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Baseline Risk Assessment Work Plan for the Building 812 Operable Unit Lawrence Livermore National Laboratory Site 300

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January 2012

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1. Introduction

1.1. Purpose of the Building 812 Baseline Risk Assessment Work Plan

The purpose of this Building 812 baseline risk assessment work plan (BRAWP) is to: (1) review the results of the Building 812 screening-level risk assessment (SLRA) to identify information needs for filling any data gaps in the screening-level risk assessment and for completing the baseline risk assessment, and (2) develop a study design for completing the screening-level and baseline risk assessments. The baseline risk assessment and this work plan include both the human health and ecological risk assessments. Consistent with U.S. Environmental Protection Agency (EPA) guidance (U.S. EPA, 1989; U.S. EPA, 1997), this work plan documents decisions made during the problem formulation step of the baseline risk assessment and presents anticipated future tasks to complete the baseline risk assessment. A separate Draft Building 812 Characterization Work Plan (Taffet et al., 2011) was previously submitted to the regulatory agencies and includes the Sampling and Analysis Plan for the Building 812 baseline risk assessment.

1.2. History of Environmental Investigations at Site 300 and Building 812

The U.S. Department of Energy (DOE) began environmental investigation activities at Lawrence Livermore National Laboratory (LLNL) Site 300 in 1981. Remediation activities at Site 300 were initiated in 1983 and continue to the present. Prior to August 1990, investigations of potential chemical contamination at Site 300 were conducted under the oversight of the California Central Valley Regional Water Quality Control Board (RWQCB). Site 300 was placed on the National Priorities List in August 1990. In June 1992, a Federal Facility Agreement (FFA) for the cleanup of Site 300 was signed by the EPA, the California Department Toxic Substance Control (DTSC), the RWQCB, and DOE. Since then, all investigations and remediation activities have been conducted in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) with oversight by the three regulatory agencies (EPA, RWQCB, and DTSC). DOE is the lead agency for all environmental restoration activities at Site 300 and is the sole source of funding.

LLNL Site 300 was originally divided into eight operable units (OUs) based on the nature and extent of contamination to effectively manage site cleanup. A Site-Wide Remedial Investigation Report, which included the human health and baseline risk assessment, was completed in 1994 (Webster-Scholten, 1994). A Site-Wide Feasibility Study, which updated the baseline risk assessment, was completed in 1999 (Ferry et al., 1999). The Interim Record of Decision for Site 300 (OUs 1 through 8) was signed in 2001 (U.S. DOE, 2001). Several potential release areas were identified outside of the eight OUs that required further characterization, including the Building 812 area. A Characterization Summary Report for the Building 812 area was completed in 2005. Based on the results of the Characterization Summary Report, the regulatory agencies requested a Remedial Investigation/Feasibility Study (RI/FS) be completed. The Building 812 area was designated as OU 9 in April 2007. An initial draft RI/FS was completed in November 2008 (Taffet et al., 2008), which included a human health and ecological SLRA. Based on comments from the regulatory agencies, the SLRA was revised and provided to the agencies in September 2010. The regulatory agencies reviewed the revised

SLRA and provided additional comments to DOE/LLNL. All comments were resolved by March 2011.

The following two sections summarize the site description and geology and hydrogeology of the Building 812 OU. Additional details can be found in the initial Draft Building 812 OU RI/FS (Taffet et al., 2008).

1.3. Site Description

LLNL Site 300 is a DOE experimental test facility operated by the University of California until the contract transferred to the Lawrence Livermore National Security LLC in 2007. Site 300 is located 17 miles east of Livermore and 8.5 miles southwest of downtown Tracy, California (Figure 1-1). Site 300 is primarily a high-explosives test facility that supports the LLNL weapons program in research, development, and testing associated with weapons components.

The Building 812 OU covers approximately 0.35 square miles in the east-central portion of Site 300 (Figure 1-1). The Building 812 Complex (Figures 1-2 and 1-3) was built in the late 1950s to early 1960s to conduct explosive tests and diagnostics in support of national defense programs. The Building 812 Complex is located at the base of the Building 812 Canyon, a southwest-northeast trending valley that rises from an elevation of about 940 feet (ft) above mean sea level (MSL) near its junction with Elk Ravine to over 1,200 ft above MSL on the steep ridges to the north. Elk Ravine trends northwest to southeast in the southern portion of the OU (Figure 1-3). A deeply incised north-south oriented channel within the Building 812 Canyon intersects Elk Ravine.

The climate at Site 300 is classified as semi-arid. Rainfall averages 10 to 11 inches per year, most of which falls during winter storms. During these storms, ephemeral surface water may flow within the Building 812 Canyon drainage towards Elk Ravine (Figure 1-3). Discharge from Spring 6 flows to a perennial surface water body that extends southeast beyond the junction of the two valleys. Surface water flowing locally in channels after rainfall events quickly infiltrates into the ground after traveling short distances. Upland areas of the Building 812 OU are characterized by steep exotic annual and native perennial grass covered ridges and valleys.

1.4. Geology and Hydrogeology

Quaternary alluvium (Qal) occurs as stream channel sediment within Elk Ravine and the Building 812 Canyon (Figure 1-3). The alluvial deposits of the Qal stratigraphic unit are comprised of silty clays, clayey and silty sands, and some gravel. The maximum thickness of alluvial deposits in the Building 812 OU is about 10 ft in the Building 812 Canyon and about 24 ft in Elk Ravine.

Rocks beneath the Building 812 area comprise two formations, the Neroly Formation and the underlying Cierbo Formation. The uppermost bedrock stratigraphic unit is a conglomerate and sandstone of the Neroly Formation ($Tnbs_1$) that contains interbeds of sandstone and siltstone. Beneath the $Tnbs_1$ conglomerate is a blue sandstone unit with interbeds of claystone and siltstone ($Tnbs_0$). The base of the Neroly Formation is a siltstone and claystone-dominated unit ($Tnsc_0$). The Neroly Formation rests on an erosional contact with massive sandstones and interbedded siltstones and claystones of the underlying Cierbo Formation (Tmss).

The hydrogeology of the Building 812 OU is controlled by stratigraphy, structure, and topography.

Four hydrostratigraphic units (HSUs) have been defined for the Building 812 OU. These are:

- The Quaternary alluvium/Weathered bedrock (Qal/WBR) HSU,
- The $Tnbs_1$/$Tnbs_0$ HSU,
- The $Tnsc_0$ HSU, and
- The Tmss HSU.

The Building 812 Canyon conveys surface runoff from a large catchment (dimensions of roughly 1,200 ft by 4,000 ft) during heavy rainfall events. Much of this runoff recharges the Qal/WBR HSU within the base of the canyon. The Qal/WBR HSU may also be recharged by spring discharge and/or baseflow from the underlying bedrock in the Building 812 Canyon and Elk Ravine. Phreatic vegetation in the canyon adjacent to the firing table and near Spring 6 in Elk Ravine is presumably supported by this shallow ground water. Perennial surface water occurs within Elk Ravine discharging from Spring 6 to beyond the confluence of the Building 812 Canyon and Elk Ravine.

2. Building 812 Baseline Human Health Risk Assessment Work Plan

The work plan presented here describes the tasks involved in completing the Building 812 baseline human health risk assessment. It begins with a problem formulation step in which the results of the screening-level human health risk assessment (SLHHRA) are reviewed, and data and information gaps identified. It concludes with a study design that identifies tasks required to fill the data and information gaps from the screening-level human health risk assessment and to complete the baseline human health risk assessment.

2.1. Baseline Human Health Risk Assessment Problem Formulation

In the problem formulation step of the Building 812 baseline human health risk assessment, the following steps were conducted using the results of the screening level risk assessment:

- Reviewed and refined the contaminants of potential concern identified in the SLHHRA to identify a list of preliminary contaminants of concern that will be the focus of additional risk assessment activities,
- Reviewed what is known about the nature and extent of contamination, and identified additional information needs,
- Reviewed what is known about contaminant fate and transport, and identified additional information needs,
- Reviewed the assumptions made concerning exposure pathways and identified additional information needs, and
- Reviewed the conceptual site model and identified how additional data will be used to refine the conceptual site model.

The results from the problem formulation step were used to identify activities required to fill gaps within the screening-level human health risk assessment and to conduct the baseline human health risk assessment.

2.1.1. Preliminary Contaminants of Concern

Table 2-1 presents the list of Contaminants of Potential Concern (COPCs) that were retained from the SLHHRA. The table includes COPCs in ground water, surface water, surface soil, and subsurface soil. COPCs are analytes identified in the SLHHRA of being of potential concern, but more information may be required to make a determination as to their final status. As part of the problem formulation step of the baseline human health risk assessment, the COPCs from the SLHHRA were further evaluated to determine: (1) if sufficient information is available to determine that the analyte poses a human health risk or risk to a resource and thus should be considered a Contaminant of Concern (COC) and progress to the Feasibility Study (FS) stage, (2) if sufficient information is available to show that the analyte does not pose a human health risk or risk to a resource and should be dropped from further consideration, or (3) the analyte should be further evaluated in the baseline risk assessment to determine its risk to human health or a resource. At the conclusion of the problem formulation stage, those analytes progressing to the baseline risk assessment are considered Preliminary Contaminants of Concern (PCOCs).

The ground water COPCs listed in Table 2-1 are analytes detected in ground water that exceeded both Site 300 background levels and Maximum Contaminant Levels (MCLs). If no MCL was available, the analyte was retained if it exceeded both background levels and regional screening levels (RSLs, for non-radiological analytes) or preliminary remediation goals (PRGs, for radiological analytes). Although ground water at Building 812 is not used as a drinking water source, DOE has agreed that the point-of-compliance for ground water directly underlies the site, and has therefore agreed to remediate ground water to Maximum Contaminant Levels (MCLs), which are also protective under a residential use scenario. This approach is consistent with the risk assessment approach and exposure scenario (industrial) used in previous LLNL Site 300 risk assessments agreed to by the regulatory agencies. Therefore, the ground water COPCs identified in the SLHHRA, with the exception of lithium, represent COCs and will move directly to the FS stage of the RI/FS. No further human health risk assessment activities will be conducted on these COCs. Table 2-2 lists the ground water COCs that will be considered in the FS.

The surface water COPC listed in Table 2-1, radium-226, is an analyte that exceeded the risk-based PRG, and although it was below the MCL, the analyte is not adequately characterized in surface water or the ground water that discharges to the surface water. The surface soil (human health) COPCs listed in Table 2-1 are analytes that exceeded Site 300 background and the risk-based PRG for onsite workers. The surface soil and subsurface soil threat to ground water COPCs listed in Table 2-1 are analytes that exceeded Site 300 background (if a background level was available) and the MCL-based RSL or PRG. If a MCL-based threat to ground water screening level was not available, then the risk-based screening level was used. These COPCs, in addition to lithium in ground water, represent the initial list of PCOCs for the Building 812 OU baseline human health risk assessment. Table 2-3 lists the initial PCOCs. The PCOCs are further evaluated in the Sections 2.1.2 and 2.1.3. A revised list of PCOCs that will be the focus of the Building 812 OU baseline human health risk assessment is presented in Section 2.2.

Although RSLs and PRGs were used in the screening-level risk assessment, it should be noted that with respect to potential onsite worker exposure from surface soil, these are risk-based concentrations/activities derived from standardized equations combining exposure assumptions with EPA toxicity data, and are considered by the EPA to be protective for onsite workers over their entire working career. With respect to threat to ground water RLSs and PRGs, these screening levels use simplified, conservative assumptions to predict ground water concentrations/activities resulting from transport from surface soil or subsurface soil, which are then compared to either risk-based concentrations or MCLs for drinking water. RSLs and PRGs are used for site screening and are not *de facto* cleanup standards. The initial role of RSLs and PRGs in site screening is to help identify areas, contaminants, and conditions that do not require further attention. Generally, at sites where contaminant concentrations/activities fall below RSLs and PRGs, no further action or study is warranted, so long as the exposure assumptions at a site are consistent with the EPA RSL and PRG calculations. Concentrations/activities above the RSL or PRG would not automatically trigger a response action. However, exceeding an RSL or PRG suggests that further evaluation of the potential risks that may be posed by site contaminants is appropriate.

2.1.2. Current Knowledge on the Nature and Extent of Contamination

As shown in Table 2-3, the initial list of PCOCs includes: (1) lithium in ground water, (2) radium-226 in surface water, (3) uranium-235 and uranium-238 in surface soil posing a potential threat to human health, (4) copper, lead, total uranium as both a metal and radionuclide, uranium-235 and uranium-238 in surface soil posing a threat to ground water, and (5) manganese, radium-226, radium-228, total uranium as both a metal and radionuclide, uranium-235 and uranium-238 in subsurface soil posing a threat to ground water. The following discussion on the nature and extent of contamination is based on characterization data presented in the initial Draft RI/FS and used in the SLRA. The only new characterization data available since the completion of the initial Draft RI/FS consists of additional ground water and Spring 6 analyses for uranium, as well as the results of surface water runoff samples collected in the winter and spring of 2010 for uranium. In addition, although characterization data for surface soil locations 3SS-15-01, 3SS-15-02, 3SS-15-03 and 3SS-58-04 were included in the data tables in the initial Draft Building 812 RI/FS, these data were inadvertently left of the figures presented in the RI/FS. These locations are included in the figures presented in this work plan if characterization data is available for the specific analyte depicted in the figure. All available characterization data are included in the following discussion, and new data are clearly identified as having been collected since the completion of the initial Draft RI/FS.

2.1.2.1. Nature and Extent of Lithium in Ground Water and Radium-226 in Surface Water

Lithium was identified as a PCOC in ground water in the SLHHRA. However, ground water was sampled for this analyte only from wells NC2-23 (constructed in the shallow Qal/WBR HSU) and NC2-22 (constructed in the deeper $Tnsc_0$ HSU). Each well was sampled a single time for lithium. Lithium was detected in the sample from each well, and was detected in NC2-22 at 0.0782 mg/L, slightly above the U.S. EPA-Region IX risk-based RSL of 0.073 mg/L. There is no MCL for lithium in drinking water. Lithium was not sampled for in Spring 6. As lithium is not well characterized in either ground water or the surface water the ground water may discharge into, lithium will be included as a PCOC for both ground water and surface water.

Radium-226 was identified as a PCOC in surface water in the SLHHRA. However, like lithium, radium-226 is not well characterized in either surface water or ground water. Spring 6 was sampled a single time for radium-226, and ground water was sampled only from wells NC2-23 and NC2-22 (a single sample from each well). Although radium-226 was below reporting limits in both wells, the single sample obtained from Spring 6 contained radium-226 activities (0.393 pCi/L) above the U.S. EPA-Region IX risk-based PRG of 0.000906 pCi/L, but below the current MCL for drinking water (5 pCi/L). The weighted average of radium-226 in subsurface soil samples collected from firing table borehole 812-01was also above background and exceeded the threat to ground water PRGs based on both risk and MCL (Figure 2-6). Thus, radium-226 will be included as a PCOC in surface water and ground water. However, analytical methods are not available that can quantify radium-226 to the risk-based PRG level in water. The current reporting limit available from analytical laboratories for radium-226 is 0.25 pCi/L. In addition, as discussed further below, it is highly unlikely the presence of radium-226 in the environment at Building 812 is due to the radioactive decay of uranium-238 introduced into the environment from the Building 812 firing table activities.

2.1.2.2. Nature and Extent of Uranium in Surface Water

The sampling location for Spring 6 in Elk Ravine currently contains background activities/concentrations of uranium in water. However, this location is located to the northwest and upstream of the confluence of Elk Ravine and the Building 812 Canyon drainage. Ground water from the Qal/WBR HSU containing uranium activities in excess of the MCL may discharge into Elk Ravine surface water southeast of the confluence with the Building 812 Canyon drainage. Surface water samples have not been collected from this location and thus analytical data are not available. However, since the data cutoff date of October 2007 for the SLHHRA and the initial Draft RI/FS, surface water runoff samples have been collected to characterize uranium activity in runoff that may ultimately flow into Elk Ravine and/or recharge the Qal/WBR HSU. Figure 2-1 shows the surface water runoff/stream channel sampling locations, total uranium activities and concentrations, and the uranium-235/uranium-238 isotopic ratios for samples collected on January 22, 2010 and June 6, 2010. Samples collected from locations 3SW-812-005 and 3SW-812-002 were collected from ponded water, all other samples were collected from flowing surface water. Samples from all locations contained some depleted uranium, as indicated by isotopic ratios lower than 0.007. Samples from two locations, 3SW-812-001 (located at the confluence of the Building 812 Canyon drainage and Elk Ravine and 3SW-812-006 (located several hundred feet north of the Elk Ravine confluence within the Building 812 Canyon drainage stream channel), contained total uranium activities of 55 and 53 pCi/L, respectively, which exceeds the MCL of 20 pCi/L. These data suggest that in addition to surface water being potentially impacted from uranium in Qal/WBR ground water discharging into Elk Ravine southeast of the Building 812 Canyon drainage confluence, surface water southeast of the confluence may also be negatively impacted from runoff during rainfall events. Therefore, uranium isotopes will be added to the list of PCOCs in surface water.

2.1.2.3. Nature and Extent of Uranium-235 and Uranium-238 in Surface Soil

As part of the SLHHRA and initial Draft RI/FS, surface soil samples were analyzed to determine the activities of individual uranium isotopes. The results from these individual samples were compared to background activities and outdoor worker PRGs to identify COPCs in the SLHHRA. The maximum uranium-235 activity detected in a surface soil sample was 0.95 pCi/g; which exceeds both the outdoor worker PRG of 0.386 pCi/g for uranium-235, and the 0.0737 pCi/g Site 300 background activity for uranium-235 in surface soil. As shown on Figure 2-2, the extent of uranium-235 in surface soil at concentrations that exceed the outdoor worker PRG is limited to within 400 ft of the Building 812 Firing Table and is bounded by samples that contain less than the PRG.

The maximum uranium-238 activity detected in a Building 812 surface soil sample was 93 pCi/g; which exceeds both the 1.65 pCi/g outdoor worker PRG for uranium-238, and the 3.1 pCi/g Site 300 background activity for uranium-238 in surface soil. As shown on Figure 2-3, the extent of uranium-238 activities exceeding the 3.1 pCi/g background level is predominantly oriented to the east and northeast and extends about 700 ft northeast of the Building 812 firing table. However, a lower density of surface soil samples, compared to closer to the firing table, is available to characterize this hillslope area. Higher activities are present closer to the firing table, as shown by a 10 pCi/g isoactivity contour (representing just over three times the Site 300 background activity) in Figure 2-4, with higher activities being within 200 to 300 ft of the firing table to the west, northwest and southwest, and within about 400 ft of the firing table to the east, northeast and southeast.

2.1.2.4. Nature and Extent of PCOCs in Surface Soil and Subsurface Soil that pose a Threat to Ground Water

For the SLHHRA, surface soil and subsurface soil was grouped into three geographic areas to evaluate threat to ground water. These areas are: (1) hillslopes, (2) the firing table area, and (3) alluvial deposits. These data were grouped into these geographic areas to account for different depths to ground water and associated dilution attenuation factors when screening for potential threat to ground water. In the SLHHRA, threat to ground water RSLs and PRGs based on a dilution attenuation factor (DAF) of 20 were used for the hillslope and firing table areas to identify COPCs, where as a DAF of 1 was used in the alluvial deposits. All threat to ground water RSLs and PRGs were based on the MCL for ground water, unless an MCL was not available, in which case the risk-based concentration in ground water was used. Tables 2-4 and 2-5 summarize the threat to ground water PRGs/RSLs, MCLs in drinking water, and Site 300 background for the initial PCOCs found in surface soil and subsurface soil, respectively.

Copper, Lead, and Uranium in Surface Soil

Figure 2-2 shows those surface soil locations that exceed the MCL-based threat to ground water PRG for uranium-235 and Site 300 background. Samples from one hillslope location (3SS-812-1902), and one firing table location (B-812-2404) exceed the threat to ground water uranium-235 PRG for hillslope/firing table locations (0.777 pCi/g) and Site 300 background (0.0737 pCi/g). These locations also exceed the outdoor worker PRG. Samples from seven surface soil locations in the alluvial deposits north and east of the firing table (3SS-812-2401, 3SS-812-2412, 3SS-812-2415, 3SS-812-1927, 3SS-812-1928, 3SS-812-1932 and 3SS-812-1933) exceed the alluvial deposits threat to ground water uranium-235 PRG (0.0389 pCi/g) and Site 300 background (0.0737 pCi/g), but do not exceed the uranium-235 outdoor worker PRG.

As shown in Table 2-4, the threat to ground water PRG for uranium-238 for both the hillslope and firing table areas (0.121 pCi/g) and the alluvial deposits (0.00604 pCi/g) is below the Site 300 background of 3.1 pCi/g. Therefore, all the surface soil locations shown in

Figure 2-3 that are within the background contour also exceed the threat to ground water PRG for uranium-238.

Figure 2-5 shows those surface soil locations that exceed the threat to ground water RSLs and Site 300 background for copper, lead, and uranium as a metal. The copper threat to ground water RSL and Site 300 background is exceeded in one hillslope location (3SS-812-1904), and one alluvial deposit location (3SS-812-1932). This alluvial deposit location also exceeds the threat to ground water RSL and Site 300 background for lead and uranium as a metal. Six additional alluvial deposit locations also exceed the threat to ground water RSL and Site 300 background for uranium as a metal: 3SS-812-2401 (not shown on figure, located north of 3SS-812-2415), 3SS-812-2415, 3SS-812-2412, 3SS-812-1927, 3SS-812-1928, 3SS-812-1932 and 3SS-812-1933. One firing table locations (B-812-2404) also exceeds the threat to ground water RSL and Site 300 background for uranium as a metal.

Manganese, Radium-226 and -228, and Uranium in Subsurface Soil

Figure 2-6 shows the locations in the Building 812 OU with available subsurface soil data. For these locations, the weighted average of each analyte was compared to the relevant threat to ground water RSL or PRG and Site 300 background to identify PCOCs. Figure 2-6 shows those locations with weighted averages exceeding threat to ground water RSLs or PRGs and Site 300 background. Most subsurface soil locations exceeding threat to ground water PRGs or RSLs and Site 300 background are located in the firing table area. Five firing area locations (B-812-2405, B-812-2404, 812-01, 812-02 and 812-03) all exceeded threat to ground water PRGs and Site 300 background for uranium-238. Although total uranium as a radionuclide does not have a PRG, the total uranium activity for each location exceeding the uranium-238 PRG and Site 300 background is also shown. Firing table location 812-01 also exceeds the treat to ground water PRGs (and Site 300 background if available) for radium-226, radium-228, and uranium-235, as well as the threat to ground water RSL and Site 300 background for uranium as a metal.

The milling process used to create depleted uranium takes uranium ore and removes other material (including radium) so that the resulting milled material is over 90% uranium. The tailings remaining can contain up to 85% of the original radioactivity. Although radium-226 is in the decay chain of uranium-238, as shown in Equation (1), it would take over 10^{18} years for the uranium-238 introduced into the environment from the firing table activities to decay to radium-226. This suggests the presence of radium-226 in borehole 812-01 is the result of the decay of naturally occurring uranium-238 in the Building 812 soil. Radium-228 is not in the uranium-238 decay chain, and thus its presence in samples from borehole 812-01 is also likely due to other naturally occurring radioisotopes in the Building 812 soil. Although the presence of radium-226 and radium-228 in borehole 812-01 is likely representative of background activities, they will be retained in the list of PCOCs posing a threat to ground water to ensure the baseline risk assessment is not discounting the cancer risk from naturally occurring sources.

Eq. (1)

$$U\text{-}238 \xrightarrow[4.5\times10^{9}\text{yr}]{} Th\text{-}234 \xrightarrow[24.1\text{d}]{} Pa\text{-}234 \xrightarrow[1.17\text{m}]{} U\text{-}234 \xrightarrow[2.4\times10^{5}\text{yr}]{} Th\text{-}230 \xrightarrow[7.7\times10^{4}\text{yr}]{} Ra\text{-}226 \xrightarrow[1600\text{yr}]{} Pb\text{-}210 \xrightarrow[\sim24\text{yr}]{} \text{Pb-206}$$

where:

yr = year d = day m = minute

U-238 = radioisotope Uranium-238

Th-234 = radioisotope Thorium-234

Pa-234 = radioisotope Protectinium-234

U-234 = radioisotope Uranium-234

Th-230 = radioisotope Thorium-230

Ra-226 = radioisotope Radium-226

Pb-210 = radioisotope Lead-210

Pb-206 = stable isotope Lead-206

—> = Indicates short-lived radioisotopes (< 5 months) not shown

The hillslope location B-812-2401, located just to the north of the firing table, also exceeds the threat to ground water PRG for uranium-238. The alluvial deposit location B-812-2407 is the only alluvial deposit location to exceed threat to ground water PRGs or RSLs, in this case exceeding the threat to ground water PRG for uranium-238.

A weighted average of subsurface soil samples from a single hillslope borehole, W-812-04, exceeded the risk-based threat to ground water RSL and Site 300 background for manganese. There is no MCL for manganese in drinking water. This location is located adjacent to a fire trail south and down gradient of the firing table and associated Building 812 facilities. Five boreholes located cross-gradient and upgradient of W-812-04 (B-812-07, B-812-1926, B-812-02, B-812-01 and B-812-03) have weighted average manganese concentrations of 50, 300, 32, 39, and 39 mg/kg, respectively, which do not exceed the threat to ground water RSL and Site 300 background. While there is no evidence manganese was specifically used in Building 812 firing table activities, its use cannot be ruled out. It is also possible that a piece of ejecta from the firing table may have resulted in an isolated hot spot. Therefore, manganese will be retained in the list of PCOCs posing a threat to ground water from the hillslope boreholes.

2.1.3. Current Knowledge of Contaminant Fate and Transport

Depleted uranium and associated metals used in explosives experiments at the Building 812 firing table were released to the environment. The most significant primary release mechanism of these contaminants into the environment was from the open-air explosive experiments conducted on the firing table. Typically, at the time of a test, ejecta containing depleted uranium would be scattered symmetrically into the air in all directions. Ejecta often consisted of pyrophoric particles of metallic depleted uranium. Some depleted uranium shrapnel was also presumably driven beneath the ground surface by the force of the explosive blasts. Based on the shape of the region of surface soil containing uranium-238 in excess of background, the preferential north-northeast wind direction over much of the year elongated the pathway of these particles in that direction, resulting in preferential deposition in that direction. Contaminants may have also been released to surface and subsurface soil through the septic system serving the Building 812 facilities, which emptied into a tile drain southeast of the facilities (Figure 1-3), as well as from the past practice of disposing firing table gravel into the ravine/drainage associated with the Building 812 Canyon or adjacent to the firing table. Contaminants may also have been released to surface soil and subsurface soil through the past use of dry wells associated with Buildings 812C and 812D.

Contaminants in surface soil may be further mobilized into ambient air as resuspended particulates by wind, resulting in some additional movement of surface soil contaminants, which could also include deposition onto surface water. Resuspension of contaminated soil would be most prevalent in areas with low vegetation cover and exposed soil.

Surface water flow, following topography, likely has resulted in transport of surficial uranium from higher elevations into lower elevations, especially the Building 812 Canyon and the deeply incised channel within it. Some dissolution and precipitation of uranium may also be responsible for the accumulation of solid-phase uranium below the ground surface.

Overland flow of water from rainfall and resuspension of contaminated surface soil and subsequent transport and deposition into the surface water may result in the migration of contaminants to the surface water in the Spring 6/Elk Ravine area. Runoff also recharges the Qal/WBR HSU within the base of the canyon. The Qal/WBR HSU may also be recharged by spring discharge and/or baseflow from the underlying bedrock in the Building 812 Canyon and Elk Ravine. In addition, the Qal/WBR and $Tnbs_1/Tnbs_0$ HSUs may also locally discharge into the Spring 6/Elk Ravine area along stratigraphic and structural contacts.

Infiltration of rainwater may mobilize contaminants in subsurface soil to ground water within the $Tnbs_1/Tnbs_0$ and Qal/WBR HSUs. The metals and radionuclides in surface soil and subsurface soil must be sufficiently soluble for transport to ground water (and direct or subsequent transport to surface water) to occur. As discussed in U.S. EPA (2005a), the fate and transport of contaminants depends on their chemical properties and the specific physical and geochemical binding mechanisms that vary among contaminants and soil types. Contaminants are generally considered to be mobile when they can be desorbed and/or dissolved from soil and soil constituents and released into the soil pore-water. Metals can exist as either cations or anions in the soil environment, which significantly affects their sorption, mobility, and solubility in soils. Soil particle surfaces are primarily negatively charged. Thus, metal cations have a higher propensity to be sorbed by soil particles relative to metal anions. Metals occur naturally in soils primarily as amorphous oxides and hydroxides, and to a lesser extent as carbonates, phosphates, sulfates, and sulfides, which are relatively insoluble. The same is generally true for metal-contaminated soils, because metals quickly undergo precipitation and coprecipitation reactions forming relatively insoluble solid phases, and/or are strongly complexed by soil minerals or organic matter (Lindsay, 1979).

The surface soil threat to ground water PCOCs copper and lead occur as cations when non-complexed. These metals can thus complex with inorganic soil constituents, e.g., carbonates, sulfates, hydroxides, and sulfides to form either precipitates or positively charged complexes. Both complexation and precipitation reactions are pH dependent. Therefore, although these metals can form complexes with a net negative charge, under most environmentally relevant scenarios (pH = 4 to 8.5), these metals either precipitate or exist as cations. These metals in their various forms can exist in the pore-water as charged species, as soluble complexes, or precipitate out of solution as solids (U.S. EPA, 2005a). Retention by soil is usually electrostatic with cationic species and anionic species being associated with negatively and positively charged sites on the soil, respectively. For most soils in the United States, negatively charged sites are more plentiful with less than 5% of the total available charge on the soil surface being positively charged. Therefore, metals existing as cationic species have a greater propensity to associate with the soil and are less mobile, whereas anionic metals generally are more mobile and more highly partitioned within the pore-water for most soil/water systems. The soil pH and availability of charged sites on soil surfaces are the primary soil factors controlling their release to the pore-water. The clay content (with its large surface area) and organic matter of soils determine the amount of charged sites available to bind with metals.

Uranium transport in soil is principally controlled by several factors: pH, redox conditions, microbial activity, types of soil mineral surfaces, mineralogy of uranium solids present, and concentration of carbon dioxide and bicarbonate alkalinity (Langmuir, 1997). The uranyl ion (UO_2^{+2}) is the principal complex-building form of uranium that predominates in oxygenated/high Eh soil moisture. It forms complexes with bicarbonate, which dominate at typical subsurface carbon dioxide concentrations. Uranium movement in oxidized soil waters is controlled by a variety of hydroxide, carbonate, silicate, and phosphate minerals. In the presence of carbon dioxide, uranyl sorption onto mineral surfaces is at a maximum at near-neutral pH (between 6.0 and 7.0), and decreases sharply toward more acidic or alkaline conditions (Sylwester et al., 2000). At pH 6-7 and higher, in the presence of carbon dioxide, uranyl bicarbonate complexes dominate and retard sorption because in this pH range, mineral surfaces are predominantly negatively charged. The presence of clays, iron oxides and iron hydroxides will reduce uranium mobility. Uranous ion, UO_2^0, and its complexes predominate in ground waters of low Eh and oxygen content. Owing to the low solubilities of reduced solids (uraninite and pitchblende), uranium is very immobile in oxygen-deficient water. Sorption of uranyl by organic matter may precede reduction to the less soluble uranous minerals when oxygen is absent. Uranous oxidation is enhanced by the carbonate and hydroxide complexes, which increase solubility and provide electron donors.

No data on grain size distribution, organic matter or pH is available from the Building 812 area. However, 80 samples have been collected and analyzed for total organic carbon in support of the Explosive Waste Treatment facility located near Pit 9 in the East Firing Area north of Building 812. Of these, over 20 samples were collected at various locations throughout the East and West Firing Area. Total organic carbon in these 80 samples ranged from 0.52 to 2.2%. The average total organic carbon was 1.30% with a standard deviation of 0.19%. These same samples had a pH ranging from 6.59 to 8.78, with an average of 7.70 and a standard deviation of 0.64. Total organic carbon data are also available from 30 boreholes scattered throughout Site 300 ranging in depth from 1.2 ft to 196 ft. Total organic carbon in from these boreholes ranged from 0.02% to 0.81%, with an average of 0.21% and standard deviation of 0.21%. A total of 34 boreholes scattered throughout the site had available pH data, collected from depths ranging from 1 to 50 ft. The pH ranged from 7.50 to 9.70, with an average of 8.55 and a standard deviation of 0.50. As discussed in Section 3.1.4, these data suggest metals in the soils at Building 812 have a medium bioavailability, and thus is at least somewhat available to be subsequently transported to ground water. Data on grain size distribution is extremely limited. Fourteen Site 300 soil samples have been analyzed for particle size distribution. Most of these samples are from the Building 834 OU. Clay content ranged from 2.4 to 59.8%. Generally, because metals may sorb to clays, metal mobility in soil decreases with increase in clay content.

Once released to surface water, the fate and transport of heavy metals is strongly dependent on various physicochemical characteristics of the water, including temperature, dissolved organic compounds, suspended particles, pH, and various inorganic cations and anions, including those composing hardness and alkalinity.

There are three principal processes controlling uranium mobility in ground water systems: (1) precipitation/dissolution of uranium-bearing solids, (2) sorption/desorption of dissolved uranium, and (3) release/filtration of colloidal uranium from/onto mineral surfaces and/or organic matter (Abdelouas et al., 1999). Changes in pH and redox conditions can result in changes in speciation and/or oxidation state that control the solubility of uranium-bearing minerals and thus the maximum dissolved concentration of uranium. Complexation of uranium with inorganic species (such as carbonate, hydroxide, and phosphate) and organic acids, can lead to sorption to solids, bioaccumulation, movement, or release due to dissolution of solid phases. The extent and degree of uranium migration are determined by the rate and direction of ground water flow, the extent to which mineral assemblages of host rocks adsorb or release uranium, and changes in pH, dissolved oxygen and bicarbonate/carbonate along the flow path that may cause dissolution or precipitation of uranium minerals. Microbial processes in the presence of electron donors such as sulfate, phosphate, and carbonate, can also hasten reduction of uranium to less soluble forms. Conversely, oxidation of uranium is accomplished by reduction of organic matter, iron, sulfur, or carbon (Langmuir, 1978). Besides existing as dissolved species, uranium can be transported in water on colloids.

2.1.4. Human Health Exposure Pathways and Conceptual Site Model

Figure 2-7 shows the revised conceptual site model (CSM). This CSM shows only those pathways identified as potentially complete in the SLHRRA for current Building 812 use patterns by on-site workers. The potential exposure pathways are:

- Incidental ingestion and external exposure of surface soil contaminated with uranium-235 and uranium-238 by outdoor adult on-site workers, and
- Inhalation of resuspended particulates of surface soil contaminated with uranium-235 and uranium-238 by outdoor adult on-site workers.

Although there are no exposure pathways present for ground water or surface water, there remains the potential for impact to these resources. There is the potential for impact to:

- Surface water by uncharacterized ground water potentially containing lithium or radium-226, or uncharacterized surface water containing uranium isotopes, and
- Ground water by metals and radioisotopes in surface soil and subsurface soil, from uncharacterized ground water potentially containing lithium or radium-226, and from recharge of surface water containing uranium isotopes.

Adult on-site workers are the population at risk from PCOCs at the Building 812 OU. As discussed in the SLHRRA, risk and hazard from potential residential exposure from constituents in the Building 812 area was not evaluated as substantial administrative/institutional and land use controls are in place at the site and documented in the Federal Facility Agreement and Site-Wide Record of Decision to prevent changes in land use (i.e., residential land use). Site access restrictions are in place (e.g., fences and guards) to prevent inadvertent exposure to site contamination by members of the public. The FFA and ROD contain provisions to ensure that DOE will not transfer lands with unmitigated contamination that could cause potential harm.

The primary exposure pathway to outdoor adult on-site workers is from surface soil contaminated with uranium-235 and uranium-238. Table 2-6 shows the ingestion, inhalation, external exposure and total PRGs for uranum-235 and uranium-238, using the EPA default outdoor worker exposure scenario. For both uranium-235 and uranium-238, external radiation exposure is the most significant pathway. Dermal contact is not considered a significant pathway for radioisotopes in surface soil (U.S. ACOE, 2002). As discussed in the SLHHRA, non-volatile analytes found in subsurface soil were not evaluated for risk to adult on-site workers as substantial administrative controls are already in place at the site to prevent worker exposure to non-volatile constituents during any excavation of soil at depths greater than 6 inches. Volatile analytes in subsurface soil to a depth of 12 ft were evaluated in the SLHHRA, and found not to be a risk to on-site workers.

Building 812 is currently non-operational. Therefore, there are no indoor exposure pathways. However, as discussed in Section 2.1.2.1, radium-226 is a naturally occurring substance in the Building 812 soils. Radon-222, a decay product of radium-226, is a volatile gas that could potentially be present in indoor air. Therefore, the inhalation of radon-222 in indoor air could be a potentially complete exposure pathway for indoor workers. Administrative controls will be part of the risk management section of the Building 812 feasibility study to ensure the assumptions made during the baseline risk assessment remain valid. DOE would be required to reopen the risk assessment if the area/building uses change. In addition, LLNL maintains the Hazards Control Department, staffed by human health toxicologists and health physicists, whose charge is to ensure the safety of LLNL workers. Should Building 812 become active again at some point in the future, they would be required to ensure the facility is safe for workers. Information concerning the presence of naturally occurring radon would be provided to the Hazards Control Department to allow them to determine the best course of action.

For the SLHHRA, the default on-site worker exposure scenario was used. This assumed an outdoor on-site worker works 225 8-hr days per year for 25 years in the Building 812 area. However, as discussed above, Building 812 is currently non-operational. The only workers at the site include intermittent visits by environmental investigation personnel (to conduct ground water sampling, treatment facility operation, and other related activities), Site 300 maintenance personnel, wildlife biologists conducting various surveys, and Site 300 security personnel. The exposure profile for each of these groups is significantly different. Security personnel would likely spend most of their time in a vehicle driving the paved roads and unpaved fire trails, and thus would be exposed to contaminants in areas directly adjacent to the roads. Wildlife biologists, on the other hand, would be more exposed to contaminants on the outlying hillslopes, and would spend their time outdoors, as would personnel conducting sampling and other environmental activities.

There are no on-site water-supply wells at or near Building 812, therefore this exposure pathway is not complete. However, DOE has agreed that the point-of-compliance for ground water directly underlies the site, and has therefore agreed to remediate ground water to Maximum Contaminant Levels (MCLs), which are also protective under a residential use scenario. This approach is consistent with the risk assessment approach and exposure scenario (industrial) used in previous LLNL Site 300 risk assessments agreed to by the regulatory agencies. In the SLHRRA, if there was no MCL for a particular constituent, and its concentration exceeded the applicable RSL/PRG and background levels, the constituent was retained for further evaluation. As discussed in Section 2.1.1, with the exception of lithium and radium-226, the ground water COPCs identified in the SLHHRA are now COCs to be considered in the FS.

Threat to ground water from constituents detected in surface soil (0 to 0.5 ft) and subsurface soil (all depths >0.5 ft) was also evaluated in the SLHHRA. As discussed in Section 2.1.2 and shown in Figures 2-4, 2-5 and 2-6, several PCOCs were identified in surface soil and subsurface soil as potentially posing a threat to ground water.

Like ground water, surface water in Spring 6/Elk Ravine is not used as a drinking water source. The only uncontrolled exposure to constituents found in surface water at Site 300 would be from volatile constituents that could be subsequently inhaled by nearby workers. No volatile substances are present in the Spring 6/Elk Ravine surface water. However, as with ground water, DOE has agreed the point of compliance for surface water is the site, and therefore has agreed the cleanup standard for surface water is the same as for ground water.

2.2. Baseline Human Health Risk Assessment Study Design

Based on the evaluation of the initial list of PCOCs presented in Section 2.1.2 and 2.1.3, the list of PCOCs was revised. The revised list is presented in Table 2-7. The PCOCs listed in Table 2-7 will be either evaluated as part of the baseline human health risk assessment or will be further considered in the SLHHRA upon the completion of additional characterization. The baseline human health risk assessment study design focuses on assessing the risk to onsite workers from uranium-238 and uranium 235 in surface soil, the impact to ground water from copper, lead, uranium-235 and uranium-238 in surface soil, and the impact to ground water from uranium-235 and uranium-238 in subsurface soil. Additional characterization of surface water and ground water for lithium and radium-226, as well as uranium isotopes in surface water, will be used to fill in gaps identified in the SLHHRA to determine their status as COCs.

2.2.1. Additional Characterization of Nature and Extent of Contamination

The following additional characterization activities are proposed to provide the data needed to fill gaps in the SLHHRA and to complete the baseline human health risk assessment:

- Conducting a surface soil gamma radiation survey to refine the areas of uranium-238 surface soil activities exceeding background,
- Installing additional boreholes and obtaining additional subsurface uranium-238 activity data,
- Collecting data on the physical characteristics and form of the uranium present in the Building 812 area to provide information on mobility in the subsurface,
- Sampling and analysis of surface water and ground water for lithium and radium-226, and
- Sampling and analysis of surface water samples for uranium isotopes.

With the exception of the surface soil gamma survey, the additional characterization activities are described in more detail in the Characterization Work Plan, which includes the numbers and locations of samples, sampling and analytical protocols, and associated quality assurance and quality control. The Uranium-238 Surface Soil Gamma Radiation Survey Work Plan (EnergySolutions, 2011) describes the surface soil survey in more detail. The additional characterization activities are briefly described below.

2.2.1.1. Surface Soil and Subsurface Soil Characterization

As discussed in Section 2.1.2, surface soil containing uranium-238 in excess of background covers a wide lateral extent as defined by surface soil samples. However, in order to better evaluate onsite worker exposure to uranium-238 in surface soil, surface soil activities are needed at a finer resolution. Additional uranium-238 in surface soil data will be obtained by conducting a surface soil gamma radiation survey. The Uranium-238 Surface Soil Gamma Radiation Survey Work Plan (EnergySolutions 2011) describes the surface soil survey in more detail. Additional characterization work for uranium-235 is not planned, as the area of surface soil containing uranium-235 activities in excess of the outdoor worker PRGs is much more limited in extent, is within the area containing elevated uranium-238 activity, and is adequately characterized by individual surface soil samples.

As discussed in Section 2.1.2, uranium-238 is also present in the subsurface at activities that may pose a threat to ground water. The amount of data available to assess this potential threat is also limited. Thus, additional boreholes will be drilled and sampled for uranium-238 as described in the Characterization Work Plan. Locations and additional sampling and analysis details can be found in the Characterization Work Plan. The weighted average of uranium-235 in a single borehole exceeds the threat to ground water PRG (812-01, Figure 2-6). This borehole is bounded by other boreholes that have weighted average activities of this isotopes below the threat to ground water PRG. Therefore, additional subsurface uranium-235 characterization will not be conducted.

The mobility of uranium in the environment will be evaluated by solid-phase characterization, as described in the Characterization Work Plan. This information will primarily be used in the evaluation of remedial technologies as part of the FS stage of the RI/FS, but may also be used in the baseline human health risk assessment in modeling threat to ground water. Several methods will be used for this characterization, including sequential extractions, scanning electron microscopy and energy dispersive spectral x-ray analysis, and x-ray diffraction. Soil samples from a range of depths and locations will be characterized. In addition, grain size distribution of the soil will be conducted to determine which fraction contains the highest uranium activities. Additional sampling and analysis details can be found in the Characterization Work Plan.

2.2.1.2. Surface Water and Ground Water Characterization

As discussed in Section 2.1.2, lithium and radium-226 are not well characterized in the Building 812 ground water or surface water. Therefore, additional surface water and ground water samples will be collected and analyzed for these substances. Locations and additional sampling and analysis details can be found in the Characterization Work Plan.

As also discussed in Section 2.1.2 and in Section 3 below, surface water in Elk Ravine is currently sampled only at the location designated as Spring 6. This location is upgradient of the confluence between Elk Ravine and the Building 812 Canyon drainage. However, uranium concentrations in excess of MCLs have been detected in the shallow alluvial ground water within the Qal/WBR HSU that may discharge into Elk Ravine at and to the southeast (downgradient) of the Building 812 Canyon drainage. Surface water runoff samples have also contained uranium activities in excess of the MCL. Therefore, surface water downgradient of the confluence of the Building 812 Canyon draining and Elk Ravine will be sampled and analyzed for uranium isotopes. Locations and additional sampling and analysis details can be found in the Characterization Work Plan.

2.2.2. Characterization of Human Health Exposure Pathways

As discussed in Section 2.1.4, the default on-site worker exposure scenario was used for the SLHHRA. However, Building 812 is currently non-operational. The only workers at the site include intermittent visits by environmental investigation personnel (to conduct ground water sampling, treatment facility operation, and other related activities), Site 300 maintenance personnel, wildlife biologists conducting various surveys, and Site 300 security personnel. In addition, as discussed in Section 2.1.4, the exposure profile for each of these groups is significantly different.

Therefore, it is necessary to more completely characterize the exposure scenarios for the populations of onsite workers reasonably expected to spend time in the Building 812 area. Exposure scenarios will be developed for the following groups of onsite workers:

- Site 300 personnel involved with environmental investigation activities,
- Site 300 maintenance personnel,
- Site 300 wildlife biologists, and
- Site 300 security personnel.

