampling Monitor Wells with Bladder and Electric Submersible Pumps.
- SOP-2.4 Sampling Monitor Wells with a Bailer.
- SOP-2.6—Sampling for Volatile Organic Compounds.
- SOP-2.9—Sampling for Tritium in Ground Water.
- SOP-4.2—Sample Control and Documentation including methodology applicable to field logbooks, sampling data collection forms, chain-of-custody records and sample identification.
- SOP-4.3—Sample Containers and Preservation including holding time information, as well as appropriate sample volume, container, and preservation techniques.
- SOP-4.4—Guide to the Handling, Packaging, and Shipping of Samples.
- SOP-4.5—General Equipment Decontamination.
- SOP-4.9—Collection of Field QC Samples.

Surface water sampling will be conducted in accordance with the LLNL SOP 2.5 (Surface Water Sampling).

Samples will be submitted to a California Department of Health Services certified analytical laboratory for analysis. Sample analysis will be conducted using the appropriate EPA Method described in Tables 7 and 8. Quality Assurance/Quality Control (QA/QC) objectives and procedures are described in LLNL SOP 4.6 and the Environmental Restoration Projects Quality Assurance Project Plan (Dibley, 1997, in preparation) including the collection and analysis of QC samples and data validation procedures.

LLNL SOPs have been submitted to and reviewed by the U.S. EPA, DTSC, and RWQCB. Any modifications to the SOPs are also submitted to the regulatory agencies.

6.1.5. Detection Monitoring Program (23 CCR 2550.8 and 22 CCR 66265.98)

The objective of the Detection Monitoring Program is to detect any future releases of contaminants to ground water from the buried waste in the Pit 6 Landfill. In order to accomplish this objective, ground water monitoring will be conducted at six detection monitoring wells (BC6-12, EP6-06, EP6-08, EP6-09, K6-01S, and K6-19), all located hydraulically downgradient of Pit 6 along the point of compliance and at four upgradient wells (K6-3, K6-04, K6-15, and K6-32) as shown in Figure 14 and listed in Table 7.

Water has been below the base of the screen in well K6-15 since May 1996. If water levels rise above the screen, well K6-15 will be sampled. In addition, well K6-01S is periodically dry. In the event that we are unable to collect a sample from this well, a sample will be collected from adjacent well K6-01.

Data from these wells will be compared to concentration limits for all COCs at each detection monitoring well to identify statistically significant concentration increases which could indicate new releases of contaminants from the Pit 6 Landfill using the statistical methods described in

Section 6.1.5.2 and Appendix B. Statistical analysis of gross alpha/gross beta data will be conducted as a surrogate for radionuclides other than uranium and tritium.

6.1.5.1. Monitoring Parameters [23 CCR 2550.7(e)(13) and 2550.8(g)]

Monitoring parameters as defined in 23 CCR 2601 are "one of the sets of parameters for which monitoring is conducted including physical parameters, waste constituents, reaction products, and hazardous constituents, that provide a reliable indication of a release" from the Pit 6 Landfill.

In addition to sampling and analysis for COCs, detection monitoring wells will be sampled and analyzed for the following parameters per 23 CCR 2550.7 (e)(12):

- pH.
- Specific conductance.
- Total dissolved solids.
- Temperature.

Samples from detection monitoring wells will also be analyzed for Freon 113, phenolics and phthalates for the first year. If these compounds are not detected during this monitoring period, these analyses will be discontinued.

Statistical tests will not be applied to the parameters or compounds listed above.

Ground water elevations will also be measured in all monitor wells each time the well is sampled or at least quarterly as described in Section 6.1.3.

6.1.5.2. Statistical Analyses [23 CCR 2550.7(e) and 22 CCR 66264.97(e)]

Formal statistical analyses of ground water monitoring data will be performed as part of the Detection Monitoring Program to detect changes in COC concentrations that may indicate a new release of a COC. Quarterly statistical analysis will be performed for all COCs listed in Table 4 at each Detection Monitoring Program well except for the radionuclides ^{125}Sb, ^{137}Cs, Co^{60}, ^{22}Na, ^{90}Sr, ^{204}, Tl, and ^{232}Th. Statistical analysis of gross alpha/gross beta data will be conducted as a surrogate for these radionuclides.

The proposed methods to be used for all statistical analyses are discussed in detail in Appendix B. This appendix also includes a discussion of:

- Determination of concentration limits and statistical limits for COCs and Detection Monitoring Program monitor wells.
- The use of statistical analysis to calculate concentration limits and statistical limits.
- The proposed approach to calculating concentration limits and statistical limits in the presence of non-detections.
- Distributional assumptions.
- Appropriate use of available data.
- Statistical significance levels.
- Implementation of retests.

- Determination of a statistically significant release.

6.1.5.3. Sampling Frequencies [23 CCR 2550.7(e)(12) and 22 CCR 66264.97 (e)(12)]

Sampling will be conducted quarterly for all COCs and monitor wells in the Detection Monitoring Program for which a concentration limit and statistical limit are proposed (Table 5). COCs and detection monitoring wells for which the statistical method is to be determined will be sampled every two months for the first year, after which a concentration limit and statistical limit will be calculated.

6.1.6. Evaluation Monitoring (23 CCR 2550.9 and 22 CCR 66264.99)

As part of the SWRI (Webster-Scholten, 1994), the nature and extent of contamination associated with the Pit 6 Landfill was assessed. The EE/CA (Devany et al., 1994) and EE/CA addendum (Berry, 1996) proposed corrective action measures designed to achieve compliance with water quality protection standards. Corrective action measures were implemented as a removal action in 1997 as described in Section 2.2. There is no significant statistical or physical evidence at this time which indicates that there have been releases from the Pit 6 Landfill other than that evaluated and described in the SWRI and EE/CA. There is recent evidence of a possible minor past release of tritium discussed in Section 2.1.3.2. Monitoring of tritium is discussed as part of the Corrective Action Monitoring Program in Section 6.1.7.

If there is statistically significant evidence or significant physical evidence of a new release for any COC, an evaluation monitoring program will be instituted. The administrative (reporting) requirements of the program will be jointly determined with the regulatory agencies at that time.

The statistical significance of a release will be determined using the statistical procedures discussed in Section 6.1.5 and data collected as part of the Detection Monitoring Program. Significant physical evidence of a release includes:

- unexplained stress in biological communities,
- unexplained changes in soil characteristics,
- unexplained water table mounding beneath or adjacent to the Pit 6 Landfill, or
- any other change to the environment that could reasonably be expected to be the result of a release from the landfill.

The details of the evaluation monitoring program, as well as potential modifications to the Corrective Action Monitoring Program, will be discussed with and approved by the appropriate regulatory agencies when and if the Detection Monitoring Program indicates the need for implementation of such a program. The contingency plan for the detection of a new release from the Pit 6 Landfill is discussed in Section 7.1.

6.1.7. Corrective Action Monitoring Program (23 CCR 2550.10 and 22 CCR 66264.100)

The objectives of the Corrective Action Monitoring Program are to: (1) continue evaluating natural attenuation of the VOC plume, (2) monitor tritium in ground water, (3) evaluate the effectiveness of the corrective action, and (4) trigger re-evaluation of the need for implementing contingency actions.

To accomplish these objectives, ground water monitoring will be conducted at 27 wells located downgradient of Pit 6 including the six downgradient wells and four upgradient wells that are part of the Detection Monitoring Program as shown in Figure 14 and listed in Table 8.

As described in Table 9, no BTEX compounds, carbon disulfide, phthalate compounds, phenolics, 1,1,1-TCA, 1,2-DCA, trans-1,2-DCE or acetone have been detected in the last two to five years. Of the five other halogenated VOCs that have been detected in the past two years, only TCE has been detected above the MCL (in two wells). As of the second quarter of 1997, the highest concentration of TCE was 15 µg/L in well EP6-09.

Because halogenated VOCs and tritium are the only contaminants currently detected in ground water, the Corrective Action Monitoring Program will include VOC analysis of ground water samples by EPA Method 601 and tritium analysis of samples collected from nine wells by EPA Method 906 (Table 8). Samples from the four background monitor wells and six wells that are part of both the Detection Monitoring Program and the Corrective Action Monitoring Program will analyzed for all COCs including halogenated VOCs, as part of the Detection Monitoring program. An additional 18 corrective action monitoring wells will be sampled and analyzed for halogenated VOCs. The data collected for these wells will be included in the Corrective Action Monitoring Program evaluation process.

Monitoring data from corrective action monitoring wells will be used to evaluate natural attenuation of the plume, the effectiveness of the corrective action, and the need for implementing contingency actions. Tritium data from selected Corrective Action Monitoring Program wells will be used to evaluate the nature of elevated tritium activities detected in well BC6-12. A variety of methods including trend analysis and frequency of detection analysis may be used at appropriate intervals to determine concentration trends within the plume.

6.2. Surface Water Monitoring [23 CCR 2550.7(c) and 22 CCR 66264.97(c)]

Surface water bodies that could be affected by a release from the Pit 6 Landfill include intermittent Springs 7 and 15. Springs 7 and 15 flow primarily during the wet season (winter). Spring 7, which is the closest to Pit 6, has been dry since the summer of 1992. Spring 15 has been dry since late 1991. For these reasons, surface water monitoring will include Springs 7 and 15 when flow is occurring.

Springs 7 and 15 are located downgradient of the Detection Monitoring Program wells which monitor ground water from the water-bearing unit which feeds these springs. Any new contaminant releases would be detected at the compliance point prior to reaching the springs. Therefore, surface water in Springs 7 and 15 will be monitored as part of the Corrective Action Monitoring Program only.

Well BC6-13 monitors ground water from the same water-bearing unit that provides flow to Spring 7. This well is approximately five ft deep and is located within 12 ft of Spring 7. This well will be monitored as part of the Corrective Action Monitoring Program and will provide an indication of the condition of ground water that may reach Spring 7.

Springs 7 and 15 will be monitored quarterly for halogenated VOCs when sufficient water is present to collect a sample. After one year of monitoring, the number of detections and non-detections will be tabulated for the background monitoring point and Springs 7 and 15. Any VOC COC sampled quarterly that has not been detected above background concentrations will have its sampling frequency reduced from quarterly to semi-annually.

As discussed in Section 2.2.3, storm water runoff does not infiltrate into the Pit 6 Landfill and therefore would not be affected by a release from the landfill. In addition, storm water runoff from the natural drainage divide is monitored as part of the LLNL Operations and Regulatory Affairs Division Site-Wide Storm Water Monitoring Program (Order 94-131). Storm water runoff monitoring is therefore not included as part of the Post-Closure Plan surface water monitoring program.

6.3. Vadose Zone Monitoring [23 CCR 2550.7(d) and 22 CCR 66264.97(d)]

Consistent with disposal practices of the time the Pit 6 Landfill was operated (1964 to 1973), no unsaturated (vadose) zone monitoring system was installed beneath the buried waste. Installing a vadose zone monitoring system is impracticable and therefore has not been included in the closure design for the Pit 6 Landfill. Installing instrumentation such as lysimeters for pore fluid collection or access casings for moisture detection by neutron logging would require drilling or excavation in close proximity to the buried waste. Although approximate locations of the waste are known, exact locations are uncertain. Installing subsurface monitoring equipment in close proximity to the buried waste poses safety risks that outweigh the incremental advantages of vadose zone monitoring. Additionally, vadose zone monitoring equipment would likely need to penetrate the landfill cap which increases the potential for liner integrity failure over time.

Ground water monitor wells located along the perimeter of the landfill provide assurance of adequate detection of releases. Ground water elevations will be monitored in these wells to ensure early identification of conditions where ground water could intercept buried waste.

6.4. Record Keeping and Reporting [23 CCR 2550.7(e)(16) and 22 CCR 66264.97(e)(16)]

The storage of all QA records is described in the LLNL Livermore Site and Site 300 SOP S4.2 (Sample Control and Documentation), the Site 300 Quality Implementing Procedure (QIP) 6.1 (Document Control), and the Environmental Protection Department (EPD) QIPs 6.1 (Document Control) and 17.1 (Quality Assurance Records). Analytical results, including ground water elevations, will be kept by EPD at the Livermore Site.

DOE/LLNL will submit written quarterly reports discussing the Detection Monitoring Program results and evaluating the effectiveness of the Corrective Action Monitoring Program to the regulatory agencies within 60 days of the end of each quarter. The fourth quarter report will contain an annual summary, including tabular and graphical summaries, of the monitoring data obtained throughout the previous year. A summary of inspection and maintenance activities will be included in the fourth quarter report. If significant repairs to the landfill cap or runoff and drainage system are required, these activities will be reported in the quarterly report for the quarter in which these activities occurred.

7. Contingency Plans

7.1. Contingency Plan for Detection of Release from Buried Waste

In the event that there is statistically significant evidence of a new release from the Pit 6 Landfill, DOE/LLNL will:

1. Notify the RWQCB of the determination within seven days, and
2. Initiate the statistical retest verification procedures described in Appendix B.

If the verification procedure confirms that there is statistically significant evidence of a release, DOE/LLNL will immediately sample all Detection Monitoring Program wells to determine the concentration of all COCs. If the release is confirmed, DOE/LLNL will submit an amended Post-Closure Plan to establish an evaluation monitoring program which will include:

- The maximum concentration of each COC at each Detection Monitoring Program well.
- Any proposed changes to the water quality monitoring system and/or monitoring frequency, sampling and analytical procedures, or statistical methods used to meet the requirements of an Evaluation Monitoring Program as required in 23 CCR 2550.9.
- A detailed description of measures to be taken to assess the nature and extent of the release.

A schedule for submittal of the amended Post-Closure Plan will be submitted to the regulatory agencies within 45 days of release confirmation.

With confirmation of a release, DOE/LLNL will also submit modifications to the Corrective Action Monitoring Program to address the release.

7.2. Contingency Plan for Corrective Action Monitoring

7.2.1. VOC Inhalation Risk at Spring 7

Spring 7 is currently dry, therefore there is no complete exposure pathway and no associated risk of inhalation of VOCs. If water begins flowing in spring 7, samples will be collected and analyzed for VOCs as discussed in Section 6.2. If VOCs are detected in these samples, risk and hazard will be recalculated. If risk or hazard for inhalation of VOCs from spring 7 is above acceptable levels, a fence would be installed surrounding the spring to mitigate the potential for human inhalation exposure to volatilizing VOCs. Warning signs would also be placed along the fence. The regulatory agencies would be notified to coordinate any required changes to the monitoring and reporting requirements, as necessary.

Well BC6-13 monitors ground water from the same water-bearing unit that provides flow to Spring 7. This well is approximately five ft deep and is located within 12 ft of Spring 7. This well will be monitored as part of the Corrective Action Monitoring Program and will provide an indication of the condition of ground water that may reach Spring 7.

7.2.2. VOC Plume Migration

Natural attenuation trends in ground water will be monitored as part of the Corrective Action Monitoring Program until the Site-Wide ROD is finalized. The need for further monitoring or other actions will be established in the Site-Wide ROD based on the cleanup standards established at that time. If natural attenuation does not reduce VOC concentrations to acceptable levels, a ground water extraction and treatment system, or another acceptable remediation technology, will be installed. Based on the current plume configuration and modeling conducted for the Pit 6 EE/CA, up to five extraction wells would be used to pump ground water. The extracted ground water would be treated by aqueous-phase granular activated carbon (GAC) units or equivalent technology. This extraction and treatment system scenario would be modified, as necessary, to account for conditions at the time of implementation.

Monitoring and reporting requirements for the treated discharge from the treatment system would likely be issued by the RWQCB either as Substantive Requirements for waste discharge or as a NPDES permit, depending on the location of the discharge point.

7.2.3. VOC Inhalation Risk at SVRA Residence Pond

Currently, there is no inhalation risk at the SVRA residence pond because VOCs have not migrated to the water-supply well (CARNRW1) used to supply the residence pond, and a complete exposure pathway does not exist. Wells CARNRW1 and CARNRW2 are sampled and analyzed quarterly by the LLNL Operations and Regulatory Affairs Division as part of the surveillance monitoring required under DOE Order 5400.

In addition, wells K6-23, K6-24, K6-26, K6-27, and K6-33, located hydraulically upgradient from CARNRW1 and CARNRW2, will be monitored on a quarterly basis as part of the Corrective Action Monitoring Program. These wells are also located downgradient of the leading edge of the VOC plume. If VOCs are detected in these guard wells, monitoring of CARNRW1 and CARNRW2 will be initiated, if they are not still being monitored as part of the surveillance monitoring program. In addition, details of a point-of-use (POU) treatment at CARNRW1 would be discussed between the DOE, the well owner (the State of California Department of Parks and Recreation), and the regulatory agencies and preparation of a plan for POU treatment installation initiated. Corrective action may be necessary if the guard wells are impacted by any COCs

If VOCs from the Pit 6 Landfill are detected in samples from well CARNRW1, the inhalation risk at the SVRA residence pond would be calculated. If the calculated inhalation risk is determined to be above acceptable levels, a POU treatment system would be installed at this well. The POU treatment system would consist of a gravity flow aqueous-phase GAC treatment system or an approved alternative technology. If POU treatment becomes necessary, DOE/LLNL will develop and submit a plan to permanently remedy the affected water supply for regulatory approval.

Figures

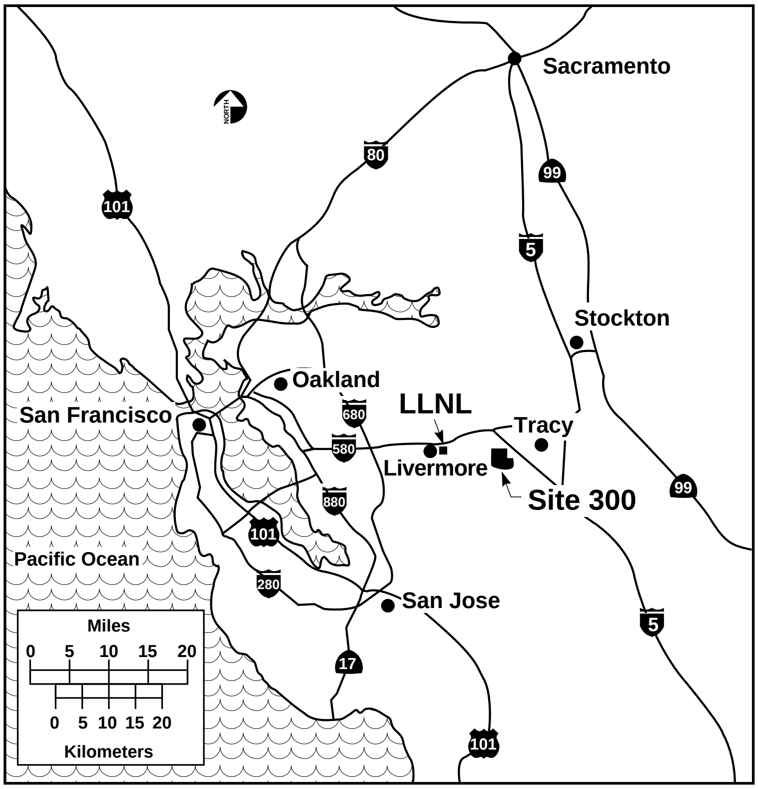

Figure 1. Locations of LLNL Livermore Site and Site 300.

