APPENDIX F ECOLOGY AND BIOLOGICAL ASSESSMENT

This appendix contains two major sections. Section F.1 is a discussion of the ecological characteristics at the LLNL Livermore site, LLNL Site 300, and SNL, Livermore (referred to collectively as the study sites); and presents information and data on the flora and fauna in the upland areas (see Appendix G for a detailed analysis of wetlands at the study sites). This section focuses on the biological features of LLNL Site 300 because this 7000-acre site is largely undeveloped and represents the most biologically diverse area under study. In contrast, the LLNL Livermore site and SNL, Livermore are developed areas that provide only marginal wildlife habitat because of the high degree of human activity and the few areas of undisturbed vegetation.

Section F.2, a biological assessment, complies with the U.S. Department of Energy (DOE) guidelines requiring that a biological assessment be prepared in conjunction with an environmental impact statement. Prepared pursuant to Section 7(c) of the U.S. Endangered Species Act and to the State of California Endangered Species Act, this biological assessment includes a description of existing biological conditions; the status of threatened and endangered species and other species of concern at the study sites; the impacts, if any, of operations on these species; a determination if effects would occur to species of concern; and mitigation measures where appropriate.

The relationship of Appendix F to other appendices and to Sections 4 and 5 of the EIS/EIR is illustrated in Figure F-1. While analyses prepared for the biological assessment provide the basis for the discussion of impacts of the proposed action as described in the EIS/EIR section 5.1.7.3, the biological assessment analyzes a broader scope of actions than does the EIS/EIR. This broader description, including analysis of the biological impacts of existing operations, is appropriate to DOE requirements as well as state and federal endangered species acts.

Flora references in section F.1 are generally made using scientific names since common names of plant species are not always available. For fauna references in sections F.1 and F.2, the reverse is generally the case, with common names preceding the scientific names, which are in parentheses.

F.1 ECOLOGY

F.1.1 Flora and Vegetation

The flora and vegetation at LLNL Site 300 have been described in Taylor and Davilla (1986a, 1986b). Because of the extensive scope of this previous study no additional studies of flora and vegetation other than surveys for rare plants were conducted in 1991. A limited amount of information regarding flora and vegetation at the LLNL Livermore site and SNL, Livermore has been collected.

F.1.1.1 Methods

A plant species list for LLNL Site 300 was generated during the 1986 rare plant surveys (conducted on foot beginning on March 30, 1986, and continuing at biweekly intervals through mid-May 1986) (Taylor and Davilla, 1986b). All plant species observed during these surveys were recorded on the plant species list.

Sampling to typify vegetation composition was conducted in 1986 using a rapid, descriptive technique generally termed as "the relevé method" (Mueller-Dombois and Ellenberg, 1974). Sites that qualified for relevé sampling were judged to possess homogeneous physiography and edaphic characteristics. Relevé size was determined by the rate of observation of the new species within a homogeneous patch of vegetation with the relevé boundary being the point where observation of new species ceased (Daubenmire, 1968).

Cover of vascular plant species within the relevé was estimated according to the following scale of precision:

Observed Cover Value	Estimated to the Nearest
<1%	0.1%
1–10%	1.0%
>10%	5.0%

Mean percent cover was determined as the average for all relevés in which a given species occurred, not the mean for all relevés. Constancy and importance values for plant species found within each plant community type were also calculated. Constancy is the percentage of all relevés in which a given species is encountered. Importance values are the sum of constancy and mean cover. As such, the importance value is a parameter that represents the frequency at which a species is observed added to the percent of groundcover of this particular species.

The survey also recorded the elevation, slope, exposure, and edaphic characteristics at each relevé site. Soil texture was estimated using visual and tactile methods (U.S. Department of Agriculture, 1951).

Data Analysis

The purpose of the analysis of vegetation data was to provide an ecological description of the LLNL Site 300 plant communities based on quantitative methods. The ecological characterization presented below is adapted from the 1986 report by Taylor and Davilla (1986a). Data collected in this study was analyzed using a variety of univariate and multivariate techniques. The object of these analyses was to quantify patterns of vegetative variation in relation to environmental factors. A detailed discussion of the methods used appears in Taylor and Davilla (1986a).

Vegetation Mapping

A standard map of habitat types was prepared for LLNL Site 300 by dividing a color photograph of the site into polygons (Avery, 1968), each corresponding to a structurally homogeneous expanse of vegetation. The available image was made at an appropriate stage of plant growth for mapping purposes (late April) when contrast between xeric (dry) and mesic (moist to wet) habitats was best developed. Mapped boundaries of each vegetation polygon were transferred to a base map using a stereo zoom transfer scope. Relevés within each polygon were compared in order to derive more detailed map units.

F.1.1.2 Results

Flora

From the 1986 survey, a total of 342 plant taxa were identified at LLNL Site 300 (Taylor and Davilla, 1986b) (Table F-1); 308 of these were recorded from the 218 relevés sampled (Figure F-2), representing a sampling intensity of 8.1 relevés/km^2 (21.0 relevés/mi^2). Relevé density varied from 5.1 to 121.7 relevés/km^2 (13.2 to 315.2 relevés/mi^2); more relevés were sampled in the southwestern portion of LLNL Site 300 because of its diverse topography and vegetation.

Of the 308 plant taxa identified in the 218 relevés, 88 species (29 percent) occurred on at least 4 relevés (Table F-2). The non-native grass species, *Avena barbata*, was the most frequently encountered plant occurring in more than 87 percent of all relevés and having a mean cover of approximately 37 percent, more than three times higher than the species with the next highest cover. Other frequently encountered species were *Bromus mollis, B. diandrus, Erodium cicutarium, B. rubens*, and *Vulpia myuros*, all non-native annuals introduced from Europe (Robbins, 1940). Collectively, these six taxa are dominant in annual grasslands over much of lowland California (Heady, 1977).

The proportion and relative importance of native versus introduced species in the vegetation on LLNL Site 300 are similar to patterns documented in other cismontane annual grassland communities, where a handful of introduced species dominate and native species are less common (Heady, 1958; Talbot et al., 1939; Pitt, 1975).

Poa scabrella was the most important native grass identified, occurring on nearly 39 percent of all relevés with an average cover of about 8 percent. Other important native species included the annual herbs *Trifolium tridentatum, Orthocarpus purpurascens, Lotus subpinnatus,* and *Amsinckia intermedia*.

Community Type Classification

Plant community classification analysis and ordination techniques resulted in the delineation of 14 plant community types that were combined to form five major types (Figure F-3, Table F-3). Of the 218 relevés sampled, 6 could not be placed in the classification scheme. Of these relevés, two were from the vernal pool and the remaining four were in other unique habitats (a clay scald, a *Quercus lobata* stand, an unusual landslide deposit dominated by *Grindelia camporum*, and a *Melica californica* sward) for which no replicate samples could be obtained.

Characteristics of the plant community types including number of stands sampled, elevation, aspect, soil, and number of species per stand are presented in Table F-4. The cover of the various life forms within each plant community type is on Table F-5.

Coastal Sage Scrub Community

The scrub communities identified from LLNL Site 300 can be characterized as mixtures of the soft-chaparral shrubs *Artemisia californica*, *Eriogonum fasciculatum*, *Salvia mellifera,* and *Gutierrezia bracteata*. These four taxa form the nucleus of coastal sage scrub vegetation, which is most commonly associated with the outer south coast ranges of California (Westman, 1981; Mooney, 1977). The mean number of species for coastal sage scrub community types is generally higher than other types on LLNL Site 300 (Table F-4). These community types occur in the southwestern part of LLNL Site 300 (Figure F-3) and cover approximately 108 acres.

Community type 1 (*Artemisia californica-Salvia mellifera/Herniaria cinerea*) is typified by high cover (approximately 44 percent) of the shrubs *Gutierrezia bracteata*, *Artemisia californica*, *Eriogonum fasciculatum*, and *Salvia mellifera* (Table F-5). Understory vegetation is dominated by introduced grasses (37 percent cover), predominantly *Avena barbata* (Table F-5). The large proportion of bare ground present in most stands of this type can be attributed to the combined effects of allelopathy and rabbit grazing (Halligan, 1975; Muller et al., 1964; Bartholomew, 1970). Community type 1 occurs on rocky outcrops of resistant sandstone or on alluvial conglomerates on moderate to steep slopes facing south to west (Table F-4).

The composition and structure of community type 1 most closely resembles coastal sage scrub communities from coastal southern California as described by Kirkpatrick and Hutchinson (1980), Wells (1962), and Westman (1981). Internal percentage similarity between stands of this type is 66 percent (Table F-4).

Community type 2 (*Artemisia californica/Bromus mollis*) is a restricted vegetation unit on LLNL Site 300, occurring only along the slopes and on the bottoms of gullies in the southern half of the site, whose structure is intermediate between those of typical coastal sage scrub and grassland. Shrub cover averages about 23 percent, and grass cover averages about 64 percent (Table F-5). *Artemisia californica* is the dominant shrub species, while predominant grass species (all introduced) are *Bromus mollis*, *B. diandrus*, *Avena barbata*, *Vulpia myuros*, and *B. rubens*. Internal percentage similarity averages 63 percent within this community type (Table F-4).

Community type 3 (*Gutierrezia bracteata/Avena barbata*), also a transitional type between coastal sage scrub and grassland, typically consists of a sparse shrub cover (14 percent) dominated by *Gutierrezia bracteata*. Grass cover, almost entirely of introduced grasses, is approximately 58 percent (Table F-5), with *Avena barbata* being the most common species. This vegetation is typical of ridges and flat terraces on moderate slopes underlain by hard conglomerates exhibiting poorly developed soils (Table F-4).

Oak Woodland Community

A single oak-woodland community type, community type 4 (*Quercus douglasii/Avena barbata*), is found on LLNL Site

300. Stands are restricted to north-facing slopes in southern canyons on the site (Figure F-3) and cover approximately 150 acres. This type includes a sparse cover of *Quercus douglasii* (averaging 13 percent) and a complete grass–dominated understory (Table F-5). Important grasses include *Avena barbata*, *Bromus mollis*, and *B. diandrus*. Only one native grass, *Elymus triticoides*, is important in this vegetation. As is typical of other California oak woodland communities (Griffin, 1977), the spatial distribution of understory grasses is patchy correlating with the effect of shade and litterfall associated with a canopy (and formerly, with the leisure habits of cattle) (Holland, 1973).

Internal similarity is low compared to that of most other community types in this study, whereas species richness is relatively high (Table F-4). Ecologically, oak woodland dominated by *Q. douglasii* is most often located in slightly more mesic sites than those supporting annual grasslands (Baker et al., 1981).

Introduced Grassland Communities

The four introduced grassland community types from LLNL Site 300, covering approximately 5647 acres, are variously proportioned mixtures of introduced annual grasses (Figure F-3). The most important species are *Avena barbata*, *Bromus diandrus*, *B. mollis*, and *B. rubens*.

Community type 5 (*Juniperus californica/Bromus diandrus-Lotus subpinnatus*) is essentially a grassland with scattered shrubs (mean percent cover of 26 percent) dominated by *Juniperus californica* (the other three introduced grassland types lack an overstory). Mean percent grass cover is 76 percent, and the introduced species, *Bromus diandrus* and *Avena barbata*, are the most common. Internal percentage similarity between stands of this type is low relative to that of other community types on LLNL Site 300 and the number of species is intermediate (Table F-4). This type characteristically occurs at the base of north-facing canyon slopes with a clay-enriched soil (Table F-4), a combination of factors found only in the southern half of LLNL Site 300.

Community types 6, 7, and 8 form the bulk of the vegetation on LLNL Site 300. Minor changes in community composition were noted along edaphic and successional gradients. Community type 6 (*Avena barbata-Brassica geniculata-Lotus subpinnatus*) is typically found on ridgecrest or spur topographic positions; community type 7 (*Avena barbata-Bromus diandrus*) is an early successional type that develops in a variety of sites following soil disturbance; while community type 8 (*Avena barbata-Triteleia laxa*) is found on more mesic sites (such as north-facing slopes) or on sites where recent soil disturbance is not indicated.

Community type 6 stands have lower *Brassica* biomass than the annual grasslands described elsewhere in lowland California (Bell and Muller, 1973). Stands on LLNL Site 300 typically exhibit moderate species richness (an average of 15.7 species per stand) (Table F-4), as diversity is not being inhibited by strong *Brassica* competition. Observation of sites adjacent to LLNL Site 300 suggest that *Brassica*-dominated vegetation is better developed where heavy grazing is the rule. The lack of *Brassica* stands on LLNL Site 300 may correlate to the greater frequency of fires there than on comparable inner Coast Range sites (see section F.1.1.3). Internal percentage similarity between stands for community type 6 is high relative to that of other grassland communities (Table F-4).

Community type 7 vegetation is characterized by codominance of only two introduced grasses, *Avena barbata* and *Bromus diandrus*, whereas the other introduced grassland community types on LLNL Site 300 often have four or five codominants. This type is most extensive in areas of past or ongoing soil disturbance, such as those sections of the facility with dense road networks. Elsewhere in lowland California, *Bromus diandrus* dominated vegetation is a general indicator of severe disturbance in ruderal sites (Frenkel, 1970). Internal percentage similarity between stands and species richness is the lowest of all vegetation types at LLNL Site 300 (Table F-4).

Community type 8 vegetation exhibits high cover of the introduced grasses (89.0 percent, Table F-5) dominated by *Avena barbata* and *Bromus mollis*. Forb cover is 30 percent, with native species exhibiting slightly more cover than non-native species (Table F-5). *Amsinckia intermedia* and *Erodium cicutarium* are conspicuous forbs.

Native Grassland Communities

The four grassland community types, dominated by mostly native perennial grasses, exhibit low compositional variation relative to introduced grassland community types. Internal percentage similarity ranged from 63 to 72 percent (Table F-4). These types cover approximately 723 acres at LLNL Site 300.

Poa scabrella, the most characteristic dominant of native grassland communities on LLNL Site 300, displayed from 20 to 43 percent average cover by community. Community type 9 (*Avena barbata*-*Poa scabrella*-*Erodium cicutarium*) is transitional between annual and perennial grasslands, and is the only native grassland type with a higher percent cover of introduced species over native species (Table F-5). This type is found on a variety of sites and exposures, consistent with the interpretation that it represents an intermediate stage in the vegetation succession. Of the native grassland communities, community type 9 exhibits the lowest average species richness (Table F-4).

Community type 10 (*Poa scabrella*-*Lasthenia minor*) is an unusual vegetation unit in which native forbs comprise the majority of plant cover, 56 percent (Table F-5); with *Lasthenia minor*, *Trifolium tridentatum*, *Orthocarpus purpurascens*, *Amsinckia intermedia*, and *L. californica* the most important. Native grass cover averages about 47 percent followed by introduced grass at 22 percent and introduced forbs at 11 percent (Table F-5). This type occurs in clay soils at the base of slopes with a northeastern exposure (Table F-4).

North-facing toe slopes typically support community type 11 (*Poa scabrella*-*Triteleia laxa*) (Table F-4). Native grasses exhibit the highest percent cover at 56 percent (Table F-5), with *Poa scabrella* exhibiting its highest cover at 43 percent. Introduced grass covers 43 percent, with *Avena barbata* being the most common species.

Community type 12 (*Poa scabrella*-*Sitanion jubatum* community) has the fewest introduced annual species on LLNL Site 300. This type is characteristic of upper topographic positions on sandy soils, and is best developed on north-facing slopes (Table F-4). Cover of native grasses and forbs is 70 percent, while introduced species coverage is 34 percent (Table F-5). Some stands are mixtures of five native perennial grasses: *Poa scabrella*, *Sitanion jubatum*, *Stipa pulchra*, *Koeleria nitida*, *Melica californica*.

Stands of native grasslands on LLNL Site 300 are confined mainly to the northern half of the facility (Figure F-3). Occurrence of native grass–dominated vegetation correlates with annual controlled burning.

The native grass–dominated communities on LLNL Site 300 represent a unique resource. The plant species composition of this community type suggests two patterns of variation that may illuminate the structure of pristine California grasslands; (1) most investigators such as Heady (1977) and Barry (1972) agree with Clements (1920) that *Stipa pulchra* should dominate native grassland communities, as it often does on very sandy soils (Hull and Muller, 1977; Robinson, 1968); however, as discussed by Bartolome and Gemmil (1981), this conclusion may not be accurate. Dominance by *Poa scabrella* of LLNL Site 300 native grasslands specifically contradicts the notion that *Stipa* would dominate California grasslands in the absence of grazing and introduced annuals; and (2) the role of native forbs in native grassland communities has not received much study (Heady, 1977). Data from LLNL Site 300 suggest that both native annual and perennial forbs can assume an important role under the conditions of frequent burning and no grazing and thus may once have been important dominants or codominants of California grassland communities.

Seeps and Springs

Seeps and springs, rare on LLNL Site 300, are most frequently found where porous sandstone formations intersect gullies. Two seep plant community types were sampled in the 1986 survey. They are dominated by *Elymus triticoides* (see Figure G-8 in Appendix G for the location of spring-fed wetlands). Community type 13 (*E. triticoides*-*Polypogon interruptus*) is found where standing water is absent for extended periods, whereas community type 14 (*E. triticoides*-*Typha latifolia*) is found where standing water is often present.

Internal percentage similarity between stands of the two spring plant communities is high, about 75 percent (Table F-4). Mesophytes occurring as associates in these types include *Juncus oxymeris, Elymus glaucus, Mimulus guttatus*, and *Distichilis spicata*. Spring and seep vegetation is generally restricted to canyons on the southern half of LLNL Site 300.

Unusual or Restricted Communities

Vernal pools are a conspicuous, floristic unit in lowland grassland sites in California (Holland and Jain, 1977). Important dominants at the vernal pool at LLNL Site 300 are *Boisduvalia glabella*, *Downingia insignis*, *Deschampsia danthonioides*, and *Plagiobothrys stipitatus*. Figure G-8 in Appendix G shows the location of the vernal pool.

The northern riparian woodland community dominated by woody plants is rare at LLNL Site 300. Extensive *Populus fremontii*–dominated riparian vegetation occurs along Corral Hollow Creek adjacent to the facility. A wooded riparian shrub community characterized by *Ribes divaricatum*, *Sambucus mexicana*, *Prunus virginiana,* and *Baccharis pilularis* occurs north of Elk Ravine; while a riparian area dominated by *Salix laevigata* and *S. mexicana* occurs along the ravine.

Several relevés sampled onsite are typical of a distinctive habitat characteristic of the arid inner south Coast Range. Erosional patterns along gullies produce steep, often clay-rich badland topography dominated by a diverse mixture of native forbs. Such habitats, frequent in Corral Hollow and other surrounding areas, are poorly developed on LLNL Site 300. This type of habitat, however, was sampled at two sites in the extreme southwestern portion of the facility. Characteristic species of this habitat are *Eriogonum angulosum*, *Amsinckia vernicosa*, *Mentzelia affinis*, and *Camissonia boothii*.

Table F-1 Vascular Plants Observed at LLNL Site 300

Scientific Name	Common Name
Pteridophyta Adiantaceae	
Pellaea andromedaefolia *Pityrogramma triangularis*	
Gymnospermae Cupressaceae	
Juniperus californica	California juniper
Angiospermae Amaranthaceae	
Amaranthus blitoides	Amaranth
Anacardiaceae	
Toxicodendron diversilobum	Poison oak
Apiaceae	
Apiastrum angustifolium *Bowlesia incana*a *Lomatium caruifolium*a *Lomatium utriculatum*a	Wild celery
Sanicula crassicaulis	Sanicle
Sanicula bipinnata	Poison sanicle
Sanicula bipinnatifida	Purple sanicle
*Torilis nodosa*b *Yabea microcarpa*a	Hedge-parsley
Asclepiadacea	
Asclepias fascicularis	Milkweed
Asteraceae	

Achillea millefolium var. *californica*	Yarrow
Achyrachaena mollis	Blow-wives
Agoseris grandiflora	Mountain dandelion
Agoseris heterophylla	Mountain dandelion
Artemisia californica	California sagebrush
Baccharis pilularis var. *consanguinea*	Chaparral broom
Baccharis viminea	Mule fat
*Carduus pycnocephalus*b	Italian thistle
*Centaurea melitensis*b	Tocalote
*Centaurea solstitialis*b	Star thistle
Cirsium proteanum	Thistle
*Cirsium vulgare*b	Bull thistle
Conyza canadensis	Horseweed
Coreopsis calliopsidea	Coreopsis
*Ericameria linearifolia*a	
Erigeron inornatus var. *angustatus*	Fleabane
*Evax caulescens*a	
*Evax sparsiflora*a	
*Filago californica*a	
Gnaphalium palustre	Cubweed
Grindelia camporum	Gum-plant
Gutierrezia bracteata	Snakeweed
Hemizonia kelloggii	Tarweed
Hemizonia lobbii	Tarweed
Heterotheca echioides	Golden aster
Holocarpha obconica	Tarweed
*Hypochoeris glabra*b	Cat's ear
*Hypochoeris radicata*b	Cat's ear
*Lactuca serriola*b	Prickly lettuce
*Lagophylla glandulosa*a	
*Lasthenia californica*a	
*Lasthenia chrysostoma*a	
*Lasthenia microglossa*a	
*Lasthenia minor*a	
*Layia gaillardioides*a	
Layia platyglossa	Tidy tips
*Logfia gallica*a,b	
Madia gracilis	Gumweed
Malacothrix coulteri	Snake's head
Matricaria matricarioides	Pineapple weed
*Micropus californicus*a	
Microseris douglasii ssp. *tenella*a	
Microseris lindleyi a	
Monolopia major a	
*Pentachaeta alsinoides*a	
*Picris echioides*b	Ox tongue
*Psilocarphus brevissimus*a	
*Psilocarphus tenellus*a	
*Rafinesquia californica*a	
Senecio breweri	Groundsel
*Senecio vulgaris*b	Groundsel
*Silybum marianum*b	Milk thistle
*Solidago canadensis*b	Canada goldenrod
Sonchus asper b	Sow thistle

*Sonchus oleraceus*b *Stylocline filaginea*a,b	Sow thistle
*Stylocline gnaphalioides*a *Taraxacum officinale*b *Xanthium strumarium* var. *canadense*	 Dandelion Cocklebur
Boraginaceae	
Amsinckia grandiflora *Amsinckia intermedia* *Amsinckia menziesii* *Amsinckia tessellata* *Amsinckia vernicosa* *Cryptantha flaccida*a *Cryptantha intermedia*a *Cryptantha microstachys*a *Heliotropium curassavicum* var. *oculatum* *Pectocarya penicillata*a *Plagiobothrys canescens*a *Plagiobothrys hystriculus*a *Plagiobothrys stipitatus*a *Plagiobothrys tenellus*a *Plagiobothrys tener* a	Large-flowered fiddleneck Fiddleneck Fiddleneck Fiddleneck Fiddleneck Seaside heliotrope
Crassicaceae	
*Alyssum alyssoides*a,b *Athysanus pusillus*a *Brassica geniculata*b *Brassica nigra*b *Capsella bursa-pastoris*b *Cardaria pubescens*b *Caulanthus flavescens* *Caulanthus lasiophyllus* *Descurainia sophia*b *Erysimum capitatum* *Lepidium nitidum* var. *insigne* *Nasturtium officinale*b *Sisymbrium altissimum* *Sisymbrium officinale*b *Thelypodium lemmonii* a *Thysanocarpus curvipes* *Thysanocarpus elegans*	 Wild mustard Black mustard Shepherd's-purse Whitetop Prince's plume Prince's plume Tansy-mustard Wall flower Peppergrass Watercress Tumble-mustard Hedge-mustard Lace-pod Lace-pod
Callitrichaceae	
*Callitriche verna*a	
Campanulaceae	
*Downingia insignis*a	
Caprifoliaceae	
Lonicera interrupta *Sambucus mexicana*	Honeysuckle Elderberry

Caryophyllaceae	
*Cerastium glomeratum*b	Mouse-ear chickweed
*Herniaria cinerea*a,b	
*Loeflingia squarrosa*a	Sandwort
Minuartia californica	Sandwort
Minuartia douglasii	Pearlwort
Sagina decumbens ssp. *occidentalis*	Catchfly
Silene antirrhina	Catchfly
*Silene gallica*b	Sand-spurrey
Spergularia marina	Common chickweed
*Stellaria media*b	Chickweed
Stellaris nitens	
Chenopodiaceae	
Atriplex patula	Saltbush
*Atriplex semibaccata*b	Australian saltbush
Chenopodium californicum	Pigweed
*Chenopodium rubrum*b	Pigweed
*Chenopodium vulvaria*b	Pigweed
*Monolepis nuttalliana*a	
Salsola kali b	Russian thistle
Crassulaceae	
Crassula erecta	Pigmy-weed
Cucurbitaceae	
Marah fabaceus var. *agrestis*	Wild cucumber
Euphorbiaceae	
Eremocarpus setigerus	Turkey mullein
Euphorbia spathulata	Spurge
Fabaceae	
Astragalus asymmetricus	Milkvetch
Astragalus didymocarpus	Milkvetch
Lotus humistratus	Bird's foot trefoil
Lotus subpinnatus	Bird's foot trefoil
Lupinus albifrons	Lupine
Lupinus benthemii	Lupine
Lupinus bicolor var. *umbellatus*	Lupine
Lupinus densiflorus var. *aureus*	Lupine
Lupinus densiflorus var. *palustris*	Lupine
Lupinus densiflorus var. *lacteus Lupinus succulentus*	Lupine Lupine
*Medicago polymorpha*b	Bur-clover
*Melilotus alba*b	White sweet-clover
*Melilotus indicus*b	Sweet-clover
Trifolium albopurpureum	Clover
Trifolium amplectens	Clover
Trifolium dichotomum	Clover
Trifolium gracilentum	Clover
Trifolium microdon	Clover

Trifolium oliganthum *Trifolium tridentatum* *Vicia tetrasperma*b *Vicia villosa* ssp. *varia*b	Clover Clover Vetch Winter vetch
Fagaceae	
Quercus douglasii *Quercus lobata*	Blue oak Valley oak
Geraniaceae	
*Erodium botrys*b *Eriodium brachycarpum*b *Erodium cicutarium* ssp. *jacquinianum*b *Erodium moschatum*b *Geranium molle*b	Storksbill Storksbill Storksbill Storksbill Cranesbill
Hippocastanaceae	
Aesculus californica	California buckeye
Hydrophyllaceae	
Eriodictyon californicum *Nemophila menziesii* *Nemophila pedunculata*a *Phacelia ciliata*a *Phacelia distans*a *Phacelia douglasii* a *Phacelia imbricata*a *Phacelia tanacetifolia*a *Pholistoma membranaceum*a	Yerba santa Baby blue-eyes
Lamiaceae	
Lamium amplexicaule *Marrubium vulgare*b *Pogogyne serpylloides*a *Salvia columbariae* *Salvia mellifera* *Stachys albens* *Trichostema lanceolatum*	Henbit Horehound Sage Black sage Hedge-nettle Vinegar weed
Linaceae	
Hesperolinon californicum	Flax
Loasaceae	
Mentzelia affinis	Blazing-star
Loranthaceae	
Phoradendron villosum	Mistletoe
Malvaceae	
Eremalche parryi a *Malva parviflora*b	Cheeseweed

*Malvella leprosa*a	
Oleaceae	
Forestiera neomexicana	Desert olive
Onagraceae	
*Boisduvalia glabella*a *Camissonia boothii* ssp. *decorticans* *Camissonia cruciata* *Camissonia graciliflora* *Camissonia hirtella* *Clarkia affinis*a *Clarkia purpurea*a *Clarkia tembloriensis*a *Clarkia unguiculata*a *Epilobium canum* ssp. *mexicana* *Epilobium paniculatum*	Evening primrose Evening primrose Evening primrose Evening primrose Willow-herb Willow-herb
Orobanchaceae	
Orobanche californica *Orobanche uniflora* var. *minuta*	Broom-rape Broom-rape
Papaveraceae	
Eschscholzia californica *Platystemon californicus* *Stylomecon heterophylla*a	California poppy Cream cups
Plantaginaceae	
Plantago bigelovii *Plantago erecta* *Plantago eriopoda* *Plantago lanceolata*b	Plantain Plantain Plantain Ribgrass
Plantanaceae	
Platanus racemosa	Sycamore
Polemoniaceae	
*Allophyllum divaricatum*a *Eriastrum plurifloruma*a *Gilia capitata* var. *abortanafolia*a *Gilia capitata* var. *staminea* a *Gilia tricolor* *Linanthus bicolor* a *Linanthus dichotomus* *Microsteris gracilis*a *Navarretia nigellaeformis*a	 Bird's eye gilia Evening snow
Polygonaceae	
*Eriogonum angulosum*a *Eriogonum fasciculatum* var. *polifolium* *Eriogonum nudum*a	 California buckwheat

Eriogonum wrightii var. *trachygonum*a *Polygonum aviculare* *Pterostegia drymarioides*a *Rumux conglomeratus*b *Rumex crispus*b *Rumex salicifolius*	 Common knotweed Sorrel Curly dock Sorrel
Portulacaceae	
Calandrinia ciliata *Claytonia parviflora* *Claytonia perfoliata* *Claytonia spathulata* var. *exigua* *Claytonia spathulata* var. *tenuifolia*	Red maids Miner's lettuce Miner's lettuce Miner's lettuce Miner's lettuce
Primulaceae	
Androsace elongata ssp. *acuta*a *Dodecatheon hendersonii*	 Shooting star
Ranunculaceae	
Delphinium gypsophilum ssp. *gypsophilum* *Delphinium hesperium* *Delphinium patens* *Ranunculus canus* var. *laetus* *Ranunculus hebecarpus* *Ranunculus sceleratus*	Larkspur Larkspur Larkspur Buttercup Buttercup Buttercup
Rosaceae	
*Alchemilla arvensis*a *Heteromeles arbutifolia* *Prunus virginiana*var. *demissa* *Rubus leucodermis*	 Christmas-berry Chock cherry Western raspberry
Rubiaceae	
*Galium aparine*b *Galium porrigens* var. *tenue*	Bedstraw Bedstraw
Salicaceae	
Populus fremontii *Salix laevigata*	Fremont cottonwood Willow
Saxifragaceae	
Lithophragma affinis *Ribes divaricatum* *Ribes malvaceum* *Saxifraga californica*	Woodland-star Currant Chaparral currant Saxifrage
Scrophulariaceae	
Castilleja foliolosa *Collinsia heterophylla* *Collinsia sparsiflora*a *Collinsia sparsiflora* var. *collina*a	Paint-brush Chinese houses Toad flax

Linaria texana *Mimulus aurantiacus* *Mimulus guttatus* *Mimulus latidens* *Mimulus nasutus* *Orthocarpus attenuatus*[a] *Orthocarpus purpurascens* *Scrophularia californica* *Veronica peregrina* ssp. *xalapensis*	Monkey-flower Seep-spring monkey-flower Monkey-flower Monkey-flower Red owl clover Figwort Speedwell
Solanaceae	
Nicotiana bigelovii *Nicotiana glauca*[b] *Solanum nodiflorum*[a,b] *Solanum umbelliferum*[a]	Tobacco Tree tobacco
Uticaceae	
Hesperocnide tenella[a] *Urtica dioica* var. *holosericea* *Urtica urens*[b]	 Nettle Dwarf nettle
Valerianaceae	
Plectritis ciliosa[a] *Plectritis congesta*[a]	
Violaceae	
Viola quercetorum	Violet
Monocotyledoneae	
Cyperaceae	
Cyperus eragrostis *Eleocharis palustris* *Scirpus acutus* *Scirpus fluviatilis*	Umbrella-sedge Spike-rush Common tule River bullrush
Juncaceae	
Juncus balticus *Juncus bufonis* *Juncus oxymeris* *Juncus patens* *Juncus tenuis* var. *congestus*	Baltic rush Toad rush Rush Rush Rush
Liliaceae	
Allium crispum *Allium serratum* *Brodiaea elegans* *Calochortus clavatus* ssp. *palidus* *Calochortus venustus* *Chlorogalum pomeridianum* *Dichelostemma pulchella* *Fritillaria biflora*	Wild onion Wild onion Harvest brodiaea Mariposa lily Mariposa lily Soap plant Blue dicks Chocolate lily

Triteleia hyacinthina *Triteleia elegans*a *Triteleia laxa*	White hyacinth Grass nut
Lemnaceae	
Lemna minuta	Duckweed
Poaceae	
Alopecurus howellii *Avena barbata*b *Avena fatua*b *Bromus arenarius*b *Bromus diandrus*b *Bromus japonicus* *Bromus madritensis*b *Bromus marginatus* *Bromus molliformis* *Bromus mollis*b *Bromus rubens*b *Bromus sterilis*b *Bromus tectorum*	Foxtail Slender oat Wild oat Australian cress Ripgut brome Japanese cress Bromegrass Bromegrass Bromegrass Soft cress Foxtail Bromegrass Downy cress
Deschampsia danthonioides *Distichlis spicata* var. *stricta* *Elymus glaucus* *Elymus triticoides* *Hordeum depressum* *Hordeum geniculatum* *Hordeum leporinum*b *Hordeum pusillum* *Koeleria cristata*b *Koeleria gerardii* b *Koeleria nitida* *Lamarckia aurea*b *Lolium multiflorum*b *Melica californica* var. *nevadensis* *Poa annua*b *Poa bulbosa*b *Poa palustris*b *Poa scabrella* *Polypogon interruptus*b *Polypogon monspeliensis*b *Schismus arabiscus*a,b *Sitanion hystrix* *Sitanion jubatum* *Stipa cernua* *Stipa pulchra* *Taeniatherum caput-medusae*a,b *Vulpia microstachys* var. *confusa* *Vulpia microstachys* var. *pauciflora* *Vulpia myuros*b Vulpia octoflora	Annual hairgrass Seashore saltgrass Blue wild-rye Alkalie wild-rye Barley Barley Barley Little barley Junegrass Junegrass Junegrass Goldentop Italian ryegrass Melicgrass Annual bluegrass Bulbous bluegrass Fowl bluegrass Pine bluegrass Ditch polypogon Rabbitfoot grass Squirreltail Big squirreltail Needlegrass Purple needlegrass Fescue Fescue Fescue Fescue
Potomogetonaceae	

Potamogeton crispus	Pondweed
Scheuchzeriaceae	
Lilaea scilloides	Flowering quillwort
Typhaceae	
Typha angustifolia *Typha domingensis* *Typha latifolia*	Cattail Cattail Soft-flag

[a] No common name.
[b] Introduced and naturalized vascular plant species.
Source: Taylor and Davilla, 1986b.