Exposure scenarios will be developed through interviews with workers within each of the groups of interest, and inspection of any relevant facility documentation. Data to be collected includes the areas visited at the Building 812 area by the worker, and the amount of time per year the worker spends in each area. Interviews will be documented through a Record of Communication (ROC) that will become part of the Building 812 OU administrative record. Data obtained from documentation review will also be summarized in ROCs that will become part of the administrative record.

Development of exposure scenarios will be limited to routine, ongoing activities (such as wildlife and security survey work, ground water sampling, and treatment facility maintenance) that may potentially exposure workers to the top six inches of soil, and will not consider non-routine construction-related activities that include any ground disturbing activities to a depth greater than six inches. This is because Site 300 has extensive administrative/institutional controls that prevent worker exposure to subsurface constituents during excavation activities. For example, there is a well-defined process and stringent requirements for any soil excavation at depths greater than six inches. These include obtaining excavation permits and Work Control Board approval for all ground-breaking activities that penetrate to a depth greater than six inches, required coordination with an Environmental Analyst and the Environmental Restoration Department, an evaluation of hazards by the Hazards Control Department (which contains industrial hygienists and health physicists), and the implementation of necessary controls. Institutional controls to prevent potential worker exposure to contaminants in subsurface soil will also be included in the Building 812 Feasibility Study (FS) as part of the Risk and Hazard Management component of all remedial alternatives (including an institutional control map that will outline area(s) that contain constituents above background levels).

2.2.3. Evaluation of Ground Water and Surface Water PCOCs

Newly collected ground water and surface water data for lithium, radium-226 and uranium isotopes will be evaluated using the same process as done for the SLHHRA. Analytes will be compared to risk-based RSLs or PRGs. If the analyte exceeds these risk-based screening levels, the results will be compared to Site 300 background, if available. If the analyte exceeds background, or if no background is available, the analyte will be compared to MCLs. If the analyte exceeds MCLs, it will be added to the COC list. If no MCL or background is available and the analyte exceeds risk-based RSLs or PRGs, background data may be collected from Site 300 background locations for the analyte. Final results of the ground water and surface water evaluation, and DOE/LLNL's interpretation of the results, will be presented to the regulatory agencies at the Scientific Management Decision Point discussed in Section 2.2.6.

2.2.4. Evaluation of Threat to Ground Water

Upon completion of the additional characterization activities, a modeling protocol will be developed to evaluate threat to ground water from the PCOCs in surface soil and subsurface soil using site-specific data. The specific modeling protocol has not yet been developed, as it will depend on the outcome of the additional characterization activities. Upon completion of the characterization activities and subsequent analysis of the resulting data, a modeling protocol will be developed and discussed with the regulatory agencies. Once the protocol is finalized, modeling will be conducted. Results of the modeling will be summarized, and modeling uncertainties will be discussed. The results of the modeling, and DOE/LLNL's interpretation of the results, will be presented to the agencies at the Scientific Management Decision Point discussed in Section 2.2.6.

2.2.5. Assessment of Human Health Exposure and Risk

Assessment of exposure of onsite workers to uranium-238 in surface soil and subsequent risk will be based on the results of the surface soil gamma survey described in Section 2.2.1 and the exposure scenarios developed as described in Section 2.2.2. Assessment of exposure of onsite workers to uranium-235 in surface soil and subsequent risk will be based on existing surface soil data and the exposure scenarios developed as described in Section 2.2.2.

Exposure for each group of workers to the two isotopes will be determined as follows. For each group of workers, the area at Building 812 where the worker group is found will be delineated on a map of surface soil activities for the specific isotope. The 95% upper confidence limit (UCL) of the arithmetic mean activity for the isotope will be calculated for that area, as described in U.S. EPA (1992). This 95% UCL represents the exposure point concentration for that particular worker group. The 95% UCL will be calculated using Excel spreadsheets. The appropriate H or Student-t statistic for the number of samples and a one-sided 95% UCL distribution will be obtained from a standard statistical reference (such as Gilbert, 1987). The statistical program R will be used to investigate the normality of the sample distribution to determine the need for data transformation and the appropriate test statistic.

Risk will be assessed as follows. Using the 95% UCL exposure point activity and the parameters associated with the particular exposure scenario, a site- and worker-group specific PRG will be calculated using the U.S. EPA online calculator (U.S. EPA, 2010b). The resulting PRG will be compared to the surface soil 95% UCL activity to determine the degree of risk by dividing the surface soil 95% UCL activity by the PRG and multiplying by 1×10^{-6}. Risk to each worker group will be evaluated in this fashion. In areas with both uranium-235 and uranium-238, the additive risk will also be determined. Results will be summarized and tabulated, and uncertainties discussed. The results of the onsite worker risk assessment, and DOE/LLNL's interpretation of the results, will be presented to the regulatory agencies at the Scientific Management Decision Point discussed in Section 2.2.6.

2.2.6. Scientific/Management Decision Point

Periodic briefings on the progress of the baseline human health risk assessment will be given to the regulatory agencies at the monthly Remedial Program Managers meeting. Upon conclusion of the activities outlined above, DOE/LLNL will present the results of the baseline human health risk assessment to the regulatory agencies. This will occur concurrent with the completion of the baseline ecological risk assessment. The results of the additional characterization activities, the evaluation of threat to ground water, and the onsite worker risk assessment will be discussed and DOE/LLNL will provide their determination as to whether the results provide sufficient information to make a remedial action decision. Any potential follow-on work would be dependent upon the availability of funding. The presentation will allow the agencies to provide initial comment to LLNL/DOE prior to finalization of the baseline human health and ecological risk assessment. The results of the Scientific/Management Decision point will determine the final list of COCs that will be evaluated during the FS.

3. Building 812 Baseline Ecological Risk Assessment Work Plan

The work plan presented here describes the tasks involved in completing the Building 812 baseline ecological risk assessment. It begins with a problem formulation step in which the results of the screening-level ecological risk assessment (SLERA) are reviewed, and data and information gaps identified. It concludes with a study design that identifies tasks required to fill the data and information gaps from the screening-level ecological risk assessment and to complete the baseline ecological risk assessment. As described in Section 1.2, an initial Draft Building 812 OU RI/FS was completed in November 2008, which included the results of the SLERA. Based on comments from the regulatory agencies, the SLERA was revised and provided to the agencies in September 2010. The regulatory agencies reviewed the revised SLERA and provided additional comments to DOE/LLNL. All comments were resolved by March 2011.

At the conclusion of a SLERA, there are only three possible decisions (U.S. EPA, 1997):

1) There is adequate information to conclude that ecological risks are negligible and therefore there is no need for remediation on the basis of ecological risk,
2) The information is not adequate to make a decision at this point, and the ecological risk assessment process will continue to the Problem Formulation Step, or
3) The information indicates a potential for adverse ecological effects, and a more thorough assessment in the baseline ecological risk assessment is warranted.

Table 3-1 presents the list of Contaminants of Potential Ecological Concern (COPECs) that were retained from the Building 812 SLERA. The initial decision for all of the COPECs retained from the SLERA was Decision 2, that is, the information is not adequate to make a decision at this point, and the ecological risk assessment process will continue to the Problem Formulation Step. Therefore, the COPECs retained from the Building 812 SLERA shown in Table 3-1 represents the initial list of Preliminary Contaminants of Ecological Concern (PCOECs) for the Building 812 OU. The PCOECs are further evaluated in the Sections 3.1.1 through 3.1.4 below as part of the Problem Formulation Step. For assessments that proceed to the Problem Formulation Step, the screening-level assessment can indicate and justify which contaminants and exposure pathways can be eliminated from further assessment because they are unlikely to pose a substantive risk (U.S. EPA, 1997). The evaluation of the final status of each initial PCOEC and a determination as to whether they should progress to the Building 812 OU baseline ecological risk assessment is presented in Section 3.1.5.

3.1. Baseline Ecological Risk Assessment Problem Formulation

In the Problem Formulation Step, the results of the screening-level risk assessment and additional site-specific information were used to determine the scope and goals of the baseline ecological risk assessment. The following tasks were conducted in the Problem Formulation Step of the Building 812 baseline ecological risk assessment:

- Reviewed what is known concerning the ecological effects of the preliminary contaminants of ecological concern,
- Reviewed what is known about the nature and extent of contamination, and identified additional information needs,
- Reviewed the assumptions made concerning contaminant fate and transport and identified additional information needs,
- Reviewed the assumptions made concerning exposure pathways and identified additional information needs,
- Refined the list of preliminary contaminants of ecological concern that will be the focus of the baseline risk assessment, and
- Identified assessment endpoints and developed conceptual site models specific to the assessment endpoints to guide the development of the baseline ecological risk assessment study design.

The results from the problem formulation step were also used to identify activities required to fill gaps within the screening-level ecological risk assessment.

3.1.1. Ecological Effects of Preliminary Contaminants of Ecological Concern

The initial PCOECs (Table 3-1) are total uranium and zinc in surface water; total uranium, copper, and nickel in shallow ground water; copper, lead, nickel, zinc, and total uranium in surface soil; and total uranium, thorium-228, and uranium-238 in subsurface soil.

3.1.1.1. Ecological Effects of Uranium, Copper, Nickel, and Zinc in Surface Water and/or Shallow Ground Water

Table 3-2 lists the National Recommended Water Quality Criteria (NRWQC) for copper, lead, nickel, and zinc that were used as ecological screening levels (ESLs) in the SLERA (U.S. EPA, 2009). For all of the metals, aquatic cladecerans such as *Ceriodaphnia dubia* (water flea) are the most sensitive organism, with vertebrates such as fish and amphibians being relatively less sensitive (U.S. EPA, 1980, 1984, 1986, 1987, 1995 and 2007f). Thus, the NRWQC were developed to be protective of these sensitive organisms. The NRWQC are below Site 300 background levels for copper and lead.

Table 3-3 lists the aquatic ESLs for uranium used in the SLERA, based on a study by Sheppard et al. (2005). These aquatic ESLs are below background levels for uranium. The 0.005 mg/L ESL is a conservative level thought to be protective of fresh water invertebrates and fresh water plants. The invertebrate ESL is based on 15 studies, in which the ESL is the Probable No Effect Concentration (PNEC), representing the 5th percentile distribution of the lowest observed effect concentration (LOEC), and thus considered to be protective of 95% of the biota. Four of these studies were on *Daphnia* species, and one study was on *Ceriodaphia dubia*. These species are appropriate test species for species expected in Spring 6/Elk Ravine. The remaining ten studies used tropical species (freshwater invertebrate species, hydra and unionid bivalves). The LOECs reported in the five studies on *Daphnia* and *Ceriodaphnia* ranged from 0.15 to 5.9 mg/L, where as the LOECs reported in the ten studies using tropical species ranged from 0.015 to 0.35 mg/L. A study using *Ceriodaphnia* (Pickett et al., 1993) reported a No Observable Effect Concentration (NOEC) of 0.0015 mg/L in 7-d chronic bioassays of eight treatments exposing 10 female test organisms each, using multiple laboratories. The NOEC was from treatments was using uranium nitrate. Other forms of uranium had higher NOECs. In addition, Poston et al. (1984) reported that toxicity to *Daphnia magna* reduced 7.5 fold with hardness increasing from 57 and 70 mg/L to 130 and 195 mg/L, respectively. The aquatic plant ESL is based on only three studies all using the algae *Chlorella*, and thus a safety factor of 10 was used.

During the spring of 1994, the *Ceriodaphnia dubia* chronic seven-day toxicity test (EPA Method 1002) and the *Selenastrum capricornutum* (algae) four-day growth test (EPA Method 1003) was conducted on Spring 6 water. No significant effects on reproduction, survival, or growth were observed in the bioassays. The uranium concentration in Spring 6 at this time (as indicated by uranium-234 and uranium-238 results) was 0.007 mg/L. Given the highly conservative nature of the uranium ESL used in the SLERA as well as the use of inappropriate invertebrate test species, along with the results of the Spring 6 bioassays, an ESL on the order of 0.05 mg/L is likely a conservative value protective of Spring 6 aquatic invertebrates and aquatic plants. The uranium ESL of 23 mg/L, developed by Sheppard et al. (2005) as protective of fish, was based on 13 studies (Table 3-3). As with the NRWQC for metals, fish are relatively less sensitive to uranium as compared to aquatic invertebrates. Although fish are not present at Spring 6, the level protective of fish is likely to be protective of amphibians as well.

3.1.1.2. Ecological Effects of Copper, Lead, Nickel, Zinc, and Total Uranium in Surface Soil

Table 3-4 lists the ESLs used in the SLERA for terrestrial plants and soil invertebrates. ESLs for copper, lead, nickel, and zinc were developed by the U.S. EPA as part of their effort to develop Ecological Soil Screening Levels (EcoSSLs). The EcoSSL represents the geometric mean of the maximum acceptable toxicant concentration or 10% Effective Concentration, whichever was lower. The number of available studies ranged from 4 to 11 focusing on growth, reproduction, and population-level endpoints. Although not developed as part of the EcoSSL effort, the uranium ESLs used in the SLERA for terrestrial plants and soil invertebrates were developed using a somewhat similar method, with 8 to 9 studies available focusing on growth, reproduction and survival. The ESL represented a probable no effect concentration. Most of the ESLs for terrestrial plants and soil invertebrates were above Site 300 background levels, with the exception of the nickel ESL for terrestrial plants (38 mg/kg), which is significantly below the Site 300 background level of 130 mg/kg.

Table 3-5 presents the EPA EcoSSLs for copper, lead, nickel, and zinc for birds and mammals. The number in red is the value used as the ESL for the Building 812 SLERA. As can be seen from this table, the most sensitive species tend to be the avian ground invertivorous American woodcock, followed by the mammalian ground invertivorous short-tailed shrew. Site 300 does not have any strictly ground invertivorous small mammals (those that feed exclusively on ground-dwelling insects), and few ground invertivorous birds. Most invertivorous birds at Site 300 tend to feed on aerial insects, which are thought not to accumulate contaminants at the same level as ground-dwelling insects (U.S. EPA, 2005a). Avian herbivores and ground invertivores tended to have lower ESLs than the wider ranging carnivores (raptors). This does not hold for the mammalian guild, with the carnivorous long-tailed weasel having a lower ESL than the herbivorous meadow vole.

Table 3-6 presents the avian and mammalian ESLs that were developed for the SLERA by DOE/LLNL for uranium. Omnivorous and carnivorous birds, and well as large herbivores had higher ESLs than the smaller mammals. The ESLs for birds and mammals were developed using Toxicity Reference Values (TRVs) based on data presented in Sheppard et al. (2005) (see Appendix D-2 of the SLERA for the compete development of the TRVs) and the modeling assumptions shown in Table 3-7. While the modeling approach used to develop the uranium ESLs generally followed that used by the EPA in developing EcoSSLs for copper, lead, nickel, and zinc, the process used to select the TRV for use in the model was not the same. As can be seen in Table 3-7, the number of studies used by the EPA significantly exceeded the number Sheppard et al. (2005) used. The process of evaluating the data presented in the studies was also substantially different, with Sheppard using a safety factor in the development of the mammalian TRV.

3.1.1.3. Ecological Effects of Uranium-238 and Thorium-228 in Subsurface Soil

The radionuclides uranium-238 and thorium-228 were identified as PCOECs in subsurface soil. In the case of uranium-238, the ESL used was from the DOE Biota Concentration Guides (BCGs). These BCGs are activities of radionuclides in ecological media below which ecological impact is not expected to occur, and are based on a dose rate criteria of 1 rad/d for aquatic animals and terrestrial plants and 0.1 rad/d for terrestrial animals determined by the United Nations Scientific Committee on the Effects of Atomic Radiation as defensible for protection of populations of plants and animals (Gentner, 2002; U.S. DOE, 2002). Avoiding measurable impairment of reproductive capability was the critical biological endpoint of concern in establishing these dose limits for aquatic and terrestrial biota. However, a BCG was not available for thorium-228, and thus the human health PRG was used. The endpoint for human health PRGs is cancer, which is not ecologically relevant. A comparison of the available BCGs to human health PRGs show that BCGs are typically several orders of magnitude higher than PRGs. Thus, it is highly unlikely that biota at Building 812 could be negatively impacted by the presence of thorium-228 in the subsurface soil.

3.1.2. Current Knowledge on the Nature and Extent of Contamination

The following discussion on the nature and extent of contamination is based on characterization data presented in the initial draft RI/FS and used in the SLRA. The only new characterization data available since the completion of the initial draft RI/FS consists of additional ground water and Spring 6 analyses for uranium, as well as the results of surface water runoff samples collected in the winter and spring of 2010 for uranium. These new characterization data are included in the following discussion, and new data are clearly identified as having been collected since the completion of the initial draft RI/FS.

3.1.2.1. Nature and Extent of Copper, Nickel, Zinc, and Uranium in Surface Water and Shallow Ground Water

Additional surface water or shallow ground water data has not been collected for copper, lead, nickel, or zinc since the completion of the SLERA (with the exception of well W-812-1921, which was sampled for lead on March 22, 2010). Table 3-8 shows the most recent results for these metals from samples collected from Spring 6 and the shallow ground water wells. Copper was not detected above the reporting limit in either Spring 6 or the shallow ground water wells. The 0.01 mg/L copper reporting limit was below background levels and just above the NRWQC in all samples from all locations except from W-812-2321, in which the reporting limit of 0.05 mg/L was at the Site 300 background level. With the exception of the sample from well NC2-23, nickel was also below the reporting limit in all locations. However, in three locations (W-812-08, W-812-1932, W-812-2321), the reporting limit of 0.01 mg/L was above both the NRWQC for nickel and Site 300 background. The most recent sample from Spring 6 for nickel was also below the reporting limit. This reporting limit (0.005 mg/L) was below both the NRWQC and Site 300 background for nickel. The most recent sample for nickel from well NC2-23 contained 0.16 mg/L of nickel, which was above the NRWQC and above Site 300 background. Zinc was below the reporting limit in surface water and shallow ground water samples from all locations except for W-812-1932, which contained 0.049 mg/L of zinc. This concentration, as well as all of the reporting limits, was below both the NRWQC for zinc and Site 300 background for zinc. Lead was below the reporting limit from all samples, although the reporting limit varied from below the NRWQC of 0.0025 mg/L to slightly above the NRWQC. All reporting limits for lead were below the Site 300 background of 0.02 mg/L.

Spring 6 and the five shallow ground water wells have been sampled for uranium since the completion of the SLERA. Table 3-8 and Figure 3-1 show the uranium data as of December 31, 2010. Figure 3-1 also shows the current sampling location for Spring 6. At the current Spring 6 sampling location, which is located northwest (upstream) of the confluence of Elk Ravine with drainage associated with the Building 812 Canyon, uranium remains below background levels and slightly above the ESL for uranium used in the SLERA. Uranium is also below background levels and slightly above the ESL for uranium used in the SLERA in samples collected from well NC2-23, which samples the shallow Qal/WBR HSU to the west of the Building 812 Canyon. Two of the wells sampling the shallow Qal/WBR HSU within the Building 812 Canyon have yielded samples containing uranium concentrations in excess of both the uranium ESL and Site 300 background (W-812-08 and W-812-1921). Well W-812-08 samples shallow ground water in the Building 812 Canyon just downgradient of the Building 812 firing table. Well W-812-1921 samples shallow ground water at the confluence of Elk Ravine and the Building 812 Canyon, downgradient of W-812-08. Uranium in samples from wells

W-812-1932 and W-812-2321 are at or below Site 300 background levels. Well W-812-1932 samples shallow ground water in the Building 812 Canyon north and upgradient of the area sampled W-812-08. Well W-812-2321 samples shallow ground water in Elk Ravine to the east of the Building 812 Canyon. Surface water within Elk Ravine southeast (downstream) of the confluence with the Building 812 Canyon drainage has not been sampled.

As discussed in Section 2.1.2, since the data cutoff date of October 2007 for the SLERA, surface water runoff samples were collected to characterize uranium activity and concentration in runoff potentially flowing into the Spring 6/Elk Ravine area as well as recharging the Qal/WBR HSU. Figure 2-1 shows the surface water runoff/stream channel sampling locations, total uranium activity and concentration, and the uranium-235/uranium-238 isotopic ratio from samples collected on January 22, 2010. Two locations, 3SW-812-001 (located at the confluence of the Building 812 Canyon drainage and Elk Ravine) and 3SW-812-006 (located north of the confluence in the Building 812 Canyon drainage stream channel), had total uranium concentrations of 130 and 120 µg/L, respectively, which exceeds the revised ESL of 50 µg/L (0.05 mg/L). As discussed in Section 2.1.2, these data suggest that in addition to surface water in Elk Ravine being potentially impacted from uranium in the Qal/WBR ground water discharging into Elk Ravine southeast of the Building 812 Canyon drainage confluence, surface water southeast of the confluence may also be negatively impacted from runoff during rain fall events.

3.1.2.2. Nature and Extent of Copper, Lead, Nickel, Zinc, and Total Uranium in Surface Soil

Figures 3-2 through 3-6 show uranium, copper, lead, nickel, and zinc concentrations in the Building 812 surface soil, as well as isoconcentration contours that represent various ESLs and background. Isoconcentration contours were hand drawn with the exception of the uranium 9.4 mg/kg background contour. This contour was generated using the commercially available software EarthVision, which uses an inverse distance weighting interpolation method. Uranium, copper, and lead all show a very similar distribution pattern. Nickel is present above background only on a knoll immediately to the south of Building 812. Copper, lead, and uranium are also present above background on this knoll. Copper, lead, and nickel are above background on this knoll at only a single sample location, their presence at this location appears discontinuous from contamination associated with the firing table. The presence of zinc above background in the Building 812 surface soil also does not appear to be associated with the Building 812 firing table, but with a drainage pipe that historically discharged from the eastern side of the Building 812 paved area.

3.1.2.3. Nature and Extent of Total Uranium, Uranium-238, and Thorium-228 in Subsurface Soil

Figure 3-7 shows total uranium concentrations and uranium-238 and thorium-228 activities in subsurface soil samples collected to a depth of 6 ft below ground surface. Most samples from boreholes located within the firing table contain total uranium concentrations in excess of the background concentration of 5.8 mg/kg and the ESL developed in the SLERA of 2 mg/kg. Only one sample, collected at 5 ft from borehole 812-01, contained uranium-238 activities in excess of the BCG (2,000 pCi/g). All samples analyzed for thorium-228 were collected from boreholes within the firing table (812-01, 812-02 and 812-03) and exceed the human health PRG that was used in the SLERA as an ESL (0.154 pCi/g). Site 300 background activities for thorium-228 have not been developed.

There are no threat to surface water or shallow ground water ESLs to evaluate the ecological threat from substances in surface soil and subsurface soil similar to the threat to ground water RSLs and PRGs used to evaluate the potential impact of surface soil and subsurface soil substances to drinking water. Therefore, it is unknown how the PCOECs in surface soil and subsurface soil could potentially impact the shallow ground water in the Qal/WBR HSU and ultimately the Spring 6/Elk Ravine surface water at levels that pose a risk to ecological receptors.

3.1.3. Current Knowledge on Contaminant Fate and Transport

Figure 3-8 shows the revised Site 300 general ecological conceptual site model for the PCOECs, which includes the exposure pathways identified as potentially significant in the SLERA. As described in Section 2.1.3, activities at the Building 812 facilities resulted in the release of heavy metals and radionuclides to surface soil and subsurface soil. Overland flow of water from rainfall and resuspension of contaminated surface soil and subsequent deposition onto the surface water may result in the migration of these contaminants to this surface water. Infiltration of rainwater may mobilize contaminants in the surface and subsurface soil to ground water within the $Tnbs_1/Tnbs_0$ and Qal/WBR HSUs. The Qal/WBR and $Tnbs_1/Tnbs_0$ HSUs may also locally discharge into the Elk Ravine area along stratigraphic and structural contacts, with the $Tnbs_1/Tnbs_0$ HSU potentially discharging into Elk Ravine northwest (upgradient) of the Building 812 Canyon drainage confluence, and the Qal/WBR HSU potentially discharging into Elk Ravine southeast (downgradient) of the confluence. The current Spring 6 sampling location is northwest of the confluence of Elk Ravine with the Building 812 Canyon drainage. Concentrations of PCOECs are currently below background in surface water samples collected at this location. No surface water samples are available from southeast of the confluence of the Elk Ravine and Building 812 Canyon drainages. Contaminants in the water column may also accumulate in the sediment in Elk Ravine. Although no PCOECs were detected in the sediment sampled from Elk Ravine directly upstream and downstream of the Building 812 Canyon confluence, sediment samples have not been collected in the pools located downstream of the Building 812 Canyon drainage confluence.

The potential fate and transport of copper, lead, and uranium in surface soil and subsurface soil was discussed in Section 2.1.3. In addition to these metals, nickel and zinc are also PCOECs in surface soil. Like copper and lead, nickel and zinc are also cations. As discussed in Section 2.1.3, soil pH and availability of charged sites on soil surfaces are the primary soil factors controlling their release to the pore-water. The EPA used pH and organic matter content in the literature evaluation for plants and invertebrates as the primary soil parameters affecting bioavailability and toxicity (U.S. EPA, 2005a). Table 3-9 presents the pH and organic matter criteria used by the EPA in their evaluation of the plant and invertebrate literature. No data on organic matter or pH are available from the Building 812 area. However, as discussed in Section 2.1.3, samples were available from other locations at Site 300. The average total organic carbon in these samples was 1.30% with a standard deviation of 0.19% (n=80). These same samples had an average pH average of 7.70 and a standard deviation of 0.64 (n=80). Available total organic carbon data from boreholes scattered throughout Site 300 averaged 0.21% with a standard deviation of 0.21% (n=30). Available pH data from borehole soil samples scattered throughout the site had an average of 8.55 and a standard deviation of 0.50 (n=34). These data suggest a medium bioavailability of metal cations to plants and soil invertebrates in the

Building 812 area based on pH and total organic carbon (Table 3-9), although the exact form and speciation of these metals will also affect bioavailability.

Like mobility, the bioavailability and subsequent toxicity of heavy metals once released to surface water is strongly dependent on various physicochemical characteristics of the water, including temperature, dissolved organic compounds, suspended particles, pH, and various inorganic cations and anions, including those composing hardness and alkalinity. Hardness is used as an indicator of these various inorganic cations and anions, and the NRWQC contain equations to adjust the criteria based on the hardness of the surface water, with the criteria increasing (i.e., toxicity decreasing) with increasing hardness (U.S. EPA, 1980, 1984, 1986, 1987, and 1995). The NRWQC used as screening levels in the SLERA were all based on a hardness of 100 mg/L as calcium carbonate ($CaCO_3$). Spring 6 hardness ranges between 230 and 260 mg/L. The NRWQC for copper has been recently revised to incorporate the concept of a biotic ligand (U.S. EPA 2007f), which is a complexing chemical that is a component of an organism (e.g., chemical site on a fish gill). Biotic ligands are affected by various inorganic species in the surface water. The biotic ligand model must be used to develop site-specific NRWQC for copper. Controls on uranium transport in water are discussed in Section 2.1.3.

Like other heavy metals, the toxicity of uranium in freshwater is dependent upon water hardness. Poston et al. (1984) conducted 48 hr acute toxicity and chronic reproduction tests on Columbia River water. The 48-hr LC_{50} of uranium (VI) was 6 mg/L. Acute toxicity diminished by a factor of 7.5 as mean water hardness and alkalinity values increased from 70 mg/L and 57 mg/L to 195 mg/L and 130 mg/L, respectively. This effect was most likely the result of complexation of the uranyl ion with carbonate ions.

3.1.4. Ecosystems at Potential Risk and Ecological Exposure Pathways

As described in Section 2.2.5 of the original Building 812 SLERA, vegetation habitats and communities at Site 300 were initially sampled and mapped in 1986 (Biosystems, 1986a). Rare plant surveys were also initially conducted in 1986 (Biosystems, 1986b). Site 300 vegetation types (including wetlands) and rare plants species were updated through additional surveys and mapping conducted in 1991, 1996, 1997, and 2002 (Jones and Stokes, 2002a and b). Appendix A lists the plant species observed at Site 300 and a discussion concerning their potential to occur at Building 812. The Building 812 OU is located within a grassland habitat consisting primarily of introduced annual and native perennial grasses. The area south and west of the firing table is composed primarily of the one-sided bluegrass native grass community. The area to the north and east of the firing table is composed primarily of annual nonnative grassland. The Big Tarplant (*Blepharizonia plumosa*), a California Native Plant Society List 1B species, is known to occur in the Building 812 area. The Building 812 area is bordered on the south and southwest by the Spring 6 riparian community within Elk Ravine. This wetland habitat is maintained by perennial water discharged from the underlying alluvial and bedrock deposits and seasonal rainfall. Red willow, mule-fat, various cattails, and rush occur in this riparian community. In addition, an ephemeral stream occurs to the east of the Building 812 Complex, and drains into the Spring 6 riparian community. Small areas of phreatic vegetation (primarily nettles) occur in this drainage, maintained by shallow alluvial ground water.

Animal surveys were initially conducted in 1986 (Biosystems, 1986c) with new surveys conducted in 2002. The new surveys were a mesocarnivore survey (CSUS, 2002), a small mammal inventory (Jones and Stokes, 2002c), a breeding raptor and loggerhead shrike status review (Bloom, 2002), an avian monitoring program (LLNL, 2003a), a bat survey (Rainey, 2003), special status reptile surveys (Swaim, 2002), amphibian surveys (LLNL, 2002), wet season branchiopod surveys (Condor Country Consulting, 2002), and valley elderberry longhorn beetle surveys (Arnold, 2002). Appendix A lists the animal species observed at Site 300 and a discussion concerning their potential to occur at Building 812. Species observed at the Building 812 area are typical of grassland species. Mammalian species include mice, hares, squirrels, skunks, foxes, coyote, and black-tailed deer. The American Badger (*Taxideae taxus*), a State species of special concern, is observed throughout Site 300, and may occur at Building 812. Site 300, and thus Building 812, is within the northern range of the federally endangered San Joaquin kit fox. However, no kit fox have ever been observed at Site 300, despite numerous surveys. Raptors are frequently observed hunting in the Building 812 area, and barn owl and great horned owl are frequently observed in the riparian area associated with Spring 6. Many raptors expected to utilize the Building 812 area are State species of special concern. Reptiles include various lizards and snakes. Amphibians also occur in the riparian area adjacent to Spring 6, including the California red-legged frog, a federally listed threatened species and State species of special concern. Spring 6 also supports the blue elderberry plant, a host species for the valley elderberry longhorn beetle (*Desmocerus californicus dimorphus*) a federally listed threatened species. Spring 6 also provides nesting habitat for red-winged blackbirds (*Agelaius phoeniceus*) and tricolored blackbirds (*A. tricolor*). The tricolored blackbird is a State species of special concern. A regionally important breeding colony of tricolored blackbirds is located in the Spring 6 riparian habitat. This species is also known to forage within the grasslands of Site 300 during the non-breeding season. Figure 3-9 shows the special-status species known to occur in the vicinity of Building 812.

The Spring 6/Elk Ravine riparian wetland ecosystem is potentially at risk from PCOECs present in the shallow alluvial groundwater. Current concentrations of PCOECs in surface water at the Spring 6 sampling location are below background levels. However, uranium and nickel are currently above background levels and ESLs in the shallow alluvial ground water within and east of the Building 812 drainage. Nickel is above the NRWQC and uranium is above the ESL for aquatic plants and aquatic invertebrates. Uranium is not above the ESL for fish. In addition, PCOECs found in the surface soil and subsurface soil may eventually migrate into the shallow ground water. This shallow ground water may then discharge into the Spring 6/Elk Ravine area at the confluence of the Building 812 Canyon drainage as well as east of this confluence. Aquatic plants and invertebrates are most directly at risk from the PCOECs that may eventually find their way to the Spring 6/Elk Ravine area surface water. The California red-legged frog is at risk primarily from secondary effects, due to a potentially diminished food supply available either during its larval or adult stage. For example, a reduction in benthic algae (a primary larval frog food source) could reduce the number of larval frogs that metamorphose into adults. A reduction in the number of aquatic invertebrates, many of which are larval stages of areal invertebrates, may reduce the food supply for adult frogs. However, the frog is unlikely to be directly at risk from the uranium levels currently detected in the shallow alluvial groundwater, given the uranium ESL for fish is well above the concentrations found in the shallow groundwater. It is also not likely to be directly at risk from heavy metals above NRWQC, given that these criteria are developed to protect the more sensitive aquatic invertebrates. Although benthos may be exposed to contaminants in Spring 6 sediment, no PCOECs were identified in the Spring 6 sediment, including in samples collected downgradient of the Building 812 drainage confluence.

The Building 812 grassland ecosystem is potentially at risk from PCOECs in surface soil, subsurface soil to a depth of 6 ft and shallow alluvial ground water. Soil invertebrates and grassland plants may be at risk from PCOECs in surface soil and subsurface soil. Assuming surface soil and subsurface soil PCOECs are sufficiently bioavailable, uptake of PCOECs by terrestrial plants may occur. Phreatic terrestrial vegetation within the Building 812 drainage may also uptake PCOECs found in the shallow alluvial ground water. Foraging animals (including mammals, birds, and invertebrates) may subsequently consume these plants. However, metals may accumulate in plant roots to a greater extent than in plant stems and leaves (Baker and Walker, 1990; Verkleij and Schat, 1990). This is particularly true for metals that are not micronutrients, such as uranium. This would limit the availability of the PCOECs to foraging animals. Incidental ingestion of surface and subsurface soil could also occur through grooming and consuming food items. Although the metals and radiological PCOECs in surface and subsurface soil have limited bioaccumulation potential (that is, concentrations increasing at higher levels in the food chain), they may bio-transfer to some degree though the food chain.

Although grassland terrestrial vertebrate species could be exposed to PCOECs through the inhalation of resuspended particulates both in ambient and burrow air, this pathway is not thought to be significant (U.S. EPA, 2005a). Amphibians may be exposed to the PCOECs in subsurface soil through adsorption if they estivate in subsurface burrows during the dry season, although little toxicological data are available on these species or this pathway. Such use of subsurface burrows by amphibians is less likely when surface water is present year round, as is the case with Spring 6.

Terrestrial species requiring daily water may also ingest PCOECs in the Spring 6/Elk Ravine area through drinking the surface water. Barn owls, California ground squirrels, and kit fox all likely obtain the majority of their water from food items (CWHRS, 2010a,d,f). Coyote, mule deer, and tricolored blackbirds all require some surface water (CWHRS, 2010b,g,j). However, all three are wide-ranging and are likely to obtain water from springs located throughout Site 300, not solely from Spring 6. The smaller ranging deer mouse likely use open water sources (CWHRS, 2010c), and populations directly adjacent to Spring 6 probably use this water source. However, populations located in more distally contaminated areas are unlikely to travel to Spring 6, and probably obtain their water from food sources.

Terrestrial species most at risk include those that have limited home ranges (thus spending the majority of their time within the contaminated area), are ground dwelling and consume primarily ground dwelling insects. The Building 812 grassland ecosystem has no strictly ground insectivorous small mammals, although ground dwelling insects do make up a portion of the deer mouse diet, and may be significant in the spring and fall (CWHRS, 2010c). Due to its arid nature, Site 300 does not have many bird species that consume primarily ground dwelling insects, and terrestrial insects such as spiders make up a significant portion of the tricolored blackbirds diet (especially during the breeding season), with grains and seeds foraged from grassland areas making up the remainder (CWHRS, 2010j). The ground dwelling insectivore rock wren (*Salpinctes obsoletus*) has been observed in the canyons east of Building 812, and likely forages in the Building 812 area. This species does not appear to require drinking water (CWHRS, 2010h). Figure 3-10 shows the Building 812 food web, which has been revised to more accurately represent species expected or known to occur at Building 812, as well as realistic food chain and environmental media relationships.

To further identify terrestrial species most at risk from PCOECs in surface soil, an evaluation of species home range, relevant biological data, quality of toxicological data, and available information concerning areal extent of contamination was conducted. Terrestrial plants, soil invertebrates, mammals, and birds were evaluated. Amphibians and reptiles were not evaluated due to the lack of available toxicological data. Small mammals and birds that: (1) live in soil or rock burrows, (2) eat soil invertebrates and (3) have very small home ranges were used as proxies for terrestrial reptiles. Amphibians were not evaluated as part of the terrestrial species evaluation, because they are unlikely to spend significant time in the dry, arid, upland portions of Building 812 when perennial water is available in Elk Ravine.

Table 3-10 presents the results of this evaluation. A total of approximately 2.6 acres in the Building 812 area exceed ESLs for terrestrial plants and soil invertebrates. While the lateral extent of copper, lead, nickel and zinc in the area southwest of facilities B, C, E and F is somewhat uncertain, the contours represent a conservative estimate of the area potentially exceeding ESLs and background levels. The lateral extent of phreatic vegetation potentially taking up shallow ground water containing elevated levels of uranium is also uncertain (and was not included in this analysis). Approximately 18 acres contain uranium levels in surface soil above background and above ESLs for ground squirrels, deer mouse, kit fox, and coyote. These 18 acres also include smaller areas above ESLs for copper, lead, nickel, and zinc (approximately 2.4 acres). For the small ranging ground squirrels and deer mouse, this area represents anywhere from 30 to 72 home ranges. However, considerable uncertainty exists with respect to the uranium TRV. In addition, the deer mouse is not a strict ground invertivore, as assumed for this analysis. These 18 acres represent between 0.07 and 2.8% of the home range for the coyote and kit fox. Approximately 1.5 of these acres exceeded ESLs for the mule deer, which represents up to 0.59% of its home range. While mule deer and coyote require open water sources, they likely use many Site 300 spring sources in addition to Spring 6 as they range through Site 300 in search of food.

Between 0.61 and 2.4 acres are above ESLs for the three avian species. For the tricolored blackbird and the barn owl, this represents 0.13% and 0.37% of their home range, respectively. Like the mule deer and coyote, the tricolored blackbird likely gets its water from multiple sources throughout Site 300. For the more locally ranging rock wren, this represents up to 12% of its home range.

3.1.5. Determination of the Status of Initial PCOECs as Final PCOECs

Based on the evaluation of the initial PCOECs in Sections 3.1.1 through 3.1.4, the initial PCOECs were categorized with respect to their status as final PCOECs that would move forward to the baseline ecological risk assessment. The following three decisions were made for each of the initial PCOECs:

1) There is adequate information on the PCOEC to conclude that ecological risks are negligible and therefore there is no need for remediation on the basis of ecological risk,
2) The information on the PCOEC is not adequate to make a decision at this point, and additional evaluation as part of the screening-level ecological risk assessment is required, or

3) The available information indicates a potential for adverse ecological effects from the PCOEC, and a more thorough assessment in the baseline ecological risk assessment is warranted.

Table 3-11 shows the results of the categorization of the initial PCOECs. Although only uranium and zinc were identified as COPECs in surface water and only copper, nickel, and uranium were identified as COPECs in shallow ground water in the SLERA, copper, lead, nickel, uranium, and zinc have all been identified as initial PCOECs in surface water and shallow ground water as a result of the evaluation in Sections 3.1.1 through 3.1.4. This is because: (1) surface water southeast of the Building 812 Canyon drainage has not been characterized, (2) data on copper, nickel, lead, and zinc in shallow ground water is up to seven years old, and (3) the potential ecological impact of copper, lead, nickel, and zinc in surface soil to shallow ground water and surface water is not known. However, there is not adequate information on copper, lead, nickel, uranium, or zinc in surface water or copper, lead, nickel or zinc in the shallow ground water to make a decision at this point concerning their status as final PCOECs for purposes of the baseline ecological risk assessment. Therefore, additional evaluation as part of the screening-level ecological risk assessment is required to determine if these PCOECs should move forward to the baseline ecological risk assessment. However, the available information on uranium in shallow ground water does indicate a potential for adverse ecological effects from this PCOEC, and a more thorough assessment in the baseline ecological risk assessment is warranted. Therefore, this PCOEC will move forward to the baseline ecological risk assessment.

While no COPECs were identified in sediment in the SLERA, because sediment samples were not collected from the pool downgradient of the existing sampling locations, copper, lead, nickel, uranium, and zinc were all identified as initial PCOECs for sediment. However, there is not adequate information on these PCOECs to make a decision at this point concerning their status as final PCOECs for purposes of the baseline ecological risk assessment. Therefore, additional evaluation as part of the screening-level ecological risk assessment is required to determine if these PCOECs should move forward to the baseline ecological risk assessment.

As discussed above in Section 3.1.1.3, there is adequate information on thorium-228 to conclude that the ecological risks associated with this PCOEC are negligible and therefore there is no need for remediation on the basis of ecological risk. Therefore, this analyte will not be included in the baseline ecological risk assessment, and will be eliminated from further consideration.

The available information on the surface soil PCOECs copper, lead, nickel, uranium, and zinc and the subsurface soil PCOECs uranium and uranium-238 indicates a potential for adverse ecological effects from these PCOECs, and a more thorough assessment is warranted. These PCOECs will therefore move forward to the baseline ecological risk assessment.

3.1.6. Identification of Assessment Endpoints

Assessment endpoints are "an explicit expression of the environmental value to be protected" (U.S. EPA, 1997). Assessment endpoints focus the risk assessment on particular components of the ecosystem that could be adversely affected by contaminants from the site. Appropriate assessment endpoints might involve local populations of a particular species, community-level integrity, and/or habitat preservation.

Based on the review of the ecological effects of the PCOECs, current nature and extent of contamination, fate and transport of the PCOECs and the ecosystems at risk, the assessment endpoints listed in Table 3-12 were selected. The single aquatic assessment endpoint is a functioning Spring 6/ Elk Ravine aquatic ecosystem. Wetland functions have been variously defined over the years by numerous authors and organizations (U.S. EPA 1995b, 2000; U.S. GS 1997, Hammer 1992). These functions can be grouped into three broad categories:

- Biological functions: this includes providing habitat and life support to microbial organisms, invertebrate and vertebrate animals, and microscopic and macroscopic plants that depend upon the wetland.
- Physical/hydrologic functions: this includes providing ground water recharge and/or stream baseflow, providing sediment traps/erosion protection, and flood control.
- Chemical functions: this includes water quality, sediment quality and biogeochemical cycling.

The Building 812 PCOECs can potentially impact the biological and chemical functions of the Spring 6/Elk Ravine aquatic ecosystem. Therefore, for the purposes of the Building 812 baseline ecological risk assessment, a functioning Spring 6/Elk Ravine aquatic ecosystem will be defined as an aquatic system in which water and sediment quality is sufficient to support local microbial, plant, invertebrate and vertebrate life. This endpoint incorporates healthy aquatic plant and invertebrate communities, which are particularly sensitive to the PCOECs. The California red-legged frog is dependent upon these communities as a food source. A functioning aquatic ecosystem also requires a healthy benthic community. Thus, a functioning Spring 6/ Elk Ravine aquatic ecosystem will provide protection these representative receptors of ecological interest.

Terrestrial assessment endpoints listed Table 3-12 include the sustainability of terrestrial plant and soil invertebrates, and the sustainability of rock wren and deer mouse populations. Sustainability refers to the community or population's ability to persist. The term comes from the management of exploited wildlife resources (i.e. hunting and fishing), in which it refers to maintaining a harvested population in sufficient numbers so it does not drop to the point that results in the extirpation of the population (Milner-Gulland and Akcakaya 2001, Peterson et al. 2004, Koons et al. 2006, Nasi et al. 2008). In addition to being large enough to withstand human harvest, the population must be sufficiently large that its key ecological functions are maintained, such a providing a prey-base for other predators (Marcot and Heyden 2001). For the purposes of the Building 812 baseline ecological risk assessment, the sustainability of a community or population is defined as the ability to persist into the future as a self-sustaining population or community while retaining its key ecological functions at the local Building 812 scale.

The terrestrial assessment endpoints represent components of a functioning ecosystem. The key ecological function of the terrestrial plant and soil invertebrate communities is providing the base of the food chains. The key ecological function of the deer mouse is to serve as an important food source to higher-level predators, while the rock wren serves as an important invertebrate predator, and may itself serve as a food source to mammalian and avian carnivores. The deer mouse and rock wren also represent vertebrate species that may be maximally exposed. In addition, the availability of toxicity information was considered when selecting the assessment endpoints. For example, no toxicity information is available for reptiles such as the side-blotched lizard. Protection of these assessment endpoints should provide protection for the entire Building 812 ecosystem.

Two conceptual site models that incorporate the assessment endpoints were developed to guide the development of measurement endpoints. These are shown in Figures 3-11 and 3-12. These conceptual site models show the complete exposure pathways that will be evaluated in the baseline ecological risk assessment.

3.2. Additional Screening-Level Ecological Risk Assessment Activities

Additional screening-level ecological risk assessment activities will be conducted on copper, lead, nickel, uranium (as a heavy metal), and zinc in sediment and surface water, and copper, lead, nickel, and zinc in shallow ground water to determine if these PCOECs should move forward to the baseline ecological risk assessment. In addition, the additional lithium and radium-226 data in shallow ground water and surface water collected as part of the human health risk assessment activities will be screened against ESLs. Activities will include the collection of additional characterization data, and the comparison of these characterization data to ecological screening levels.