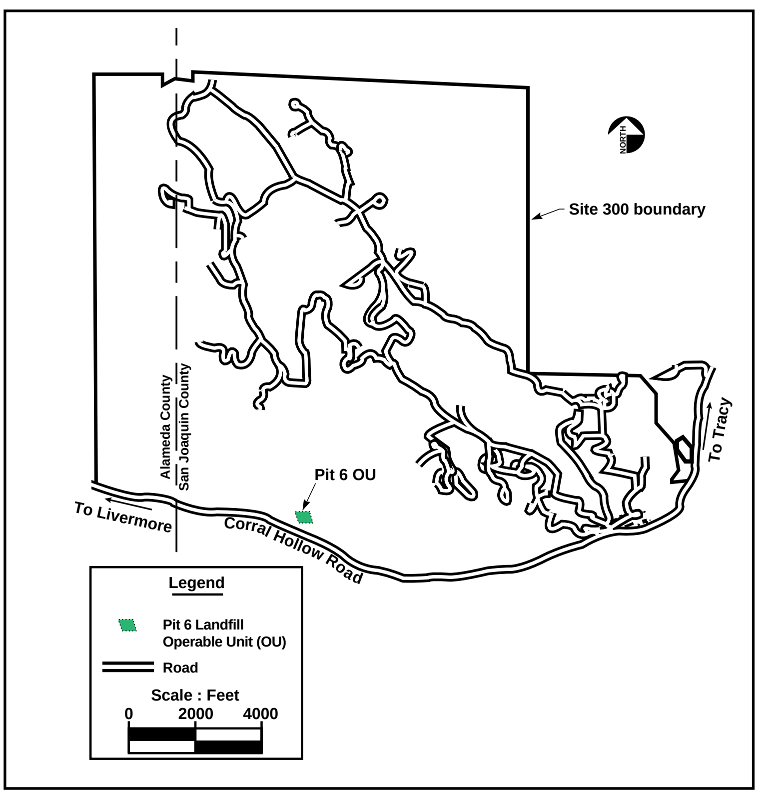

Figure 2. Location of the Pit 6 Landfill Operable Unit (OU) at LLNL Site 300.

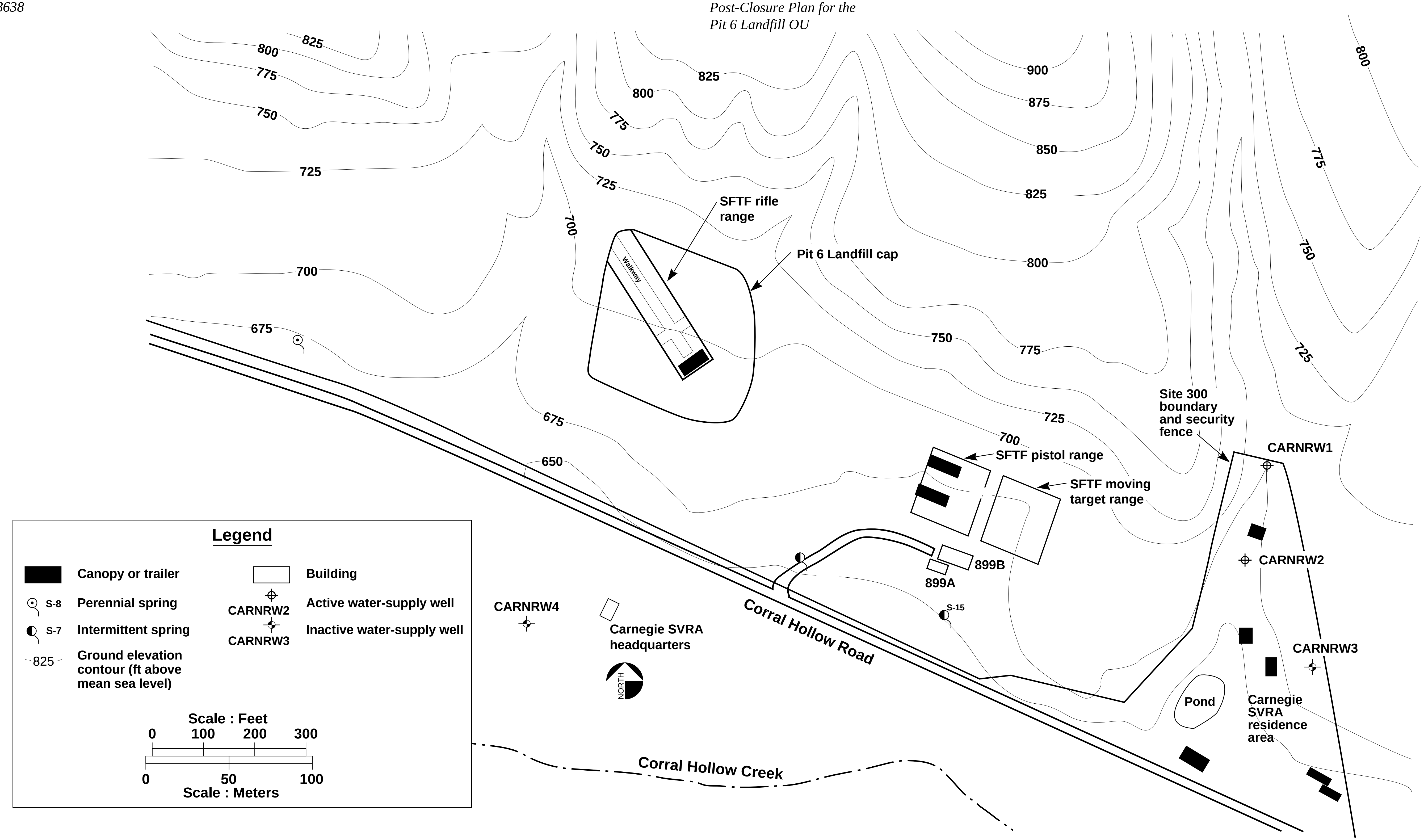

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Figure 3. Topography of the Pit 6 Landfill area.

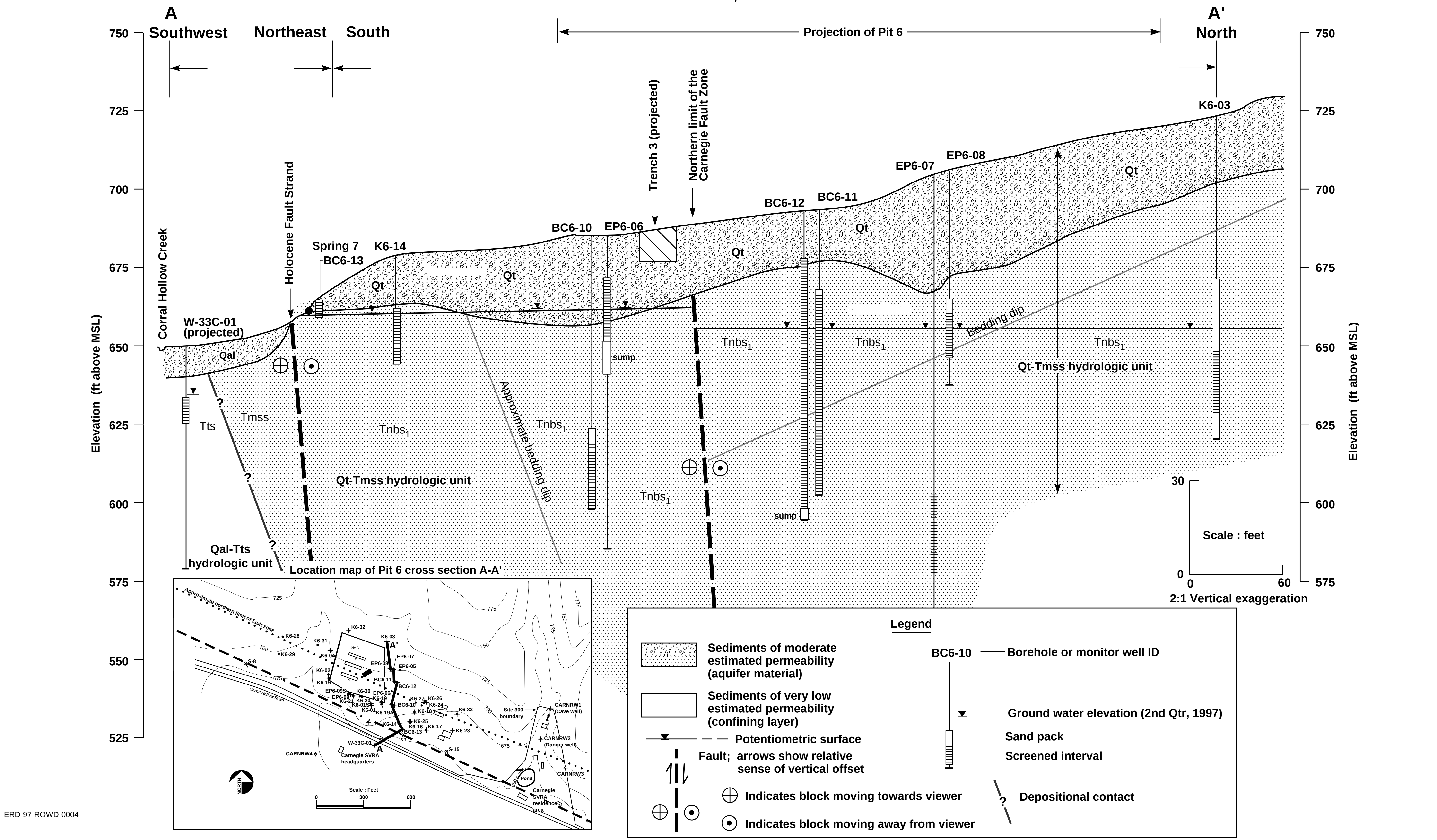

Figure 4. Hydrogeologic cross-section A-A', Pit 6 Landfill Operable Unit.

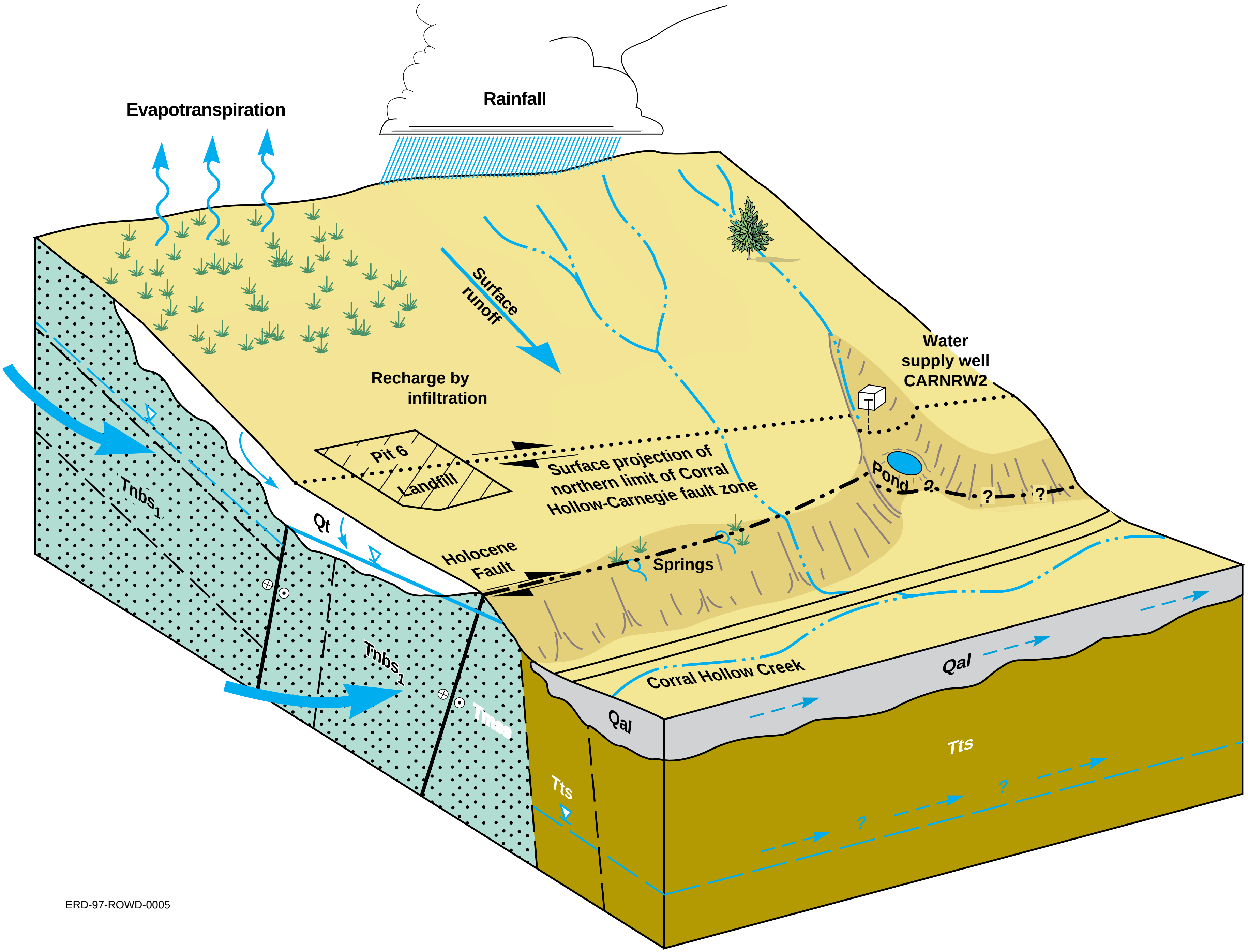

Figure 5. Conceptual hydrogeologic model for the Pit 6 Landfill Operable Unit.

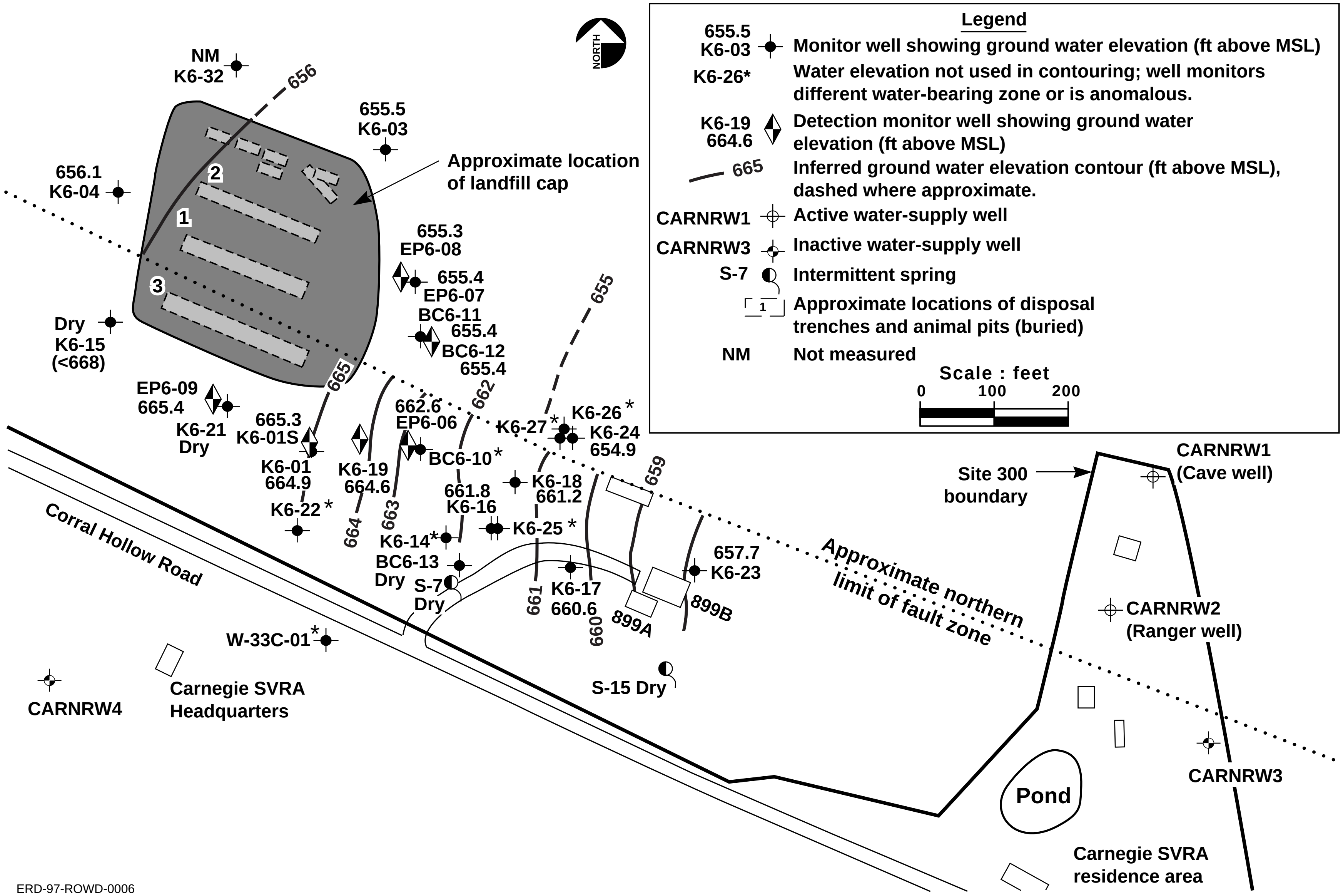

Figure 6. Potentiometric surface map of the Qt-Tmss hydrogeologic unit, April 1997.

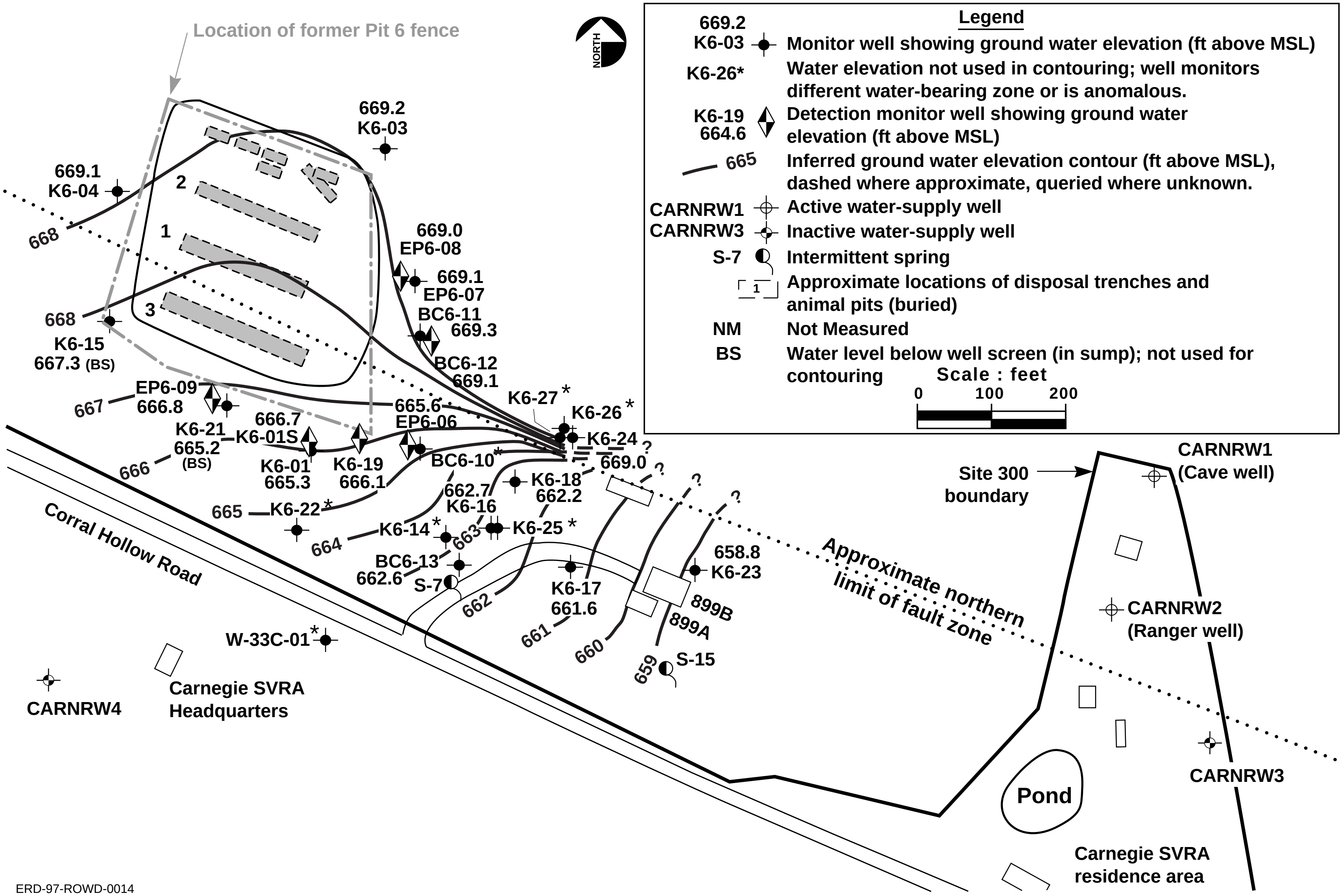

Figure 7. Potentiometric surface map of the Qt-Tmss hydrogeologic unit, April 1991.