Table F-2 Constancy, Cover, and Importance Values for the More Important Plant Taxa at LLNL Site 300

Species	Constancy	Cover		Importance Value
		Mean	Standard Error	
Avena barbata	87.62	36.66	2.17	124.28
Bromus mollis	73.85	7.27	0.72	81.12
Bromus diandrus	62.84	11.73	1.25	74.57
Erodium cicutarium	65.60	3.62	0.58	69.21
Bromus rubens	61.47	6.17	0.68	67.64
Vulpia myuros	55.96	5.66	0.68	61.62
Poa scabrella	38.53	7.98	1.33	46.52
Trifolium tridentatum	43.12	2.44	0.44	45.56
Orthocarpus purpurascens	39.91	0.89	0.39	40.80
Lotus subpinnatus	38.07	0.87	0.18	38.94
Amsinckia intermedia	36.70	1.26	0.26	37.95
Gutierrezia bracteata	27.52	1.43	0.31	28.95
Brassica geniculata	27.52	0.93	0.23	28.45
Sanicula bipinnata	26.61	0.23	0.07	26.83
Grindelia camporum	25.69	1.04	0.27	26.73
Vulpia microstachys	23.85	1.71	0.31	25.56
Trifolium gracilentum	22.94	1.33	0.37	24.26

Triteleia laxa	22.02	0.57	0.17	22.58
Herniaria cinerea	20.64	0.35	0.13	20.99
Lupinus bicolor	19.73	0.41	0.17	20.14
Artemisia californica	17.89	1.69	0.38	19.58
Astragalus didymocarpus	18.81	0.69	0.22	19.49
Holocarpha obconica	18.81	0.59	0.37	19.40
Clarkia purpurea	18.81	0.12	0.03	18.93
Achillea millefolium	16.97	0.47	0.12	17.44
Amsinckia testillata	15.14	0.13	0.04	15.27
Galium aparine	14.68	0.26	0.07	14.94
Elymus triticoides	9.63	3.25	0.96	12.88
Eriogonum fasciculatum	11.93	0.88	0.25	12.80
Allium serra	12.39	0.08	0.03	12.46
Matricaria matricarioides	11.93	0.35	0.19	12.28
Marah fabaceus agrestis	11.47	0.10	0.03	11.56
Crassula erecta	11.47	0.09	0.05	11.55
Stipa pulchra	10.55	0.70	0.23	11.25
Stellaria nitens	11.01	0.09	0.05	11.10
Delphinum hesperium	10.55	0.10	0.04	10.65
Dichelostemma pulchellum	10.58	0.03	0.01	10.57
Hemizonia kelloggii	10.09	0.47	0.30	10.56
Claytonia perfoliata	10.09	0.32	0.13	10.41
Carduus pychnocephalus	10.09	0.23	0.12	10.33
Lupinus succulentus	10.09	0.17	0.05	10.27
Sonchus oleraceus	10.09	0.04	0.02	10.13
Senecio vulgaris	10.09	0.01	0.00	10.11
Eschscholzia californica	9.63	0.23	0.11	9.86
Collinsia heterophylla	9.17	0.26	0.12	9.43
Eriogonum nudum	9.17	0.21	0.08	9.38
Lupinus densiflorus lacteus	9.17	0.14	0.04	9.31
Chlorogalum pomeridianum	8.72	0.15	0.06	8.86
Sonchus aspera	8.72	0.03	0.02	8.75

Pterostegia drymerioides	8.72	0.04	0.02	8.75
Caulanthus lasiophyllus	8.72	0.03	0.01	8.75
Eremocarpus setigerus	8.72	0.03	0.01	8.74
Lasthenia californica	8.26	0.28	0.16	8.53
Eriogonum angulosum	7.80	0.11	0.05	7.91
Delphinium gypsophilum	7.34	0.32	0.17	7.65
Gilia tricolor	7.34	0.10	0.05	7.44
Plantago eriopoda	7.34	0.05	0.03	7.39
Gilia capitata abortanifolia	7.34	0.03	0.01	7.37
Juniperus californicus	6.88	0.47	0.28	7.35
Polypogon interruptus	6.42	0.70	0.36	7.13
Monolophia major	6.88	0.24	0.13	7.12
Erodium botrys	6.88	0.10	0.05	6.98
Silene antirrhinam	6.88	0.10	0.04	6.98
Brassica nigra	6.88	0.08	0.05	6.96
Bromus madritensis	6.42	0.42	0.16	6.84
Melica california nevadensis	6.42	0.29	0.13	6.71
Centaurea melatensis	6.42	0.22	0.13	6.64
Trifolium oliganthum	6.42	0.13	0.05	6.55
Stylocline gnaphalioides	6.42	0.07	0.03	6.49
Typha latifolia	5.05	1.26	0.48	6.30
Microseris lindleyi	5.96	0.01	0.01	5.98
Sitanion hystrix	5.51	0.34	0.14	5.84
Salvia mellifera	5.05	0.68	0.26	5.72
Mimulus guttatus	5.51	0.20	0.12	5.70
Microseris douglasii	5.51	0.15	0.08	5.66
Linanthus bicolor	5.51	0.16	0.09	5.66
Claytonia parviflora	5.51	0.05	0.03	5.56
Quercus douglasii	5.05	0.50	0.20	5.55
Logfia gallica	5.51	0.04	0.02	5.55
Calochortus invenustus	5.51	0.02	0.01	5.52
Hordeum leporinum	5.05	0.12	0.06	5.16

Amsinckia menziesii	5.05	0.03	0.02	5.08
Delphinium patens	5.05	0.03	0.02	5.08
Stylocline filaginea	5.05	0.03	0.01	5.07
Microsteris gracilis	5.05	0.02	0.01	5.07
Achyrachoena mollis	4.59	0.22	0.21	4.81
Silene gallica	4.59	0.08	0.05	4.67
Schismus arabicus	4.59	0.07	0.03	4.65

Source: Taylor and Davilla, 1986a.

Table F-3 Plant Community Types at LLNL Site 300

Plant Community Type	Major Plant Community Types
	Coastal Sage Scrub
Type 1 Type 2 Type 3	*Artemisia californica-Salvia mellifera/Herniaria cinerea* *Artemisia californica/Bromus mollis* *Gutierrezia bracteata/Avena barbata*
	Oak Woodland
Type 4	*Quercus douglasii/Avena barbata*
	Introduced Grasslands
Type 5 Type 6 Type 7 Type 8	*Juniperus californica/Bromus diandrus-Lotus subpinnatus* *Avena barbata-Brassica geniculata-Lotus subpinnatus* *Avena barbata-Bromus diandrus* *Avena barbata-Triteleia laxa*
	Native Grasslands
Type 9 Type 10 Type 11 Type 12	*Avena barbata-Poa scabrella-Erodium cicutarium* *Poa scabrella-Lasthenia minor* *Poa scabrella-Triteleia laxa* *Poa scabrella-Sitanion jubatum*
	Seeps and Springs
Type 13 Type 14	*Elymus triticoidos-Polypogon interruptus* *Elymus triticoidos-Typha latifolia*

Source:Taylor and Davilla, 1986a.

Table F-4 Site Characteristics of Plant Community Types on LLNL Site 300

Plant Community Types[a]	Number of Species	Elevation (feet)		Mean Aspect	Typical Topographic Position	Typical Substrate/ Soil	Number of Species Per Stand		Mean Internal Percent Similarity Within Type
		Mean ± S.E.[b]	Range				Mean ± S.E.	Range	
Coastal Sage Scrub									
Type 1	14	1067±99	730–1460	Southwest	Slopes	Sandstone rock	23.4±2.3	10–35	66
Type 2	9	978±72	780–1200	Southwest	Gullies	Sandstone rock	22.5±3.9	13–41	63
Type 3	10	884±86	700–1240	All exposures	Ridges	Conglomerate	17.8±2.5	9–27	67
Oak Woodland									
Type 4	8	1030±97	740–1400	North & west	Steep slopes	Silty loam	21.8±2.2	15–31	54
Introduced Grassland									
Type 5	5	1018±32	900–1080	North	Lower slopes	Clay loams	17.2±1.1	14–20	52
Type 6	27	1148±127	680–1675	South	Ridges/spurs	Rocky-sandy	15.7±2.3	9–32	68
Type 7	34	1212±93	840–1600	Various	Lower slopes	Loams	14.0±2.7	3–30	51
Type 8	48	1148±106	740–1700	North	Toe slopes	Clay	16.9±2.7	6–34	58
Native Grassland									
Type 9	15	1244±112	790–1680	Various	Various	Sandy clay	15.8±2.0	9–23	63
Type 10	7	1185±75	1060–1560	Northeast	Toe slopes	Clay	18.0±2.6	11–25	65
Type 11	13	1185±116	830–1485	North	Toe slopes	Clay loam	21.6±3.9	11–39	66
Type 12	7	1212±88	900–1420	North	Upper slopes	Sandy loam	22.7±2.4	14–32	72
Seeps and Springs									
Type 13	5	838±48	650–940	All aspects	Ravines	Silty sand	16.2±4.8	10–36	75
Type 14	12	985±99	700–1540	All aspects	Springs	Silty clays	14.0±2.9	7–32	76

[a] Corresponds with plant community types listed in Table F-3.
[b]

S.E. = Standard error. Source: Taylor and Davilla, 1986a.

Table F-5 Percent Cover by Life-Form for Community Types Found on LLNL Site 300a

Plant CommunityType[b]	Trees	Shrubs	Grasses			Forbs			Grass and Forbs		
			Total	**Native**	**Introduced**	**Total**	**Native**	**Introduced**	**Total**	**Native**	**Introduced**
Coastal Sage Scrub											
Type 1	0	43.8	42.9	5.9	37.0	9.7	6.0	3.7	52.6	11.9	40.7
Type 2	0	23.4	63.9	2.2	61.7	8.7	3.0	5.7	72.6	5.2	67.4
Type 3	0	13.9	57.6	0.3	57.3	18.3	6.8	11.5	75.9	7.1	68.8
	0										
Oak Woodland											
Type 4	13.0	0.3	112.8	10.5	102.3	10.0	7.9	2.1	122.8	18.4	104.4
Introduced Grasslands											
Type 5	0	25.8	76.2	0.0	76.2	3.8	1.8	2.0	80.0	1.8	78.2
Type 6	0	0.5	94.4	5.8	88.6	23.8	17.4	6.4	118.2	23.2	95.0
Type 7	0	0.7	96.5	3.8	92.7	10.4	6.1	4.3	106.9	9.9	97.0
Type 8	0	0.5	97.3	8.3	89.0	30.3	16.0	14.3	127.6	24.3	103.3
Native Grasslands											
Type 9	0	0.0	101.1	24.2	76.9	24.6	19.2	5.4	125.7	43.4	82.3
Type 10	0	0.0	68.6	47.1	21.5	66.7	56.1	10.6	135.3	103.2	32.1
Type 11	0	0.0	98.8	56.3	42.9	43.1	32.3	10.8	141.9	88.6	53.7
Type 12	0	0.0	81.3	49.4	31.9	22.3	20.5	1.8	103.6	69.9	33.7
Seeps and Springs											
Type 13	0	0.0	100.0	61.3	38.7	3.1	0.3	2.8	103.1	61.6	41.5
Type 14	0	0.0	84.8	52.8	32.0	18.8	11.4	7.4	103.6	64.2	39.4

[a] Percent cover may be greater than 100 percent due to overlap of vegetation of different heights.
[b] Corresponds with plant community types listed in Table F-3.
Source: Taylor and Davilla, 1986a.

F.1.1.3 Impacts of Current Operations

Disturbances to vegetation on LLNL Site 300 from current operations are much less than the impacts of land use practices on private lands nearby, where upland and riparian plant communities have been altered by grazing and other agricultural activities. Impacts at LLNL Site 300, however, do include the direct loss of vegetation by construction of facilities such as testing sites, firing tables, closed landfills, wastewater facilities, maintenance buildings, security facilities, fences, and roads. These disturbed areas, totaling about 220 acres, are almost devoid of vegetation. Facilities in the southern half of the site have disturbed mostly introduced grassland plant communities. The generally small facilities in the northern half of the site have not significantly disturbed large areas of land even when adjacent to native grassland habitats.

Other operational practices on LLNL Site 300 include the exclusion of grazing and other agricultural practices;

construction and maintenance of fire roads and breaks; vegetation management using controlled burning for fire control and weed control along roads, power poles, and security fence perimeters using herbicides and disking; and minor construction in or adjacent to existing facilities.

Because no livestock grazing has been permitted since 1953, baseline comparisons of the flora on LLNL Site 300 with that of neighboring, grazed parcels show a greater complement of native grasses and herbs on LLNL Site 300. Slopes and substrates show less instability and erosion, probably the result of a more stable plant cover and the retention of soil-binding native plant species.

Most of the property has not been disked or dry-farmed since it was acquired. The limited disking for fire control has had a minor impact on the overall vegetation of LLNL Site 300. Currently, only a narrow swath of land is disked along the northern, and part of the western and eastern boundaries of the site. This perimeter disking is done in May, providing added protection during controlled burning against the possible escape of fire to offsite properties. The disked areas favor establishment and maintenance of introduced grasses and moderate cover of tarweeds (*Holocarpha obconica*, *Hemizonia kelloggii*, *H. lobbii*).

For weed and fire control, herbicides such as Roundup® and Amitrol® are applied in the fall and winter along paved roads, and Hyvar-X® is used around security fences, power poles, and on a 90-ft-wide strip surrounding Building 829, a high explosives burn unit. Herbicides have favored the introduction and maintenance of ruderal type vegetation in these areas (Frenkel, 1970).

Controlled burning is conducted annually as a means of wildfire control. LLNL Site 300 began a burning program in the northeastern half of the site in the 1950s and has continued the program annually since 1960. All areas of the site have been burned at least once since 1960. The northern half of the site is burned annually, whereas the southern half has been burned only four times since 1960 (and portions of sections 21 and 28 have been burned twice). Burning typically begins about the middle of May and lasts several weeks, though this schedule depends on the length of the growing season and amount of rainfall.

Fire limits the development of coastal sage scrub vegetation on LLNL Site 300 to rocky sites, and also influences the composition and distribution of native grasslands. Restriction of coastal sage scrub to rocky sites is associated with reduced dry grass fuel levels and increased patchiness of all fuels. Although vegetation in rocky areas is subject to local fires, the rocks offer some protection and the vegetation may not be burned in every fire. Shrubs that would otherwise be eliminated then increase in importance. Native grassland communities on LLNL Site 300 occur almost exclusively in areas with annual controlled burning.

Remarkably little quantitative ecological literature exists on the role of fire in establishing and restoring native grassland communities in California (Heady, 1977); however, both Barry (1972) and Heady (1972) indicate that frequent fire is required to establish and maintain grasslands dominated by native grasses in lowland California. This conclusion is borne out by grassland vegetation found at LLNL Site 300. Figure F-4 shows the distribution of native grassland vegetation in relation to the limits of annual controlled fires, with a high correspondence between them. Not all plant communities within the perimeter of annual controlled fire on LLNL Site 300 are native grass–dominated, but the lack of introduced grasses on some habitats strongly correlates with the pattern and frequency of fires (Taylor and Davilla, 1986a).

A comprehensive inventory of native grasslands has not been conducted for California. Notably, Barry (1972) did not mention the presence of native grasslands in the vicinity of LLNL Site 300. An estimated 723 acres of native grassland communities occur on LLNL Site 300. Using the evaluation criteria established by Barry (1972), LLNL Site 300 could be judged one of the largest native grasslands of this kind currently known in California.

F.1.2 Fauna

The fauna at the study sites have been described in a number of previous reports (DOE, 1982; UC, 1987; Orloff, 1986; Environmental Science Associates, 1990) and in surveys conducted in 1991 for this EIS/EIR. The 1991 surveys were conducted to assess the status of threatened and endangered species and other sensitive species, and to map wetlands. The surveys were not conducted to provide comprehensive fauna species list or assess the ecological characteristics of nonthreatened or endangered species; nonetheless, all species of wildlife observed were noted, resulting in a comprehensive inventory of amphibians, reptiles, and mammals, especially at LLNL Site 300 where the majority of the field work occurred. Many species of breeding birds were noted because most of the field work occurred during the nesting season. Observation of additional migrant and wintering species would be expected if surveys occurred during other seasons.

F.1.2.1 Methods

Species of wildlife observed during field work were recorded when possible. In addition, during threatened and endangered surveys, sensitive species surveys, and wetlands surveys notes were kept on species of amphibians, reptiles, birds, and mammals observed. Notes on all wildlife species observed were also kept during night spotlighting, scent station maintenance, and small mammal trapping.

F.1.2.2 Results

Amphibians and Reptiles

A total of 20 species of amphibians and reptiles including two subspecies of the whipsnake were observed in 1986 (Orloff, 1986) and 1991 at LLNL Site 300; three species were recorded at the LLNL Livermore site and SNL, Livermore (Table F-6). The scarcity of permanent water limits the potential for the study sites to support more than a few species of amphibians. Ponds occur along the perimeter of LLNL Site 300, and some of the drainages onsite contain aquatic vegetation supported by underground springs and seeps. Two species of salamanders were observed at LLNL Site 300: the California slender salamander (*Batrachoseps attenuatus*) and the tiger salamander (*Ambystoma tigrinum californiense*). Frog and toad species known to occur on site are the western toad (*Bufo boreas*), Pacific treefrog (*Hyla regilla*), and the red-legged frog (*Rana aurora draytoni*). The Pacific treefrog was the only amphibian species recorded at the LLNL Livermore site and SNL, Livermore.

Conditions are far more favorable for reptiles than amphibians at LLNL Site 300. Grassland provides ideal habitat for racers (*Coluber constrictor*) and gopher snakes (*Pituophis melanoleucus*). Rock sites provide suitable habitat for such species as the western fence lizard (*Sceloporus occidentalis*), western skink (*Eumeces skiltonianus*), common kingsnake (*Lampropeltis getulus*), and the western rattlesnake (*Crotalus viridis*). The western rattlesnake have been observed to be widespread and abundant in all habitats on LLNL Site 300. Seeps and springs provide excellent habitat for the northern alligator lizard (*Gerrhonotus coeruleus*). Side-blotched lizards (*Uta stansburiana*) and California horned lizards (*Phrynosoma coronatum frontale*), more commonly found in southern California, frequent areas with more open vegetation and sandy soils. The western fence lizard and gopher snake were the only two reptile species observed at the LLNL Livermore site and SNL, Livermore.

The California Department of Fish and Game Ecological Preserve along the Corral Hollow drainage adjacent to LLNL Site 300 was established to protect the unusual diversity of reptiles and amphibians. Species more typical of southern deserts have been found, including the glossy snake (*Arizona elegans*), long-nosed snake (*Rhinocheilus lecontel*), and the coachwhip (*Masticophis flagellum*). Of the three species, only the coachwhip has been observed onsite.

One federal candidate species and state species of special concern, the red-legged frog, was recorded at LLNL Site 300 in 1991. A state species of special concern, the California horned lizard was also observed. Details regarding the results of surveys for these species are provided in Section F.2.

Birds

A total of 75 species of birds were observed at the study sites; this includes 70 species observed at LLNL Site 300, and 31 species at the LLNL Livermore site and SNL, Livermore (Table F-7). These species were recorded during springtime surveys for threatened and endangered species in 1986 (Orloff, 1986) and 1991, and concurrent with 1991 wetland surveys.

LLNL Site 300, with its interspersion of several different habitats and its abundance of seeds and insects, supports a variety of birds. The western meadowlark (*Sturnella neglecta*), horned larks (*Eremophila alpestris*), and savannah sparrow (*Passerculus sandwichensis*) were the most common small birds seen throughout the open grassland areas. Vegetation at springs and seeps provides nesting habitat for red-winged blackbirds (*Agelaius phoeniceus*) and tricolored blackbirds (*A. tricolor*). Tricolored blackbirds were observed onsite in 1986 but not in 1991 (see section F.2 for more details regarding the tricolored blackbird). These water sources attract a greater number of birds than normally found in the adjacent grasslands. For example, the mourning dove (*Zenaida macroura*), cliff and barn swallow (*Hirundo pyrrhonota* and *H. rustica*), and California quail (*Callipepla californica*) all require water daily.

Oak woodlands and a few cottonwoods provide nesting habitat for the western kingbird (*Tyrannus verticalis*), northern oriole (*Icterus galbula*), loggerhead shrike (*Lanius ludovicianus*), and American goldfinch (*Carduelis tristis*). Coastal sage scrub supports the scrub jay (*Aphelocoma coerulescens*), Anna's hummingbird (*Calypte anna*), rufous-crowned sparrow (*Aimophila ruficeps*), and white-crowned sparrow (*Zonotrichia leucophrys*). Ecotones of sage scrub and grassland provide ideal habitat for the mourning dove, California quail, lazuli bunting (*Passerino amoena*), and lark sparrow (*Chondestes grammacus*). Rocky outcrops and cliffs provide breeding sites for white-throated swift (*Aeronautes saxatalis*), cliff swallow, Say's phoebe (*Sayornis saya*), and rock wren (*Salpinctes obsoletus*).

LLNL Site 300 also supports a population of nesting raptors. Several great horned owl (*Bubo virginianus*) and barn owl (*Tyto alba*) nests were found on rock ledges of steeper cliffs. The great horned owl was recorded nesting onsite in 1986 and 1991 while the barn owl was recorded only in 1986. The cliffs onsite may also be suitable for golden eagles (*Aquila chrysaetos*) and prairie falcons (*Falco mexicanus*), although no nests were observed. Red-tailed hawk (*Buteo jamaicensis*) nests were found in 1986 and 1991. This species nested in large trees and on a utility pole in 1991. Areas with taller grasses may also allow ground-nesting raptors such as the northern harrier (*Circus cyaneus*) and short-eared owl (*Asio flammeus*) to successfully breed onsite (Orloff, 1986); however, these species were not observed to nest onsite in 1991.

Six sensitive raptor species were observed onsite during either the 1986 or the 1991 field survey: burrowing owl (*Athene cunicularia*), short-eared owl, golden eagle, northern harrier, black-shouldered kite (*Elanus caeruleus*), and prairie falcon. These species are of concern to the federal and/or state government, and are discussed in the biological assessment (section F.2).

Bird species nesting at the LLNL Livermore site and SNL, Livermore include those recorded in the building areas, the security zone, and Arroyo Seco. Species nesting in the builtup area are those typical of suburban areas, and include the killdeer (*Charadrius vociferus*), rock dove (*Columbia livia*), scrub jay, American crow (*Corvus brachyrhynchos*), American robin (*Turdus migratorius*), European starling (*Sturnus vulgaris*), house finch (*Carpodacus mexicanus*), and house sparrow (*Passer domesticus*). Species observed in the grass–dominated security zones include the western kingbird (*Tyrannus verticalis*), horned lark, and western meadowlark. Species recorded from the wooded portion of Arroyo Seco were the mourning dove, acorn woodpecker (*Melanerpes formicivorus*), western wood pewee (*Canotopus sordidulus*), plain titmouse (*Parus inornatus*) and northern oriole. The only raptors observed at these sites were the turkey vulture (*Cathartes aura*), red-tailed hawk, and barn owl.

Mammals

A total of 26 species of mammals were recorded during threatened and endangered species surveys in 1986 (Orloff, 1986) and 1991. All the species were seen at LLNL Site 300, and 10 species were observed at the LLNL Livermore site and SNL, Livermore (Table F-8). The investigation included ground surveys in all open areas, night spotlighting, establishment of scent stations, and small mammal trapping.

Productive and diverse grasslands on LLNL Site 300 support an abundance of rodents and lagomorphs (rabbits and hares). Conditions are ideal for California ground squirrels (*Spermophilus beecheyi*) in the northern portion of LLNL Site 300 where the terrain is less rugged. Other common rodents include the house mouse (*Mus musculus*), deer mouse (*Peromyscus maniculatus*), Heermann's kangaroo rat (*Dipodomys heermanni*), valley pocket gopher (*Thomomys bottae*) and, in the higher grass cover, the California vole (*Microtus californicus*) and western harvest mouse (*Reithrodontomys* *megalotis*). Lagomorphs such as black-tailed hares (*Lepus californicus*) and desert cottontails (*Sylvilagus audubonii*) are also widespread and abundant, with the latter tending to occupy areas with more cover.

Rocky areas with associated coastal sage scrub support the California pocket mouse (*Perognathus californicus*) and desert woodrat (*Neotoma lepida*). The woodrat occurs primarily in rocky areas in this northern extreme of its range.

Many mammalian predators are supported by the rich prey base. Grassland predators include the long-tailed weasel (*Mustela frenata*), western spotted skunk (*Spilogale gracilis*), striped skunk (*Mephitis mephitis*), coyote (*Canis latrans*), badger (*Taxidea taxus*), and bobcat (*Lynx rufus*). Only the badger is restricted to open grasslands. Red foxes (*Vulpes vulpes*), which have been reported from nearby areas to the east and north of the site (California Department of Fish and Game, 1983; Bio-Tech, 1983), have greatly expanded their range in the Central Valley in recent years. They show a preference for more disturbed areas, often denning in roadside culverts, and were observed near LLNL Site 300 in 1991. Sage scrub, wooded, and riparian habitats attract other mammalian predators not normally found in grasslands including bobcat, gray fox (*Urocyon cinereoargenteus*), raccoon (*Procyon lotor*), and mountain lion (*Felis concolor*). Although these habitats are preferred, they are relatively limited on LLNL Site 300; consequently, grassland areas are used as well. Only minor areas of riparian vegetation are associated with the seeps and springs that occur along the canyon bottoms. Black-tailed deer (*Odocoileus hemionus*) prefer these habitats but are frequently seen in the open grasslands.

The most commonly recorded mammal species during 1991 night spotlighting at LLNL Site 300 were the desert cottontail, Heermann's kangaroo rat, black-tailed deer, and black-tailed hare (Table F-9). Feral house cat (*Felis domesticus*) tracks were relatively frequent at the scent stations but only one was observed during night spotlighting. Medium-sized predators recorded included the coyote and bobcat.

Small-mammal trapping took place May 5 to 8, 1986, at LLNL Site 300 and totaled 415 trap nights (a trap night equals one trap set out for one night). Species trapped included the western harvest mouse, house mouse, deer mouse, desert woodrat, and Heermann's kangaroo rat (Table F-10) with deer mice being the most common species captured.

Surveys were conducted in 1991 at the LLNL Livermore site, LLNL Site 300, and SNL, Livermore for one endangered species, the San Joaquin kit fox (*Vulpes macrotis mutico*), and at LLNL Site 300 for two federal candidate species, the San Joaquin pocket mouse (*Perognathus inornatus*) and the riparian woodrat (*Neotoma fuscipes riparia*). Of the three species only the San Joaquin pocket mouse was observed; the San Joaquin kit fox was not observed onsite. Results of surveys for these species are provided in section F.2.

A total of 10 species of mammals were recorded at the LLNL Livermore site and SNL, Livermore (Table F-8). Common species recorded during night spotlighting and at scent stations were the feral house cat, desert cottontail, black-tailed hare, red fox, and gray fox. In addition, the Virginia opossum was recorded frequently at the scent stations (Table F-9).

Table F-6 Amphibian and Reptile Species Observed at the LLNL Livermore Site, LLNL Site 300, and SNL, Livermore

Species		**Study Site**	
Scientific Name	**Common Name**	**LLNL Site 300**	**LLNL Livermore Site and SNL, Livermore**
Ambystoma tigrinum californiense	Tiger salamander	X	
Batrachoseps attenuatus	California slender salamander	X	
Bufo boreas	Western toad	X	
Hyla regilla	Pacific treefrog	X	X

Rana aurora draytoni	Red-legged frog	X	
Sceloporus occidentalis	Western fence lizard	X	X
Sceloporus graciosus	Sagebrush lizard	X	
Uta stansburiana	Side-blotched lizard	X	
Phrynosoma coronatum frontale	California horned lizard	X	
Eumeces skiltonianus	Western skink	X	
Eumeces gilberti	Gilbert's skink	X	
Cnemidophorus tigris	Western whiptail	X	
Gerrhonotus coeruleus	Northern alligator lizard	X	
Coluber constrictor	Racer	X	
Masticophis flagellum	Coachwhip	X	
Masticophis lateralis euryxanthus	Alameda whipsnake	X	
Masticophis lateralis lateralis	California whipsnake	X	
Pituophis melanoleucus	Gopher snake	X	X
Lampropeltis getulus	Common king snake	X	
Thamnophis sirtalis	Common garter snake	X	
Crotalus viridis	Western rattlesnake	X	

Table F-7 Bird Species Observed at the LLNL Livermore Site, LLNL Site 300 and SNL, Livermore

Species		**Study Site**	
Scientific Name	**Common Name**	**LLNL Site 300**	**LLNL Livermore Site and SNL, Livermore**
Bucephala clangula	Common goldeneye		X
Anas platyrhynchos	Mallard	X	
Rallus limicola	Virginia rail	X	
Ardea herodias	Great blue heron		X
Butorides striatus	Green-backed heron	X	
Cathartes aura	Turkey vulture	X	X
Elanus caeruleus	Black-shouldered kite	X	
Circus cyaneus	Northern harrier	X	

Buteo jamaicensis	Red-tailed hawk	X	X
Accipiter cooperii	Cooper's hawk		X
Aquila chrysaetos	Golden eagle	X	
Falco sparverius	American kestrel	X	
Falco mexicanus	Prairie falcon	X	
Callipepla californica	California quail	X	
Charadrius vociferus	Killdeer	X	X
Columba livia	Rock dove	X	X
Zenaida macroura	Mourning dove	X	X
Geococcyx californianus	Greater roadrunner	X	
Tyto alba	Barn owl	X	X
Bubo virginianus	Great horned owl	X	
Athene cunicularia	Burrowing owl	X	
Asio flammeus	Short-eared owl	X	
Chordeiles minor	Common nighthawk	X	
Aeronautes saxatalis	White-throated swift	X	
Calypte anna	Anna's hummingbird	X	
Selasphorus rufus	Rufous hummingbird	X	
Selasphorus sasin	Allen's hummingbird	X	
Melanerpes formicivorus	Acorn woodpecker	X	X
Colaptes auratus	Northern flicker	X	X
Tyrannus verticalis	Western kingbird	X	X
Myiarchus cinerascens	Ash-throated flycatcher	X	
Contopus sordidulus	Western wood-pewee	X	X
Empidonax difficilis	Western flycatcher	X	
Sayornis nigricans	Black phoebe	X	
Sayornis saya	Say's phoebe	X	
Eremophila alpestris	Horned lark	X	X
Hirundo pyrrhonota	Cliff swallow	X	
Hirundo rustica	Barn swallow	X	X
Aphelocoma coerulescens	Scrub jay	X	X
Corvus brachyrhynchos	American crow	X	X
Corvus corax	Common raven	X	X

Parus inornatus	Plain titmouse	X	X
Salpinctes obsoletus	Rock wren	X	
Turdus migratorius	American robin		X
Catharus guttatus	Hermit thrush	X	
Mimus polyglottos	Northern mockingbird	X	X
Anthus rubescens	American pipit	X	
Lanius ludovicianus	Loggerhead shrike	X	X
Sturnus vulgaris	European starling	X	X
Vireo huttoni	Hutton's vireo	X	
Dendroica petechia	Yellow warbler	X	
Dendroica coronata	Yellow-rumped warbler	X	
Oporornis tolmiei	MacGillivray's warbler	X	
Wilsonia pusilla	Wilson's warbler	X	
Piranga ludoviciana	Western tanager	X	
Passerina amoena	Lazuli bunting	X	
Pheucticus melanocephalus	Black-headed grosbeak	X	
Pipilo crissalis	California towhee	X	
Aimophila ruficeps	Rufous-crowned sparrow	X	
Pooecetes grammineus	Vesper sparrow	X	
Chondestes grammacus	Lark sparrow	X	
Passerculus sandwichensis	Savannah sparrow	X	
Passerella iliaca	Fox sparrow	X	
Melospiza melodia	Song sparrow	X	
Zonotrichia atricapilla	Golden-crowned sparrow	X	
Zonotrichia leucophrys	White-crowned sparrow	X	
Agelaius phoeniceus	Red-winged blackbird	X	X
Agelaius tricolor	Tricolored blackbird	X	
Sturnella neglecta	Western meadowlark	X	X
Euphagus cyanocephalus	Brewer's blackbird	X	X
Molothrus ater	Brown-headed cowbird		X
Icterus galbula	Northern oriole	X	X

Carpodacus mexicanus	House finch	X	X
Carduelis tristis	American goldfinch	X	X
Passer domesticus	House sparrow	X	X

Table F-8 Mammal Species Observed at the LLNL Livermore Site, LLNL Site 300, and SNL, Livermore

Species		**Study Site**	
Scientific Name	**Common Name**	**LLNL Site 300**	**LLNL Livermore Site and SNL, Livermore**
Didelphis virginiana	Virginia opossum	X	X
Tadarida brasiliensis	Mexican free-tailed bat	X	
Sylvilagus audubonii	Desert cottontail	X	X
Lepus californicus	Black-tailed hare	X	X
Spermophilus beecheyi	California ground squirrel	X	X
Thomomys bottae	Valley pocket gopher	X	
Perognathus californicus	California pocket mouse	X	
Perognathus inornatus	San Joaquin pocket mouse	X	
Dipodomys heermanni	Heermann's kangaroo rat	X	
Reithrodontomys megalotis	Western harvest mouse	X	
Peromyscus maniculatus	Deer mouse	X	
Neotoma lepida	Desert woodrat	X	
Microtus californicus	California vole	X	
Mus musculus	House mouse	X	
Canis latrans	Coyote	X	X
Vulpes vulpes	Red fox	X	X
Urocyon cinereoargenteus	Gray fox	X	X
Procyon lotor	Raccoon	X	X
Mustela frenata	Long-tailed weasel	X	
Taxidea taxus	Badger	X	
Spilogale gracilis	Western spotted skunk	X	
Mephitis mephitis	Striped skunk	X	X
Felis concolor	Mountain lion	X	
Felis domesticus	Feral house cat	X	X

Lynx rufus	Bobcat	X	
Odocoileus hemionus	Black-tailed deer	X	

Table F-9 Species and Numbers of Individual Mammals Recorded During Night Spotlighting and at Scent Stations at the LLNL Livermore Site, LLNL Site 300, and SNL, Livermore in April, May, and June 1991

Species	Spotlighting		Scent Station	
	LLNL Site 300[a]	LLNL Livermore Site and SNL, Livermore [b]	LLNL Site 300[c]	LLNL Livermore Site and SNL, Livermore [c]
Virginia opossum	---	---	---	8
Desert cottontail	32	31	1	---
Black-tailed hare	14	24	---	---
Heermann's kangaroo rat	32	---	---	---
California ground squirrel	---	---	7	---
Coyote	9	1	---	---
Red fox	---	24	---	7
Gray fox	---	3	---	26
Raccoon	---	1	---	1
Long-tailed weasel	---	---	1	---
Badger	---	---	1	---
Western spotted skunk	---	---	2	---
Striped skunk	1	1	---	4
Bobcat	2	---	---	---
Feral house cat	1	37	14	19
Black-tailed deer	22	---	---	---

[a] Six surveys from April 30 through May 8, 1991.
[b]Nine surveys from May 10 through June 5, 1991.
[c]Six surveys from April 30 through May 9, 1991.