3.2.1. Collection of Additional Characterization Data to Support the SLERA

The following additional characterization data will be collected to support filling in data gaps in the SLERA:

- Sampling and analysis of a sediment sample for uranium, copper, lead, nickel, zinc, total organic carbon, and pH,
- Sampling and analysis of surface water for uranium, copper, lead, nickel, zinc, pH, total hardness, total dissolved solids, and total suspended solids,
- Sampling and analysis of shallow ground water samples for copper, lead, nickel, and zinc.

The additional characterization activities are described in more detail in the Characterization Work Plan, which includes the numbers and locations of samples, sampling and analytical protocols, and associated quality assurance and quality control. These characterization activities are briefly described below.

3.2.1.1. Sediment Characterization

Results from three sediment samples collected southeast of the confluence between Elk Ravine and the Building 812 drainage down to the Elk Ravine pool are available. However, data are not available from the pool downgradient from Building 812 that is the primary habitat for the California red-legged frog. Therefore, additional sampling is necessary to completely characterize the presence of uranium and metals, and their potential bioavailability, in the sediment within the pool for the baseline ecological risk assessment. One sediment sample is proposed to be collected from the pool and analyzed for uranium, copper, lead, nickel, zinc, pH, and total organic carbon (TOC). Sediment sampling is planned for fall of 2011. Additional sampling and analysis details can be found in Section 3.6 of the Characterization Work Plan.

3.2.1.2. Surface Water and Shallow Ground Water Characterization

As discussed above, surface water in Elk Ravine is currently sampled only at the location designated as Spring 6. This location is upgradient of Elk Ravine and the Building 812 Canyon drainage (Figure 3-1). However, high uranium concentrations are consistently detected in the shallow alluvial/weathered bedrock (Qal/WBR) HSU ground water that appears to discharge into Elk Ravine at and to the southeast (downgradient) of the Building 812 drainage (Figure 3-1). In addition, there have been sporadic detections of copper and nickel in the shallow ground water above background and ecological screening levels, although shallow ground water samples are not regularly analyzed for these metals. Uranium and zinc have also been historically detected in Spring 6 above background and ecological screening levels (Table 3-8). Concentrations of copper, lead, nickel, and zinc have also been detected in surface soil exceeding ecological screening levels and above background that could potentially infiltrate to the shallow ground water. Therefore, it is necessary to further characterize the shallow ground water for the presence of copper, lead, nickel, and zinc and surface water to the south of the Building 812 drainage for the presence of copper, lead, nickel uranium and zinc to complete the SLERA. Information on the pH, total hardness (as $CaCO_3$), total dissolved solids (TDS), and total suspended solids (TSS) content of the surface water is also needed to better assess the bioavailability of these metals in the Spring 6/Elk Ravine area surface water. The current Spring 6 sampling location and surface water present in Elk Ravine east of the Building 812 drainage will be sampled for uranium, copper, lead, nickel, and zinc, total hardness, TDS, TSS, and pH. Shallow alluvial ground water will be sampled for copper, lead, nickel and zinc (shallow alluvial ground water will also be sampled for uranium for purposes of the baseline risk assessment). Locations and additional sampling and analysis details can be found in Section 3.5 of the Characterization Work Plan.

3.2.2. Evaluation of Additional Characterization Data for the SLERA

Table 3-13 lists the ESLs that will be used to evaluate the additional characterization data to fill in data gaps identified in the Building 812 SLERA. The concentrations of copper, lead, nickel, and zinc from each sediment sample (existing and planned) will be compared to ESLs in the Screening Quick Reference Tables (SQuiRTs), developed by the National Oceanic and Atmospheric Administration (Buchman, 2008) for sediment. Uranium concentrations in each sediment sample will be compared to the ESL used in the SLERA (100 mg/kg) from Shephard et al. (2005). Results exceeding ESLs will then be compared to Site 300 background values for surface soil. Results exceeding ESLs and background will be mapped to identify specific locations exceeding both ESLs and background (especially with respect to the Building 812 drainage). Data on total organic carbon and pH will be evaluated to qualitatively assess potential bioavailability. For analytes that are potentially screened out as being below the SQuiRTs but above Site 300 background, additional relevant toxicology data available in the U.S. EPA ACQUIRE data set will be reviewed to ensure the most current toxicology data are considered prior to screening out the analyte. The spatial extent and the extent to which concentrations exceed ESLs and background will be evaluated to qualitatively assess ecological significance.

The concentrations of copper, lead, nickel, and zinc detected in the most recently collected surface water samples will be adjusted for hardness if equations are available to conduct the adjustment. Adjusted concentrations will be compared to the appropriate NRWQC ESL. No existing ESL is available for lithium in surface water. Therefore, the EPA EcoTox database (www.epa.gov/ecotox/) was queried on October 12, 2011 for available aquatic toxicity information on lithium. The search endpoints included growth, ecosystem effects, mortality, reproduction, and population level effects, which produced a total of 89 records. Records reporting NOEC, LOEC and MATC data were further reviewed. The lowest NOEC reported was 0.2 mg/L of lithium for the growth of larval fathead minnows (Long et al., 1998). This value was selected as the ESL for lithium in surface water. Activities of radiuim-226 collected to support the human health risk assessment will be compared to the U.S. DOE Biota Concentration Guide for Aquatic Life for radium-226 (U.S. DOE, 2005). Concentrations of uranium will be compared to the ESL recommended in Section 3.1.1.1 (0.05 mg/L), based on data presented in Shepard et al. (2005). Any concentration exceeding ESLs will be compared to Site 300 background. Results exceeding ESLs and background will be mapped to identify specific locations exceeding both ESLs and background (especially with respect to the Building 812 drainage).

The concentrations of copper, lead, nickel, and zinc detected in the most recently collected ground water sample will be compared to the appropriate NRWQC ESL assuming a baseline hardness of 100 mg/L. Any concentration exceeding ESLs will be compared to Site 300 background. Shallow ground water concentrations will not be adjusted for actual hardness as aquatic organisms are not actually exposed to the shallow ground water. The screening of shallow ground water against the NRWQC and Site 300 background will be conducted to determine if the analytes should move forward to the baseline ecological risk assessment in which their potential impact on surface water would be modeled and their uptake by phreatic vegetation considered.

3.2.3. Screening-Level Ecological Risk Assessment Scientific/Management Decision Point

The results of the SLERA evaluation of additional sediment, surface water and ground water data will be presented to the regulatory agencies upon completion of the additional characterization activities and subsequent SLERA evaluation. DOE/LLNL will present their conclusions as to the status of each initial PCOEC and whether the PCOEC should progress to the baseline ecological risk assessment. Any potential follow-on work would be dependent upon the availability of funding.

3.3. Baseline Ecological Risk Assessment Study Design

The baseline ecological risk assessment study design focuses on assessing the ecological impact of copper, lead, nickel, uranium (as a heavy metal), and zinc in surface soil, uranium (as a heavy metal) in subsurface soil, and uranium in shallow ground water to the Building 812 aquatic and terrestrial environment. The radionuclide uranium-238 in subsurface soil will not be directly assessed in this phase of the baseline ecological risk assessment. This is because the single borehole in which this PCOEC was detected in excess of the BCG (812-01, Figure 3-7) is located within the boundary of the firing table, and is bounded by other boreholes with uranium-238 activities below the BCG. This area will most likely be addressed in any remedial alternative selected. If this area is not addressed in the selected remedial alternative, the ecological impact of this PCOEC will be evaluated.

3.3.1. Identification of Measurement Endpoints

A measurement endpoint is defined as "a measureable ecological characteristic that is related to the valued characteristic chosen as the assessment endpoint" and is a measure of biological effects. This includes measures of exposure as well as measures of effect. Table 3-14 lists the proposed measurement endpoint for each of the proposed assessment endpoints and each associated PCOEC. While the concentrations of copper, nickel, uranium, and zinc in surface soil and uranium in subsurface soil are in excess of their respective ESLs for terrestrial plants and soil invertebrates, the area exceeding ESLs for these assessment endpoints and PCOECs are relatively small. The size of this area suggests these endpoints will not drive remediation. Therefore, neither the terrestrial plant assessment endpoint nor the soil invertebrate endpoint will be evaluated in the Building 812 baseline ecological risk assessment at this time and associated measurement endpoints are not provided for these assessment endpoints. Upon completion of the human health risk assessment and rock wren/deer mouse ecological risk assessment, the PCOECs associated with the terrestrial plant and soil invertebrate assessment endpoints will be re-evaluated to determine if they should progress to a baseline ecological risk assessment.

Table 3-15 describes the associated activities required to develop and evaluate the Building 812 measurement endpoints. Measurement endpoints for this phase of the Building 812 baseline ecological risk assessment consists of comparing modeled predicted contaminant levels in surface water to ESLs, and identifying terrestrial areas containing a Hazard Quotient (HQ) greater than 1 for the deer mouse and rock wren and relating that area to the species habitat requirements. As described in more detail in Sections 3.3.4.3 and 3.3.4.4 below, the uranium exposure to the deer mouse and rock wren will be determined by: 1) measuring the uranium concentrations in soil invertebrates, plants and surface and subsurface soil, 2) developing a defensible uranium Toxicity Reference Value using the methods used by the EPA to develop ecological soil screening levels (EcoSSLs) for mammals and birds, 3) conducting exposure modeling to estimate exposure to these two receptors, 4) comparing the modeled exposure to the developed TRV and calculating a HQ. The copper, lead, nickel and zinc exposure to the deer mouse and rock wren will be determined by: 1) conducting exposure modeling using available biotransfer factors used by the EPA in developing EcoSSLs, and 2) comparing the modeled exposure to the available TRVs developed by the EPA in developing EcoSSLs and calculating a HQ. The characterization of risk from the estimated exposure will be done by: 1) determining the percentage of the local and Site 300 population occurring in areas with an HQ>1 for each PCOEC, 2) identifying areas with HQs>1 for multiple PCOECs, and 3) reviewing the literature for available information on habitat area requirements for viable populations, as well as the synergistic effects of the PCOECs. Similar to the concept of sustainable populations, a viable population refers to a population that persists over a relatively long time period (Gilpin and Soule 1986, Bergman et al. 1993).

DOE/LLNL may propose follow-on laboratory bioassays or population field studies depending on the outcome of the initial phase of the baseline ecological risk assessment and discussion with the regulatory agencies at the Scientific Management Decision Point at the completion of the work outlined in Table 3-15. Any potential follow-on work would be dependent upon the availability of funding. The following sections contain additional detail concerning the data requirements and the evaluation of the measurement endpoints.

3.3.2. Collection of Additional Characterization Data to Support the Baseline Ecological Risk Assessment

The following additional characterization activities are proposed to provide the data needed to carry out the activities listed in Table 3-15:

- Conducting a surface soil gamma radiation survey to refine the areas where concentrations of uranium in surface soil exceed background,
- Installing additional boreholes and obtaining additional subsurface uranium data,
- Collecting data on the physical characteristics and form of the solid phase uranium present in the Building 812 area to provide information on bioavailability,
- Mapping of the extent of phreatic vegetation in the Building 812 drainage,
- Determining the concentrations of uranium in representative terrestrial and phreatic vegetation and soil invertebrates along a uranium concentration gradient, and
- Collecting additional surface water and shallow ground water data to support modeling the potential impact of surface and subsurface soil PCOECs on surface water in Spring 6/Elk Ravine.

High resolution maps of the distribution of uranium-238 in excess of background in surface soil and subsurface soil data to a depth of 6 ft will provide the basis from which to conduct additional ecological exposure assessment activities. As discussed in Section 2.2.1.1, a surface soil gamma radiation survey will be conducted to refine the activities of uranium-238 in surface soil. The Uranium-238 Surface Soil Gamma Radiation Survey Work Plan (Energy Solutions, 2011) describes the surface soil survey in more detail. As total uranium for both natural and depleted uranium is composed of over 99% uranium-238 by mass, the results of this survey will be used to create a uranium surface soil concentration map. Also as discussed in Section 2.2.1.1, a limited number of additional boreholes will be drilled and sampled for uranium-238 as described in the Characterization Work Plan. As with the surface soil data, the uranium-238 activity will be used to calculate a uranium concentration. A weighted average of the uranium concentration will then be calculated for each location with data from more than one depth. This weighted average data will be combined with the surface soil map to create a second uranium soil concentration map that combines the surface soil and any available subsurface soil uranium concentration data.

As described in Section 2.2.1.1, uranium solid phase and grain size distribution characterization will be conducted. This information can also provide information on potential mobility and bioavailability. Additional details can be found in Sections 3.2 and 3.3 of the Characterization Work Plan.

Additional surface water and shallow ground water characterization activities to fill in data gaps identified in the SLERA are described above in Section 3.2.1.2. In addition to the analytes described in Section 3.2.1.2, uranium data will also be collected from the shallow ground water wells to provide data for the modeling effort. Additional details can be found in Section 3.5 of the Characterization Work Plan.

The following additional characterization activities are described in more detail in the Characterization Work Plan, which includes the numbers and locations of samples, sampling and analytical protocols, and associated quality assurance and quality control. These characterization activities are briefly described below.

3.3.2.1. Phreatic Vegetation Mapping

The phreatic vegetation within the Building 812 drainage is a potential pathway to expose terrestrial vertebrates species to uranium via uptake of the shallow ground water and subsequent foraging by the terrestrial species. The extent of the phreatic vegetation, and the plant species present, is not well defined. Phreatic species present will be identified to a minimum of genus level. Additional mapping details can be found in Section 3.7 of the Characterization Work Plan.

3.3.2.2. Characterization of Uranium Uptake by Vegetation

A pilot study was initiated in May of 2010 to develop a vegetation sampling and analysis protocol for use in the baseline ERA. The goals of the study were to: 1) develop a sampling methodology for the vegetation types found in the Building 812 area (annual exotic and native perennial grasses in the upland areas, phreatic vegetation in the Building 812 drainage), 2) determine if uranium reporting limits in vegetation were adequate for baseline ERA, and 3) obtain preliminary information concerning uptake characteristics along a uranium concentration gradient. Four locations were sampled in the pilot study, which spanned a uranium concentration gradient of 3.6 to 65 pCi/g. Preliminary results indicate adequate reporting limits can be reached for use in the baseline ERA. Final locations will be selected based on the results of the gamma radiation surface soil survey, planned for the summer of 2011. Additional sampling and analysis details can be found in Section 3.8 of the Characterization Work Plan.

Results will be used to determine if uptake of uranium by vegetation is dependent upon the uranium concentrations in the soil. That is, is the ratio between uranium in the soil and uranium in vegetation a constant, or does uptake by vegetation increase with increasing uranium in the soil? If the uptake is constant, a single bioaccumulation factor (uranium in vegetation/uranium in soil) will be developed. If the uptake increases with increasing soil uranium, a vegetation uptake regression equation will be developed.

3.3.2.3. Characterization of Uranium Uptake by Soil Invertebrates

A pilot study is planned for the fall of 2011 to develop a soil invertebrate sampling and analysis protocol for use in the baseline ecological risk assessment. The goals of the study are to: 1) develop a sampling methodology for the types of soil invertebrates found in the Building 812 area, 2) determine if uranium reporting limits in soil invertebrates are adequate for the baseline ERA, and 3) obtain preliminary information concerning uptake characteristics along a uranium concentration gradient. The results of the pilot study will be used to adjust the protocol as needed. Four locations are planned for the pilot study, which span a uranium concentration range of 3.6 to 65 pCi/g. The locations to be used in the invertebrate pilot study are coincident with the locations used in the vegetation pilot study. This pilot study is dependent upon receiving a Scientific Collecting Permit from the California Department of Fish and Game, as well as the approval of various work permits. If it is not possible to complete the pilot study in the fall of 2011, soil invertebrate sampling will go forward in the spring of 2012 based in part on techniques verified by the vegetation pilot study. Final locations will be selected based on the results of the gamma radiation surface soil survey, planned for the summer of 2011. Additional sampling and analysis details can be found in Section 3.9 of the Characterization Work Plan.

Results will be used to determine if uptake of uranium by soil invertebrates is dependent upon the uranium concentrations in the soil. The data will allow evaluation if the ratio between uranium in the soil and uranium in soil invertebrates is a constant, or if uptake by soil invertebrates increases with higher uranium concentrations in the soil. If the uptake is constant, a single bioaccumulation factor (uranium in soil invertebrates/uranium in soil) will be developed. If the uptake increases with increasing soil uranium concentration, a soil invertebrate uptake regression equation will be developed.

3.3.3. Evaluation of Aquatic Measurement Endpoints

Currently, the only potential adverse ecological impact identified to the Spring 6/Elk Ravine assessment endpoint is from copper, lead, nickel, uranium, and zinc in surface soil, and uranium in subsurface soil and shallow ground water. This potential adverse ecological impact would be from the migration of these PCOECs to the surface water in Spring 6/Elk Ravine at concentrations exceeding their respective ESLs. The measurement endpoint for these PCOECs is their modeled future concentrations in the surface water in Spring 6/Elk Ravine. The modeled concentrations are evaluated by comparing them to surface water ESLs shown in Table 3-13.

3.3.3.1. Fate and Transport Modeling

Upon completion of the additional characterization activities, a modeling methodology will be developed to evaluate the threat to the Spring 6/Elk Ravine surface water from copper, lead, nickel, uranium and zinc in surface soil, and uranium in subsurface soil and shallow ground water using site-specific data. The specific approach has not yet been developed, as it will depend on the outcome of the additional characterization activities. Upon completion of the characterization activities and subsequent analysis of the resulting data, a modeling methodology will be developed and discussed with the regulatory agencies. Predicted concentrations of PCOECs in the Spring 6/Elk Ravine area surface water will be compared to NRWQCs (for copper, lead, nickel, and zinc), the uranium ESL, and Site 300 background. Results will be summarized, and uncertainties discussed. The ecological significance of the modeled concentrations will be qualitatively assessed by determining the magnitude the modeled concentrations exceed ESLs/Site 300 background and the predicted spatial extent of any elevated concentrations.

3.3.4. Evaluation of Terrestrial Measurement Endpoints

The assessment of potential adverse terrestrial ecological impacts will focus on evaluating the ecological impacts of copper, lead, nickel, and zinc in surface soil, and uranium in surface and subsurface soil to the rock wren and deer mouse. Although the terrestrial vegetation community and terrestrial soil invertebrate community assessment endpoints are discussed below, no baseline ecological risk assessment activities are proposed for these assessment endpoints at this time.

For the rock wren and the deer mouse assessment endpoints, exposure modeling using site-specific exposure parameters will be conducted, and exposure to multiple PCOECs will be considered. In addition, new TRVs and bioaccumulation factors for uranium will be developed, as there is much less confidence associated with these parameters than with the available parameters for copper, lead, nickel, and zinc. The risk associated with the estimated exposure will be characterized by relating the area of impacted habitat to that needed to maintain viable populations. The focus of the baseline ecological risk assessment will be on further refining the concentration of PCOECs in surface soil and subsurface soil that represents an actual ecological hazard.

3.3.4.1. Terrestrial Vegetation Community Assessment Endpoint

As described above in Section 3.3.1, there are currently no measurement endpoints proposed for the terrestrial vegetation community assessment endpoint. Although no baseline ecological risk assessment activities are planned for this assessment endpoint, the copper, lead, nickel and zinc ESL contours in surface soil will be updated using the EarthVision software. In addition, the uranium concentrations maps and associated ESL contours in surface soil and subsurface soil will be updated to include the new characterization data.

At the conclusion of the human health risk assessment and the rock wren/deer mouse ecological risk assessment, the area containing copper, nickel, uranium, or zinc concentrations above ESLs for terrestrial plants and Site 300 background will be re-evaluated to determine if they should progress to a baseline ecological risk assessment.

The results of the re-evaluation will be presented to the regulatory agencies at the Scientific/Management Decision Point (Section 3.3.5) at the completion of the human health and ecological baseline risk assessment activities. DOE/LLNL will present their conclusions as to whether there is enough information to make a remedial action decision or if the PCOECs associated with this assessment endpoint should progress to a baseline ecological risk assessment. Any potential follow-on work would be dependent upon the availability of funding.

3.3.4.2. Terrestrial Soil Invertebrate Community Assessment Endpoint

As described above in Section 3.3.1, there are currently no measurement endpoints proposed for the terrestrial soil invertebrate community assessment endpoint. Although no baseline ecological risk assessment activities are planned for this assessment endpoint at this time, the copper, lead, nickel, and zinc ESL contours in surface soil will be updated using the EarthVision software. In addition, the uranium concentration maps and associated ESL contours in surface soil and subsurface soil will be updated to include the new characterization data.

At the conclusion of the human health risk assessment and the rock wren/deer mouse ecological risk assessment the area containing copper, nickel, uranium or zinc concentrations above ESLs for terrestrial soil invertebrates and Site 300 background will be re-evaluated to determine if they should progress to a baseline ecological risk assessment.

The results of the re-evaluation will be presented to the regulatory agencies at the Scientific/Management Decision Point (Section 3.3.5) at the completion of the human health and ecological baseline risk assessment activities. DOE/LLNL will present their conclusions as to whether there is enough information to make a remedial action decision or if the PCOECs associated with this assessment endpoint should progress to a baseline ecological risk assessment. Any potential follow-on work would be dependent upon the availability of funding.

3.3.4.3. Local Rock Wren Population Assessment Endpoint

For copper, lead, nickel, and zinc in surface soil, and for uranium in surface soil and subsurface soil to a depth of 6 ft, exposure to the rock wren will be modeled using site-specific data and species-specific exposure parameters. The exposure modeling for uranium will be conducted as follows. First, using the results of the uranium soil invertebrate uptake study (Section 3.3.2.3), a map of soil invertebrate uranium concentrations will be constructed based on the combined surface soil/subsurface soil uranium concentration map. Next, suitable rock wren habitat will be identified. Within this area, rock wren home ranges will be mapped and a 95%

UCL of uranium concentration in soil invertebrates calculated for each home range. The surface soil only uranium concentration map will be used to estimate exposure from incidental soil ingestion using the 95% UCL of uranium concentration in surface soil for each mapped home range. For each rock wren home range, rock wren exposure as mg of uranium/kg of body weight/day will be estimated using rock wren-specific exposure parameters for diet, body weight, area use and incidental ingestion of soil. Rock wren exposure parameters will be developed and approved by the regulatory agencies prior to the commencement of exposure modeling.

The exposure modeling for copper, lead, nickel and zinc in surface soil will be conducted as follows. First, a map of soil invertebrate concentrations will be constructed for each metal using the biotransfer factors used by EPA in developing the Ecological Soil Screening Levels (U.S. EPA, 2007g) based on the surface soil concentration maps for each metal. An invertebrate biotransfer factor is not available for nickel, due to extreme inconsistency in the available data (U.S. EPA, 2007g). EPA found some studies in which nickel soil concentrations were positively correlated with nickel uptake in invertebrates, and other studies in which nickel uptake was negatively correlated. In order to estimate nickel concentrations in the invertebrate food source for the rock wren, a biotransfer factor of 0.5 will be used. Next, suitable rock wren habitat will be identified. Within this area, rock wren home ranges will be mapped and a 95% UCL of concentrations for each metal in soil invertebrates will be calculated for each home range. Exposure from incidental soil ingestion will use the 95% UCL of the individual metal concentrations in surface soil for each mapped home range. For each rock wren home range, rock wren exposure as mg of metal/kg of body weight/day will be estimated using rock wren-specific exposure parameters for diet, body weight, area use and incidental ingestion of soil. Rock wren exposure parameters will be developed and approved by the regulatory agencies prior to the commencement of exposure modeling.

Rock wren exposure for each metal will be compared to a Toxicity Reference Value (TRV) expressed as mg of metal/kg of body weight/day to determine a Hazard Quotient (HQ). For copper, lead, nickel, and zinc, the avian TRV will be based on the TRV developed by the EPA for use in developing the EcoSSLs will be used (U.S. EPA, 2007c, 2005b, 2007d, 2007e, Table 3-7). For uranium, a new TRV will be developed by evaluating all available TRVs identified from the literature following as closely as possible the method used by the U.S. EPA in developing TRVs for use in developing EcoSSLs (U.S. EPA, 2003a,b and U.S. EPA, 2007a,b). All TRVs will be approved by the regulatory agencies prior to the commencement of exposure modeling.

The characterization of risk associated with metal exposure to the rock wren will be conducted as follows. Home ranges with an HQ>1 for each PCOEC will be mapped on a single map. Areas with multiple metals with an HQ>1 will be identified. Areas with an HQ>1 but below Site 300 background will also be identified. A review of the literature to identify synergistic or antagonistic effects of PCOECs will be conducted to evaluate the effects of multiple PCOECs. The number of home ranges impacted will be compared to the total number of home ranges available at Building 812 and Site 300. The literature on area requirements for viable populations will be reviewed to determine the potential ecological significance of the impacted area to the continued existence of the population.

The results of the exposure estimation and risk characterization will be presented to the regulatory agencies at the Scientific/Management Decision Point (Section 3.3.5) at the completion of the human health and ecological baseline risk assessment activities. DOE/LLNL will present their conclusions as to whether there is enough information to make a remedial action decision or if additional assessment is needed. This will allow the agencies to provide comment to DOE/LLNL prior to finalization of the baseline human health and ecological risk assessment. Any potential follow-on work would be dependent upon the availability of funding.

3.3.4.4. Local Deer Mouse Population Assessment Endpoint

For copper, lead, nickel, and zinc in surface soil, and for uranium in surface soil and subsurface soil, exposure to the deer mouse will be modeled using site-specific data and species-specific exposure parameters. The exposure modeling for uranium will be conducted as follows. First, using the results of the uranium vegetation uptake study (Section 3.3.2.2), a map of the vegetation uranium concentrations will be constructed based on the combined surface soil/subsurface soil uranium concentration map. Next, suitable deer mouse habitat will be identified. Within this area, deer mouse home ranges will be mapped, and a 95% UCL of uranium concentration in vegetation calculated for each home range. The combined surface soil/subsurface soil uranium concentration map will be used to estimate exposure from incidental soil ingestion using the 95% UCL of uranium concentration for each mapped home range. The invertebrate uranium concentration map developed for the rock wren will also be used to estimate exposure from invertebrate consumption using a 95% UCL of uranium concentration in invertebrates for each mapped home range. For each deer mouse home range, deer mouse exposure as mg of uranium/kg of body weight/day will be estimated using deer mouse-specific exposure parameters for diet, body weight, area use and incidental ingestion of soil. Deer mouse exposure parameters will be developed and approved by the regulatory agencies prior to the commencement of exposure modeling.

The exposure modeling for copper, lead, nickel, and zinc in surface soil will be conducted as follows. First, a map of soil invertebrate concentrations and a map of terrestrial vegetation concentrations will be constructed for each metal using the biotransfer factors used by EPA in developing the EcoSSLs (U.S. EPA, 2007g) based on available Building 812 soil concentration data. An invertebrate biotransfer factor is not available for nickel, due to extreme inconsistency in the available data (U.S. EPA, 2007g). EPA found some studies in which nickel soil concentrations were positively correlated with nickel uptake in invertebrates, and other studies in which nickel uptake was negatively correlated. In order to estimate nickel concentrations in the invertebrate food source for the deer mouse, a biotransfer factor of 0.5 will be used. Next, suitable deer mouse habitat will be identified. Within this area, deer mouse home ranges will be mapped and a 95% UCL of concentrations for each metal in soil invertebrates and in vegetation will be calculated for each home range. Exposure from incidental soil ingestion will use the 95% UCL of the individual metal concentrations in surface soil for each mapped home range. For each deer mouse home range, deer mouse exposure as mg of metal/kg of body weight/day will be estimated using deer mouse-specific exposure parameters for diet, body weight, area use and incidental ingestion of soil. Deer mouse exposure parameters will be developed and approved by the regulatory agencies prior to the commencement of exposure modeling.

Deer mouse exposure for each metal will be compared to a TRV expressed as mg of uranium/kg of body weight/day to determine a HQ. For copper, lead, nickel, and zinc, the TRV will be based on the TRV developed for mammals by the EPA for use in developing the EcoSSLs will be used (U.S. EPA, 2007c, 2005b, 2007d, 2007e, Table 3-7). For uranium, a new

TRV will be developed by evaluating all available TRVs in the literature following as closely as possible the method used by the U.S. EPA in developing TRVs for use in developing EcoSSLs (U.S. EPA, 2003a,b and U.S. EPA, 2007a,b). All TRVs will be approved by the regulatory agencies prior to the commencement of exposure modeling.

The characterization of risk associated with metal exposure to the rock wren will be conducted as follows. Home ranges with an HQ>1 for each PCOEC will be mapped on a single map. Areas of with multiple metals with an HQ>1 will be identified. Areas with an HQ>1 but below Site 300 background will also be identified. A review of the literature to identify synergistic or antagonistic effects of PCOECs will be conducted to evaluate the effects of multiple PCOECs. The number of home ranges impacted will be compared to the total number of home ranges available at Building 812 and Site 300. The literature on area requirements for viable populations will be reviewed to determine the potential ecological significance of the impacted area to the continued existence of the population.

The results of the exposure estimation and risk characterization will be presented to the regulatory agencies at the Scientific/Management Decision Point (Section 3.3.5) at the completion of the human health and ecological baseline risk assessment activities. DOE/LLNL will present their conclusions as to whether there is enough information to make a remedial action decision or if additional assessment is needed. This will allow the agencies to provide comment to DOE/LLNL prior to finalization of the baseline human health and ecological risk assessment. Any potential follow-on work would be dependent upon the availability of funding.

3.3.5. Baseline Ecological Risk Assessment Scientific/Management Decision Point

Periodic updates on the progress of the baseline ecological risk assessment will be given to the regulatory agencies at the monthly Remedial Program Manager's meeting. Upon conclusion of the activities outlined above and in Table 3-15, DOE/LLNL will present the results of the measurement endpoint assessment to the regulatory agencies. This will occur concurrent with the completion of the baseline human health risk assessment. The results of each measurement endpoint evaluation for each assessment endpoint will be discussed and DOE/LLNL will provide their determination as to whether the results provide sufficient information to make a remedial action decision. For example, DOE/LLNL may conclude that the impact copper, lead, nickel, and zinc in surface soil on terrestrial vegetation and invertebrates may not warrant additional assessment if they occur within the footprint of uranium in surface soil that the results of the baseline human health and ecological risk assessment indicate the need for remedial action. In another example, concentrations of uranium or metals in sediment may be found at or slightly above the sediment ESLs and background. DOE/LLNL may conclude that the estimated ecological hazard is too low to warrant additional assessment activities or remediation, but that surface soil must be addressed to prevent future releases into shallow ground water and surface water, this preventing additional accumulation in sediment. The presentation will allow the agencies to provide initial comments to DOE/LLNL prior to finalization of the baseline human health and ecological risk assessment. The results of the Scientific/Management Decision point will determine the final list of COECs that will be evaluated during the Feasibility Study.

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5. Acronyms and Abbreviations

ACOE	Army Corps of Engineers
bgs	Below ground surface
BCG	U.S. DOE Biological Concentration Guide
BRAWP	Baseline Risk Assessment Work Plan
$CaCO_3$	Calcium carbonate
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
COPEC	Contaminant of Potential Ecological Concern
COPC	Contaminant of Potential Concern
COC	Contaminant of Concern
COEC	Contaminant of Ecological Concern
CWHRS	California Wildlife Habitat Relationship System
DOE	U.S. Department of Energy
DTSC	California Department of Toxic Substances Control
EcoSSL	Ecological Soil Screening Level
EPA	Environmental Protection Agency
ERA	Ecological risk assessment
ESL	Ecological Screening Level
FS	Feasibility Study
ft	Feet
HHRA	Human health risk assessment
hr	Hour
HSU	Hydrostratigraphic unit
HQ	Hazard Quotient
L	Liter
LC_{50}	Lethal Concentration for 50% of the test population
LLNL	Lawrence Livermore National Laboratory
LOEC	Lowest Observable Effect Concentration
MATC	Maximum Acceptable Toxicant Concentration
MCL	Maximum Contaminant Level
ml	Milliliter
mm	Millimeter
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
MSL	Mean sea level
NOEC	No Observable Effect Concentration
NRWQC	U.S. EPA National Recommended Water Quality Criteria
OU	Operable Unit

pCi/g	Picocuries per gram
pCi/L	Picocuries per liter
PCOC	Preliminary Contaminant of Concern
PCOEC	Preliminary Contaminant of Ecological Concern
PNEC	Probably No Effect Concentration
PRG	U.S. EPA Preliminary Remediation Goal
Qal	Quaternary alluvium
Qal/WBR	Quaternary alluvium/weathered bedrock
RI/FS	Remedial Investigation/Feasibility Study
RSL	U.S. EPA Regional Screening Level
RWQCB	Regional Water Quality Control Board-Central Valley Region
SLERA	Screening-level ecological risk assessment
SLHHRA	Screening-level human health risk assessment
SLRA	Screening-level risk assessment
SWAMP	Surface Water Ambient Monitoring Program
SWEIS	Site-Wide Environmental Impact Statement
TDS	Total dissolved solids
TOC	Total organic carbon
TRV	Toxicity Reference Value
TSS	Total suspended solids
95% UCL	95 percent Upper Confidence Limit of the Arithmetic Mean
^{235}U	Uranium-235
^{238}U	Uranium-238
U.S.	United States

Figures

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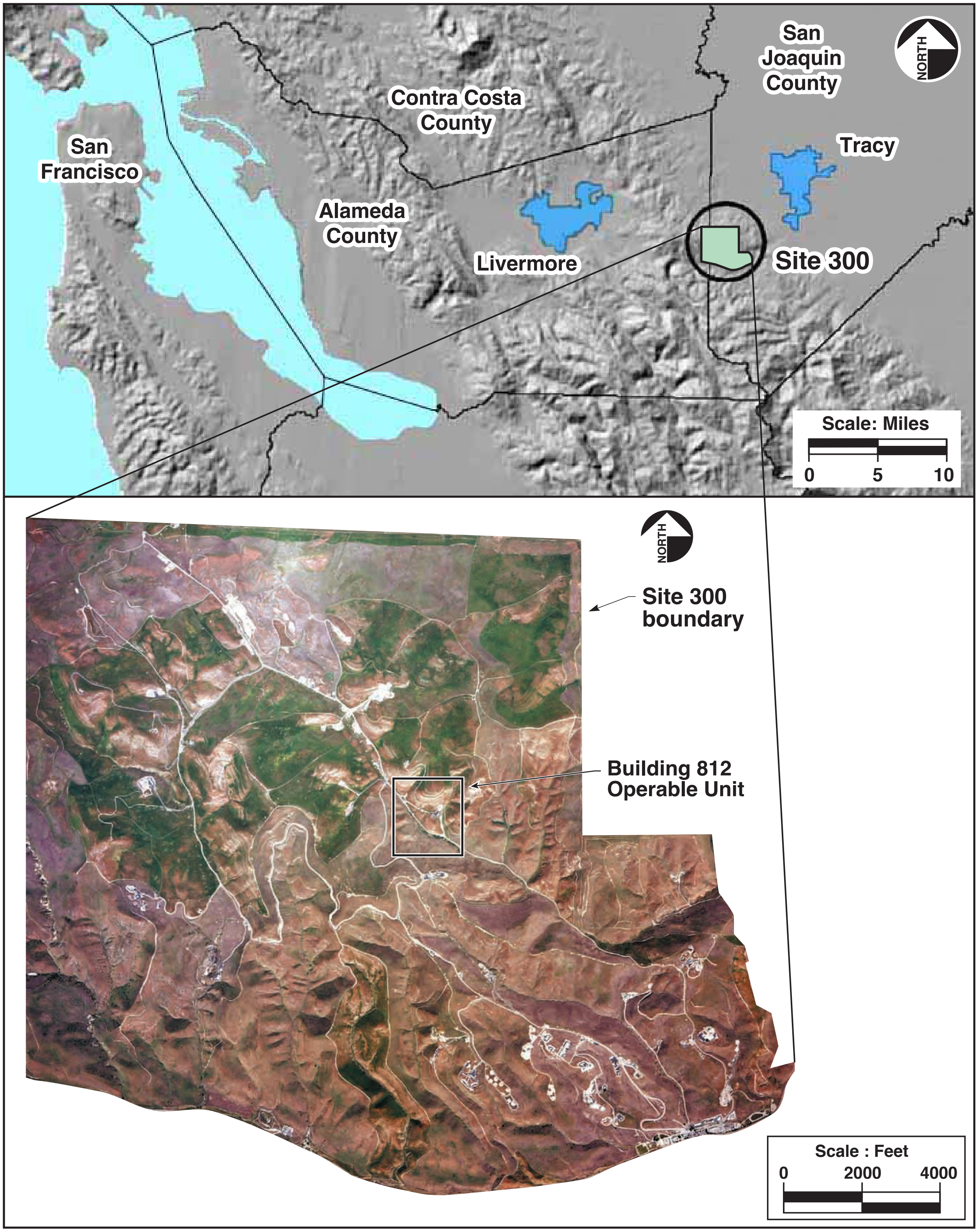

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Figure 1-1. Location of LLNL Site 300 and the Building 812 Operable Unit.

Figure 1-2. Panoramic photograph of Building 812 area looking northeast, February 2008.

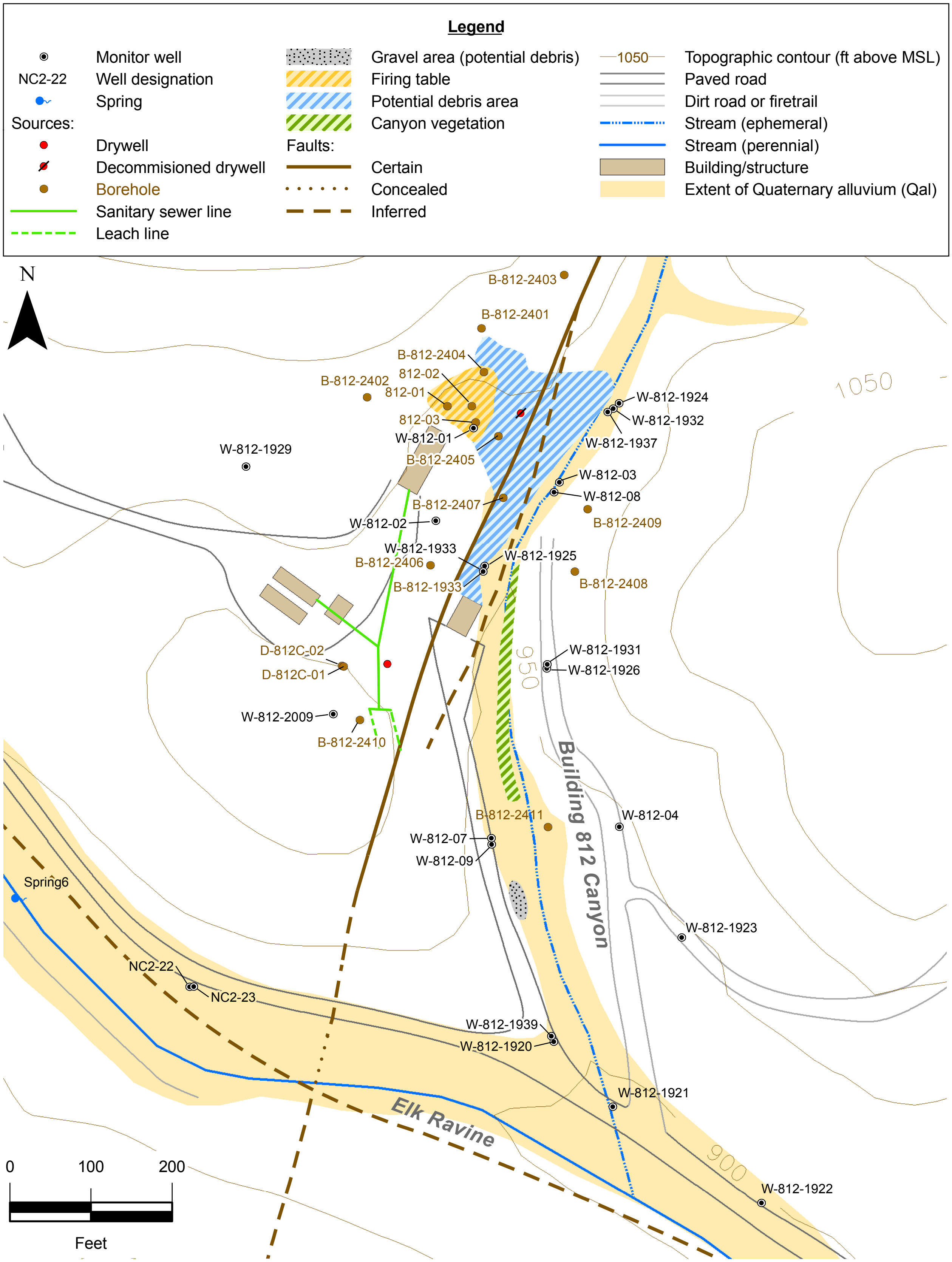


Figure 1-3. Miscellaneous features at the Building 812 Operable Unit.

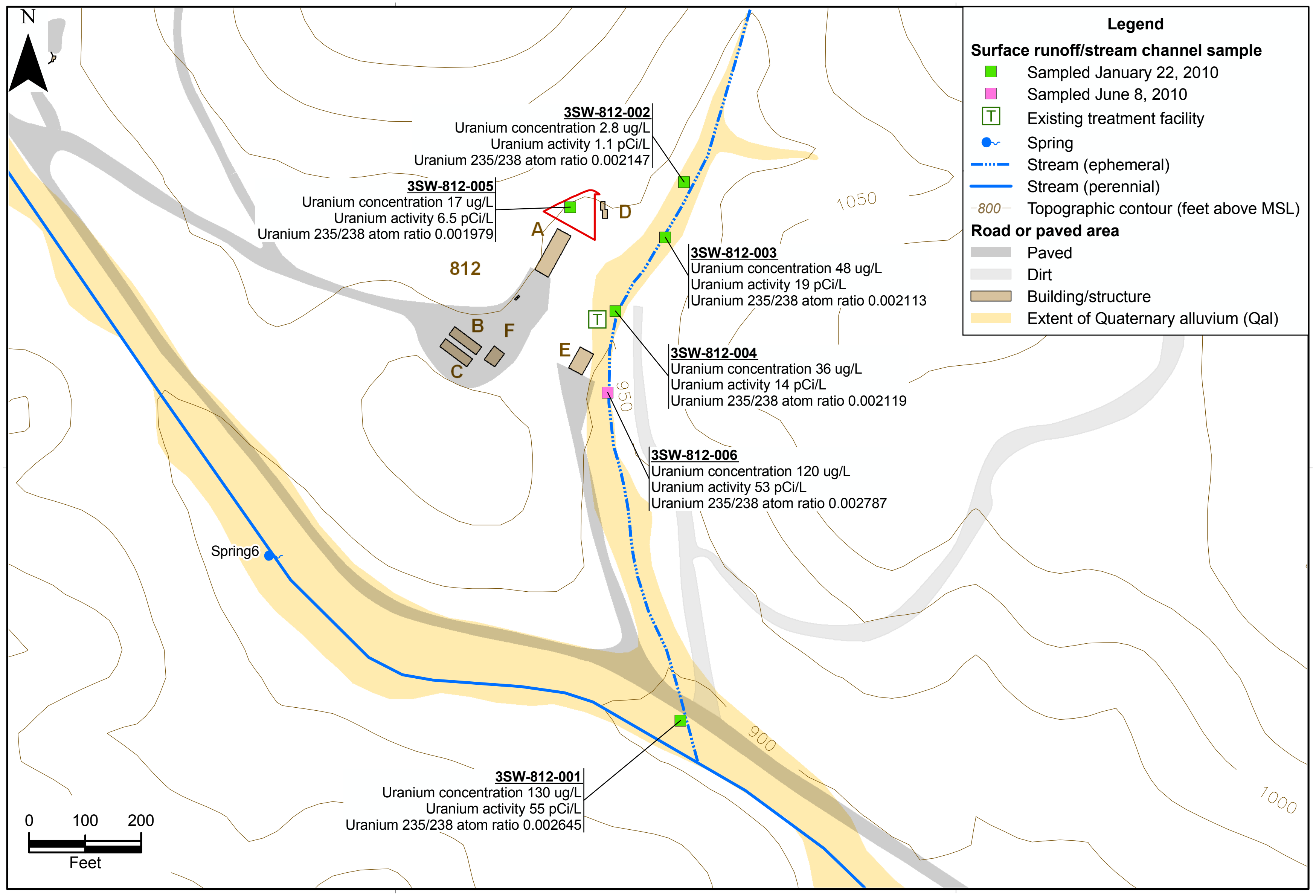


Figure 2-1. Total uranium activity in picoCuries per liter (pCi/L), total uranium concentration in micrograms per liter (µg/L), and uranium 235/238 atom ratio data for surface runoff and stream channel samples collected from the Building 812 Operable Unit.