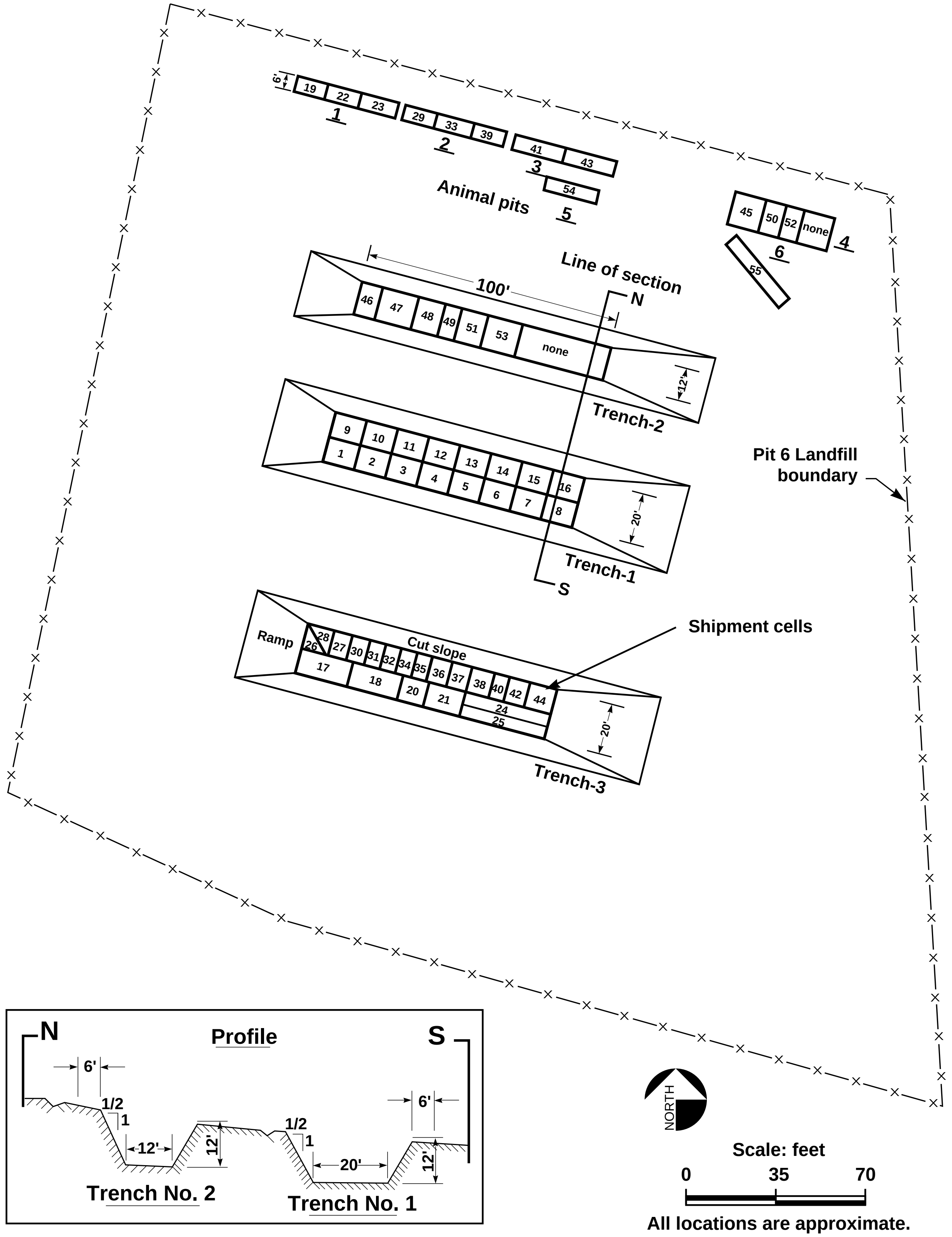

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Figure 8. Pit 6 Landfill trench and animal pit locations.

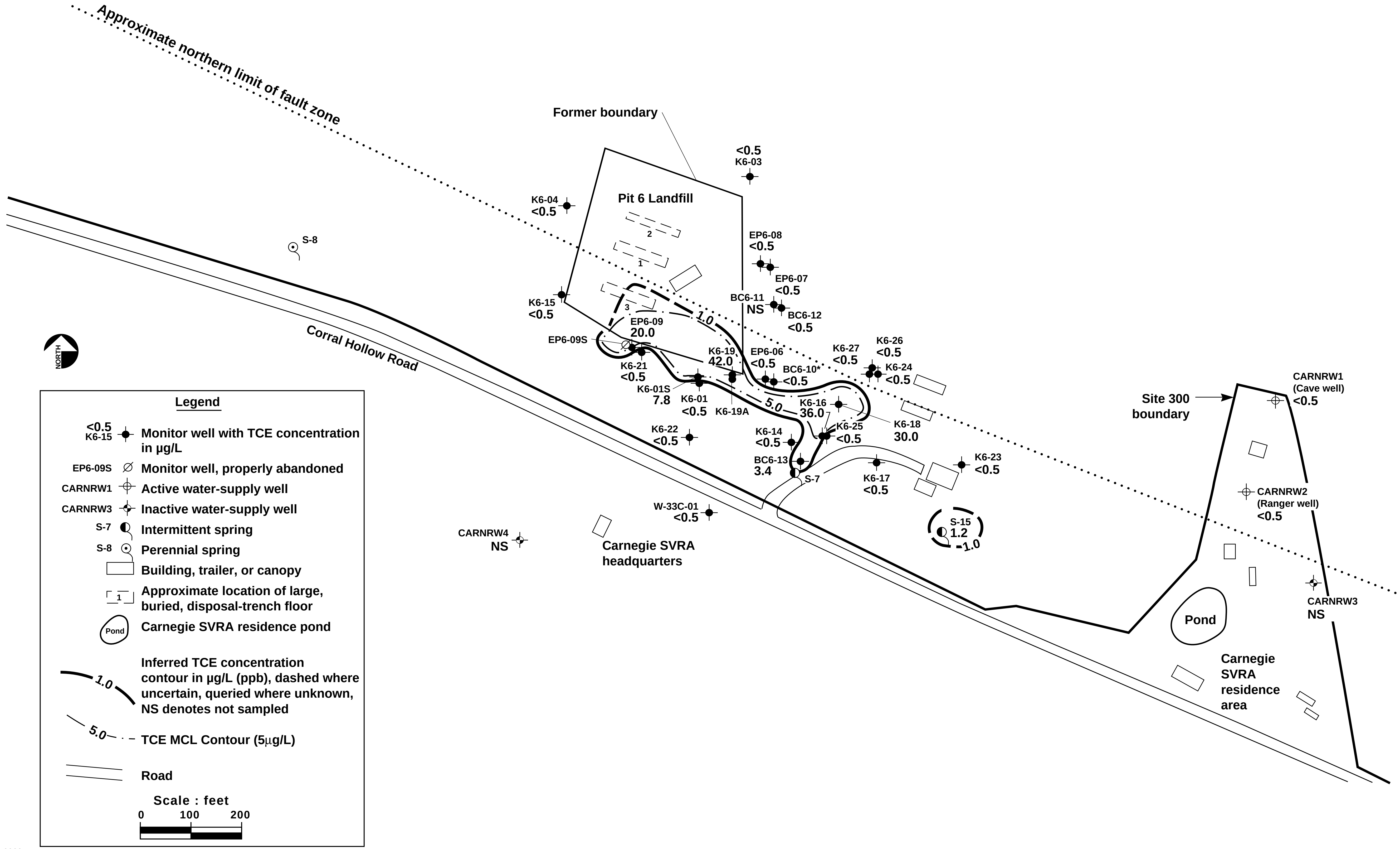


Figure 9. Distribution of TCE in ground water of the Qt-Tmss hydrogeologic unit for the Pit 6 Landfill Operable Unit, December 1991.

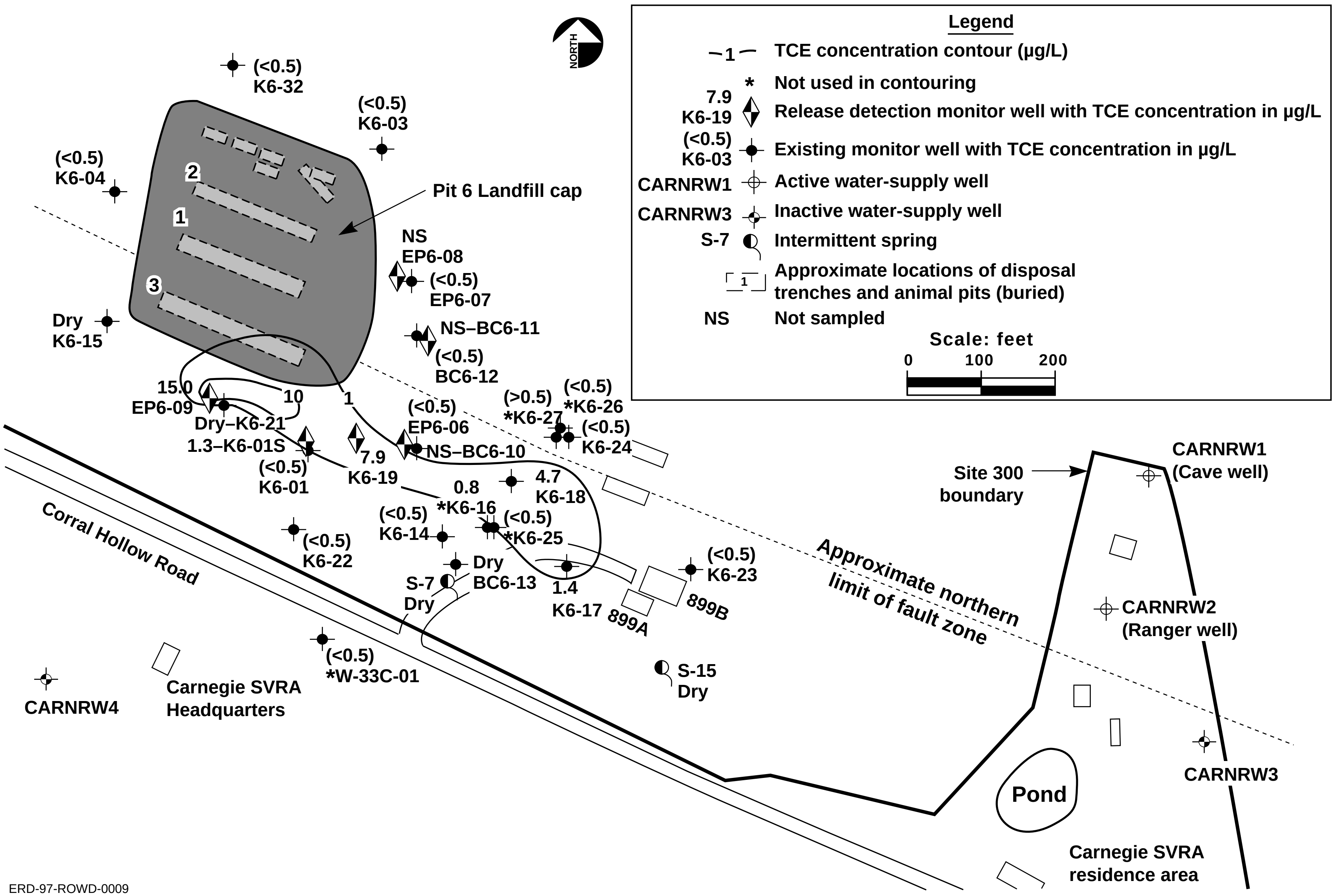
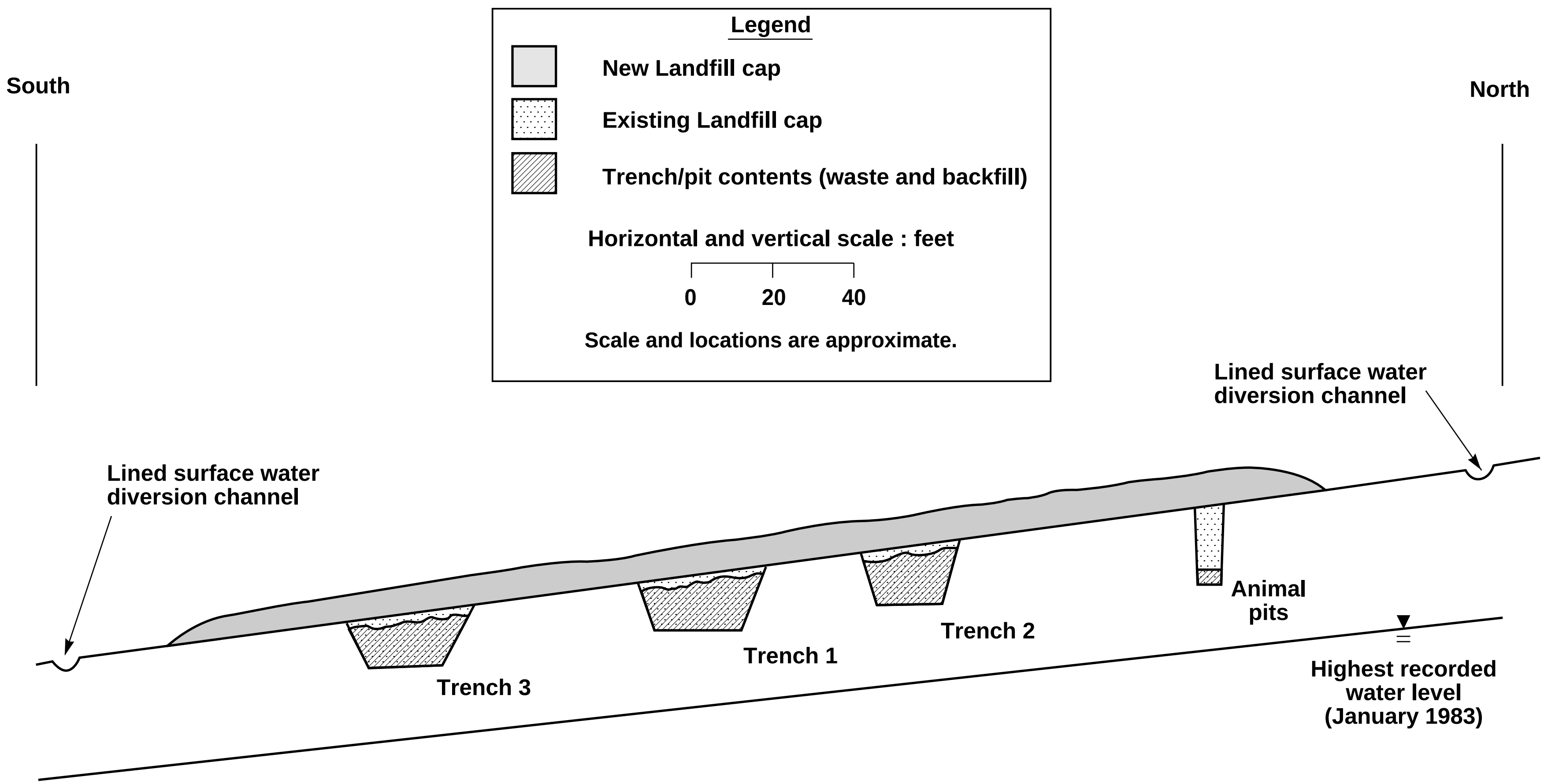


Figure 10. Distribution of TCE in ground water of the Qt-Tmss hydrogeologic unit, second quarter 1997.



Location of cross section shown on Figure 12.

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Figure 11. Cross section through the Pit 6 Landfill cap.

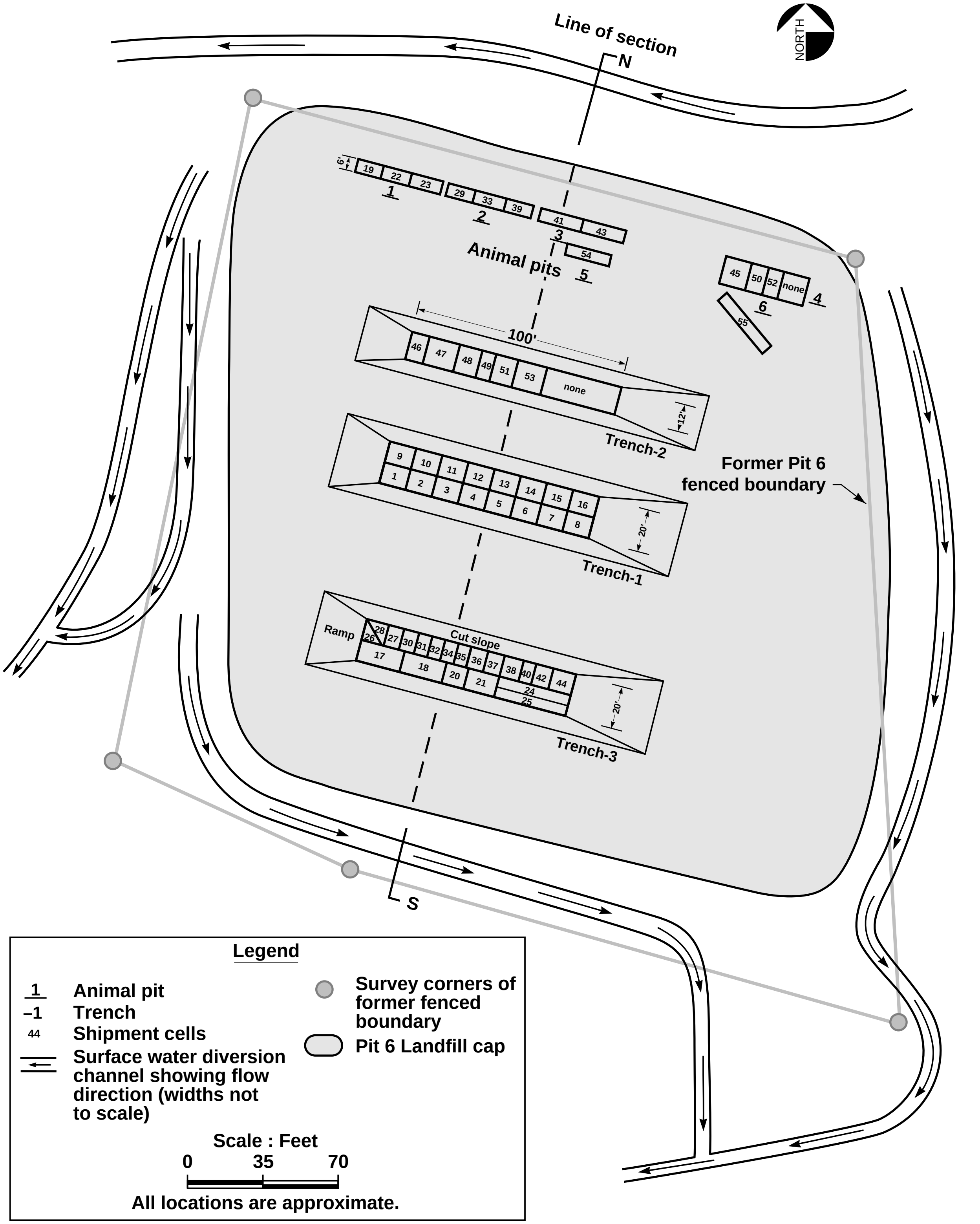

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Figure 12. Location of Pit 6 Landfill cap and surface water diversion channels.