Table F-10 Small Mammal Trapping Results at LLNL Site 300 During May 1986

Trap Location	Trap Habitat	Trap Nights	Number and Species	Success
Drop tower	Annual grasslands low to high vegetation density	150	5 deer mice	3%
Northwest corner	Annual grassland, sandy soils, low to high vegetation density	200	7 deer mice 2 western harvest mice 1 house mouse	5%
Facility 845	Perennial grassland, medium to high vegetation density	60	2 deer mice 1 western harvest mouse 1 Heermann's kangaroo rat	7%
Do-all Road	Rocky outcrops	5	1 desert woodrat	20%
Total:		415	20	5%

Source: Orloff, 1986.

F.1.2.3 Impacts of Current Operations

Program activities for LLNL Site 300 are discussed in section 3.1 and Appendix A. The activities discussed in section F.1.1 for vegetation would also impact wildlife at LLNL Site 300, as would vehicle traffic, fencing of facilities, explosives testing, surface impoundments, and the sewage lagoon.

Controlled Burn

The controlled burn generally has a positive effect on wildlife. Animals living underground (ground squirrels, burrowing owls, and pocket mice) or animals such as lizards, which escape into crevices and holes, are unlikely to be directly affected by fast-moving grass fires. Rodents inhabiting this region are adapted to periodic grass fires, so burning should not have an adverse impact on them. Burns stimulate new vegetative growth and create range conditions that probably support a greater diversity of wildlife than if the area were not burned. These newly burned areas provide excellent foraging habitat for open-country raptors. Annual burning provides a diversity of habitat for ground-nesting bird species, including raptors, but also may result in mortality for the young before they have fledged.

Lack of Livestock Grazing

LLNL Site 300, which is surrounded on three sides by heavily grazed lands, has not been grazed for almost 40 years. Studies have suggested that grazing may increase habitat stability for rodent species including the California ground squirrel (Balestreri, 1981; Laughrin, 1970; Jensen, 1972; Orloff, in press). Other studies have indicated that heavy grazing lowers the density of some rodent species such as kangaroo rats and pocket mice (O'Farrell and McCue, 1981; O'Farrell et al., 1981). The exclusion of grazing on LLNL Site 300 appears to have resulted in an abundance of several granivorous rodents (e.g., kangaroo rats and pocket mice) that no longer need to compete with livestock for food. Despite the lack of grazing, however, ground squirrel populations have remained plentiful in the flatter, northern half of the site. Many herbivorous animals generally prefer perennial grasses to the less nutritious annuals (Sampson et al., 1951). These perennial grasslands have developed in areas where grazing has been excluded and where annual controlled burns occur.

The exclusion of livestock grazing may have a mixed effect on the bird population. Ground-nesting species including raptors probably benefit from the resultant tall grass. Foraging suitability for other open-country raptors, such as golden eagles, is enhanced by the presence of low cover perennial grasslands; in other areas, foraging suitability is reduced where tall annuals obscure ground visibility. Overall, however, raptor habitat potential is excellent onsite.

The exclusion of livestock grazing also has a positive impact because springs and associated wetlands that are important to many species of wildlife have not been degraded or destroyed by livestock.

Ground Squirrel Poisoning

Ground squirrel poisoning has been conducted annually at LLNL Site 300 on an as-needed basis for almost a decade, using fumarin poison (grain treated with 0.025 percent fumarin). Some 20 acres at existing facilities were poisoned during 1984 and 1985. The use of fumarin has been replaced by sulfur cartridges placed directly into active ground squirrel burrows. Presently, there is no active control program, except for the surface impoundment area where a poisoning regime has been established and will be maintained annually.

Poisons such as fumarin, an anticoagulant, not only can reduce populations of their primary prey but can also poison predators such as foxes, coyote, or raptors. Poisoned bait can also kill other species that feed on it. The San Joaquin pocket mouse, for example, is probably affected much more severely by rodenticides than are the target species.

As long as the use of sulfur cartridges is confined to the high explosive wastewater impoundments, impacts are expected to be insignificant. The high explosive impoundment area is in the southern portion of the site in an area of relatively high human activity, and the impoundments are fenced to prevent access to most species of wildlife. This poison is not used in other areas onsite.

Disking, Grading Fire Roads, and Applying Herbicides to Contain Fires

As mentioned for vegetation, the disking of the 150-ft wide perimeter firebreaks on the northern, and part of the western and eastern boundaries of LLNL Site 300 has taken place since 1980. For several years before that, the same areas were sprayed annually with herbicides. Herbicides also have been applied along paved roads and around some facilities. Approximately 85 miles of fire roads are graded every spring along existing routes.

Some ground-dwelling species could be adversely impacted by disking and grading if they occupy dens in the disturbed areas. The same areas are graded or disked every year, so the impacts would be minimal.

The open space created by dirt roads within the grassland increases the visibility of prey species and hence the suitability of the habitat for many land and air predators. Herbicide applications are currently so minor that only very slight impacts would be expected on herbivorous rodents with small home ranges such as the San Joaquin pocket mouse.

Vehicle Traffic

Vehicles traveling along the paved roads and the better fire trails could cause wildlife mortality. This cause of wildlife mortality, however, would be minimal along the dirt roads and fire trails in the more remote and biologically diverse areas.

The nocturnal seasonal migrations of amphibians such as the tiger salamander and red-legged frogs could result in mortality along roads. But again, impacts should be minimal as nighttime vehicle traffic is sparse and migrations are infrequent.

Fencing of Facilities

The cyclone fencing around the site and around several of the facilities on LLNL Site 300 should not prevent most wildlife from traversing the area, since the fences have many openings through which large mammals can travel. However, fencing around the surface impoundments mentioned below exclude most species of wildlife. On the contrary, fences provide perches for many species of birds, including burrowing owls.

Explosive Testing

At LLNL Site 300, all three primary explosives testing facilities are approximately 1 mile from the site's northern border where explosives testing is conducted almost entirely during the day. The explosions are relatively infrequent (an average of one every 3.5 days in 1990), and wildlife exist near these facilities with minimal impact.

Diurnal raptors that forage directly over the facilities are the species most vulnerable to flying debris and shock overpressure; these include the golden eagle, prairie falcon, northern harrier, black-shouldered kite, ferruginous hawk, and red-tailed hawk. A stunned golden eagle, which may have been injured as the result of explosives testing at Building 801, was discovered in 1985; however, the exact cause of this injury was not determined. This bird recovered and was subsequently released (Orloff, 1986). Warning sounds have been and will continue to be broadcast prior to explosives testing. This serves to discourage raptor use of the area during explosives testing.

High Explosive Process Water Surface Impoundments and Sewage Lagoon

Visual inspection of the high explosive process water surface impoundments revealed few life forms existing within the waters. The impoundments are lined with plastic. A few scattered cattail were observed in one small area; the remainder of this shoreline is devoid of vegetation. Shorebirds have been seen foraging along the edge. Although LLNL Site 300 personnel have reported seeing dead birds in the impoundments on occasion, these deaths cannot be conclusively linked to the impoundments, which have recently passed a water quality control test for fish species (California Assessment Manual-Bioassay-Title 22 screening). Amphibians might use these impoundments, but they are considered suboptimal habitats because they lack submergent and emergent vegetation. Amphibian use of the impoundments probably would be strictly transitory with accompanying minimal impacts. The impenetrable fenced perimeter screens out many species of wildlife.

The highly eutrophic sewage lagoon supports many aquatic species, including a nesting pair of mallards. Wading birds such as the green-backed heron and amphibians such as the red-legged frog have also been observed at this lagoon. Observations in 1991 indicated that a dense stand of bullrush (*Scirpus* sp.) grows in a small portion of the lagoon.

ATTACHMENT 1 U.S. FISH AND WILDLIFE SERVICE LETTER

ATTACHMENT 2 U.S. FISH AND WILDLIFE SERVICE LETTER CALIFORNIA DEPARTMENT OF FISH AND GAME LETTER

The following response was written in reply to the letter commenting on the Draft EIS/EIR Biological Assessment from Mr. Wayne S. White, United States Department of Interior, Fish and Wildlife Service, dated February 20, 1992:

The mitigation measures identified in the biological assessment will be included in the Mitigation Monitoring and Reporting Program for LLNL. There are no changes to the proposed action that would or may result in a "may affect" determination for listed species that were not considered in the EIS/EIR.

The following response was written in reply to the letter commenting on the Draft EIS/EIR from Mr. James D. Messersmith, California Department of Fish and Game, Region 2, dated October 23, 1991:

As indicated in section 4.9.3 of the EIS/EIR, ground squirrel poisoning is restricted to the two high explosives wastewater surface impoundments. These impoundments occupy a very small portion of LLNL Site 300 land and are in an area of relatively high levels of human activity. In addition, the impoundments are fenced, preventing most species of wildlife, including the San Joaquin kit fox, from gaining access to these sites. Further, as shown in Appendix F of the EIS/EIR, surveys for the San Joaquin kit fox in 1991 indicate that potential dens (ground squirrel dens) for the kit fox do not occur at or near these impoundments.

Although the San Joaquin pocket mouse has been recorded in very small numbers at LLNL Site 300, the potential does exist for this species to occur near the impoundments. The ground squirrel poisoning program could result in limited San Joaquin pocket mouse mortality; however, this species is no longer considered a sensitive species and was removed from the U.S. Fish and Wildlife Service candidate species list subsequent to the publication of the EIS/EIR. Habitat for other sensitive species such as the dens and burrows of the burrowing owl and American badger; raptor nests; and potential habitat for the elderberry longhorn beetle, tiger salamander, red-legged frog, and Alameda whipsnake do not occur in the area of the impoundments. For these reasons, DOE and UC do not believe that rodent control at these impoundments poses a threat to sensitive species including the San Joaquin kit fox, and do not believe that alternative methods for rodent control are required.

When the runoff from the cooling towers ceases, less than 0.5 acre of artificially created wetlands will also be eliminated. This impact cannot be avoided. It is believed that three remaining discharges from LLNL Site 300 facilities will continue to support wetlands. As indicated in Appendix G of the EIS/EIR, the discharge of water into Corral Hollow Creek adjacent to LLNL Site 300 will likely result in the creation of artificial wetlands as part of the ground water restoration project at LLNL Site 300. These artificially created wetlands, in addition to sustaining wetlands at Buildings 801, 836A, and 865, will provide mitigation for the loss of the less than 0.5 acre of artificially created wetlands. The development of wetlands in Corral Hollow Creek will be monitored as part of the ground water restoration project at LLNL Site 300.

APPENDIX F GLOSSARY

Candidate species	Species being reviewed by the U.S. Fish and Wildlife Service for possible listing as endangered or threatened, but for which substantial biological information to support a listing is lacking.
Critical habitat	"Specific areas within the geographical area occupied by [an endangered or threatened] species . . . , essential to the conservation of the species and which may require special management considerations or protection; and specific areas outside the geographical area occupied by the species . . . that are essential for the conservation of the species" (Endangered Species Act section 3).
Edaphic characteristics	Soil factors.
Endangered species	Species of plants and animals that are threatened with either extinction or serious depletion in their range and that are formally listed as such by the U.S. Fish and Wildlife Service.
Eutrophic	Rich in dissolved nutrients.
Explosives	*See* High explosives.
Feral	Escaped from domestication and became wild.
Forbs	Herbs other than grasses.
Half-life	Time required for a radioactive substance to lose 50 percent of its activity by decay.
High explosives (HE)	Chemically energetic materials with the potential to react explosively; nuclear explosives are not included.
Hydrodynamic testing	Testing the properties of solid materials or the behavior of components made of such materials by subjecting them to strong shock from explosives or high-velocity impact.
Kit fox biologist	*See* Trained kit fox biologist.
Lagomorphs	Rabbits, conies, and hares.
Phenologic period	Period during the year when characteristic activities take place, such as (for vegetation) flowering and fruiting.
Relevé	A descriptive technique for sampling vegetation.
Riparian	Located along the banks of a stream, rivers, lakes, and other bodies of water.
Scat	Animal droppings, feces.
Taxon (pl: taxa)	The name applied to a plant or animal group in a formal system of nomenclature.
Threatened species	A species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.
Trained kit fox biologist	A trained kit fox biologist must have at least four years of college or university training in wildlife biology or a related field, and have demonstrated field expertise in the identification and life history of the San Joaquin kit fox.
Transect	A sample area (as of vegetation), usually in the form of a long continuous strip.

Vascular plants	Plants characterized by channels or ducts for the transfer of sap upward from the roots to their above-ground growing portions.
Vernal pool	A wetland created from standing water, typically in the spring, hence its name.

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APPENDIX G FLOODPLAIN AND WETLANDS ASSESSMENT

G.1 INTRODUCTION

This appendix is prepared to provide an analysis of the potential impacts on floodplains and wetlands from the proposed action and the alternatives (see Section 3 of the EIS/EIR). It is also prepared to demonstrate compliance with DOE's policy of avoiding, as much as possible, adverse impacts to floodplains and wetlands located at its facilities. G-1 illustrates the relationship of Appendix G to other EIS/EIR appendices, sections of the text, and DOE requirements.

The Floodplain and Wetlands Assessment is prepared pursuant to the U.S. Department of Energy's (DOE) "Compliance with Floodplain/Wetlands Environmental Review Requirements" (10 C.F.R. part 1022, 1979). The compliance review requirements are based on Executive Order 11988 - Floodplain anagement (May 24, 1977): Federal agencies must evaluate actions taken in a floodplain, and Executive Order 11990 - Protection of Wetlands (May 24, 1977): Federal agencies must consider protection of wetlands in the decision-making process. To comply with these Executive Orders, it is DOE policy, as indicated in 10 C.F.R. part 1022, to avoid to the extent possible, long- and short-term adverse impacts to floodplains and wetlands.

A floodplain is defined as the valley floor adjacent to the incised channel, which may be inundated during high water (Linsley, Kohler, and Paulhus, 1982). In the context of this assessment, the floodplain is further defined as ". . . at a minimum, that area inundated by a 1 percent or greater chance of flood in any given year. The base floodplain is defined as the 100-year (1.0 percent) floodplain" (10 C.F.R. part 1022.4). Wetlands means "those areas that are inundated by surface or ground water with a frequency sufficient to support, and under normal circumstances does or would support, a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth or reproduction" (10 C.F.R. part 1022.4(v)). This definition includes all wetlands including vernal pools.

Approximately 56 percent of the wetlands in the United States have been lost since the 1800s and many existing wetlands have been degraded (U.S. Fish and Wildlife Service, 1990). The ecological importance of these areas, brought into focus by such losses, has stimulated interest in wetlands protection. Since publication of 10 C.F.R. part 1022 in 1979, the commitment to protecting our nation's wetlands has intensified. In fact, the President has called for the goal of "no net loss" of wetlands, and many federal and state statutes have been enacted in recent years to protect them.

The elimination and degradation of wetlands in the Central Valley and surrounding areas of California has been extensive. The estimated 2 to 3 million acres of wetlands in the Central Valley have, through the impact of human intervention, been reduced by an estimated 90 percent. The major reasons for this decline have been the draining of wetlands for agriculture, changes in surface hydrology, livestock grazing, and development within the riparian zone (Warner, 1981). Of the remaining wetlands in the Central Valley area, only 2.5 percent are unaltered, 12.4 percent are in good shape, and the remaining 85 percent are disturbed, degraded, or severely degraded (Katibah, Drummer, and Nedeff, 1981). Although the LLNL Livermore site, LLNL Site 300, and SNL, Livermore are not in the Central Valley, these sites are located in the overall area analyzed by Katibah, Drummer, and Nedeff (1981).

G.2 FLOODPLAIN EFFECTS

G.2.1 Methods

LLNL, Livermore Site and SNL, Livermore

The 100-year floodplain at the LLNL Livermore site and SNL, Livermore was identified from studies performed in 1986 for the Federal Emergency Management Agency to determine flood hazards in the Alameda County area. These floodplains were incorporated in the Flood Insurance Rate Maps (FEMA, 1981, 1986). In addition, floodplain parameters were obtained from a study conducted by Holmes and Narver, Inc. (1985) for the LLNL Livermore site.

LLNL Site 300

LLNL Site 300 includes several large canyons that drain into Corral Hollow Creek. The Flood Insurance Rate Map of Corral Hollow Creek (U.S. Department of Housing and Urban Development, 1980) was used to characterize the 100-year floodplain for Corral Hollow Creek in the area adjacent to the site. Because onsite analysis of floodplains was unavailable, DOE performed modeling to characterize the 100-year floodplain for the canyons on LLNL Site 300. Rather than model every ravine onsite, however, three canyons were chosen with lengths and depths representative of other onsite drainage. The 100-year flood characteristics were analyzed for two ravines/canyons (Oasis/Draney Canyon or drainage basin A and Elk Ravine or drainage basin B), and a third smaller canyon (Middle Canyon or drainage basin C), all shown in Figure G-2.

The U.S. Army Corps of Engineers Hydrologic Engineering Center Flood Hydrograph Package (HEC-1) computer program was used to model the three representative drainage basins A, B, and C. This model simulates the surface runoff response of a drainage basin to a storm (precipitation event) by representing the basins as an interconnected system of hydrologic and hydraulic components. Each basin comprises smaller basins, or subbasins, and each component models the precipitation-runoff process within drainage subbasins. The modeling results in streamflow hydrographs, which provide peak discharges at locations in the drainage basin (U.S. Army Corps of Engineers, 1981). Model parameters, which represent average conditions within subbasins, include subbasin drainage area, rainfall, precipitation loss factor, unit hydrograph parameter, and flood routing parameter.

The three basins were delineated on a U.S. Geological Survey map of Midway, California, and divided into subbasins (Figure G-2). Table G-1 identifies the basins and subbasins, and their total drainage area.

Rainfall data, in the form of rainfall in inches for any given duration or time, were obtained for East Alameda County (Welch et al., 1966). The data were used to develop incremental rainfall intensities over 6 hours. The incremental amounts were arranged in a sequence that would produce the peak storm event. The resulting time-distributed incremental precipitation represents a precipitation hyetograph. The hyetograph was input into the HEC-1 model according to the precipitation time increment value used in the model.

To calculate precipitation loss, a parameter called a "curve number" is used to estimate the amount of precipitation lost to surface interception, depression storage, and infiltration. This precipitation, therefore, does not contribute to runoff. The Soil Conservation Service has described the relationship among drainage characteristics of soil groups using the curve number, based on soil cover, land use, and antecedent moisture conditions. The HEC-1 model uses this curve number to determine the amount of precipitation lost to infiltration. Soil types are categorized into hydrologic soil groups, and the curve number is weighted according to group (U.S. Department of Agriculture Soil Conservation Service, 1975). The model calculates an average precipitation loss for a computation interval and subtracts it from the precipitation hyetograph. The net precipitation is used to compute an outflow discharge for each subbasin (U.S. Army Corps of Engineers, 1981).

The unit hydrograph computation transforms the subarea precipitation hyetograph to runoff outflow for each subbasin outflow. The Soil Conservation Service Dimensionless Unit Hydrograph method (Viessman et al., 1977) was used to generate a synthetic hydrograph for each subbasin. This method also has a single input parameter, called lag time, which is equivalent to the lag between the center of mass of the rainfall runoff and the peak of the unit hydrograph. The lag time is calculated using the following empirical formula:

$$L = (hl^{0.8}[S + 1]^{0.7}) / (1{,}900Y^{.05})$$

where,

L = lag time in hours
hl = hydraulic length of watershed in feet

S = 1,000/CN - 10 (where CN is the retardance factor = 77)

Y = average watershed land slope in percent

The HEC-1 program uses lag time values to generate the unit hydrographs and subsequent runoff outflows for each subbasin. The parameter values used for the subbasins are listed in Table G-2.

Once outflows for each subbasin are calculated, they must be routed and combined throughout the larger basin area. The Muskingum flood routing technique (Viessman, et al., 1977) was used to simulate flood wave movement through the channel. This method calculates the outflow from a channel reach using the inflow into the reach, the travel time through the reach, and a routing constant. As the hydrograph is moved downstream, the peak is attenuated.

The input parameters to the Muskingum Technique are the travel time, expressed as the K factor, and the routing constant, expressed as x. The K factors for each subarea were calculated by dividing the reach length by the flow velocities. Channel slopes were used to estimate the velocities. The routing constant expresses the relative importance of inflow and outflow in determining storage in the channel. A mean value of 0.2 was used for all subareas. Table G-3 lists the parameters for the reaches in each basin.

The results from the HEC-1 modeling were used to calculate the depth and width of the 100-year floodplain for each basin. An empirical formula, anning's equation (American Iron and Steel Institute, 1971), relates the channel geometry and slope to the amount of flow it can convey. The peak flows were input as the solution to Manning's equation.

$Q = 1.49/n \times A \times R^{2/3} \times S^{1/2}$

where,

Q = flow rate (ft^3 per second)
n = roughness coefficient (0.03 for grass-lined waterways)
A = cross-sectional area of flow
R = hydraulic radius
S = channel slope

A representative channel cross section consisting of a 10-ft bottom width and two horizontal to one vertical (2h:1V) side slopes was used for each ravine/canyon. With depth as a variable, the equation was solved to determine the normal flow depth in addition to the top widths, and velocities could then be calculated.

Table G-1 Drainage Areas in Three Drainage Basins at LLNL Site 300

Drainage Basin	Subarea	Area (square miles)
Oasis and Draney Canyon (A)	A1	0.97
	A2	0.80
	A3	0.44
	A4	0.44
	Total:	2.65
Elk Ravine (B)	B1	0.83
	B2	0.91

	B3	0.56
	B4	0.38
	B5	0.39
	Total:	3.07
Middle Canyon (C)	C1	0.21
	C2	0.26
	C3	0.15
	Total:	0.62

* See Figure G-2 for locations.

Table G-2 Hydrograph Parameter Values for Subareas in Three Drainage Basins at LLNL Site 300

Drainage Basin	Subarea	Hydraulic Length (hl) (feet)	Slope (Y) (percent)	Hours (L)
Oasis and Draney Canyon	A1	8,000	10.2	0.57
	A2	8,900	9.6	0.65
	A3	8,000	10.0	0.58
	A4	7,000	10.5	0.51
Elk Ravine	B1	6,700	8.3	0.55
	B2	6,000	9.5	0.47
	B3	5,600	11.3	0.41
	B4	5,500	11.1	0.41
	B5	6,000	11.3	0.43
Middle Canyon	C1	3,800	20.0	0.23
	C2	3,600	18.0	0.23
	C3	4,200	15.0	0.28

Table G-3 Muskingum Routing Parameters for Three Drainage Basins at LLNL Site 300

Drainage Basin	Reach	Length (feet)	Channel Slope (percent)	Velocity (feet per second)	Travel Time (K factor)
Oasis and Draney	10 to	7,000	5.30	3.5	0.56

Canyon (A)	20				
	20 to 30	4,200	6.70	4.0	0.29
Elk Ravine (B)	10 to 20	4,650	1.08	1.5	0.86
	20 to 30	3,950	4.05	3.1	0.27
	30 to 40	1,500	2.67	2.5	0.17
	40 to 50	3,900	2.56	2.4	0.45
Middle Canyon (C)	10 to 20	2,900	7.1	4.0	0.20
	20 to 30	3,250	4.0	3.0	0.30

G.2.2 Results

LLNL Livermore Site

The LLNL Livermore site is located at the eastern end of the Livermore valley in southeastern Alameda County, California. The surrounding land is mostly agricultural, residential, and light industrial. The site covers 821 acres that slope to the northwest at a grade of 1.5 percent.

The original course of Arroyo Las Positas was through what is now the LLNL Livermore site. In the 1940s, it was diverted around the site by the U.S. Navy. The arroyo now runs along the eastern boundary of the LLNL Livermore site for approximately 1000 ft, then turns west and flows through the site. Open ditches and storm drains designed for a 10-year storm event drain the site, most running northward and outfalling in the Arroyo Las Positas. A small percentage of land in the southwest corner drains southward to the Arroyo Seco. These arroyos, dry for most of the year, are the two potential sources of onsite flooding. Localized flooding is most likely to occur during the rainy season from October to April.

Arroyo Las Positas drains approximately 3300 acres in the northeastern and eastern hills above the LLNL Livermore site. Arroyo Las Positas has a 100-year base flood peak flow of 822 cubic ft per second (Holmes and Narver, Inc. 1985). The 100-year floodplain extends along most of its length as it flows through the site (Figure G-3). Upstream of the eastern border, approximately 1400 ft from Greenville Road, the floodplain width is 100 ft at a flood elevation of 640 ft. At Greenville Road, it spreads to 1500 ft at an elevation of 620 ft and covers the road. This spread is due to the shallow channel depth that cannot contain the 100-year flood; therefore, the flood water spreads until it reaches the elevation of the surrounding topography. The 100-year floodplain along the northern end of the site varies to a width of 120 ft. The elevation is 602 ft at the east end and 566 feet at the west end.

The Arroyo Seco crosses the LLNL Livermore site at the southwestern corner for a distance of about 900 ft. Information from Flood Insurance Rate Map panel 210 indicates there is no floodplain associated with this channel onsite. The 100-year storm event is contained within the channel and poses no flooding threat to the site.

SNL, Livermore

The 413 acre SNL, Livermore site of grassland, is about half developed with buildings and parking lots; the remainder is grasslands. The land slopes from the southeast to northwest at 2.5 percent.

The only surface water feature at SNL, Livermore that may be a flood hazard is the Arroyo Seco, which enters the site on the eastern boundary and exits on the northwestern corner (Figure G-4). An intermittent stream that drains the foothills southeast of SNL, Livermore has a drainage area of 8960 acres. Narrow and shallow where it enters the site, it reaches a depth of 20 ft further downstream.

The Arroyo Seco has a 100-year base flood peak flow of 1220 cubic ft per second (Holmes and Narver, Inc. 1985). The 100-year flood is contained within the channel through most of the site until approximately 3000 ft upstream of East Avenue. The floodplain inundates the overbank area to a maximum width of 70 ft at an elevation of 658 ft. All onsite storm water is collected and channeled to the Arroyo Seco through gutters, culverts, and open ditches. Four bridges, three security fences, and several storm sewer outfalls have the potential to impede the flow of floodwaters through the channel.

LLNL Site 300

LLNL Site 300 is located approximately 15 miles southeast of the LLNL Livermore site in the hills of the Diablo Range. The site occupies approximately 7000 acres and consists of mostly undeveloped land characterized by steep hills and deep ravines. A small percentage is covered with buildings and roads. Corral Hollow Road coincides with the southern boundary.

The 100-year floodplain of Corral Hollow Creek would not impact LLNL Site 300, although parts of Corral Hollow Road would be inundated (Figure G-5). The widths of the 100-year floodplain varied from 13.9 ft in Middle Canyon to 19.6 ft in Oasis and Draney canyons (Table G-4). The depth of flow ranged from 1.0 to 2.4 ft, while peak flow ranged from 91 cu ft/second to 367 cu ft/second. These results indicate that there are no 100-year floodplains onsite; however, due to the steep slopes and high runoff potential, drainage velocities could be excessive during a peak flood event.

G.2.3 Impacts Proposed Action

Currently, only roadways exist within the boundaries of the 100-year floodplains, of the arroyos on the LLNL Livermore site and SNL, Livermore. At LLNL Site 300, the 100-year floodplain of Corral Hollow Creek extends across Corral Hollow Road to the site. The proposed action, however, would not require construction in, or otherwise alter, the floodplains of Arroyo Las Positas, Arroyo Seco, Corral Hollow Creek, or basins on LLNL Site 300.

Table G-4 100-Year Floodplain Parameters for Three Drainage Basins at LLNL Site 300

Drainage Basin	Depth of Flow (feet)	Width of Flow (feet)	Velocity (feet per second)	Peak Flow (cubic feet per second)
Oasis and Draney Canyon	2.4	19.6	10.0	355
Elk Ravine	2.4	19.5	10.5	367
Middle Canyon	1.0	13.9	7.9	91

G.3 WETLANDS EFFECTS

G.3.1 Methods

The wetlands at LLNL and SNL, Livermore were delineated using the *Federal anual for Identifying and Delineating Jurisdictional Wetlands* (referred to as the federal manual) (Federal Interagency Committee for Wetlands Delineation, 1989). Techniques and criteria in the federal manual emphasize the delineation of the wetland-upland boundary to facilitate the determination of the area covered by wetlands. Although revisions to the federal manual have been proposed, the 1989 version remains in effect until the revisions become final (56 Fed. Reg. 40,446–40,480, 1991).

According to the federal manual, three criteria must be met before an area can be identified as a wetland:

- Hydrophytic vegetation.
- Hydric soils.
- Wetland hydrology.

The wetland indicator status of plants has been determined under the following scheme: species that occur in wetlands 99 percent of the time are called obligate species; those that occur in wetlands 67 to 99 percent of the time are facultative-wet species; those equally likely to occur in wetlands or non-wetlands are facultative plant species; and those that occur 67 to 99 percent of the time in non-wetlands are facultative-upland species. Hydrophytic vegetation is defined as "macrophytic plant life growing in water, soil, or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content." An area has hydrophytic vegetation when, under normal circumstances, more than 50 percent of the vegetation is obligate, facultative-wet, or facultative species. In cases where obligate species (e.g., cattail [*Typha* sp.]) compose the dominant portion of the plant community, "the area can be considered wetland without detailed examination of soils and hydrology, provided significant hydrologic modifications are not evident" (Federal Interagency Committee for Wetlands Delineation, 1989).

"Hydric soils are defined as soils that are saturated, flooded, or ponded long enough (7 days or longer) during the growing season to develop anaerobic conditions in the upper part" (Federal Interagency Committee for Wetlands Delineation, 1989). The two most common soil features that reflect wetness in mineral soils are gleying (contains mostly gray soils) and mottling. Prolonged saturation of mineral soil causes it to become gleyed throughout; this soil feature is especially useful for delineating wetland boundaries when standing water and/or saturated soil conditions are not present and/or when obligate plant species are not in evidence.

An area is said to have wetland hydrology when it is permanently or periodically inundated (at least 7 days) during the growing season. Hydrological conditions that form wetlands can be found in such places as floodplains along rivers and lakes, estuaries, isolated depressions surrounded by uplands, surface water drainages, and at springs and seeps. "Frequency and duration of inundation or soil saturation are important in separating wetlands from non-wetlands" (Federal Interagency Committee for Wetlands Delineation, 1989).

The observation of wetland hydrological conditions, such as surface water or saturated soils, may be obvious at certain times of year (e.g., early spring) or in certain wetlands (e.g., cattail marsh or spring-fed wetlands), and not so obvious at other times, especially at the wetland-upland boundary. "Consequently, the emphasis on delineating wetland boundaries should be placed on hydrophytic vegetation and hydric soils in the absence of significant hydrologic modification, although wetland hydrology should always be considered" (Federal Interagency Committee for Wetlands Delineation, 1989).

The California Department of Fish and Game administers the state wetlands program consistent with California Fish and Game Commission Policy "to provide for the protection, preservation, restoration, enhancement and expansion of wetland habitat in California." Furthermore, the commission's policy calls for "no net loss" of either wetland habitat values or acreage (California Fish and Game Commission, 1987).

The California Department of Fish and Game also adheres to the U.S. Fish and Wildlife Service wetlands definition and classification systems as presented by Cowardin et al. (1979). This definition includes the three factors listed in the federal manual (Federal Interagency Committee for Wetlands Delineation, 1989). The major difference is that the federal manual requires all three factors be present for an area to be considered a wetland while the state definition requires only one factor (Rollins, 1987a, 1987b). This means that the state may consider areas wetlands (e.g., nonvegetated mud flats) that would not be defined as wetland by the federal manual.