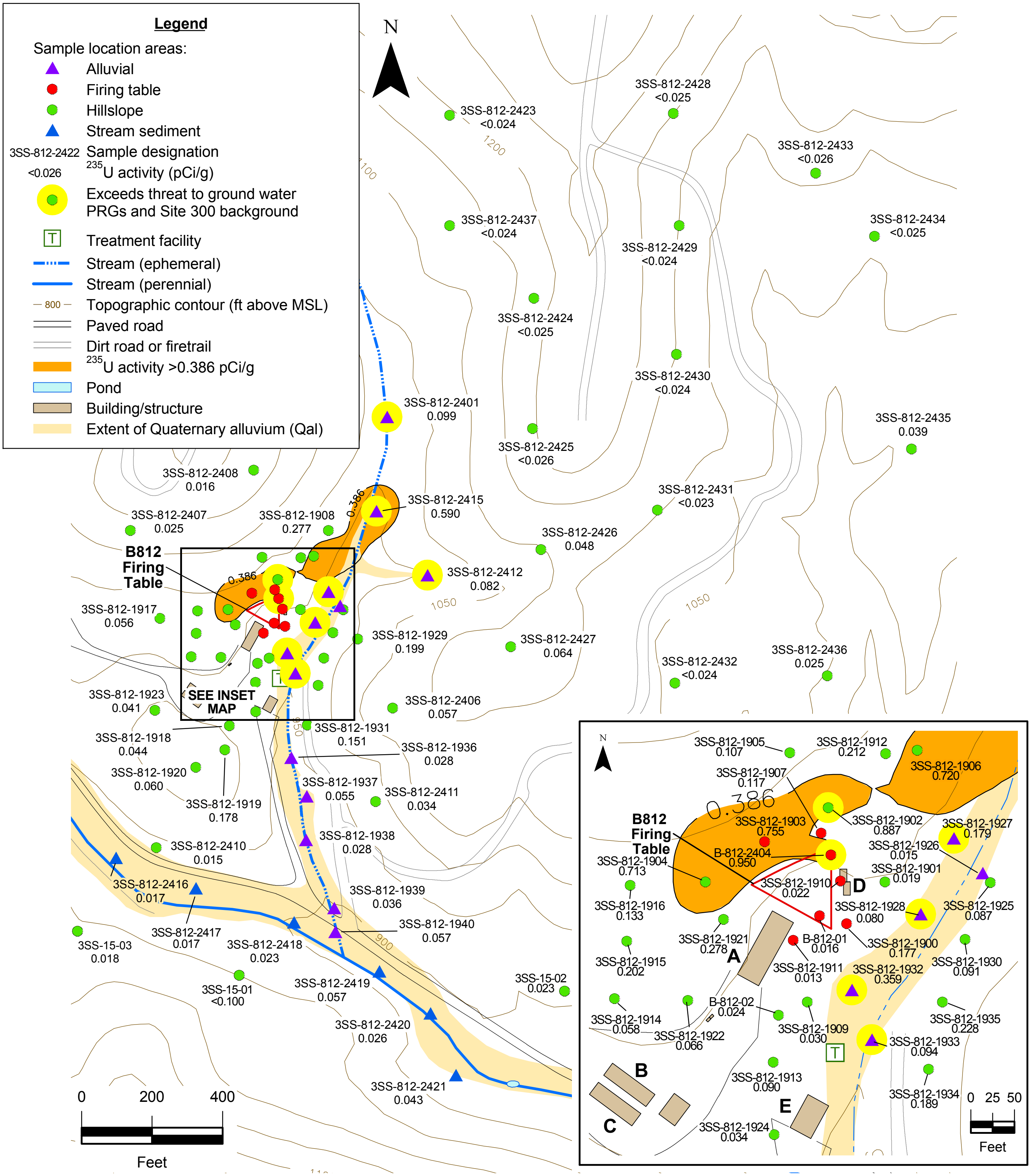


Figure 2-2. Surface soil sample locations at the Building 812 Operable Unit showing uranium-235 activities, the EPA Region 9 Outdoor Worker Preliminary Remediation Goal (PRG) contour (0.386 picoCuries per gram [pCi/g]), and surface soil locations with activities exceeding the threat to ground water PRGs and Site 300 background for hillslope, firing table, and alluvial deposits areas.

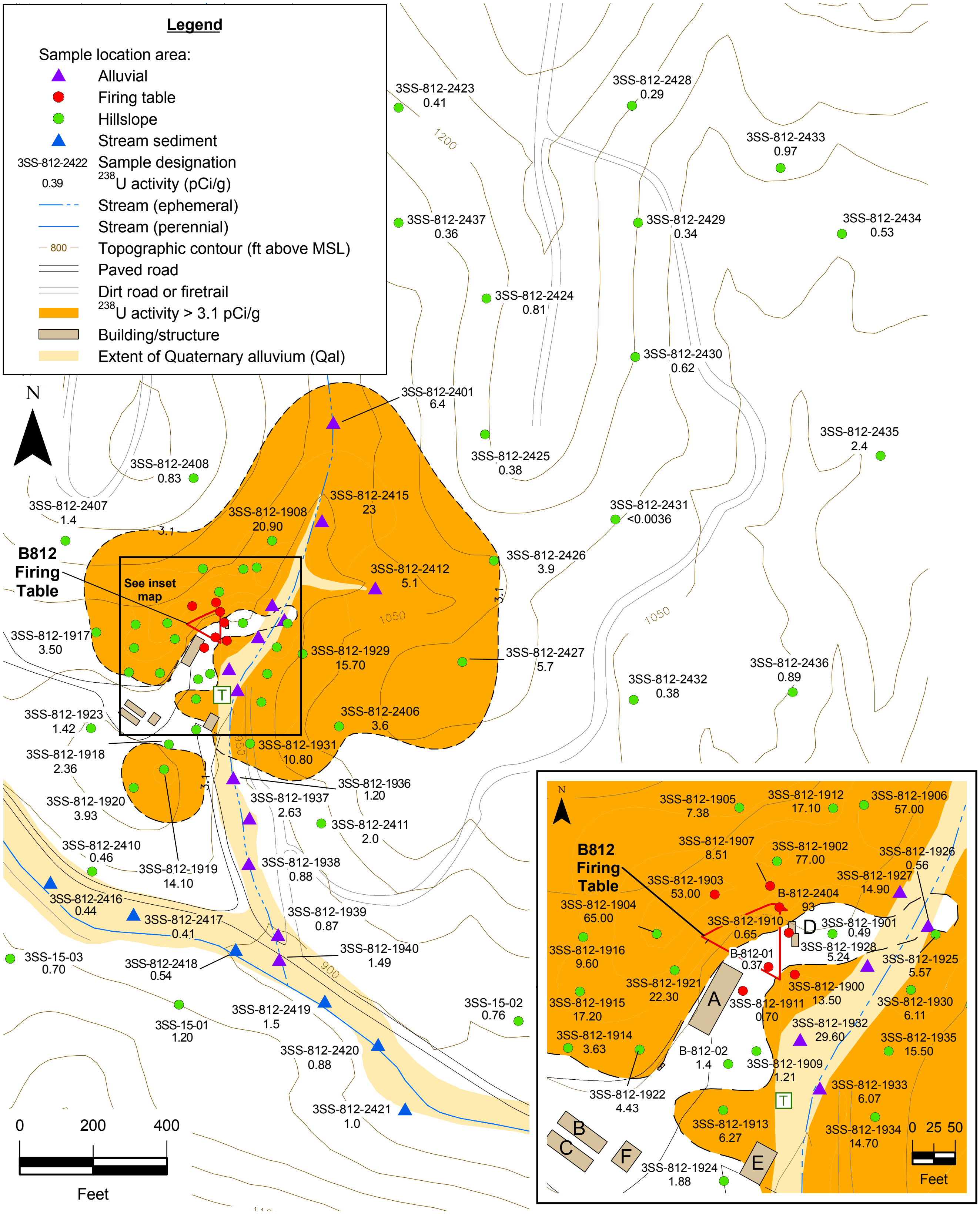


Figure 2-3. Surface soil sample locations at the Building 812 Operable Unit showing uranium-238 activities and the background contour (3.1 picoCuries per gram [pCi/g]).

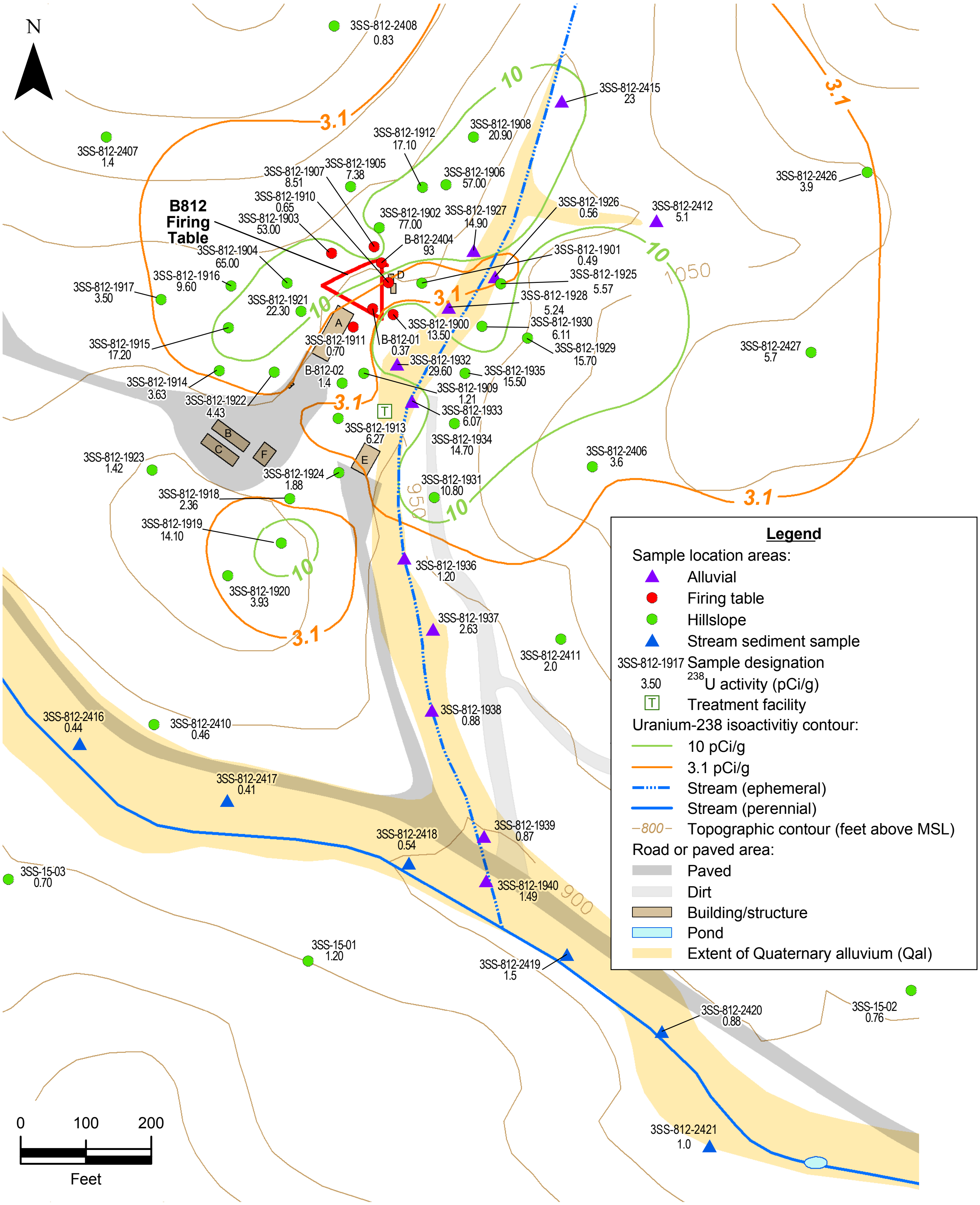


Figure 2-4. Surface soil sample locations at the Building 812 Operable Unit showing uranium-238 activities in picoCuries per gram (pCi/g) and the 10 and 3.1 pCi/g isoactivity contours representing approximately three times the Site 300 background and the Site 300 background, respectively.

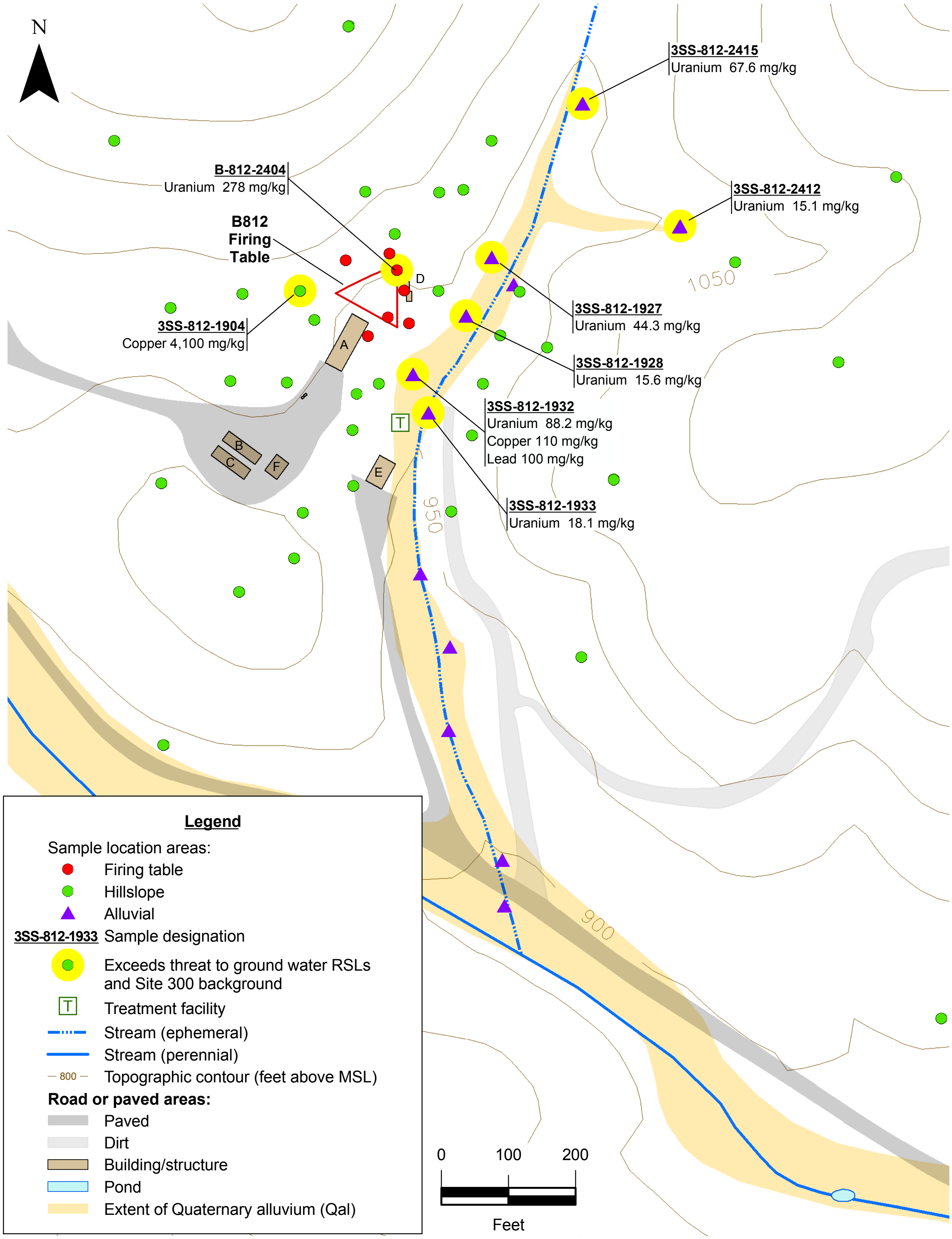


Figure 2-5. Surface soil sample locations at the Building 812 Operable Unit exceeding EPA Region 9 Regional Screening Levels (RSLs) for threat to ground water and Site 300 background in the hillslope, firing table and alluvial deposits areas.

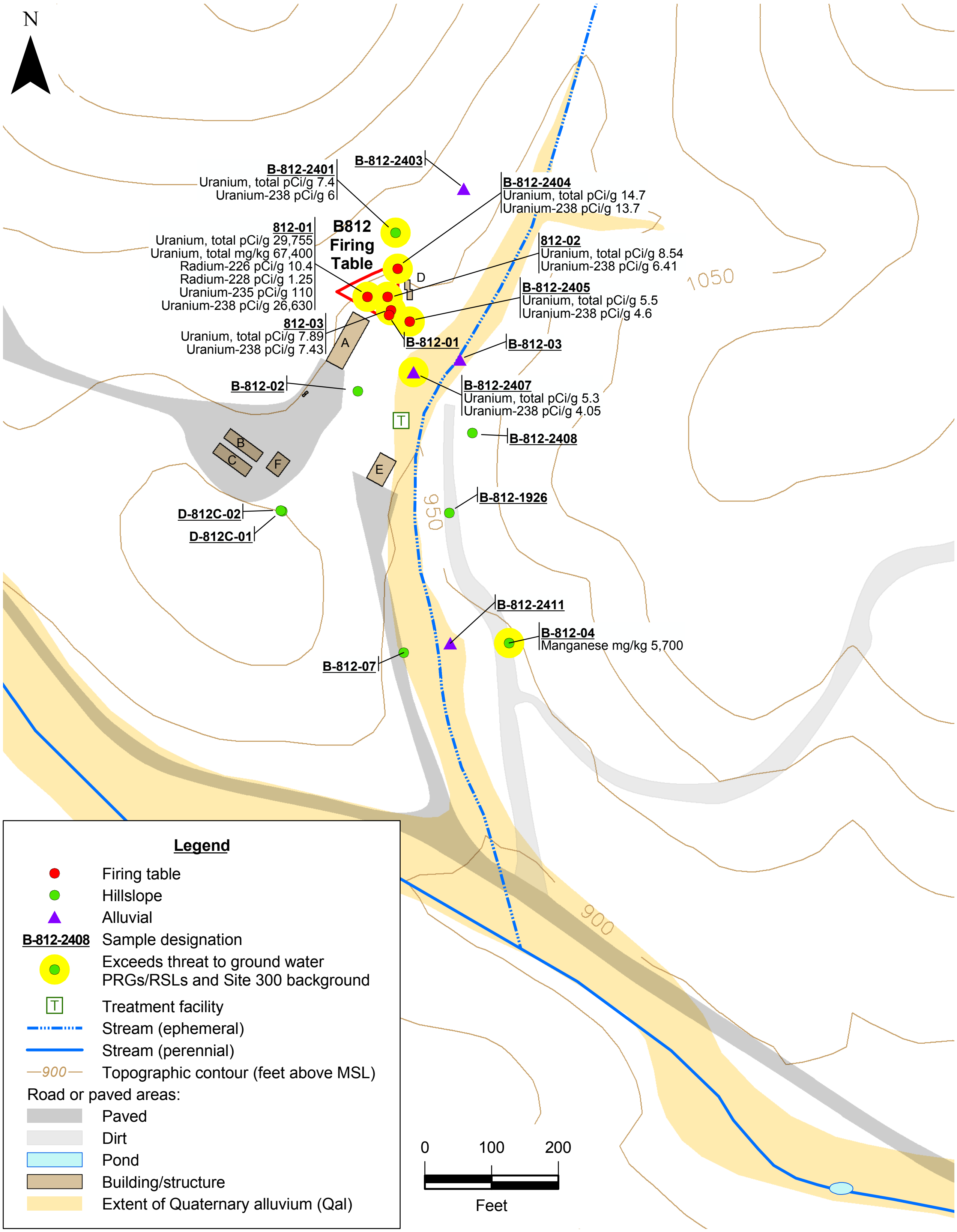


Figure 2-6. Locations at the Building 812 Operable Unit in the hillslope, firing table and alluvial deposits areas with available subsurface soil data, and locations with weighted averages exceeding EPA Region 9 Regional Screening Levels (RSLs) and Preliminary Remediation Goals (PRGs) for threat to ground water and Site 300 background (if available).

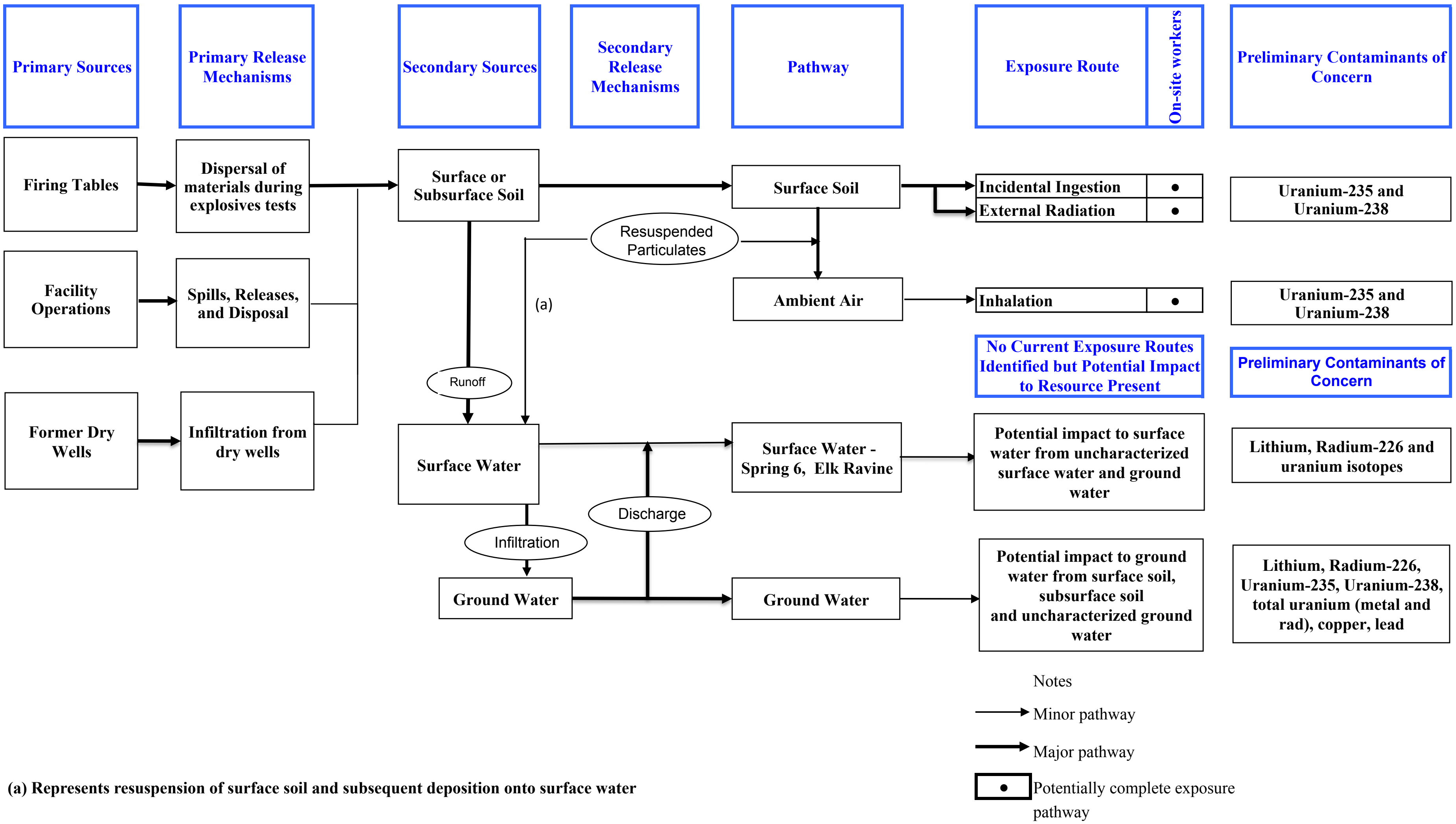


Figure 2-7. Revised Conceptual Site Model for exposure of onsite workers and threat to ground water and surface water from contaminants at the Building 812 Operable Unit.

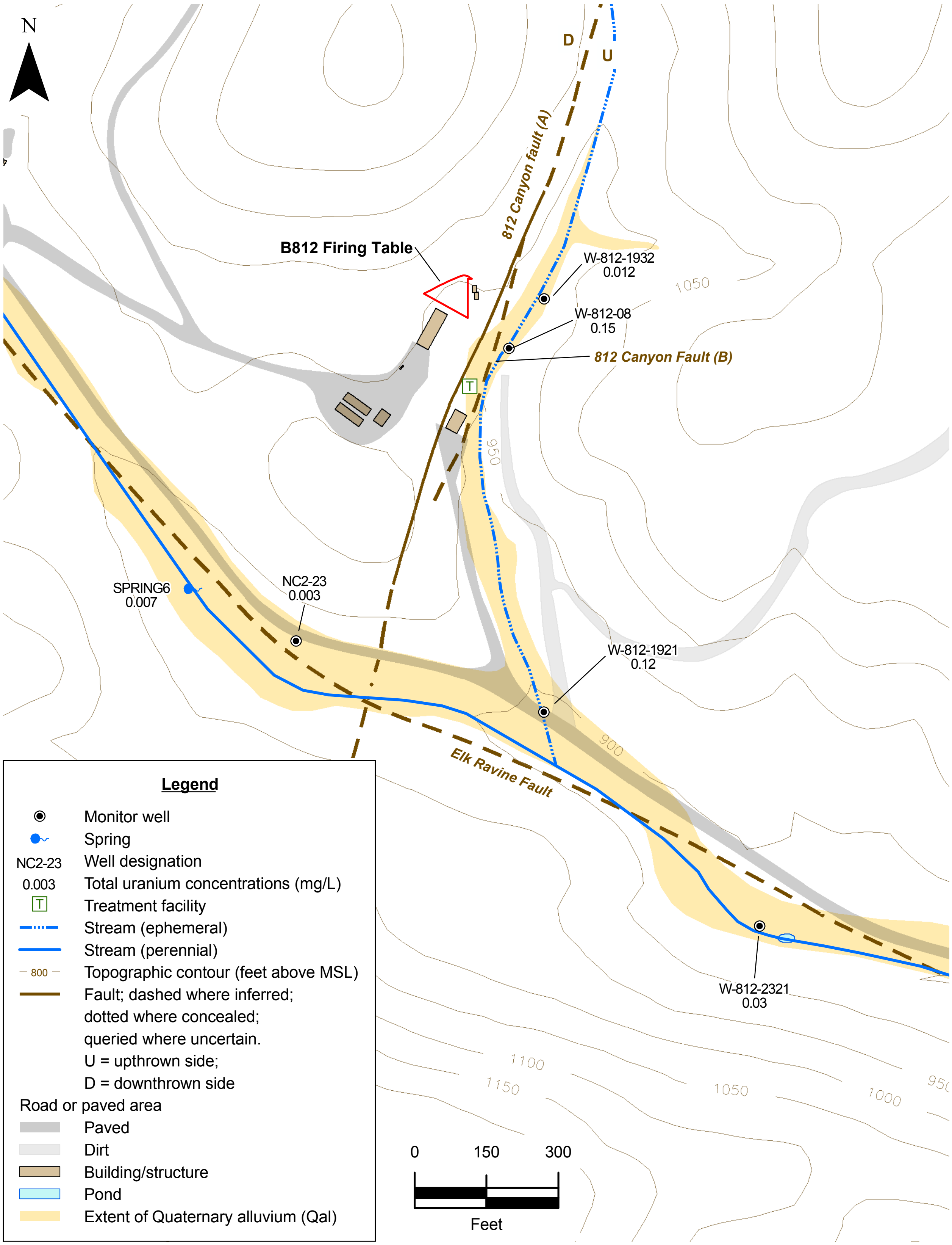


Figure 3-1. Total uranium concentrations in milligrams per liter (mg/L) in Spring 6 and the Quaternary alluvium/weathered bedrock hydrostratigraphic unit at the Building 812 Operable Unit as of December 31, 2010.

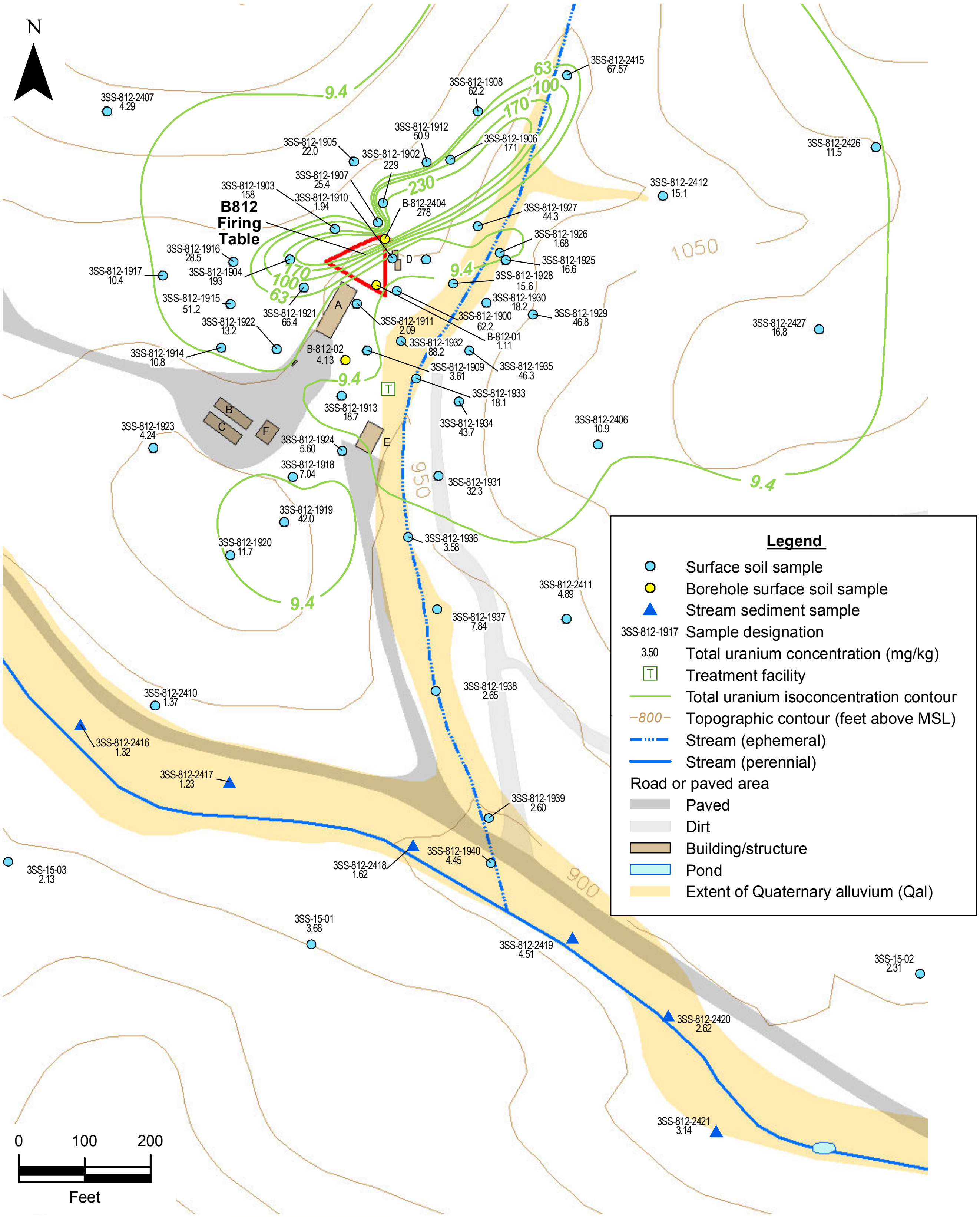


Figure 3-2. Surface soil (0 to 0.5 ft depth) sample locations at the Building 812 Operable Unit showing total uranium concentrations in milligrams per kilogram (mg/kg) and the 230, 170, 100, 63 and 9.4 mg/kg isoconcentration contours representing the omnivorous bird, carnivorous bird, terrestrial plant/soil invertebrate, and herbivorous large mammal Ecological Screening Values and Site 300 background, respectively.

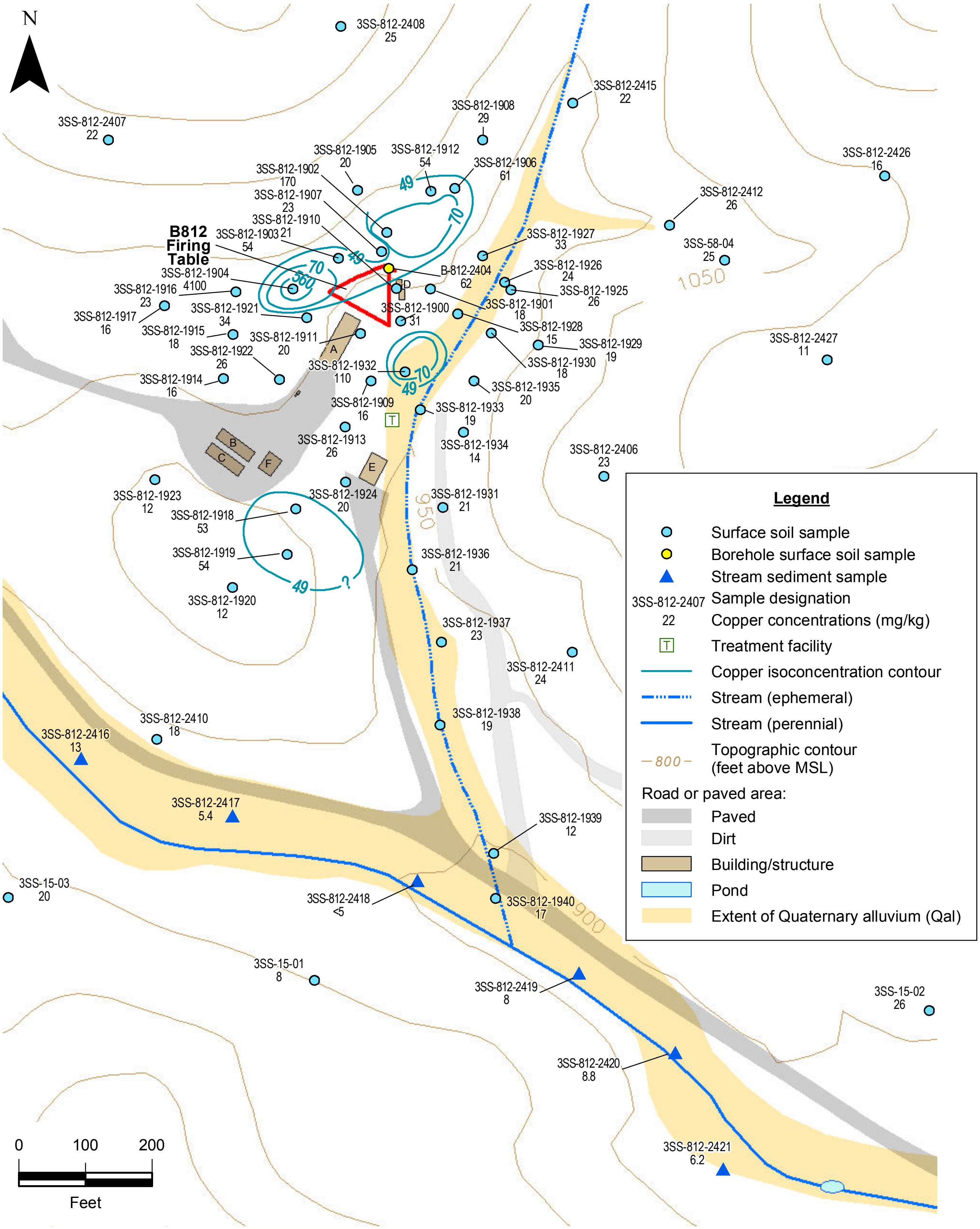


Figure 3-3. Surface soil (0 to 0.5 ft depth) sample locations at the Building 812 Operable Unit showing copper concentrations in milligrams per kilogram (mg/kg) and the 560, 70 and 49 mg/kg isoconcentration contours representing the carnivorous mammal, terrestrial plant/soil invertebrate and invertivorous mammal Ecological Screening Values, respectively. The Site 300 background is 39 mg/kg.

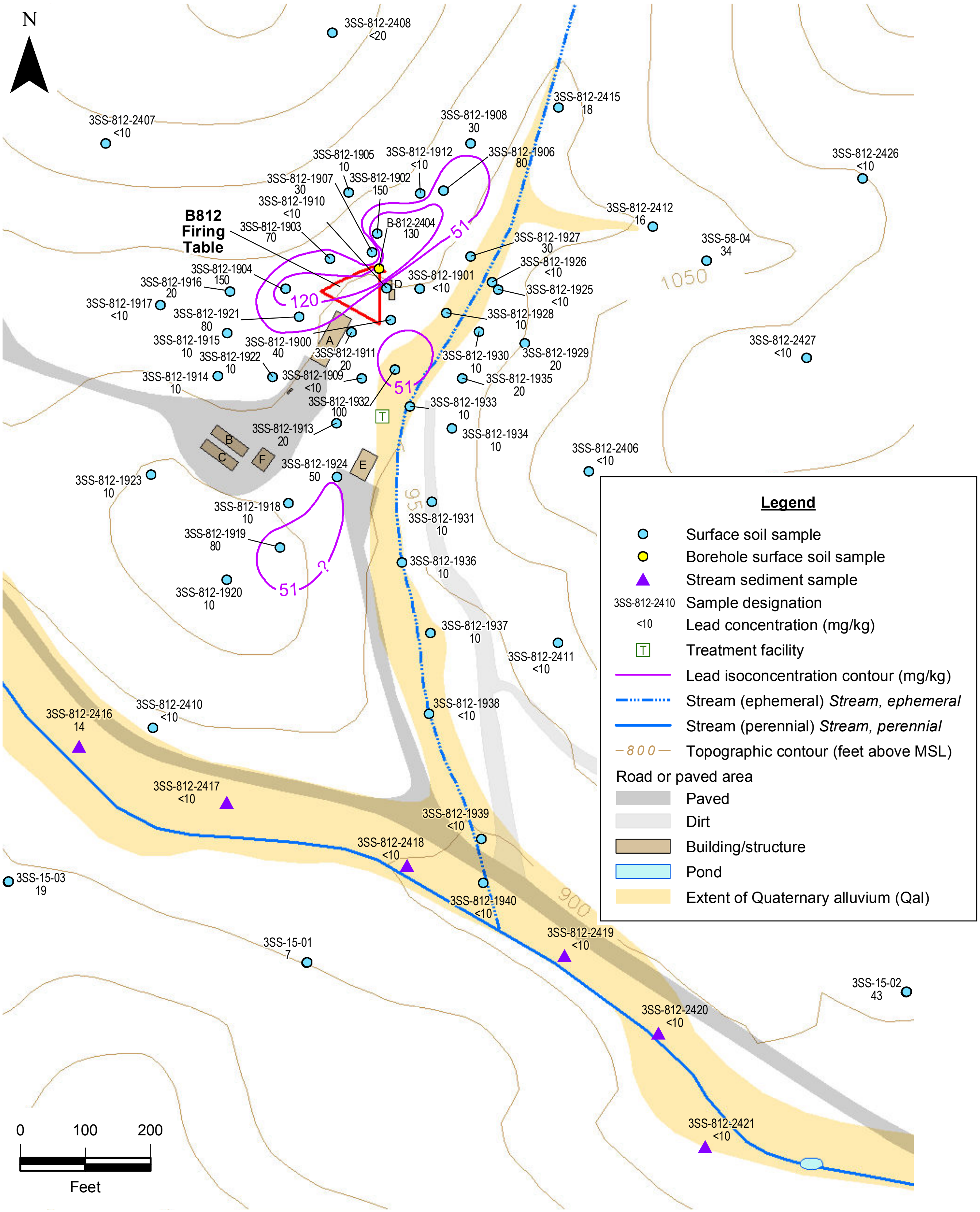


Figure 3-4. Surface soil (0 to 0.5 ft depth) sample locations at the Building 812 Operable Unit showing lead concentrations in milligrams per kilogram (mg/kg) and the 120 and 51 mg/kg isoconcentration contours representing the terrestrial plant Ecological Screening Value and Site 300 background, respectively.

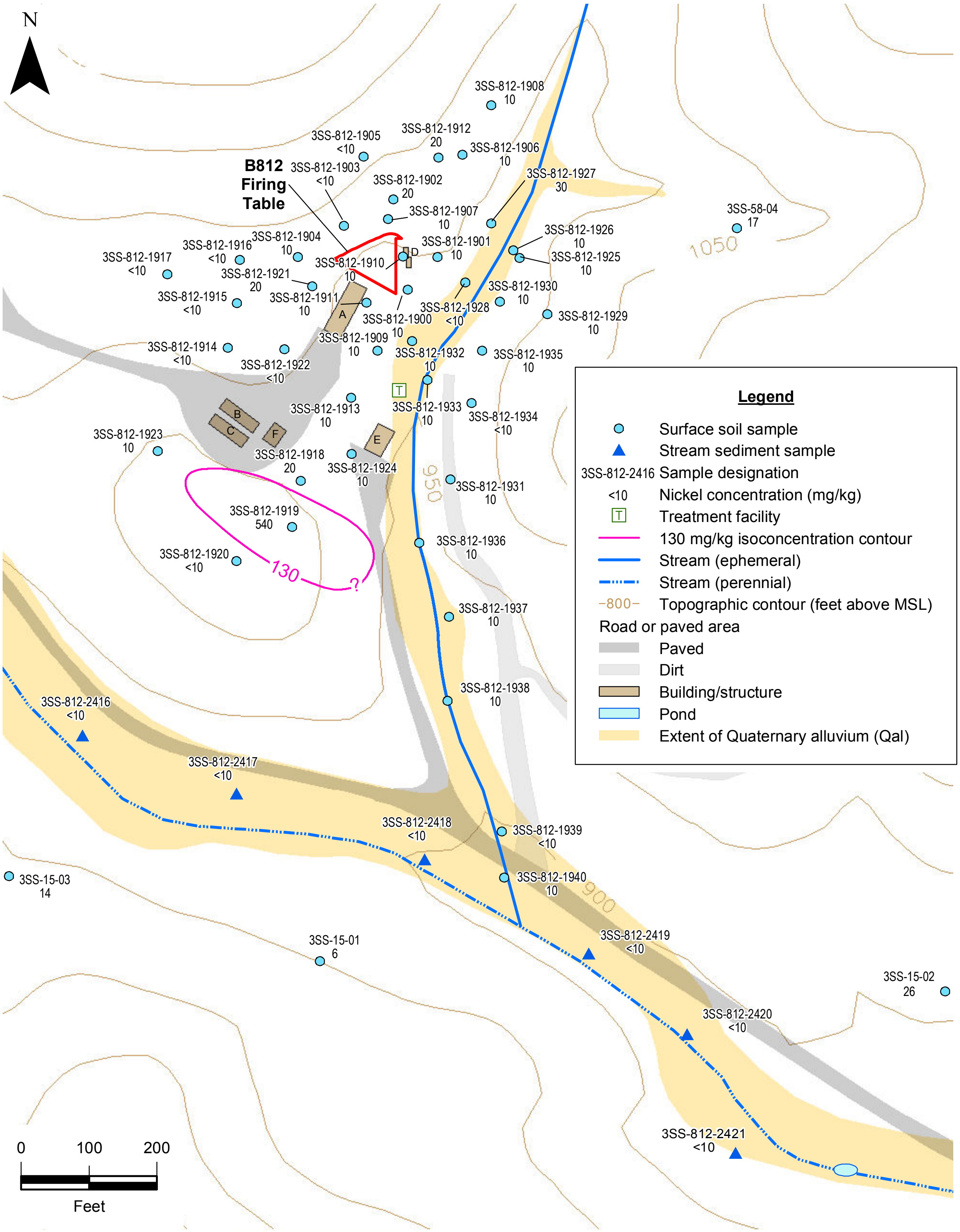


Figure 3-5. Surface soil (0 to 0.5 ft depth) sample locations at the Building 812 Operable Unit showing nickel concentrations in milligrams per kilogram (mg/kg) and the 130 mg/kg isoconcentration contour representing the Ecological Screening Value for carnivorous mammals. The Site 300 background value is 110 mg/kg.