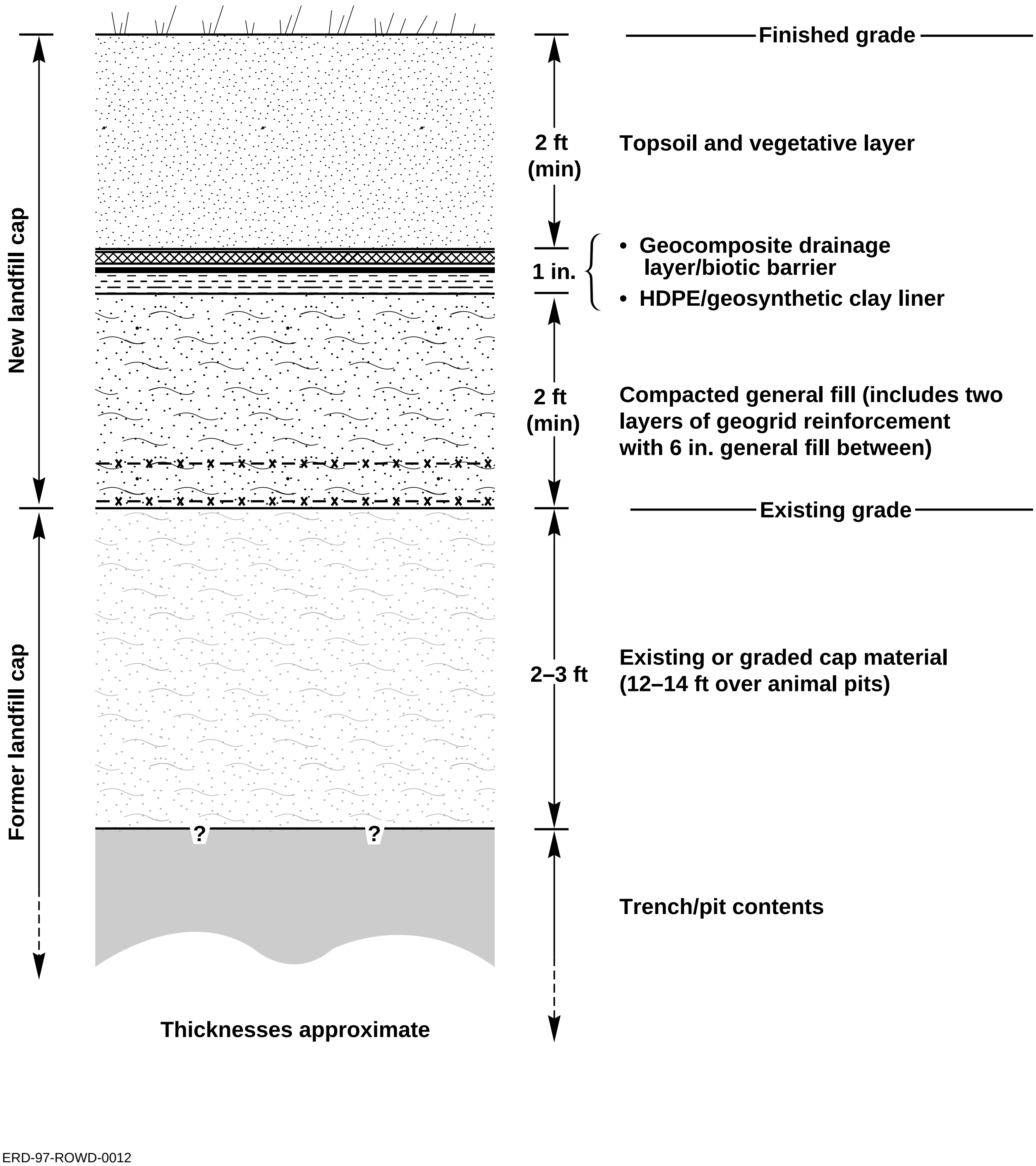
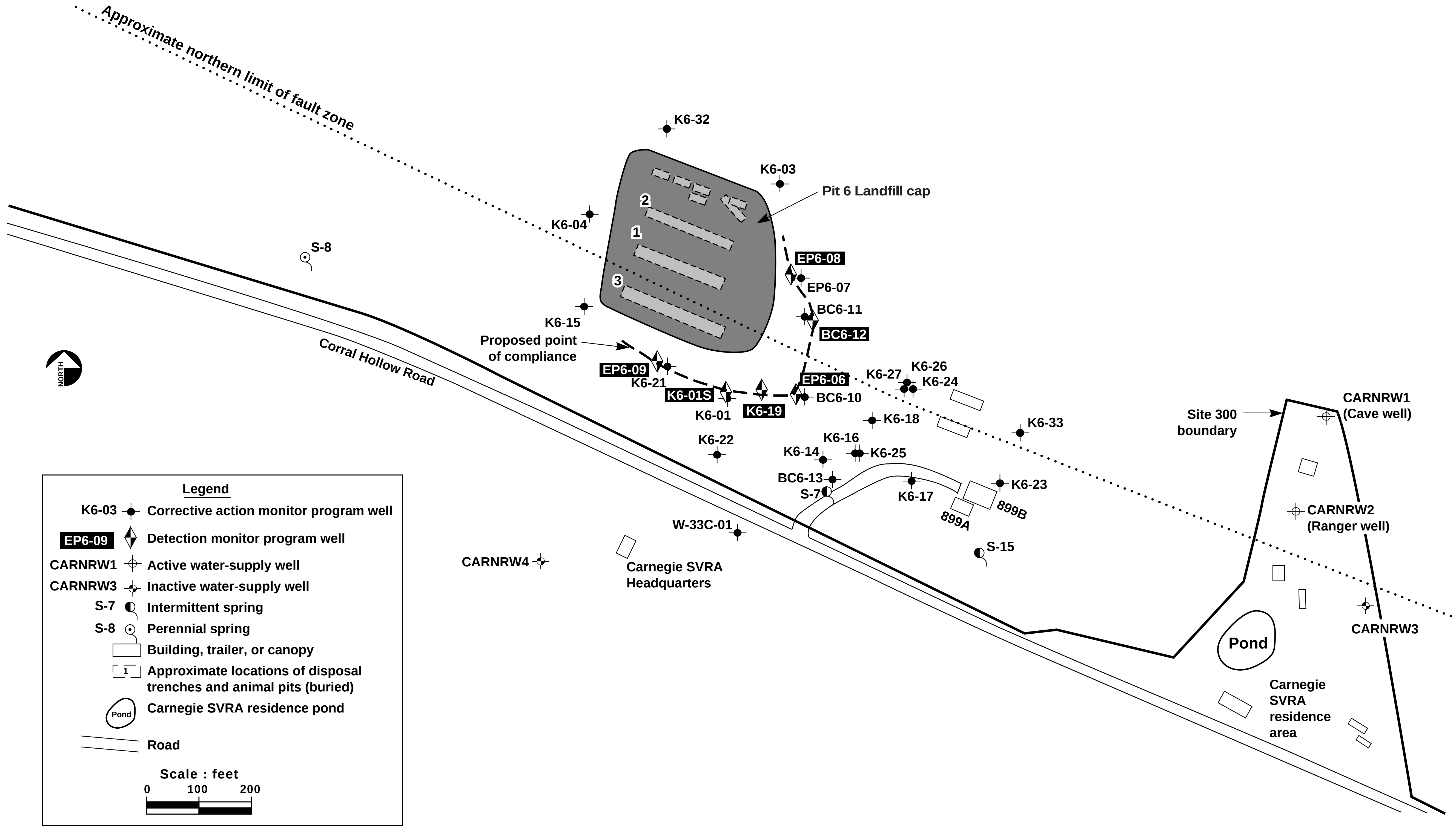


Figure 13. Typical section of the Pit 9 Landfill cap system.



ERD-97-ROWD-0013

Figure 14. Detection and corrective action program monitor wells in the vicinity of the Pit 6 Landfill.

Tables

Table 1. Inventory of waste disposed of in the Pit 6 Landfill (LLNL, 1973).

Shipment no.	Date	Load	Contents[a]
1	07/01/64	1 truckload	Miscellaneous dry waste drums, cargo pallets, metal parts 1 metal tank 2 glove boxes 2 shell furnaces
2	07/08/64	1 truckload	1 large glove box 2 small glove boxes 1 degreaser 2 pallets of filters Miscellaneous dry waste drums 1 large u-shaped ducting and other ducting waste lumber and metal parts
3	07/15/64	1 truckload	8 pallets of dry nonradioactive waste 1 metal tank 2 drums full of varnish [solidified polymer] 4 pallets of capacitors 1 pallet electron tubes 1 pallet nonradioactive waste paper Miscellaneous ducting
4	07/22/64	1 truckload	4 pallets sewer pipe and concrete 1 pallet of gas bottles 1 pallet of filters 1 stack old pallets pallets of 5-in. piping
5	07/29/64	1 truckload	3 pallets of capacitors (2 small and 2 large) 1 pallet of gas bottles 18 pallets of empty oil drums 2 stacks old pallets
6	08/05/64	1 truckload	24 pallets of empty oil drums
7	08/12/64	1 truckload	24 pallets of empty oil drums
8	08/19/64	1 truckload	1 pallet of capacitors 1 pallet of waste drums 22 pallets of empty oil drums
9	08/26/64	1 truckload	22 pallets of oil drums
10	09/02/64	1 truckload	22 pallets of oil drums
11	09/09/64	1 truckload	One 2,000-gal tank 20 pallets of waste drums and waste oil drums
12	09/16/64	1 truckload	One 824-gal tank full of waste paper and green basket waste 8 stacks of 4 ft $\times$ 4 ft cargo pallets 2 pallets of capacitors 2 pallets of waste drums

Table 1. (Continued)

Shipment no.	Date	Load	Contents[a]
13	09/23/64	1 truckload	One 2,000-gal tank full of empty carboys and lard cans (not contaminated), and miscellaneous parts 2 pallets of wooden boxes of miscellaneous chemicals One 500-gal tank 1 pallet with two 55-gal and two 30-gal waste drums full of assorted chemicals 1 wooden box full of waste paper 4 pallets of waste oil drums 8 pallets of dry waste drums full of cans, boards, trash and miscellaneous parts 2 stacks of 4 ft × 4 ft cargo pallets 1 pallet of capacitors 2 small glove boxes
14	09/30/64	1 truckload	Two 2,000-gal tanks full of empty carboys (not hot), empty cans, and miscellaneous parts 8 pallets of empty waste drums (black) 2 stacks of pallets
15	10/07/64	1 truckload	1 steel tank 4 ft × 2 ft × 20 ft (rack) 5 small tanks (1 ft × 3 ft × 4 ft) (w/lids) 7 stacks cargo pallets 2 pallets of miscellaneous parts
16	10/12/64	1 small trailer	1 glove box (10 ft × 4 ft × 8 ft) 2 stacks of cargo pallets 1 pallet of empty 5-gal cans 2 filters (2 ft × 1 ft) 2 pallets of 3-in. pipe
17	12/15/64	1 truck and 2 trailers	2 pallets of chips (18 drums) 3 pallets of empty oil and waste drums 1 pallet of dry chemicals 2 pallets of capacitors 5 aluminum shelves 1 sink 3 filters (2 ft × 2 ft × 2 ft) 5 glove boxes 2 furnaces and hardware 1 large enclosure (8 ft × 8 ft × 5 ft) 1 glove box (4 ft × 4 ft × 4 ft) w/vacuum cleaner 1 metal rack, hood, and table Ducting 1 large wooden box full of miscellaneous trash

Table 1. (Continued)

Shipment no.	Date	Load	Contents[a]
18	02/24/65	1 truckload and 2 trailers	2 glove boxes 1 bench 1 PVC hood 5 pallets of ducting 6 pallets of filters 2 stacks of old pallets 2 pallets of capacitors 2 small furnaces 4 pallets of waste drums 1 large mercury-contaminated manifold
19	03/22/65	[not listed]	4 lard cans and 1 package of animal waste (rats)
20	05/04/65	1 truckload with 2 trailers	5 pallets of capacitors 7 pallets of filters 1 enclosure (4 ft $\times$ 4 ft $\times$ 6 ft) 1 furnace (3 ft $\times$ 4 ft $\times$ 5 ft) 1 small glove box 5 pallets of trash cans 1 pallet of dollies
21	06/08/65	2 trailers	2 pallets of drums 6 pallets of capacitors 3 glove boxes 1 shop table 3 pallets of pumps 1 pallet of transformers miscellaneous ducting 2 pallets of ducting
22	06/08/65	[not listed]	2 lard cans containing animal waste
23	06/18/65	[not listed]	Five 55-gal drums of animals (rats, dogs, and rabbits) Two 55-gal drums of animals (rats)
24	07/20/65	[not listed]	One 2,000-gal empty truck tanker
25	07/27/65	1 truck and 2 trailers	1 large work table 5 pallets of capacitors 1 empty 500-gal water tanker 3 pallets of empty drums 1 pallet of filters 1 pallet of small cans 20 pallets (4 ft $\times$ 4 ft)
26	08/06/65	1 truck and 2 trailers	16 pallets of empty drums 4 pallets of capacitors
27	09/17/65	1 truck and 1 trailer	6 pallets of capacitors 1 pallet of drums 1 pallet of filters 2 pallets of miscellaneous cans 1 pallet of carboys 1 pallet of pipe

Table 1. (Continued)

Shipment no.	Date	Load	Contents[a]
28	10/22/65	1 truck and 1 trailer	1 large glove box 3 small glove boxes 1 work table 1 pallet of filters and ducting 1 pallet of capacitors 2 large boxes 1 pallet of drums
29	02/25/66	[not listed]	1 drum animal waste (ram) [and one ram]
30	03/01/66	1 truck and 1 trailer	3 pallets of drums 13 pallets of capacitors 1 large wooden box 15 pallets (4 ft × 4 ft)
31	03/28/66	1 truck and 1 trailer	2 large wooden boxes of trash 1 pallet of pipe and ducting 1 pallet of trash One 1,000-gal portable tank 5 pallets of capacitors 3 stacks of pallets
32	04/19/66	1 truck and 1 trailer	8 pallets of capacitors 3 glove boxes 2 pallets of drums 2 pallets of miscellaneous and pipe 2 boxes mercury lights
33	05/10/66	[not listed]	3 cows 5 bags of lime to cover animals
34	06/21/66	1 truck and 1 trailer	1 large wooden box 3 pallets of ducting and tubing 4 pallets of large filters 5 pallets of capacitors 1 pallet of miscellaneous metal bracing
35	07/01/66	1 truck and 1 trailer	1 vent hood 3 pallets of capacitors 1 glove box 10 drums 3 pallets of filters 1 pallet of filter fittings 1 pallet miscellaneous 1 metal stand 1 pallet of piping ductwork
36	09/09/66	1 trailer load	5 glove boxes 6 pallets of capacitors Two 55-gal drums One 55-gal drum of small capacitors 1 pallet assorted miscellaneous 1 pallet of round capacitors

Table 1. (Continued)

Shipment no.	Date	Load	Contents[a]
37	09/28/66	1 trailer load	1 pallet of 7.5-gal carboys 1 box capacitors 2 pallets miscellaneous Ten 55-gal drums 1 roll flooring Two 30-gal waste cans 2 pallets of capacitors 2 pallets of filters One 300-gal gas tank
38	01/13/67	1 trailer	2 chemical (sink type) lab work benches 4 pallets of ducting 2 hood vent tops 3 large filters 2 pallets of capacitors 3 pallets of miscellaneous cans and containers 1 pallet of drums (4) 4 hood tops 2 wooden glove boxes 1 large furnace 1 pallet metal sheets (sections)
39	01/16/67	[not listed]	3 cows
40	05/10/67	1 trailer	1 pallet small plastic pipes 1 pallet of glass doors 1 pallet of filters 1 pallet of large plastic pipes 1 pallet of ventilating ducting 2 pallets of canvas and pipes 1 large pallet of filters, motors, pipe 1 box pallet of capacitors, filters 12 pieces rectangular ducting
41	05/13/67	[not listed]	1 cow
42	08/11/67	One 40-ft trailer	1 glove box 6 pallets of lard cans One 1000-gal tank 10 pallets of capacitors 1 box pallet of miscellaneous capacitors 1 pallet of red (non-rad) chemical drums 1 pallet of miscellaneous pieces of equipment 1 pallet of flexible tubing of various sizes several large (>15-ft) pieces of pipe and ducting
43	09/01/67	[not listed]	2 cows
44	10/25/67	One 40-ft trailer	6 pallets of capacitors 6 carboys Two 10-ft wooden boxes 14 drums miscellaneous 2 pallets of filters 2 pallets of concrete blocks One 3-ft wooden box 4 lard cans of miscellaneous gas bottles

Table 1. (Continued)

Shipment no.	Date	Load	Contents[a]
45	11/01/67	[not listed]	4 technically contaminated calves
46	04/12/68	One 40-ft trailer	9 pallets of capacitors 1 glove box 4 pallets of drums 1 pallet of wooden case filters 2 pallets of wood planks 1 large wood box 1 pallet of styrofoam 6 pieces aluminum ducting 1 pallet of large electrical coils
47	04/26/68	One 40-ft trailer	4 pallets of wood from pit covers 4 pallets of drums 2 pallets of capacitors 2 pallets of miscellaneous ducting One 20-ft section of aluminum ducting 1 pallet of miscellaneous metal (Fe) parts
48	07/19/68	One 40-ft trailer	9 retention tanks—no activity using portable alpha meter, no alpha/beta readings with Geiger counter E-400 1 pallet of technically contaminated waste (aluminum brackets and cross-braces for storage shelves)
49	07/02/69	One 40-ft trailer	1 box (3 ft $\times$6 ft $\times$4.5 ft) miscellaneous small junk 2 boxes of approximately 200 small capacitors 2 large boxes of approximately 50 small capacitors 1 ignition tube filled with Hg 3 mercury tubes 1 pallet of PVC pipe 87 capacitors 1 large pallet of soil samples 2 boxes [drums] of depleted U^{238} (drums exhumed on June 14-15, 1971) 166 drums of 55-gal, compressed 1 pallet of air ducting 1 mercury lamp
50	08/29/69	[not listed]	3 drums of biomedical waste calf: carcass, feces, urine cow: feces, urine, milk, blood
51	09/17/69	[not listed]	28 ignition tubes 8 lid-filled drums 2 boxes small capacitors 25 capacitors approximately 100 boxes of S.E.D.A.N. dirt 1 filter/depleted U^{238} 1 drum Hg waste (drum exhumed on June 14-15, 1971) 3 boxes of prefilters 19 drums/depleted U^{238} [drums exhumed on June 14-15, 1971] 1 drum/Mulberry [depleted U^{238}](drum exhumed on June 14-15, 1971)
52	09/24/69	[not listed]	1 cow

Table 1. (Continued)

Shipment no.	Date	Load	Contents[a]
53	09/01/70	[not listed]	1 mercury stripper 34 drums of depleted U^{238} (drums exhumed on June 14-15, 1971) 771 capacitors
54	04/28/71	[not listed]	2 cows
55	02/20/73	[not listed]	5 cows and 1 ram

Notes:

[a] Contents are summarized from LLNL (1973) except where data shown in brackets are revised using Decker (1971).