DOE and UC mapped wetlands during ground reconnaissance of the LLNL Livermore site and LLNL Site 300. Wetlands at SNL, Livermore had previously been mapped during a recent survey (Environmental Science Associates, 1990). Wetlands at all three sites were plotted on aerial photographs or detailed site maps. The dominant plant species were noted along with hydrological conditions. The size of the wetlands was determined from measurements made in the field and wetlands were plotted on field maps. Data collected for each wetland were recorded on the field maps and in a field notebook. The soil was inspected for evidence of inundation (i.e., gleying) or saturated soil beneath the surface. The Muncell Soil Color Charts (Kollmorgen Corporation, 1988) were consulted to determine soil chroma (indicates soil color strength or purity): chromas of two or less are often indicators of hydric soils.

G.3.2 Results

Wetlands observed at the three sites are consistent with DOE definition of wetlands (10 C.F.R. part 1022.4(v), 1979), with the criteria in the federal manual (Federal Interagency Committee for Wetlands Delineation, 1989), and with the California Department of Fish and Game definition (Cowardin et al., 1979) of wetlands. No areas were observed that would be considered wetlands based solely on the state definition.

LLNL Livermore Site

Wetlands at the LLNL Livermore site are limited to three small areas along Arroyo Las Positas (Figure G-6) found at and downstream from culverts that channel runoff from the surrounding areas. Two areas, totaling 0.3 acre, were dominated by saltgrass (*Distichlis spicata*); a species of *Carex* was also common. Other species observed were willow (*Salix* sp.), cattail, curly dock (*Rumex crispis*), ryegrass (*Elymus* sp.), and Hooker's evening primrose (*Oenothera hookeri*). One saltgrass wetland had standing and flowing water with other areas of very wet soil. The other wetland was drier, with sandy soil. The third wetland was a small area (0.06 acre) at a culvert near Building 194. Cattail was the dominant species with other species such as *Carex* sp. and saltgrass also commonly observed. Both standing and flowing water were in this area and the soil was sandy (observations were made in May 1991).

SNL, Livermore

Wetland habitat at SNL, Livermore consists of a 1.44 acres in two areas at the western end of the Arroyo Seco (Figure G-7) (Environmental Science Associates, 1990). This wetland consists of 1.32 acres of a remnant wooded riparian area with valley oak (*Quercus lobata*) and sycamore (*Platanus racemosa*) the dominant tree species. Red willow (*Salix lasiandra*), mule fat (*Baccharis viminea*), seaside heliotrope (*Heliotropium curassavicum*), Curly Dock (*Rumex crispus*), and tree tobacco (*Nicotiana glauca*) were common in the understory. The groundcover is dominated by patches of cattail and rush (*Juncus* sp.). The remainder of the wetland (0.12 acre) is an alkali marsh with such species as alkali ryegrass (*Elymus triticoides*) and saltgrass.

LLNL Site 300

Wetlands observed were small, with many occurring in a series of isolated wetlands in deep canyons. Each series is termed a wetlands complex. The wetlands were categorized according to source of water as follows:

- Wetlands arising from natural springs.
- Artificial wetlands created from runoff from LLNL Site 300 buildings. The runoff from the LLNL Site 300 buildings is permitted through a water quality permit from the State of California.
- The vernal pool, which is a wetland created from standing water.

The spring-fed and artificial wetlands were mapped on the basis of dominant vegetation. Sections of these wetlands were dominated by cattail, alkali ryegrass, or rush (*Juncus oxymeris*). Those wetlands dominated by cattail, rush, and alkali ryegrass are referred to as herbaceous wetlands. A total of 16 wetlands or wetlands complexes were identified at LLNL Site 300 (Figure G-8) and are discussed in terms of both the source of water and the dominant plant species. The wetlands locations summarized in Figure G-8 are mapped separately and are shown on Figure G-9 through Figure G-23

Many of the natural wetlands arise from springs at the bottom of deep canyons in the southern half of the site, except for a vernal pool in the northwestern section of the site. These springs occur where water-bearing sandstone units crop out in the canyon or valley bottoms. The wetlands that have developed at these springs are confined by the steep-sided canyon walls; they range in width from 5 to 30 ft and most are 10 to 20 ft wide. Most are relatively short, 100 to 600 ft long; the longest is in Oasis Canyon and is approximately 2800 ft long (Figure G-9).

The plant species observed in these wetlands grew in relatively homogenous stands. Cattail was dominant in areas of flowing or saturated soil where it formed dense stands, typically at the spring and downstream. Species such as *Juncus oxymeris*, seep-spring monkey-flower (*Mimulus guittatus*), whitestem hedge nettle (*Stachys albens*) and, in some places, white watercress (*Rorippa nasturtium*) were frequently observed in areas of flowing water. In limited areas, *J. oxymeris* was dominant in standing water or saturated soil. Proceeding to areas of decreasing soil moisture, alkali ryegrass became the dominant species, ultimately giving way to the upland plant species. Alkali ryegrass grew in homogenous stands, which stood out sharply from the surrounding brown upland grasses because of their conspicuous green color. It was observed in dense stands in very moist soil and became sparse as the soil became drier. Large isolated cottonwood (*Populus fremontii*) were often present in the spring-fed deep canyon wetlands. Plant species observed at LLNL Site 300 wetlands are listed in Table G-5. These species were either recorded during detailed vegetation studies in 1986 (Taylor and Davilla, 1986) or observed during the 1991 wetlands surveys.

The wetlands dominated by herbaceous species were mapped according to the dominant plant species. Wetlands dominated by cattail covered 3.54 acres; those dominated by alkali ryegrass covered 2.04 acres; those dominated by *Juncus oxymeris* covered 0.22 acre; and those dominated by willow (*Salix laevigata*) covered 0.64 acre. The vernal pool covered 0.32 acre. The total area of all wetlands at LLNL Site 300 is 6.76 acres (Table G-6). Many of the natural wetlands at LLNL Site 300 are essentially unaltered by human activities. This is particularly true for the wetlands in the larger canyons in the southern portion of the site (Oasis, Draney, Drop Tower, Middle, and Long canyons) and the wooded riparian wetland along Elk Ravine. Grazing or other human-induced land uses have not occurred in these wetlands since the early 1950s. In addition, these wetlands are remote from human activities at LLNL Site 300. The cover and available water in these spring-fed wetlands are important resources for the resident wildlife. They provide habitat for amphibians such as the California slender salamander (*Batrachoseps attenuatus*), western toad (*Bufo boreas*), and Pacific tree frog (*Hyla regilla*), and for reptiles such as the northern alligator lizard (*Gerrhonotus coeruleus*).

Vegetation at some of these springs provides nesting habitat for the red-winged blackbird (*Agelaius phoeniceus*). The springs are important for species that require daily water such as the lazuli bunting (*Passerina amoena*), California quail (*Callipepla californica*), cliff swallow (*Hirundo pyrrhanota*), and mourning dove (*Zenaida macroura*). The great horned owl (*Bubo virginianus*) was often observed in trees in these riparian zones. Aquatic species of birds are limited to a pair of mallards (*Anas platyrhynchos*) and one green-backed heron (*Butorides striatus*) observed at the LLNL Site 300 sewage lagoon.

No aquatic mammal species were observed; however, the small wetlands and associated available water are important to such species as the striped skunk (*Mephitis mephitis*) and black-tailed deer (*Odocoileus hemionus*). Various species of bats are known to forage over the sewage lagoon.

The remaining natural wetlands near Buildings 827 and 832 and at the lower spring, firing range wetland, and Corral Draw springs and the artificial wetlands (Buildings 827, 865, 801, and 851) are closer to human activity zones and are less important for wildlife habitat. In addition, some of these wetlands (especially Buildings 827 and 832 natural wetlands) are clogged with an accumulation of dead Russian thistle (*Solsola kali*), which had blown in from surrounding areas, further reducing their value to wildlife.

The only wetland not created by springs or by runoff from buildings is a vernal pool in the northwestern part of LLNL

Site 300 (Figure G-8). This pool is oval-shaped and bounded by gently sloping hillsides on the northern and southern sides, a man-made mound on the eastern side, and a gently sloping valley to the west (Figure G-19). "Generally speaking, a vernal pool or hogwallow is a small, hardpan-floored depression in a valley grassland mosaic that fills with water during the winter. As it dries up in the spring, various annual plant species flower, often in conspicuous concentric rings of showy colors" (Holland and Jain, 1977).

The vernal pool at LLNL Site 300 consists of a center area that is bare of vegetation (as observed in May 1991) and concentric circles of different plant species until upland grasses became dominant. The species composition and growth pattern of plants (typically low-growing plants) in the vernal pool are distinct from the surrounding grasslands. Some plant species observed in the vernal pool (Table G-5) are typical of such pools (Holland and Jain, 1977). The soil in the vernal pool is dark gray, and moist at 4 to 6 inches. A hardpan occurs at a depth of 12 to 15 inches.

Table G-5 Plant Species Observed in Three Wetland Plant Community Types at LLNL Site 300

Species and Common Name	Wetland Type			Wetland Indicator Status[b]
	Herbaceous[a] Wetlands	Wooded Riparian Wetlands	Vernal Pool	
Native Grasses and Grass-like Species				
Deschampsia donthonioides Annual hairgrass			X	FACW
Elymus triticoides Alkali ryegrass	X			FAC
Elymus glaucus Ryegrass	X			FACU
Distichlis spicata Saltgrass	X			FACW
Juncus oxymeris Rush	X			FACW
Typha latifolia Cattail	X	X		OBL
Poa scabrella Pine bluegrass	X			---
Introduced Grasses				
Bromus diandrus Brome grass	X			---
Bromus mollis Soft cress	X			FAC
Bromus rubens Foxtail	X			---
Avena barbata Slender oat	X			---
Lolium perenne Italian ryegrass	X			FAC*
Polypogon interruptus Ditch polypogon	X			OBL
Polypogon monspeliensis Rabbitfoot grass	X			FACW
Vulpia myuros Fescue	X			FACU*

Native Forbs				
Boisduvalia glabella Smooth spike-primrose			X	OBL
Downingia insignis Cupped downingia			X	OBL
Eremocarpus setigerus Turkey mullein			X	---
Grindelia camporum Great valley gumplant	X			FACU
Mimulus guttatus Seep-spring onkey-flower	X	X		OBL
Plagiobothrys stipitatus			X	OBL
Rorippa nasturtium White watercress	X	X		OBL
Sanicula bipinnatus Poison sanicle	X			---
Scrophularia californica California figwort	X			FAC
Stachys albens Whitestem hedge nettle	X			OBL
Introduced Forbs				
Brassica geniculata Short-pod mustard	X			---
Carduus pycnocephalus Italian thistle	X			---
Centaurea melitensis Tocalote	X			---
Cerastium glomeratum Chickweed	X			---
Cirsium vulgare Bull thistle	X			FACU
Galium aparine Bedstraw	X			FACU
Marrubium vulgare Horehound	X			FAC
Rumex crispus Curly dock	X			FACW
Sonchus asper Sow thistle	X			FAC
Sonchus oleraceus Common sow thistle	X			---
Urtica dioica Stinging nettle	X	X		FACW
Woody Species				
Populus fremontii Cottonwood	X			FACW

Salix laevigata Smooth willow		X		FACW to OBL[c]
Sambucus mexicana Elderberry		X		FAC

[a]Includes those wetlands dominated by cattail, rush, and alkali ryegrass.

[b] OBL = obligate wetland species; FACW = usually occurs in wetlands; FAC = equally as likely to occur in wetland or nonwetland; FACU = usually occurs in nonwetlands; --- = not on list and assumed to be nonwetland species; * = based on limited ecological information.

[c]Species not on U.S. Fish and Wildlife Service wetland indicator status list, but all willow are OBL or FACW. Source: Taylor and Davilla, 1986; U.S. Fish and Wildlife Service, 1988.

Table G-6 Acres of Wetlands by Plant Community Type at LLNL Site 300

Location*	**Wetland Type**					**Total**
	Typha latifolia	***Elymus triticoides***	***Juncus oxymearis***	**Wooded riparian**	**Vernal pool**	
Oasis Canyon	0.60	0.10	0.12	0.00	0.00	0.82
Draney Canyon	0.07	0.04	0.00	0.00	0.00	0.11
Drop Tower Canyon	0.19	0.29	0.03	0.00	0.00	0.51
Lower Spring	0.05	0.00	0.01	0.00	0.00	0.06
Firing Range Spring	0.00	0.08	0.03	0.00	0.00	0.11
Middle Canyon	0.03	0.19	0.03	0.00	0.00	0.25
Long Canyon	0.04	0.02	0.00	0.00	0.00	0.06
Building 827: Artificial	0.25	0.00	0.00	0.00	0.00	0.25
Natural	0.24	0.12	0.00	0.00	0.00	0.36
Building 832 Canyon	0.48	0.00	0.00	0.00	0.00	0.48
Corral Draw Springs	0.04	0.20	0.00	0.00	0.00	0.24
Vernal Pool	0.00	0.00	0.00	0.00	0.32	0.32
Building 865: Artificial	0.41	0.82	0.00	0.00	0.00	1.23
Building 801: Artificial	0.14	0.00	0.00	0.00	0.00	0.14
Elk Ravine	0.92	0.00	0.00	0.64	0.00	1.56
Building 851: Artificial	0.08	0.18	0.00	0.00	0.00	0.26
Total:	3.54	2.04	0.22	0.64	0.32	6.76

* See Figure G-8 for locations.

G.3.3 Impacts Proposed Action

LLNL Livermore Site and SNL, Livermore

The proposed action is described in Section 3 and Appendix A. Wetlands at the LLNL Livermore site and SNL, Livermore are located away from any planned development and the proposed projects would not impact the wetlands at these two sites.

LLNL Site 300

Planned proposed action construction activities that would not impact wetlands at LLNL Site 300 include the replacement of a fire station and the construction of the Explosives Waste Storage Facility, Explosives Waste Treatment Facility, Contained Firing Facility, and Cheap Access to Orbit Facility. These activities would not take place at or near any onsite wetlands; more information regarding these projects appears in section 3.1.2 of the EIS/EIR and in Appendix A.

A proposed action project that would impact wetlands has to do with the elimination of surface water runoff from some of the cooling towers at LLNL Site 300. Surface water runoff from the cooling towers have created wetlands at and near Buildings 801, 827, 851, and 865. Surface water runoff may be eliminated from many of the cooling towers, including those at Buildings 827 and 851, to comply with the State of California Regional Water Quality Control Board requirements. Implementation of this project would result in the disappearance of approximately 0.5 acre of artificial wetlands at these two buildings. At this time, it is expected that this impact would occur within 2 years. Within 5 years, the artificial wetlands at Buildings 801 and 865 may be reduced due to an estimated 75 percent decrease in the discharge of water.

The U.S. Army Corps of Engineers currently regulates some artificial wetlands, however, the artificial wetlands at LLNL Site 300 are not regulated (Coe, 1991). The artificial wetlands at Site 300 fall under state jurisdiction and under the states no net loss requirement. Section G.5 discusses potential mitigation for the loss of 0.5 acre of wetland.

Direct or indirect negative impacts from future projects should be avoided at natural wetlands identified as sensitive areas at LLNL Site 300. This is especially true for the vernal pool, a unique wetland resource that should be protected from alterations of any kind.

G.4 ALTERNATIVES

No Action Alternative

The no action alternative involves continued operations, including authorized facilities and funded projects such as internal upgrades to buildings, the site revitalization plan, and the on-going ground water restoration project (see section 3.2.1).

The diagnostic upgrades at firing bunkers 801 and 851 would not impact the 100-year floodplain or wetlands. The artificial wetlands at Building 801 are the result of water draining from this site; they begin about 600 ft south down the access road at the corner of Linac Road. Upgrading this building would not result in a direct impact to these wetlands. In addition, the water-use patterns at this site would likely remain the same resulting in no impact to the artificial wetlands.

The artificial wetlands at Bunker 851 occur on a steep slope at the east end of the building area and approximately 500 ft down the canyon to the east (Figure G-23). The revitalization program at Building 851 involves upgrading the computer system; there were no impacts to the artificial wetlands at this site or the 100-year floodplain.

Road upgrades are part of the site revitalization plan and would not impact the artificial wetlands that are formed by runoff from Building 865. Wetlands occur along a section of Linac Road between Building 802 and Do-all Road. Linac Road will be widened by 3 ft on either side to provide shoulders. The wetlands in this area are far enough away from the road (Figure G-20) and would not be impacted. These upgrades also would not impact the 100-year floodplain.

Analysis of ground water at LLNL Site 300 indicates that there is ground water contamination below Buildings 833, 834, 850, landfill Pit 6, the high explosives process area, and the general services area (Bryn, Landgraf, and Booth, 1990; Crow and Lamarre, 1990; Ferry, Lamarre, and Landgraf, 1990; Taffet, Copland, and Ferry, 1991; Taffet and Oberdorfer, 1991; Webster-Scholten et al., 1991). These studies indicate that the contamination is restricted to the ground water and has not come to the surface at any of the spring-fed wetlands onsite.

A plume from the General Services Area has contaminated the alluvia/shallow bedrock aquifer under a segment of Corral Hollow Creek offsite (Ferry, Lamarre, and Landgraf, 1990). There is no indication that springs along Corral Hollow Creek have been contaminated by this plume.

The proposed remedial action for the central General Services Area and the current remedial action at the eastern General Services Areas is to extract and treat the contaminated ground water and then discharge the treated ground water into Corral Hollow Creek. In the vicinity of the General Services Area, the creek is bordered by wooded riparian vegetation, with cottonwood the dominant canopy tree species. Mulefat and willow occur in the understory. One spring dominated by rush (*Juncus* sp.) occurs approximately 700 ft downstream from the eastern General Services Area (Ferry, Lamarre, and Landgraf, 1990). The wooded riparian vegetation is well developed in some areas and sparse in others.

The discharge of treated ground water the central and eastern General Services Areas and other ground water remedial action projects is expected to result in five different release points into Corral Hollow Creek. These release points are well over 200 ft apart, and the potential exists for perennial flow for at least a short distance downstream from each discharge point. For example, the predicted length of flowing water from the General Services Area discharge point was 100 ft (Ferry, Lamarre, and Landgraf, 1990). Treated ground water from the eastern General Services Area has been released into Corral Hollow Creek since June 1991, and the area of wet ground and shallow surface water is approximately 100 ft as predicted. Flows from these discharge points would result in an increase in wetland vegetation with such species as cattail, rush, and alkali ryegrass becoming established. Also, an increase in cottonwood and willow can be expected. This increase in riparian wetland vegetation would benefit wildlife. One possible negative impact would be the development of an extensive area of perennial flow, which could promote fish migration up the creek and result in a reduction of sensitive amphibian species such as the tiger salamander and red-legged frog. However, the relatively low flows at the discharge points (60 to 100 gal per minute at each point), the high porosity of the Corral Hollow Creek bed, and the low rainfall/high evapotransporation climate all join to make this outcome unlikely.

Modification of Operations Alternative

The modification of operations alternative would affect existing and near-term proposed projects to reduce adverse impacts. Based on the modifications discussed in section 3.2.1, natural wetlands and the 100-year floodplains would not be impacted by implementation of this alternative. The artificial wetlands at Buildings 801, 827, 851, and 865, however, may be eliminated or reduced by this alternative. If this were to occur, the impact of this alternative would be similar to the impact of the proposed action.

Shutdown and Decommissioning Alternative

Implementation of the shutdown and decommissioning alternative would remove any potential impact from LLNL activities (once shutdown and decommissioning activities were complete) to the 100-year floodplain at any of the sites or to the wetlands at the LLNL Livermore site and SNL, Livermore. The artificial wetlands at LLNL Site 300 would eventually disappear as operations at the site were phased out. This would result in the loss of 1.9 acres of artificial wetlands. In addition, if grazing were allowed on LLNL Site 300 after shutdown, degradation of the natural wetlands could be expected. This is especially true for the small unaltered spring-fed wetlands in the deep canyons onsite. As stated by Katibah, Drummer, and Nedeff, (1981), "Heavy grazing in riparian zones would eventually lead to the total destruction of the riparian vegetation within them (wetlands). Forage is then lost, shade is gone, and water, now exposed to the sun, evaporates more rapidly." As indicated in section G.3.2, many of the natural wetlands at LLNL Site 300 are unaltered by human activities. Katibah, Drummer, and Nedeff, (1981) determined that unaltered wetlands form a very small percentage (2.5 percent, or 5000 to 7500 acres) of the remaining wetlands in the Central Valley. The impact of grazing would be the elimination or degradation of unaltered natural wetlands (estimated at 3.9 acres) onsite and the loss of these important areas to resident wildlife.

G.5 MITIGATION

The proposed action would result in the elimination of the 0.5 acre of artificial wetlands at LLNL Site 300. These wetlands are not regulated by the U.S. Army Corp of Engineers, so a permit from this agency would not be required to eliminate the wetlands (Coe, 1991). The State of California, however, has a policy of no net loss of wetlands (Rollins, 1987a, 1987b) that applies to all wetlands including artificial wetlands (Bradovitch, 1991). Mitigation for the loss of these wetlands would be determined in consultation with the California Department of Fish and Game.

The ground water restoration project may provide mitigation for loss of wetlands through the creation of wetland vegetation in Corral Hollow Creek. It is difficult to predict the area of wetlands that would be created in Corral Hollow Creek. Assuming five discharge points along Corral Hollow Creek, then five distinct areas of saturated soil totalling 600-ft long by 35-ft wide would result in almost 0.5 acre of wetland vegetation. This scenario is entirely possible given the nature of the ground water restoration project.

APPENDIX G GLOSSARY

Facultative plant species	Species that are equally likely to occur in wetlands and nonwetlands.
Facultative-upland plant species	Species that occur in nonwetlands 67 to 99 percent of the time.
Facultative-wet plant species	Species that occur in wetlands 67 to 99 percent of the time.
Floodplain	The valley floor adjacent to the incised channel of a stream, which may be inundated during high water.
Forbs	Herbs other than grasses.
Hydric soils	Soils that are saturated, flooded, or ponded long enough (7 days or longer) during the growing season to develop anaerobic conditions in their upper layer.
Hydrograph, rainfall	A graph of water level versus time.
Hydrophytic vegetation	Vegetation that grows in water, soil, or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content.
Hyetograph	A graph of rainfall versus time.
Obligate species	Species that occur in wetlands most of the time (99 percent).
Riparian	Located along the banks of streams, rivers, lakes, and other bodies of water.
Vernal pool	A wetland created from standing water, typically in the spring, hence its name.
Wetland hydrology	Permanent or periodic inundation for at least 7 days during the growing season.

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APPENDIX H PREHISTORIC AND HISTORIC CULTURAL RESOURCES

H.1 INTRODUCTION

This appendix provides an evaluation of the prehistoric and historic cultural resources at the Lawrence Livermore National Laboratory (LLNL) Livermore site, LLNL Site 300, and Sandia National Laboratories, Livermore (SNL, Livermore). Prehistoric cultural resources refer to any material remains of items utilized or modified by people prior to the establishment of the Mission Dolores in San Francisco, the first San Francisco Bay Area mission, in 1776. These resources can include artifacts of stone, bone, shellfish, or wood. Physical alteration of the landscape that occurred during the prehistoric time, such as hunting blinds, remains of structures, excavated house pits, caches of artifacts, and concentrations of stones (such as cooking stones), are also considered prehistoric cultural resources. Historic cultural resources include all material remains from the time period subsequent to the establishment of Mission Dolores, including trash dumps; architectural features such as structures, foundations, basements, and wells; and any other physical alteration of the landscape, such as ponds, roads, landscaping and fences.

The relationship of this appendix to other appendices and to sections and requirements of the EIS/EIR, is shown in Figure H-1. Implementation of major programs and facilities described in Appendix A could affect potentially important cultural resources at the three sites. Evaluation of important cultural resources, and implementation of appropriate mitigation for impacts to these resources, will occur in compliance with the requirements of the National Historic Preservation Act.

Sections H.1.1 and H.1.2 of this appendix contain an overview of the federal and state regulatory requirements concerning cultural resources. Compliance with these requirements forms the basis of the project's mitigation of potential impacts to prehistoric and historic cultural resources. Section H.1.3 defines the Area of Potential Effect where impacts to cultural resources could occur as a result of the proposed action. Section H.2 includes a description of cultural resources (both prehistoric and historic) recorded at the three project sites and their potential importance under federal and state criteria for assessing significant cultural resources. In addition to a review of previous cultural resources investigations, an updated literature review and field investigations were conducted. Section H.3 identifies the necessary steps LLNL will undertake prior to approval of funding for proposed action construction projects to comply with Section 106 of the National Historic Preservation Act.

H.1.1 Federal Regulations Related to Cultural Resources

The National Historic Preservation Act was passed in 1966 to identify, record, and preserve significant prehistoric and historic properties. Section 106 of the National Historic Preservation Act (16 U.S.C. 470 et seq.) requires a federal agency (in this case, the U.S. Department of Energy) with jurisdiction over a proposed federal undertaking to take into account the effect of the agency's undertaking on properties included in or eligible for the National Register of Historic Places. Prior to approval of an undertaking, Section 106 also requires DOE to afford the Advisory Council on Historic Preservation a reasonable opportunity to comment on the undertaking. Section 110(f) of the National Historic Preservation Act (16 U.S.C. 470h-2) requires that federal agency heads, to the maximum extent possible, undertake such planning and actions as may be necessary to minimize harm to any National Historic Landmark that may be directly and adversely affected by an undertaking and, prior to approval of such undertaking, afford the Advisory Council on Historic Preservation a reasonable opportunity to comment. The process used by a federal agency to meet these responsibilities, is commonly called the Section 106 process.

The Advisory Council on Historic Preservation seeks through the Section 106 process to accommodate historic preservation concerns with the needs of federal undertakings. The Section 106 process is designed to identify potential conflicts between the two and to help resolve such conflicts in the public interest. The Advisory Council on Historic Preservation encourages this accommodation through consultation among the federal agency official (in this case, DOE), the State Historic Preservation Officer, and other interested persons during the early stages of project planning.

The State Historic Preservation Officer coordinates state participation in the implementation of the National Historic Preservation Act and is a key participant in the Section 106 process. The State Historic Preservation Officer reflects the interests of the state and its citizens in the preservation of their cultural heritage and will help DOE identify those persons interested in an undertaking and its effects on historic properties. It is also the role of the State Historic Preservation Officer to consult with and assist DOE in identifying historic properties, assessing effects on them, and considering alternatives to avoid or reduce those effects.

Section 106 of the National Historic Preservation Act specifies the following review process:

- Step one requires federal agencies (in this case, DOE) to identify and evaluate prehistoric and historic properties that may be affected by a project. For Section 106 review, properties are those that are eligible for, or listed on, the National Register of Historic Places, and may have significance at a national, state, or local level.

Properties to be considered include those that (1) are associated with the events that have made a significant contribution to the broad patterns of history; or (2) that are associated with the lives of persons significant in the past; or (3) that embody the distinctive characteristics of a type, period, method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant distinguishable entity whose components may lack individual distinction; or (4) that have yielded, or may be likely to yield, information important in prehistory or history (36 C.F.R. section 60.4).

- Step two requires DOE, in consultation with the State Historic Preservation Officer, to determine what effect a project may have on historic properties.
- If the effect will be adverse, step three requires DOE to consult the relevant State Historic Preservation Officer (and, in many cases, the Advisory Council on Historic Preservation) to avoid, minimize, or mitigate the adverse effect.
- Step four requires the federal agency to provide the Advisory Council on Historic Preservation an opportunity to comment on the process, usually in the form of a review of the preceding steps and the subsequent execution of an agreement document.

In response to concerns on the part of the scientific community that efforts to preserve or protect historic scientific and technological resources through compliance with federal historic preservation law might impede efforts to remain at the forefront of international research and achievement, in 1989 Congress requested the Advisory Council on Historic Preservation to study the designation of scientific research institutions as historically significant. Concerns were raised by agencies faced with altering or renovating existing or abandoned research facilities which were considered eligible for the National Register by the Advisory Council on Historic Preservation. The resulting document, entitled "Balancing Historic Preservation with the Operations of Historic Technical or Scientific Facilities," discusses the needs of research institutions to upgrade their facilities and the responsibility of preservation agencies to implement the requirements of federal historic preservation regulations. LLNL and SNL, Livermore are "active," "pure," or "applied" research facilities carrying out "essential, often state-of-the-art, research and development" and as such are directly addressed by the report (Advisory Council on Historic Preservation, 1991).

The study concluded that Advisory Council regulations and the Section 106 review process are flexible enough to accommodate the legitimate needs of the scientific and engineering community and their activities at historic facilities. Among the recommendations outlined in the 1991 report are the following:

- Congress should reaffirm the national commitment to historic preservation by upholding the existing national historic preservation program and rejecting individual program or project requests for legislative waivers of historic preservation statutes.
- Future scientific achievement, as well as an adequate serving of the public interest, depends on an understanding of past scientific successes and failures. To the extent that they do not already, future authorizations for major scientific and technological programs should include public education components focusing in part on the

communication of the relevant history of science.

- Decisions about projects that may affect historic properties need to be made with as complete an understanding as possible of such effects. However, considerations of preservation options should be kept distinct from the peer review process of awarding research grants and the determination of research priorities central to the scientific research process.
- The Advisory Council on Historic Preservation and affected federal agencies should jointly subscribe to a statement of policy that acknowledges the sensitive relationship between scientific research and the evolving history of science and its physical manifestations.
- Over the next two years, affected federal agencies, in cooperation with the Advisory Council on Historic Preservation, should examine current administrative procedures for historic preservation. This should include evaluating existing mechanisms for meeting responsibilities for National Historic Landmarks and other properties eligible for or listed on the National Register of Historic Places. As part of this process, affected federal agencies should determine how they might better coordinate historic preservation programs and planning among facilities managers, public affairs offices, archivists, historians, external affairs offices, and other staff. The Advisory Council should recommend measures to these agencies to improve the effectiveness, consistency, and coordination of those procedures with the purposes of the National Historic Preservation Act as prescribed by Section 202(a)(6).
- Innovative ways for minimizing and meeting the costs of historic preservation that may be associated with the operation and management of historic facilities must be explored by federal agencies, in cooperation with other concerned parties.
- The Advisory Council on Historic Preservation, in cooperation with the Smithsonian Institution and the National Park Service, should foster better communication between the preservation and museum communities and federal agencies, with the aim of establishing a consensus about what kinds of facilities and objects should be physically preserved for the future. This would include deciding how the historic value of facilities and objects should be determined, and which of these could be "preserved" through documentation. Most probably that option would be best suited to historic facilities that remain active today.

In conducting the historic evaluation of the LLNL Livermore site that is required to comply with the National Historic Preservation Act (presented later in this appendix), DOE will integrate recommendations from the 1991 Advisory Council on Historic Preservation publication.

A comprehensive discussion of the compliance process for both Section 106 and the California Environmental Quality Act (CEQA) (see section H.1.2) is presented by Busby and Garaventa (1990).

H.1.2 State Regulations Related to Cultural Resources

CEQA (California Resource Code, section 21083.2) requires the lead agency to determine whether a project may have a significant effect on prehistoric and historic cultural resources (referred to in CEQA as archaeological resources). Appendix K of the State CEQA Guidelines (California Office of Planning and Research, 1986) states that "public agencies should seek to avoid damaging effects on an archaeological resource whenever feasible. If avoidance is not feasible, the importance of the site shall be evaluated using the criteria outlined in Section III [of State CEQA Guidelines Appendix K]" (California Office of Planning and Research, 1986). Section III of CEQA Guidelines Appendix K states:

If the Lead Agency determines that a project may affect an archaeological resource, the agency shall determine whether the effect may be a significant effect on the environment. If the project may cause damage to an important archaeological resource, the project may have a significant effect on the environment. For the purposes of CEQA, an "important archaeological resource" is one which:

A. Is associated with an event or person of:

1. Recognized significance in California or American history, or

2. Recognized scientific importance in prehistory.

B. Can provide information which is both of demonstrable public interest and useful in addressing scientifically consequential and reasonable or archaeological research questions;

C. Has a special or particular quality such as oldest, best example, largest, or last surviving example of its kind;

D. Is at least 100 years old and possesses substantial stratigraphic integrity; or

E. Involves important research questions that historical research has shown can be answered only with archaeological methods.

With regard to determining the significance of cultural resources under CEQA, Appendix G in the State CEQA Guidelines states that "a project will normally have a significant effect on the environment if it will disrupt or adversely affect a prehistoric or historic archaeological site or a property of historic or cultural significance to a community or ethnic or social group" (California Office of Planning and Research, 1986).

In certain instances where federal- and state-related projects overlap, Section VI of the State CEQA Guidelines Appendix K states that "a public agency following the federal clearance process under the National Historic Preservation Act or the National Environmental Policy Act may use the documentation prepared under the federal guidelines in the place of documentation called for in this appendix" (California Office of Planning and Research, 1986).

H.1.3 Definition of the Area of Potential Effect

In the context of Section 106 of the National Historic Preservation Act, the Area of Potential Effect is the area in which planned development may directly or indirectly affect a cultural resource. Direct effects would include alteration of the surface by construction, while indirect effects would include human activity around the construction area. The Area of Potential Effect for each of the Laboratory sites is as follows:

LLNL Livermore Site

For purposes of this EIS/EIR, the Area of Potential Effect for prehistoric and historic cultural resources evaluation at the LLNL Livermore site is defined as the entire site.

LLNL Site 300

The Area of Potential Effect for LLNL Site 300 (for both prehistoric and historic cultural resources) is delineated on Figure H-2 and includes several discrete areas across the site. These areas represent areas of activity/disturbance anticipated in conjunction with the proposed action.