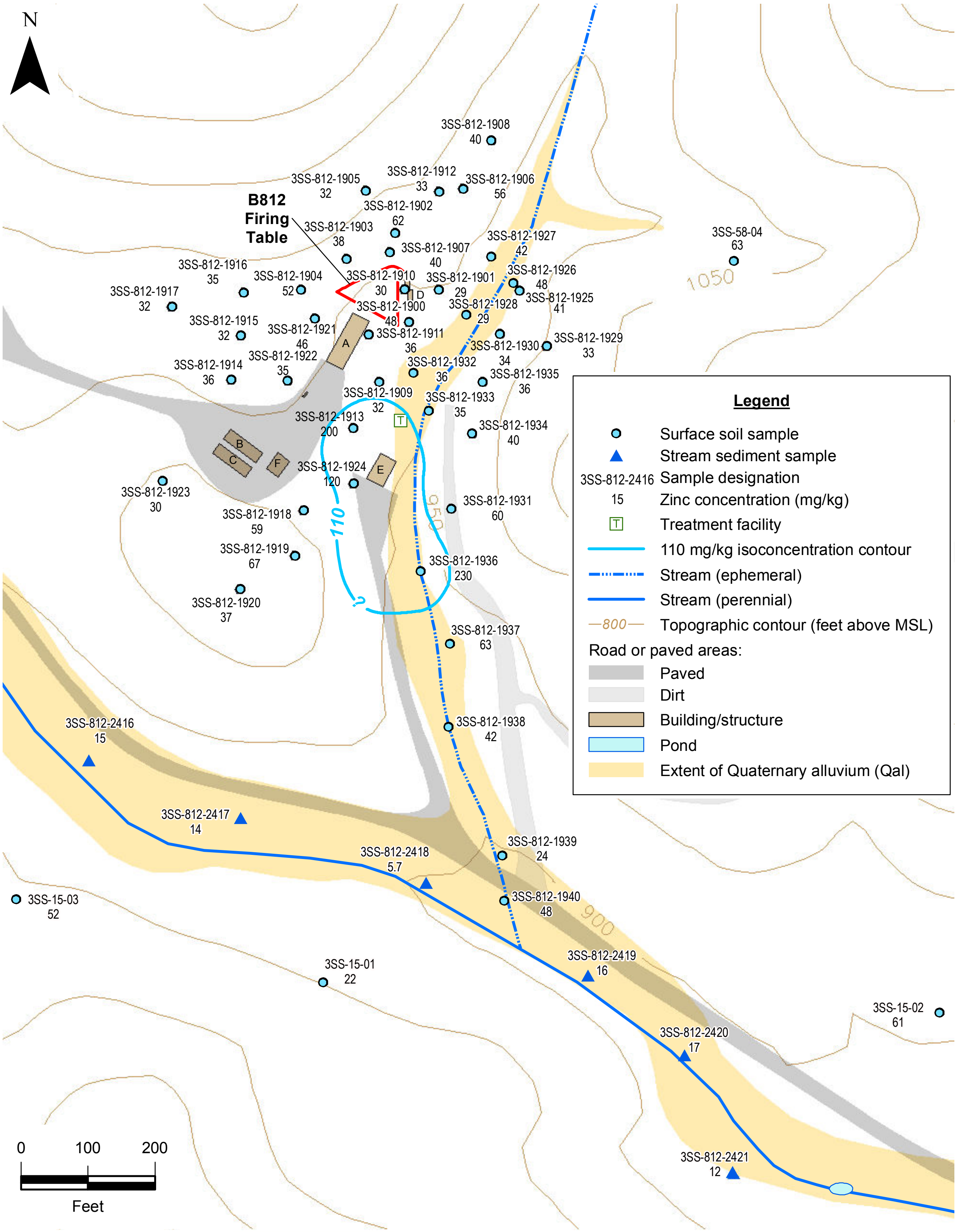


Figure 3-6. Surface soil (0 to 0.5 ft depth) sample locations at the Building 812 Operable Unit showing zinc concentrations in milligrams per kilogram (mg/kg) and the 110 mg/kg isoconcentration contour representing Site 300 background.

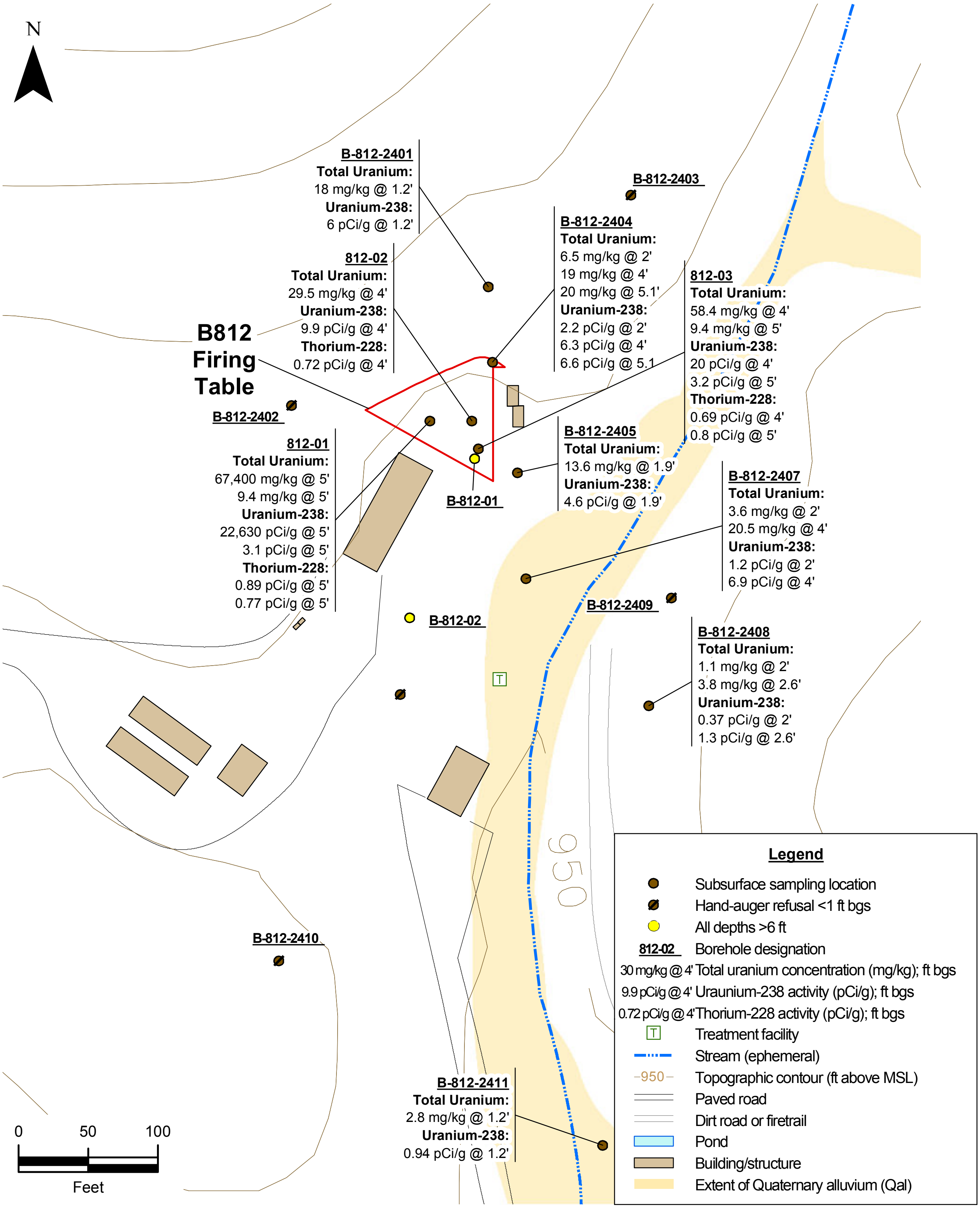


Figure 3-7. Subsurface soil (0.5 to 6 ft depth) sample locations at the Building 812 Operable Unit showing total uranium concentrations in milligrams per kilogram (mg/kg), and uranium-238 and thorium-228 activities in picoCuries per gram (pCi/g).

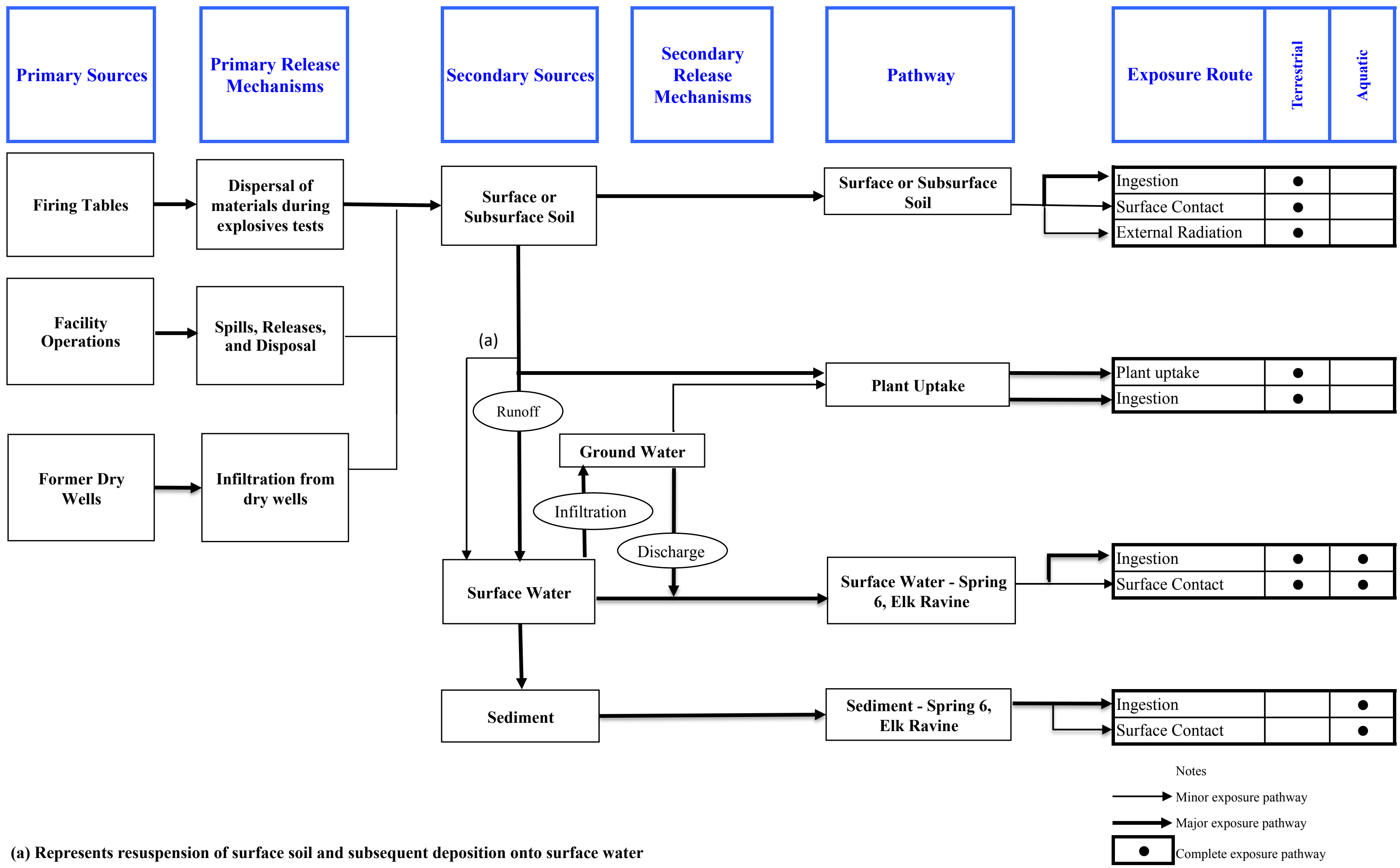


Figure 3-8. General Conceptual Site Model for exposure of ecological receptors to preliminary contaminants of ecological concern at the Building 812 Operable Unit.

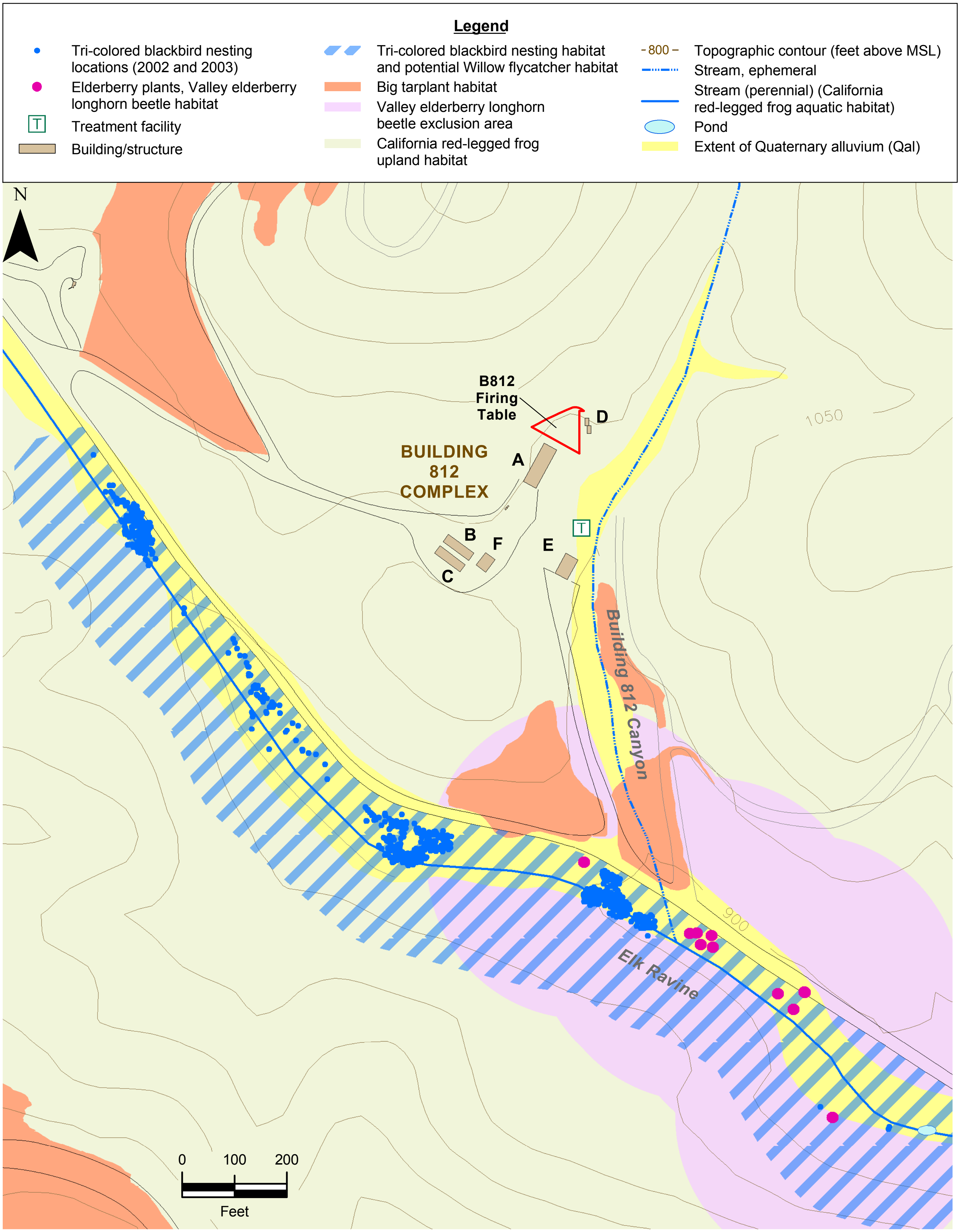


Figure 3-9. Special-status species in the vicinity of the Building 812 Operable Unit.

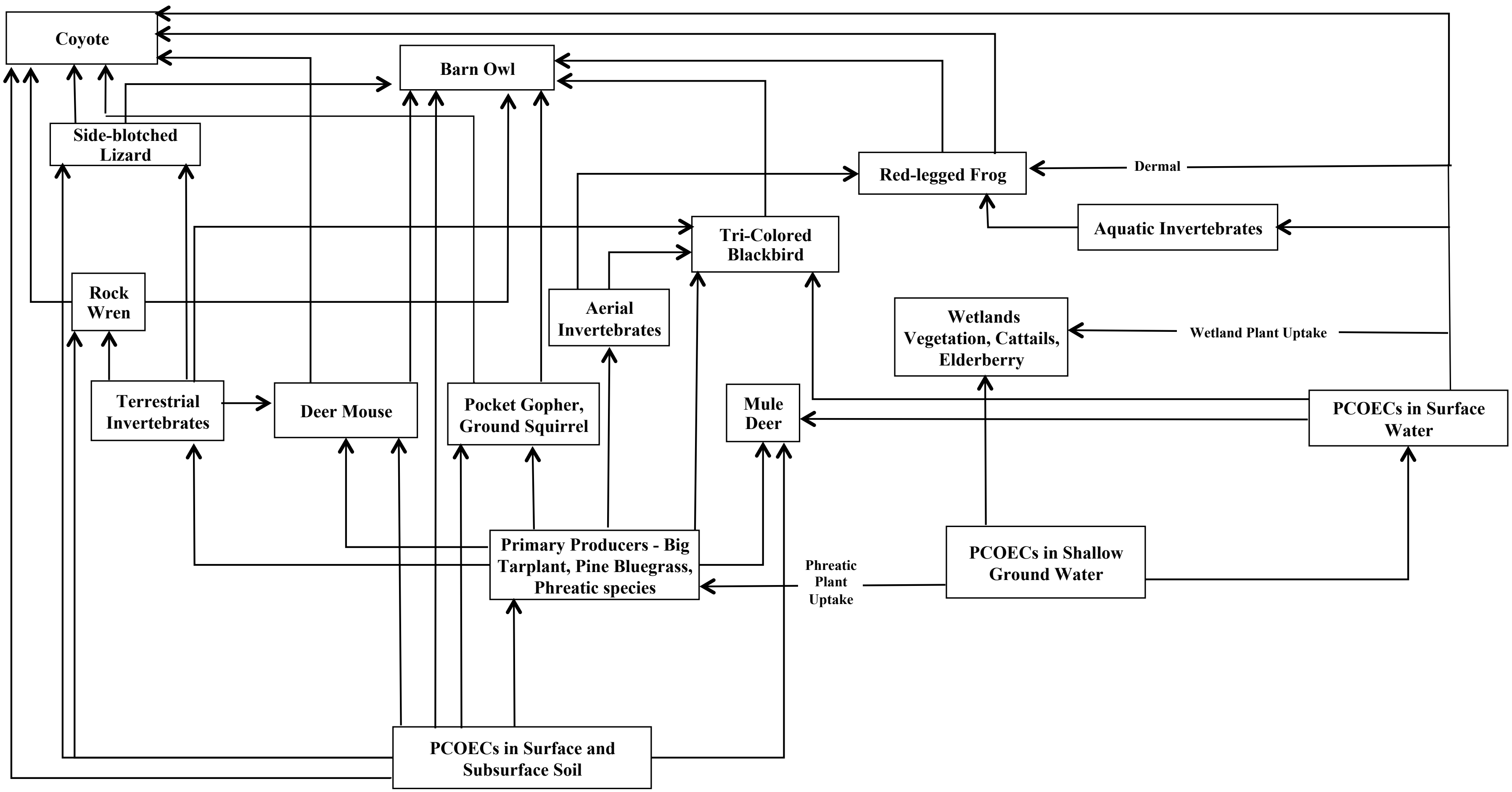


Figure 3-10. Revised Building 812 Operable Unit foodweb. All pathways are ingestion except where noted.

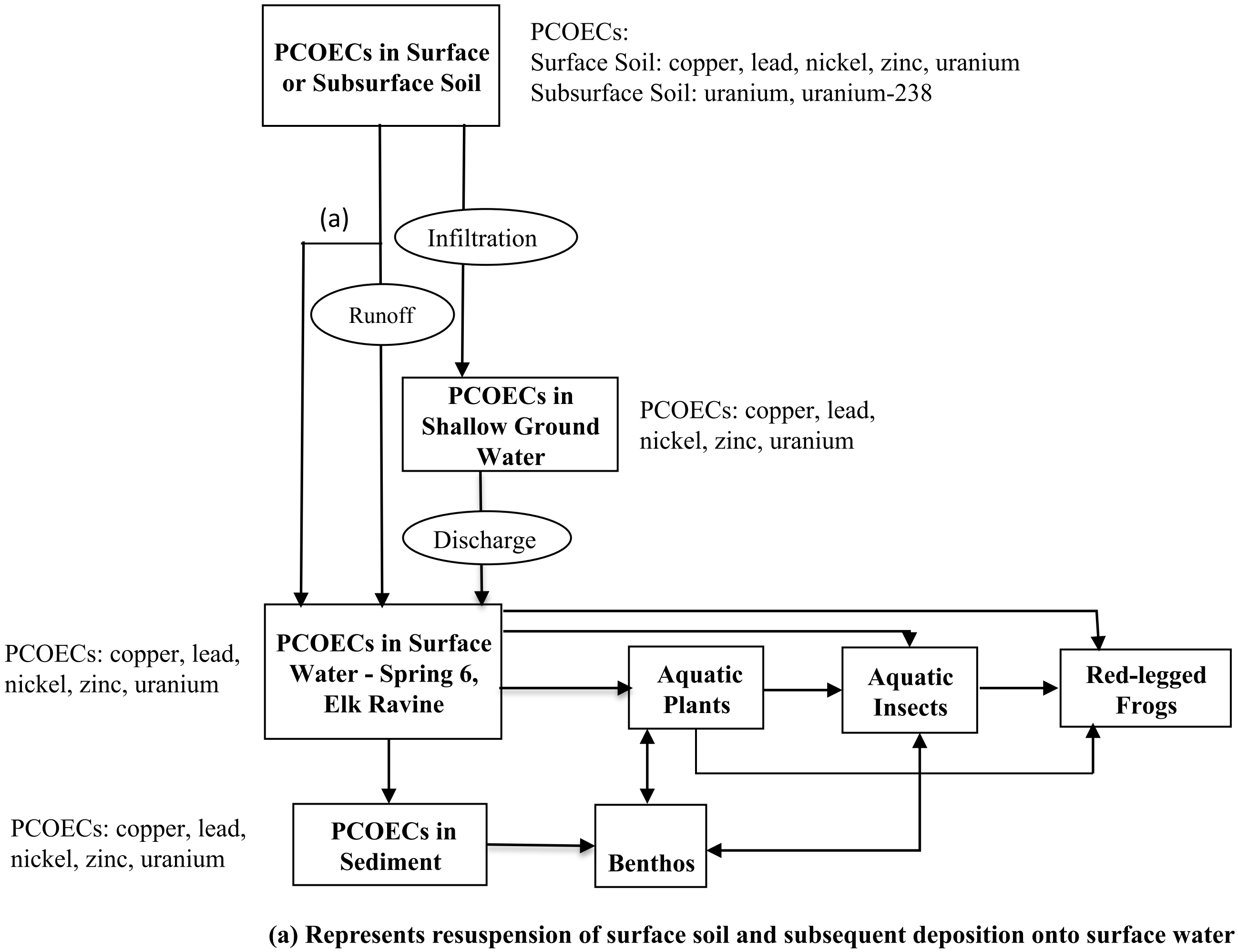
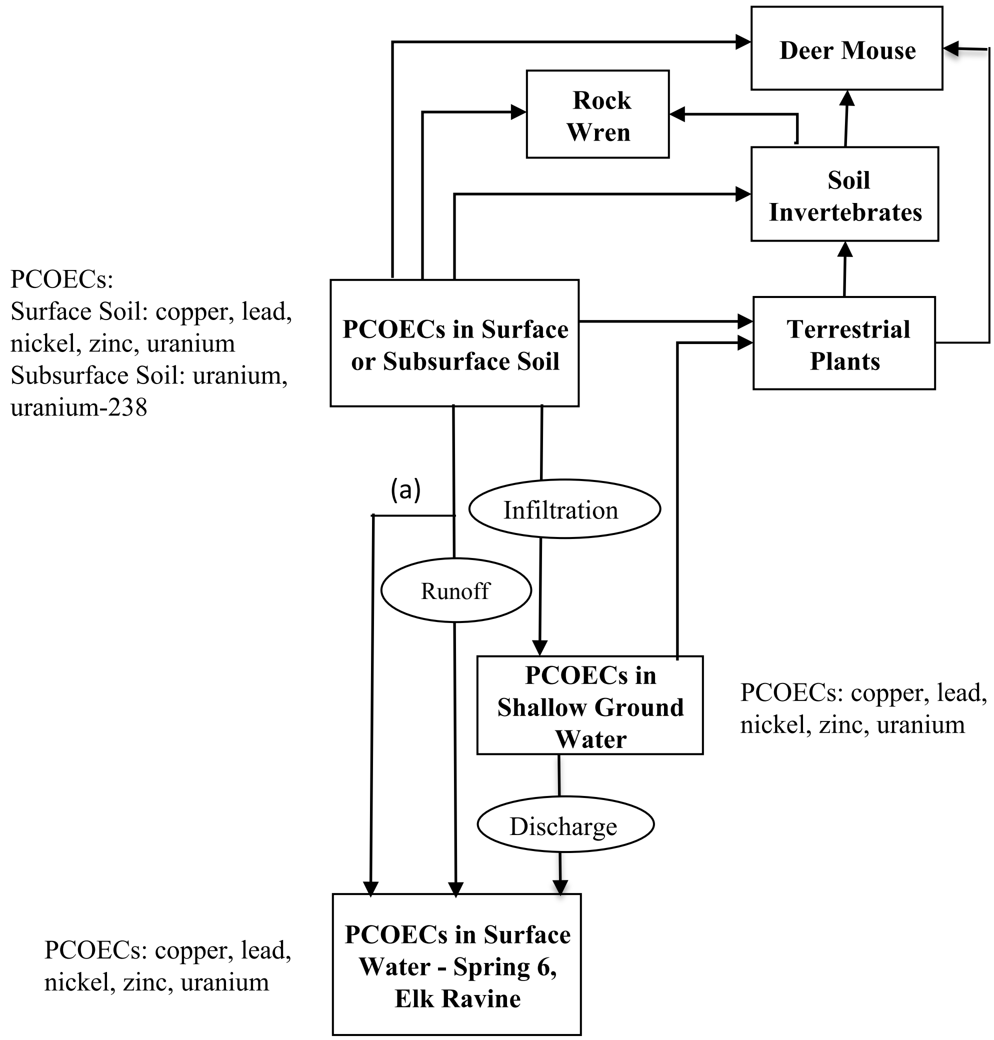


Figure 3-11. Conceptual site model for the aquatic assessment endpoint at the Building 812 Operable Unit.



(a) Represents resuspension of surface soil and subsequent deposition onto surface water

Figure 3-12. Conceptual site model for terrestrial assessment endpoints at the Building 812 Operable Unit.

Tables

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Table 2-1. Contaminants of potential concern (COPC) retained from the Building 812 screening-level human health risk assessment for further evaluation.

COPC	Maximum Result[a]	Units	Rationale
Ground Water			
General Minerals and Nutrients			
Nitrate (as NO_3)	**120**	**mg/L**	**Above background. Potential human health hazard identified based on RSL screening-level comparison, however there is no exposure pathway. Analyte retained due to MCL exceedance.**
Metals			
Lithium	**0.0782**	**mg/L**	**No background. A single detection slightly above RSL (NC2-22, June 1994). No MCL. Only two samples available. Analyte retained as presence in ground water not well characterized.**
Uranium, total	**230**	**µg/L**	**Above background. Potential human health hazard identified based on RSL screening-level comparison, however there is no exposure pathway. Analyte retained due to MCL exceedance.**
Radionuclides			
Uranium, total	**143**	**pCi/L**	**Above background. No PRG available. Potential human health hazard was identified based on RSL screening-level comparison, however there is no exposure pathway. Analyte retained due to MCL exceedance.**
Uranium-234	**69.3**	**pCi/L**	**Potential human health risk identified based on PRG screening-level comparison, however there is no exposure pathway. Above background. No MCL. Analyte retained as a component of total uranium.**
Uranium-235	**6.37**	**pCi/L**	**Potential human health risk identified based on PRG screening-level comparison, however there is no exposure pathway. Above background. No MCL. Analyte retained as a component of total uranium.**
Uranium-238	**76**	**pCi/L**	**Potential human health risk identified based on PRG screening-level comparison, however there is no exposure pathway. Above background. No MCL. Analyte retained as a component of total uranium.**
VOCs and Organics			
1,2-Dichloro-ethane	**0.9**	**µg/L**	**Detected in one well (W-812-2009) greater than MCL. Potential human health risk identified based on RSL screening-level comparison, however there is no exposure pathway. Analyte retained due to MCL exceedance.**
1,1-Dichloro-ethylene	**20**	**µg/L**	**No human health risk or hazard identified. Analyte detected in one well (W-812-2009) >MCL. Analyte retained due to MCL exceedance.**

Table 2-1 (continued). Contaminants of potential concern (COPC) retained from the Building 812 screening-level human health risk assessment for further evaluation.

COPC	Maximum Result[a]	Units	Rationale
Ground Water (continued)			
VOCs and Organics (continued)			
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	3.5	µg/L	Potential human health risk identified based on RSL screening-level comparison, however there is no exposure pathway. Detection occurred in most recently collected sample. No MCL. Retained due to precedent set in Site Wide Record of Decision.
Perchlorate	21	µg/L	No human health risk or hazard identified. Analyte retained due to MCL exceedance.
Trichloro-ethylene	60	µg/L	Potential human health risk identified based on RSL screening-level comparison, however there is no exposure pathway. Analyte retained due to MCL exceedance.
Surface Water			
Radionuclides			
Radium-226	0.393	pCi/L	No background. Potential human health risk identified based on PRG screening-level comparison in the single sample collected from Spring 6, however there is no exposure pathway. Below MCL. Analyte retained as presence in Spring 6 and ground water that discharges into Spring 6 not well characterized.
Surface soil (0 to 0.5 ft)-Overall (human health)			
Radionuclides			
Uranium-235	0.95	pCi/g	Above background. Potential human health risk identified based on PRG screening-level comparison.
Uranium-238	93	pCi/g	Above background. Potential human health risk identified based on PRG screening-level comparison.
Surface Soil (0 to 0.5 ft)-Hillslopes (threat to ground water)			
Metals			
Copper	4,100	mg/kg	Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.
Radionuclides			
Uranium, total	87	pCi/g	No background or threat to ground water SSL available. Risk characterization of Uranium-235 and Uranium-238 indicate a potential threat to ground water from total uranium.

Table 2-1 (continued). Contaminants of potential concern (COPC) retained from the Building 812 screening-level human health risk assessment for further evaluation.

COPC	Maximum Result[a]	Units	Rationale
Surface Soil (0 to 0.5 ft)-Hillslopes (threat to ground water) (continued)			
Radionuclides (continued)			
Uranium-235	**0.887**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Uranium-238	**77**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Surface Soil (0 to 0.5 ft)-Firing table (threat to ground water)			
Metals			
Uranium, total	**278**	**mg/kg**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and slightly exceeds MCL-based SSL based on DAF 20.**
Radionuclides			
Uranium, total	**95**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-235 and Uranium-238 indicate a potential threat to ground water from total uranium.**
Uranium-235	**0.95**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Uranium-238	**93**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Surface Soil (0 to 0.5 ft) -Alluvial deposits (threat to ground water)			
Metals			
Copper	**110**	**mg/kg**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.**
Lead	**100**	**mg/kg**	**Above background. No threat to ground water risk-based SSL available. Exceeds threat to ground water MCL-based SSL based on DAF 1.**
Uranium, total	**88.2**	**mg/kg**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.**

Table 2-1 (continued). Contaminants of potential concern (COPC) retained from the Building 812 screening-level human health risk assessment for further evaluation.

COPC	Maximum Result[a]	Units	Rationale
Surface Soil (0 to 0.5 ft) -Alluvial deposits (threat to ground water) (continued)			
Radionuclides			
Uranium, total	**34.1**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 and Uranium-235 indicate a potential threat to ground water from total uranium.**
Uranium-235	**0.59**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.**
Uranium-238	**29.6**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.**
Subsurface soil (0.5 to 12 ft)-Overall (human health)			
None	—	—	***No COPCs were retained***

COPC/Boring	Weighted Average	Units	Rationale
Soil borings (all data)--Hillslopes (threat to ground water)			
Metals			
Manganese			
B-812-04	**5,700**	**mg/kg**	**Above background. Result from the only sample collected from B-812-04 (5 ft). Exceeds threat to ground water risk-based SSL based on DAF 1 and risk-based SSL based on DAF 20. No MCL-based SSL available.**
Radionuclides			
Uranium, total			
B-812-2401	**7.4**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**

Table 2-1 (continued). Contaminants of potential concern (COPC) retained from the Building 812 screening-level human health risk assessment for further evaluation.

COPC/Boring	Weighted Average	Units	Rationale
Soil borings (all data)--Hillslopes (threat to ground water) (continued)			
Radionuclides (continued)			
Uranium-238			
B-812-2401	**6**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Soil borings (all data)--Firing table (threat to ground water)			
Metals			
Uranium, total			
812-01	**67,400**	**mg/kg**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Radionuclides			
Radium-226			
812-01	**10.4**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Radium-228			
812-01	**1.25**	**pCi/g**	**No background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Uranium, total			
812-01	**29,755**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-235 and Uranium-238 indicate a potential threat to ground water from total uranium.**
812-02	**8.542**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
812-03	**7.89**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**

Table 2-1 (continued). Contaminants of potential concern (COPC) retained from the Building 812 screening-level human health risk assessment for further evaluation.

COPC/Boring	Weighted Average	Units	Rationale
Soil borings (all data)--Firing table (threat to ground water) (continued)			
Radionuclides (continued)			
Uranium, total (continued)			
B-812-2404	**14.7**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
B-812-2405	**5.5**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
Uranium-235			
812-01	**110**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Uranium-238			
812-01	**22,630**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
812-02	**6.413**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
812-03	**7.43**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
B-812-2404	**13.67**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
B-812-2405	**4.6**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**

Table 2-1 (continued). Contaminants of potential concern (COPC) retained from the Building 812 screening-level human health risk assessment for further evaluation.

COPC/Boring	Weighted Average	Units	Rationale
Soil borings (all data)--Alluvial deposits (threat to ground water)			
Radionuclides			
Uranium, total			
B-812-2407	**5.3**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
Uranium-238			
B-812-2407	**4.05**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.**

Notes:

COPC =	Contaminant of potential concern.
MCL =	Maximum Contaminant Level.
VOC =	Volatile Organic Compounds.
RDX =	Research Department Explosive.
NO_3 =	Nitrate.
HQ =	Hazard Quotient.
DAF =	Dilution Attenuation Factor.
ft =	Feet.
mg/kg =	Milligrams per kilogram.
mg/L =	Milligrams per liter.
pCi/g =	PicoCuries per gram.
pCi/L =	PicoCuries per liter.
PRG =	Preliminary Remediation Goals
RSL =	Regional Screening Levels.
µg/L =	Micrograms per liter.

[a] **Based on data collected between January 1, 1988 and October 21, 2007.**

Table 2-2. Building 812 ground water Contaminants of Concern (COCs) that will move forward to the Building 812 Feasibility Study.

COPC	Maximum Result[a]	Units	Rationale
General Minerals and Nutrients			
Nitrate (as NO_3)	120	mg/L	Above background. Potential human health hazard identified based on RSL screening-level comparison, however there is no exposure pathway. Analyte retained due to MCL exceedance.
Metals			
Uranium, total	230	µg/L	Above background. Potential human health hazard identified based on RSL screening-level comparison, however there is no exposure pathway. Analyte retained due to MCL exceedance.
Radionuclides			
Uranium, total	143	pCi/L	Above background. No PRG available. Potential human health hazard was identified based on RSL screening-level comparison, however there is no exposure pathway. Analyte retained due to MCL exceedance.
Uranium-234	69.3	pCi/L	Potential human health risk identified based on PRG screening-level comparison, however there is no exposure pathway. Above background. No MCL. Analyte retained as a component of total uranium.
Uranium-235	6.37	pCi/L	Potential human health risk identified based on PRG screening-level comparison, however there is no exposure pathway. Above background. No MCL. Analyte retained as a component of total uranium.
Uranium-238	76	pCi/L	Potential human health risk identified based on PRG screening-level comparison, however there is no exposure pathway. Above background. No MCL. Analyte retained as a component of total uranium.
VOCs and Organics			
1,2-Dichloro-ethane	0.9	µg/L	Detected in one well (W-812-2009) greater than MCL. Potential human health risk identified based on RSL screening-level comparison, however there is no exposure pathway. Analyte retained due to MCL exceedance.
1,1-Dichloro-ethylene	20	µg/L	No human health risk or hazard identified. Analyte detected in one well (W-812-2009) >MCL. Analyte retained due to MCL exceedance.
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	3.5	µg/L	Potential human health risk identified based on RSL screening-level comparison, however there is no exposure pathway. Detection occurred in most recently collected sample. No MCL. Retained due to precedent set in Site Wide Record of Decision.

Table 2-2 (continued). Building 812 ground water Contaminants of Concern (COCs) that will move forward to the Building 812 Feasibility Study.

COPC	Maximum Result[a]	Units	Rationale
VOCs and Organics (continued)			
Perchlorate	**21**	**µg/L**	**No human health risk or hazard identified. Analyte retained due to MCL exceedance.**
Trichloro-ethylene	**60**	**µg/L**	**Potential human health risk identified based on RSL screening-level comparison, however there is no exposure pathway. Analyte retained due to MCL exceedance.**

Notes:

COPC = **Contaminant of potential concern.**
MCL = **Maximum Contaminant Level.**
VOC = **Volatile Organic Compounds.**
RDX = **Research Department Explosive.**
NO_3 = **Nitrate.**
HQ = **Hazard Quotient.**
DAF = **Dilution Attenuation Factor.**
ft = **Feet.**
mg/kg = **Milligrams per kilogram.**
mg/L = **Milligrams per liter.**
pCi/g = **PicoCuries per gram.**
pCi/L = **PicoCuries per liter.**
PRG = **Preliminary Remediation Goals.**
RSL = **Regional Screening Levels.**
µg/L = **Micrograms per liter.**

[a] **Based on data collected between January 1, 1988 and October 21, 2007.**

Table 2-3. Initial list of Preliminary Contaminants of Concern (PCOCs) for the Building 812 Operable Unit.

PCOC	Maximum Result[a]	Units	Rationale
Ground Water			
Metals			
Lithium	0.0782	mg/L	A single detection slightly above RSL (NC2-22, June 1994). No MCL. Only two samples available. Analyte retained as presence in ground water not well characterized.
Surface Water			
Radionuclides			
Radium-226	0.393	pCi/L	No background. Potential human health risk identified based on PRG screening-level comparison in the single sample collected from Spring 6, however there is no exposure pathway. Below MCL. Analyte retained as presence in Spring 6 and ground water that discharges into Spring 6 not well characterized.
Surface soil (0 to 0.5 ft)-Overall (human health)			
Radionuclides			
Uranium-235	0.95	pCi/g	Above background. Potential human health risk identified based on PRG screening-level comparison.
Uranium-238	93	pCi/g	Above background. Potential human health risk identified based on PRG screening-level comparison.
Surface Soil (0 to 0.5 ft)-Hillslopes (threat to ground water)			
Metals			
Copper	4,100	mg/kg	Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.
Radionuclides			
Uranium, total	87	pCi/g	No background or threat to ground water SSL available. Risk characterization of Uranium-235 and Uranium-238 indicate a potential threat to ground water from total uranium.
Uranium-235	0.887	pCi/g	Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.
Uranium-238	77	pCi/g	Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.

Table 2-3 (continued). Initial list of Preliminary Contaminants of Concern (PCOCs) for the Building 812 Operable Unit.

PCOC	Maximum Result[a]	Units	Rationale
Surface Soil (0 to 0.5 ft)-Firing table (threat to ground water)			
Metals			
Uranium, total	278	mg/kg	Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and slightly exceeds MCL-based SSL based on DAF 20.
Radionuclides			
Uranium, total	95	pCi/g	No background or threat to ground water SSL available. Risk characterization of Uranium-235 and Uranium-238 indicate a potential threat to ground water from total uranium.
Uranium-235	0.95	pCi/g	Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.
Uranium-238	93	pCi/g	Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.
Surface Soil (0 to 0.5 ft) -Alluvial deposits (threat to ground water)			
Metals			
Copper	110	mg/kg	Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.
Lead	100	mg/kg	Above background. No threat to ground water risk-based SSL available. Exceeds threat to ground water MCL-based SSL based on DAF 1.
Uranium, total	88.2	mg/kg	Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.
Radionuclides			
Uranium, total	34.1	pCi/g	No background or threat to ground water SSL available. Risk characterization of Uranium-238 and Uranium-235 indicate a potential threat to ground water from total uranium.
Uranium-235	0.59	pCi/g	Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.
Uranium-238	29.6	pCi/g	Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.

Table 2-3 (continued). Initial list of Preliminary Contaminants of Concern (PCOCs) for the Building 812 Operable Unit.

PCOC	Maximum Result[a]	Units	Rationale
Subsurface soil (0.5 to 12 ft)-Overall (human health)			
None	—	—	*No COPCs were retained*

PCOC/Boring	Weighted Average	Units	Rationale
Soil borings (all data)--Hillslopes (threat to ground water)			
Metals			
Manganese			
B-812-04	**5,700**	**mg/kg**	**Above background. Result from the only sample collected from B-812-04 (5 ft). Exceeds threat to ground water risk-based SSL based on DAF 1 and risk-based SSL based on DAF 20. No MCL-based SSL available.**
Radionuclides			
Uranium, total			
B-812-2401	**7.4**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
Uranium-238			
B-812-2401	**6**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Soil borings (all data)--Firing table (threat to ground water)			
Metals			
Uranium, total			
812-01	**67,400**	**mg/kg**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**

Table 2-3 (continued). Initial list of Preliminary Contaminants of Concern (PCOCs) for the Building 812 Operable Unit.

PCOC/Boring	Weighted Average	Units	Rationale
Soil borings (all data)--Firing table (threat to ground water) (continued)			
Radionuclides			
Radium-226			
812-01	**10.4**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Radium-228			
812-01	**1.25**	**pCi/g**	**No background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Uranium, total			
812-01	**29,755**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-235 and Uranium-238 indicate a potential threat to ground water from total uranium.**
812-02	**8.542**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
812-03	**7.89**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
B-812-2404	**14.7**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
B-812-2405	**5.5**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
Uranium-235			
812-01	**110**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**

Table 2-3 (continued). Initial list of Preliminary Contaminants of Concern (PCOCs) for the Building 812 Operable Unit.

PCOC/Boring	Weighted Average	Units	Rationale
Soil borings (all data)--Firing table (threat to ground water) (continued)			
Radionuclides (continued)			
Uranium-238			
812-01	**22,630**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
812-02	**6.413**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
812-03	**7.43**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
B-812-2404	**13.67**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
B-812-2405	**4.6**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Soil borings (all data)--Alluvial deposits (threat to ground water)			
Radionuclides			
Uranium, total			
B-812-2407	**5.3**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
Uranium-238			
B-812-2407	**4.05**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.**

Notes appear on the following page.

Table 2-3 (continued). Initial list of Preliminary Contaminants of Concern (PCOCs) for the Building 812 Operable Unit.

Notes:

PCOC =	**Preliminary Contaminant of Concern.**
MCL =	**Maximum Contaminant Level.**
DAF =	**Dilution Attenuation Factor.**
ft =	**Feet.**
mg/kg =	**Milligrams per kilogram.**
mg/L =	**Milligrams per liter.**
pCi/g =	**PicoCuries per gram.**
pCi/L =	**PicoCuries per liter.**
PRG =	**Preliminary Remediation Goals.**
RSL =	**Regional Screening Levels.**

[a] **Based on data collected between January 1, 1988 and October 21, 2007.**

Table 2-4. EPA Regional Screening Levels (RSLs) and Preliminary Remediation Goals (PRGs) used to identify the initial threat to ground water preliminary contaminants of concern (PCOCs) in Building 812 surface soil.

PCOC	MCL-based RSL/PRG for threat to ground water	MCL in drinking water	Site 300 Background in surface soil	Site 300 Background in ground water
Hillslope and Firing Table areas (RSL/PRG based on DAF 20)				
Copper	915 mg/kg	1.3 mg/L[a]	39 mg/kg	0.05 mg/L
Uranium, total (metal)	270 mg/kg	30 µg/L[a]	9.39 mg/kg[b]	2.8 µg/L[b]
Uranium, total (radionuclide)	none	20 pCi/L[c]	none	none
Uranium-235 (+D)[d]	0.777 pCi/g	64.8 pCi/L[e]	0.0737 pCi/g	1.79 pCi/L
Uranium-238 (+D)[d]	0.121 pCi/g	10.1 pCi/L[e]	3.1 pCi/g	9.28 pCi/L
Alluvial Fill area (RSL/PRG based on DAF 1)				
Copper	45.8 mg/kg	1.3 mg/L[a]	39 mg/kg	0.05 mg/L
Lead	13.5 mg/kg	0.015 mg/L[a]	51 mg/kg	0.02 mg/L
Uranium, total (metal)	13.5 mg/kg	30 µg/L[a]	9.39 mg/kg[b]	2.8 µg/L[b]
Uranium, total (radionuclide)	none	20 pCi/L[c]	none	none
Uranium-235 (+D)[d]	0.0389 pCi/g	64.8 pCi/L[e]	0.0737 pCi/g	1.79 pCi/L
Uranium-238 (+D)[d]	0.00604 pCi/g	10.1 pCi/L[e]	3.1 pCi/g	9.28 pCi/L

Notes:

PRG = Preliminary Remediation Goal.
RSL= Regional Screening Level.
MCL = Maximum Contaminant Level.
DAF = Dilution Attenuation Factor.
PCOC = Preliminary Contaminant of Concern.
mg/L = Milligrams per liter.
mg/kg = Milligrams per kilogram.
pCi/g = Picocuries per gram.
pCi/L = Picocuries per liter.

[a] Federal MCL as listed in the EPA Region 9 November 2010 Regional Screening Level summary table, obtained from http://www.epa.gov/region09/superfund/prg/ on March 21, 2011 (U.S. EPA 2010a).

[b] Based on Site 300 background for uranium-238.

[c] State of California MCL for uranium as listed in CDPH (2011).

[d] The +D designation indicates that the slope factor includes the contribution from ingrowth of daughter isotopes out to 100 years. Thus it includes the contributions from short-lived decay products, assuming equal activity concentrations (i.e., secular equilibrium) with the principal or parent nuclide in the environment.

[e] MCL listed in the EPA Preliminary Remediation Goal August 2010 residential soil to ground water summary table obtained from http://epa-prgs.ornl.gov/radionuclides/ obtained on March 21, 2011 (U.S. EPA 2010b). Based on the 30 µg/L MCL and assumes only a single radioisotope present.

Table 2-5. EPA Regional Screening Levels (RSLs) and Preliminary Remediation Goals (PRGs) used to identify the initial threat to ground water preliminary contaminants of concern (PCOCs) in Building 812 subsurface soil.