S.E.D.A.N. denotes Project Sedan which was a nuclear excavation and cratering experiment conducted at the Nevada Test Site (LRL, 1963). Shipment 51 lists S.E.D.A.N. dirt.

Mulberry probably refers to a metallurgy experiment.

Table 2. Radioactive isotopes and daughter products potentially associated with Pit 6 Landfill waste.

Isotope	Decay mode	Half life	1st daughter product	Decay mode	Half life	2nd daughter product	Decay mode	Half life	$t_{1/2}$ (days)	Residual activity (μCi) in 1997 per Ci of source term in 1972[a]	Constit-uent of concern (Yes/No)	Remaining percentage of 1972 source term in 1997
antimony-124	beta -, gamma	60.4 days	tellurium-124	Stable	NA	NA	NA	NA	60.4	0.0	No	0.00%
antimony-125	beta -	2.7 yr	tellurium-125	Stable	NA	NA	NA	NA	985.5	1,632	Yes	0.16%
arsenic-74	beta + & -, gamma	18 days	selenium-74 or germanium-74	Stable	NA	NA	NA	NA	18	0.0	No	0.00%
beryllium-7	EC, gamma	53.6 days	lithium-7	Stable	NA	NA	NA	NA	53.6	0.0	No	0.00%
cadmium-109	EC, gamma	470 days	silver-109	Stable	NA	NA	NA	NA	470	0.0	No	0.00%
cerium-141	beta -, gamma	32.5 days	praseodymium-141	Stable	NA	NA	NA	NA	32.5	0.0	No	0.00%
cerium-144	beta -, gamma	284.6 days	praseodymium-144	beta-, gamma	17.3 min				284.6	0.0	No	0.00%
						neodymium-144	alpha	2.4×10^{15} yr	8.8×10^{17}	0.0	No	0.00%
cesium-137	beta -, gamma	30 yr	barium-137	Stable	NA	NA	NA	NA	9750	522,717	Yes	52.27%
chromium-51	EC, gamma	27.8 days	vanadium-51	Stable	NA	NA	NA	NA	27.8	0.0	No	0.00%
cobalt-60	beta -, gamma	5.26 yr	nickel-60	Stable	NA	NA	NA	NA	1709.5	24,726	Yes	2.47%
copper-64	beta + & -, gamma	12.8 hr	nickel-64 or zinc-64	Stable	NA	NA	NA	NA	0.53333333	0.0	No	0.00%
gold-195	EC, beta +, gamma	186 days	platinum-195	Stable	NA	NA	NA	NA	186	0.0	No	0.00%
gold-198	beta -, gamma	2.7 days	mercury-198	Stable	NA	NA	NA	NA	2.7	0.0	No	0.00%
iodine-125	EC, beta +, gamma	60.1 days	tellurium-125	Stable	NA	NA	NA	NA	60.1	0.0	No	0.00%
iodine-131	beta -, gamma	8 days	xenon-131	Stable	NA	NA	NA	NA	8	0.0	No	0.00%
iron-59	beta -, gamma	45.6 days	cobalt-59	Stable	NA	NA	NA	NA	45.6	0.0	No	0.00%
iridium-192	beta -, gamma	74.2 days	osmium-192 or platinum-192	Stable	NA	NA	NA	NA	74.2	0.0	No	0.00%
manganese-54	EC, gamma	312 days	chromium-54	Stable	NA	NA	NA	NA	312	0.0	No	0.00%
mercury-203	beta -, gamma	47 days	thallium-203	Stable	NA	NA	NA	NA	47	0.0	No	0.00%
molybdenum-99	beta -, gamma	66.7 hr							2.77916667	0.0	No	0.00%
			technetium-99	beta-, gamma	2.1×10^5 yr	ruthenium-99	Stable	NA	7.7×10^7	0.0	No	0.00%
niobium-95	beta -, gamma	35 days	molybdenum-95	Stable	NA	NA	NA	NA	35	0.0	No	0.00%
phosphorus-32	beta -	14.28 days	sulfur-32	Stable	NA	NA	NA	NA	14.28	0.0	No	0.00%
rhenium-186	beta -, gamma	88.9 hr	osmium-186 or tungsten-186	Stable	NA	NA	NA	NA	3.70416667	0.0	No	0.00%
rubidium-86	beta -, gamma	18.7 days	strontium-86	Stable	NA	NA	NA	NA	18.7	0.0	No	0.00%
ruthenium-103	beta -, gamma	39.5 days	rhodium-103	Stable	NA	NA	NA	NA	39.5	0.0	No	0.00%
ruthenium-106[b]	beta-	1.02 yr	rhodium-106	beta-, gamma	30 sec	palladium-106	Stable	NA	372.3	0.0	No	0.00%
selenium-75	EC, gamma	120.4 days	arsenic-75	Stable	NA	NA	NA	NA	120.4	0.0	No	0.00%
silver-110m	beta -, gamma	249.8 days	cadmium-110	Stable	NA	NA	NA	NA	249.8	0.0	No	0.00%

Table 2. (Continued)

Isotope	Decay mode	Half life	1st daughter product	Decay mode	Half life	2nd daughter product	Decay mode	Half life	$t_{1/2}$ (days)	Residual activity (μCi) in 1997 per Ci of source term in 1972[a]	Constit-uent of concern (Yes/No)	Remaining percentage of 1972 source term in 1997
sodium-22	EC, beta +, gamma	2.58 yr	neon-22	Stable	NA	NA	NA	NA	941.7	1,211	Yes	0.12%
strontium-89	beta -, gamma	50.5 days	yttrium-89	Stable	NA	NA	NA	NA	50.5	0.0	No	0.00%
strontium-90	beta -, gamma	29 yr	yttrium-90	beta -	64 hr	zirconium-90	Stable	NA	10585	550,163	Yes	55.02%
sulfur-35	beta -, gamma	87.9 days	chlorine-35	Stable	NA	NA	NA	NA	87.9	0.0	No	0.00%
tantalum-182	beta -, gamma	115 days	tungsten-182	Stable	NA	NA	NA	NA	115	0.0	No	0.00%
tellurium-132	beta -, gamma	3.26 days	iodine-1342	beta -, gamma	2.3 hr	xenon-132	Stable	NA	3.26	0.0	No	0.00%
thallium-204	beta -	3.78 yr	lead-204	Stable	NA	NA	NA	NA	1379.7	10,211	Yes	1.02%
thorium-232	alpha	1.4×10^{10} yr	Many, primary is radium-228	beta -, gamma	5.78 yr	_c	_c	_c	5.1×10^{12}	<1,000,000	Yes	<100.00%
tritium	beta-	12.2 yr	helium-3	Stable	NA	NA	NA	NA	4453	241,621	Yes	24.16%
tungsten-181	EC, gamma	121.2 days	tantalum-181	Stable	NA	NA	NA	NA	121.2	0.0	No	0.00%
tungsten-185	beta -, gamma	75 days	rhenium-185	Stable	NA	NA	NA	NA	75	0.0	No	0.00%
tungsten-187	beta -, gamma	24 hr							1	0.0	No	0.00%
			rhenium-187	beta -	4.3×10^{10} yr	osmium-187	Stable	NA	1.60×10^{13}	0.0	No	0.00%
uranium-238 (D-38)	alpha	4.47×10^{9} yr	uranium-234, thorium-230, radium-226….	_c	_c	_c	_c	_c	1.6×10^{12}	<1,000,000	Yes	<100.00%
yttrium-91	beta -, gamma	58.5 days	zirconium-91	Stable	NA	NA	NA	NA	58.5	0.0	No	0.00%
zinc-65	EC, beta +, gamma	245 days	copper-65	Stable	NA	NA	NA	NA	245	0.0	No	0.00%
zirconium-95	beta -, gamma	65 days	niobium-95	beta -, gamma	35 days	molybdenum-95	Stable	NA	65	0.0	No	0.00%

[a] Source terms were conservatively assumed to be 1 Ci as of 1972 for all isotopes except thorium-232, tritium, and uranium isotopes.

[b] Radium-106 was noted in historical waste records. As there is no radium isotope with a mass of 106, this was mistakely interpreted in later documents to be radium-212. The current interpretation is that the most likely isotope is ruthenium-106 based on the type of biomedical experiments conducted at the time.

[c] Dependent on 1st daughter product generated.

Notes:

Ci = Curie(s).

EC = Electron capture.

hr = Hour(s).

min = Minute(s).

NA = Not applicable.

t1/2 = Isotope half life.

yr = Year(s).

μCi = Microcurie(s).

Table 3. Pit 6 Landfill post-closure inspection checklist.

Location: ______________________ **Name of Inspector:** ______________________

Date: ______________________ **Time:** ______________________

	Corrections needed Y/N	Description	Corrections completed Y/N	Date
Condition of facility:				
1. Run-on is diverted away from Pit 6 Landfill.				
2. Erosion controls are present and in good condition (i.e., grading, vegetation, and clear diversion channels and culverts).				
3. Permanent, surveyed benchmarks are present and maintained.				
4. The ground water monitoring network is in good working order.				
5. The cap is in good repair; no settlement, large plants, gullying, bare vegetation, etc.				
6. No evidence of animal burrows on cap.				
7. List any other observations.				

Safety: The following systems are present and/or functional (list exceptions):

	Corrections needed Y/N	Description	Corrections completed Y/N	Date
1. Emergency Coordinator and phone number.				
2. Telephone/radio in working order.				
3. Copy of Contingency Plan/Post-Closure Plan on file at facility.				
4. Warning signs.				
5. Access available to emergency vehicles.				

RECOMMENDED ACTIONS/CORRECTIONS MADE:

Signature: ______________________

Table 4. Proposed constituents of concern for the Pit 6 Landfill Detection Monitoring Program.

Constituent of concern	Identified in waste disposal records	Potentially associated with buried waste	Detected in soil and/or ground water	Potential breakdown/ daughter product
Halogenated Volatile Organic Compounds:				
1,1,1-TCA	–	–	×	–
1,2-DCA	–	–	×	–
cis-1,2-DCE	–	–	×	×
Chloroform	–	–	×	–
Methylene chloride	–	–	×	×
Tetrachloroethylene	–	–	×	–
Trichloroethylene	–	–	×	×
Aromatic VOCs:				
Benzene	–	–	×	–
Ethylbenzene	–	–	×	–
Toluene	–	–	×	–
Total xylenes	–	–	×	–
Metals:				
Beryllium	×	–	×	–
Mercury	×	–	×	–
Other:				
Carbon disulfide	–	–	×	–
PCBs	–	×	–	–
Radiologicals:				
Antimony-125	×	–	–	–
Cesium-137	×	–	–	–
Cobalt-60	×		–	–
Sodium-22	×	–	–	–
Strontium-90	×	–	–	–
Thallium-204	×	–	–	–
Thorium-232	×	–	–	–
Tritium	×	–	×	–
Uranium-238	×	–	–	–

Table 5. Constituent of concern concentration limits and statistical limits for the Detection Monitoring Program wells.

Constituent of concern (COC)	Laboratory reporting limit for COC	COC concentration limit/statistical limit in Detection Monitoring Program well[a] (in μg/L unless otherwise indicated)						
		BC6-12	EP6-06	EP6-08	EP6-09	K6-01S	K6-01 (Alt.)	K6-19
1,1,1-TCA	0.5 μg/L	RL/RL	RL/RL	RL/RL	RL/RL	RL/RL	RL/RL	RL/RL
1,2-DCA	0.5 μg/L	RL/RL	RL/RL	RL/RL	RL/RL	RL/RL	RL/RL	RL/RL
cis-1,2-DCE	0.5 μg/L	RL/RL	RL/RL	RL/RL	RL/RL	5.44/6.98	RL/RL	RL/RL
Chloroform	0.5 μg/L	RL/RL	RL/RL	0.08/0.97	RL/RL	RL/RL	RL/RL	0.15/1.48
Methylene chloride	1.0 μg/L	RL/RL	RL/RL	RL/RL	RL/RL	RL/RL	RL/RL	RL/RL
PCE	0.5 μg/L	RL/RL	RL/RL	0.39/1.57	RL/RL	RL/RL	RL/RL	RL/RL
TCE	0.5 μg/L	0.51/1.08	RL/RL	RL/RL	13.8/17.4	1.10/1.52	RL/RL	8.16/12.59
Benzene	0.5 μg/L	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Ethylbenzene	0.5 μg/L	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Toluene	0.5 μg/L	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Total xylenes	0.5 μg/L	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Beryllium	0.0005 μg/L	RL/RL	RL/RL	RL/RL	RL/RL	TBD	RL/RL	RL/RL
Mercury	0.0002 μg/L	RL/RL	RL/RL	RL/RL	RL/RL	TBD	RL/RL	RL/RL
Carbon disulfide	1.0 μg/L	TBD	TBD	TBD	TBD	TBD	TBD	TBD
PCBs	0.5 μg/L	RL/RL	RL/RL	RL/RL	RL/RL	RL/RL	RL/RL	RL/RL
Tritium	100 pCi/L[b]	TBD	TBD	RL/RL	RL/RL	TBD	RL/RL	RL/RL
Uranium	0.1 pCi/L[b]	0.35/0.66	TBD	1.19/1.50	2.05/3.68	TBD	0.89/1.51	3.22/7.24
Gross alpha	1 pCi/L[b]	RL/RL	2.68/7.70 pCi/L	0.92/3.98 pCi/L	1.00/4.85 pCi/L	TBD	2.02/20.03 pCi/L	1.99/9.19 pCi/L
Gross beta	1 pCi/L[b]	8.61/21.3 pCi/L	8.61/21.3 pCi/L	8.61/21.3 pCi/L	8.61/21.3 pCi/L	TBD	8.61/21.3 pCi/L	8.61/21.3 pCi/L

[a] In some detection monitor wells, COCs have been detected above the reporting limit due to : (1) background concentrations of naturally-occurring metals and radionuclides or (2) a previous release of the COC. For these reasons, the concentration limit may exceed the reporting limit in some wells.

[b] Reporting limit as requested in analytical laboratory contract. Reporting limit may vary with counting time, sample turbidity, and other variables.

Notes:

COC = Constituent of concern.

RL = Analytical laboratory reporting limit; may vary with laboratory performing analysis.

TCA = Trichloroethane.

DCA = Dichloroethane.

DCE = Dichloroethylene.

PCE = Tetrachloroethylene.

TCE = Trichloroethylene.

PCBs = Polychorinated biphenyls.

TBD = To Be Determined.

Table 6. Pit 6 Landfill monitor well construction details.

Well	Purpose	Shiner elevation (ft/MSL)	POM elevation (ft/MSL)	Screen interval depth (ft/bgs)	Sand pack interval depth (ft/bgs)	Well inner diameter (in.)	Casing depth (ft/bgs)	Pump intake depth (ft/bgs)	Pump type	Date well completed
BC6-10	Deep, clean monitor well	685.60	687.55	65-85	62-85	4.5	85	87.8	Grundfos	12/03/86
BC6-11	Same screened interval as BC6-12	691.90	693.90	25-90	23.5-90	4.5	90	–	NA	12/09/86
BC6-12	Detection monitor well	692.03	694.03	15-95	14-99	6.0	99	97.8	Grundfos	12/16/86
BC6-13	Spring 7 monitor well	664.99	667.66	0-5	0-5	4.5	5	–	NA	12/17/86
CARNRW1	Active water-supply well	678.73	678.73	63-503	50-503	6.25	503	unknown	Grundfos	02/02/72
CARNRW2	Active water-supply well	663.52	665.06	150-300	50-300	6.0	300	unknown	Grundfos	05/19/83
CARNRW3	Inactive water-supply well	702.72	703.00	76.0-236.7	50-236.7	6.0	236.7	234.8	Grundfos	00/01/75
CARNRW4	Inactive water-supply well	651.11	651.75	21.0-103.7	unknown	8.0	103.7	–	NA	00/01/65
EP6-06	Detection monitor well	686.11	688.11	15-35	10.75-45	4.0	45	44.4	NA	10/06/84
EP6-07	Deep monitor well	705.55	707.55	108-128	99-128	4.0	128	122.1	Grundfos	10/8/84
EP6-08	Detection monitor well	706.41	708.41	47-62	41-62	4.0	62	55.1	Grundfos	10/10/84
EP6-09	Detection monitor well	692.28	694.28	35-65	32-70	4.0	70	55.0	Standard	10/11/84
K6-01	Monitor well within plume	689.46	691.09	35-66	29-70.5	3.5	70	35.0	Grundfos	9/16/82
K6-01S	Detection monitor well	689.52	692.52	20.75-25.5	19.75-27	4.5	30.5	29.5	Grundfos	10/22/87
K6-03	Upgradient, clean monitor well	724.03	726.75	73-94	51-104	3.5	94	80.0	Standard	09/13/82
K6-04	Upgradient, clean monitor well	706.12	708.32	43-68.5	38-68.5	3.5	68.5	50.0	Standard	09/21/82
K6-14	Downgradient, clean boundary well	677.86	680.87	19-34.5	17-35	4.5	34.5	unknown	Well Wizard	01/28/88
K6-15	Cross-gradient, clean monitor well	697.29	700.29	24-29	20.5-31	4.5	33	–	NA	02/02/88
K6-16	Monitor well within plume	676.45	679.45	12-17	10.5-18	4.5	22	–	NA	02/03/88
K6-17	Monitor well within plume	675.71	678.71	12-32	9-32	4.5	32	31.0	Well Wizard	02/23/88
K6-18	Monitor well within plume	683.59	685.60	19.5-24.5	17-30	4.5	30	–	NA	04/0/88
K6-19	Detection monitor well	690.37	693.04	21.75-36.25	16.5-41	4.5	41	38.0	Grundfos	04/12/88
K6-21	Monitor well within plume	692.37	694.95	19-24	14.75-24.3	4.5	27	–	NA	05/17/89
K6-22	Downgradient, clean boundary well	679.83	681.53	30.1-40.3	23.4-40.5	4.5	40.4	39.8	Well Wizard	01/05/90
K6-23	Downgradient, clean boundary well	679.94	680.99	19.3-24.3	15.5-25.7	4.5	24.4	–	NA	01/08/90
K6-24	Cross-gradient, clean monitor well	685.23	686.93	35.7-40.5	33.9-40.7	4.5	40.5	39.0	Grundfos	01/16/90
K6-25	Deep, clean monitor well	676.75	679.75	100-120	94-123	4.5	120.6	119.6	Grundfos	03/14/90
K6-26	Deep, clean monitor well	684.33	687.33	222-242.5	217-244.5	4.5	242.5	239.5	Grundfos	04/25/89
K6-27	Deep, clean monitor well	684.19	687.19	150-170	146-170.25	4.5	170	168.7	Grundfos	05/01/90
K6-32	Upgradient, clean monitor well	727.09	730.09	59.5-79	56.5-82	5.0	80	78.9	Well Wizard	11/19/96
K6-33	Downgradient, clean boundary well	618.14	618.14	38-52	36-53	5.0	52.3	50.5	Well Wizard	07/31/97
W-33C-01	Clean, offsite monitor well	649.51	652.51	16.9-21.75	15.9-23.5	4.5	21.8	21.3	Well Wizard	04/03/90

Notes:

ft/MSL = Elevation relative to mean sea level.