SNL, Livermore

The Area of Potential Effect for prehistoric and historic cultural resources at SNL, Livermore is defined as the entire site.

H.2 EXISTING SETTING AND REVIEW OF PREVIOUS INVESTIGATIONS

The following sections describe the current knowledge of prehistoric and historic cultural resources on the LLNL Livermore site, LLNL Site 300, and SNL, Livermore. These sections consider previously published investigations, archival research, and field verification of recorded resources.

H.2.1 Prehistoric Resources

The following brief overview of prehistoric resources in the vicinity of the Laboratories is derived from many sources and represents a consensus view of current knowledge. Additional information regarding the prehistoric settlement of the Livermore Valley and the vicinity of LLNL Site 300 is presented in the Basin Research Associates reports prepared for LLNL Site 300 and SNL, Livermore (Busby, Garaventa, and Kobori, 1981; Busby and Garaventa, 1990).

Native Americans are known to have inhabited Central California for the last 10,000 to 12,000 years, including the area in and around the LLNL Livermore site, LLNL Site 300, and SNL, Livermore. During that period, the amount and type of use of the land by Native American groups varied primarily due to environmental conditions, and also due to changes in cultural conditions. The remains and effects (archaeological sites) left from this human use vary as well (e.g., different amounts of faunal remains; different types of tools and other artifacts) which enables scientists to reconstruct both environmental changes and human cultural history.

The people who first inhabited Central California were most likely generalized hunter-gatherers spreading across the area, speaking a "Hokan" language, and having the ability to use a wide range of natural resources. The most ancient sites in the area reflect this type of economy. Later, perhaps 3000 to 5000 years ago, depending on location, the Hokan speakers were replaced by a physically and culturally distinct people who spoke "Penutian" languages. The Penutians seem to have perfected more specialized economies based on intensive use of specific abundant resources. These people are the ancestors of the Native Americans who inhabited Central California when the first Europeans arrived in the 1770s. The people in the San Francisco–Monterey Bay area at that time were called "Costaños" or coast-dwellers (Costanoans) by the Spanish, and are now perhaps better known as Ohlones. Native American Yokuts occupied the Central Valley, and the ranges of these two groups probably met somewhere in the vicinity of LLNL Site 300. Late prehistoric Indian tribelets in these areas had developed elaborate religious, cultural, economic, and social systems grounded in thousands of years of tradition.

Central California contains numerous prehistoric archaeological sites, many of which contain irreplaceable and valuable scientific information. The LLNL Livermore site, LLNL Site 300, and SNL, Livermore are perhaps not as relatively rich due to environmental factors (such as scarcity of food resources and other raw materials used as tools and ornamentation), but the area along the eastern slopes of the Diablo Range, which includes the area encompassed by LLNL Site 300, is poorly known due to lack of research. The scarcity of data for this area makes any archaeological data recovered relatively more important.

H.2.1.1 Resources at the LLNL Livermore Site

Information on prehistoric resources at the LLNL Livermore site is from an updated archival literature review conducted at the California Archaeological Inventory at Sonoma State University and at California State University Stanislaus; from records in the possession of Basin Research Associates, San Leandro, California; and from records on file at the LLNL Livermore site. These sources are cited in the text where appropriate. In addition, the results of field surveys conducted on May 16, 1991 and October 28, 1991 by Holman & Associates are presented.

Previous Prehistoric Resources Investigations

In 1974, a visual inspection of the LLNL Livermore site was completed, concentrating on areas where historic alteration of the ground was limited (Archaeological Consulting and Research Services, 1974). No surface indicators (i.e., artifacts or features found on the ground surface) of prehistoric resources were discovered. Approximately 35 acres were surveyed in 1982, including a short stretch of the small, intermittent Arroyo Seco at the southwest corner of the LLNL Livermore site and northward up Vasco Road to Mesquite Way, and no cultural (prehistoric or historic) resources were recorded (Busby, 1982). Woodruff (1990) evaluated two LLNL Livermore site properties, Building 310 on East Avenue and the Lighty property (Building 051) on Vasco Road, an area of less than two acres. Neither area was reported to contain significant cultural resources. A recent (1991) records search by Holman & Associates at the California Archaeological Inventory Northwest Information Center at Sonoma State University did not report any recorded sites or cultural resources on or near the LLNL Livermore site.

Field inspections for cultural resources in the western and northern perimeter areas surrounding the developed LLNL Livermore site were conducted on May 16 and October 28, 1991, by Holman & Associates. No prehistoric resources were discovered during the field inspection of the two perimeter areas.

The hot, flat valley floor environment and only intermittent sources of potable water in the immediate vicinity of the LLNL Livermore site made the property an unlikely location for prehistoric habitation, though the area has undoubtedly been used as a resource exploitation area. Rapid sedimentation since the advent of European culture in the region has very often obscured Livermore Valley floor prehistoric sites. The area with the greatest potential for harboring prehistoric materials is the southwest corner of the LLNL Livermore site, where the seasonal Arroyo Seco crossed the property prehistorically; however, previous surveys of the site have not located resources in this area.

H.2.1.2 Resources at LLNL Site 300

Previous Prehistoric Resources Investigations

LLNL Site 300 has been the subject of a Class III cultural resources inventory according to Bureau of Land Management standards (Busby, Garaventa, and Kobori, 1981). This inventory essentially involved an intensive visual field inspection of the site to identify surface indicators of cultural activity, but no subsurface presence or absence testing. A total of 24 cultural resource sites (both prehistoric and historic) and several more areas of potential resources were recorded during the 1981 report, and the recent 1991 field and archival research. A small 14-acre portion of the eastern protrusion of the property was surveyed in 1990 (Banet and Busby, 1990). The 1990 survey did not result in the discovery of any additional cultural resources.

The 1981 report presented the prehistoric background and resources of the region, outlined current archaeological research paradigms and problems, and detailed field, archival, and public response methods. The records search in conjunction with the report showed that no prehistoric cultural resources had been previously recorded at LLNL Site 300, nor had the project area been surveyed for cultural resources prior to 1981 (Busby, Garaventa, and Kobori, 1981).

The area in which LLNL Site 300 is located is generally known as "Corral Hollow." The approximately 7000-acre site consists of rolling to steeply divided grass-covered hills, with small tree-lined seasonal or intermittent drainages running mostly to the south into Corral Hollow Creek. Currently, the area is composed largely of introduced grassland, with some coastal sage scrub and oak woodlands. Prehistorically, the site probably contained more varied habitats, which would have been attractive to either prehistoric or historic populations, that have since been eliminated by modern agricultural and industrial uses. LLNL Site 300 does, however, contain at least a few potentially important prehistoric resources. This potential importance arises at least partly from the scarcity of prehistoric sites in the region.

During the 1981 survey, most of the 7000 acres of LLNL Site 300 was surveyed on foot in straight transects spaced at 25-meter intervals; a smaller portion was surveyed in contour transects (i.e., following the natural topographic contours). The 1981 report specifies certain areas that were not inspected due to pavement and other surface disturbances, extreme slopes, and areas where access was not allowed. A survey coverage map is not furnished in the report. One area not surveyed was an area called the "golf course" (grassy, landscaped area) of unstated size, which has since been determined to encompass approximately 0.25 acre. The percentage of the total LLNL Site 300 area not inspected is not estimated in the 1981 report. However, based on the recorded areas of LLNL Site 300 which are discussed in the 1981 report, and the recent 1991 field surveys by Holman & Associates, it has been determined that the areas within the currently defined Area of Potential Effect have been adequately surveyed with the exception of the Carnegie area in the southern portion of the site.

The 1981 surface reconnaissance of LLNL Site 300 resulted in the recording of three sites with prehistoric cultural resources and one site with both prehistoric and historic resource components. The prehistoric sites included three rock shelters with associated artifacts and one surface lithics resource (stone artifact). Sites and isolates (i.e., single items not associated with a site) were defined by the then-current Bureau of Land Management criteria (five artifacts within a 20-meter circle). Sites, isolates, rock art, and historic graffiti were sketched and/or sketch-mapped and photographed. The recorded prehistoric and multicomponent sites were submitted to the relevant Information Center of the California Archaeological Inventory and "trinomials" (i.e., a three-part unique identification number in the format: state abbreviation–county code–site number; for example, CA-SJo-177 refers to State of California–County of San Joaquin–Site Number 177) were issued by those facilities. The three prehistoric sites and one site with a prehistoric and historic component were registered in San Joaquin County.

The 1981 reconnaissance report noted that research through the ethnographic literature and the California Archaeological Inventory records searches, as well as an inquiry to the California Native American Heritage Commission, did not reveal the presence of any known Native American Indian traditional use areas, sacred areas, or resources.

Potential for Eligibility to the National Register of Historic Places

Although documentation on the recorded sites was submitted to the State Historic Preservation Office for a formal concurrence of National Register eligibility in accordance with the provisions of 36 C.F.R. 800.4(c), no record of a formal Determination of Eligibility is currently available. The 1981 report provides preliminary field evaluations of the resources recorded, based on the professional opinion of the researchers involved, using the Bureau of Land Management evaluation criteria (Bureau of Land Management Cultural Resource Evaluation System). Under these criteria, as applied in the field and based on recorded visible surface data and informal mapping, the report concluded: "Of the 24 cultural properties identified during the inventory, only four are either potential or eligible resources for the National Register of Historic Places" (Busby, Garaventa, and Kobori, 1981). Two of the four "potential or eligible" sites were prehistoric rock shelter/bedrock mortar sites with probable subsurface deposits. The prehistoric/historic site was listed as potentially eligible to the National Register of Historic Places. The historic townsite of Carnegie, a portion of which is within LLNL Site 300 boundaries, was assessed as eligible for National Register listing and is discussed in section H.2.2.2. In addition to the four sites identified as "potential or eligible," two other historic resources were noted as possibly meeting National Register criteria, and testing was recommended. No further evaluation or testing has been conducted for the above six sites since the 1981 report.

Following Bureau of Land Management procedures (the Cultural Resource Evaluation System Rating), significance levels were assigned for all other recorded resources on the basis of the surface survey.

Specific research or management recommendations were made for the six sites evaluated as eligible, potentially eligible, or possibly eligible. Interim management measures were proposed to protect the resources until impacts were specified. For the remaining prehistoric and historic resources field evaluated as not significant at the National Register level, a variety of "passive" resource protection and preservation measures were identified and recommended in the 1981 report. These included patrolling, fencing, or leaving the area undisturbed. These recommendations have not been implemented at LLNL Site 300.

Adequacy of Previous Research

Though generally comprehensive and thoroughly documented, a few important fields of data required in resource management deliberations are not present in the 1981 investigation; this is partly the result of Bureau of Land Management methods in use at that time, and partly the result of the level of the investigation conducted in 1981. The 1981 cultural resources investigation was a Level I evaluation only, which means that the sites were located and recorded, but the importance of the sites was not evaluated. The 1981 report acknowledged these limitations, which are discussed below, and recommended additional efforts in prehistoric and historic field and archival research to fully and accurately evaluate the resources in LLNL Site 300. It should be noted that not all the limitations cited in the 1981 report are required to be addressed as part of this EIS/EIR evaluation. This EIS/EIR focuses on areas at LLNL Site 300 that are within the identified Area of Potential Effect (refer to section H.1.3) and, therefore, only includes an evaluation of prehistoric and historic resources within this defined area. Resources outside the Area of Potential Effect do not require additional evaluation in conjunction with this EIS/EIR.

- It cannot be determined from the 1981 report exactly where and how much of LLNL Site 300 was inspected due to the lack of a survey coverage map. However, as stated earlier, the data that is contained within the 1981 report, supplemented by the 1991 field surveys by Holman & Associates, provides an adequate survey of the area contained within the Area of Potential Effect with the exception of the Carnegie area in the southern portion of the site.
- The criteria used in 1981 for identification and evaluation of cultural resources in the field (the Bureau of Land Management Cultural Resource Evaluation System) is not congruent with current practice advocated by the State of California Office of Historic Preservation, in compliance with Section 106 and other historic preservation statutes and regulations. Specifically, the definition of what constitutes a "site" under Bureau of Land Management standards in 1981 is considerably different from the definition now advocated by the Office of Historic Preservation. The following definition was utilized in the 1981 evaluation:

  > For the purposes of the project, a site was defined as an area with five or more cultural objects occurring within a 20-meter diameter circle. Locations of fewer than five cultural objects were treated as isolated finds. Site loci were identified utilizing standard Bureau of Land Management–Department of the Interior site definitions. . . . Rock art and rockshelter sites were identified by the presence of one or more permanent cultural features . . . as well as by the presence of any portable cultural objects (Busby, Garaventa, and Kobori, 1981).

  Though not directly stated, the common standard in use for assessing historic sites on most federal projects in 1981 was a requirement that the historic resource be 50 years or older to qualify as a site. However, the Bureau of Land Management–defined "Class III Inventory," completed for LLNL Site 300 sought to identify and record "all cultural resources" within the project area. The site and isolate records appended to the 1981 report included some historic features (graffiti) less than 50 years old, but the ages of most historic artifacts and features were not stated or estimated. It is unclear, therefore, whether the 50-year standard was applied.

At the present time, the Office of Historic Preservation advocates the use of the standards set forth in the California Archaeological Inventory *Handbook for Completing an Archaeological Site Record* (California Office of Historic Preservation, 1989):

> . . . a "Site" is defined as a location of associated artifacts and features, regardless of temporal placement or complexity. Minimally, a "Site" must meet two criteria:
>
> 1. It must consist of at least three associated artifacts or a single feature. "Isolates" (less than three associated artifacts) will not be assigned a Trinomial Designation. . . .
> 2. A site must be at least 45 years of age. The age of the site may be determined by artifactual evidence, documentary evidence, or similarity of the site to others which have firm dating.

The differences between these definitions presents at least two potential difficulties. The more restrictive definition of a "site" used in the 1981 report may have prevented some resources from being recorded. First, what were recorded as "isolates" under the numerical definition from Bureau of Land Management may be more properly considered "sites" under current practice. Second, the above California Archaeological Inventory definition of the spatial criterion for a site is nonspecific, allowing for artifacts that are "associated" even if separated by more than the dimensions of a 20-meter circle. These two factors could increase the number of "sites" found within LLNL Site 300 boundaries, especially in the zones identified in 1981 as "areas of probable historic archaeological impact," which include the Carnegie area in the southern portion of the site. Conversely, if in the unlikely event the 1981 investigation recorded all visible, nonrecent cultural manifestations as resources, the number of sites could be reduced.

Over 10 years have passed since the 1981 reconnaissance, and therefore the historic resources on LLNL Site 300 are perhaps past or at least much closer to the 45-year limit. Further, if the 1981 study only recorded resources that appeared to be at least 50 years old, and the more current Office of Historic Preservation standard of 45 years is now applied, resources up to 15 years more recent than those recorded in 1981 may now merit recording. This factor could increase the number of Section 106 properties within LLNL Site 300.

Based on a review of the 1981 report by Holman & Associates and their followup surveys in 1991, no additional sites are expected within the Area of Potential Effect except those potentially associated with the townsite of Carnegie, which have recently undergone additional evaluation (William Self Associates, 1992; see section H.3.2).

- The existing sketch maps and field evaluations of the LLNL Site 300 cultural resources were made from surface observations; these are appropriate for a Phase I Inventory but most likely insufficient for specific planning purposes. Subsurface investigations were not undertaken in 1981. The 1981 report indicated that some of the historic areas were not adequately mapped, and that the three prehistoric rock shelter sites may have subsurface deposits that still require accurate mapping. However, only sites falling within the Area of Potential Effect would need to be mapped as part of the current cultural resources evaluation (see section H.3.2). In addition, none of the above-mentioned prehistoric sites fall within the Area of Potential Effect, so no subsurface testing of these sites is required for purposes of this EIS/EIR evaluation.

Reinspection of Prehistoric Resources

A reinspection of the 24 previously recorded prehistoric and historic resource sites was conducted during field visits in April, May, and July, 1991. The reinspection visits were designed to accomplish the following objectives:

- Ensure that the original recorded locations and descriptions of the sites were accurate. The reinspections also allowed an assessment of the relationship of the recorded resource locations to the Area of Potential Effect designated in Figure H-2.
- Evaluate the adequacy of the 1981 field inspections. Any areas within the Area of Potential Effect having a high potential to contain cultural materials (such as rock outcrops, rock shelters) that may not have been field inspected in 1981 necessitated a resurvey.

Although the primary focus of the 1991 field visits to LLNL Site 300 was to inspect the currently defined Area of Potential Effect for adequacy of field coverage, and to relocate the cultural resources inside or near the Area of Potential Effect, an attempt was also made to relocate all 24 cultural resources inside the LLNL Site 300 borders. The field inspection of the previously recorded site locations yielded the following results for the prehistoric sites, none of which are located within the Area of Potential Effect (historic sites are described in section H.2.2.2):

CA-SJo-188: Described as a light lithic scatter of white chalcedony and chert waste flakes from tool manufacture, this site is accurately mapped along the northern border of the LLNL Site 300 property and shows no signs of alteration in the 10 years since it was recorded. This site is outside the Area of Potential Effect.

CA-SJo-184: Described as a rock shelter with three bedrock mortars, this location may have an extended midden (cultural soils) extending from the mouth of the shelter to the east. This site was relocated and found to fall outside the Area of Potential Effect. Dense grasses and weeds prevented plotting the actual surface extent of the midden outside the cave.

CA-SJo-183: Described as a shallow and narrow rock shelter with one bedrock mortar, facing northwest in a ravine 960 meters southeast of Building 812E and 220 meters northeast from Elk Ravine Road. Repeated attempts to relocate this site in the designated ravine and the ravines to the north and south of it were unsuccessful. Either the previous 1981 mapping is inaccurate, or the sandstone conglomerate which housed the shelter has fallen in and destroyed or obscured the shelter. The site is not located within the currently designated Area of Potential Effect.

CA-SJo-174H: This site contains both a prehistoric and historic component. Described as a prehistoric milling rock shelter (and historic petroglyphs), this site was found to be largely intact; there appears to have been some erosion to the surface of the rock shelter since 1981. This site does not fall within the Area of Potential Effect.

The 1991 field investigation by Holman & Associates concluded that the 1981 field inspection of the area encompassed by the currently defined Area of Potential Effect was adequate in determining the presence or absence of cultural resources. Those areas where prehistoric and historic resources have not been recorded to date from a surface inspection are not likely to yield such resources in the future.

H.2.1.3 Resources at SNL, Livermore

Previous Prehistoric Resources Investigations

SNL, Livermore has been the subject of a recent, thorough cultural resources overview and inventory (Busby and Garaventa, 1990) and a cultural resources assessment (Busby, Garaventa, and Harmon, 1990). Prior to these reviews, a records search conducted by the California Archaeological Inventory Northwest Information Center during the preparation of the above reports showed that the SNL, Livermore area had not been previously inventoried, nor were any cultural resources recorded within the SNL, Livermore property. The 1990 studies were completed under the most recent guidelines and regulations regarding federal cultural resources procedures. A prehistoric background, a thorough history of the Livermore area and the LLNL Livermore site, and the recent history of SNL, Livermore since its inception are presented in the 1990 reports. Although all structures and features at SNL, Livermore were informally evaluated in the 1990 reports for potential inclusion in the National Register of Historic Places or National Historic Landmark status, no structures or features were found that could potentially qualify for inclusion. The State Historic Preservation Office concurred with this finding (State Historic Preservation Office, 1990). Consequently, no further investigation of prehistoric resources, or evaluation pursuant to the National Historic Preservation Act, is needed at SNL, Livermore.

H.2.2 Historic Resources

The following regional overview of the historic background of LLNL and SNL, Livermore areas is summarized from the 1981 report for LLNL Site 300 (Busby, Garaventa, and Kobori, 1981), and the 1990 report on SNL, Livermore (Busby and Garaventa, 1990).

The Livermore family farmed and ranched in the Livermore Valley in the early American period, and by 1869 the town of Livermore was established as an important rail stop on the Niles to Stockton route. Livermore and Stockton were the only important towns on the overland route from San Francisco to Sacramento and the East. The population remained sparse, however, and the area continued to be used for agriculture (including viticulture), and cattle and sheep ranching well into this century. At the turn of the century, the town of Livermore was much less heavily populated than the Corral Hollow area. The establishment of the Livermore Naval Air Station during World War II, and its subsequent decommissioning, led to the transfer of the properties to what are now the LLNL Livermore site and SNL, Livermore. The role of these two facilities in nuclear weapons research and development, as well as important research in other advanced technologies, has contributed to the growth of the urban area and altered the character of the region.

The LLNL Site 300 area was not traversed during the earliest Spanish explorations of Central California in the 1770s, but by about 1795 the route along Corral Hollow Road was in use by the Spanish as "El Camino Viejo." During the Hispanic era (approximately 1776 to 1849), the area was isolated and virtually unused, except for grazing of horses and cattle, due to the hilly terrain, lack of water, and the usually high winds. The low rate of use of the area continued during the early American period except for the establishment of several roadhouses along the Corral Hollow route. Coal was discovered in the steep hillsides in the 1850s and the first mining began in 1857. The Tesla mines, located primarily to the west of LLNL Site 300 and north of Corral Hollow Road, eventually produced coal used throughout central California. The coal was of poor quality and high sulfur content, and the mines went through repeated cycles of operation and closure before they were finally abandoned around 1912.

Suitable clay and other materials for commercial ceramic production were also found in the canyon. The towns of Pottery (Walden) and Carnegie succeeded Tesla as population centers, and were the centers of ceramic pipe, pottery, tile, and brickmaking industries which exported goods to an international market. The town of Pottery, just outside the southwest corner of LLNL Site 300, was established before Carnegie and was so successful in the manufacturing of ceramic specialties that the larger Carnegie facility was constructed about 1895. The boom period for the ceramics industry was brief (1892 to 1912), after which the company towns closed. During that boom period, however, population in the canyon reached 10,000. Carnegie produced ceramic pipes for the growing cities of San Francisco and Oakland, and it was the source of the renowned "Carnegie" firebricks (the term "carnegie" came to mean the best quality firebricks; carnegie bricks are commonly in post-earthquake San Francisco buildings). Portions of the Carnegie area are located to the south and north of Corral Hollow Road, including an area in the southern portion of LLNL Site 300. Because Tesla, Pottery, and Carnegie were classic company towns with distinct ethnic group neighborhoods of immigrant workers, the area presents an opportunity to study economic, demographic, and ethnic history.

LLNL (then known as the University of California Radiation Laboratory, Livermore site) was established in 1952 on the previous site of the Livermore Naval Air Station. The facility was owned by the federal government and operated and managed by the University of California under a contract with the Atomic Energy Commission (a predecessor agency to DOE). DOE and UC began LLNL Site 300 in 1953 to perform non-nuclear high explosives testing in support of LLNL's mission. In 1956, Sandia National Laboratories (then the Sandia Corporation) established facilities at Livermore (SNL, Livermore) to support LLNL in ordnance engineering.

H.2.2.1 Resources at the LLNL Livermore Site

Previous Historic Resources Investigations

As discussed under section H.2.1, none of the previous surveys (Archaeological Consulting and Research Services, 1974; Busby, 1982; Woodruff, 1990) nor the 1991 records search conducted as part of this EIS/EIR identified any significant cultural (prehistoric or historic) resources in the areas surveyed. Work has recently been conducted to address the history of the LLNL Livermore site facility and its potential eligibility for the National Register in relation to the facility's Cold War mission during the 1950s and early 1960s (William Self Associates, 1992). In the 1991 field survey of the western perimeter area, remnants of what may be a former historic building location were seen at the northwest corner of the perimeter. Several eucalyptus trees and other ornamental trees surround a small area in a configuration typical of vegetation planted as a windbreak around a farmhouse. This area was not considered to be eligible for the National Register of Historic Places by the researcher involved (Woodruff, 1990); however, formal State Historic Preservation Office concurrence on eligibility has not yet been sought.

H.2.2.2 Resources at LLNL Site 300

Previous Historic Resources Investigations

Archival research prior to and during the 1981 field survey revealed that the LLNL Site 300 area has a high potential to contain important historic resources (Busby, Garaventa, and Kobori, 1981). A previously recorded historic resource was found in 1981 to have been designated by the State of California near LLNL Site 300 (i.e., the town of Carnegie, State Historic Landmark Number 740). The historic landmark marker is on the opposite side of Corral Hollow Road from LLNL Site 300; however, research indicates that the historic townsite was on both sides of the road. Corral Hollow is also designated as a State Historic Landmark (Number 755), but the marker is placed well outside LLNL Site 300 (about 1.5 miles west of Interstate 5 on Corral Hollow Road). Neither State Historic Landmark designation delineates an exact areal extent of the historic resources (i.e., no map exists that outlines the historic resource area on the ground).

The 1981 surface reconnaissance of the LLNL Site 300 project area resulted in the recording of 21 historic cultural resource sites, including 20 sites with historic resources and one site with both prehistoric and historic resource components. In addition to the historic townsite of Carnegie, the historic sites recorded on LLNL Site 300 during the 1981 surface reconnaissance included two isolates, seven historic graffiti sites, three trash scatters, two structures, one foundation, two rubble piles, one pipeline, one mine adit, and one telegraph or power line (Busby, Garaventa, and Kobori, 1981). As mentioned previously under the discussion of prehistoric resources, sites and isolates (i.e., single items not associated with a site) were defined by the then current Bureau of Land Management criteria (five artifacts within a 20-meter circle). Sites, isolates, rock art and historic graffiti were sketched and/or sketch-mapped and photographed. The recorded historic and multicomponent sites were submitted to the relevant information Center of the California Archaeological Inventory and "trinomials" (i.e., a three part unique identification number in the format: state abbreviation-county code-site number; for example, CA-SJo-177 refers to State of California-County of San Joaquin-Site Number 177) were issued by those facilities. Three historic sites were registered in Alameda County and 18 sites (17 historic sites and one site with a prehistoric and historic component) in San Joaquin County.

Potential for Eligibility to the National Register of Historic Places

As described in section H.2.1.2, the townsite of Carnegie was recommended for nomination to the National Register following a proposed subsurface testing program and formal evaluation report (Busby, Garaventa, and Kobori, 1981). The report recommended that the townsite be made a "special management area" with active protective measures then contemplated for the near future. The combined prehistoric and historic site recorded during the 1981 survey (CA-SJo-174H) was also identified as being eligible for National Register listing. Two other historic resources were listed as possibly meeting National Register criteria; testing, as a means of establishing National Register eligibility, was recommended. The above four sites, and two additional prehistoric sites, constitute the six sites at LLNL Site 300 recommended in 1981 as eligible, potentially eligible, or possibly eligible for the National Register. As discussed in section H.2.1.2, with the exception of the Carnegie townsite, no management measures or further testing have been conducted for these sites to date. Of these six sites, only the historic townsite of Carnegie, a portion of which falls within the Area of Potential Effect in the southern portion of LLNL Site 300, requires evaluation in conjunction with this EIS/EIR.

General comments were offered on three other "areas of probable historic archaeological impact" in which materials may "be of potential archaeological significance" (Busby, Garaventa, and Kobori, 1981). Most of the potential resources identified were not recorded as sites; either these areas could not be visited, surface indications were lacking, or definitions used in the field did not require the recording of some materials. These potential resource areas, which are associated with the Carnegie era, included mining effects and artifacts, in addition to site CA-Ala-425H, along the slopes north of Corral Hollow Road for virtually the entire length of the LLNL Site 300 boundary. Residential areas in Sections 33 and 34, also along the north side of the road, were thought to contain additional resources in the wide general area of site CA-SJo-173H (the town of Carnegie). Finally, the potential for historic resources associated with ranching existed in several widely separate areas, which are located within six different sections. At least two resources identified with ranching were recorded as sites (CA-SJo-177H and CA-SJo-168H).

The 1981 report recommended additional historic research to clarify the locations and characteristics of the Carnegie townsite-era residential, industrial, and other types of resources (Busby, Garaventa, and Kobori, 1981) within LLNL Site 300. The report contained recommendations for the completion of historical archival research to identify existing resources and to predict the potential locations of additional resources associated with historic Carnegie that are within the LLNL Site 300 boundaries. Additional archival research recently conducted will assist in defining the extent and potential significance of the Carnegie site (William Self Associates, 1992). The 1981 report discussed various uncertainties concerning the exact locations of numerous historic resources that should be found north of Corral Hollow Road. Correlations between extant records, old topographic maps, and discoveries on the ground were apparently not possible with the level of data developed for the 1981 inventory.

Adequacy of Previous Research

As previously discussed in section H.2.1.2, the 1981 cultural resources investigation was a Level I evaluation only. The sites were located and recorded, and a preliminary field evaluation of the sites' eligibility to the National Register was made. A formal request for concurrence regarding National Register eligibility was submitted to the State Historic Preservation Office; however, no record of a formal Determination of Eligibility is currently available. Additional archival research recently conducted (William Self Associates, 1992) will provide information necessary to permit documentation and evaluation of the Carnegie townsite. This issue is discussed in section H.3.2.

Reinspection of Historic Resources

For this EIS/EIR, all 21 previously recorded historic sites at LLNL Site 300 were reinspected. Seven of these sites, four of which are within the Area of Potential Effect, were not relocated, and an eighth site was revisited but the artifact associated with the site had been collected during the 1981 survey. The results of the field investigation of the historic sites are as follows:

CA-SJo-185H: This site is described as a petroglyph consisting of four vertical lines incised into sandstone, probably historic in origin. This site was located, is accurately mapped, and shows no signs of damage since it was recorded. This site is not within the currently defined Area of Potential Effect.

CA-SJo-186H: Described as a localized trash scatter on a flat south of the road to Bunker 851, this site was not found, and may have been removed over the past 10 years. It is not within the Area of Potential Effect.

CA-SJo-182H: Described as a rusted metal band, this find was located near the southeastern border of the property very near the fence line. High grasses in this area hampered the relocation of this item; it is either obscured or was removed. This site is within the Area of Potential Effect.

CA-SJo-187H: Described as a pile of weathered wood mixed in with some bailing wire in the southeastern corner of the property. This site is within the Area of Potential Effect in the southeastern portion of LLNL Site 300. The entire area surrounding the recorded location of the material was visually inspected and it appears that this resource has been removed.

CA-SJo-181H: Described as a jumbled pile of assorted wood boards, some of which are standard-gauge railroad ties with spikes. This site is within the Area of Potential Effect in the southeastern portion of LLNL Site 300. Inspection of the recorded location failed to find any traces of the material; it appears that this resource has been removed.

CA-SJo-180H: Described as a wooden structure, partly collapsed, which crossed the streambed in this area. The recorded location of the material was visually inspected as well as approximately 1000 ft of the creek to the north and south of it, but no remains of this structure were encountered. It appears that this structure has been removed. The site is not within the Area of Potential Effect.

CA-SJo-179H: Described as a historic trash dump containing the frame of a Model T, this feature is undisturbed on the side of the road near Bunker 812. It is not within the Area of Potential Effect.

CA-SJo-178H: Described as a historic site comprised of wood and metal pipes, this site was found to be intact in the location recorded in 1981. It does not fall within the Area of Potential Effect.

CA-SJo-177H: Described as a wooden building, this site was found to be intact in the location recorded in 1981. It does not fall within the Area of Potential Effect.

CA-SJo-175H: Described as a historic dump, this location failed to yield any of the materials described in 1981. It should be noted that grasses were extremely dense in this area at the time of the field inspection; the resource could still exist at this location. The site does not fall within the identified Area of Potential Effect.

CA-SJo-176H: Described as historic graffiti (a single date) carved into a sandstone rock shelter. This location is intact and is accurately mapped. It is not within the Area of Potential Effect.

CA-SJo-174H: This site contains both a prehistoric and historic component. Described as historic petroglyphs (and a prehistoric milling rock shelter), this site was found to be largely intact, although there appears to have been some erosion to the surface of the rock shelter since 1981. It does not fall within the Area of Potential Effect.

CA-Ala-425H: Described as a mine shaft, it was discovered during the 1991 field visit that this site was not accurately recorded. The site includes a rock shelter with a fire-blackened ceiling which may be prehistoric and/or historic in nature. This area falls outside of the designated Area of Potential Effect.

CA-SJo-173H: Described as a residential area of the factory town of Carnegie, historic surface indicators were observed in areas roughly corresponding to the 1981 mapped locations. The Carnegie site extends for about a mile along the southern perimeter of LLNL Site 300, north of Corral Hollow Road, both within and outside the Area of Potential Effect.

CA-SJo-172H: Described as a rock shelter with historic petroglyphs, the location was originally described by Dietz and Jackson (no date) as a prehistoric site. The reinspection of the site in May 1991 indicated that this designation may be accurate based on the surface presence of prehistoric midden; however, additional subsurface testing would be required to verify the designation. This site falls outside of the currently designated Area of Potential Effect; therefore, no additional evaluation is required.

CA-SJo-171H: Described as historic graffiti on the wall of a shallow rock shelter, this site was revisited and has suffered some erosion since it was originally mapped. The site does not fall within the currently designated Area of Potential Effect.

CA-SJo-170H: Described as historic graffiti on two panels of a sandstone face in the canyon, this feature is intact and is accurately mapped. It is not located within the Area of Potential Effect.

CA-SJo-169H: Described as an historic rock shelter with historic petroglyphs, this location is intact and is accurately mapped. It is not located within the Area of Potential Effect.

CA-SJo-168H: Described as a possible windmill foundation of concrete measuring 13.5 sq ft and 7 inches thick. This site is within the Area of Potential Effect in the southeastern portion of LLNL Site 300. An inspection of the recorded location of this feature, along with the surrounding area, was undertaken and it appears that the slab has been removed, possibly during construction activities in the area.

Ala-426H Described as a number of telegraph poles with wires strung between them, this site was found to be intact in the location recorded in 1981. It is not located within the Area of Potential Effect.