PCOC	MCL-based RSL/PRG for threat to ground water	MCL in drinking water	Site 300 Background in surface soil	Site 300 Background in ground water
Hillslope and Firing Table areas (RSL/PRG based on DAF 20)				
Manganese	None: Risk-based RSL 1,140 mg/kg	None: Risk-based RSL 0.88 mg/L[a]	710 mg/kg	0.77 mg/L
Uranium, total (metal)	270 mg/kg	30 µg/L[a]	5.76 mg/kg[b]	2.8 µg/L[b]
Radium-226 (+D)[c]	0.322 pCi/g	5 pCi/L[d,f]	1.04 pCi/g	none
Radium-228 (+D)[c]	1.19 pCi/g	5 pCi/L[d,f]	none	none
Uranium, total (radionuclide)	none	20 pCi/L[e]	none	none
Uranium-235 (+D)[c]	0.777 pCi/g	64.8 pCi/L[d,g]	0.094 pCi/g	1.79 pCi/L
Uranium-238 (+D)[c]	0.121 pCi/g	10.1 pCi/L[d,g]	1.9 pCi/g	9.28 pCi/L
Alluvial Fill area (RSL/PRG based on DAF 1)				
Uranium, total (radionuclide)	none	20 pCi/L[e]	none	none
Uranium-238 (+D)[c]	0.00604 pCi/g	10.1 pCi/L[d,g]	1.9 pCi/g	9.28 pCi/L

Notes:

- PRG = Preliminary Remediation Goal.
- RSL= Regional Screening Level.
- MCL = Maximum Contaminant Level.
- DAF = Dilution Attenuation Factor.
- PCOC = Preliminary Contaminant of Concern.
- mg/L = Milligrams per liter.
- mg/kg = Milligrams per kilogram.
- pCi/g = Picocuries per gram.
- pCi/L = Picocuries per liter.

[a] Federal MCL as listed in the EPA Region 9 November 2010 Regional Screening Level summary table, obtained from http://www.epa.gov/region09/superfund/prg/ on March 21, 2011 (U.S. EPA 2010a).

[b] Based on Site 300 background for uranium-238.

[c] The +D designation indicates that the slope factor includes the contribution from ingrowth of daughter isotopes out to 100 years. Thus it includes the contributions from short-lived decay products, assuming equal activity concentrations (i.e., secular equilibrium) with the principal or parent nuclide in the environment.

[d] MCL listed in the EPA Preliminary Remediation Goal August 2010 residential soil to ground water summary table obtained from http://epa-prgs.ornl.gov/radionuclides/ on March 21, 2011 (U.S. EPA 2010b).

[e] State of California MCL for uranium as listed in CDPH (2011).

[f] MCL is for the combined Radium-226 and Radium-228 activities. Threat to ground water PRG assumes only a single radioisotope present.

[g] MCL as activity is based on the 30 µg/L MCL for total uranium, and assumes only a single radioisotope present.

Table 2-6. Outdoor worker ingestion, inhalation, external exposure and total Preliminary Remediation Goals (PRGs) for uranium-235 and uranium-238 in Building 812 surface soil.

PCOC	Ingestion PRG pCi/g[a]	Inhalation PRG pCi/g[a]	External Exposure PRG pCi/g[a]	Total PRG pCi/g[a]
Uranium-235[b]	36.1	1,200	0.391	0.386
Uranium-238 (+D)[c]	31.6	1,290	1.74	1.65

Notes:

PRG = **Preliminary Remediation Goal.**

pCi/g = **PicoCuries per gram.**

[a] **Obtained from the U.S. EPA Preliminary Remediation Goal outdoor worker calculator at http://epa-prgs.ornl.gov/cgi-bin/radionuclides/ on March 21, 2011.**

[b] **The PRG for the +D designation was not used for uranium-235, as external exposure slope factor was inadvertently left out of the uranium-235+D PRG calculations (Dolislager 2011). Therefore the uranium-235 PRG without the +D designation (no daughter product contribution) was used.**

[c] **The +D designation indicates that the slope factor includes the contribution from ingrowth of daughter isotopes out to 100 years.**

Table 2-7. Revised list of Preliminary Contaminants of Concern (PCOCs) that will be the focus of the Building 812 baseline human health risk assessment.

PCOC	Maximum Result[a]	Units	Rationale
Ground Water			
Metals			
Lithium	**0.0782**	**mg/L**	**No background. A single detection slightly above RSL (NC2-22, June 1994). No MCL. Only two samples available. Analyte retained as presence in ground water not well characterized.**
Radionuclides			
Radium-226	**NA**	**NA**	**Retained due to presence of radium-226 in surface water that is not well characterized.**
Surface Water			
Metals			
Lithium	**NA**	**NA**	**Retained due to presence of lithium in ground water that is not well characterized.**
Radionuclides			
Radium-226	**0.393**	**pCi/L**	**No background. Potential human health risk identified based on PRG screening-level comparison in the single sample collected from Spring 6, however there is no exposure pathway. Below MCL. Analyte retained as presence in Spring 6 and ground water that discharges into Spring 6 not well characterized.**
Surface soil (0 to 0.5 ft)-Overall (human health)			
Radionuclides			
Uranium-235	**0.95**	**pCi/g**	**Above background. Potential human health risk identified based on PRG screening-level comparison.**
Uranium-238	**93**	**pCi/g**	**Above background. Potential human health risk identified based on PRG screening-level comparison.**
Surface Soil (0 to 0.5 ft)-Hillslopes (threat to ground water)			
Metals			
Copper	**4,100**	**mg/kg**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**

Table 2-7 (continued). Revised list of Preliminary Contaminants of Concern (PCOCs) that will be the focus of the Building 812 baseline human health risk assessment.

PCOC	Maximum Result[a]	Units	Rationale
Surface Soil (0 to 0.5 ft)-Hillslopes (threat to ground water) (continued)			
Radionuclides			
Uranium, total	**87**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-235 and Uranium-238 indicate a potential threat to ground water from total uranium.**
Uranium-235	**0.887**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Uranium-238	**77**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Surface Soil (0 to 0.5 ft)-Firing table (threat to ground water)			
Metals			
Uranium, total	**278**	**mg/kg**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and slightly exceeds MCL-based SSL based on DAF 20.**
Radionuclides			
Uranium, total	**95**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-235 and Uranium-238 indicate a potential threat to ground water from total uranium.**
Uranium-235	**0.95**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Uranium-238	**93**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Surface Soil (0 to 0.5 ft) -Alluvial deposits (threat to ground water)			
Metals			
Copper	**110**	**mg/kg**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.**
Lead	**100**	**mg/kg**	**Above background. No threat to ground water risk-based SSL available. Exceeds threat to ground water MCL-based SSL based on DAF 1.**

Table 2-7 (continued). Revised list of Preliminary Contaminants of Concern (PCOCs) that will be the focus of the Building 812 baseline human health risk assessment.

PCOC	Maximum Result[a]	Units	Rationale
Surface Soil (0 to 0.5 ft) -Alluvial deposits (threat to ground water) (continued)			
Metals (continued)			
Uranium, total	**88.2**	**mg/kg**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.**
Radionuclides			
Uranium, total	**34.1**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 and Uranium-235 indicate a potential threat to ground water from total uranium.**
Uranium-235	**0.59**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.**
Uranium-238	**29.6**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.**
Subsurface soil (0.5 to 12 ft)-Overall (human health)			
None	**—**	**—**	***No COPCs were retained***

PCOC/Boring	Weighted Average	Units	Rationale
Soil borings (all data)--Hillslopes (threat to ground water)			
Metals			
Manganese			
B-812-04	**5,700**	**mg/kg**	**Above background. Result from the only sample collected from B-812-04 (5 ft). Exceeds threat to ground water risk-based SSL based on DAF 1 and risk-based SSL based on DAF 20. No MCL-based SSL available. Although the spatial distribution of manganese in borings crossgradient and upgradient suggests manganese at this location not related to firing table activities, use of manganese at the firing table could not be ruled out.**

Table 2-7 (continued). Revised list of Preliminary Contaminants of Concern (PCOCs) that will be the focus of the Building 812 baseline human health risk assessment.

PCOC/Boring	Weighted Average	Units	Rationale
Soil borings (all data)--Hillslopes (threat to ground water) (continued)			
Radionuclides			
Uranium, total			
B-812-2401	**7.4**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
Uranium-238			
B-812-2401	**6**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Soil borings (all data)--Firing table (threat to ground water)			
Metals			
Uranium, total			
812-01	**67,400**	**mg/kg**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Soil borings (all data)--Firing table (threat to ground water) (continued)			
Radionuclides			
Radium-226			
812-01	**10.4**	**pCi/g**	**Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20. Above Site 300 background, although length of time required for depleted uranium-238 to decay to radium-226 suggest this activity is not related to firing table activities. Retained to ensure the cancer risk from naturally occurring substances is not discounted in the baseline risk assessment.**
Radium-228			
812-01	**1.25**	**pCi/g**	**Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20. No background. Not a part of the uranium-238 decay chain, and thus not likely to be related to firing table activities. Retained to ensure the cancer risk from naturally occurring substances is not discounted in the baseline risk assessment.**

Table 2-7 (continued). Revised list of Preliminary Contaminants of Concern (PCOCs) that will be the focus of the Building 812 baseline human health risk assessment.

PCOC/Boring	Weighted Average	Units	Rationale
Soil borings (all data)--Firing table (threat to ground water) (continued)			
Radionuclides (continued)			
Uranium, total			
812-01	**29,755**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-235 and Uranium-238 indicate a potential threat to ground water from total uranium.**
812-02	**8.542**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
812-03	**7.89**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
B-812-2404	**14.7**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
B-812-2405	**5.5**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
Uranium-235			
812-01	**110**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Uranium-238			
812-01	**22,630**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
812-02	**6.413**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
812-03	**7.43**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**

Table 2-7 (continued). Revised list of Preliminary Contaminants of Concern (PCOCs) that will be the focus of the Building 812 baseline human health risk assessment.

PCOC/Boring	Weighted Average	Units	Rationale
Soil borings (all data)--Firing table (threat to ground water) (continued)			
Radionuclides (continued)			
B-812-2404	**13.67**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
B-812-2405	**4.6**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 20.**
Soil borings (all data)--Alluvial deposits (threat to ground water)			
Radionuclides			
Uranium, total			
B-812-2407	**5.3**	**pCi/g**	**No background or threat to ground water SSL available. Risk characterization of Uranium-238 indicate a potential threat to ground water from total uranium.**
Uranium-238			
B-812-2407	**4.05**	**pCi/g**	**Above background. Exceeds threat to ground water risk-based SSL based on DAF 1 and MCL-based SSL based on DAF 1.**

Notes:

PCOC = Preliminary Contaminant of Concern.
MCL = Maximum Contaminant Level.
DAF = Dilution Attenuation Factor.
ft = Feet.
mg/kg = Milligrams per kilogram.
mg/L = Milligrams per liter.
pCi/g = PicoCuries per gram.
pCi/L = PicoCuries per liter.
PRG = Preliminary Remediation Goals.
RSL = Regional Screening Levels.

[a] **Based on data collected between January 1, 1988 and October 21, 2007.**

Table 3-1. List of Contaminants of Potential Ecological Concern (COPEC) retained from the Building 812 OU screening-level ecological risk assessment and used as the initial list of Preliminary Contaminants of Ecological Concern (PCOECs) for the Building 812 OU baseline ecological risk assessment.

COPEC	Maximum Result[a]	Units	Rationale
Surface Water			
Metals			
Uranium, total	0.146	mg/L	Although current concentrations are below background, uranium concentrations exceeding background are present in the ground water that may discharge into Spring 6, as well as in surface soil and subsurface soil.
Zinc	0.49	mg/L	Only a single detection above background. Current concentrations are below background. However, zinc is a COPEC in surface soil.
Shallow Ground Water			
Metals			
Copper	0.12	mg/L	Single detection above background and ESL. Current concentrations below background. However, copper is a COPEC in surface soil. May discharge into Spring 6. Phreatic vegetation present.
Nickel	0.16	mg/L	Single detection from the most recent sample from well NC2-23 above background and ESL. Nickel is a surface soil COPEC. May discharge into Spring 6. Phreatic vegetation present.
Uranium, total	0.230	mg/L	Above background and ESL. May discharge into Spring 6. Phreatic vegetation present.
Saturated sediment (0 to 0.5 ft)			
None			No COPECs retained.
Surface soil (0 to 0.5 ft)			
Metals			
Copper	4,100	mg/kg	Above background and screening levels. All samples exceeding background located within approximately 200 ft of the firing table or Building 812 facilities.
Lead	150	mg/kg	Above background and screening levels. All samples exceeding background located within approximately 200 ft of the firing table or Building 812 facilities.
Nickel	540	mg/kg	The single sample above background and screening levels (3SS-812-1919) located south of Building 812F.

Table 3-1 (continued). List of Contaminants of Potential Ecological Concern (COPEC) retained from the Building 812 OU screening-level ecological risk assessment and used as the initial list of Preliminary Contaminants of Ecological Concern (PCOECs) for the Building 812 OU baseline ecological risk assessment.

COPEC	Maximum Result[a]	Units	Rationale
Surface soil (0 to 0.5 ft) continued			
Metals (continued)			
Uranium, total	278	mg/kg	Above background and screening levels. Samples exceeding background found at a greater areal extent than the other metals.
Zinc	230	mg/kg	Above background and screening levels. All samples exceeding background located within approximately 200 ft of the firing table or Building 812 facilities.
Subsurface Soil (0.5 to 6 ft)			
Metals			
Uranium, total	67,400	mg/kg	Above background and screening level. Single sample collected at 5 ft within the firing table exceeds ecological screening level.
Radionuclides			
Thorium-228	0.89	pCi/g	No background available. Above human health screening level. Ecological dose criteria = 0.1 rad/d, but has not been estimated.
Uranium-238	22,630	pCi/g	Above background and screening level. Single sample collected at 5 ft within the firing table exceeds ecological screening level.

Notes:

ft = Feet.
rad/d = Rads per day.
mg/kg = Milligrams per kilogram.
mg/L = Milligrams per liter.
pCi/g = Picocuries per gram.
COPEC = Contaminant of Potential Ecological Concern.
ESL = Ecological Screening Level.

[a] Based on data collected between January 1, 1988 and October 31, 2007.

Table 3-2. National Recommended Water Quality Criteria (NRWQC) and maximum Site 300 surface water background concentrations for copper, lead, nickel, and zinc.

Analyte	NRWQC Chronic (mg/L)[a]	Maximum Site 300 spring background concentration (mg/L)
Copper	0.009[b]	0.05
Lead	0.0025	0.02
Nickel	0.052	0.021
Zinc	0.12	0.12

Notes:

NRWQC = National Recommended Water Quality Criteria.

[a] U.S. EPA (2009a). National Recommended Water Quality Criteria: Freshwater aquatic life. Based on a hardness of 100 mg/L.

[b] New copper guidelines came out in 2007 (U.S. EPA 2007f) that require running a site-specific biotic ligand model. Value in this table is the 2002 (U.S. EPA 2002) copper criteria. Based on a hardness of 100 mg/L.

Table 3-3. Uranium freshwater ecological screening levels used in the Building 812 screening-level ecological risk assessment[a].

Back-ground	ESL	Test Organisms	Method
Fresh Water Invertebrates			
0.028 mg/L	0.005 mg/L	Four studies used *Daphnia sp.* and one study used *Ceriodaphnia dubia*. Ten studies used tropical species (various fresh water invertebrates, hydra, and unionid bivalves).	All 15 studies were combined, the PNEC is the 5th percentile of the distributions of the lowest observed effect concentration, thus protecting 95% of biota. However, the five studies with temperate species had LOECs ranging from 0.15 to 5.9 mg/L and were hardness dependent, where as the LOECs for the tropical species ranged from 0.015 to 0.35 mg/L.
Fresh Water Plants			
0.028 mg/L	0.005 mg/L	*Chlorella* sp (algae)	3 studies, PNEC the geometric mean of data and a safety factor of 10
Fresh Water Fish			
0.028 mg/L	23 mg/L	Various	13 studies, PNEC based on water hardness

Notes:

ESL = Ecological Screening Level.
mg/L = Milligrams per liter.
PNEC= Probable No Effect Concentration.
LOEC = Lowest Observable Effect Concentration.

[a] Sheppard et al. 2005.

Table 3-4. Test organisms and endpoints used in developing ecological soil screening levels for plants and invertebrates used in the Building 812 screening-level ecological assessment.

	Terrestrial Plants				Soil Invertebrates			
Analyte	**Test Organisms**	**Number of Studies and Endpoints**	**Method for determining ESL**	**EcoSSL (mg/kg)**	**Test Organism**	**Number of Studies and Endpoints**	**Method for determining ESL**	**EcoSSL (mg/kg)**
Copper[a]	**Black bindweed, Citrus cultivar, Perennial ryegrass*[b]*, Alfalfa*[b]***	**GRO: 1 REP: 5**	**Geometric mean of MATC and EC_{10}**	**70**	**Springtails, Earthworms, Nematodes**	**GRO: 1 REP: 7 POP[c]: 2**	**Geometric mean of MATC and EC_{10}**	**80**
Lead[d]	**Loblolly pine, Red maple, Berseem clover, Ryegrass[e]**	**GRO: 5**	**Geometric mean of MATC**	**120**	**Collembola**	**REP: 4**	**Geometric mean of MATC**	**1,700**
Nickel[f]	**Alfalfa, Barley, Brassica, Red Oak, Ryegrass, Oat**	**GRO: 10 REP: 1**	**Geometric mean of MATC and EC_{10}**	**38**	**Springtails, Earthworms**	**REP: 5**	**Geometric mean of MATC**	**280**
Zinc[g]	**Soybeans, Oats, Lettuce**	**GRO: 5**	**Geometric mean of MATC**	**160**	**Springtails, Nematodes**	**REP: 4 POP[c]: 2**	**Geometric mean of MATC and EC_{10}**	**120**
Uranium[h]	**Pines, grass species, crop species (corn, lettuce, beans, mustard)**	**9 citations looking at germination, growth and survival**	**PNEC using a safety factor**	**100**	**Collembola, earthworms, springtails**	**8 citations looking at survival and reproduction**	**PNEC using a safety factor**	**100**

Notes appear on the following page.

Table 3-4 (continued). Test organisms and endpoints used in developing ecological soil screening levels for plants and invertebrates used in the Building 812 screening-level ecological assessment.

Notes:

EcoSSL = **Ecological Soil Screening Level.**
mg/kg = **Milligrams per kilogram.**
GRO = **Growth endpoint.**
REP = **Reproductive endpoint.**
POP = **Population-level effects endpoint.**
MATC = **Maximum Acceptable Toxicant Concentration.**
EC_{10} = **10% Effective Concentration.**
PNEC = **Probable No Effect Concentration.**

[a] **U.S. EPA (2007c). Ecological Soil Screening Levels for Copper. Interim Final. OSWER Directive 9285.7-68. US. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. Issued July 2007, Revised February 2007.**

[b] **Ryegrass had a toxicity value of 16 mg/kg for copper (as determined by Torres and De Varennes, 1998), and alfalfa had a toxicity value between 32 and 115 mg/kg (as determined by Gonzalez, 1991).**

[c] **Measurements and endpoints regarding a group of organisms or plants of the same species occupying the same area at a given time. Measurements include population dynamics/changes over time. Examples include changes in size and age class structures, changes in sex ratio, population change over time, population growth rate, survivability of subsequent generations, biomass or weight for total population, live mass, diversity, evenness, index to population size (count, number, abundance), life table data, number of animals per population, population density (number/area), primary productivity, standing crop biomass, CO2 uptake, oxygen release, germination rates, population growth, intrinsic rate of increase, and biomass/abundance in relation to time.**

[d] **U.S. EPA (2005b). Ecological Soil Screening Levels for Lead. Interim Final. OSWER Directive 9285.7-70. US. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. Issued March 2005.**

[e] **Ryegrass had a toxicity value of 22 mg/kg for lead (as determined by Singh and Jeng, 1993).**

[f] **U.S. EPA (2007d). Ecological Soil Screening Levels for Nickel. Interim Final. OSWER Directive 9285.7-76. US. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. Issued March 2007.**

[g] **U.S. EPA (2007e). Ecological Soil Screening Levels for Zinc. Interim Final. OSWER Directive 9285.7-73. US. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. Issued June 2007.**

[h] **Sheppard et al. 2005.**

Table 3-5. Species, assessment and measurement endpoints, and exposure modeling assumptions used in developing the U.S. EPA ecological soil screening levels for birds (Avn) and mammals (Mml)[a]. The value in red corresponds to the Ecological Screening Level used in the Building 812 screening-level ecological risk assessment.

	Surrogate Species					EcoSSL (mg/kg)							
						Copper[b]		Lead[c]		Nickel[d]		Zinc[e]	
Species Guild	Avn	Mml	Assessment Endpoints	Measurement Endpoint	Exposure Modeling Assumptions	Avn	Mml	Avn	Mml	Avn	Mml	Avn	Mml
Herbi-vore	Mourning Dove	Meadow Vole	Growth and Repro-duction	Modeled oral exposure compared to TRV equal to the geometric mean of NOAEL data obtained from the literature[f]	Absorbed fraction 100%; spends 100% time in area; consumes 100% seeds/foliage[g]; high bioavailability; high food and soil ingestion rates	76	1,100	46	1,200	210	340	950	6,800
Ground Inverti-vore	American Woodcock	Short Tailed Shrew	Growth and Repro-duction	Modeled oral exposure compared to TRV equal to the geometric mean of NOAEL data obtained from the literature[f]	Absorbed fraction 100%; spends 100% time in area; consumes 100% earthworms; high bioavailability; high food and soil ingestion rates	28	49	11	56	NA	NA	46	79
Carni-vore	Red-tailed Hawk	Long-Tailed Weasel	Growth and Repro-duction	Modeled oral exposure compared to TRV equal to the geometric mean of NOAEL data obtained from the literature[f]	Absorbed fraction 100%; spends 100% time in area; consumes 100% small mammals[h]; high bioavailability; high food and soil ingestion rates	1,600	560	510	460	2,800	130	30,000	10,000

Notes appear on the following page.

Table 3-5 (continued). Species, assessment and measurement endpoints, and exposure modeling assumptions used in developing the U.S. EPA ecological soil screening levels for birds (Avn) and mammals (Mml)[a]. The value in red corresponds to the Ecological Screening Level used in the Building 812 screening-level ecological risk assessment.

Notes:

EcoSSL =	Ecological Soil Screening Level.
mg/kg =	Milligrams per kilogram.
TRV=	Toxicity Reference Value
NOAEL=	No Observed Adverse Effect Level.
LOAEL =	Lowest Observed Adverse Effect Level.
Avn =	Avian.
Mml =	Mammal.

a U.S. EPA (2005a). Guidance for Developing Ecological Soil Screening Levels. Interim Final. OSWER Directive 9285.7-55. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. Issued November 2003, Revised February 2005.

b U.S. EPA (2007c). Ecological Soil Screening Levels for Copper. Interim Final. OSWER Directive 9285.7-68. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. Issued July 2007, Revised February 2007.

c U.S. EPA (2005b). Ecological Soil Screening Levels for Lead. Interim Final. OSWER Directive 9285.7-70. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. Issued March 2005.

d U.S. EPA (2007d). Ecological Soil Screening Levels for Nickel. Interim Final. OSWER Directive 9285.7-76. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. Issued March 2007.

e U.S. EPA (2007e). Ecological Soil Screening Levels for Zinc. Interim Final. OSWER Directive 9285.7-73. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. Issued June 2007.

f In cases where the geometric mean NOAEL is higher than the lowest bounded LOAEL (bounded refers to a LOAEL that has a paired NOAEL) for either growth, reproduction or mortality endpoints, the TRV is equal to the highest bounded NOAEL below the lowest bounded LOAEL.

g Avian herbivore assumed to consume 100% seeds, mammalian herbivore assumed to consume 100% foliage.

h Avian carnivore assumed to consume 100% small mammals that consume 100% earthworms.

Table 3-6. Species, assessment and measurement endpoints, and exposure modeling assumptions used in developing uranium ecological soil screening levels for birds and mammals used in the Building 812 screening-level ecological risk assessment.

Species Guild	RREI	Assessment Endpoints	Measurement Endpoint	Exposure Modeling Assumptions	EcoSSL (mg/kg)
Omnivorous Bird	Tri-colored blackbird	Growth and Reproduction	Modeled oral exposure compared to TRV developed for birds based on data in Sheppard et al. (2005).	Absorbed fraction 100%; spends 100% time in area; consumes 40% vegetation, 60% ground invertebrates; conservative BAFs	230
Carnivorous Bird	Barn owl	Growth and Reproduction	Modeled oral exposure compared to TRV developed for birds based on data in Sheppard et al. (2005).	Absorbed fraction 100%; spends 100% time in area; consumes 90% small mammals, remaining ground invertebrates; conservative BAFs	170
Omnivorous Mammal	Deer mouse	Growth and Reproduction	Modeled oral exposure compared to TRV developed for small mammals based on data in Sheppard et al. (2005).	Absorbed fraction 100%; spends 100% time in area; consumes 70% vegetation, 30% ground invertebrates; conservative BAFs	2.0
Granivorous mammal	Ground squirrel	Growth and Reproduction	Modeled oral exposure compared to TRV developed for small mammals based on data in Sheppard et al. (2005).	Absorbed fraction 100%; spends 100% time in area; consumes 100% vegetation; conservative BAFs	5.2
Herbivorous mammal, small	Pocket gopher	Growth and Reproduction	Modeled oral exposure compared to TRV developed for small mammals based on data in Sheppard et al. (2005).	Absorbed fraction 100%; spends 100% time in area; consumes 100% vegetation; conservative BAFs	5.8
Herbivorous mammal, large	Black tailed deer	Growth and Reproduction	Modeled oral exposure compared to TRV developed for small mammals based on data in Sheppard et al. (2005).	Absorbed fraction 100%; spends 100% time in area; consumes 100% vegetation; conservative BAFs	63.2
Carnivorous mammal	Kit fox	Growth and Reproduction	Modeled oral exposure compared to TRV developed for small mammals based on data in Sheppard et al. (2005).	Absorbed fraction 100%; spends 100% time in area; consumes 50% small mammals, 50% invertebrates; used ground invertebrate BAF; conservative BAFs	2.9

Notes:

EcoSSL = Ecological Soil Screening Level.
mg/kg = Milligrams per kilogram.
RREI = Representative Receptor of Ecological Interest.
BAF = Bioaccumulation Factor.
TRV = Toxicity Reference Value.

Table 3-7. Toxicity Reference Values (TRVs) used in developing avian and mammalian ecological soil screening levels used in the Building 812 screening-level ecological risk assessment.

	Avian				Mammal			
Analyte	**TRV mg/kg/d**	**Test Species**	**Number of Studies**	**Method for determining TRV**	**TRV mg/kg/d**	**Test Species**	**Number of Studies**	**Method for determining TRV**
Copper	4.05	Chicken, turkey, duck	REP: 25 GRO: 130 MOR: 50	Highest bounded NOAEL that is lower than the lowest bounded LOAEL for REP, GRO or MOR[a,e]	5.60	Mink, pig, mouse, rat, cattle, guinea pig, rabbit, horse, common shrew, goat, sheep	REP: 11 GRO: 82 MOR: 30	Highest bounded NOAEL that is lower than the lowest bounded LOAEL for REP, GRO or MOR[a,e]
Lead	1.63	Japanese quail, chicken, mallard, American kestrel, ringed-tailed turtle dove, duck, pigeon, goose	REP: 14 GRO: 30 MOR: 13	Highest bounded NOAEL that is lower than the lowest bounded LOAEL for REP, GRO or MOR[b,e]	4.70	Rat, Guinea pig, sheep, cotton rate, hamster, mouse, horse, cattle, dog, rabbit, shrew	REP: 94 GRO: 90 MOR: 39	Highest bounded NOAEL that is lower than the lowest bounded LOAEL for REP, GRO or MOR[b,e]
Nickel	6.71	Duck, chicken	REP: 2 GRO: 11 MOR: 4	Geometric mean of NOAEL data for REP and GRO[c]	1.70	Rat, mouse, dog, cattle, meadow vole	REP: 17 GRO: 32 MOR: 12	Highest bounded NOAEL that is lower than the lowest bounded LOAEL for REP, GRO or MOR[c,e]
Zinc	66.1	Chicken, mallard, Japanese quail, turkey	REP: 16 GRO: 52 MOR: 26	Geometric mean of NOAEL data for REP and GRO[d]	75.4	Pig, mouse, rat, cattle, rabbit, hamster, rat, water buffalo, cattle, mink, golden hamster, sheep, horse	REP: 32 GRO: 54 MOR: 18	Geometric mean of NOAEL data for REP and GRO[d]
Uranium	10	Black duck, leghorn chicks	2 citations with growth and mortality endpoints	Observation that lowest lethal dose for leghorn chicks was 100 fold high for birds than mammals[f]. NOAEL reported as 160 mg/kg/d for black duck.	0.1	Rats, dogs, rabbits, mice	5 citations with various growth, reproductive, and physiological endpoints	NOAEL ranged from 2.8 to 7.7 mg/kg/d, LOAEL ranged from 2.8 to 7.7 mg/kg/d. PNEC of 1.3 mg/kg/d and an applied safety factor of 10[f].

Notes appear on the following page.

Table 3-7 (continued). Toxicity Reference Values (TRVs) used in developing avian and mammalian ecological soil screening levels used in the Building 812 screening-level ecological risk assessment.

Notes:

EcoSSL =	Ecological Soil Screening Level.
mg/kg/d=	Milligrams per kilogram per day.
TRV=	Toxicity Reference Value.
NOAEL=	No Observed Adverse Effect Level.
LOAEL=	Lowest Observed Adverse Effect Level.
REP=	Reproductive endpoint.
GRO=	Growth endpoint.
MOR=	Mortality (survivorship) endpoint.
PNEC=	Predicted No Effect Concentration

[a] USEPA (2007c). Ecological Soil Screening Levels for Copper. Interim Final. OSWER Directive 9285.7-68. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. Issued July 2007, Revised February 2007.

[b] USEPA (2005b). Ecological Soil Screening Levels for Lead. Interim Final. OSWER Directive 9285.7-70. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. Issued March 2005.

[c] USEPA (2007d). Ecological Soil Screening Levels for Nickel. Interim Final. OSWER Directive 9285.7-76. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. Issued March 2007.

[d] USEPA (2007e). Ecological Soil Screening Levels for Zinc. Interim Final. OSWER Directive 9285.7-73. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC. Issued June 2007.

[e] In cases where the geometric mean NOAEL is higher than the lowest bounded LOAEL (bounded refers to a LOAEL that has a paired NOAEL) for either growth, reproduction or mortality endpoints, the TRV is equal to the highest bounded NOAEL below the lowest bounded LOAEL.

[f] Sheppard et. al 2005.

Table 3-8. Most recent concentrations of copper, nickel, zinc, lead and uranium in Spring 6 and shallow alluvial ground water wells.

Location	Date	Copper mg/L	Nickel mg/L	Zinc mg/L	Date	Lead mg/L	Date	Uranium mg/L
Spring 6	29-Oct-07	<0.01[a]	<0.005[c]	<0.01[f]	29-Oct-07	<0.0020[g]	27-Jul-10	0.007
NC2-23	16-May-05	<0.01[a]	0.16[d]	<0.02[f]	14-May-07	<0.0050[h]	18-Nov-10	0.003
W-812-08	25-May-05	<0.01[a]	<0.1[d]	<0.02[f]	28-May-07	<0.0002[g]	21-Jul-10	0.15
W-812-1921	13-Feb-04	<0.01[a]	<0.02[e]	<0.02[f]	22-Mar-10	<0.0050[h]	22-Mar-10	0.12
W-812-1932	17-May-05	<0.01[a]	<0.1[d]	0.049[f]	13-Sep-05	<0.0020[g]	21-Jul-10	0.012
W-812-2321	13-Nov-07	<0.05[b]	<0.1[d]	<0.05[f]	13-Nov-07	<0.0050[h]	18-Nov-10	0.03

Notes:

[a] Slightly above NRWQC for copper (0.009 mg/L), below background (0.05 mg/L).

[b] Above NRWQC for copper and right at background (0.05 mg/L).

[c] Below NRWQC for nickel (0.052 mg/L) and below background (0.021).

[d] Above NRWQC for nickel (0.052 mg/L) and above background (0.021).

[e] Below NRWQC for nickel (0.052 mg/L) and just below background (0.021).

[f] Below NRWQC for zinc (0.12 mg/L) and below background (0.12 mg/L).

[g] Below NRWQC for lead (0.0025 mg/L) and below background (0.02 mg/L).

[h] Slightly above NRWQC for lead (0.0025 mg/L) and below background (0.02 mg/L).

Table 3-9. Qualitative bioavailability of metal cations to plants and invertebrates used by the U.S. EPA in evaluating the toxicity literature used to develop ecological soil screening levels.[a]

Soil pH	Soil Organic Matter: Low Organic Matter (< 2%)	Medium Organic Matter (2% to < 6%)	High Organic Matter (6% to 10%)
Plants			
$4 \leq$ Soil pH ≤ 5.5	Very High	High	Medium
$5.5 <$ Soil pH < 7	High	Medium	Low
$7 \leq$ Soil pH ≤ 8.5	Medium	Low	Very Low
Soil Invertebrates			
$4 \leq$ Soil pH ≤ 5.5	Very High	High	Medium
$5.5 <$ Soil pH < 7	High	Medium	Low
$7 \leq$ Soil pH ≤ 8.5	Medium	Medium	Very Low

Notes:

[a] **From Table 2.4a and Table 2.4b in U.S. EPA (2005a).**

Table 3-10. Evaluation of home range and relevant biological, toxicological and areal extent of contamination information for Building 812 terrestrial species.

Species	Home-range (ac)	Copper ESL/ Ac>ESL[a]	Lead ESL/ Ac>ESL[a]	Nickel ESL/ Ac>ESL[a]	Zinc ESL/ Ac>ESL[a]	Uranium ESL/ Ac>ESL[a]	Total Ac Impacted/ % or # Home range	Evaluation of relevant biological, toxicological and areal extent of contamination information
Terrestrial Plants	NA	70 mg/kg 0.36 ac[j]	120 mg/kg 0.30 ac[m]	38 mg/kg 0.63 ac[o]	160 mg/kg 1.0 ac[p]	100 mg/kg 0.93 ac[q]	2.6 ac NA	Copper, lead and uranium areas overlap. Copper, lead, nickel and zinc areas uncertain. Lateral extent of phreatic vegetation uncertain.
Soil Invertebrates	NA	80 mg/kg 0.36 ac[j]	1,700 mg/kg 0 ac	280 mg/kg 0.63 ac[o]	120 mg/kg 1.0 ac[p]	100 mg/kg 0.93 ac[q]	2.6 ac NA	Copper and uranium areas overlap. Copper, nickel and zinc areas uncertain.
Ground Squirrel (mammalian herbivore)	0.4-0.6[b]	1,100 mg/kg 0.03 ac[k]	1,200 mg/kg 0 ac	340 mg/kg 0.63 ac[o]	6,800 mg/kg 0 ac	5.2 mg/kg 18 ac[r]	18 ac 30-45 home ranges	Not 100% herbivore, some insects are consumed. Uranium area overlaps copper and nickel areas. Copper and nickel areas uncertain. Uranium TRV uncertain. Does not require drinking water.
Deer Mouse (mammalian insectivore)	0.25-0.5[c]	49 mg/kg 1.2 ac[l]	56 mg/kg 1.4 ac[n]	NAV	79 mg/kg 1.0 ac[p]	2.0 mg/kg 18 ac[r]	18 ac 36-72 home ranges	Not 100% insectivore, vegetation an important part of diet. Uranium area overlaps zinc, lead and copper areas. Copper, lead and zinc areas uncertain. Uranium TRV uncertain. Will use adjacent open water sources when available.
Rock Wren (avian insectivore)	20[d]	28 mg/kg 1.2 ac[l]	11 mg/kg 1.4 ac[n]	NAV	46 mg/kg 1.0 ac[p]	230 mg/kg 0.38 ac[s]	2.4 ac 12%	No home range information available. Assumed 20 ac based on observations of 5 pairs per 100 acres. Copper, lead and uranium areas overlap. Copper, lead and zinc areas uncertain. Uranium TRV uncertain. Does not require drinking water.
Tricolored Blackbird (avian insectivore)	1,920[e]	28 mg/kg 1.2 ac[l]	11 mg/kg 1.4 ac[n]	NAV	46 mg/kg 1.0 ac[p]	230 mg/kg 0.38 ac[s]	2.4 ac 0.13%	Not 100% insectivore, grains an important part of diet. Home range reported to be up to 80 mi^2. Assumed 3 mi^2 (1,920 ac). Copper, lead and uranium areas overlap. Copper, lead and zinc areas uncertain. Uranium TRV uncertain. Drinking water may be required when consuming grains.

Table 3-10 (continued). Evaluation of home range and relevant biological, toxicological and areal extent of contamination information for Building 812 terrestrial species.

Species	Home-range (ac)	Copper ESL/ Ac>ESL[a]	Lead ESL/ Ac>ESL[a]	Nickel ESL/ Ac>ESL[a]	Zinc ESL/ Ac>ESL[a]	Uranium ESL/ Ac>ESL[a]	Total Ac Impacted/ % or # Home range	Evaluation of relevant biological, toxicological and areal extent of contamination information
Barn Owl (avian carnivore)	165[f]	1,600 mg/kg 0.03 ac[k]	510 mg/kg 0 ac	2,800 mg/kg 0 ac	30,000 mg/kg 0 ac	170 mg/kg 0.61 ac[t]	0.61 ac 0.37%	Copper and uranium areas overlap. Uranium TRV uncertain. Copper area uncertain. Uranium TRV uncertain. Does not require drinking water.
Mule Deer (mammalian herbivore)	256-704[g]	1,100 mg/kg 0.03 ac[k]	1,200 mg/kg 0 ac	340 mg/kg 0.63 ac[o]	6,800 mg/kg 0 ac	63 mg/kg 1.3 ac[u]	1.5 ac 0.21-0.59%	Copper and uranium areas overlap. Copper and nickel areas uncertain. Uranium TRV uncertain. Requires drinking water.
Kit Fox (mammalian carnivore)	640-1,280[h]	560 mg/kg 0.03 ac[k]	460 mg/kg 0 ac	130 mg/kg 0.63 ac[o]	10,000 mg/kg 0 ac	2.9 mg/kg 18 ac[r]	18 ac 1.4-2.8%	Uranium area overlaps copper and nickel area. Copper and nickel areas uncertain. Uranium TRV uncertain. Does not require drinking water.
Coyote (mammalian carnivore)	1,920-24,960[i]	560 mg/kg 0.03 ac[k]	460 mg/kg 0 ac	130 mg/kg 0.63 ac[o]	10,000 mg/kg 0 ac	2.9 mg/kg 18 ac[r]	18 ac 0.07-0.94%	Uranium area overlaps copper and nickel area. Copper and nickel areas uncertain. Uranium TRV uncertain. Requires drinking water.

Notes:

ESL = Ecological Screening Level.
mg/kg = Milligrams per kilogram.
Ac = Acre.
Mi = Mile.
NA = Not applicable.
NAV = Not available.
TRV = Toxicity Reference Value.

Notes continued on the following page.

Table 3-10 (continued). Evaluation of home range and relevant biological, toxicological and areal extent of contamination information for Building 812 terrestrial species.

Notes:

[a] If ESL was below background levels, the background value was used for the analysis.

[b] CWHRS (2010d). Polite, C. and G. Ahlborn. Life History Account for California Ground Squirrel (*Spermophilus beecheyi*). M072. California Wildlife Habitat Relationship System. California Department of Fish and Game. California Interagency Wildlife Task Group. Accessed from http://www.dfg.ca.gov/biogeodata/cwhr/ on December 16, 2010.

[c] CWHRS (2010c). Brylski, P. Life History Account for the Deer Mouse (*Peromyscus maniculatus*). M117. California Wildlife Habitat Relationship System. California Department of Fish and Game. California Interagency Wildlife Task Group. Accessed from http://www.dfg.ca.gov/biogeodata/cwhr/ on December 16, 2010.

[d] CWHRS (2010h). Dobkin, D. Life History Account for the Rock Wren (*Salpinctes obsoletus*). B366. California Wildlife Habitat Relationship System. California Department of Fish and Game. California Interagency Wildlife Task Group. Accessed from http://www.dfg.ca.gov/biogeodata/cwhr/ on February 21, 2010.

[e] CWHRS (2010j). Granholm, S. Life History Account for the Tri-color Blackbird (*Agelaius tricolor*). B520. California Wildlife Habitat Relationship System. California Department of Fish and Game. California Interagency Wildlife Task Group. Accessed from http://www.dfg.ca.gov/biogeodata/cwhr/ on December 16, 2010.

[f] CWHRS (2010a). Polite, C. Life History Account for the Barn Owl (*Tyto alba*). B262. California Wildlife Habitat Relationship System. California Department of Fish and Game. California Interagency Wildlife Task Group. Accessed from http://www.dfg.ca.gov/biogeodata/cwhr/ on December 16, 2010.

[g] CWHRS (2010g). Ahlborn, G. Life History Account for the Mule Deer (*Odocoileus hemionus*). M818. California Wildlife Habitat Relationship System. California Department of Fish and Game. California Interagency Wildlife Task Group. Accessed from http://www.dfg.ca.gov/biogeodata/cwhr/ on December 16, 2010.

[h] CWHRS (2010f). Ahlborn, G. Life History Account for the Kit Fox (*Vulpes macrotis*). M148. California Wildlife Habitat Relationship System. California Department of Fish and Game. California Interagency Wildlife Task Group. Accessed from http://www.dfg.ca.gov/biogeodata/cwhr/ on February 21, 2011.

[i] CWHRS (2010b). Ahlborn, G. Life History Account for the Coyote (*Canis latrans*). M146. California Wildlife Habitat Relationship System. California Department of Fish and Game. California Interagency Wildlife Task Group. Accessed from http://www.dfg.ca.gov/biogeodata/cwhr/ on February 21, 2011.

[j] Area within the 70 mg/kg copper contour on Figure 3-3.

[k] Area within the 48 mg/kg copper contour on Figure 3-3 which represents Site 300 background.

[l] Area within the 560 mg/kg copper contour on Figure 3-3.

[m] Area within the 120 mg/kg contour on Figure 3-4.

[n] Area within the 51 mg/kg lead contour on Figure 3-4 which represents Site 300 background.

[o] Area within the 130 mg/kg nickel contour on Figure 3-5.

[p] Area within the 110 mg/kg zinc contour on Figure 3-6 (including paved areas) which represents Site 300 background.

[q] Area within the 100 mg/kg uranium contour on Figure 3-2.

[r] Area within the 9.4 mg/kg uranium contour on Figure 3-2 (including paved areas) which represents Site 300 background.

[s] Area within the 230 mg/kg uranium contour on Figure 3-2.

[t] Area within the 170 mg/kg uranium contour on Figure 3-2.

[u] Area within the 63 mg/kg uranium contour on Figure 3-2.

Table 3-11. Status of the Initial Preliminary Contaminants of Ecological Concern (PCOEC) with respect to their inclusion in the Building 812 OU baseline ecological risk assessment.

Initial PCOEC	Most Recent Result	Units	Results of Problem Formulation Evaluation	Status as Final PCOEC
Surface Water (Spring 6)				
Metals				
Copper	**< 0.1 (29-Oct-07)**	**mg/L**	**Analyte added as an initial surface water PCOEC due to its potential presence in shallow ground water, its presence as a surface soil PCOEC with the potential to impact shallow ground water and surface water, and the lack of current surface water analytical data.**	**The information on the PCOEC is not adequate to make a decision at this point, and additional evaluation as part of the screening-level ecological risk assessment is required.**
Lead	**<0.0020 (29-Oct-07)**	**mg/L**	**Analyte added as an initial surface water PCOEC due to its presence as a surface soil PCOEC with the potential to impact shallow ground water and surface water, and the lack of current surface water analytical data.**	**The information on the PCOEC is not adequate to make a decision at this point, and additional evaluation as part of the screening-level ecological risk assessment is required.**
Nickel	**<0.005 (29-Oct-07)**	**mg/L**	**Analyte added as an initial surface water PCOEC due to its potential presence in shallow ground water, its presence as a surface soil PCOEC with the potential to impact shallow ground water and surface water, and the lack of current surface water analytical data.**	**The information on the PCOEC is not adequate to make a decision at this point, and additional evaluation as part of the screening-level ecological risk assessment is required.**
Uranium, total	**0.007 (27-Jul-10)**	**mg/L**	**Current concentrations at Spring 6 are below background for this analyte. However, concentrations exceeding background are present in shallow ground water that may discharge into Spring 6 downgradient of the current sampling location. Analyte was detected in surface water runoff at concentrations exceeding background and the ESL. Analyte is present as a surface soil and subsurface soil PCOEC, found at concentrations exceeding ESLs that could potentially impact shallow ground water and surface water.**	**The information on the PCOEC is not adequate to make a decision at this point, and additional evaluation as part of the screening-level ecological risk assessment is required.**
Zinc	**<0.01 (29-Oct-07)**	**mg/L**	**A single historical detection above background and the NRWQC. The most recent concentration is below background, however there is a lack of current analytical data. Present as a surface soil PCOEC with the potential to impact shallow ground water and surface water.**	**The information on the PCOEC is not adequate to make a decision at this point, and additional evaluation as part of the screening-level ecological risk assessment is required.**

Table 3-11 (continued). Status of the Initial Preliminary Contaminants of Ecological Concern (PCOEC) with respect to their inclusion in the Building 812 OU baseline ecological risk assessment.