POM = Point of measurement.

ft/bgs = Depth below ground surface.

NA = Not applicable.

Table 7. Analytical and statistical methods and sampling frequencies during post-closure detection monitoring.

Monitoring parameter or constituent of concern (COC)	Analytical method number	Statistical method[a]	Sampling and statistical analysis frequency
Constituents of concern:			
Halogenated Volatile Organic Compounds (VOCs):			
1,1,1-TCA			
1,2-DCA			
cis-1,2-DCE	EPA 8010/601	Prediction interval with retests and/or control charts	Quarterly
Chloroform			
Methylene chloride			
Tetrachloroethylene			
Trichloroethylene			
Aromatic VOCs:			
Benzene, ethylbenzene, toluene, total xylenes	EPA 8020/602	Prediction interval with retests and/or control charts	Quarterly
Metals:			
Be	EPA 210.2	Prediction interval with retests and/or control charts	Quarterly
Mercury	EPA 245.1		
Other:			
Carbon disulfide	EPA 624	Prediction interval with retests and/or control charts	Quarterly
PCBs	EPA 608	Prediction interval with retests and/or control charts	Quarterly

Table 7. (Continued)

Monitoring parameter or constituent of concern (COC)	Analytical method number	Statistical method[a]	Sampling and statistical analysis frequency
Radiological Compounds:			
Tritium	EPA 906	Prediction interval with retests and/or control charts[b]	Quarterly
Total uranium	Alpha spectroscopy[c]		
Antimony-125, cesium-137, cobalt-60, sodium-22, strontium-90, thallium-204, and thorium-232	Gross alpha/gross beta by EPA 900		
Monitoring parameters:			
pH	Field measurements[d]	None	Quarterly[e]
Total dissolved solids	EPA 160.1	None	Quarterly[e]
Specific conductance	Field measurements[d]	None	Quarterly[e]
Temperature	Field measurements[d]	None	Quarterly[e]
Phenolics	EPA 420.1 or 625	None	Quarterly[f]
Phthalates:			
Bis (2-ethylhexyl) phthalate and butylbenzylphthalate	EPA 625	None	Quarterly[f]

[a] Statistical analysis will be performed on data for COCs only.

[b] Statistical analysis will be performed on tritium, total uranium and gross alpha/gross beta data.

[c] Total uranium activities will be calculated by adding the activities of uranium-234, -235, and -238.

[d] Field measurements will be conducted in accordance with LLNL SOP 2.2.

[e] Sampling frequency only, no statistical analysis performed.

[f] Sampling to be conducted quarterly for one year with no statistical analysis. If no phenolics or phthalate compounds are detected after one year, this analysis will be dropped.

Table 8. Analytical methods and sampling frequencies for the Corrective Action Monitoring Program.

Wells	Monitoring parameter or constituent of concern (COC)	Analytical method	Sampling frequency	Comments
BC6-12	All COCs	a	Quarterly	Buried waste compliance well; sampled as part of Detection Monitoring Program (DMP)
EP6-06	All COCs	a	Quarterly	Buried waste compliance well; sampled as part of DMP
EP6-08	All COCs	a	Quarterly	Buried waste compliance well; sampled as part of DMP
EP6-09	All COCs	a	Quarterly	Buried waste compliance well; sampled as part of DMP
K6-01S	All COCs	a	Quarterly	Buried waste compliance well; sampled as part of DMP
K6-19	All COCs	a	Quarterly	Buried waste compliance well; sampled as part of DMP
K6-03	All COCs	a	Quarterly	Upgradient, clean monitor well for background monitoring; sampled as part of DMP
K6-04	All COCs	a	Quarterly	Upgradient, clean monitor well for background monitoring; sampled as part of DMP
K6-15	All COCs	a	Quarterly	Upgradient, clean monitor well for background monitoring; sampled as part of DMP
K6-32	All COCs	a	Quarterly	Upgradient, clean monitor well for background monitoring; sampled as part of DMP
BC6-10	Halogenated volatile organic compounds (VOCs)	EPA 8010/601	Annually	Deep, clean monitor well
BC6-13	Halogenated VOCs	EPA 8010/601	Quarterly	Spring 7 monitor well, acts as plume boundary well
EP6-07	Halogenated VOCs	EPA 8010/601	Annually	Deep, clean monitor well
K6-01[b]	Halogenated VOCs	EPA 8010/601	Annually	Monitor well within plume
K6-14	Halogenated VOCs	EPA 8010/601	Quarterly	Downgradient, clean plume boundary well

Table 8. (Continued)

Wells	Monitoring parameter or constituent of concern (COC)	Analytical method	Sampling frequency	Comments
K6-16	Halogenated VOCs	EPA 8010/601	Annually	Monitor well within plume
K6-17	Halogenated VOCs	EPA 8010/601	Quarterly	Clean plume boundary well
K6-18	Halogenated VOCs	EPA 8010/601	Annually	Monitor well within plume
K6-21	Halogenated VOCs	EPA 8010/601	Annually	Monitor well within plume
K6-22	Halogenated VOCs	EPA 8010/601	Quarterly	Downgradient, clean plume boundary well
K6-23	Halogenated VOCs	EPA 8010/601	Quarterly	Downgradient, clean plume boundary well
K6-24	Halogenated VOCs	EPA 8010/601	Annually	Cross-gradient clean monitor well
K6-25	Halogenated VOCs	EPA 8010/601	Annually	Deep, clean monitor well
K6-26	Halogenated VOCs	EPA 8010/601	Annually	Deep, clean monitor well
K6-27	Halogenated VOCs	EPA 8010/601	Annually	Deep, clean monitor well
K6-33	Halogenated VOCs	EPA 8010/601	Quarterly	Downgradient, clean plume boundary well
W-33C-01	Halogenated VOCs	EPA 8010/601	Quarterly	Clean, offsite monitor well
BC6-12, EP6-06, EP6-07, EP6-08, K6-19, K6-24, K6-26, K6-27	Tritium	EPA 906	Quarterly	Tritium previously detected in BC6-12; other wells are clean, adjacent wells

[a] Analytical methods presented in Table 7.

[b] To be sampled quarterly for all COCs if well K6-01S is dry.

Table 9. Historical concentration trends for anthropogenic compounds detected in Pit 6 Landfill ground water.

Potential COC in SWRI	Federal/State MCL (μg/L)	Detections in ground water samples: Above detection limit	Above MCL	Above detection limit in the past 5 years	Above MCL in the past 5 years	COC
Halogenated VOCs						
1,1,1-TCA	200/200	15 samples from 12 wells @ conc. of 0.3 to 10 μg/L	None	None	None	Yes
1,2-DCA	5/0.5	18 samples from 7 wells @ conc. from 0.5 to3.5 μg/L	9 samples in 6 wells above state MCL; none above fed. MCL	2 samples in 1 well (EP6-09) @ conc. from 0.58 to 1 μg/L	2 samples in 1 well (EP6-09) above state MCL; none above Federal MCL.	Yes
cis-1,2-DCE	70/6	29 samples from 5 wells @ conc. from 0.5 to 12 μg/L	10 samples from 2 wells over state MCL; none over fed. MCL	4 samples from 2 wells @ conc. from 0.5 to 9.2 μg/L	1 sample from 1 well (BC6-13-9.2 μg/L) over state MCL; none over Federal MCL	Yes
Acetone	None/None	4 samples from 4 wells in 10/90: K6-17, K6-22, K6-23, W-33C-01	No MCL; all sample conc. below RfD (100 μg/L)[a]	None	No MCL; all sample conc. below RfD (100 μg/L)[a]	No
Chloroform	100/100 TTHMs	31 samples from 7 wells @ conc. from 0.58 to 14 μg/L	None	18 samples from 6 wells @ conc. from 0.58 to 14 μg/L	None	Yes
Methylene chloride	5/None	16 samples from 14 wells @ conc. from 0.44 to 160 μg/L	3 samples from three wells: BC6-13 @ 8.9 μg/L (11/87); K6-16 @5.2 μg/L (7/89); CARNRW2 @ 160 μg/L (10/84)	Once in one well: CARNRW-2 @ 0.44 μg/L in 4/96 (other detections 1990 or before)	None	Yes
PCE	5/5	48 samples from 9 wells @ conc. from 0.5 to 3.2 μg/L	None	6 samples from 2 wells @ conc. from 0.6 to 1 μg/L	None	Yes

Table 9. (Continued)

Potential COC in SWRI	Federal/State MCL (μg/L)	Detections in ground water samples				
		Above detection limit	Above MCL	Above detection limit in the past 5 years	Above MCL in the past 5 years	COC
TCE	5/5	212 samples from 14 wells @ conc. from 0.5 to 250 μg/L.	Conc. > MCL in 7 wells	8 wells @ conc. of 0.5 to 20 μg/L.	Conc. >MCL in 3 wells: K6-18, -19, EP6-09 @ conc. from 2.3 to 20 μg/L	Yes
Freon 113	None/150	5 samples from 5 wells@ conc. from 0.9 to 4.7 μg/L.	None	1 sample from 1 well@ conc. of 1.1 μg/L in 1994.	None	No
Aromatic VOCs						
Benzene	5/1	1 sample from 1 well @ conc. of 0.6 μg/L	None	None	None	Yes
Ethylbenzene	700/680	8 samples from 6 wells @ conc. from 0.5 to 7.3 μg/L	None	None	None	Yes
Toluene	1,000/None	23 samples from 16 wells @ conc. from 0.4 to 4.8 μg/L.	None	None	None	Yes
Total xylenes	10,000/1,750	27 samples from 17 wells @ conc. from 0.6 to 15 μg/L.	None	None	None	Yes
Phthalate compounds						
Bis(2-ethyhexyl) phthalate	6/4	2 samples from 2 wells: K6-01 at 44 μg/L in 10/84; K6-04 at 70 μg/L in 10/84 (upgradient well).	2 samples from 2 wells: K6-01 at 44 μg/L in 10/84; K6-04 at 70 μg/L in 10/84	None	None[b]	No

Table 9. (Continued)

		Detections in ground water samples				
Potential COC in SWRI	**Federal/State MCL (μg/L)**	**Above detection limit**	**Above MCL**	**Above detection limit in the past 5 years**	**Above MCL in the past 5 years**	**COC**
Butylbenzyl phthalate	100 (proposed)/ None	2 samples from 2 wells: K6-01 @ 50 μg/L in 10/84; K6-04 @ 78 μg/L in 10/84 (upgradient well).	None	None	None	No
Other compounds						
Carbon disulfide	None/None	9 samples from 6 wells in conc. from 0.5-1.3 μg/L: BC6-10, K6-22, K6-24, K6-25, K6-27, CARNRW3.	No MCL; all sample conc. below RfD (100 μg/L)[a]	None	No MCL; all sample conc. below RfD (100 μg/L)[a]	Yes
Phenolics (phenol)	None/None	14 samples from 7 wells @ conc. from 0.001 to 0.09 μg/L	No MCL; all sample conc. below State Action Levels (5 μg/L)[c]	9 samples from 7 wells @ conc. from 0.001 to 0.014 μg/L	No MCL; all sample conc. below State Action Levels (5 μg/L)[c]	No

[a] Reference dose (RfD) is the daily oral intake (on a body weight basis) that is below the level USEPA believes to be without adverse, non cancer health risk (zero risk). (U.S. Drinking Water Standards and Health Advisory Table, July 1994).

[b.] Detection limit 100 μg/L after 19888.

[c.] Calif. State Action Level for Taste and Odor.

Notes:

COC = Constituent of concern.

conc. = Concentration

DCA = Dichloroethane.

DCE = Dichloroethylene.

PCE = Tetrachloroethylene.

TCE = Trichloroethylene.

TTHMs = Total trihalomethanes.

VOCs = Volatile organic compounds.

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Appendix A

Ground Water Monitoring Data for Constituents of Concern in Detection Monitoring Program Wells

(Tables A-1 through A-5 are not included in this document. Hard copies are available in ERD Library or contact Division Office at (925) 424-6783).

Table A-6. Uranium in ground water (pCi/L), Pit 6 Area.

Location	Date sampled	Lab	Uranium 234	Uranium 235	Uranium 238	Total uranium
BC6-12	06/24/87	TM	0.2 +/- 0.1	0.1	0.1	0.4 +/- 0.1
	05/23/90	TM	0.2	0.1	0.1	0.4
	03/08/94	IT	0.13 +/- 0.16	0.25 +/- 0.1	0.11 +/- 0.14	0.49 +/- 0.23
	05/30/95	LH	0.19 +/- 0.11	0 +/- 0.04	0.14 +/- 0.09	0.33 +/- 0.15
	05/30/95	LH	0.31 +/- 0.13	0.02 +/- 0.04	0.09 +/- 0.07	0.42 +/- 0.15
	05/29/96	LH	0.15 +/- 0.05	0.01 +/- 0.01	0.1 +/- 0.04	0.26 +/- 0.07
	06/12/97	LH	0.19 +/- 0.03	0.02 +/- 0.01	0.12 +/- 0.03	0.33 +/- 0.04
	06/12/97	LH	0.16 +/- 0.04	0.01 ± 0.01	0.12 +/- 0.03	0.29 +/- 0.05
EP6-06	05/24/90	TM	1 +/- 0.2	0.1	0.6 +/- 0.1	1.7 +/- 0.22
	07/26/90	TM	0.6 +/- 0.2	0.1	0.6 +/- 0.2	1.3 +/- 0.28
	10/25/90	TM	0.7 +/- 0.2	0.1	0.4 +/- 0.1	1.2 +/- 0.22
	01/24/91	TM	1.1 +/- 0.2	0.1	0.7 +/- 0.2	1.9 +/- 0.28
	04/23/91	TM	0.8 +/- 0.1	0.1	0.7 +/- 0.1	1.6 +/- 0.14
	07/17/91	TM	0.9 +/- 0.2	0.1 +/- 0.1	0.7 +/- 0.2	1.7 +/- 0.3
	11/15/91	TM	0.6 +/- 0.1	0.1 +/- 0.1	0.4 +/- 0.1	1.1 +/- 0.17
	06/19/92	TM	0.47 +/- 0.12	0.02 +/- 0.04	0.32 +/- 0.1	0.81 +/- 0.16
	12/09/92	TM	1.3 +/- 0.2	0.2 +/- 0.2	1 +/- 0.2	2.5 +/- 0.35
	05/05/93	IT	0.44 +/- 0.1	0 +/- 0.06	0.15 +/- 0.08	0.59 +/- 0.14
	03/09/94	IT	4.84 +/- 0.25	1.75 +/- 0.15	1.91 +/- 0.16	8.5 +/- 0.33
	05/29/96	LH	0.89 +/- 0.12	0.03 +/- 0.02	0.47 +/- 0.09	1.39 +/- 0.15
	06/11/97	LH	0.76 +/- 0.07	0.03 +/- 0.01	0.53 +/- 0.06	1.32 +/- 0.09
EP6-08	03/18/85	TM	0.8 +/- 0.1	0.1	0.6 +/- 0.1	1.5 +/- 0.14
	05/02/85	TM	0.8 +/- 0.1	0.1	0.5 +/- 0.1	1.0 +/- 0.14
	07/30/85	TM	0.6 +/- 0.1	0.1	0.5 +/- 0.1	1.4 +/- 0.14
	11/14/85	TM	0.3 +/- 0.1	0.1	0.1	0.5 +/- 0.1
	02/24/86	TM	0.5 +/- 0.1	0.1	0.4 +/- 0.1	1 +/- 0.14
	05/22/86	TM	0.6 +/- 0.1	0.1	0.5 +/- 0.1	1.2 +/- 0.14
	08/05/86	TM	0.6 +/- 0.1	0.1	0.4 +/- 0.1	1.1 +/- 0.14
	10/18/86	TM	0.6 +/- 0.1	0.1	0.6 +/- 0.1	1.3 +/- 0.14
	01/31/87	TM	0.9 +/- 0.1	0.1	0.8 +/- 0.1	1.8 +/- 0.14
	05/12/87	TM	0.7 +/- 0.1	0.1	0.4 +/- 0.1	1.2 +/- 0.14
	08/13/87	TM	0.6 +/- 0.1	0.1 +/- 0.1	0.5 +/- 0.1	1.2 +/- 0.17
	10/05/87	TM	0.6 +/- 0.1	0.1	0.4 +/- 0.1	1.1 +/- 0.14
	01/26/88	TM	0.8 +/- 0.1	0.1	0.4 +/- 0.1	1.3 +/- 0.14
	04/05/88	TM	0.9 +/- 0.1	0.1	0.4 +/- 0.1	1.4 +/- 0.14
	04/05/88	TM	0.6 +/- 0.1	0.1	0.4 +/- 0.1	1.1 +/- 0.14
	07/28/88	TM	1.4 +/- 0.2	0.1	0.7 +/- 0.2	2.2 +/- 0.28

Table A-6. (Continued)