Ala-427H Described as an historic isolate consisting of a single claw hammer hanging from the section line fence, this item was collected by Basin Research Associates during their 1981 survey. The site area was revisited and does not fall within the Area of Potential Effect.

It should be noted that some of the above historic sites recorded in 1981 would likely be considered isolates by current standards. Because these resources have already been officially recorded (in conjunction with the 1981 study), no action is required to revise these records.

H.2.2.3 Resources at SNL, Livermore

Previous Historic Resources Investigations

As discussed previously in section H.2.1.3, it has been determined that no existing cultural resources at the SNL, Livermore facility are currently eligible for inclusion on the National Register of Historic Places (Busby and Garaventa, 1990; Busby, Garaventa, and Harmon, 1990). Consequently, no further review of historic cultural resources at SNL, Livermore, pursuant to the National Historic Preservation Act, is needed (State Historic Preservation Office, 1990).

H.3 SECTION 106 COMPLIANCE ASSOCIATED WITH THE PROPOSED ACTION

This section discusses the resources on the two LLNL sites that require further investigation to satisfy the Section 106 process, and outlines the necessary steps LLNL will undertake prior to approval of funding for proposed action construction projects to comply with the National Historic Preservation Act. Preliminary informal consultation with the State Historic Preservation Office has been made regarding potentially important historic resources at the LLNL Livermore site and LLNL Site 300 (Meeting on April 4, 1991, with Mr. Hans Kreutzberg and Ms. Leslie Hartsell, State Historic Preservation Office, Sacramento, California). Additional consultation will be undertaken as the Section 106 process unfolds. As discussed previously, it is not anticipated that any facilities at SNL, Livermore qualify for inclusion on the National Register. Consequently, no further Section 106 review of prehistoric or historic cultural resources is needed at SNL, Livermore.

H.3.1 LLNL Livermore Site

A final determination of the historic value and potential National Register significance of the LLNL Livermore site has yet to be determined. Given the overview of LLNL operations and history presented in section H.2.2.1, it appears that the LLNL Livermore site may contain resources that are eligible for the National Register.

With regard to the age criteria for eligibility to the National Register, preliminary research indicates that few portions of the LLNL Livermore site are 45 years old or older; however, most of the facility was built in the 1950s and would reach 45 years of age during the time frame of the proposed action (5–10 years). In addition, the Advisory Council on Historic Preservation (1991) indicates that under Section 106 guidelines, the 45-year rule does not apply to facilities where the historic importance of their operations override the consideration of age.

Associating the historic importance of the LLNL Livermore site and events that have occurred there with actual buildings or locations may be problematic. The perceived "historic importance" of LLNL was discussed with the director of the LLNL Livermore site archives. It was noted that while actual buildings or locations were not necessarily considered to be historically significant, the people who have worked at the site since its inception and the results of the various research programs may be. Many such people are now gone and the material results of their work and programs are not necessarily found at the LLNL Livermore site, other than reports or other documentation currently stored in the archives.

Although DOE is required to consider the historic importance of facilities at the LLNL Livermore site, there is no obligation to nominate the LLNL Livermore site in its entirety to the National Register. To satisfy the National Historic Preservation Act, DOE will evaluate which facilities within the Laboratory are eligible to the National Register, consider the potential effects of the proposed action on these facilities, and describe mitigations for adverse effects, if any. The following actions will, thus, be undertaken:

- Prior to approval of federal funding for proposed action construction projects, and in compliance with Section 106 of the National Historic Preservation Act, a comprehensive evaluation of the historic importance of buildings and facilities within the LLNL Livermore site will be conducted to identify which are eligible for the National Register. This will require research in conjunction with the LLNL Livermore site archives and other relevant sources, as well as documentation of descriptive information about specific buildings or facilities that are potentially eligible. It will also be necessary to associate historic events with specific buildings or facilities if possible. The objective of this evaluation is to identify the discrete facilities within the LLNL Livermore site that are eligible for the National Register.
- Also in compliance with the National Historic Preservation Act, LLNL and DOE will coordinate efforts to define a process for securing an agreement document between DOE, the Advisory Council on Historic Preservation, and possibly the State Historic Preservation Officer. Once a process is defined, DOE will consult with the Advisory Council on Historic Preservation and the State Historic Preservation Officer to agree on the process for determining eligibility of portions of the LLNL Livermore site to the National Register and of developing the agreement document pursuant to Section 106. Approval of the agreement by all parties would conclude compliance with Section 106 requirements. The agreement will outline the process for establishing a cultural resources management plan, if necessary, for handling eligible facilities at the LLNL Livermore site. This approach is consistent with the intent of the 1991 Advisory Council on Historic Preservation publication to

protect the ability of the LLNL Livermore site to perform its mission and upgrade facilities, while fulfilling regulatory requirements to consider significant historic resources. For instance, the cultural resources management plan will define which facilities are eligible for the National Register; how alterations of those facilities will be managed in order to consider the historic importance of the facility (e.g., recording information before alterations affecting historic value are made); when and how consultation with the Office of Historic Preservation will occur; and what role the LLNL Livermore site archives and visitor center will play in preserving and interpreting historic information.
- Prior to completion of an agreement document, if individual projects of the proposed action are being considered for funding, Section 106 compliance will occur through the normal environmental review of individual projects in accordance with the National Historic Preservation Act, NEPA, and CEQA.

H.3.2 LLNL Site 300

Reconnaissance in 1981 (Busby, Garaventa, and Kobori, 1981) located a number of historic resources described in preceding sections of this appendix. Seven of these resources (none of which were considered by the researchers to be eligible for the National Register) could not be relocated during the 1991 field survey and are either obscured or have disappeared. No record of a formal Determination of Eligibility by the State Historic Preservation Office is currently available. One additional historic resource was collected during the 1981 survey. The recorded locations of four of the historic resources which have apparently disappeared fall within the Area of Potential Effect in the southeastern portion of LLNL Site 300. Because these resources could not be relocated in the field, and the initial evaluation of the sites was, in the researchers opinion, one of non-significance, they are considered no further in this EIS/EIR.

Busby, Garaventa, and Kobori (1981) stated that the inventory of potentially important historic resources at LLNL Site 300 is not considered complete; additional archival research was recommended in the 1981 report to clarify identification of existing resources and to locate new areas of potential historic resources associated with the industrial uses of the Corral Hollow area at the turn of the century. Archival research and site evaluation for the Carnegie area has recently been conducted (William Self Associates, 1992).

The presence of historic resources in the Carnegie area within the southern portion of LLNL Site 300 is being evaluated. No record of a formal Determination of Eligibility by the State Historic Preservation Office is currently available for any identified cultural resources at LLNL Site 300. The following measures have been or will be undertaken to address historic resources inside LLNL Site 300 in compliance with the Section 106 process.

- In compliance with Section 106 of the National Historic Preservation Act, additional archival research for the area in the southern portion of LLNL Site 300 has recently been undertaken to further define what historic remnants of the town of Carnegie lie within the LLNL Site 300 boundaries. The archival leads identified in the 1981 report have been investigated and efforts have been made to rectify the lack of correlation between resources located in archives and surface indicators discovered onsite.
- If warranted, based on the results of the archival research, a program of surface inspections and subsurface testing will be implemented in those portions of the Area of Potential Effect along the southern site boundary. This will clarify the locations and characteristics of the additional historic resources associated with the town of Carnegie thought to be on the hills and in the drainages on the north side of Corral Hollow Road.
- Precise mapping of all historic cultural resource areas discovered within the Area of Potential Effect will be prepared. This mapping may require small-scale mechanical subsurface investigations and/or surface clearing. If exact resource boundaries cannot be defined, resource areas will be mapped to include a buffer area clearly outside the cultural deposits or features.
- Additional steps to satisfy the Section 106 process will be implemented if any sites are determined, in consultation with the State Historic Preservation Office, to be eligible for the National Register. Application of the Criteria of Effect and Adverse Effect would be applied to sites determined eligible for the National Register. Should adverse effects be anticipated, an agreement document would be prepared between DOE, the Advisory Council on Historic Preservation and/or the State Historic Preservation Office as a means of mitigating potential effects and developing a cultural resource management plan to direct preservation and custodial responsibilities

for the properties. Approval of the agreement by all parties would conclude the Section 106 process.

- Until such time that a cultural resources management plan is developed as part of the agreement document, if necessary, Section 106 compliance will occur through the normal environmental review of individual projects in accordance with the National Historic Preservation Act, NEPA, and CEQA.

APPENDIX H GLOSSARY

Archaeological resources	*See* Cultural resources (prehistoric).
Archival research	Examination of records at the regional offices of the State Historic Preservation Office for evidence of recorded historic and/or prehistoric sites; the use of other archival sources (libraries, private collections, museums) to gather information on historic and prehistoric sites that have not been formally recorded or that have not been completely documented.
Area of Potential Effect (APE)	In the context of Section 106 of the National Historic Preservation Act, the area in which planned development may directly or indirectly affect a cultural resource. The area is determined by the federal lead agency in the Section 106 process.
Augering	Use of a hand or power auger to investigate areas for evidence of archaeological midden deposits.
Bedrock mortar	Depression worn in the floors of rock shelters or on the flat portions of exposed bedrock where prehistoric peoples ground grass seeds and acorns into meal. The depression is created by the continual grinding motion of a stone pestle, which is alternately used to pound and grind from side to side.
Cultural resources (historic)	Material remains, such as trash dumps and architectural features, including structures, foundations, basements, and wells; any other physical alteration of the landscape, such as ponds, roads, landscaping, and fences.
Cultural resources (prehistoric)	Any material remains of items used or modified by people, such as artifacts of stone, bone, shellfish, or wood. Animal bone, fish remains, bird bone, or shellfish remains used for food are included. Physical alteration of the landscape, such as hunting blinds, remains of structures, excavated house pits, and caches of artifacts or concentrations of stones (such as cooking stones) are also prehistoric cultural resources.
Hispanic era	The period in California history from the arrival of the Spanish missions in central California, circa 1776, to the start of the Gold Rush era in 1849.
Historic resources	The sites, districts, structures, and objects considered limited and nonrenewable because of their association with historic events or persons, or social or historic movements.
Lithic scatter	Concentrations of stone once used for the manufacture of artifacts. The stone includes finished artifacts, roughly formed artifacts, the cores of the stone from which they were made, and the waste flakes from the manufacturing process.
Midden	Characteristic soils containing cultural resources and other evidence of use of an area, such as the decomposed organic remains of vegetal foods, animals, and evidence of fires (e.g., ash, carbon, charcoal). Because of the organic content, midden soils tend to differ from surrounding soils in texture and color.
National Register of Historic Places	A register of districts, sites, buildings, structures, and objects significant in American history, architecture, archaeology, engineering, and culture. It is in the Department of the Interior and was established pursuant to the National Historic Preservation Act of 1966, as amended (16 U.S.C. section 470a).
Paleontological resources	Fossils.
Petroglyph	Art that was carved or inscribed into bedrock by historic or prehistoric people.
Prehistoric resources	*See* Cultural resources (prehistoric).

Rock shelter	An opening in exposed rock of sufficient size to allow people to be sheltered from the weather. Used by both historic and prehistoric people, rock shelters contain midden deposits, grinding holes, evidence of fires, artifacts, and sometimes artwork carved or inscribed onto the walls of the shelters.
Section 106 process	A historic preservation review process involving identification and evaluation of historic properties, consideration of project effects on them, and resolution of these effects in the public interest through consultation.
Trinomial designation	A numeric site designation assigned by the regional offices of the State Historic Preservation Office for recording a prehistoric or historic site.

APPENDIX H REFERENCES

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APPENDIX I SEISMIC SAFETY PROGRAM

I.1 INTRODUCTION

The purpose of this appendix is to analyze the potential for earthquake-induced damage to structures and equipment containing hazardous and/or radioactive materials, and to structures and equipment important for emergency response to hazardous and/or radioactive material releases. The general description in section I.2 briefly highlights the main steps undertaken in order to make these analyses.

The relationship of this appendix to others, and to Sections 4 and 5 of the EIS/EIR, is shown in Figure I-1. The results of this appendix are used in Appendix D to estimate onsite and offsite potentials for dispersals of hazardous and/or radioactive materials due to an earthquake; and in Appendix J, where emergency planning and response is discussed.

Throughout Appendix I both English units (feet, inches, etc.) and metric units (meters, centimeters, etc.) of measurement are used. The use of different measurements in different parts of the appendix, often within the same section, occurs primarily because the appendix attempts to report data strictly as presented by the referenced source. Rather than converting all measurement data to a single set of units, conversion equations for the most common units are provided in the Glossary at the end of this appendix.

I.2 GENERAL DESCRIPTION OF APPENDIX I CONTENTS

In the following sections I.3 through I.6, the steps undertaken to analyze potentials for earthquake-induced damage are discussed. The main steps were:

- Identifying structures and equipment for which a prediction is necessary;
- Obtaining the original design calculations (or any more recent evaluations that may exist) that address the seismic capacities of the building and critical equipment;
- Defining the seismic hazards to which the structures and equipment would be subjected, based on the most recent site-specific seismological studies available;
- Selecting criteria for evaluating whether or not the seismic strength of the structures and equipment is adequate to resist the seismic hazards;
- Developing and implementing a methodology that utilizes the selected criteria in a simplified manner so that a number of different types of structures and equipment could be evaluated. The developed methodology utilizes the original design calculation, or more recent reevaluation (and the seismic design criteria upon which they were based), as the basis from which extrapolations are made in developing predictions of current seismic adequacy; and
- Performing the comparison of the seismic strength of structures and equipment to the seismic hazards postulated to act on them.

Structures and equipment with seismic strength inadequate to meet the criteria in section I.5 when subjected to the forces from the postulated earthquake were assumed to sustain damage. Building function was assumed to be lost, and hazardous and/or radioactive material confinement was assumed to be compromised as described in Appendix D. Section I.7 describes the historical seismic design criteria used at LLNL and SNL, Livermore.

Section I.8 summarizes the predicted potentials for loss of hazardous/radioactive materials confinement and/or building function, and provides guidance in interpreting the tabular results.

Two major conservative assumptions were made in arriving at the predictions described in section I.8. When a structure or piece of equipment was found not to meet current seismic strength requirements, it was *assumed* to be deficient to the point where hazardous and/or radioactive material release was possible. Also, if no existing seismic documentation could be found for a particular structure, it was *assumed* not to meet seismic strength requirements.

I.3 SELECTION OF STRUCTURES FOR SEISMIC EVALUATION

Structures and equipment were evaluated for seismic response for two reasons: (1) they contain quantities of hazardous and/or radioactive materials that are in a dispersable form such as gases or powders that could become airborne, or (2) they are considered important for emergency response to a seismic event that could release hazardous and/or radioactive materials. (These structures and equipment are hereafter referred to as "emergency response structures.") Sources identifying structures that contain hazardous and/or radioactive materials were reviewed and verified as described in Appendix D. Identification of structures important to emergency response is discussed in Appendix J. The complete list of structures evaluated is provided in section I.8.

LLNL Livermore Site

Most of the structures at LLNL which were identified in Appendix D as representing the bounding cases for potential accidental releases of dispersable hazardous and/or radioactive materials, were already listed by LLNL as either moderate or high hazard in accordance with DOE Order 5481.1B. The other buildings identified in Appendix D to be of concern from the standpoint of potential releases were listed by LLNL as low hazard. These were Buildings 141, 151, 166, 322, 518, and the 490 complex. As identified in Appendix D, only Building 493 within the 490 complex represented an accidental release scenario with potentially bounding consequences. The structures at LLNL identified in Appendix J as important to emergency response, and evaluated here in Appendix I, were not given a hazard ranking by LLNL. However, structural calculations reviewed treated these structures as moderate or high hazard. It should be noted that not all structures classified by LLNL as moderate hazard required evaluation. It was determined that the dispersable quantities of radioactive and/or hazardous materials in some structures were too low to model in an accident analysis, even assuming a seismic reaction resulting in maximum dispersion of materials. For some hazardous or radioactive materials, such a reaction would be a structural collapse followed by a fire; for others it would be structural collapse followed by inundation by water (e.g., from broken water pipes). Examples of moderate hazard structures not requiring seismic evaluation are Building 854, Dynamic Test Facility, and Building 191 High Explosives Applications Facility. While these structures represent a potential health and safety hazard because of the presence of high explosives, they do not contain dispersable radioactive or hazardous materials.

LLNL Site 300

No structures at LLNL Site 300 were identified as containing sufficient quantities of dispersable hazardous material to warrant concern; therefore, emergency response structures at LLNL Site 300 would not be needed to mitigate the consequences of releases of hazardous materials after an earthquake. For this reason, seismic evaluation of LLNL Site 300 emergency structures was unnecessary for purposes of this EIS/EIR. However, for purposes of assessing risks associated with seismic hazards for future proposed actions at LLNL Site 300, those hazards and applicable design criteria at LLNL Site 300 are provided in this appendix.

SNL, Livermore

At SNL, Livermore the review and limited verification of sources identifying structures that contain hazardous and/or radioactive materials resulted in only two structures identified as requiring a seismic response prediction. Building 968, Tritium Research Laboratory, is evaluated because it contains hazardous and/or radioactive materials. Building 964, Emergency Communications Building, is required to be operational after a seismic event that causes a hazardous and/or radioactive material release at Building 968. As described in Appendix J, all other emergency response operations required after a seismic event that releases hazardous and/or radioactive materials at SNL, Livermore are carried out via the emergency response facilities at the LLNL Livermore site.

I.4 SEISMIC HAZARDS

This section describes the characteristics of the postulated earthquake event as well as the site-specific geologic data which provides the basis for the postulated event.

I.4.1 Seismic Event Definition

As described more fully in section I.5, the primary initiating event considered here is an earthquake with a mean return period of 5000 years. In other words, there is a 1 in 5000 chance that an earthquake producing larger ground accelerations than those postulated would occur in any given year; thus, the annual exceedence probability is 2×10^{-4}. The key characteristics of this potential earthquake were developed based on site-specific geologic data corresponding to the LLNL and SNL, Livermore areas (see section 4.7 of the EIS/EIR for details of site geology) and are described in detail in section I.4.2. The earthquake would have a 0.8g effective peak ground acceleration (where 1.0g is the acceleration due to gravity) and maximum ground motion amplification factors of 2.12 at 5 percent damping, and 1.64 at 10 percent damping. Mean amplifications were selected for the reasons discussed in section I.5.

Secondarily, an "Above Design Basis" seismic event is also defined. Because the highest design basis event used at either LLNL or SNL, Livermore is a 0.8g, 5000-year return interval earthquake, an Above Design Basis event must exceed this. Consequently, the Above Design Basis event assumes a return period of 10,000 years corresponding to the maximum extension of published data for the LLNL and SNL, Livermore sites as expressed in Geomatrix (1991). This earthquake would have a 0.9g effective peak ground acceleration with the same amplification factors as described above for the 5000-year event. Limiting this event to a 10,000-year return interval is based on the lack of any research (published or unpublished) indicating that a larger magnitude earthquake is conceivable on the local fault systems. As for the 5000-year event, the key characteristics of this earthquake were developed based on site-specific geologic data corresponding to the LLNL and SNL, Livermore areas. As a rough comparison the January 24 and January 27, 1980, Livermore earthquakes, recorded as 5.4 and 5.6 Richter Magnitude events, generated maximum measured peak ground accelerations of 0.26g at a distance of 18 km from the epicenter. The October 17, 1989, Loma Prieta earthquake, recorded as a 7.1 Richter Magnitude event, generated maximum measured peak ground accelerations of 0.68g at a distance of 7 km from the epicenter.

As a comparison with the seismic events evaluated in this study, the 1990 *Design and Evaluation Guidelines for DOE Facilities Subjected to Natural Phenomena Hazards*, UCRL 15910 (Kennedy et al., 1990), reported that the 1988 Uniform Building Code and the Applied Technology Council recommended a design seismic hazard level which has about a 10 percent frequency of exceedence in 50 years, or about a 2×10^{-3} annual exceedence probability (a return period of 500 years). The most current versions of these two codes are currently used in the design and evaluation of not only common industrial facilities but more important structures such as schools, hospitals, and fire stations. Kennedy et al. (1990) also report that recent probabilistic hazard studies have been performed to assess the governing seismic design ground motions (Safe Shutdown Earthquake) at U.S. commercial nuclear power plants. The design Safe Shutdown Earthquake levels were found to generally correspond to an estimated mean annual exceedence probability of between 10^{-3} and 10^{-4} (Kennedy et al., 1990).

I.4.2 Seismicity of LLNL and SNL, Livermore

I.4.2.1 Seismotectonic Setting

Lawrence Livermore National Laboratory (LLNL) and Sandia National Laboratories, Livermore (SNL) are located in the southeastern portion of Livermore Valley, a fault-bounded valley within the Diablo Range of the Coast Ranges Geologic Province (Figure I-2). The tectonics of the Coast Ranges are characterized by northwest-trending right-lateral, strike-slip faults of the San Andreas fault system. Geological, seismological, and geodetic data all indicate that this fault system accommodates the relative motion between the North American and Pacific plates across a zone approximately 100 km wide (Ellsworth et al., 1981; Prescott et al., 1981). Situated east of the San Francisco Bay, the Laboratory sites are in the vicinity of the transform plate margin of the North American and Pacific plates. At the latitude of LLNL and SNL, Livermore, the faults of the San Andreas fault system include, from west to east, the San Gregorio, San Andreas, Hayward, Calaveras, and Greenville faults (Figure I-2). The Livermore Valley, underlain by thick alluvial deposits, is bounded by the Calaveras fault to the west and the Greenville fault to the east (Figure I-2 and Figure I-3).

East of the Coast Ranges lies the Sierran block, which is composed of the Great Valley and Sierra Nevada Mountain Range. The boundary between the Coast Ranges and Sierran block lies approximately 15 km east of LLNL Site 300 (Figure I-2) and marks a significant change in tectonic structure and seismicity. Recent studies indicate the Coast Range–Sierran block boundary is characterized by east-northeast directed compression, resulting in reverse and thrust faulting (Wong et al., 1988; Wentworth and Zoback, 1989).

I.4.2.2 Historical Seismicity

Preinstrumental

The greater San Francisco Bay Area has experienced several damaging earthquakes since 1800 when the first reported earthquake damage occurred at Mission San Juan Bautista. The historical record of seismicity from 1800 to 1932 is based primarily on the felt effects and damage reported by the population and is considered the preinstrumental record. The instrumental record of seismicity in California is based on the instrumental measurement of earthquakes, which began in 1932 with the establishment of statewide seismographic coverage. Interpretation of the preinstrumental record has provided the approximate locations and magnitudes of many important California earthquakes. Because the preinstrumental record covers a longer period than the instrumental record, it is an important indicator of the larger, less frequent earthquakes (Toppozada et al., 1986).

Significant preinstrumental earthquakes greater than magnitude 5.8 that have occurred in the greater San Francisco Bay Area are shown in Figure I-2 and listed in Table I-1. It can be readily seen that the San Andreas and Hayward faults have repeatedly produced damaging earthquakes in the region. The largest was the great 1906 San Francisco earthquake of estimated magnitude 8.3, which ruptured nearly 450 km of the San Andreas Fault from near Cape Mendocino on the north to San Juan Bautista on the south. This event produced limited damage in Livermore Valley (Lawson et al., 1908). The 1861 Calaveras earthquake (magnitude 6), located along the western margin of Livermore Valley, caused damage in Livermore (Radbruch, 1968).

The Vacaville and Winters earthquakes of 1892 were located north of the LLNL Livermore site and SNL, Livermore along the Coast Range–Sierran block boundary. These two events may have been centered on a blind-thrust fault, similar to the recent 1983 magnitude 6.7 Coalinga and 1985 magnitude 5.7 North Kettleman earthquakes, located to the south along the Coast Range–Sierran block boundary (Eaton, 1986).

With the possible exception of the 1861 earthquake on the Calaveras fault, the Modified Mercalli intensities at the LLNL and SNL, Livermore sites, for the preinstrumental earthquakes shown in Table I-1 are unknown but probably would have been lower than those shown in that table based on the significant distances from the estimated epicenters.

Instrumental

The ability to record earthquakes and their characteristics has increased dramatically since the first seismometers were deployed in the region. Seismic networks today, combined with an increased understanding of crustal structure and velocity models, have not only allowed a greater number of events to be recorded but also increased the amount and resolution of data collected regarding the location, depth, and focal mechanisms for these events. Seismicity can now be used to identify and characterize seismic sources that have not yet been recognized from the surface geology, as well as identify seismic gaps where future earthquakes are more likely to occur.

The seismicity of the eastern San Francisco Bay Area is characterized by both an alignment of earthquake epicenters along major faults and a random distribution of earthquakes that do not display any obvious relation to mapped faults (Ellsworth et al., 1982). While many of the mapped faults are easily identified by a concentration of seismicity, other mapped faults, such as those in the Livermore Valley, are not well defined by seismicity (Ellsworth et al., 1982).

In 1980, LLNL installed a digitally recorded seismic network in the Livermore Valley region to augment the existing U.S. Geological Survey Calnet stations (Scheimer et al., 1982). Seismicity patterns in the valley show a well-defined region of activity along the Greenville fault, which is predominantly associated with the 1980 Livermore earthquake sequence (Figure I-3). The 1986 Mt. Lewis earthquake sequence forms a north-south linear pattern which is not coincident with any mapped fault (Figure I-3). The largest earthquake during this sequence was a ML 5.7 (Person, 1986). A less well defined area of activity may be associated with either the Williams or Valle fault (Figure I-3). In most cases earthquakes are predominantly strike-slip, consistent with generally north-south compression (Scheimer et al., 1982; Followill and Mills, 1982).

Since 1932 there have been only two earthquakes greater than magnitude 6 in the greater San Francisco Bay Area, one event on the southern portion of the Calaveras fault and the other on the San Andreas fault (Table I-2). The earthquake causing the most damage in the Livermore Valley region since the beginning of the instrumental period was the 1980 magnitude 5.5 event that was centered on the Greenville fault approximately 20 km northwest of the LLNL Livermore site (Figure I-3; Bolt et al., 1981). This earthquake, which occurred on January 24, was followed by a series of events, including a magnitude 5.6 shock on January 26 located 14 km south of the main shock (Bolt et al., 1981). The earthquake sequence produced minor amounts of surface rupture along portions of the Greenville fault and perhaps the Las Positas fault. The Greenville fault produced right-lateral displacements up to 25 mm and the Las Positas fault exhibited left-lateral displacements of 1.5 mm across fractures and 6 mm across an alignment array (Bonilla et al., 1980). At the time of the earthquake there were no strong-motion instruments in the Livermore Valley, but estimates of ground acceleration at LLNL ranged from 0.2 to 0.3g (Freeland, 1984).

Table I-1 Preinstrumental Earthquakes Greater Than Richter Magnitude 5.8 in the Greater San Francisco Bay Region for 1800–1932

Date (year/month/day)	Epicenter Location	Fault	Modified Mercalli Intensity[a]	Estimated Richter Magnitude[a]
1836/06/10	Hayward	Hayward	VIII	6.8
1838/06	San Francisco	San Andreas	VIII	7.0
1858/11/26	San Jose	Hayward	VII	6.1
1865/10/08	Santa Cruz Mtns	San Andreas	IX	6.3
1861/07/03	Amador Valley	Calaveras	VIIIb	~6.0[c]
1886/07/15	North San Joaquin Valley	?	VI	5.8
1881/04/10	Modesto (or farther west)	?	VI	6.0
1889/05/19	Antioch	?	VIII	6.0
1868/10/21	Hayward	Hayward	IX+	6.8

1892/04/19	Vacaville	?	IX	6.4
1892/04/21	Winters	?	IX	6.2
1892/04/30	NE of Vacaville	Midland?	VI	6.0[b]
1898/03/31	Napa?	?	IX	6.2
1906/04/18	San Francisco	San Andreas	IX+	8.3
1911/07/01	San Jose	Hayward	VII	6.6

[a] From Toppozada et al., 1986. Note: Mercalli intensity values are the maximum observed in any location for a particular earthquake. They may or may not have been located at the epicenter. See Table I-2 for a description of the Modified Mercalli levels.

[b] Wong et al., 1988.

[c] From U.S. Geological Survey, 1982; Radbruch, 1968.

? Indicates uncertainty expressed by authors in the referenced text.

Table I-2 Instrumental Earthquakes Greater Than Richter Magnitude 5.5 in the San Francisco Bay Region for 1932–1990

Date (year/month/day)	Epicenter Location	Fault	Modified Mercalli Intensity[a]	Estimated Richter Magnitude
1955/09/04	San Jose?	Calaveras?	VII	5.5[b]
1969/10/01	Santa Rosa?	?		5.7[b]
1979/08/06	Coyote Reservoir	Calaveras	VII	5.8[c]
1980/01/24	Livermore	Greenville	VII	5.5[d]
1980/01/27	Livermore	Greenville	VI	5.6[d]
1984/04/24	Morgan Hill	Calaveras	VII	6.2[c]
1986/03/31	Mount Lewis	?	VI	5.7[e]
1989/10/17	Loma Prieta	San Andreas	VIII	7.1[f]

[a]Toppozada et al., 1986. Note: Mercalli intensity values are the maximum recorded in any location for a particular earthquake. They may or may not have been located at the epicenter. See below for description of Modified Mercalli levels.

MODIFIED MERCALLI INTENSITY SCALE OF 1931

I Not felt except by a very few under especially favorable

V Felt by nearly everyone, many awakened,

circumstances.	some dishes, windows, etc., broken; a few instances of cracked plaster; unstable objects overturned. Disturbances of trees, poles, and other tall objects sometimes noticed. Pendulum clocks may stop.
II Felt only by a few persons at rest, especially on upper floors of buildings. Delicately suspended objects may swing.	VI Felt by all, many frightened and run outdoors. Some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
III Felt quite noticeably indoors, especially on upper floors of buildings, but many people do not recognize it as an earthquake. Standing motorcars may rock slightly. Vibration like passing of truck. Duration estimated.	VII Everybody runs outdoors. Damage negligible in building of good design and construction; slight to moderate in well-built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving motorcars.
IV During the day felt indoors by many, outdoors by few. At night some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motorcars rocked noticeably.	X Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations; ground badly cracked. Rails bent. Landslides considerable from river banks and steep slopes. Shifted sand and mud. Water splashed (slopped) over banks.
VIII Damage slight in specially designed structures; considerable in ordinary substantial buildings, with partial collapse; great in poorly built structures. Panel walls thrown out of frame structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned. Sand and mud ejected in small amounts. Changes in well water. Persons driving motorcars disturbed.	XI Few, if any, (masonry) structures remain standing. Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service. Earth slumps and land slips in soft ground. Rails bent greatly.
IX Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb; great in substantial buildings, with partial collapse. Buildings shifted off foundations. Ground cracked conspicuously. Underground pipes broken.	XII Damage total. Practically all works of construction are damaged greatly or destroyed. Waves seen on ground surface. Lines of sight and level are distorted. Objects are thrown upward into the air.

[b] Uhrhammer, 1986.

[c] Uhrhammer and Darragh, 1984.

[d] Bolt et al., 1981.

[e] Person, 1986.

[f] McNutt and Sydnor, 1990.

? Indicates uncertainty expressed by authors in the referenced text.

I.4.2.3 Seismic Sources

The three principal strands of the San Andreas fault system, the San Andreas, Hayward, and Calaveras faults, have produced the majority of significant historical earthquakes in the San Francisco Bay Area. As these three faults also accommodate the majority of dextral motion across the Pacific–North American plate boundary, they would likely continue to generate moderate to large earthquakes more frequently than other faults in the region; however, it is the local faults in the Livermore Valley region that contribute the majority of the seismic hazard to LLNL and SNL, Livermore (Figure I-4; TERA Corporation, 1983; Scheimer, 1985). Based on probabilistic seismic hazard analyses, the largest contribution to the ground-shaking hazard (in terms of both magnitude and return interval) at the LLNL Livermore site is produced by moderate earthquakes on the Greenville, Las Positas, Verona, and Calaveras faults (Geomatrix Consultants, 1985; Scheimer, 1985). Larger earthquakes on more distant faults such as the San Andreas do not significantly affect the hazard estimation.

For seismic hazard assessments, various criteria have been proposed for defining an "active fault." The State of California defines a fault as active if it displays evidence of displacement within the last 11,000 years (Hart, 1988). The U.S. Army Corps of Engineers, in evaluating critical facilities, defines a fault as active if it shows evidence of having displaced materials approximately 35,000 years old or younger. The U.S. Nuclear Regulatory Commission defines a fault as active if it shows evidence of a single rupture in the last 35,000 years or multiple displacements within the last 500,000 years. The LLNL Site Seismic Safety Project staff has decided to consider a fault that has displaced materials of 35,000 years or younger as active (Carpenter et al., 1984).

San Andreas Fault

The LLNL Livermore site and SNL, Livermore lie approximately 58 km northeast of the San Andreas fault (Figure I-2), which traverses over 1100 km of California. The San Andreas fault is responsible for generating great earthquakes in 1857 and 1906. The recent 1989 Loma Prieta earthquake of magnitude 7.1, centered approximately 72 km from LLNL and SNL, Livermore, occurred on the southern Santa Cruz Mountains segment of the San Andreas fault. The maximum peak horizontal ground acceleration recorded was 0.65g approximately 7 km from the epicenter and 1 km from the fault (Corralitos station). In Livermore, a strong-motion instrument located approximately 8 km northeast of the LLNL Livermore site recorded 0.04g during the 1989 event (Shakal et al., 1989).

Slip rates for the central and south central segments of the San Andreas fault are 33 mm/yr (Thatcher, 1979) and 33.9 mm/yr (Sieh and Jahns, 1984) using geodetic and geologic data, respectively. Due to the partitioning of slip from the San Andreas fault to the Hayward and Calaveras fault zones, slip-rate estimates decrease northward to 22 mm/yr near Olema (Niemi and Hall, 1991) and 23 mm/yr at Point Arena (Prentice, 1989).