Initial PCOEC	Most Recent Result	Units	Results of Problem Formulation Evaluation	Status as Final PCOEC
Shallow Ground Water (wells NC2-23, W-812-08, W-812-1921, W-812-1932, and W-812-2321)				
Metals				
Copper	<0.01 – <0.05 (13-Feb-04 to 13-Nov-07)	mg/L	A single detection above background and NRWQC. Most recent concentrations below background but wells are not regularly sampled for analyte. Shallow ground water may discharge into Spring 6 downgradient of current sampling location. Phreatic vegetation present. Present as a surface soil PCOEC with the potential to impact shallow ground water and surface water.	The information on the PCOEC is not adequate to make a decision at this point, and additional evaluation as part of the screening-level ecological risk assessment is required.
Lead	<0.0002 – <0.0050 (13-Sep-05 to 22-Mar-10)	mg/L	Analyte added as an initial shallow ground water PCOEC due to its presence as a surface soil PCOEC with the potential to impact shallow ground water and surface water. Phreatic vegetation present. Wells not regularly sampled for analyte.	The information on the PCOEC is not adequate to make a decision at this point, and additional evaluation as part of the screening-level ecological risk assessment is required.
Nickel	0.16 – <0.02 (13-Feb-04 to 13-Nov-07)	mg/L	Single detection from the most recent sample from well NC2-23 above background and NRWQC. Wells are not regularly sampled for analyte. Shallow ground water may discharge into Spring 6 downgradient of current sampling location. Phreatic vegetation present. Analyte present as a surface soil PCOEC with potential to impact shallow ground water and surface water.	The information on the PCOEC is not adequate to make a decision at this point, and additional evaluation as part of the screening-level ecological risk assessment is required.
Uranium, total	0.003 – 0.15 (22-Mar-10 to 18-Nov-10)	mg/L	Several wells above background and the ESL. Wells are regularly sampled for analyte. Shallow ground water may discharge into Spring 6 downgradient of current sampling location. Phreatic vegetation present. Analyte is present as a surface soil PCOEC.	The available information indicates a potential for adverse ecological effects from the PCOEC, and a more thorough assessment in the baseline ecological risk assessment is warranted.
Zinc	<0.02 – 0.049 (13-Feb-04 to 13-Nov-07)	mg/L	Analyte added as an initial shallow ground water PCOEC due to its presence as a surface soil PCOEC with the potential to impact shallow ground water and surface water. Phreatic vegetation present. Wells are not regularly sampled for the analyte.	The information on the PCOEC is not adequate to make a decision at this point, and additional evaluation as part of the screening-level ecological risk assessment is required.

Table 3-11 (continued). Status of the initial Preliminary Contaminants of Ecological Concern (PCOEC) with respect to their inclusion in the Building 812 OU baseline ecological risk assessment.

Initial PCOEC	Maximum Result	Units	Results of Problem Formulation Evaluation	Status as Final PCOEC
Saturated sediment (0 to 0.5 ft)				
Copper, Lead, Nickel, Uranium, Zinc	**NA**	**NA**	**No PCOECs identified from the existing six sediment sampling locations in the SLERA. Analytes were added as initial sediment PCOECs because sediment from pools located downgradient of the current locations that are habitat for the California red-legged frog have not been sampled.**	**The information on the PCOEC is not adequate to make a decision at this point, and additional evaluation as part of the screening-level ecological risk assessment is required.**
Surface soil (0 to 0.5 ft)				
Metals				
Copper	**4,100**	**mg/kg**	**Above background and screening levels. All samples exceeding background located within approximately 200 ft of the firing table or Building 812 facilities.**	**The available information indicates a potential for adverse ecological effects from the PCOEC, and a more thorough assessment in the baseline ecological risk assessment is warranted.**
Lead	**150**	**mg/kg**	**Above background and screening levels. All samples exceeding background located within approximately 200 ft of the firing table or Building 812 facilities.**	**The available information indicates a potential for adverse ecological effects from the PCOEC, and a more thorough assessment in the baseline ecological risk assessment is warranted.**
Nickel	**540**	**mg/kg**	**The single sample above background and screening levels (3SS-812-1919) located south of Building 812F.**	**The available information indicates a potential for adverse ecological effects from the PCOEC, and a more thorough assessment in the baseline ecological risk assessment is warranted.**
Uranium, total	**282**	**mg/kg**	**Above background and screening levels. Samples exceeding background found at a greater areal extent than the other metals.**	**The available information indicates a potential for adverse ecological effects from the PCOEC, and a more thorough assessment in the baseline ecological risk assessment is warranted.**
Zinc	**230**	**mg/kg**	**Above background and screening levels. All samples exceeding background located within approximately 200 ft of the firing table or Building 812 facilities.**	**The available information indicates a potential for adverse ecological effects from the PCOEC, and a more thorough assessment in the baseline ecological risk assessment is warranted.**

Table 3-11 (continued). Status of the initial Preliminary Contaminants of Ecological Concern (PCOEC) with respect to their inclusion in the Building 812 OU baseline ecological risk assessment.

Initial PCOEC	Maximum Result	Units	Results of Problem Formulation Evaluation	Status as Final PCOEC
Subsurface Soil (0.5 to 6 ft)				
Metals				
Uranium, total	**67,400**	**mg/kg**	**Above background and screening level. Single sample collected at 5 ft within the firing table exceeds ecological screening level.**	**The available information indicates a potential for adverse ecological effects from the PCOEC, and a more thorough assessment in the baseline ecological risk assessment is warranted.**
Radionuclides				
Thorium-228	**0.89**	**pCi/g**	**No background available. Above the human health screening level, but the endpoint for this screening level (cancer) is not ecologically relevant. Available information suggest current activities are likely to be far below the ecological dose criteria of 0.1 rad/d.**	**There is adequate information on the PCOEC to conclude that ecological risks are negligible and therefore there is no need for remediation on the basis of ecological risk.**
Uranium-238	**22,630**	**pCi/g**	**Above background and screening level. Single sample collected at 5 ft within the firing table exceeds ecological screening level.**	**The available information indicates a potential for adverse ecological effects from the PCOEC, and a more thorough assessment in the baseline ecological risk assessment is warranted.**

Notes:

ft = **Feet.**
mg/kg = **Milligrams per kilogram.**
mg/L = **Milligrams per liter.**
pCi/g = **Picocuries per gram.**
PCOEC = **Preliminary Contaminant of Ecological Concern.**
ESL = **Ecological Screening Level.**
NA = **Not Applicable.**
NRWQC = **National Recommended Water Quality Criteria.**

Table 3-12. Proposed representative receptors of ecological interest (RREIs) and assessment endpoints for the Building 812 baseline ecological risk assessment.

Taxonomic Groups	RREIs	Assessment Endpoint	Rationale
Aquatic			
Benthos, aquatic plants and invertebrates, amphibians	Local benthic, aquatic plant and invertebrate communities, California red-legged frog	Functioning Spring 6/ Elk Ravine aquatic ecosystem[a]	A fully functioning Spring 6/ Elk Ravine ecosystem will provide for the protection of the California red-legged frog.
Terrestrial			
Terrestrial plants	Local grassland species	Sustainability of local community[b]	Primary producer, forms the base of the food chain.
Soil invertebrates	Local soil invertebrates	Sustainability of local community[b]	Important in grassland ecosystem functioning. Important food source.
Insectivorous bird	Rock Wren	Sustainability of local population[b]	Maximally exposed avian species.
Omnivorous small mammal	Deer mouse	Sustainability of local population[b]	Important food source for higher-level predators. Maximally exposed mammal species.

Notes:

RREI = Representative Receptor of Ecological Interest.

[a] Defined as an aquatic system in which water and sediment quality is sufficient to support local microbial, plant, invertebrate and vertebrate life.

[b] Defined as the ability to persist into the future as a self-sustaining population or community while retaining its key ecological functions at the local Building 812 scale.

Table 3-13. Proposed Ecological Screening Levels for use in evaluating new ground water, surface water and sediment characterization data in the Building 812 Screening-Level Ecological Risk Assessment, and predicted ground water and surface water concentrations in the Building 812 Baseline Ecological Risk Assessment.

Analyte	ESL	Units	Source
Ground water (for SLERA and BERA)			
Copper	0.009[a]	mg/L	2002 NRWQC: Freshwater aquatic life (U.S. EPA 2002).
Lead	0.0025[a]	mg/L	2009 NRWQC: Freshwater aquatic life (U.S. EPA 2009a).
Lithium	0.200	mg/L	Long et al. (1998).
Nickel	0.052[a]	mg/L	2009 NRWQC: Freshwater aquatic life (U.S. EPA 2009a).
Radium-226	4	pCi/L	BCGs for aquatic life (U.S. DOE 2005).
Zinc	0.12[a]	mg/L	2009 NRWQC: Freshwater aquatic life (U.S. EPA 2009a).
Uranium	0.050	mg/L	See Section 3.1.1.1, based on Shephard et al. 2005.
Surface water (for SLERA and BERA)			
Copper	0.009[b]	mg/L	2002 NRWQC: Freshwater aquatic life (U.S. EPA 2002).
Lead	0.0025[b]	mg/L	2009 NRWQC: Freshwater aquatic life (U.S. EPA 2009a).
Lithium	0.200	mg/L	Long et al. (1998).
Nickel	0.052[b]	mg/L	2009 NRWQC: Freshwater aquatic life (U.S. EPA 2009a).
Radium-226	4	pCi/L	BCGs for aquatic life (U.S. DOE 2005).
Zinc	0.12[b]	mg/L	2009 NRWQC: Freshwater aquatic life (U.S. EPA 2009a).
Uranium	0.050	mg/L	See Section 3.1.1.1, based on Shephard et al. 2005.
Sediment (for SLERA only)			
Copper	16	mg/kg	NOAA SQuiRT: Inorganics and organics in fresh water sediment (Buchman 2008).
Lead	31	mg/kg	NOAA SQuiRT: Inorganics and organics in fresh water sediment (Buchman 2008).
Nickel	16	mg/kg	NOAA SQuiRT: Inorganics and organics in fresh water sediment (Buchman 2008).
Zinc	120	mg/kg	NOAA SQuiRT: Inorganics and organics in fresh water sediment (Buchman 2008).
Uranium	100	mg/kg	Shephard et al. 2005.

Notes:

ESL = Ecological Screening Level.
SLERA = Screening-Level Ecological Risk Assessment.
BERA = Baseline Ecological Risk Assessment.
SQuiRT = Screening Quick Reference Tables.
NRWQC = National Recommended Water Quality Criteria.
NOAA = National Oceanic and Atmospheric Administration.
mg/L = Milligrams per liter.
mg/kg = Milligrams per kilogram.
BCG = Biota Concentration Guides.

[a] Based on a hardness of 100 mg/L.

[b] To be adjusted for actual hardness.

Table 3-14. Proposed measurement endpoints associated with the representative receptors of ecological interest, assessment endpoints and preliminary contaminants of ecological concern for the Building 812 baseline ecological risk assessment.

Taxonomic Groups	RREI	Assessment Endpoint	PCOEC	Measurement Endpoint
Aquatic				
Benthos, aquatic plants, aquatic invertebrates, amphibians	Local benthic, aquatic plant and invertebrate communities, California red-legged frog	Functioning Spring 6/ Elk Ravine aquatic ecosystem	Copper, lead, nickel and zinc in surface soil. Uranium in surface and subsurface soil. Uranium in shallow surface water.	Predicted future concentrations of PCOECs in Spring 6/Elk Ravine surface water compared to ESLs/background.
Terrestrial				
Terrestrial plants	Local grassland species	Sustainability of local community	Copper, nickel and zinc in surface soil. Uranium in surface and subsurface soil.	None at this time.
Soil invertebrates	Local soil invertebrates	Sustainability of local community	Copper, nickel and zinc in surface soil. Uranium in surface and subsurface soil.	None at this time.
Insectivorous bird	Rock Wren	Sustainability of local population	Copper, lead, and zinc in surface soil. Uranium in surface and subsurface soil.	Number of home ranges with HQ>1 compared to total number of home ranges at Building 812 and Site 300 and the area required for a viable population. Number of home ranges with HQ>1 for multiple PCOECs compared to potential synergistic effects identified from the literature.
Omnivorous small mammal	Deer mouse	Sustainability of local population	Copper, lead, and zinc in surface soil. Uranium in surface and subsurface soil.	Number of home ranges with HQ>1 compared to total number of home ranges at Building 812 and Site 300 and the area required for a viable population. Number of home ranges with HQ>1 for multiple PCOECs compared to potential synergistic effects identified from the literature.

Notes:

RREI = Representative Receptor of Ecological Interest.
HQ = Hazard Quotient.
PCOEC = Preliminary Contaminant of Ecological Concern.

Table 3-15. Proposed measurement endpoint development and evaluation for the Building 812 baseline ecological risk assessment.

Taxonomic Group RREI Assessment Endpoint	PCOEC	Measurement Endpoint Development	Measurement Endpoint Evaluation	Scientific Management Decision Point
Aquatic				
Amphibian California red-legged Frog Protection of Spring 6/Elk Ravine Habitat	Copper, lead, nickel and zinc in surface soil Uranium in surface and subsurface soil Uranium in shallow ground water	Collect surface water data on copper, lead, nickel, uranium and zinc to determine current concentrations. Collect shallow ground water data on copper, lead, nickel, uranium and zinc to determine current concentrations. Conduct modeling to predict future potential concentrations of copper, lead, nickel, uranium and zinc in Spring 6/Elk Ravine surface water.	Compare predicted future PCOEC concentrations in Spring 6/Elk Ravine surface water to NRWQC, uranium ESL and Site 300 background. Determine the magnitude that the predicted concentrations exceed ESLs and/or background and the predicted amount of spatial area impacted.	DOE/LLNL to present to the regulatory agencies determination as to whether there is enough information to make a remedial action decision. Any potential follow-on work would be dependent on the availability of funding.
Terrestrial				
Insectivorous bird Rock wren Sustainability of local population	Uranium in surface soil and subsurface soil	Determine site-specific uptake of uranium by soil invertebrates (see Section 3.9 of the CWP). Develop a uranium invertebrate concentration map based on combined surface soil/subsurface soil uranium concentration map. Map rock wren home ranges. Calculate 95% UCL of uranium in invertebrates for each home range. Utilize the uranium surface soil only concentration map for incidental ingestion. Map rock wren home ranges. Calculate 95% UCL of uranium in surface soil for each home range. Identify species-specific area use factors, dietary requirements and representative body weight. Develop new uranium TRV following EPA protocol (U.S. EPA, 2003a,b and U.S. EPA, 2007a,b) as closely as possible. Conduct modeling using site-specific invertebrate data, species-specific exposure parameters and newly developed TRV to identify home ranges with an HQ>1 for uranium.	Determine total area and number of home ranges containing HQ>1 and metal/uranium concentrations greater than Site 300 background. Map home ranges with HQ>1 and greater than Site 300 background for all PCOECs on a single map. Identify home ranges with multiple PCOECs. Review the literature to identify synergistic or antagonistic effects of PCOECs. Compare the number of home ranges impacted to total number of home ranges available at Building 812 and Site 300. Review the literature to identify area requirements for viable populations.	DOE/LLNL to present to the regulatory agencies determination as to whether there is enough information to make a remedial action decision. Any potential follow-on work would be dependent on the availability of funding.
	Copper, lead, nickel and zinc in surface soil.	Develop invertebrate concentration maps based on Building 812 surface soil concentration maps (see Section 3.3.5.3). Map rock wren home ranges. Calculate 95% UCL of concentration of each metal in invertebrates for each home range. Map rock wren home ranges onto surface soil concentration maps. Calculate 95% UCL of each metal in surface soil for each home range for use in incidental ingestion. Use species-specific area use factors, dietary requirements and representative body weight identified for uranium exposure modeling. Conduct modeling using site-specific concentration data, species-specific exposure parameters and EPA TRVs to identify home ranges with an HQ>1 for each metal.		

Table 3-15. Proposed measurement endpoint development and evaluation for the Building 812 baseline ecological risk assessment.

Taxonomic Group RREI Assessment Endpoint	PCOEC	Measurement Endpoint Development	Measurement Endpoint Evaluation	Scientific Management Decision Point
Terrestrial (continued)				
Omnivorous small mammal Deer mouse Sustainability of local population.	Uranium in surface soil and subsurface soil	Map extent of phreatic vegetation. Determine site-specific uptake of uranium by vegetation (see Section 3.8 of the CWP). Develop a uranium vegetation concentration map (phreatic and grassland vegetation) based on the combined surface soil/subsurface soil uranium concentration map. Map deer mouse home ranges. Calculate 95% UCL of uranium in invertebrates for each home range. Utilize the uranium invertebrate concentration map developed for the rock wren analysis. Map deer mouse home ranges. Calculate 95% UCL of uranium in invertebrates for each home range. Map deer mouse home ranges on combined surface soil/subsurface soil map. Calculate 95% UCL of uranium in soil for each home range for use for incidental ingestion. Identify species-specific area use factors, dietary requirements and representative body weight. Utilize the combined surface soil/subsurface soil uranium concentration map for incidental ingestion. Develop new TRV following EPA protocol (U.S. EPA, 2003a,b and U.S. EPA, 2007a,b) as closely as possible. Conduct modeling using site-specific invertebrate and vegetation data, species-specific exposure parameters and newly developed TRV to identify areas with an HQ>1.	Determine total area and number of home ranges containing HQ>1 and metal/uranium concentrations greater than Site 300 background. Map home ranges with HQ>1 and greater than Site 300 background for all PCOECs on a single map. Identify home ranges with multiple PCOECs. Review the literature to identify synergistic or antagonistic effects of PCOECs. Compare the number of home ranges impacted to total number of home ranges available at Building 812 and Site 300. Review the literature to identify area requirements for viable populations.	DOE/LLNL to present to the regulatory agencies determination as to whether there is enough information to make a remedial action decision. Any potential follow-on work would be dependent on the availability of funding.
	Copper, lead, nickel and zinc in surface soil.	Develop metal invertebrate and vegetation concentration maps based on Building 812 surface soil concentration maps (see Section 3.3.5.4). Map rock deer mouse ranges. Calculate 95% UCL of concentration of each metal in invertebrates and vegetation for each home range. Map rock deer mouse ranges onto surface soil concentration maps. Calculate 95% UCL of each metal in surface soil for each home range for use in incidental ingestion. Use species-specific area use factors, dietary requirements and representative body weight identified for uranium exposure modeling. Conduct modeling using site-specific concentration data, species-specific exposure parameters and EPA TRVs to identify home ranges with an HQ>1 for each metal.		

Notes:

RREI = Representative Receptor of Ecological Interest.
ESL = Ecological Screening Level.
TRV = Toxicity Reference Value.
HQ = Hazard Quotient.
UCL = Upper Confidence Limit.
EPA = U.S. Environmental Protection Agency.
TOC = Total Organic Carbon.
PCOECs = Preliminary Contaminants of Ecological Concern.
CWP = Characterization Work Plan.

Appendices

List of Appendices

Appendix A

Plants and Animals Observed at Lawrence Livermore National Laboratory Site 300

Appendix A

Plants and Animals Observed at Lawrence Livermore National Laboratory Site 300

This appendix summarizes the plant and animals species known to occur at Lawrence Livermore National Laboratory Site 300. Plant and animal surveys have been conducted at Site 300 periodically since 1986 to support the preparation of a Site-Wide Environmental Impact Statement (SWEIS) for the continued operation of Lawrence Livermore National Laboratory. A SWEIS is prepared approximately every five years. The last SWEIS was completed in March 2005 (U.S. DOE, 2005). A supplemental analysis of the 2005 SWEIS was conducted in August 2011 to ensure the continued adequacy of the SWEIS (U.S. DOE, 2011). The supplemental analysis found the 2005 SWEIS to continue to be adequate for the continued operation of LLNL. In addition, LLNL wildlife and plant biologists conduct resource surveys for all ground-disturbing projects conducted at Site 300, as well as on-going surveys to support special status species management. The plant and animal lists initially presented in U.S. DOE (2005) are annually updated in the Lawrence Livermore National Laboratory Site-Wide Annual Environmental Report. The most recent Site-Wide Annual Environmental Report was released in September 2011 (LLNL, 2011), and reported on the year 2010. Figure A-1 shows the locations of special-status plants at Site 300. Figure A-2 shows the locations of special-status animals at Site 300. Both figures are from LLNL (2011).

Table A-1 lists the plants species known to occur at Site 300. This list is adapted from Jones and Stokes (2002a), which was compiled from Jones & Stokes site surveys performed in May and September 1997, and March and April 2002 (Jones and Stokes, 2002a and 2002b). It also incorporates species reported by BioSystems (BioSystems, 1986a and 1986b) as well as information from ongoing surveys by LLNL plant biologists. Habitat and location information is Site 300 specific as determined by Jones and Stokes (2002a), except when noted in bold, in which habitat information comes from *The Jepson Manual* (Hickman 1993). Synonyms [in brackets] are provided for plant names used in BioSystems' checklist that have been superceded. Introduced species are followed with an asterisk. The plants species listed in Table A-1 are organized by: 1) plant species known to occur at Building 812, 2) plant species that may potentially occur at Building 812, and 3) plants species that do not occur at Building 812. Plant species listed as known to occur at Building 812 were identified by direct observations from LLNL wildlife and plant biologists, and specific observations from the above listed surveys. Species that may potentially occur at Building 812 are those species whose habitat characteristics suggest they may occur at Building 812 but have not been directly observed. Species that do not occur at Building 812 are those species that are specifically known not to occur at Building 812 either through specific site-wide surveys or specific habitat characteristics (for example, vernal pool species and blue oak woodland species).

Tables A-2 through A-5 lists the herpetofauna (amphibians and reptiles), birds, mammals and special-status invertebrates known to occur at Site 300. These tables are adapted from LLNL (2011) and were developed from animal surveys conducted in 2002 to support the SWEIS, as well as ongoing surveys conducted by LLNL wildlife biologists. The surveys conducted in 2002 include a mesocarnivore survey (CSUS, 2002), a small mammal inventory (Jones and Stokes, 2002c), a breeding raptor and loggerhead shrike status review (Bloom, 2002), an avian monitoring program (LLNL, 2003), special status reptile surveys (Swaim, 2002), amphibian surveys (LLNL, 2002), a bat survey (Rainey 2003), wet season branchiopod surveys (Condor Country Consulting, 2002), and valley elderberry longhorn beetle surveys (Arnold, 2002). Due to the transitory nature of many of the species listed in Tables A-2 through A-5, many have the potential to be at least periodic visitors to the Building 812 area. Species specifically known to either occur (through direct observation by LLNL wildlife biologists or specific survey information) or not occur at Building 812 (as a consequence of specific habitat requirements) are identified in the notes field of each table.

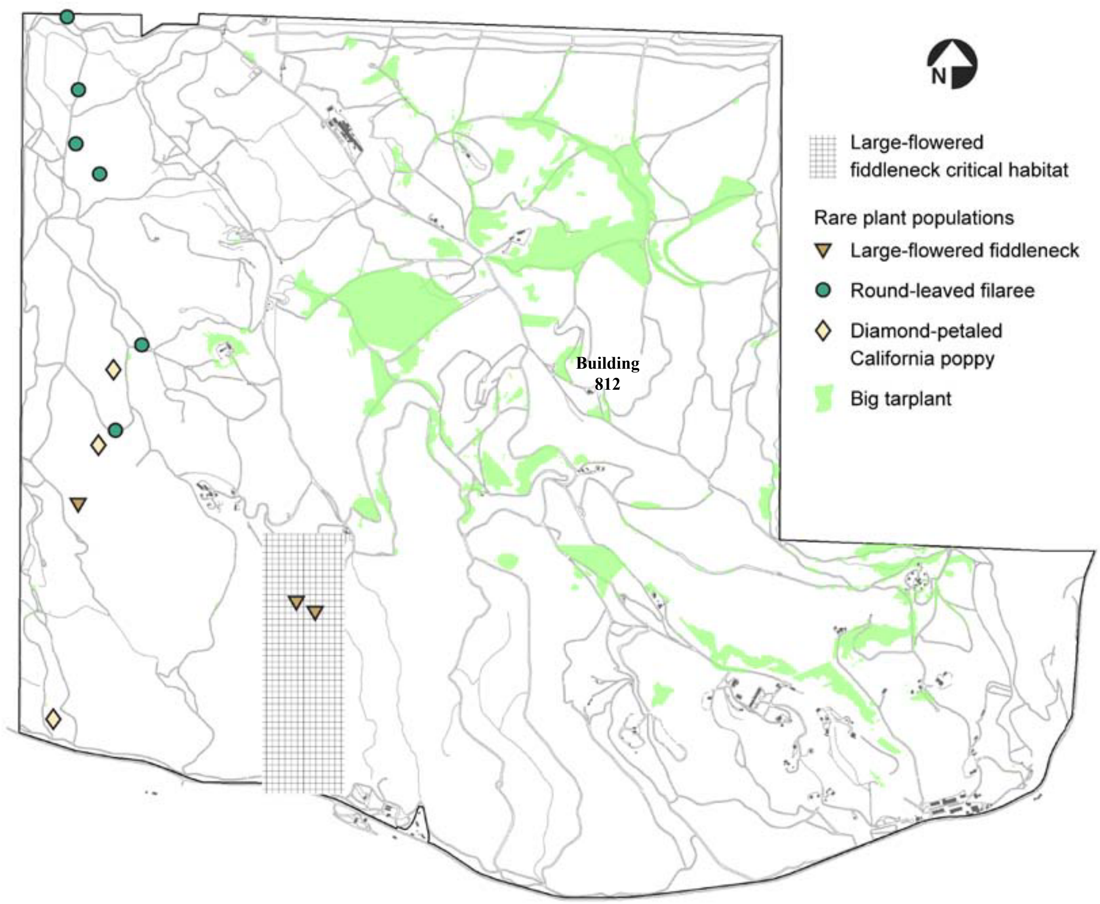

Figure A-1. Distribution of special-status plants at Site 300 in 2010 (LLNL, 2011).

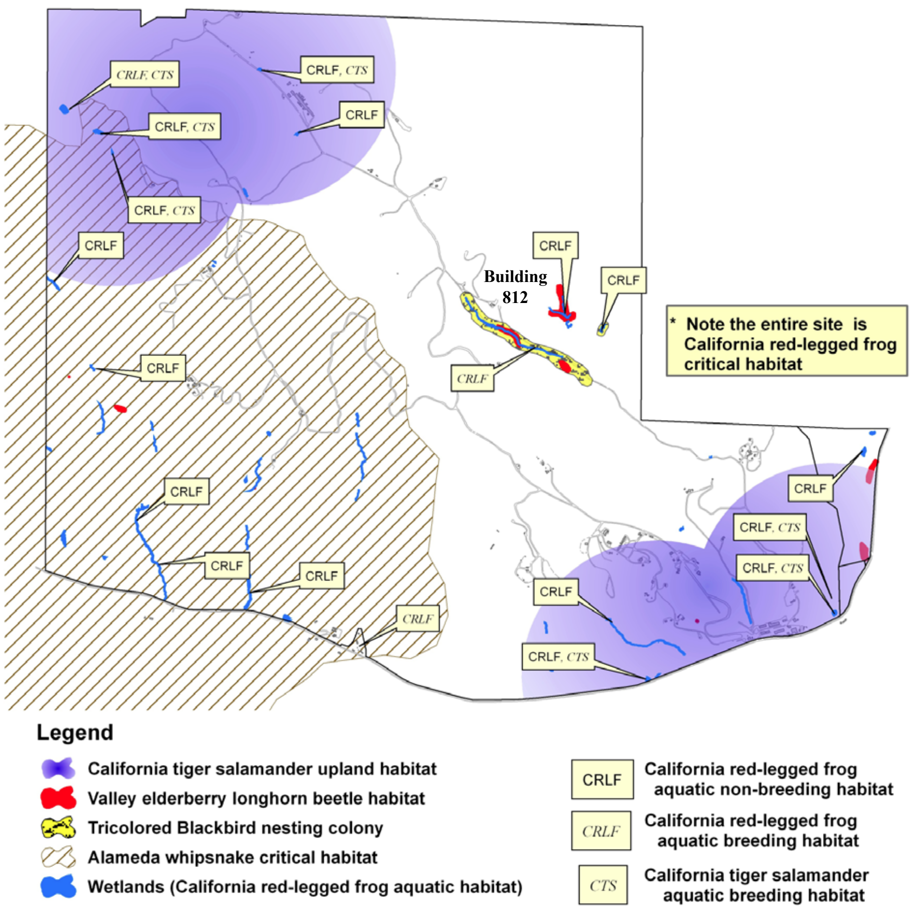

Figure A-2. Distribution of special-status wildlife at Site 300 in 2010 (LLNL, 2011).

Table A-1. Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Observed at Building 812	
Asclepiadaceae (Milkweed Family)	
Asclepias fascicularis	Narrow-leaf milkweed. Grassland. Uncommon.
Asteraceae (Sunflower Family)	
Baccharis pilularis	Coyote brush. Blue oak woodland, along drainages. Local, uncommon. [*B. pillularis* var. *consanguinea*]
Baccharis salicifolius	Mule fat. Along stream channels. Local, uncommon. [*B. viminea*]
Blepharizonia laxa	Viscid big tarplant. Grasslands, ruderal. Uncommon. [*B. plumosa* ssp. *viscida*; see Baldwin et al. 2001 for nomenclature]
Blepharizonia plumosa	CNPS List 1B. Big tarplant. Grasslands, ruderal. Widespread, common (Figure A-1).
Carduus pycnocephalus*	Italian thistle. Grasslands. Widespread but uncommon.
Centaurea solstitialis*	Yellow star-thistle. Grasslands. Uncommon.
Centromadia pungens ssp. ***pungens***	Common spikeweed. Grasslands, ruderal. Local, uncommon. [*Hemizonia pungens*; see Baldwin 1999 for revised nomenclature]
Cirsium vulgare*	Bull thistle. Freshwater seeps. Local, uncommon.
Dittrichia graveolens*	Stinkweed. Ruderal. Local, uncommon. [Not in The Jepson Manual; see Preston (1997)]
Grindelia camporum	Great Valley gumplant. Grasslands, coastal scrub, blue oak woodland; Widespread, common.
Gutierrezia californica	California matchweed. Coastal scrub, grasslands. Widespread, common. [*G. bracteata*]
Holocarpha obconica	San Joaquin tarplant. Grasslands, coastal scrub. Common.
Silybum marianum*	Milk thistle. In stream channels. Widespread but uncommon.
Boraginaceae (Borage Family)	
Heliotropium curassavicum	Salt heliotrope. Freshwater seeps. Uncommon. [*H. curassavicum* var. *oculatum*]
Brassicaceae (Mustard Family)	
Hirschfeldia incana*	Mediterranean mustard. Grasslands, coastal scrub, ruderal. Widespread, common. [*Brassica geniculata*]
Caprifoliaceae (Honeysuckle Family)	
Sambucus mexicana	Blue elderberry. Elderberry scrub, scattered along stream channels, or at base of rock outcrops. Local, uncommon.
Cupressaceae (Cypress Family)	
Juniperus californica	California juniper. Juniper woodland and scrub, juniper-oak woodland, and scattered in grasslands. Widespread, common.
Fabaceae (Pea Family)	
Melilotus indica*	Indian sweet-clover. Ruderal. Widespread but uncommon.
Geraniaceae (Geranium Family)	
Erodium cicutarium*	Red-stemmed filaree. Grasslands, coastal scrub, oak woodland. Widespread, common.
Lamiaceae (Mint Family)	
Marrubium vulgare*	Horehound. Coastal scrub, freshwater seep, ruderal. Widespread but uncommon.

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Observed at Building 812 (continued)	
Poaceae (Grass Family)	
Avena barbata*	Slender wild oat. Grasslands, coastal scrub, blue oak woodland. Widespread, common.
Bromus diandrus*	Ripgut brome. Grasslands, coastal scrub, blue oak woodland. Widespread, common.
Bromus hordeaceus*	Soft chess. Grasslands, coastal scrub, blue oak woodland. Widespread, common. [*B. mollis*, *B. molliformis*]
Bromus madritensis ssp. ***rubens****	Red brome. Grasslands, coastal scrub, blue oak woodland. Widespread, common. [*B. rubens*]
Hordeum marinum ssp. ***gussoneanum****	Mediterranean barley. Vernal pool. Local, uncommon. [*H. geniculatum*]
Nassella pulchra	Purple needlegrass. Grasslands. Common. [*Stipa pulchra*]
Phalaris paradoxa*	Paradox canary grass. Swale in grasslands; Local, uncommon.
Poa secunda	One-sided bluegrass. Grasslands. Widespread, common. [*P. scabrella*]
Polypogon monspeliensis*	Annual rabbit's-foot grass. Freshwater seep, vernal pool. Local, uncommon.
Salicaceae (Willow Family)	
Populus fremontii	Fremont cottonwood. Fremont cottonwood riparian forest, valley oak woodland. Local, uncommon.
Salix laevigata	Red willow. Great Valley willow scrub, Fremont cottonwood riparian forest. Local, uncommon.
Scrophulariaceae (Figwort Family)	
Mimulus guttatus	Seep-spring monkey flower. Freshwater seep, vernal pool. Uncommon. [*M. nasutus*]
Scrophularia californica	California figwort. Rock outcrops in blue oak woodland, elderberry scrub. Local, uncommon.
Solanaceae (Nightshade Family)	
Nicotiana glauca*	Tree tobacco. Along streams. Local, uncommon.
Solanum americanum	Small-flowered nightshade. Ruderal. Uncommon. [*S. nodiflorum*]
Urticaceae (Nettle Family)	
Urtica dioica ssp. ***holosericea***	Hoary nettle. Freshwater seep. Local, uncommon.
Possibly Occurs at Building 812	
Amaranthaceae (Amaranth Family)	
Amaranthus albus*	Tumbleweed. Wetlands. Uncommon.
Amaranthus blitoides	Prostrate amaranth. **Waste places.**
Amaranthus californicus	California amaranth. Wetlands. Uncommon.
Apiaceae (Carrot Family)	
Bowlesia incana	Bowlesia. At base of rocks in grasslands. Local, uncommon.
Lomatium caruifolium	Caraway-leaved lomatium. Grasslands. Widespread but uncommon.
Lomatium utriculatum	Common lomatium. Grasslands. Widespread but uncommon.

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Possibly Occurs at Building 812 (continued)	
Apiaceae (Carrot Family) (continued)	
Sanicula bipinnata	Poison sanicle. Blue oak woodland, coastal scrub. Widespread, common.
Sanicula crassicaulis	Pacific sanicle. Elderberry scrub. Local, uncommon.
Torilis nodosa*	Knotted hedge parsley. **Disturbed places.**
Asteraceae (Sunflower Family)	
Achillea millefolium	Common yarrow. Grasslands, coastal scrub, blue oak woodland. Widespread, common. [*A. millefolium* var. *californica*]
Achyrachaena mollis	Blow-wives. Grasslands, vernal pool. Widespread but uncommon.
Agoseris grandiflora	Large-flowered agoseris. Grassland. Local, uncommon.
Agoseris heterophylla	Annual agoseris. Grasslands. Widespread but uncommon.
Ancistrocarphus filagineus	Woolly fishhooks. Bare soil in grasslands, coastal scrub. Local, uncommon. [*Stylocline filaginea*]
Carduus tenuiflorus*	Slender-flowered thistle. Wetlands, blue oak woodland. Common.
Centaurea melitensis*	Tocalote. Grasslands. Local, uncommon.
Centromadia fitchii	Fitch's spikeweed. Ruderal. Local, uncommon. [*Hemizonia fitchii*; see Baldwin 1999 for revised nomenclature]
Chamomilla suaveolens*	Pineapple weed. Ruderal. Local, uncommon. [*Matricaria matricarioides*]
Cirsium occidentale ssp. ***venustum****	Venus thistle. Grasslands. Local, uncommon. [*C. proteanum*]
Conyza canadensis	Horseweed. Wetlands, ruderal. Uncommon.
Coreopsis calliopsidea	Leafy-stemmed coreopsis. **Deserts, dry grassy places.**
Cynara cardunculus*	Artichoke thistle. Grasslands. Local, uncommon.
Deinandra kelloggii	Kellogg's tarplant. Grasslands, coastal scrub, ruderal. Common. [*Hemizonia kelloggii*; see Baldwin 1999 for revised nomenclature]
Deinandra lobbii	Lobb's tarplant. Coastal scrub. Common. [*Hemizonia lobbii*; see Baldwin 1999 for revised nomenclature]
Ericameria linearifolia	Interior goldenbush. Coastal scrub. Local, uncommon.
Erigeron reductus var. ***angustatus***	California rayless daisy. [*E. inornatus* var. *angustatus*]
Filago californica	California filago. Thin soils, coastal scrub. Widespread but uncommon.
Filago gallica*	Narrow-leaved filago. Grasslands. Local, uncommon. [*Logfia gallica*]
Gnaphalium californicum	California cudweed. Grasslands. Local, uncommon.
Gnaphalium luteo-album*	Weedy cudweed. Along stream channel. Local, uncommon.
Gnaphalium palustre	Marsh cudweed. Vernal pool, freshwater seep. Local, uncommon.
Helianthus annuus	Common sunflower. Wetlands. Uncommon.
Hesperevax sparsiflora	Erect evax. [*Evax sparsiflora*]
Heterotheca grandiflora	Telegraph weed. Rock outcrops in grassland. Uncommon.
Heterotheca sessiflora ssp. ***echioides***	Goldenaster. Grasslands. Uncommon. [*H. echioides*]

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Possibly Occurs at Building 812 (continued)	
Asteraceae (Sunflower Family) (continued)	
Hypochaeris glabra*	Smooth cat's-ear. Grasslands. Widespread but uncommon.
Hypochaeris radicata*	Rough cat's-ear. Blue oak woodland, grasslands. Local, uncommon.
Lactuca serriola*	Prickly lettuce. Grassland. Common.
Lagophylla ramosissima	Common hareleaf. Grassland. Common.
Lasthenia gracilis	California goldfields. Thin soil in grasslands, coastal scrub. Widespread but uncommon. [*L. chrysostoma*; recently segregated from *L. californica* by Chan (2001)]
Lasthenia microglossa	Small-rayed goldfields. Moist areas in grasslands. Widespread, common.
Lasthenia minor	Woolly goldfields. Grasslands. Widespread but uncommon.
Layia gaillardioides	Woodland layia. Grasslands. Widespread but uncommon.
Layia platyglossa	Tidytips. Grasslands. Local, uncommon.
Madia gracilis	Slender tarweed.
Malacothrix coulteri	Snake's-head. Grasslands. Widespread but uncommon.
Micropus californicus	Slender cottonweed. Grasslands. Local, uncommon.
Microseris acuminata	Needle microseris. Grasslands. Local, uncommon.
Microseris douglasii ssp. ***douglasii***	Douglas' microseris. Grasslands. Local, uncommon.
Microseris douglasii ssp. ***tenella***	Small microseris. Grasslands. Local, uncommon.
Monolopia major	Cupped monolopia. Grasslands. Widespread, common.
Pentachaeta alsinoides	Pentachaeta. Grassland. Local, uncommon.
Picris echioides*	Bristly ox-tongue. Freshwater seep. Local, uncommon.
Psilocarphus tenellus	Slender woolly marbles. **Dry slopes on generally disturbed soils.**
Senecio vulgaris*	Common groundsel. Grasslands, coastal scrub. Widespread, common.
Solidago canadensis	Canada goldenrod. **Meadows, thickets.**
Sonchus asper*	Prickly sow-thistle. Freshwater seeps. Uncommon.
Sonchus oleraceus*	Common sow-thistle. Ruderal. Widespread but uncommon.
Stebbinsoseris heterocarpa	Derived microseris. Grasslands. Uncommon.
Stephanomeria virgate var. ***pleurocarpa***	Tall stephanomeria. Grasslands. Uncommon.
Stylocline gnaphaloides	Everlasting nest straw. Rock outcrops in coastal scrub. Observed in canyon east of Building 812 by Biosystems (1986a). Local, uncommon.
Taraxacum officinale*	Common dandelion.
Uropappus lindleyi	Silver puffs. Grasslands, coastal scrub. Widespread but uncommon. [*Microseris lindleyi*]
Xanthium strumarium	Common cocklebur. Freshwater seeps, along stream channels. Uncommon. [*X. strumarium* var. *canadense*]
Boraginaceae (Borage Family)	
Amsinckia eastwoodiae	Eastwood's fiddleneck. Moist areas in grasslands. Widespread but uncommon.

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Possibly Occurs at Building 812 (continued)	
Boraginaceae (Borage Family) (continued)	
Amsinckia lycopsoides	Tarweed fiddleneck. Grasslands, blue oak woodland. Widespread, common.
Amsinckia menziesii var. ***intermedia***	Common fiddleneck. Grasslands, coastal scrub, blue oak woodland. Widespread, common.
Amsinckia menziesii var. ***menziesii***	Menzies' fiddleneck. Grasslands. Widespread but uncommon.
Amsinckia tessellata var. ***tessellata***	Devil's lettuce. Grasslands, oak woodland, coastal scrub. Widespread, common.
Cryptantha flaccida	Weak-stemmed cryptantha. Rock outcrops in grassland. Uncommon.
Cryptantha intermedia	Common cryptantha. Rock outcrops in grassland. Uncommon.
Cryptantha microstachys	Tejon cryptantha. **Open sites, chapparal, woodlands.**
Pectocarya penicillata	Winged pectocarya. Coastal scrub. Widespread but uncommon.
Plagiobothrys canescens	Soft popcorn flower. Grasslands. Widespread, common.
Plagiobothrys tenellus	Grasslands. Local, uncommon.
Brassicaceae (Mustard Family)	
Athysanus pusillus	Petty athysanus. Rock outcrops in grassland. Widespread but uncommon.
Brassica nigra*	Black mustard. Grasslands. Uncommon.
Capsella bursa-pastoris*	Shepherd's purse. Blue oak woodland. Widespread, common. Observed in canyon east of Building 812 by Biosystems (1986a).
Cardaria pubescens*	White-top. **Saline soils, fields, ditch banks.**
Descurainia sophia*	Tansy mustard. Grasslands. Local, uncommon.
Erysimum capitatum	Western wallflower. **Many habitats.**
Guillenia flavescens	Yellow-flowered guillenia. Grasslands. Local, uncommon. Flower color varies from pale yellow to lilac within Site 300. Hoover (1936) treated the lilac- to purple-flowered forms as *Streptanthus lilacinus*. [*Caulanthus flavescens*]
Guillenia lasiophylla	California mustard. Grasslands. Widespread, common. [*Caulanthus lasiophyllus*]
Lepidium nitidum	Shining peppergrass. Grasslands. Widespread, common. [var. *insigne*]
Nasturtium officinale	Watercress. Freshwater seeps. Local, uncommon. [*Rorippa nasturtium-aquaticum*; see Al-Shehbaz & Price (1998) for nomenclature]
Sinapis arvensis*	Grasslands. Uncommon.
Sisymbrium altissimum*	Tumble mustard. **Disturbed areas, fields, roadsides.**
Sisymbrium officinale*	Hedge mustard. **Disturbed areas, gardens, roadsides.**
Sisymbrium orientale*	Oriental mustard. Outcrops in coastal scrub, grasslands. Locally common.
Thysanocarpus curvipes var. ***curvipes***	Lacepod. Blue oak woodland, grasslands. Widespread, common.
Thysanocarpus curvipes var. ***elegans***	Fringepod. Grasslands. Local, uncommon. [*T. elegans*]
Tropidocarpum gracile	Dobie pod. Grasslands. Widespread but uncommon.
Caryophyllaceae (Pink Family)	
Cerastium glomeratum*	Mouse-ear chickweed. Grasslands, coastal scrub. Local, uncommon.