Location	Date sampled	Lab	Uranium 234	Uranium 235	Uranium 238	Total uranium
	10/11/88	TM	0.6 +/- 0.2	0.2	0.5 +/- 0.2	1.3 +/- 0.28
	10/11/88	TM	0.6 +/- 0.2	0.2	0.5 +/- 0.2	1.3 +/- 0.28
	02/16/89	TM	1.2 +/- 0.3	0.08	0.8 +/- 0.3	2.08 +/- 0.42
	04/20/89	TM	0.73 +/- 0.19	0.1	0.49 +/- 0.15	1.32 +/- 0.24
	07/25/89	TM	0.6 +/- 0.2	0.1	0.5 +/- 0.2	1.2 +/- 0.28
	10/09/89	TM	0.6 +/- 0.2	0.1	0.5 +/- 0.2	1.2 +/- 0.28
	02/07/90	TM	0.7 +/- 0.2	0.1	0.5 +/- 0.1	1.3 +/- 0.22
	08/10/90	TM	0.6 +/- 0.1	0.1	0.4 +/- 0.1	1.1 +/- 0.14
	10/15/90	TM	0.7 +/- 0.1	0.1	0.5 +/- 0.1	1.3 +/- 0.14
	01/24/91	TM	0.3 +/- 0.1	0.1	0.2 +/- 0.1	0.6 +/- 0.14
	04/23/91	TM	0.51 +/- 0.11	0.04 +/- 0.03	0.43 +/- 0.09	0.98 +/- 0.14
	08/07/91	TM	0.63 +/- 0.17	0.03 +/- 0.05	0.4 +/- 0.13	1.06 +/- 0.22
	11/07/91	TM	0.46 +/- 0.14	0.01 +/- 0.06	0.53 +/- 0.16	1.0 +/- 0.22
	02/05/92	TM	0.65 +/- 0.17	0.06 +/- 0.07	0.42 +/- 0.13	1.13 +/- 0.22
	04/15/92	TM	0.64 +/- 0.1	0.01 +/- 0.02	0.47 +/- 0.08	1.12 +/- 0.13
	07/17/92	TM	0.64 +/- 0.16	0.02 +/- 0.04	0.44 +/- 0.12	1.1 +/- 0.2
	10/08/92	TM	0.85 +/- 0.17	0.01 +/- 0.03	0.36 +/- 0.1	1.22 +/- 0.2
	01/28/93	TM	0.65 +/- 0.19	0 +/- 0.03	0.42 +/- 0.14	1.07 +/- 0.24
	04/21/93	IR	0.55 +/- 0.18	0.06 +/- 0.06	0.43 +/- 0.16	1.04 +/- 0.24
	07/23/93	IT	0.66 +/- 0.07	0.01 +/- 0.02	0.49 +/- 0.06	1.16 +/- 0.09
	02/01/94	IT	0.7 +/- 0.07	0.02 +/- 0.02	0.51 +/- 0.06	1.23 +/- 0.09
	08/24/94	IT	0.76 +/- 0.1	0.03 +/- 0.02	0.49 +/- 0.06	1.28 +/- 0.12
EP6-09	03/19/85	TM	1.2 +/- 0.2	0.1	0.8 +/- 0.1	2.1 +/- 0.22
	05/2/85	TM	1 +/- 0.1	0.1	1.1 +/- 0.1	2.2 +/- 0.14
	07/31/85	TM	1.4 +/- 0.1	0.1	1.1 +/- 0.1	2.6 +/- 0.14
	11/13/85	TM	1 +/- 0.1	0.1	0.1	1.2 +/- 0.1
	02/26/86	TM	0.1	0.1	1.2 +/- 0.1	1.4 +/- 0.1
	05/22/86	TM	0.1	0.1	0.9 +/- 0.1	1.1 +/- 0.1
	08/05/86	TM	1.2 +/- 0.1	0.1	0.8 +/- 0.1	2.1 +/- 0.14
	10/18/86	TM	0.8 +/- 0.1	0.1	0.8 +/- 0.1	1.7 +/- 0.14
	01/31/87	TM	2.1 +/- 0.1	0.1	1.8 +/- 0.1	4 +/- 0.14
	01/31/87	TM	1.9 +/- 0.2	0.1	1.6 +/- 0.2	3.6 +/- 0.28
	05/12/87	TM	1.2 +/- 0.2	0.1	1 +/- 0.1	2.3 +/- 0.22
	08/13/87	TM	1 +/- 0.2	.	0.9 +/- 0.1	.
	10/05/87	TM	1 +/- 0.1	0.1	0.9 +/- 0.1	2 +/- 0.14
	01/25/88	TM	1.3 +/- 0.1	0.1	1 +/- 0.1	2.4 +/- 0.14
	04/05/88	TM	0.8 +/- 0.2	0.1	0.8 +/- 0.1	1.7 +/- 0.22
	07/28/88	TM	1 +/- 0.2	0.1	0.9 +/- 0.2	2 +/- 0.28
	10/11/88	TM	0.8 +/- 0.3	0.2	0.1 +/- 0.3	1.1 +/- 0.42

Table A-6. (Continued)

Location	Date sampled	Lab	Uranium 234	Uranium 235	Uranium 238	Total uranium
	02/16/89	TM	1.6 +/- 0.3	0.1	1.5 +/- 0.3	3.2 +/- 0.42
	04/20/89	TM	0.88 +/- 0.21	0.1	0.74 +/- 0.19	1.72 +/- 0.28
	07/25/89	TM	1 +/- 0.2	0.1	0.6 +/- 0.2	1.7 +/- 0.28
	10/09/89	TM	1.1 +/- 0.2	0.1	1 +/- 0.2	2.2 +/- 0.28
	10/31/89	TM	1.1 +/- 0.2	0.1	0.9 +/- 0.2	2.1 +/- 0.28
	02/07/90	TM	1 +/- 0.2	0.1	0.9 +/- 0.2	2 +/- 0.28
	08/10/90	TM	1 +/- 0.2	0.1	0.8 +/- 0.2	1.9 +/- 0.28
	10/17/90	TM	1.2 +/- 0.2	0.1	0.9 +/- 0.2	2.2 +/- 0.28
	01/24/91	TM	0.4 +/- 0.1	0.1	0.4 +/- 0.1	0.9 +/- 0.14
	04/22/91	TM	0.87 +/- 0.2	0.11 +/- 0.08	0.65 +/- 0.18	1.63 +/- 0.28
	04/22/91	TM	1.11 +/- 0.15	0.04 +/- 0.04	0.92 +/- 0.14	2.07 +/- 0.21
	08/07/91	TM	0.09 +/- 0.08	0 +/- 0.06	0.01 +/- 0.03	0.1 +/- 0.1
	11/07/91	TM	1.02 +/- 0.23	0.05 +/- 0.06	0.78 +/- 0.21	1.85 +/- 0.32
	02/05/92	TM	1.07 +/- 0.22	0.04 +/- 0.05	0.89 +/- 0.2	2 +/- 0.3
	04/15/92	TM	1.08 +/- 0.13	0.06 +/- 0.03	0.91 +/- 0.12	2.05 +/- 0.18
	07/18/92	TM	1.38 +/- 0.23	0.02 +/- 0.04	1 +/- 0.19	2.4 +/- 0.3
	10/08/92	TM	1.22 +/- 0.21	0.04 +/- 0.04	0.94 +/- 0.17	2.2 +/- 0.28
	10/08/92	TM	1.21 +/- 0.2	0.05 +/- 0.05	0.83 +/- 0.16	2.09 +/- 0.26
	01/28/93	TM	1.13 +/- 0.23	0.05 +/- 0.07	0.85 +/- 0.19	2.03 +/- 0.31
	04/21/93	IR	1.89 +/- 0.44	0.64 +/- 0.23	0.81 +/- 0.27	3.34 +/- 0.57
	04/21/93	IR	0.94 +/- 0.22	0.09 +/- 0.06	0.73 +/- 0.19	1.76 +/- 0.3
	07/23/93	IT	1.09 +/- 0.08	0.12 +/- 0.03	0.97 +/- 0.08	2.18 +/- 0.12
	07/23/93	IT	0.97 +/- 0.09	0.26 +/- 0.05	0.89 +/- 0.09	2.12 +/- 0.14
	02/01/94	IT	1.11 +/- 0.08	0.01 +/- 0.02	0.86 +/- 0.07	1.98 +/- 0.11
	08/24/94	IT	1.27 +/- 0.12	0.14 +/- 0.07	1.11 +/- 0.11	2.52 +/- 0.18
	05/30/95	LH	1.26 +/- 0.24	0.11 +/- 0.07	0.97 +/- 0.21	2.34 +/- 0.33
	05/28/97	LH	1.03 +/- 0.09	0.06 +/- 0.02	0.87 +/- 0.08	1.96 +/- 0.12
	05/28/97	LH	1.06 +/- 0.14	0.12 +/- 0.05	0.81 +/- 0.12	1.99 +/- 0.19
K6-01	02/20/85	TM	0.8 +/- 0.1	0.1	1 +/- 0.1	1.9 +/- 0.14
	05/01/85	TM	0.5 +/- 0.1	0.1	0.4 +/- 0.1	1 +/- 0.14
	07/25/85	TM	0.7 +/- 0.1	0.1	0.6 +/- 0.1	1.4 +/- 0.14
	11/14/85	TM	1.5 +/- 0.2	0.1	0.4 +/- 0.1	2 +/- 0.22
	02/26/86	TM	0.6 +/- 0.1	0.1	0.4 +/- 0.1	1.1 +/- 0.14
	05/22/86	TM	0.6 +/- 0.1	0.1	0.3 +/- 0.1	1 +/- 0.14
	08/05/86	TM	0.7 +/- 0.1	0.1	0.5 +/- 0.1	1.3 +/- 0.14
	10/18/86	TM	0.6 +/- 0.1	0.1	0.2 +/- 0.1	0.9 +/- 0.14
	01/31/87	TM	0.6 +/- 0.1	0.1	0.4 +/- 0.2	1.1 +/- 0.22
	05/12/87	TM	0.7 +/- 0.1	0.1	0.4 +/- 0.2	1.2 +/- 0.22
	08/13/87	TM	0.3 +/- 0.1	0.1 +/- 0.1	0.3 +/- 0.1	0.7 +/- 0.17

Table A-6. (Continued)

Location	Date sampled	Lab	Uranium 234	Uranium 235	Uranium 238	Total uranium
	10/05/87	TM	0.3 +/- 0.1	0.1	0.3 +/- 0.1	0.7 +/- 0.14
	01/25/88	TM	0.4 +/- 0.1	0.1	0.3 +/- 0.1	0.8 +/- 0.14
	04/05/88	TM	0.9 +/- 0.3	0.2	0.4 +/- 0.2	1.5 +/- 0.36
	07/28/88	TM	0.9 +/- 0.2	0.1	0.5 +/- 0.2	1.5 +/- 0.28
	07/28/88	TM	0.5 +/- 0.2	0.1	0.2 +/- 0.1	0.8 +/- 0.22
	10/11/88	TM	0.3 +/- 0.2	0.2	0.2	0.7 +/- 0.2
	02/16/89	TM	0.5 +/- 0.2	0.04	0.4 +/- 0.1	0.94 +/- 0.22
	04/19/89	TM	0.43 +/- 0.16	0.1	0.38 +/- 0.14	0.91 +/- 0.21
	04/20/89	TM	0.33 +/- 0.15	0.01	0.23 +/- 0.12	0.57 +/- 0.19
	07/25/89	TM	0.4 +/- 0.1	0.1	0.3 +/- 0.1	0.8 +/- 0.14
	07/25/89	TM	0.3 +/- 0.1	0.1	0.3 +/- 0.1	0.7 +/- 0.14
	10/09/89	TM	0.6 +/- 0.1	0.1	0.3 +/- 0.1	1 +/- 0.14
	02/07/90	TM	0.3 +/- 0.1	0.1	0.5 +/- 0.2	0.9 +/- 0.22
	08/10/90	TM	0.4 +/- 0.1	0.1	0.3 +/- 0.1	0.8 +/- 0.14
	10/15/90	TM	0.4 +/- 0.1	0.1	0.3 +/- 0.1	0.8 +/- 0.14
	01/24/91	TM	0.2	0.1	0.1	0.4
	04/22/91	TM	0.31 +/- 0.11	0.02 +/- 0.04	0.24 +/- 0.09	0.57 +/- 0.15
	08/07/91	TM	0.53 +/- 0.16	0 +/- 0.06	0.28 +/- 0.12	0.81 +/- 0.21
	11/07/91	TM	0.31 +/- 0.11	0.01 +/- 0.02	0.25 +/- 0.09	0.57 +/- 0.14
	02/05/92	TM	0.42 +/- 0.15	0.01 +/- 0.03	0.35 +/- 0.13	0.78 +/- 0.2
	04/15/92	TM	0.23 +/- 0.23	0.22 +/- 0.09	0.31 +/- 0.23	0.76 +/- 0.34
	04/15/92	TM	0.32 +/- 0.13	0.06 +/- 0.05	0.26 +/- 0.1	0.64 +/- 0.17
	07/16/92	TM	0.41 +/- 0.12	0.08 +/- 0.02	0.3 +/- 0.1	0.79 +/- 0.16
	10/8/92	TM	0.72 +/- 0.15	0.01 +/- 0.03	0.29 +/- 0.09	1.02 +/- 0.18
	01/28/93	TM	0.42 +/- 0.15	0 +/- 0.06	0.18 +/- 0.1	0.60 +/- 0.18
	01/28/93	TM	0.43 +/- 0.14	0.04 +/- 0.05	0.31 +/- 0.12	0.78 +/- 0.2
	04/21/93	IR	0.57 +/- 0.18	0.26 +/- 0.11	0.21 +/- 0.11	1.04 +/- 0.24
	07/23/93	IT	0.43 +/- 0.05	0.08 +/- 0.03	0.4 +/- 0.05	0.91 +/- 0.08
	02/01/94	IT	1.3 +/- 0.11	0.25 +/- 0.05	0.89 +/- 0.09	2.44 +/- 0.15
	08/24/94	IT	0.69 +/- 0.06	0.05 +/- 0.03	0.37 +/- 0.05	1.11 +/- 0.08
	08/24/94	IT	0.36 +/- 0.08	0 +/- 0.02	0.25 +/- 0.07	0.61 +/- 0.11
	05/28/97	LH	0.48 +/- 0.07	0.06 +/- 0.02	0.39 +/- 0.06	0.93 +/- 0.1
K6-01S	10/30/89	TM	0.5 +/- 0.1	0.1	0.4 +/- 0.1	1 +/- 0.14
	01/08/90	TM	0.4 +/- 0.1	0.1	0.4 +/- 0.1	0.9 +/- 0.14
	05/21/90	TM	0.5 +/- 0.2	0.1	0.3 +/- 0.1	0.9 +/- 0.22
	11/15/91	TM	0.3 +/- 0.2	0.1 +/- 0.1	0.2 +/- 0.2	0.6 +/- 0.3
K6-03	03/26/85	TM	0.5 +/- 0.1	0.1	0.3 +/- 0.1	0.9 +/- 0.14
	06/18/85	TM	0.2 +/- 0.1	0.1	0.3 +/- 0.1	0.6 +/- 0.14
	09/11/85	TM	0.6 +/- 0.1	0.1	0.5 +/- 0.1	1.2 +/- 0.14

Table A-6. (Continued)

Location	Date sampled	Lab	Uranium 234	Uranium 235	Uranium 238	Total uranium
	11/13/85	TM	0.6 +/- 0.1	0.1	0.5 +/- 0.1	1.2 +/- 0.14
	02/24/86	TM	0.2 +/- 0.1	0.1	0.2 +/- 0.1	0.5 +/- 0.14
	05/22/86	TM	0.3 +/- 0.1	0.1	0.3 +/- 0.1	0.7 +/- 0.14
	08/05/86	TM	0.3 +/- 0.1	0.1	0.2 +/- 0.1	0.6 +/- 0.14
	10/18/86	TM	0.3 +/- 0.1	0.1	0.2 +/- 0.1	0.6 +/- 0.14
	01/31/87	TM	0.1 +/- 0.1	0.1	0.2 +/- 0.1	0.4 +/- 0.14
	05/12/87	TM	0.1 +/- 0.1	0.1	0.2 +/- 0.1	0.4 +/- 0.14
	08/13/87	TM	0.2 +/- 0.1	0.1 +/- 0.1	0.2 +/- 0.1	0.5 +/- 0.17
	10/05/87	TM	0.1	0.1	0.1	0.3
	01/26/88	TM	0.2 +/- 0.1	0.1	0.2 +/- 0.1	0.5 +/- 0.14
	04/05/88	TM	0.3 +/- 0.1	0.1	0.2 +/- 0.1	0.6 +/- 0.14
	08/01/88	TM	0.2 +/- 0.1	0.2	0.2 +/- 0.1	0.6 +/- 0.14
	10/11/88	TM	0.2	0.2	0.2	0.6
	02/16/89	TM	0.4 +/- 0.1	0.06	0.3 +/- 0.1	0.76 +/- 0.14
	04/20/89	TM	0.29 +/- 0.13	0.01	0.13 +/- 0.08	0.43 +/- 0.15
	07/25/89	TM	0.4 +/- 0.1	0.1	0.2 +/- 0.1	0.7 +/- 0.14
	10/09/89	TM	0.6 +/- 0.2	0.1	0.4 +/- 0.2	1.1 +/- 0.28
	02/07/90	TM	0.1	0.1	0.1	0.3
	08/10/90	TM	0.3 +/- 0.1	0.1	0.2 +/- 0.1	0.6 +/- 0.14
	10/15/90	TM	0.3 +/- 0.1	0.1	0.2 +/- 0.1	0.6 +/- 0.14
	10/15/90	TM	0.5 +/- 0.1	0.1	0.2 +/- 0.1	0.8 +/- 0.14
	01/24/91	TM	0.2	0.1	0.2	0.5
	04/22/91	TM	0.35 +/- 0.13	0 +/- 0.03	0.32 +/- 0.13	0.67 +/- 0.18
	08/08/91	TM	.	0 +/- 0.02	0.1 +/- 0.05	.
	11/07/91	TM	0.45 +/- 0.17	0.02 +/- 0.03	0.27 +/- 0.14	0.74 +/- 0.22
	02/05/92	TM	0.29 +/- 0.13	0.05 +/- 0.08	0.25 +/- 0.11	0.6 +/- 0.19
	04/15/92	TM	0.31 +/- 0.07	0.03 +/- 0.03	0.24 +/- 0.06	0.58 +/- 0.1
	07/16/92	TM	0.3 +/- 0.1	0.01 +/- 0.02	0.1 +/- 0.07	0.41 +/- 0.13
	10/08/92	TM	0.38 +/- 0.14	0.01 +/- 0.05	0.11 +/- 0.06	0.50 +/- 0.16
	01/28/93	TM	0.21 +/- 0.1	0.01 +/- 0.03	0.17 +/- 0.08	0.39 +/- 0.14
	04/21/93	IR	0.2 +/- 0.11	0.02 +/- 0.04	0.16 +/- 0.09	0.38 +/- 0.15
	07/23/93	IT	0.3 +/- 0.05	0.04 +/- 0.02	0.18 +/- 0.04	0.52 +/- 0.07
	02/01/94	IT	0.27 +/- 0.06	0.03 +/- 0.02	0.27 +/- 0.06	0.57 +/- 0.09
	02/01/94	IT	0.48 +/- 0.06	0.08 +/- 0.02	0.38 +/- 0.05	0.94 +/- 0.08
	08/24/94	IT	0.43 +/- 0.05	0.04 +/- 0.14	0.33 +/- 0.04	0.8 +/- 0.15
	05/28/97	LH	0.41 +/- 0.05	0.03 +/- 0.01	0.36 +/- 0.05	0.8 +/- 0.07
K6-04	04/03/85	TM	0.7 +/- 0.1	0.1	0.4 +/- 0.1	1.2 +/- 0.14
	06/18/85	TM	0.8 +/- 0.1	0.1	0.5 +/- 0.1	1.4 +/- 0.14
	07/25/85	TM	0.6 +/- 0.1	0.1	0.4 +/- 0.1	1.1 +/- 0.14

Table A-6. (Continued)