The Working Group on California Earthquake Probabilities (1990) has estimated 30-year conditional probabilities of 23 percent for a magnitude 7 event occurring on the San Francisco Peninsula segment, and 2 percent for a magnitude 8 event occurring on the north coast segment of the San Andreas fault.

Hayward Fault

The strike-slip Hayward fault is approximately 80 km long and extends along the eastern margin of the San Francisco Bay plain from Suisun Bay on the north to its convergence with the Calaveras fault southeast of San Jose. The Hayward fault, which lies about 26 km southwest of the LLNL Livermore site and SNL, Livermore (Figure I-3) at its closest approach, is the southern segment of a zone of faulting that extends 280 km northwest to Mendocino County and includes the Rodgers Creek, Healdsburg, and Maacama faults (Slemmons and Chung, 1982).

Historically, the Hayward fault has produced two earthquakes of approximately magnitude 7, in 1836 and 1868, which produced Modified Mercalli Intensities of VIII and IX+ (Toppozada et al., 1986). Both events produced surface faulting on the Hayward fault (Coffman and von Hake, 1973; Radbruch, 1968).

Paleoseismic studies near Fremont (Figure I-3) have revealed evidence of a minimum of five and possibly seven earthquakes in the past 2000 years, inferring a maximum average recurrence time of 250 to 400 years (Williams, 1991). A Holocene slip rate of 7 to 9 mm/yr has been established for the central portion of the Hayward fault where the historic creep rate has been about 5 mm/yr, implying that strain is accumulating on the fault (Lienkaemper and Borchardt, 1991). Galehouse (1990) has measured creep rates of about 4.5 mm/yr at five locations along the Hayward fault for the past 10 years.

The Working Group on California Earthquake Probabilities (1990) has estimated 30-year conditional probabilities of 23 percent and 28 percent for a magnitude 7 event occurring on the southern and northern segments of the Hayward fault.

Calaveras Fault

The Calaveras fault zone is approximately 115 km in length from its southern junction with the San Andreas near Hollister to its northern terminus in San Ramon Valley. The Calaveras fault forms the western margin of Livermore Valley and is located about 17 km west of the LLNL Livermore site and SNL, Livermore (Figure I-3).

The Calaveras fault has generated several moderate and a few large earthquakes. In 1861 an estimated magnitude 6+ earthquake occurred along the western margin of the Livermore Valley (Amador Valley) and produced strong ground shaking (Radbruch, 1968). More recent events in 1979 and 1984 ruptured adjacent segments of the fault near Coyote Reservoir and Halls Valley. The 1979 ML 5.8 Coyote Lake earthquake ruptured a 22-km segment of the Calaveras fault, while the 1984 ML 6.2 Morgan Hill (Halls Valley) earthquake ruptured a 26-km-long segment immediately north of the 1979 event (Uhrhammer and Darragh, 1984). During the past 11 years near its southern end the Calaveras fault has been creeping at average rates of about 7.5 mm/yr and 11.5 mm/yr at two separate locations, whereas at its northern end in San Ramon Valley almost no creep has been detected for the past 10 years (Galehouse, 1990). Slip along the northern Calaveras fault appears to step across to the Concord–Green Valley fault zone along a northeast-trending conjugate left-lateral fault that produced the April 1990 Alamo earthquake sequence with the largest event of magnitude 4.5 (Oppenheimer and MacGregor-Scott, 1991).

Microseismicity occurs along much of the length of the Calaveras fault except for the 30-km-long segment from Calaveras Reservoir to Dublin, which Oppenheimer and MacGregor-Scott (1991) have identified as a seismic gap capable of generating a magnitude 6.0 to 6.5 earthquake.

Greenville Fault

The northwest-trending central Greenville fault system, consisting of several segments or strands, is located approximately 1.5 km east of the LLNL Livermore site and 3.7 km east of SNL, Livermore (Figure I-4 and Figure I-5). The fault is exposed for over 80 km along its length, from the north end, near Mt. Diablo, to its southern terminus in San Antonio Valley along the eastern side of Livermore Valley (Herd, 1977; Dibblee 1980a, 1980b).

On January 24, 1980, an earthquake of magnitude 5.5 (Bolt et al., 1981) caused discontinuous right-lateral surface displacements along the southeastern branch of the Greenville fault, approximately 20 km northeast of the LLNL Livermore site. Fault-plane solutions indicate a focal depth of 11.8 km (Bolt et al., 1981). The first principal shock was followed by a rapid succession of magnitude 5.0 and 4.0 earthquakes, resulting in a relatively long duration of ground shaking. The earthquake was followed by a series of aftershocks, culminating in a magnitude 5.6 (Bolt et al., 1981) event on January 27, 1980, located 14 km to the south of the first principal shock. The focal depth of the January 27 earthquake was 11.8 km (Bolt et al., 1981). The maximum peak horizontal ground acceleration recorded during the earthquake was 0.26g at Del Valle Reservoir (Freeland, 1984), located 18 km from the epicenter (Figure I-4). Although there were no strong-motion instruments at the LLNL Livermore or SNL, Livermore sites, estimates of accelerations were approximately 0.2 to 0.3g (Freeland, 1984).

The southernmost segment of the Greenville Fault extends for over 36 km. Based on offset stream terraces, the slip rate is estimated at 0.5 to 0.7 mm/yr (Wright et al., 1982). The segment of the fault located east and north of the Laboratories extends approximately 34 km to the north, with slip rates estimated at 0.1 to 0.3 mm/yr based on an offset paleosol (Wright et al., 1982). Immediately following the January 1980 event described above, surface displacements were observed along a 6.2-km length of the fault, with a maximum right lateral displacement of approximately 25 mm (Bonilla et al., 1980). No surface displacements were observed along the northernmost segment of the Greenville Fault. The slip-rate estimates for the Greenville Fault are consistent with the Carpenter et al. (1984) estimated average slip rate of 0.5 to 0.75 mm/yr, based on the apparent right-lateral offset of a Plio-Pleistocene syncline, southeast of the LLNL Livermore site and SNL, Livermore.

Las Positas Fault

The northeast-trending left-lateral Las Positas fault zone, consisting of a northern and southern branch, is located less than 0.5 km southeast of the LLNL Livermore site (Figure I-4 and Figure I-5) along the southeast margin of Livermore Valley (Dibblee, 1980a). The northern branch, which crosses the SNL, Livermore site, can be traced for over 18 km and intersects the Verona and Williams faults to the southwest (Figure I-4; Dibblee, 1980a, 1980c). Left-lateral offsets on modern stream drainages, tonal contrast in soil and vegetation, and a well-defined topographic lineament have been identified along the north branch of the Las Positas fault. The most significant historical earthquake tentatively assigned to the Las Positas fault zone occurred on June 11, 1903, with an estimated magnitude of 5.5 (Wong and Biggar, 1989). Minor aseismic slip along the southern branch of the Las Positas may have been triggered by the January 1980 Greenville earthquakes (Bonilla et al, 1980). Left-lateral displacement, approximately 1.5 mm across fractures and 6 mm across an alignment array, was reported by Bonilla et al., (1980). In the following weeks two events, ML 2.6 on February 12, 1980, and ML 3.2 on February 21, 1980, produced minor ground shaking at the LLNL Livermore site (Scheimer et al., 1982). Peak ground accelerations from these earthquakes were approximately 0.04g (Scheimer et al., 1982). The February earthquakes occurred quite close to ground fractures documented by Bonilla et al. (1980). Slip rates for the Las Positas fault zone were determined by different lines of geologic evidence, including offset late Quaternary erosion surfaces and colluvial deposits. The estimated average slip rate for the northern branch ranges from 0.05 to 0.9 mm/yr and for the southern branch from 0.3 to 0.5 mm/yr (Carpenter et al., 1984). The overall estimated slip rates for the Las Positas fault zone are broadly similar to the calculated rates for the Greenville fault. It is likely that motion on the Greenville Fault may trigger slip along portions of the Las Positas fault (Bonilla et al., 1980). An active growth anticline may be presently forming between the two branches of the Las Positas fault and beneath the southernmost edge of SNL, Livermore. Evidence for a growth structure is provided by the presence of topographically high wind gaps and isolated hills that are underlain by deformed Plio-Pleistocene gravels (Shlemon and Qualheim, 1991).

Verona Fault

The arcuate, northwest-trending Verona fault is approximately 6 km long and is located approximately 9 km southwest of the LLNL Livermore site and SNL, Livermore (Figure I-4; Herd, 1977). The fault is truncated by the Las Positas fault to the southeast and by the Calaveras Fault system to the northwest (Rogers, 1966; Herd, 1977). The Verona fault, a moderately to steeply dipping reverse fault, cuts Plio-Pleistocene gravels along a discontinuous line of springs and seeps (Herd, 1977). It is likely that a low-angle decollement projects to the northeast beneath Plio-Pleistocene gravels towards Livermore Valley along the subsurface trace of the Verona fault.

Minor seismicity associated with the Verona Fault has been reported by Ellsworth and Marks (1980). Historical events with estimated magnitudes of 3.0 to 4.0 were recently relocated along the Verona fault (Wong and Biggar, 1989). Based on offset buried soils and Plio-Pleistocene gravels, the estimated slip rate for the Verona fault is approximately 0.2 mm/yr (Clark et al., 1984).

Williams Fault

The northwest-trending Williams fault, approximately 18 km long, is truncated by the Las Positas fault system to the north and is located approximately 10.5 km from the LLNL Livermore site and SNL, Livermore (Figure I-4). The fault juxtaposes older Great Valley Sequence rocks on the northeast against Plio-Pleistocene sediments and older Franciscan Assemblage rocks to the southwest (Dibblee, 1980c, 1981a). Based on strike-slip *focal plane* mechanisms for microearthquakes (Followill and Mills, 1982) and stratigraphic offset, the Williams fault is interpreted as a right-lateral reverse fault.

Although no large historic earthquakes have been documented along the Williams fault, in August 1980 a swarm of microearthquakes (ML 1.0–3.0) (Followill and Mills, 1982) occurred along the Williams fault system. In addition, recent seismicity along the fault (Ellsworth et al., 1982) suggests it is active and a potential seismic source. Slip rates have not been determined for the Williams Fault.

Corral Hollow–Carnegie Fault

The northwest-trending Corral Hollow–Carnegie fault zone is located along the southern edge of LLNL Site 300, and extends northwest to within approximately 4 km east of the LLNL Livermore site (Figure I-4). The Carnegie fault merges with the Corral Hollow fault approximately 8 km southeast of the LLNL Livermore site (Dibblee, 1980d). Recent geologic studies along the Corral Hollow–Carnegie fault system have demonstrated Holocene activity (Carpenter et al., 1991). This fault system is discussed in greater detail in section I.4.3.3.

Tesla Fault

The north-northwest-trending Tesla fault, located 8.5 km southwest of the LLNL Livermore site and SNL, Livermore (Figure I-4), is truncated by the Greenville fault to the northwest and continues to the southeast along the east side of the Diablo Range (Figure I-4). Toward the southeast, the Tesla fault merges with or is truncated by the Carnegie Fault. The segment of the Tesla fault southeast of this junction may merge with the Ortigalita fault through a complex series of splays. The fault is approximately 29 km long (Figure I-4) and separates Franciscan Assemblage rocks of the Diablo Range from the Great Valley sequence and younger Tertiary rocks in the Altamont Hills (Herd, 1977).

Black Butte Fault

The northwest-trending Black Butte fault is exposed along the eastern flank of the Diablo Range, approximately 18 km east-southeast of the LLNL Livermore site and SNL, Livermore (Figure I-3 and Figure I-4; Dibblee, 1980a, 1980d, 1981b). The fault has a strike length of approximately 15 km and juxtaposes Plio-Pleistocene deposits against older Great Valley sequence rocks (Dibblee, 1981b). The fault dips steeply to the west and appears to have reverse or thrust motion. The western subsurface continuation of the fault is not known; however, it is likely the fault projects as a low-angle decollement beneath the Diablo Range. This fault is considered potentially active.

I.4.2.4 Seismic Hazards

Ground Motion

Strong ground shaking is responsible for producing almost all damaging effects of earthquakes, except for surface fault rupture. Ground shaking generally causes the most widespread effects, not only because it propagates to considerable distance from the earthquake source, but also because it may trigger secondary effects associated with ground failure and water inundation (Borcherdt, 1985). These secondary effects include liquefaction, lateral spreading, landslides and rockfalls, densification and settlement, tsunamis, and seiches.

The Livermore Valley has experienced strong ground shaking during historic earthquakes. The July 1861 earthquake centered on the Calaveras fault had an estimated magnitude of 6.0 and produced severe damage in the Livermore Valley, near the present site of the city of Livermore (Radbruch, 1968). In 1906, the great San Francisco Earthquake (of magnitude 8+) on the San Andreas fault produced minor structural damage in Livermore Valley. Damage included cracked brick chimneys (approximately 50 percent collapsed), a fallen water tank, and ground fissures located about 1 mile (1.6 km) north of the city of Livermore with a maximum vertical uplift of about 19 inches (48 cm) (Lawson et al., 1908). The January 24, 1980, Livermore earthquake, which was centered approximately 20 km north of the LLNL and SNL, Livermore sites, produced accelerations estimated to be 0.2 to 0.3g at the facilities (Freeland, 1984). Although no one at the Laboratory was seriously injured, this earthquake and aftershocks caused structural and nonstructural damage to LLNL, Livermore facilities (Freeland, 1984) and similar consequences at SNL, Livermore.

Potential sources of future ground motion at the LLNL Livermore site and SNL, Livermore include the major regional faults such as the San Andreas, Hayward, and Calaveras fault zones, as well as local structures including the Greenville, Las Positas, Verona, Corral Hollow, and Williams faults. The largest contribution to the ground shaking hazard at the LLNL Livermore site is produced by moderate earthquakes on nearby faults rather than large earthquakes on distant sources (Scheimer, 1985; Geomatrix Consultants, 1985). Since the sites are adjacent to one another, the ground motions developed for the LLNL Livermore site are considered applicable to the SNL, Livermore site, although probabilistic SNL, Livermore seismic hazards were not specifically calculated. Future ground motions at the two sites would likely be similar. DOE seismic design criteria consider the hazard of ground shaking to be the same for both sites (Kennedy et al., 1990).

Several probabilistic seismic hazard analyses have been conducted for the LLNL Livermore site. Probabilistic analyses are used to quantify the hazard in terms of the annual probability of exceeding a given peak ground acceleration or spectral acceleration values. Four of these studies generated seismic hazard curves, which express their results in terms of peak horizontal ground acceleration versus annual probability of exceedence or return period (TERA Corporation, 1983; Woodward-Clyde Consultants, 1984; Geomatrix Consultants 1985, 1990). The values reported in Geomatrix Consultants (1991) reflect further studies to account for the reductions in accelerations when "effective" versus "instrumental peak" accelerations (Aeff vs. Apeak) are considered. (See Appendix I section I.4.2.5 for a more detailed discussion of "effective" versus "instrumental peak" accelerations.) The results of these studies are summarized in Table I-3 as mean peak ground accelerations corresponding to return periods of 500, 1000, and 5000 years. These return periods correspond to the levels of risk specified in the LLNL seismic design criteria (or "Design Basis") for low, moderate, and high hazard facilities (Freeland, 1984). Selection of an event with a 10,000 year return interval, described in section I.4.1 as the "Above Design Basis" event, results in mean peak ground accelerations substantially in excess of those used in the design of the high hazard structures.

A deterministic approach, which is based on estimating the largest earthquakes that might occur on local faults, is useful to provide a comparison with values estimated from the probabilistic seismic hazard analyses. This comparison is used to check that the probabilistic hazard analyses have adequately accounted for maximum magnitude earthquakes that could reasonably occur in the vicinity of the Livermore sites.

Considering the size and proximity of all the nearby faults, the Greenville fault is the controlling source which would produce the maximum ground accelerations at the sites. Maximum magnitude estimates for the segment of the Greenville fault closest to the LLNL Livermore site have ranged from 6.5 (Wright et al., 1982) to 6.7 (Shedlock et al., 1980). Carpenter et al. (1984), using methods outlined by Slemmons and Chung (1982), estimated a range of maximum earthquake magnitudes of 6.3 to 6.8 with an average of MS 6.6 for the Greenville fault. Considering a MS 6.6 earthquake to be the best estimate of the maximum earthquake on the Greenville fault at a distance of 1.5 km from the LLNL Livermore site, the estimated mean peak ground accelerations could range from 0.43 to 0.50g, depending upon the assumed attenuation relationships, with an average of 0.47g (Table I-4). The mean + s values (where s is one standard deviation) for the same attenuation relationships range from 0.66 to 0.89g, with an average of 0.76g (Table I-4). The mean + s values are presented for comparison because prior to the development of more recent criteria (e.g., Kennedy et al., 1990) mean + s values were in common usage with standard design codes.

Using the same deterministic analysis approach for SNL, Livermore, a MS 6.6 earthquake on the Greenville fault at a distance of 3.7 km would produce mean peak ground acceleration estimates ranging from 0.36 to 0.44g, with an average of 0.40g (Table I-5). The mean + s values (where s is one standard deviation) for the same attenuation relations range from 0.57 to 0.76g, with an average of 0.64g (Table I-5). Similarly, the maximum earthquake magnitude estimates for the Las Positas fault range from 5.6 to 6.6, with an average of 6.0 as the best estimate of the maximum earthquake (Carpenter et al., 1984). An earthquake of magnitude 6.0 located 0.1 km away on the Las Positas fault would produce similar accelerations to those resulting from a magnitude 6.6 earthquake on the Greenville fault 3.7 km distant (Table I-5). The magnitude 6.0 event on the Las Positas fault would generate average mean and mean + s values of 0.38 and 0.64g for the attenuation relationships listed in Table I-5.

Based only on the deterministic analyses described above (WESTON, 1991a), a reasonable maximum intensity of strong ground shaking at the LLNL Livermore site and SNL, Livermore is approximately 0.8g.

Surface Faulting

Surface faulting is the displacement of ground along the surface trace of a fault and can be devastating to structures straddling the fault. Fortunately the hazard of surface faulting is not regional in extent as is ground shaking, but instead is restricted to the displaced segment of a relatively narrow linear fault zone. The amount of relative displacement at the surface can range from a few millimeters to several meters in either a horizontal or vertical direction, depending on the size of the earthquake and type of fault.

There have been two historical occurrences of surface faulting in Livermore Valley. The July 3, 1861 earthquake (estimated ML 6.0) caused major surface faulting along the Calaveras fault in the westernmost Livermore (Amador) and San Ramon valleys (Radbruch, 1968). More recently, the January 24 and 27, 1980, Livermore earthquakes (ML 5.5 and 5.6) centered on the Greenville fault 20 km northwest of the LLNL Livermore site and SNL, Livermore, produced minor amounts of displacement on the Greenville fault and may have also been responsible for producing minor aseismic slip approximately 20 km southwest along the Las Positas fault (Bonilla et al., 1980). The maximum right-lateral displacement on the Greenville fault was 25 mm and the maximum left-lateral displacements measured across ground cracks and an alignment array on the Las Positas fault were 1.5 and 6 mm (Bonilla et al., 1980).

In California, many known active faults have been zoned in accordance with the Alquist-Priolo Special Studies Zone Act of 1972 (Hart, 1988). This legislation, which regulates development along faults, serves to prevent construction directly on fault traces that may be expected to rupture in the future. Portions of the Las Positas and Greenville faults are included in Special Studies Zones and shown in Figure I-5 (California Division of Mines and Geology, 1982). Due to the proximity of the Las Positas fault zone, a small portion of the southeast corner of the LLNL Livermore site is included in the Special Studies Zone for this fault. No fault strands were found in exploratory trenches across this small triangular parcel of approximately 1400 m2 (15,000 ft2) (Carpenter et al., 1984). The north branch of the Las Positas fault zone and its approximately 800-ft-wide Special Studies Zone crosses SNL, Livermore (Figure I-5) along the base of the prominent northeast-facing slope. Although the south branch of the fault does not transect the site, the southeastern corner of the SNL, Livermore site has been designated a Special Studies Zone (Figure I-5).

The potential for surface faulting does exist at SNL, Livermore. The areas adjacent to the active strand of the Las Positas fault would most likely experience ground deformation, associated with fault rupture. Due to the limited amount of subsurface information along the fault and the relatively wide zone of shears (50 to 100 m) associated with both strands of the Las Positas fault (Carpenter et al., 1984), unrecognized strands of the Las Positas fault may be present beneath the SNL, Livermore facilities. The north branch of the Las Positas fault runs along the north ends of buildings 970, 972, 973, and 976 (California Division of Mines and Geology, 1982). It is not clear whether the fault projects beneath the buildings or misses them completely. It is clear that buildings 970, 972, 973, and 976 are exposed to the greatest risk of surface faulting due to their proximity to the north branch of the Las Positas fault. Building 968 is also located within the Las Positas fault special studies zone, but is located further from the mapped fault (Blume and Associates, 1978; Herd, 1977) than Buildings 970, 972, 973, and 976. While Building 968 is exposed to a greater risk of damage due to surface faulting than other structures not within the special studies zone, its distance from the actual mapped fault indicates this risk is still small.

Faults which were previously inferred to cross or project toward the LLNL Livermore site (e.g., Tesla, Dougherty, and Ramp thrust faults) (Huey, 1948, 1972; Blume and Associates, 1972, 1978) are either truncated by the active Greenville and Las Positas faults or are no longer interpreted as faults. As reported in the DEIS for Decontamination and Waste Treatment Facility for the LLNL site (DOE, 1988) a crack in the pavement east of Building 618 was discovered in 1985. An investigation was unable to verify that the crack was or was not fault-induced (DOE, 1988). The possibility that an old, abandoned strand of the Greenville fault, located immediately southeast of the LLNL Livermore site between the active branches of the Las Positas fault zone (Carpenter et al., 1984) could be reactivated or triggered by coseismic slip on a nearby fault is possible, but highly unlikely. This possibility is remote due to: (1) the lack of geologic and geophysical evidence for any displacement in sediments 300,000 years and older (Carpenter et al., 1984); (2) the seismologic evidence for earthquake activity concentrated to the east along the modern Greenville fault (Bolt et al., 1981); and (3) the likely truncation of the fault by the north branch of the Las Positas fault. The inferred abandoned strand of the Greenville fault was not recognized by Herd (1977) and Dibblee (1980a); therefore, the potential for surface faulting within the LLNL Livermore site is insignificant.

Liquefaction

Liquefaction is a type of soil failure where a mass of saturated soil is transformed from a solid to a fluid state. Liquefaction of soils supporting foundations can lead to a loss of bearing capacity and excessive settlement of foundations. The liquefaction potential of a soil deposit is controlled by several factors such as the depth to ground water, the type and density of the soil, and the intensity and duration of ground shaking. Soils most susceptible to liquefaction are geologically young, saturated, uniformly graded sandy soils in a loose to medium-dense condition.

Alluvial deposits underlying the LLNL Livermore site and the adjacent SNL, Livermore do not possess the physical properties of materials generally subject to liquefaction (Carpenter et al., 1984). In addition, depths to ground water range from 13 m to about 49 m beneath the LLNL Livermore site and from 27 m to about 38 m beneath SNL, Livermore (Carpenter et al., 1984). No perched ground water bodies have been identified beneath the LLNL Livermore site. Based on fairly deep ground water levels, uniformly distributed, poorly sorted sediments beneath the sites, and a relatively high degree of sediment compaction or density, the potential for liquefaction at the LLNL Livermore site and SNL, Livermore is insignificant.

Seismically Induced Landslides

Landslide is a general term for a variety of processes and land forms resulting from the downslope movement, under gravity, of masses of soil and rock material. Types of landslides include translational and rotational block slides, slumps, rockfalls, mud flows, and debris flows. Earthquake ground motion is only one of several factors that contribute to the instability of a rock or soil mass.

The LLNL Livermore site consists of a relatively smooth land surface that slopes gently downward to the northwest. Elevations within the laboratory range from a low of 174 m at the northwest corner of the site to 206 m at the southeast corner (Carpenter et al., 1984). The total relief across the 1.9 km wide site is 32 m, and slopes onsite generally do not exceed 2· (Carpenter et al., 1984). Because of the very low relief at the site, the potential for slope instability at the LLNL Livermore site is insignificant.

SNL, Livermore consists of two different types of terrain separated by the north branch of the Las Positas fault. The area north of the fault consists of a relatively smooth land surface that gently slopes downward to the northwest. Elevations within the northern portion of the site range from a low of 195 m at the northwest corner to about 207 m adjacent to the Las Positas fault. The total relief across the northern portion of the site is approximately 12 m. The steepest slopes are along the banks of Arroyo Seco, which flows northward across the site. Due to the very low relief, the potential of slope instability on the northern portion of SNL, Livermore is insignificant.

The terrain south of the Las Positas fault consists of a portion of the foothills and is bounded to the south by the south branch of the Las Positas fault. The southern end of the SNL, Livermore site includes the crest of the foothills, which is 259 m, the highest elevation on the site. The relief between the fault and the ridge crest is 52 m over a distance of approximately 366 m. The slope of the northwest-facing flank of the foothills in the southern portion of the site is approximately 8·, with steeper slopes locally. Due to the slightly higher relief in the southern portion of the site and the soil types found there, the potential for slope instability at the southern portion of SNL, Livermore is sufficiently high to require consideration.

Table I-3 LLNL Livermore Site and SNL, Livermore Ground Motion Hazard Estimates, Design Criteria, and EIS/EIR Demand Criteria Expressed as Peak Horizontal Ground Acceleration (g)

Source	Average Return Period (years)		
	500	1000	5000
Ground Motion Hazard Estimates			
TERA Corporation (1983)	0.41	0.48	0.68
Woodward-Clyde Consultants (1984) and Geomatrix Consultants (1985)[a]	0.49	0.58	0.79
Geomatrix Consultants (1990)	0.57	0.68	0.98
Geomatrix Consultants (1991)	0.51	0.61	0.88
Seismic Design Criteria			

LLNL (1980–1989) Criteria (Freeland, 1984)[b] and (Tokarz, 1991a)	0.25	0.25/0.5	0.5/0.8
DOE Criteria (Kennedy et al., 1990)	0.41	0.48	0.68
LLNL Proposed Criteria (Coates, 1991)	0.47	0.57	0.82
Seismic Demand Criteria for 1991 EIS/EIR[c]			
WESTON (1991a)	0.5	0.6	0.8

[a] The 5000-year peak ground acceleration was reported in Geomatrix Consultants (1985).

[b] The values of 0.25g/0.5g, and 0.5g/0.8g were required by the referenced criteria for all new designs and/or modifications of General/Low Hazard, Moderate Hazard, and High Hazard facilities, respectively. These values were not developed specifically to reflect the 500-, 1000-, and 5000-year return periods.

[c] See section I.4.2.5 for description of demand criteria.

Table I-4 Deterministic Estimates of Peak Horizontal Ground Accelerations for the LLNL Livermore Site for Maximum Credible Magnitude Earthquakes on the Greenville and Las Positas Faults

Attenuation Relations	Peak Accelerations (g)			
	M = 6.6 on Greenville Fault at 1.5 km Distance		M = 6.0 on Las Positas Fault at 0.3 km Distance	
	mean	mean + s	mean	mean + s
Joyner and Boore (1982)—random	0.43	0.82	0.32	0.61
Campbell (1989)	0.49	0.75	0.45	0.69
Crouse et al. (1987)	0.50	0.89	0.51	0.91
Idriss (1987)	0.45	0.66	0.25	0.38
Sadigh et al. (1986)	0.49	0.69	0.35	0.53
Average:	0.47	0.76	0.38	0.62

Note: s indicates one standard deviation from the mean. Source: WESTON, 1991a.

Table I-5 Deterministic Estimates of Peak Horizontal Ground Accelerations at SNL, Livermore for Maximum Credible Magnitude Earthquakes on the Greenville and Las Positas Faults

Attenuation Relations	Peak Accelerations (g)			
	M = 6.6 on Greenville Fault at 3.7 km Distance		M = 6.0 on Las Positas Fault at 0.1 km Distance	

	mean	mean + s	mean	mean + s
Joyner and Boore (1982)—random	0.40	0.76	0.32	0.61
Campbell (1989)	0.44	0.66	0.45	0.69
Crouse et al. (1987)	0.36	0.64	0.55	0.99
Idriss (1987)	0.39	0.57	0.25	0.38
Sadigh (1987)	0.41	0.58	0.35	0.53
Average:	0.40	0.64	0.38	0.64

Note: s indicates one standard deviation from the mean. Source: WESTON, 1991a.

I.4.2.5 Demand Criteria for EIS/EIR

Based on the previous analyses as discussed in section I.4.2.4, values for maximum ground acceleration at the LLNL Livermore and SNL, Livermore sites for return periods of 500, 1000, and 5000 years are 0.5g, 0.6g and 0.8g, respectively. These values are listed in Table I-3 where they can be compared with the results of previous ground motion hazard studies, as well as seismic design criteria for Laboratory facilities. These acceleration values are considered reasonable and appropriate and are close to the mean peak estimates in the Woodward-Clyde (1984) study and the mean effective estimates in the Geomatrix (1991) study. These values are also supported by a simplified probabilistic seismic hazard analysis (WESTON, 1991a). The differences in predicted values of acceleration from the first four studies (TERA Corporation, 1983; Woodward-Clyde, 1984; Geomatrix 1985, 1990) are primarily due to differences in attenuation relations, computational methods incorporating varying degrees of conservatism, and the earthquake source characterizations used in the analyses.

In an earthquake, in the vicinity of the causative fault, the "instrumental peak" ground acceleration motion is generally greater than the smaller motions that occur many times during an earthquake. These smaller motions are considered the "effective" values. They are calculated by averaging the several largest instrumental peak accelerations. The Geomatrix Consultants (1991) values reported in Table I-3 are effective accelerations, conservatively shown using a ratio of effective acceleration divided by instrumental peak acceleration (Aeff/Apeak) equal to 0.9. Geomatrix Consultants (1991) provides additional guidance for utilizing lower Aeff/Apeak ratios which would result in lower acceleration values than those shown in Table I-3. The values proposed in Coates (1991) are based on the studies by Geomatrix Consultants (1990, 1991). However, Coates (1991) provides the technical basis for selecting the lower ratios of Aeff/Apeak actually reported in Geomatrix Consultants (1991). Another example of the use of the effective peak ground acceleration values is given in the Geological Survey Circular No. 672 (Page et al., 1972), which reported values for near-fault (3 to 5 km) horizontal ground accelerations to be used in evaluating the Trans-Alaskan Pipeline System. For local magnitude 7 earthquakes, the average of the 5 largest instrumental acceleration peaks expressed as a ratio to the peak instrumental acceleration (Aeff/Apeak) is 0.83. The corresponding ratio (Aeff/Apeak) for the 10 largest acceleration peaks is 0.71.

The use of effective peak ground accelerations instead of instrumental peak ground accelerations reflects the generally accepted understanding of how earthquake motions damage structures and equipment. Typical structures and equipment such as those found at LLNL and SNL, Livermore are more susceptible to damage from multiple cycles of lower level ground accelerations than they are to a single peak acceleration "shock" which is not repeated. The accelerations presented in Table I-3 as the demand criteria for the 1991 EIS/EIR have the same values as the instrumental peak accelerations presented in Geomatrix Consultant (1991) multiplied by an Aeff/Apeak ratio of 0.83, and rounded to a single significant digit. Tokarz (1991b) and Coates (1991) report that the LLNL Livermore site will be officially adopting the values of 0.47g, 0.57g, and 0.82g peak ground accelerations for the 500-, 1000-, and 5000-year return intervals, respectively.

More complete estimates of the seismic ground motion hazard are provided by acceleration response spectra, and effective peak ground acceleration values are key starting point inputs to the development of such spectra. Acceleration response spectra are considered to be primary elements of a seismic demand criteria because it is from them that seismic forces postulated to act on structures are calculated.

Based on the seismicity parameters used by Woodward-Clyde Consultants (1984), Geomatrix Consultants (1985) developed equal-hazard response spectra for the LLNL Livermore site and updated these spectra in Geomatrix Consultants (1990, 1991) using more recent spectral ordinate attenuation relationships. Equal-hazard response spectra were derived for return periods of 100, 500, 1000, and 5000 years.

The mean acceleration response spectra developed in WESTON (1991a) were calculated following the procedures in Newmark and Hall (1982) for Soil Type 2 (see Newmark and Hall, 1982, for a detailed discussion of soil types). These spectra are shown in Figure I-6, Figure I-7, Figure I-8, and Figure I-9 for effective peak ground accelerations of 0.5g, 0.6g, 0.8g, and 0.9g and for critical damping values of 2 percent, 5 percent, and 10 percent. Figure I-9 with an effective peak ground acceleration of 0.9g corresponds to the Above Design Basis seismic event described in sections I.4.1 and I.4.2.4. Mean *spectral amplification curves* were provided, recognizing that the most recent guidelines for seismic design and evaluation of DOE facilities (Kennedy et al., 1990) recommend the use of mean amplification spectra (no conservative bias).

As discussed in sections I.4.1 and I.5, only the spectra corresponding to earthquakes with effective peak ground accelerations of 0.8g and 0.9g were used in the building assessments reported in section I.8. The spectra corresponding to lower peak ground accelerations are shown to demonstrate the degree of extra conservatism associated with the low and moderate hazard building assessment results presented in section I.8.

I.4.3 Seismicity of LLNL Site 300

I.4.3.1 Seismotectonic Setting

LLNL Site 300 is located on the eastern side of the Altamont Hills, between Livermore and San Joaquin valleys, near the eastern margin of the Diablo Range in the Coast Range province (see Figure I-2). It is located east of the transform plate margin of the North American and Pacific plates. At the latitude of LLNL Site 300, faults of the San Andreas system include, from west to east, the San Gregorio, San Andreas, Hayward, Calaveras, and Greenville faults (Figure I-2). LLNL Site 300, underlain by Tertiary marine and nonmarine sedimentary rocks, and locally Quaternary terrace deposits, is bounded by the Tesla fault system to the south and the Midway and Black Butte faults to the east (Figure I-2 and Figure I-3).