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Possibly Occurs at Building 812 (continued)	
Caryophyllaceae (Pink Family) (continued)	
Herniaria hirsute* ssp. *cinerea*	Gray herniaria. Coastal scrub. Widespread but uncommon.
Minuartia douglasii	Douglas' sandwort. **Chaparral or oak woodland.**
Minuartia californica	California sandwort. Thin soils in coastal scrub. Local, uncommon
Sagina apetala	Dwarf pearlwort. Rock outcrop in grasslands. Local, uncommon.
Sagina decumbens* var. *occidentalis	Western pearlwort. **Dry streams, chaparral, grassy areas, rock outcrops, vernal pools.**
Silene antirrhina	Snapdragon catchfly. Grasslands, coastal scrub. Uncommon.
Silene gallica*	Common catchfly. Grasslands, coastal scrub. Widespread but uncommon.
Spergularia marina	Saltmarsh sand-spurry. **Mud flats, alkaline fields, sandy river bottoms**.
Stellaria media*	Common chickweed. Grasslands, blue oak woodland, coastal scrub. Widespread but uncommon.
Stellaria nitens	Shining chickweed. Rock outcrops in grassland, coastal scrub. Widespread but uncommon.
Chenopodiaceae (Goosefoot Family)	
Atriplex patula	Spear oracle. Saline soils.
Atriplex rosea*	Tumbling oracle. Ruderal. Uncommon.
Atriplex semibaccata*	Australian saltbush. Ruderal, grasslands. Local, uncommon.
Atriplex serenana	Bractscale. Ruderal. Uncommon.
Chenopodium album*	Pigweed. Ruderal. Uncommon.
Chenopodium californicum	California goosefoot. Grasslands; uncommon.
Chenopodium murale*	Nettle-leaved goosefoot. Rock outcrops in grasslands. Uncommon.
Chenopodium rubrum	Red goosefoot. **Open saline places, dry mudflats.**
Chenopodium vulvaria*	Stinking goosefoot. **Open, disturbed places.**
Monolepis nuttalliana	Poverty weed**. Open, disturbed, often wet places.**
Salsola tragus*	Russian thistle. Grasslands, ruderal. Widespread, common. [*S. kali*]
Convolvulaceae (Morning-glory Family)	
Convolvulus arvensis*	Field bindweed. Grasslands. Uncommon.
Crassulaceae (Stonecrop Family)	
Crassula connata	Pygmyweed. Rock outcrops in grasslands, coastal scrub. Widespread, common. [*C. erecta*]
Cucurbitaceae (Gourd Family)	
Marah fabaceus	California manroot. Grasslands. Widespread, common. [*M. fabaceus* var. *agrestis*]
Cyperaceae (Sedge Family)	
Scirpus acutus	Bigelow. Hard-stem bulrush. **Marshes, lakes, streambanks.**
Scirpus fluviatilis	River bulrush. **Marshes.**
Euphorbiaceae (Spurge Family)	
Chamaesyce ocellata	Valley spurge. Grasslands. Uncommon.

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Possibly Occurs at Building 812 (continued)	
Euphorbiaceae (Spurge Family) (continued)	
Croton setigerus	Turkey mullein. Grasslands, ruderal. Common. [*Eremocarpus setigerus*; see Webster (1992) for nomenclature]
Fabaceae (Pea Family)	
Astragalus asymmetricus	Rattleweed. Grasslands. Widespread but uncommon.
Astragalus didymocarpus	Two-seeded milkvetch. Grassland, coastal scrub. Widespread but uncommon.
Astragalus gambelianus	Grasslands. Widespread but uncommon.
Lotus humistratus	Hairy lotus. Grasslands, coastal scrub. Widespread but uncommon.
Lotus wrangellianus	Chile lotus. Grasslands. Widespread, common. [*L. subpinnatus*]
Lupinus benthamii	Spider lupine. Grasslands. Uncommon.
Lupinus bicolor	Miniature lupine. Grasslands, coastal scrub, oak woodland. Widespread, common. [*L. bicolor* var. *umbellatus*]
Lupinus microcarpus var. ***densiflorus***	Chick lupine. Grasslands, blue oak woodland. Widespread, common. [*L. densiflorus* var. *aureus* and var. *lacteus*]
Lupinus microcarpus var. ***microcarpus***	Chick lupine**. Open and disturbed areas.** [*L. densiflorus* var. *palustris*]
Lupinus succulentus	Arroyo lupine. Grasslands. Widespread, common.
Medicago polymorpha*	California bur-clover. Grasslands. Widespread, common.
Melilotus alba*	White sweet-clover. Ruderal. Uncommon.
Trifolium albopurpureum var. ***albopurpureum***	Common Indian clover. Grasslands. Widespread but uncommon.
Trifolium albopurpureum var. ***dichotomum***	Branched Indian clover. **Coastal dunes, open slopes, wet meadows, oak woodlands, disturbed areas.** [*T. dichotomum*]
Trifolium ciliolatum	Tree clover. Grasslands. Local, uncommon.
Trifolium depauperatum var. ***amplectans***	Pale sac clover. **Grasslands, coastal woodlands.** [*T. amplectans*]
Trifolium depauperatum var. ***truncatum***	Narrow-leaved sac clover. Grasslands. Local, uncommon.
Trifolium gracilentum	Pinpoint clover. Grasslands, coastal scrub. Widespread, common.
Trifolium hirtum*	Rose clover. Grasslands, ruderal. Local, uncommon.
Trifolium microcephalum	Small-headed clover. Grasslands. Local, uncommon.
Trifolium microdon	Valparaiso clover. **Open, moist or dry, generally disturbed areas.**
Trifolium oliganthum	Few-flowered clover. Coastal scrub.
Trifolium willdenovii	Tomcat clover. Grasslands; coastal scrub, oak woodland. Widespread, common. [*T. tridentatum*]
Vicia sativa*	Common vetch, Grassland. Uncommon.
Vicia tetrasperma*	Slender vetch. **Disturbed areas. Woodlands or borders**.
Vicia villosa ssp. ***varia****	Winter vetch. **Roadsides, fields.**
Vicia villosa ssp. ***villosa****	Hairy vetch. Grassland. Uncommon.

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Possibly Occurs at Building 812 (continued)	
Geraniaceae (Geranium Family) (continued)	
Erodium botrys*	Big heronbill. Grassland, coastal scrub. Widespread, common.
Erodium brachycarpum*	Heronbill. Grasslands. Widespread, uncommon.
Erodium moschatum*	White-stemmed filaree. Grasslands. Local, uncommon.
Geranium dissectum*	Cut-leaf geranium. Grasslands. Uncommon.
Geranium molle*	Dove's-foot geranium. **Open to shaded sites, disturbed ground.**
Grossulariaceae (Gooseberry Family)	
Ribes malvaceum	Chaparral current. Elderberry scrub. Local, uncommon.
Ribes quercetorum	Oak gooseberry. Elderberry scrub. Local, uncommon.
Hydrophyllaceae (Waterleaf Family)	
Emmenanthe penduliflora var. ***penduliflora***	Whispering bells. Coastal scrub. Local, uncommon.
Eriodictyon californicum	Yerba santa. Coastal scrub. Local, uncommon.
Nemophila menziesii	Baby blue-eyes. Grasslands. Local, uncommon.
Nemophila pedunculata	Spreading nemophila. **Many habitats including grasslands.**
Phacelia ciliata	Great Valley phacelia. Grasslands. Widespread, common.
Phacelia distans	Common phacelia. Rock outcrops in grasslands, coastal scrub. Widespread, common.
Phacelia douglasii	Douglas' phacelia. Coastal scrub. Local, uncommon.
Phacelia imbricata	Imbricate phacelia. Rock outcrops in grasslands, coastal scrub. Local, uncommon.
Phacelia tanacetifolia	Tansy phacelia. Rock outcrops in grasslands, coastal scrub. Widespread, common.
Pholistoma membranaceum	White fiesta-flower. Blue oak woodland, base of rock outcrops in grasslands. Local, uncommon.
Iridaceae (Iris Family)	
Sisyrinchium bellum	Blue-eyed grass. Grasslands. Local, uncommon.
Juncaceae (Rush Family)	
Juncus balticus	Baltic rush. Freshwater seep. Local, uncommon.
Juncus bufonius	Toad rush. Freshwater seep. Local, uncommon.
Juncus occidentalis	Western rush. **Moist areas.** [*Juncus tenuis* var. *congestus*]
Juncus oxymeris	Pointed rush. **Montane meadows, shrubland.**
Juncus patens	Spreading rush. Freshwater seep. Local, uncommon.
Juncus xiphioides	Iris-leaved rush. Freshwater seep. Local, uncommon.
Lamiaceae (Mint Family)	
Lamium amplexicaule*	Henbit. **Disturbed sites.**
Mentha pulegium*	Pennyroyal. Freshwater seep. Local, uncommon.
Pogogyne serpylloides	Thyme-like pogogyne. Elderberry scrub. Local, uncommon.
Salvia columbariae	Chia. Coastal scrub. Locally common.
Stachys albens	White hedgenettle. Freshwater seep. Local, uncommon.

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Possibly Occurs at Building 812 (continued)	
Lamiaceae (Mint Family) (continued)	
Trichostema lanceolatum	Vinegar curls. Grasslands. Common.
Lemnaceae (Duckweed Family)	
Lemna miniscula	Least duckweed. **Freshwater.** [*L. minuta* Kunth]
Liliaceae (Lily Family)	
Allium crispum	Crinkled onion. Grasslands. Local, uncommon.
Allium serra	Serrated onion. Grasslands, blue oak woodland. Widespread, common. [*A. serratum*]
Brodiaea elegans	Harvest brodiaea. Grasslands. Common.
Calochortus clavatus ssp. ***pallidus***	Mariposa lily. Grasslands. Uncommon.
Calochortus venustus	Mariposa lily. Grasslands. Uncommon.
Chlorogalum pomerideanum	Soap plant. Grasslands. Widespread, common
Dichelostemma capitata	Blue dicks. Grasslands, blue oak woodland. Widespread, common. [*D. pulchellum*]
Triteleia hyacinthina	White hyacinth. Grasslands. Uncommon.
Triteleia laxa	Ithuriel's spear. Grasslands, blue oak woodland, coastal scrub. Widespread, common.
Linaceae (Flax Family)	
Hesperolinon californicum	California dwarf flax. Grasslands. Uncommon.
Linum usitatissimum*	Common flax. Grassland, ruderal. Uncommon.
Loasaceae (Loasa Family)	
Mentzelia affinis	Hydra stick-leaf. Rock outcrops. Local, uncommon.
Mentzelia dispersa	Small-flowered mentzelia. Rock outcrops in grasslands, coastal scrub. Local, uncommon.
Malvaceae (Mallow Family)	
Eremalche parryi	Parry's mallow. Grasslands, on lower canyon slope. Local, uncommon.
Malvella leprosa	Alkali mallow. Freshwater seep, grasslands, ruderal. Uncommon.
Onagraceae (Evening Primrose Family)	
Camissonia boothii ssp. ***decorticans***	Shredding evening primrose. Coastal scrub. Local, uncommon.
Camissonia contorta	Plains evening primrose. Coastal scrub. Local, uncommon. [*Camissonia cruciata*, an unpublished name based on *Oenothera cruciata*]
Camissonia graciliflora	Slender-flowered primrose. Open area in grasslands. Local, uncommon.
Camissonia hirtella	Hairy sun-cups. Coastal scrub. Widespread but uncommon.
Camissonia intermedia	Intermediate sun-cups. Coastal scrub. Local, uncommon.
Clarkia affinis	Clarkia. Blue oak woodland, grasslands. Common.
Clarkia purpurea ssp. ***purpurea***	Purple clarkia. Grasslands. Uncommon.
Epilobium brachycarpum	Panicled willow-herb. Grasslands. Uncommon. [*E. paniculatum*]

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Possibly Occurs at Building 812 (continued)	
Onagraceae (Evening Primrose Family) (continued)	
Epilobium canum	California fuschia. Coastal scrub. Local, uncommon. [*E. canum* ssp. *mexicana*]
Orobanchaceae (Broomrape Family)	
Orobanche californica	Jepson's broom-rape. Coastal scrub. Local, uncommon.
Orobanche uniflora	Naked broom-rape. Grassland, parasitic on *Saxifraga californica*. Local, uncommon. [*O. uniflora* var. *minuta*]
Papaveraceae (Poppy Family)	
Eschscholzia californica	California poppy. Grasslands. Widespread, common.
Papaver californicum	Fire poppy. Grasslands. Local, uncommon.
Platystemon californicus	Cream cups. Grasslands. Widespread, common.
Stylomecon heterophylla	Wind poppy. Moist areas in grasslands. Widespread, common.
Plantaginaceae (Plantain Family)	
Plantago erecta	California plantain. Grasslands, coastal scrub. Widespread, common.
Plantago lanceolata*	English plantain. **Weed or waste places, lawns, roadsides.**
Poaceae (Grass Family)	
Avena fatua*	Wild oat. Grasslands. Widespread but uncommon.
Bromus arenarius*	Australian brome. Grasslands. Uncommon.
Bromus carinatus	California brome. Blue oak woodland, grasslands. Local, uncommon. [*B. marginatus*]
Bromus japonicus*	Japanese brome. **Open, disturbed places.**
Bromus madritensis* ssp. *madritensis*	Foxtail chess. Grasslands, blue oak woodland. Widespread but uncommon.
Bromus sterilis*	Poverty brome. **Open, often disturbed places.**
Bromus tectorum*	Cheat grass. Grasslands. Uncommon.
Cynodon dactylon*	Bermuda grass. Freshwater seep, ruderal. Local, uncommon.
Distichlis spicata	Grasslands, Freshwater seep. Local, uncommon. [*D. spicata* var. *stricta*]
Elymus elymoides	Squirreltail. **Dry, open areas.** [*Sitanion hystrix*]
Elymus multisetus	Big squirreltail. Grasslands, blue oak woodland. Common. [*Sitanion jubatum*]
Gastridium ventricosum*	Nitgrass. Grasslands. Local, uncommon.
Hordeum depressum	Low barley. Swale in grasslands. Local, uncommon.
Hordeum murinum* ssp. *leporinum*	Foxtail barley. Grasslands. Widespread, common. [*H. leporinum*]
Koeleria macrantha	Prairie junegrass. Grasslands. Local, uncommon. [*K. cristata*, *K. nitida*]
Koeleria phleoides*	Bristly junegrass. Open, thin-soiled areas in grasslands, coastal scrub. Local, uncommon. [*K. gerardii*]
Lamarckia aurea*	Goldentop. Coastal scrub. Widespread but uncommon. Observed in canyon east of Builing 812 by Biosystems (1986a).
Leymus triticoides	Creeping wildrye. Grasslands, freshwater seep. Common. [*Elymus triticoides*]
Lolium multiflorum*	Italian ryegrass. Grasslands, vernal pool. Common.

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Possibly Occurs at Building 812 (continued)	
Poaceae (Grass Family) (continued)	
Lolium perenne*	Perennial ryegrass. Swale in grasslands. Local, uncommon.
Melica californica	California melic. Rock outcrops in grasslands, blue oak woodland. Local, uncommon.
Nassella cernua	Nodding needlegrass. Grasslands. Common. [*Stipa cernua*]
Poa annua*	Annual bluegrass. Grasslands. Local, uncommon.
Poa bulbosa*	Bulbous bluegrass. Grasslands. Local, uncommon.
Polypogon interruptus*	Ditch beard grass. Freshwater seep. Local, uncommon.
Schismus arabicus*	Arabian grass. Rock outcrops in grasslands, ruderal. Widespread but uncommon.
Schismus barbatus*	Mediterranean grass. Coastal scrub. Widespread but uncommon.
Taeniatherum caput-medusae*	Medusa-head. **Noxious weed.**
Vulpia bromoides*	Foxtail fescue. Grasslands. Uncommon.
Vulpia microstachys var. ***ciliata***	Ciliate fescue. Blue oak woodland, grasslands. Widespread but uncommon.
Vulpia microstachys var. ***confusa***	Hairy-leaved fescue. Grasslands. Widespread but uncommon.
Vulpia microstachys var. ***pauciflora***	Few-flowered fescue. Grasslands. Widespread but uncommon.
Vulpia myuros*	Rattail fescue. Grasslands. Widespread but uncommon.
Vulpia octoflora var. ***hirtella***	Eight-weeks fescue. Coastal scrub. Local, uncommon.
Polemoniaceae (Phlox Family)	
Allophyllum divericatum	Straggling gilia. **Sandy areas, chaparral, woodlands.**
Eriastrum pluriflorum	Many-flowered eriastrum. Grasslands. Local, uncommon.
Gilia capitata ssp. ***staminea***	Blue field gilia. Rock outcrops in coastal scrub. Widespread, common.
Gilia clivorum	Many-stemmed gilia. Grasslands, coastal scrub. Widespread but uncommon.
Gilia tricolor	Bird's-eye gilia. Grasslands. Widespread, common.
Linanthus bicolor	Bicolored linanthus. Coastal scrub. Widespread, common
Linanthus dichotomus	Evening snow. Coastal scrub.
Navarretia nigelliformis	Adobe navarretia. Grasslands. Uncommon.
Navarretia pubescens	Downy navarretia. Grasslands. Uncommon.
Phlox gracilis	Slender phlox. Moist areas in grasslands. Widespread, common.
Polygonaceae (Buckwheat Family)	
Eriogonum angulosum	Angle-stemmed buckwheat. Open areas in grasslands, coastal scrub. Widespread, common.
Eriogonum fasciculatum var. ***polifolium***	California buckwheat. Coastal scrub. Widespread, common. Observed in canyon east of Building 812 by Biosystems (1986a).
Eriogonum gracile	Slender woolly wild buckwheat. Grasslands. Uncommon.

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Possibly Occurs at Building 812 (continued)	
Polygonaceae (Buckwheat Family) (continued)	
Eriogonum nudum var. ***pauciflorum***	Naked-stemmed buckwheat. Grassland. coastal scrub. Widespread, common.
Eriogonum wrightii var. ***subscaposum***	Wright's buckwheat. Coastal scrub. Local, uncommon.
Eriogonum wrightii var. ***trachygonum***	Wright's buckwheat. **Dry gravel or rocks.**
Polygonum arenastrum*	Common knotweed. **Abundant, disturbed places.**
Pterostegia drymarioides	At base of rock outcrops and under shrubs, in blue oak woodland, coastal scrub, and grasslands. Widespread, common.
Rumex conglomeratus*	Whorled dock. **Common, moist places.**
Rumex crispus*	Curly dock. Freshwater seep. Local, uncommon.
Rumex salicifolius var. ***denticulatus***	Willow dock. Freshwater seep. Local, uncommon.
Portulacaceae (Purslane Family)	
Calandrinia ciliata	Red maids. Grasslands, ruderal. Widespread, common.
Claytonia exigua	Common montia. Rock outcrops. Local, uncommon. [*C. spathulata* var. *exigua* and *C. spathulata* var. *tenuifolia*]
Claytonia perfoliata	Miner's lettuce. Blue oak woodland, coastal scrub. Widespread, common.
Claytonia rubra	Red miner's lettuce. Grasslands. Uncommon.
Potamogetonaceae (Potamogeton Family)	
Potamogeton crispus*	Crispate-leaved pondweed. **Shallow water, ponds, streams.**
Primulaceae (Primrose Family)	
Androsace elongata ssp. ***acuta***	CNPS List 4. California androsace. Moss-covered rock outcrops and open areas in adjacent grassland. Widespread and common, but restricted to highly localized microhabitat sites (Figure A-1).
Dodecatheon hendersonii	Mosquito bills. Grasslands. Locally common.
Pteridaceae (Brake Family)	
Pellaea andromedifolia	Coffee fern. At base of rocks in coastal scrub. Local, uncommon.
Ranunculaceae (Buttercup Family)	
Delphinium gypsophilum ssp. ***gypsophilum***	CNPS List 4. Gypsum-loving larkspur. Grasslands. Restricted to several occurrences along the east side of Site 300, some near Building 812.
Delphinium hesperium	Western larkspur. **Grassland, open woodland.**
Delphinium hesperium ssp. ***pallescens***	Pale western larkspur. Blue oak woodland, grasslands. Common.
Delphinium parryi	Parry's larkspur. Blue oak woodland, grasslands. Common.
Delphinium patens	Coastal scrub, oak woodland. Spreading larkspur. Widespread, common.
Ranunculus canus	Sacramento Valley buttercup. Grasslands. Local, uncommon. [*R. canus* var. *laetus*]
Ranunculus hebecarpus	Pubescent-fruited buttercup. **Shaded areas, chaparral, oak or juniper woodland.**

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Possibly Occurs at Building 812 (continued)	
Ranunculaceae (Buttercup Family) (continued)	
Ranunculus muricatus*	Prickle-fruited buttercup. Wetlands. Uncommon.
Ranunculus sceleratus	Celery-leaved buttercup. **Shallow water, lake or pond margins, streambanks.**
Rosaceae (Rose Family)	
Aphanes occidentalis	Western ladies'-mantle. Grasslands, oak woodland. Widespread but uncommon.
Prunus virginiana var. ***demissa***	Western choke-cherry. Elderberry scrub. Local, uncommon.
Rubus leucodermis	Blackcap raspberry. **Generally rock, especially moist paces.**
Rubus ursinus	California blackberry. Elderberry scrub. Local, uncommon.
Rubiaceae (Madder Family)	
Galium aparine	Common bedstraw. Blue oak woodland, grasslands. Widespread but uncommon.
Galium parisiense*	Wall bedstraw. Ruderal, grasslands. Widespread but uncommon.
Salicaceae (Willow Family)	
Salix lasiolepis	Arroyo willow. Great Valley willow scrub. Local, uncommon.
Saxifragaceae (Saxifrage Family)	
Lithophragma affine	Woodland star. **Open, grassy slopes.**
Lithophragma parviflorum var. ***parviflorum***	Moist areas in grasslands. Widespread, common.
Saxifraga californica	California saxifrage. Moist areas in grasslands. Widespread, common.
Scrophulariaceae (Figwort Family)	
Castilleja attenuata	Valley tassels. Grasslands. Local, uncommon. [*Orthocarpus attenuatus*]
Castilleja exerta	Purple owl's-clover. Grasslands, coastal scrub, blue oak woodland. Widespread, common. [*Orthocarpus purpurascens*]
Castilleja foliolosa	Ash-grey Indian paintbrush. Coastal scrub. Local, uncommon.
Collinsia sparsiflora	Few-flowered blue-eyed Mary. **Grassy, disturbed areas.**
Collinsia sparsiflora var. ***collina***	Remote-flowered blue-eyed Mary. Rock outcrops and open, moist areas in grasslands. Widespread, common.
Linaria canadensis	Blue toadflax. **Sand or gravel.** [*L. texana*]
Mimulus aurantiacus	Bush monkey flower. Elderberry scrub. Local, uncommon.
Solanaceae (Nightshade Family)	
Datura wrightii	Jimson weed. Ruderal, Great Valley willow scrub. Uncommon.
Nicotiana acuminata var. ***multiflora****	Many-flowered tobacco. Freshwater seep. Uncommon.
Nicotiana quadrivalvis	Indian tobacco. **Open, well-drained washes, slopes.** [*N. bigelovii*]
Solanum umbelliferum	Blue witch. Grasslands. Uncommon.
Typhaceae (Cattail Family)	
Typha angustifolia	Narrow-leaved cattail. Cattail wetland, freshwater seep. Local, uncommon.
Typha domingensis	Southern cattail. **Marshes.**
Typha latifolia	Broad-leaved cattail. Cattail wetland, freshwater seep. Local, uncommon.

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Possibly Occurs at Building 812 (continued)	
Urticaceae (Nettle Family)	
Hesperocnide tenella	Western nettle. Rock outcrops in grasslands, coastal scrub. Local, uncommon.
Urtica urens*	Dwarf nettle. Ruderal, blue oak woodland. Local, uncommon.
Valerianaceae (Valerian Family)	
Plectritis brachystemon	Short-spurred plectritis. Moist areas in grasslands. Local, uncommon.
Plectritis ciliosa ssp. ***insignis***	Long-spurred plectritis. Blue oak woodland, grasslands. Widespread but uncommon.
Plectritis congesta	Pink plectritis. **Coastal bluffs, open, partly shaded slopes.**
Plectritis macrocera	White plectritis. Grasslands. Local, uncommon.
Violaceae (Violet Family)	
Viola pedunculata	Johnny jump-up. Grasslands. Local, uncommon.
Viola purpurea ssp. ***quercetorum***	Foothill violet. **Dry foothill slopes in grass or shrubs.** [*V. quercetorum*]
Does not occur at Building 812	
Anacardiaceae (Sumac Family)	
Toxicodendron diversilobum	Poison-oak. Poison-oak scrub. Local, in one stand on the west side of Site 300.
Apiaceae (Carrot Family)	
Apiastrum angustifolium	Wild celery. Blue oak woodland. Local, uncommon.
Yabea microcarpa	California hedge-parsley. Blue oak woodland. Local, uncommon.
Asteraceae (Sunflower Family)	
Artemisia californica	California sage. Coastal scrub. Widespread, common.
Hesperevax caulescens	CNPS List 4. Hogwallow starfish. Grasslands, with moist, clay soils. One population known at Site 300. [*Evax caulescens*]
Psilocarphus brevissimus	Woolly marbles. **Vernal pools and flats.**
Rafinesquia californica	California chicory. **Shrubby slopes, open woods.**
Senecio breweri	Brewer's butterweed. Blue oak woodland. Local, uncommon.
Boraginaceae (Borage Family)	
Amsinckia grandiflora	FE, SE. Large-flowered fiddleneck. Blue oak woodland. Restricted to a single population (Figure A-1).
Amsinckia vernicosa	Green fiddleneck. Clay barrens. Uncommon.
Plagiobothrys bracteatus	Bracted popcorn flower. Vernal pool. Local, uncommon.
Plagiobothrys stipitatus var. ***micranthus***	Small-flowered popcorn flower. Vernal pool. Local, uncommon.
Callitrichaceae (Water Starwort Family	
Callitriche marginata	California water-starwort. Vernal pool. Local, uncommon.
Callitriche verna	Vernal water-starwort.

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Does not occur at Building 812 (continued)	
Campanulaceae (Bluebell Family)	
Downingia insignis	Cupped downingia. Vernal pool. Local, uncommon.
Caprifoliaceae (Honeysuckle Family)	
Lonicera interrupta	Chaparral honeysuckle. Along stream, in blue oak woodland. Local, uncommon.
Caryophyllaceae (Pink Family)	
Loeflingia squarrosa	California loeflingia. **Sandy, gravelly areas.**
Cyperaceae (Sedge Family)	
Cyperus eragrostis	Umbrella sedge. Vernal pool. Local, uncommon.
Eleocharis macrostachya	Creeping spikerush. Vernal pool. Local, uncommon. [*E. palustris*]
Euphorbiaceae (Spurge Family)	
Euphorbia spathulata	Reticulate-seeded spurge. Blue oak woodland. Local, uncommon.
Fabaceae (Pea Family)	
Lupinus albifrons	Bush lupine. Blue oak woodland, coastal scrub. Widespread, common, often dominant in small stands.
Fagaceae (Beech Family)	
Quercus douglasii	Blue oak. Blue oak woodland, juniper oak woodland. Widespread, common.
Quercus lobata	Valley oak. Valley oak woodland, blue oak woodland. Local, uncommon.
Geraniaceae (Geranium Family)	
California macrophylla	CNPS List 1B. Round-leaved filaree. Grassland, on friable clay soil. Restricted to western portion of the site (Figure A-1). Formerly known as *Erodium macrophyllum.*
Hippocastanaceae (Buckeye Family)	
Aesculus californicus	California buckeye. Blue oak woodland. Local, uncommon.
Juncaginaceae (Arrowgrass Family)	
Lilaea scilloides	Flowering quillwort. Vernal pool. Local, uncommon.
Lamiaceae (Mint Family)	
Salvia mellifera	Black sage. Coastal scrub. Local, uncommon.
Liliaceae (Lily Family)	
Fritillaria agrestis	CNPS list 4. Stinkbells. Grasslands. Local, uncommon, one known location in northwestern corner of Site 300.
Malvaceae (Mallow Family)	
Malva parviflora*	Cheeseweed. Blue oak woodland. Uncommon.
Oleaceae (Olive Family)	
Forestiera pubescens	Desert olive. Along stream. Single stand on west side of Site 300. [*F. neomexicana*]
Onagraceae (Evening Primrose Family)	
Clarkia temblorensis	Temblor clarkia. Blue oak woodland. Uncommon.
Clarkia unguiculata	Elegant clarkia. Blue oak woodland. Uncommon.
Epilobium cleistogamum	Cleistogamous spike primrose. Vernal pool. Local, uncommon.

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Does not occur at Building 812 (continued)	
Onagraceae (Evening Primrose Family) (continued)	
Epilobium pygmaeum	Smooth spike-primrose. Vernal pool.
Papaveraceae (Poppy Family)	
Eschscholzia rhombipetala	CNPS List 1B. Diamond-petaled poppy. Grasslands. Restricted to three small occurrences on the west side of Site 300 (Figure A-1).
Plantaginaceae (Plantain Family)	
Plantago elongata	Annual coast plantain. **Saline and alkaline places, beaches, vernal pools.** [*Plantago bigelovii*]
Platanaceae (Sycamore Family)	
Platanus racemosa	Western sycamore. **Streamsides, canyons.**
Poaceae (Grass Family)	
Alopecurus carolinianus	Carolina foxtail. Vernal pool. Local, uncommon.
Alopecurus saccatus	Pacific foxtail. Vernal pool. Local, uncommon. [*A. howellii*]
Crypsis schoenoides*	Swamp timothy. Vernal pool. Local, uncommon.
Deschampsia danthonioides	Annual hairgrass. Vernal pool. Local, uncommon.
Elymus glaucus	Blue wildrye. Oak woodlands. Local, uncommon.
Portulacaceae (Purslane Family)	
Claytonia parviflora var. ***parviflora***	Narrow-leaved miner's lettuce. Blue oak woodland. Widespread but uncommon.
Pteridaceae (Brake Family)	
Pellaea mucronata	Bird's-foot fern. Rock outcrops in blue oak woodland. Uncommon.
Pentagramma triangularis	Gold-back fern. Rock outcrops in blue oak woodland. Locally common. [*Pityrogramma triangularis*]
Rosaceae (Rose Family)	
Heteromeles arbutifolia	Blue oak woodland. Local, uncommon.
Rubiaceae (Madder Family)	
Galium porrigens var. ***tenue***	Climbing bedstraw. Blue oak woodland. Local, uncommon.
Scrophulariaceae (Figwort Family)	
Collinsia heterophylla	Chinese houses. Blue oak woodland. Locally common.
Mimulus latidens	Broad-toothed monkey flower. **Vernally wet depressions.**
Veronica peregrina L. ssp. ***xalapensis***	Purslane speedwell. Vernal pool. Local, uncommon.
Verbenaceae (Vervain Family)	
Verbena bracteata	Prostrate vervain. Vernal pool. Local, uncommon.
Viscaceae (Mistletoe Family)	
Phoradendron villosum	Oak mistletoe. Blue oak woodland. Local, uncommon.

Table A-1 (continued). Vascular Plants Observed at Lawrence Livermore National Laboratory Site 300.

Family Species	Notes[a]
Does not occur at Building 812 (continued)	
Vitaceae (Grape Family)	
Vitus californica	California wild grape. Along stream in blue oak woodland. Local, uncommon.

Notes:

CNPS = California Native Plant Society.
FE = Endangered under the Federal Endangered Species Act.
SE = Endangered under the State Endangered Species Act.
var = Variety.
ssp = Subspecies.

*** Indicates an introduced species.**

[a] Adapted from Jones and Stokes (2002). Location and habitat information is Site 300 specific expect where bolded, in which habitat information comes from *The Jepson Manual* (Hickman 1993). Nomenclature follows *The Jepson Manual* (Hickman 1993), except where noted. Synonyms [in brackets] are provided for plant names used in BioSystems (1986) checklist that have been superceded. Common names generally are taken from *The Jepson Manual* or CalFlora (2000).

Table A-2. Herpetofauna Species Observed at Lawrence Livermore National Laboratory Site 300[a].

Common Name	Scientific Name	Notes
Amphibians		
Arboreal salamander	*Aneides lugubris*	
California tiger salamander	*Ambystoma californiense*	FT, ST, CASSC. Found in northwest and southeastern corners of the site (Figure A-2). Has not been observed in Building 812.
California slender salamander	*Batrachoseps attenuatus*	
Coast Range newt	*Taricha torosa torosa*	CASSC.
California red-legged frog	*Rana aurora draytonii*	FT, CASSC. Found in Elk Ravine south of Building 812 (Figure A-2).
Pacific treefrog	*Hyla regilla*	
Western spadefoot toad	*Spea hammondii*	CASSC.
Western pond turtle	*Actinemys marmorata*	CASSC.
Western toad	*Bufo boreas*	
Reptiles		
Alameda whipsnake	*Masticophis lateralis euryxanthus*	FT, ST. Found in coastal sage scrub in southern portion of the site (Figure A-2).
Chaparral whipsnake	*Masticophis lateralis lateralis*	
San Joaquin coachwhip	*Masticophis flagellum ruddocki*	CASSC. Has been observed in the canyon east of Building 812 and near Building 801 to the north of Building 812.
Coast horned lizard	*Phrynosoma coronatum frontale*	CASSC. Has been observed in canyons east and north of Building 812.
California legless lizard	*Anniella pulchra pulchra*	CASSC. Observed in coast sage scrub in the southern portion of Site 300.
Side-blotched lizard	*Uta stansburiana*	
Western whiptail	*Aspidoscelis tigris*	
Northwestern fence lizard	*Sceloporus occidentalis occidentalis*	
Western skink	*Eumeces skiltonianus*	
Gilbert skink	*Eumeces gilberti*	
California alligator lizard	*Elgaria multicarinata multicarinata*	
Northern alligator lizard	*Elgaria coeruleus*	
Sagebrush lizard	*Sceloporus graciosus*	
Racer	*Coluber constrictor*	
Common garter snake	*Thamnophis sirtalis*	
Gopher snake	*Pituophis catenifer*	
California kingsnake	*Lampropeltis getula californiae*	
Northern Pacific rattlesnake	*Crotalus oreganus oreganus*	
Night snake	*Hypsiglena torquata*	
Glossy snake	*Arizona elegans*	
Long-nosed snake	*Rhinocheilus lecontei*	
California black-headed snake	*Tantilla planiceps*	
Pacific ring-necked snake	*Diadophis punctatus amabilis*	

Notes appear on the following page.

Table A-2 (continued). Herpetofauna Species Observed at Lawrence Livermore National Laboratory Site 300[a].

Notes:

CASSC = California Species of Special Concern (CA Dept. of Fish and Game, Special Animals List, March 2006).
FT = Threatened under the Federal Endangered Species Act.
ST = Threatened under the State Endangered Species Act.

[a] Adapted from LLNL (2011) and U.S. DOE (2005).

Table A-3. Birds Observed at Lawrence Livermore National Laboratory Site 300[a].

Common Name	Scientific Name	Notes
Pied-billed grebe	*Podilymbus podiceps*	MBTA
Double-crested cormorant	*Phalacrocorax auritus*	MBTA
Great egret	*Ardea alba*	MBTA
Green-backed heron	*Butorides striatus*	
Black-crowned night-heron	*Nycticorax nycticorax*	
Turkey vulture	*Cathartes aura*	MBTA
Bufflehead	*Bucephala albeola*	MBTA
Common goldeneye	*Bucephala clangula*	MBTA
Mallard	*Anas platyrhynchos*	MBTA
Northern shoveller	*Anas clypeata*	MBTA
Cinnamon teal	*Anas cuamptera*	MBTA
Red-shouldered hawk	*Buteo lineatus*	MBTA
Osprey	*Pandion minimus*	MBTA
Golden eagle	*Aquila chrysaetos*	CAFPS, MBTA, EPA
Rough-legged hawk	*Buteo lagopus*	MBTA
Ferruginous hawk	*Buteo regalis*	MBTA
Red-tailed hawk	*Buteo jamaicensis*	MBTA
Swainson’s hawk	*Buteo swainsoni*	ST, MBTA
White-tailed kite	*Elanus leucurus*	CAFPS, MBTA
Cooper's hawk	*Accipiter cooperii*	MBTA
Sharp-shinned hawk	*Accipiter striatus*	MBTA
Common nighthawk	*Chordeiles minor*	
Northern harrier	*Circus cyaneus*	CASSC, MBTA
Prairie falcon	*Falco mexicanus*	MBTA
American kestrel	*Falco sparverius*	MBTA
Wild turkey	*Meleagris gallopavo*	
California quail	*Callipepla californica*	
Virginia rail	*Rallus limicola*	MBTA
Killdeer	*Charadrius vociferous*	MBTA
Greater yellowlegs	*Tringa meanoleuca*	MBTA
Wilson’s Snipe	*Gallinago delicata*	MBTA
Common snipe	*Gallinago gallinago*	MBTA
Mourning dove	*Zenaida macroura*	MBTA
Rock dove	*Columba livia*	
Greater roadrunner	*Geococcyx californianus*	MBTA
Barn owl	*Tyto alba*	MBTA
Short-eared owl	*Asio flammeus*	CASSC, MBTA
Great horned owl	*Bubo virginianus*	MBTA. Observed to roost in Elk Ravine south Building 812. Nests in the canyons east of Building 812.
Burrowing owl	*Athene cunicularia*	CASSC, BCC, MBTA. Known to nest in northern portion of the site. Not observed at Building 812.

Table A-3 (continued). Birds Observed at Lawrence Livermore National Laboratory Site 300[a].

Common Name	Scientific Name	Notes
Western screech owl	*Otus kennicottii*	MBTA
Common poorwill	*Phalaenoptilus nuttallii*	MBTA
White-throated swift	*Aeronautes saxatalis*	MBTA
Allen's hummingbird	*Selasphorus sasin*	BCC, MBTA
Rufous hummingbird	*Selasphorus rufus*	MBTA
Costa’s hummingbird	*Calypte costae*	BCC, MBTA
Anna's hummingbird	*Calypte anna*	MBTA
Northern flicker	*Colaptes auratus*	MBTA
Nutall’s woodpecker	*Picoides nuttallii*	BCC, MBTA
Acorn woodpecker	*Melanerpes formicivorus*	MBTA
Ash-throated flycatcher	*Myiarchus cinerascens*	MBTA
Cassin’s kingbird	*Tyrannus vociferans*	MBTA
Western kingbird	*Tyrannus verticalis*	MBTA
Western wood-pewee	*Contopus sordidulus*	MBTA
Willow flycatcher	*Empidonax traillii*	SE, MBTA. Observed in Elk Ravine southeast of Building 812.
Pacific-slope flycatcher	*Empidonax difficilis*	MBTA
Black phoebe	*Sayornis nigricans*	MBTA
Say's phoebe	*Sayornis saya*	MBTA
Loggerhead shrike	*Lanius ludovicianus*	CASSC, BCC, MBTA
Western scrub jay	*Aphelocoma coerulescens*	MBTA
American crow	*Corvus brachyrhynchos*	MBTA
Common raven	*Corvus corax*	MBTA
Horned lark	*Eremophila alpestris*	MBTA
American pipit	*Anthus rubescens*	
Tree swallow	*Tachycineta bicolor*	MBTA
Cliff swallow	*Petrochelidon (Hirundo) pyrrhonota*	MBTA
Northern rough winged swallow	*Stelgidopterxyx serripennis*	MBTA
Barn swallow	*Hirundo rustica*	
Oak titmouse	*Baeolphus inornatus*	BCC, MBTA
Bushtit	*Psaltriparus minimus*	MBTA
Rock wren	*Salpinctes obsoletus*	MBTA
Bewick’s wren	*Thyothorus ludovicianus*	MBTA
House wren	*Thyothorus aedon*	MBTA
Ruby-crowned kinglet	*Regulus calendula*	MBTA
Hermit thrush	*Catharus guttatus*	MBTA
Swainson’s thrush	*Catharus ustulatus*	MBTA
Western bluebird	*Sialia mexicana*	MBTA
Mountain bluebird	*Sialia currucoides*	MBTA

Table A-3 (continued). Birds Observed at Lawrence Livermore National Laboratory Site 300[a].

Common Name	Scientific Name	Notes
American robin	*Turdus migratorius*	MBTA
Varied thrush	*Ixoreus naevius*	MBTA
California thrasher	*Toxostoma redivivum*	MBTA
Northern mockingbird	*Mimus polyglottos*	MBTA
European starling	*Sturnus vulgaris*	
Cedar waxwing	*Bombycilla garrulus*	MBTA
Hutton's vireo	*Vireo huttoni*	
Phainopepla	*Phainopepla nitens*	MBTA
MacGillivray's warbler	*Oporornis tolmiei*	MBTA
Common yellowthroat	*Geothlypis trichas*	MBTA
Wilson's warbler	*Wilsonia pusilla*	MBTA
Yellow warbler	*Dendroica petechia*	CASSC, MBTA
Yellow-rumped warbler	*Dendroica coronata*	MBTA
Black-throated gray warbler	*Dendroica nigrescens*	MBTA
Western tanager	*Piranga ludoviciana*	MBTA
House sparrow	*Passer domesticus*	
Song sparrow	*Melospiza melodia*	MBTA
Lincoln's sparrow	*Melospiza lincolnii*	MBTA
Fox sparrow	*Passerella iliaca*	MBTA
Golden-crowned sparrow	*Zonotrichia atricapilla*	MBTA
White-crowned sparrow	*Zonotrichia leucophrys*	MBTA
Oregon junco	*Junco hyemalis*	MBTA
Black-throated sparrow	*Amphispiza bilineata*	MBTA
California towhee	*Pipilo crissalis*	MBTA
Vesper sparrow	*Pooecetes grammineus*	MBTA
Lark sparrow	*Chondestes grammacus*	MBTA
Bell's sage sparrow	*Amphispiza belli*	MBTA
Savannah sparrow	*Passerculus sandwichensis*	MBTA
Grasshopper sparrow	*Ammodramus savannarum*	CASSC, MBTA. Has been observed in the northern third of the site. Has not been observed in the bird banding station located in the canyon east of Building 812.
Rufous-crowned sparrow	*Aimophila ruficeps*	MBTA
Lazuli bunting	*Passerina amoena*	MBTA
Blue-grosbeak	*Passerina caerulea*	MBTA
Black-headed grosbeak	*Pheucticus melanocephalus*	MBTA
Bullock's oriole	*Icterus bullockii*	MBTA
Brown-headed cowbird(b)	*Molothrus ater*	MBTA
Red-winged blackbird	*Agelaius phoeniceus*	MBTA
Tricolored blackbird	*Agelaius tricolor*	CASSC, BCC, MBTA. Nests in Elk Ravine south of Building 812 (Figure A-2).

Table A-3 (continued). Birds Observed at Lawrence Livermore National Laboratory Site 300[a].

Common Name	Scientific Name	Notes
Western meadowlark	*Sturnella magna (neglecta)*	
Brewer's blackbird	*Euphagus cyanocephalus*	
Lesser goldfinch	*Carpodacus psaltia*	
House finch	*Carpodacus mexicanus*	
American goldfinch	*Carduelis tristis*	

Notes:

BCC = **U.S. Fish and Wildlife Service Birds of Conservation Concern (US Fish and Wildlife Service 2008).**

CAFPS = **California Department of Fish and Game Fully Protected Species (CA Fish and Game Code Section 3511).**

CASSC = **California Species of Special Concern (CA Dept. of Fish and Game, Special Animals List, March 2006).**

EPA = **Eagle Protection Act.**

FT = **Threatened under the Federal Endangered Species Act.**

MBTA = **Migratory Bird Treaty Act.**

SE = **Endangered under the State Endangered Species Act.**

ST = **Threatened under the State Endangered Species Act.**

[a] **Adapted from LLNL (2011) and U.S. DOE (2005).**

Table A-4. Mammals Observed at Lawrence Livermore National Laboratory Site 300[a].

Common Name	Scientific Name	Notes
Pallid bat	*Antrozous pallidus*	CASSC
Western red bat	*Lasiurus blossevillii*	CASSC
Hoary bat	*Lasiurus cinereus*	
California myotis	*Myotis californicus*	
Yuma myotis	*Myotis yumanensis*	
Long-legged myotis	*Myotis volans*	
Western pipistrelle	*Pipistrellus hesperus*	
Brazillian free-tailed bat	*Tadarida brasiliensis*	
Desert cottontail	*Sylvilagus audubonii*	
Black-tailed jackrabbit	*Lepus californicus*	
Heermann's kangaroo rat	*Dipodomys heermanni*	
California pocket mouse	*Chaetodipus californicus*	
San Joaquin pocket mouse	*Perognathus inornatus inornatus*	
California ground squirrel	*Spermophilus beecheyi*	Has been directly observed at Building 812.
Botta's pocket gopher	*Thomomys bottae*	
California vole	*Microtus californicus*	
House mouse	*Mus musculus*	
Dusky-footed woodrat	*Neotoma fuscipes*	
Desert woodrat	*Neotoma lepida*	
Brush mouse	*Peromyscus boylii*	
Deer mouse	*Peromyscus maniculatus*	
Western harvest mouse	*Reithrodontomys megalotis*	
Red fox	*Vulpes vulpes*	
Gray fox	*Urocyon cinereoargenteus*	
Coyote	*Canis latrans*	Has been directly observed at Building 812.
Raccoon	*Procyon lotor*	
Virginia opossum	*Didelphis virginiana*	
Long-tailed weasel	*Mustela frenata*	
Striped skunk	*Mephitis mephitis*	
Western spotted skunk	*Spilogale gracilis*	
American Badger	*Taxidea taxus*	CASSC
Feral house cat	*Felis domesticus*	
Bobcat	*Lynx rufus*	
Mountain lion	*Felis concolor*	
Mule deer	*Odocoileus hemionus*	Has been directly observed at Building 812.
Wild pig	*Sus scrofa*	

Notes:

CASSC = California Species of Special Concern (CA Dept. of Fish and Game, Special Animals List, March 2006).

[a] **Adapted from LLNL (2011) and U.S. DOE (2005).**

Table A-5. Special-Status Invertebrates Observed at Lawrence Livermore National Laboratory Site 300[a].

Common Name	Scientific Name	Notes
Valley elderberry longhorn beetle	*Desmocerus californicus dimorphus*	FT. Found in Elk Ravine south of Building 812 (Figure A-2).
California fairy shrimp	*Linderiella occidentalis*	Found only in vernal pools in the northern part of the site.
California clam shrimp	*Cyzicus californicus*	Found only in vernal pools in the northern part of the site.

Notes:

FT = Threatened under the Federal Endangered Species Act.

[a] **Adapted from LLNL (2011) and U.S. DOE (2005).**

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