Location	Date sampled	Lab	Uranium 234	Uranium 235	Uranium 238	Total uranium
	11/13/85	TM	0.7 +/- 0.2	0.1	0.3 +/- 0.1	1.1 +/- 0.22
	02/24/86	TM	0.8 +/- 0.1	0.1	0.4 +/- 0.1	1.3 +/- 0.14
	05/22/86	TM	0.5 +/- 0.1	0.1	0.5 +/- 0.1	1.1 +/- 0.14
	08/05/86	TM	0.6 +/- 0.1	0.1	0.5 +/- 0.1	1.2 +/- 0.14
	10/18/86	TM	0.8 +/- 0.1	0.1	0.4 +/- 0.1	1.3 +/- 0.14
	01/31/87	TM	0.5 +/- 0.1	0.1	0.4 +/- 0.1	1 +/- 0.14
	05/12/87	TM	0.9 +/- 0.2	0.1	0.5 +/- 0.2	1.5 +/- 0.28
	08/13/87	TM	0.6 +/- 0.1	0.1 +/- 0.01	0.5 +/- 0.1	1.2 +/- 0.17
	10/05/87	TM	0.6 +/- 0.1	0.1	0.5 +/- 0.1	1.2 +/- 0.14
	10/05/87	TM	0.6 +/- 0.1	0.1	0.5 +/- 0.1	1.2 +/- 0.14
	01/26/88	TM	0.7 +/- 0.1	0.1	0.5 +/- 0.1	1.3 +/- 0.14
	04/05/88	TM	0.7 +/- 0.2	0.1	0.6 +/- 0.2	1.4 +/- 0.28
	08/01/88	TM	0.8 +/- 0.1	0.1	0.5 +/- 0.1	1.4 +/- 0.14
	10/11/88	TM	0.6 +/- 0.2	0.2	0.5 +/- 0.2	1.3 +/- 0.28
	02/16/89	TM	1.3 +/- 0.3	0.2	0.6 +/- 0.2	2.1 +/- 0.36
	04/20/89	TM	0.8 +/- 0.1	0.01	0.49 +/- 0.09	1.3 +/- 0.15
	07/25/89	TM	0.8 +/- 0.2	0.1	0.8 +/- 0.2	1.7 +/- 0.28
	10/09/89	TM	0.6 +/- 0.2	0.1	0.5 +/- 0.2	1.2 +/- 0.28
	02/07/90	TM	0.6 +/- 0.2	0.1	0.5 +/- 0.1	1.2 +/- 0.22
	02/07/90	TM	0.5 +/- 0.1	0.1	0.4 +/- 0.1	1 +/- 0.14
	08/10/90	TM	0.5 +/- 0.1	0.1	0.5 +/- 0.1	1.1 +/- 0.14
	10/15/90	TM	0.6 +/- 0.1	0.1	0.5 +/- 0.1	1.2 +/- 0.14
	01/24/91	TM	0.3 +/- 0.1	0.1	0.2 +/- 0.1	0.6 +/- 0.14
	01/24/91	TM	0.3 +/- 0.1	0.1	0.3 +/- 0.1	0.7 +/- 0.14
	04/22/91	TM	0.47 +/- 0.15	0.05 +/- 0.05	0.52 +/- 0.15	1.04 +/- 0.22
	08/08/91	TM	0	0.02 +/- 0.07	0.49 +/- 0.14	.
	11/07/91	TM	0.65 +/- 0.17	0.01 +/- 0.06	0.58 +/- 0.17	1.24 +/- 0.25
	11/07/91	TM	0.54 +/- 0.15	0.02 +/- 0.04	0.51 +/- 0.15	1.07 +/- 0.21
	02/05/92	TM	0.6 +/- 0.17	0.04 +/- 0.05	0.56 +/- 0.15	1.2 +/- 0.24
	04/15/92	TM	0.69 +/- 0.28	0.07 +/- 0.09	0.54 +/- 0.2	1.3 +/- 0.36
	07/16/92	TM	0.67 +/- 0.16	0.04 +/- 0.05	0.39 +/- 0.12	1.1 +/- 0.2
	07/16/92	TM	0.64 +/- 0.14	0.04 +/- 0.04	0.53 +/- 0.13	1.21 +/- 0.19
	10/08/92	TM	0.63 +/- 0.18	0.06 +/- 0.07	0.4 +/- 0.14	1.09 +/- 0.23
	01/28/93	TM	0.79 +/- 0.19	0.06 +/- 0.07	0.51 +/- 0.15	1.35 +/- 0.25
	04/21/93	IR	0.62 +/- 0.22	0.01 +/- 0.05	0.52 +/- 0.2	1.15 +/- 0.3
	07/23/93	IT	0.61 +/- 0.08	0.04 +/- 0.04	0.61 +/- 0.08	1.26 +/- 0.12
	02/01/94	IT	0.68 +/- 0.07	0.05 +/- 0.02	0.64 +/- 0.06	1.37 +/- 0.09
	08/24/94	IT	0.9 +/- 0.09	0.06 +/- 0.05	0.56 +/- 0.08	1.52 +/- 0.13
	05/29/97	LH	0.8 +/- 0.13	0.03 +/- 0.03	0.67 +/- 0.12	1.5 +/- 0.18

Table A-6. (Continued)

Location	Date sampled	Lab	Uranium 234	Uranium 235	Uranium 238	Total uranium
K6-19	10/30/89	TM	0.2 +/- 0.1	0.1	0.2 +/- 0.1	0.5 +/- 0.14
	01/08/90	TM	0.3 +/- 0.2	0.1	0.2 +/- 0.1	0.6 +/- 0.22
	05/21/90	TM	0.5 +/- 0.2	0.1	0.2 +/- 0.1	0.8 +/- 0.22
	07/27/90	TM	0.2 +/- 0.1	0.1	0.1	0.4 +/- 0.1
	01/22/91	TM	0.3 +/- 0.1	0.1	0.2 +/- 0.1	0.6 +/- 0.14
	04/26/91	TM	0.2 +/- 0.1	0.1	0.2 +/- 0.1	0.5 +/- 0.14
	07/15/91	TM	0.44 +/- 0.15	0.1 +/- 0.1	0.28 +/- 0.12	0.82 +/- 0.22
	11/20/91	TM	0.3 +/- 0.1	0.1 +/- 0.1	0.2 +/- 0.1	0.6 +/- 0.17
	06/29/92	TM	1.03 +/- 0.21	0.1 +/- 0.07	0.43 +/- 0.13	1.56 +/- 0.25
	12/09/92	TM	1.9 +/- 0.3	0.1 +/- 0.1	1.1 +/- 0.2	3.1 +/- 0.37
	05/05/93	IT	2.48 +/- 0.18	0.31 +/- 0.06	1.37 +/- 0.13	4.16 +/- 0.23
	05/30/95	LH	1.94 +/- 0.3	0.12 +/- 0.07	0.91 +/- 0.2	2.97 +/- 0.37
	05/06/96	LH	2.8 +/- 0.25	0.2 +/- 0.06	1.72 +/- 0.18	4.72 +/- 0.31
	06/13/97	LH	1.74 +/- 0.14	0.05 +/- 0.02	1.01 +/- 0.09	2.81 +/- 0.17

Lab Codes:

IR IT Analytical Services, Richland, WA

IT International Technology Corp.

LH Lockheed Analytical Services, Las Vegas, NV

TM Thermo Analytical Inc., Richmond, CA

Appendix B

Summary of Proposed Statistical Methods for the Detection Monitoring Program

Appendix B

Statistical Analyses for the Detection Monitoring Program

As discussed in Section 6.1.5 of the Post-Closure Plan, formal statistical analyses of ground water monitoring data will be performed as part of the Detection Monitoring Program to detect changes in constituent of concern (COC) concentrations that may indicate a new release of a COC.

The proposed statistical methods are contained in the California Code of Regulations (CCR) Title 23 and are consistent with U.S. Environmental Protection Agency (EPA) guidance (EPA, 1992).

The statistical methods described in this appendix are used with the COCs and monitor wells that are part of the Detection Monitoring Program.

B-1. Proposed Statistical Methods [23 CCR 2550.7(e)(7) and 22 CCR 66264.97(e)(7)]

For each COC and detection monitor well with sufficient data (Section 6.1.3.2, Table 5), either a prediction interval or a control chart will be used to generate a concentration limit and a statistical limit. Statistical limits are statistically derived upper bounds (i.e., prediction or control limits) which, when conditions are stable and natural variation of COC concentrations is taken into account, should rarely be exceeded by a COC at a specific monitor well location. Statistical limits are used to detect potential releases of COCs to ground water.

Each COC and detection monitor well for which there is insufficient data to select an appropriate statistical method will be sampled quarterly until at least six data points per well are obtained, after which concentration limits and statistical limits will be determined.

Prediction interval and control chart statistical methods are sensitive indicators of COC concentration increases. In order to determine whether detection monitor well concentrations exceed their concentration limit, samples will be collected quarterly at each detection monitor well and analyzed for each COC. Individual sample results for each COC will be compared with their respective statistical limits. If a sample concentration exceeds its statistical limit, then two discrete retest samples will be collected [23 CCR 2550.7(e)(8)(E)(1)]. If either retest exceeds its statistical limit, then the initial result is considered confirmed (see Sections B-8 and B-9). The retest samples use the same statistical limit as the initial sample.

B-2. Determination of Concentration and Statistical Limits [23 CCR 2550.7(e)(7) and 22 CCR 66264.97(e)(7)]

Use of the prediction interval method to determine concentration and statistical limits is appropriate when there is little or no spatial variation of a COC concentration in ground water surrounding the monitored unit. In this case, the concentration limit and statistical limit for the COC are based on upgradient data (interwell comparisons). To determine if a statistically significant COC concentration increase has occurred, the concentration measurements of a COC in ground water samples taken from all the downgradient detection monitor wells are compared with a single statistical limit.

When spatial variability is present, due either to natural causes or to human activities, the control chart method is used to determine concentration and statistical limits. In this case, the limits are based on previous COC results at each detection monitor well. The control chart statistical limit compares the quarterly COC measurement for each well with its concentration history in ground water samples from that well (an intrawell comparison).

The most important distinction between the prediction limit approach and the control chart approach is:

- Prediction limits use upgradient data for background data.
- Control charts use previous downgradient data for background data.

Pursuant to 23 CCR 2550.4(a)(1) and 2550.7(e)(10A, 10B, 11A, 11B), concentration limits and statistical limits will be updated periodically.

Additional factors affecting the determination of concentration and statistical limits are discussed in Sections B-3 through B-7.

B-3. Non-detections [23 CCR 2550.7(e)(9)(E) and 22 CCR 66264.97(e)(9)(E)]

The presence of non-detections complicates the calculation of concentration limits and statistical limits. The proposed approach is as follows:

- When all analytical results are above the reporting limit, the concentration limit will be the mean of the background data. The statistical limit will be calculated by the prediction interval or control chart method from the background mean and standard deviation.
- When some analytical results are below the reporting limit, but there are enough results above the reporting limit, the concentration limit will be the mean of the background data. However, the background mean and standard deviation will be calculated based on guidance in U.S. EPA (1992), Section 5.1.2.2.1, "Evaluation of Censored Data Sets." The statistical limit will then be calculated by the prediction interval or control chart method.
- When all but a few analytical results are below the reporting limit and those few results are more than a few years old, the reporting limit will be used for both the concentration limit and the statistical limit.
- When all but a few analytical results are below the reporting limit and at least one of them is recent, but the number of detections is not enough to calculate mean and standard deviation values, the maximum recent detection will be used for the concentration limit and the statistical limit.
- When all analytical results are below the reporting limit, the reporting limit will be used for both the concentration limit and the statistical limit.

Statistical limits for the prediction limit and control chart methods are calculated by multiplying the standard deviation by a constant determined by the regulations, and then adding the product to the mean.

B-4. Synthetic compounds

Synthetic volatile organic compounds (VOCs) are not naturally occurring substances; their presence in ground water at Site 300 is assumed to result from past human activities. Because halogenated and aromatic VOCs and carbon disulfide detected in ground water in the Pit 6 Landfill operable unit are believed to be anthropogenic in origin, natural concentrations are assumed to be below the analytical laboratory reporting limit. Where no anthropogenic COCs have been detected in a detection monitor well, the statistical limit will be the reporting limit.

In some detection monitor wells, VOCs and carbon disulfide have been detected above the reporting limits. The presence of the compounds has been documented as a result of a previous release, as discussed in Section 2.1.3. In order to detect a new release of these COCs, the concentration and statistical limits for these COCs must take into account previous releases detected in these wells. Therefore, for wells where VOCs and carbon disulfide have been detected, the concentration limit and statistical limit are based on historical data rather then being set at the reporting limit.

B-5. Distributional Assumptions [23 CCR 2550.7(e)(9)(A) and 22 CCR 66264.97(e)(9)(A)]

Parametric prediction interval or control chart methods are used when there is sufficient data to calculate a mean and standard deviation (Section C-3) and the background COC concentration data are approximately normally distributed. These methods are used on log-transformed data if the transformation causes the data to follow a normal distribution. Nonparametric methods, e.g., the maximum concentration in the recent history, are used when the data are not normally distributed, and cannot be transformed to a normal distribution. Use of the reporting limit when there are too few detections is also considered to be a nonparametric method.

B-6. Appropriate Use of Available Data

Generally, all available data are used. However, we require that results from at least six recent samples be available. For example, if there were several samples collected in the early 1990s followed by a gap of several years, and then two samples collected in 1997, then this would be considered insufficient data. With a large gap in available data it can not be assumed that the older data is representative of current conditions. However, if sampling has been continuous since the late 1980's then the older data may be used.

Sometimes, older data appear to have a different distribution than more recent data. For example, data from the late 1980s may show a great deal more variability than data from the last four or five years. In this case, we believe that the older data is not representative of current conditions, so the concentration limit and statistical limit are based on the recent data. Inclusion of the older data in a case like this would weaken the ability of the statistical method to detect a new release.

The prediction interval and control chart methods assume that the average COC concentration is not changing significantly over time. For example, if the COC concentration history indicates a trend that has leveled off in recent years, then only the recent data is used.

Single isolated outliers are excluded from the calculation of concentration and statistical limits. This causes the statistical method to be more sensitive to future COC concentration increases.

B-7. Statistical Significance Levels [23 CCR 2550.7(e)(8) and (9) and 22 CCR 66264.97(e)(8) and (9)]

Statistical significance levels (false positive error rates) will be set separately for each COC at each detection monitor well. 23 CCR 2550.7(e)(8)(E)5b states that for methods employing retests, the Type I error rate for each individual monitor well comparison, including retests, is greater than or equal to the larger of

$$[1 - 0.95^{1/M*W*S}]^{0.5} * [1/R]^{0.5} \text{ and}$$

$$1 - 0.99^{1/S},$$

where M = the number of COCs using a prediction interval, W = the number of monitor wells, S = the number of times that suites of data are analyzed within a period of six months, and R = the number of discrete retests to be conducted in the event the initial sample result exceeds the statistical limit. This formula typically gives values slightly less than 0.01. However M, W, and S are uncertain at this time, so the proposed statistical limits use a significance level of 0.01.

The non-parametric statistical limits may have a false positive error rate either much smaller than 0.01, or much greater than 0.01. It is not possible to design the monitoring program to control this error rate. For example, if naturally occurring COC concentrations are far below the reporting limit, then the statistical false positive error rate will be much smaller than 0.01. On the other hand, if naturally occurring COC concentrations are slightly below the reporting limit, and the background data consists of only a small number of samples (none of which has exceeded the reporting limit), then the statistical false positive rate will be greater than 0.01.

B-8. Implementation of Retests [23 CCR 2550.7(e)(8)(E) and 22 CCR 66264.97(e)]

If a regularly scheduled quarterly sample result exceeds its statistical limit, then two additional verification (retest) samples will be collected to address the possibility of false evidence of a release consistent with 23 CCR 2550.8. The entire resampling effort will be completed, if possible, during the same quarter as the initial sample, but no more than 30 days after the initial result is found to exceed its statistical limit [23 CCR 2550.7(e)(8)(E)(3)]. The additional samples will be collected at least one week apart, to assure the samples are independent. The retest samples will be analyzed only for the COC(s) that exceeded their statistical limit(s).

B-9. Determination of a Statistically Significant for a Release [23 CCR 2550.8(i) and 22 CCR 66264.98(i)]

If either of the two retest results (Section C-9) exceeds its statistical limit, then the initial result is considered to be confirmed [23 CCR 2550.7(e)(8)(E)1]. If not previously reported, the results will be reported to the Regional Water Quality Control Board (RWQCB) - Central Valley Region in a 7-day letter as statistically significant evidence of a release. If the sample result is shown to be unconfirmed, (i.e. neither retest exceeds its the statistical limit), then there is no statistically significant evidence of a release. However, all COC measurements and all retest results will be reported to the RWQCB and discussed in routine reports.

The determination of statistically significant evidence for a release will be made separately for each COC at each monitor well.

Appendix C

Monitor Well Logs and Completion Information

(Monitor Well Logs are not included in this document. Hard copies are available in ERD Library or contact Division Office at (925) 424-6783).

Acronyms and Abbreviations

Acronyms and Abbreviations

Ag	silver
ARARs	Applicable or Relevant and Appropriate Requirements
^{195}Au	gold-195
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene and xylenes (total)
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm/sec	centimeters per second
COC	constituent(s) of concern
^{60}Co	cobalt-60
CQA	Construction Quality Assurance
^{137}Cs	cesium-137
D-38	depleted uranium
DCA	dichloroethane
DCE	dichloroethylene
DOE	Department of Energy
DTSC	Department of Toxic Substances Control
EE/CA	Engineering evaluation/cost analysis
EPA	Environmental Protection Agency
EPD	Environmental Protection Division
˚F	degrees Fahrenheit
FFA	Federal Facility Agreement
ft	feet
ft/yr	feet per year
GAC	granular activated carbon
gpm	gallons per minute
^{3}H	tritium
HE	high explosive
HDPE	high-density polyethylene

^{125}I	iodine-125
ID	identification
in.	inch(es)
in./hr	inches per hour
LLNL	Lawrence Livermore National Laboratory
MCL	Maximum Contaminant Level
mg/kg	milligrams per kilogram or parts per million
mg/L	milligrams per liter
mil	milli-inch or 1/1,000 of an inch
^{99}Mo	molybdenum-99
MSL	mean sea level
^{22}Na	sodium-22
^{95}Nb	niobium-95
^{144}Nd	neodymium-144
OU	Operable unit
PCBs	polychlorinated biphenyls
PCE	Tetrachloroethylene (or perchloroethylene)
pCi/L	picocuries/L
PMP	probable maximum precipitation
POU	point-of-use
PVC	polyvinyl chloride
Qal	Quaternary alluvium
QA/QC	Quality assurance/quality control
QIP	Quality Implementing Procedure
Qt	Quaternary terrace deposits
^{187}Re	rhenium-187
RL	reporting limit for analytical laboratory
ROD	Record of Decision
RWQCB	Regional Water Quality Control Board
Sb	antimony
^{125}Sb	antimony-125
SFTF	Small Firearms Training Facility

SOP	Standard Operating Procedure
sq. ft	square feet
^{89}Sr	strontium-89
^{90}Sr	strontium-90
SSD	Safeguards and Security Department
SVRA	State Vehicular Recreation Area
SWRI	Site-Wide Remedial Investigation
TBD	to be determined
^{99}Tc	technetium-99
TCA	trichloroethane
TCE	trichloroethylene
TDS	total dissolved solids
^{132}Te	tellurium-132
^{232}Th	thorium-232
THMs	trihalomethanes
^{204}Tl	thallium-204
Tmss	Miocene Cierbo Formation
$Tnbs_1$	Lower Blue Sandstone Member of the Miocene Neroly Formation
Tts	Eocene Tesla Formation
^{238}U	uranium-238 (also known as depleted uranium)
VOC	volatile organic compound
^{187}W	tungsten-187
^{91}Y	yttrium-91
yd^3	cubic yards
µCi	microcuries
µmhos/cm	micromhos per centimeter
µg/L	micrograms per liter or parts per billion