The boundary between the Coast Ranges and Sierran block lies approximately 3 km east of LLNL Site 300 (Figure I-2) and is characterized by east-northeast directed compression, resulting in reverse and thrust faulting (Wong et al., 1988; Wentworth and Zoback, 1989).

Seismicity along the Coast Range–Sierran block transition at the latitude of LLNL Site 300 is spatially diffuse and episodic, with shallow earthquakes (Wong et al., 1988). The seismogenic sources are generally west-dipping high-angle faults, although north-trending right-slip faults are also present. To the south, earthquake focal mechanisms indicate northeast-east compression, normal to the Coast Range–Sierran block boundary (Wong et al., 1988). Large earthquakes, such as the 1983 Coalinga earthquake (ML 6.7) and the previously discussed 1892 Winters earthquakes (ML 6), characterize the boundary; thus, the potential exists for large earthquakes along the 600-km margin of the San Joaquin and Sacramento valleys.

I.4.3.2 Historical Seismicity

Preinstrumental

For a discussion of preinstrumental seismicity relative to LLNL Site 300, see section I.4.2.2.

Instrumental

The local seismicity in the Altamont Hills surrounding LLNL Site 300 is characterized as diffuse and of a low level (Carpenter et al., 1991). Most earthquakes recorded since 1969 are smaller than magnitude 2.0 and have occurred at depths less than 10 km (Wong et al., 1988). Although Wong et al. (1988) plotted earthquakes on or adjacent to the Black Butte, Midway, and Tesla faults, suggesting recent activity, there are 5–10 km of uncertainty associated with the location of earthquake epicenters within the Altamont Hills. The Corral Hollow–Carnegie fault zone, which traverses the southwest portion of LLNL Site 300, has no visible expression in the seismicity data (Carpenter et al., 1991). No large earthquakes have been recorded on the Corral Hollow–Carnegie, Black Butte, Midway, and Tesla fault zones, which are discussed further in section I.4.3.3.

For a discussion of the regional instrumental seismicity, see section I.4.2.2.

I.4.3.3 Seismic Sources

The three principal strands of the San Andreas fault system, the San Andreas, Hayward, and Calaveras faults, have produced the majority of significant historical earthquakes in the Bay Area. The San Andreas and Hayward faults are discussed as the seismic sources for the LLNL Livermore site and SNL, Livermore in section I.4.2; however, it is the local faults in the region that contribute the majority of the seismic hazard to LLNL Site 300 (Figure I-4). The largest contribution to the ground shaking hazard at LLNL Site 300 may be produced by moderate earthquakes on the Greenville, Las Positas, Corral Hollow–Carnegie, Midway, and Black Butte faults. The Greenville and Las Positas faults are discussed in section I.4.2.3. Larger earthquakes on more distant faults do not significantly affect the hazard estimates.

In addition to the Corral Hollow–Carnegie fault zone, numerous other faults have been mapped at LLNL Site 300 (Figure I-10). Most of these faults are relatively short in length and apparently have only minor separation within the Miocene and Pliocene bedrock. The faults can be grouped into four geographic areas within the site: (1) northwest-trending, en echelon, high-angle strike-slip and reverse faults along Elk Ravine; (2) north-northeast-trending, high-angle faults that truncate the Elk Ravine Fault in the eastern part of the site; (3) northeast- and east-trending reverse faults in the southern and central portions of the site; and (4) northwest-trending, high-angle faults that are truncated by the Carnegie fault. The youngest rocks offset by these aforementioned faults are Pliocene in age. Based on the lack of geomorphic expression, age of the youngest offset strata, and cross-cutting relationships, the faults are likely pre-Holocene in age.

Corral Hollow–Carnegie Fault

The northwest-trending Corral Hollow–Carnegie fault zone is located along the southern portion of LLNL Site 300 (Figure I-4 and Figure I-10). The Corral Hollow–Carnegie fault zone is approximately 29 km long (Figure I-4) and is mostly buried beneath present-day alluvial cover along Corral Hollow Creek. The Carnegie fault strand branches from the Corral Hollow fault in Corral Hollow Creek immediately south of LLNL Site 300 and merges back into the Corral Hollow fault approximately 7 km to the northwest (Dibblee, 1980d). The fault zone is subparallel to the Greenville fault to the north and merges with the Tesla fault to the south (Figure I-4) and probably transfers slip between the Tesla-Ortigalita fault system and the Greenville fault (Herd, 1977; Dibblee, 1980a, 1980d).

Recent geologic studies along the Corral Hollow–Carnegie fault zone at LLNL Site 300 have demonstrated Holocene activity (Carpenter et al., 1991). A previously unrecognized strand of the fault, exposed 60 to 75 m south of the Carnegie Fault, as mapped by Dibblee (1980d), displaces late Pleistocene terrace deposits and Holocene colluvium

(Figure I-10; Dugan et al., 1991). These offset terrace gravels are the youngest of a flight of Quaternary river terraces that are present along Corral Hollow in the southern part of LLNL Site 300 (Figure I-10).

The zone of active faulting is approximately 3 to 4 m wide. A thrust fault and a high-angle fault, exposed just to the north of the Holocene fault, cut Lower Tertiary rocks of the Tesla Formation. The thrust fault offsets a shear that displaces Holocene sediments approximately 54 cm, which demonstrates Holocene thrust faulting (Carpenter et al., 1991). Several springs and seeps align along the northwest-trending active strand. Based on a limited number of slickenside striae and a large scatter in the data set, Carpenter et al. (1991) estimated an average plunge of 30· for the slickensides, suggesting an average horizontal to vertical displacement ratio of 2:1. Using this ratio, it is estimated that a late Pleistocene erosion surface near Pit 6 (Figure I-10) is offset horizontally by 3.75 m (Carpenter et al, 1991). Minor thrust faults, that apparently deform Pleistocene river terrace deposits, have been identified immediately north of the Corral Hollow–Carnegie fault zone (Figure I-10; Dugan et al., 1991).

Slip rates for the Corral Hollow–Carnegie fault system are based on right-lateral offsets of Late Tertiary erosion surfaces and Holocene colluvial horizons. An older strand of the Corral Hollow–Carnegie fault offsets a Plio-Pleistocene syncline approximately 3 km (Dibblee, 1980a). Based on the offset syncline, an estimated slip rate for the fault is 0.13 mm/yr (Sweeney, 1982). The estimated slip rate for the Holocene strand ranges from 0.06 to 2 mm/yr (Carpenter et al., 1991). The broad range of Holocene slip rates are due to the absence of piercing points along the fault and large uncertainties in the ages of the offset sediments.

Midway Fault

The northwest-trending, right-lateral Midway fault is located approximately 1 km north of LLNL Site 300 (Figure I-4; Dibblee, 1980d). The fault has a strike length of approximately 10 km and locally juxtaposes Plio-Pleistocene sediments against Miocene deposits. The Midway fault lies to the east and parallel to the Greenville fault system. Based on regional correlations, Clark et al. (1984) interpret the Midway fault as a moderately dipping reverse fault; however, based on the straight, linear fault trace and seismic focal mechanisms, the Midway fault is a near-vertical feature, with predominantly right-lateral strike slip separation, east-side up. This fault is considered potentially active.

Black Butte Fault

The northwest-trending Black Butte fault is exposed along the eastern flank of the Diablo Range, approximately 2.5 km east-southeast of LLNL Site 300 (Figure I-3 and Figure I-4; Dibblee 1980a, 1980d, 1981b). This fault is considered potentially active and is discussed in more detail in section I.4.2.3.

Tesla Fault

The north-northwest-trending Tesla fault, located 1.5 km southwest of LLNL Site 300 (Figure I-4), is truncated by the Greenville fault to the northeast and continues to the southeast along the east side of the Diablo Range (Figure I-4). It is discussed in more detail in section I.4.2.3.

I.4.3.4 Seismic Hazards

Ground Motion

The region surrounding LLNL Site 300 has experienced strong ground shaking during historic earthquakes. In 1906 the great San Francisco earthquake (magnitude 8+) on the San Andreas fault produced structural damage a few kilometers west of LLNL Site 300. Damage included a large brick smokestack which collapsed on a pottery works and a fallen water tank (Nason, 1982).

Potential sources of future ground motion at LLNL Site 300 include the major regional fault zones such as the San Andreas, Hayward, and Calaveras, as well as smaller faults including the Greenville and Las Positas. The faults nearest LLNL Site 300, the Corral Hollow–Carnegie, Black Butte, and Midway faults (Figure I-4), represent the greatest hazard to the site.

Only one probabilistic seismic hazard analysis has been conducted for LLNL Site 300. This study, performed by TERA Corporation (1983), generated hazard curves, which express results in terms of peak horizontal ground acceleration versus return period, for two locations within LLNL Site 300. The two locations were Complex 854 near the western boundary of the site and Complexes 834 and 836 near the eastern boundary, selected because of the dominant importance of these two complexes to the operation of LLNL Site 300. Peak ground accelerations corresponding to return periods of 500, 1000, and 5000 years were estimated as 0.32, 0.38, and 0.56g for Complex 854; and 0.28, 0.34, and 0.51g for Complexes 834 and 836 (TERA Corporation, 1983). These return periods correspond to the levels of risk specified in the LLNL seismic design criteria for low, moderate, and high hazard facilities (Freeland, 1984).

A deterministic approach, which is based on estimating the largest earthquakes that might occur on local faults, is useful to provide a comparison with values estimated from the probabilistic seismic hazard analyses. This comparison is used to check that the probabilistic hazard analyses have adequately accounted for maximum magnitude earthquakes that could reasonably occur in the vicinity of the site. The Carnegie fault, which traverses the southwest portion of the site, has recently been shown to offset likely Holocene colluvium and is therefore considered active (Carpenter et al., 1991). The Black Butte and Midway faults displace Pleistocene materials and are considered potentially active. No significant earthquakes have occurred on any of these three faults during historic time.

Given a recent study of Holocene faulting at LLNL Site 300, maximum earthquake magnitude (MS) estimates based on fault length, for the Corral Hollow–Carnegie fault zone were estimated from 6.3 to 7.1 with an average of 6.5 (Carpenter et al., 1991). For the 15-km-long Black Butte fault, maximum surface wave magnitude estimates range from 6.5 to 6.8 with an average of 6.6 using various empirical equations relating fault length to maximum magnitude (Bonilla et al., 1984; Slemmons, 1982; Wyss, 1979). An average maximum magnitude of 6.4 was obtained from a range of 6.1 to 6.9 for the 10-km-long Midway fault (Bonilla et al., 1984; Slemmons, 1982; Wyss, 1979). These average maximum magnitudes were then used in the deterministic hazard analysis of Complex 854 and Complexes 834 and 836. A comparison of the peak horizontal ground accelerations generated from the three aforementioned earthquakes are presented in Table I-6 and Table I-7 for both complexes at LLNL Site 300. For Complex 854, a MS 6.5 earthquake on the Corral Hollow–Carnegie fault produces the greatest accelerations (Table I-6), whereas a MS 6.6 earthquake on the Black Butte fault generates the maximum accelerations for Complexes 834 and 836 (Table I-7). Considering a MS 6.5 earthquake on the Corral Hollow–Carnegie fault at a distance of 1.4 km from Complex 854, the mean peak ground accelerations could range from 0.41 to 0.65g with an average of 0.53g (Table I-6). The mean + s (where s is one standard deviation from mean) values for the same attenuation relations range from 0.74 to 0.92g, with an average of 0.82g (Table I-6).

Given a MS 6.6 earthquake on the Black Butte fault at a distance of 2.4 km from Complexes 834 and 836, the mean peak ground accelerations could range from 0.42 to 0.71g with an average of 0.59g. The mean + s values for the same attenuation relations range from 0.76 to 1.06g, with an average of 0.91g (Table I-7).

In addition to the above three local seismic sources, there is the possibility that a buried or blind thrust fault may produce strong ground motions at LLNL Site 300. Recent studies have inferred that the entire boundary between the Coast Ranges and Sierran block (San Joaquin Valley) is characterized by east-northeast directed compression and thrust faulting similar to that which occurred in the 1983 Coalinga earthquake (Wong et al., 1988; Wentworth and Zoback, 1989). Blind-thrust faults have recently been found several kilometers to the north along the southwestern margin of the Sacramento Valley (Unruh et al., 1991; Phipps et al., 1991). Although no similar structures are known to exist beneath the Altamont Hills where LLNL Site 300 is located, a comprehensive evaluation of the potential for these buried structures needs to be undertaken, as they could significantly add to the hazard at LLNL Site 300. This uncertainty is considered when establishing the demand criteria for LLNL Site 300, which is discussed in section I.4.3.5.

Surface Faulting

There have been no historical occurrences of surface faulting in the vicinity of LLNL Site 300. The nearest documented occurrences of surface faulting were in the Livermore Valley region. The July 3, 1861 earthquake (estimated ML 6.0) caused surface faulting along the Calaveras fault in the westernmost Livermore (Amador) and San Ramon valleys (Radbruch, 1968). More recently, the January 24 and 27, 1980 Livermore earthquakes (ML 5.5 and 5.6) centered on the Greenville fault, produced minor amounts of displacement on the Greenville fault and may have also been responsible for producing minor aseismic slip along the Las Positas fault (Bonilla et al., 1980).

The potential for surface faulting does exist at LLNL Site 300. The areas adjacent to the active strand of the Carnegie fault would most likely experience ground deformation, associated with fault rupture, should an earthquake occur on the fault. A 3- to 4-m-wide zone of faulting is present in Holocene and late Pleistocene deposits along the Carnegie fault, attesting to the potential for surface rupture. Due to the limited amount of subsurface information along the fault, unrecognized strands of the Carnegie fault may be present beneath LLNL Site 300. However, any such strands are likely to be limited to the area south of the Carnegie fault which forms a well-defined bedrock discontinuity.

In addition to the principal Holocene strike-slip Carnegie fault strand located south of Pit 6, there are two subsidiary reverse faults that could potentially produce minor amounts of surface rupture (Dugan et al., 1991). These subparallel strands that extend east of Pit 6 may represent a partitioning of the compressional component of slip within the Corral Hollow–Carnegie fault zone.

The only structures located adjacent to the Holocene strand of the Carnegie fault, and therefore subject to the hazard of surface faulting, are Buildings 899A and 899B at the pistol range. However, these two structures contain no hazardous or radiological materials.

Liquefaction

LLNL Site 300 is underlain mostly by Tertiary bedrock, which does not possess the physical properties of materials generally subject to liquefaction. There are no perennial streams in the site, and except for a few isolated springs and seeps, soils beneath river channels are unsaturated (Raber and Carpenter, 1983). Quaternary alluvial deposits are not saturated, except locally at Pit 6 (Figure I-10), where ground water is present in Pleistocene gravel-bearing terrace deposits (Raber and Carpenter, 1983). These terrace deposits are not considered susceptible to liquefaction (Helley et al., 1979). Based on the presence of bedrock beneath LLNL Site 300 and the relatively high degree of compaction or density of the terrace deposits, the potential for liquefaction at LLNL Site 300 is insignificant.

Seismically Induced Landslides

LLNL Site 300 has moderate relief, with elevations ranging from about 152 m along Corral Hollow Creek to approximately 489 m in the northwest portion of the site. Slopes are generally moderate, with local steeper slopes up to approximately 25·. There are numerous landslides located at LLNL Site 300 with the largest landslide covering approximately 1.4 km2 (Figure I-10). The Miocene Cierbo Formation, consisting of sandstone, shale, and tuff, appears to be the geologic unit most susceptible to landsliding at LLNL Site 300. In addition, landslides appear to be most prevalent on northeast-facing slopes, perhaps due to localized increase of water retention and associated stream incision in the hillslope.

Due to the moderate relief and the presence of ancient landslide deposits, the potential for seismically induced slope instability at LLNL Site 300 is considered moderate. Furthermore, the potential for slope instability would be greater on northeast-facing slopes that have strata of the Cierbo Formation exposed. Buildings 825, M825, 826, M51, 857, 851A, 851B, 854, 855, and 856 are located on old landslides. The potential for future ground deformation at the above buildings located on landslide deposits is sufficiently high to require consideration.

Table I-6 Deterministic Estimates of Peak Horizontal Ground Accelerations at LLNL Site 300–Complex 854 for Maximum Credible Magnitude Earthquakes on the Corral Hollow–Carnegie, Black Butte, and Midway Faults

Attenuation Relations	Peak Accelerations (g)					
	M = 6.5 on Corral Hollow–Carnegie Fault at 1.4 km Distance		M = 6.6 on Black Butte Fault at 5.7 km Distance		M = 6.4 on Midway Fault at 4.5 km Distance	
	mean	mean + s	mean	mean + s	mean	mean + s
Joyner and Boore (1982)—random	0.41	0.78	0.35	0.67	0.34	0.65
Campbell (1989)	0.49	0.74	0.55	0.84	0.39	0.59
Idriss (1987)	0.57	0.83	0.40	0.59	0.44	0.65
Sadigh (1987)	0.65	0.92	0.54	0.76	0.47	0.67
Average:	0.53	0.82	0.46	0.72	0.41	0.64

Note: s indicates one standard deviation from the mean. Source: WESTON, 1991a.

Table I-7 Deterministic Estimates of Peak Horizontal Ground Accelerations at LLNL Site 300–Complexes 834 and 836 for Maximum Credible Magnitude Earthquakes on the Corral Hollow–Carnegie, Black Butte, and Midway Faults

Attenuation Relations	Peak Accelerations (g)					
	M = 6.5 on Corral Hollow–Carnegie Fault at 3.0 km Distance		M = 6.6 on Black Butte Fault at 2.4 km Distance		M = 6.4 on Midway Fault at 5.8 km Distance	
	mean	mean + s	mean	mean + s	mean	mean + s
Joyner and Boore (1982)—random	0.39	0.74	0.42	0.80	0.32	0.60
Campbell (1989)	0.45	0.68	0.69	1.06	0.35	0.54
Idriss (1987)	0.50	0.73	0.52	0.76	0.40	0.59
Sadigh (1987)	0.55	0.79	0.71	1.01	0.41	0.60
Average:	0.47	0.74	0.59	0.91	0.37	0.58

Note: s indicates one standard deviation from the mean. Source: WESTON, 1991a.

I.4.3.5 Demand Criteria for EIS/EIR

Based on the previous analyses as discussed in section I.4.3.4, values for maximum ground acceleration at both complexes at LLNL Site 300 (854 and 834/836) for return periods of 500, 1000, and 5000 years are 0.5g, 0.6g and 0.8g, respectively. These values are listed in Table I-8 where they can be compared with the results of the previous ground motion hazard study, as well as the present DOE criteria and the LLNL criteria for LLNL Site 300.

These values, which are the same values used as the EIS/EIR demand criteria for the LLNL Livermore site and SNL, Livermore, are more conservative than those estimated in the TERA Corporation (1983) study. Although the 0.5, 0.6, and 0.8g values are not site-specific to LLNL Site 300, they are more appropriate for use because the TERA values probably underestimate the seismic hazard at LLNL Site 300 for the following reasons: (1) recent studies by Woodward-Clyde Consultants (1984) and Geomatrix Consultants (1990) have estimated greater values for peak ground acceleration at the LLNL Livermore site than did the 1983 TERA Corporation study of the LLNL Livermore site (Table I-3 in section I.4.2). In addition, Geomatrix Consultants (1985) compared the 1983 TERA Corporation and 1984 Woodward-Clyde Consultants seismic hazard studies and concluded that the differences between the two studies were due primarily to the use of different attenuation relations. TERA Corporation (1983) used the same attenuation relation and modeling techniques for their LLNL Livermore site analysis and for their LLNL Site 300 analysis; (2) the seismic sources in the vicinity of LLNL Site 300 are poorly understood and may not be properly characterized in the analysis; and (3) the potential for blind-thrust faults in the vicinity of LLNL Site 300 presents the possibility that an additional seismic source is unaccounted for in past evaluations. Therefore, in the absence of any additional seismic hazard studies, the peak ground acceleration values of 0.5, 0.6, and 0.8g are considered to be appropriate for use at LLNL Site 300.

As discussed previously, more complete estimates of the seismic ground motion hazard are provided by acceleration response spectra, and peak ground acceleration values are key starting point inputs to the development of such spectra. Acceleration response spectra are considered to be primary elements of a seismic demand criteria because it is from them that seismic forces postulated to act on structures are calculated.

The mean acceleration response spectra developed in WESTON (1991a) were calculated following the procedures in Newmark and Hall (1982) for soil Type 1 (see Newmark and Hall, 1982, for a detailed discussion of soil types). These spectra are shown in Figure I-11 to Figure I-13 for peak ground accelerations of 0.5g, 0.6g, and 0.8g and for critical damping values of 2 percent, 5 percent, and 10 percent.

Table I-8 LLNL Site 300 Ground Motion Hazard Estimates, Design Criteria, and EIS/EIR Demand Criteria Expressed as Peak Horizontal Ground Acceleration (g)

Source	**Complex 854**			**Complex 834/836**		
	Average Return Period (years)					
	500	**1000**	**5000**	**500**	**1000**	**5000**
Ground Motion Hazard Estimates						
TERA Corporation (1983)	0.32	0.38	0.56	0.28	0.34	0.51
Seismic Design Criteria						
DOE (Kennedy et al., 1990)	0.32	0.38	0.56	0.28	0.34	0.51
LLNL (1980–1989) Criteria[a,b]	0.25	0.25/0.5	0.5/0.8	0.25	0.25/5	0.5/0.8
Seismic Demand Criteria for 1991 EIS/EIR						
WESTON (1991a)	0.5	0.6	0.8	0.5	0.6	0.8

[a] The values of 0.25g, 0.25g/0.5g, and 0.5g/0.8g were required by the referenced criteria for all new designs and/or modifications of General/Low Hazard, Moderate Hazard, and High Hazard facilities, respectively. These values were not developed specifically to reflect the 500-, 1000-, and 5000-year return periods.

[b] From Freeland (1984) and Tokarz (1991a). No specific statement in these criteria requires their use at LLNL Site 300. Knowledgeable lab personnel (F. Tokarz and G. Freeland) state that these criteria were applied to LLNL Site 300.

I.5 EVALUATION CRITERIA

Criteria contained within the 1990 DOE document *Design and Evaluation Guidelines for DOE Facilities Subjected to Natural Phenomena Hazards* - UCRL 15910 (Kennedy et al., 1990) are used to evaluate potentials for structure and equipment damage. These guidelines recommend that performance goals be used for the design of each usage category of structure. Table I-9 provides a description of these usage categories. Table I-10 provides the recommended performance goals for each usage category, as well as recommended annual exceedence probabilities of these performance goals. Table I-11 shows that if a structure receives a facility categorization of low, moderate, or high hazard under DOE Order 5481.1B "Safety Analysis Report System," its categorization is consistent with the usage category descriptions under UCRL 15910 (Kennedy et al., 1990) design guidelines. A 10^{-5} annual exceedence probability for the high hazard structure's performance goal indicates that there should only be a one in one-hundred thousand chance in any given year that the structure is damaged to the extent that loss of hazardous and/or radiological material confinement is possible. The performance goal of 10^{-5} annual exceedence probability for a high hazard structure is obtained by postulating a mean level seismic hazard event with a 2×10^{-4} annual exceedence probability, and evaluating the structures with design procedures that have no greater than a one in twenty chance of overestimating the actual structure's physical strength properties. This relationship can be expressed mathematically as follows:

If A = Annual Exceedence Probability of a Performance Goal
B = Annual Exceedence Probability of the Seismic Event
C = Exceedence Probability of Strength Properties in Design Procedures

Then $A = (B) \times (C)$

For a High Hazard structure, this becomes;

$10^{-5} = (2 \times 10^{-4}) \times (1/20)$

As a comparison, UCRL-15910 (Kennedy et al., 1990) reports that the Department of Defense (DOD) tri-services seismic design provisions for Essential Buildings recommended a performance goal of 10^{-3} annual exceedence probability. As shown in Table I-11, a building classified as Essential under the DOD Tri-Service Manual corresponds to a high hazard structure under UCRL-15910 (Kennedy et al., 1990) or DOE Order 5481.1B.

The evaluation criteria in UCRL-15910 (Kennedy et al., 1990) allows the evaluation of low or moderate hazard structures using lower magnitude earthquakes than would be used to evaluate high hazard structures. It is partly this use of differing magnitude earthquakes, corresponding to different probabilities of their occurrence, that results in achieving the different performance goals discussed above in this section. However, as described in section I.4.1, only the seismic events corresponding to 5000 and 10,000 year return-intervals were used in making the seismic building assessments reported in section I.8. Except for this, all other parts of the evaluation criteria in UCRL-15910 (Kennedy et al., 1990) were used in the assessments.

Table I-9 Usage Category Guidelines

Usage Category	Description
General Use Facilities	Facilities that have a non–mission-dependent purpose, such as administration buildings, cafeterias, storage, maintenance, and repair facilities that are plant- or grounds-oriented.

Important or Low Hazard Facilities	Facilities that have mission-dependent use (e.g., laboratories, production facilities, and computer centers) and emergency handling or hazard recovery facilities (e.g., hospitals, fire stations).
Moderate Hazard Facilities	Facilities where confinement of contents is necessary for public or employee protection. Examples would be uranium enrichment plants, or other facilities involving the handling or storage of significant quantities of radioactive or toxic materials.
High Hazard Facilities	Facilities where confinement of contents and public and environment protection are of paramount importance (e.g., facilities handling substantial quantities of in-process plutonium or fuel reprocessing facilities). Facilities in this category represent hazards with potential long-term and widespread effects.

Source: Kennedy et al., 1990.

Table I-10 Performance Goals for Each Usage Category

Usage Category	Performance Goal Description	Performance Goal Annual Probability of Exceedence*
General Use	Maintain occupant safety	10^{-3} of the onset of major structural damage to the extent that occupants are endangered
Important or Low Hazard	Occupant safety, continued operation with minimal interruption	$5x10^{-4}$ of facility damage to the extent that the facility cannot perform its function
Moderate Hazard	Occupant safety, continued function, hazard confinement	10^{-4} of facility damage to the extent that the facility cannot perform its function
High Hazard	Occupant safety, continued function, very high confidence of hazard confinement	10^{-5} of facility damage to the extent that the facility cannot perform its function

* A 10^{-3} annual probability of exceedence of the performance goal for a General Use facility indicates that there should be only a one-in-one-thousand chance in any given year that occupant safety would not be maintained.

Source: Kennedy et al., 1990.

Table I-11 Comparison of Usage Categories from Various Sources

Source	Facility Categorization			
UCRL-15910—DOE Natural Phenomena Hazard Guidelines	General Use	Important or Low Hazard	Moderate Hazard	High Hazard
1988 Uniform Building Code	General Facilities	Essential Facilities	---	---
DOD Tri-Service Manual for Seismic Design of Essential Buildings	---	---	High Risk	Essential

IAEA-TECDOC-348—Nuclear Facilities with Limited Radioactive Inventory	---	Class C	Class B	Class A
DOE 5481.1B SAR System	---	Low Hazard	Moderate Hazard	High Hazard
NFPA 13 (Classifications for Sprinkler Systems)	Light Hazard	Ordinary Hazard (Group 1)	Ordinary Hazard (Group 3)	Extra Hazard
Nuclear Regulatory Commission	---	---	---	---*

* NRC licensed commercial nuclear power plants have slightly more conservative criteria than the criteria recommended for High Hazard facilities by these guidelines.
--- = Document does not address this kind of facility.
Source: Kennedy et al., 1990.

I.6 EVALUATION METHODOLOGY

Many of the structures identified as discussed in section I.3 had previously been designed using static Uniform Building Code type evaluations without accounting for the dynamic characteristics of their seismic force–resisting systems. The newer criteria (Kennedy et al., 1990) for moderate and high hazard structures requires that seismic forces be calculated by dynamic response spectra analyses, and that the capacity of seismic force resisting systems be calculated by inelastic methods. The latter methods, described in more detail in section I.7.1, are more rigorous than the static, elastic Uniform Building Code calculations.

The basic methodology used for this EIS/EIR evaluation was to extrapolate from results of existing seismic documentation to estimate what the probable result *would* be if existing facilities were evaluated against the selected probabilistic criteria. Once a building's design (or reevaluation) calculations were obtained, the first step of this extrapolation process was to identify from those existing calculations what constitutes the lateral and vertical seismic force resisting systems of the structure. These systems may be very different for different structures. One structure may resist seismic forces using reinforced concrete shear walls (such as the plutonium facility, Building 332), while another may use a welded steel frame (such as the medical facility, Building 663). Due to modifications or additions (sometimes referred to as increments) to structures over the years, some structures will have different lateral force resisting systems in different increments of the same structure. Typically, these increments are slightly separated from the original building or other increments by gaps, usually no more than 6 inches. These gaps are required (unless the lack of gaps is accounted for in the structural design calculations), because the different increments, having different force resisting systems, would vibrate differently in an earthquake. Without the presence of gaps, the different increments could pound together, further amplifying the loading on adjacent increments. If all increments of the structure might contain the identified hazardous and/or radioactive materials, then the seismic force resisting systems of all of the increments were identified. If, however, only certain increments of a structure contain the identified hazardous and/or radioactive materials, then the seismic force resisting systems were identified for only those increments. An example of this situation is the Material Fab Shop, Building 321. It is classified by LLNL as a moderate hazard structure, but only the Material Fab Shop contains hazardous and/or radioactive materials. The Material Fab Shop is structurally isolated from the rest of the Building 321 complex so only the seismic force-resisting systems of increment C were identified.

The possibility of a lower classification structure collapsing in such a way as to cause collapse of a higher classification structure was investigated (WESTON, 1991b) but no credible instances could be identified.

Having identified the seismic force-resisting systems, only the key components of those systems most heavily loaded due to seismic forces are identified; again, based on the results of existing calculations. Some examples of key components are roof diaphragms, individual shear walls, diagonal bracing, and floor or roof connections to shear walls. In cases where the existing calculations were based on a static Uniform Building Code type analysis, it was assumed that the relative distribution of seismic forces to the key components of the resisting systems would be unchanged if a dynamic analysis were to be performed consistent with the requirements of the criteria in section I.5.

The ability of the key components to resist increased seismic forces predicted from the postulated earthquake (see Figures I-8 and I-9 in section I.4) is estimated based on the remaining strength of those components as documented in the existing calculations. From the existing calculations, the seismic margin is extracted for most key components. The seismic margin ratio is the ability of the component to resist seismic forces (seismic capacity) divided by the seismic forces postulated to act on that component (seismic demand). A seismic margin of 1.0 or greater indicates the component is capable of resisting, within code allowables, the seismic forces assumed to act on it. A seismic margin of less than 1.0 indicates the component is not capable of resisting those forces within code allowables. In order to make the calculation of the new seismic margin, both the seismic capacity and seismic demand were recalculated in accordance with sections I.4 and I.5. If the new seismic margin for any one of the key components of a structure was found to be less than 1.0, loss of confinement of hazardous and/or radioactive materials (or in the case of emergency response structures, loss of function) was considered "possible."

The evaluation methods used in the existing design calculations were often incompatible with some of the methods of the new criteria. These inconsistencies required that assumptions be made in order to arrive at new seismic capacity and demand numbers. Whenever possible, these assumptions were conservative, but in some instances it was impossible to know the extent of conservatism (as in the case described above for assuming relative seismic force distributions remain constant) without actually performing the detailed building analyses. An example of a conservative assumption made is that, unless the existing calculations identified the different vibrational modes of a structure, it was assumed essentially all of the structure's mass acted in the first primary mode, thus maximizing seismic induced forces. The results of the extrapolations provided in section I.8 thus represent a best engineering judgment.

In cases where the original documentation could not be located, the result for that particular building structure defaulted to "possible" failure. In most cases there were no formally issued or documented functional requirements for equipment operability (either program or safety equipment) following an earthquake. Critical equipment was identified by knowledgeable lab personnel during facility walkthroughs. If none were identified, it was assumed that none exist.

If documentation of seismic evaluations of the critical equipment was available, potentials for damage due to the postulated earthquake were estimated as described above and in section I.5. In most cases, however, this documentation was not available for review. As a result, the potentials for equipment damage due to an earthquake, summarized in section I.8, were estimated utilizing best engineering judgment during a facility walkthrough. These estimates focused only on equipment anchorages and did not attempt to address equipment operability either during or after the postulated earthquake.

Walkthroughs of all facilities (with the exceptions noted below) for which seismic response predictions were required, were performed to verify selected information provided in existing calculations, drawings, Safety Analysis Reports, or other documents. The kind of information verified was limited to those items considered most important for predicting structural and equipment responses to the postulated earthquake. The most important of these items were:

- Determine the status of any seismic strengthening modification recommended by existing documentation.
- Verify that the general building configuration as it exists today is adequately represented in the existing calculations.
- Verify that selected critical assumptions noted in the existing calculations are still valid.
- Verify that potential for damage to equipment (program or safety) due to obvious falling or sliding hazards is addressed by existing calculations.
- Verify the identification of safety equipment and its location with knowledgeable LLNL and SNL, Livermore facility personnel.

Consistent with the major assumptions for this appendix (see section I.2), walkthroughs were not performed for the buildings or areas shown below due to the lack of structural and equipment seismic documentation.

Gas Cylinder Loading Dock - Building 518

Tank Area - Near Building 622

The results of the extrapolations discussed above for structures and equipment, as well as the results from the building walkthroughs, were documented in new calculations (WESTON, 1991b).

I.7 SEISMIC DESIGN CRITERIA

I.7.1 LLNL Livermore Site

Before 1980, LLNL required that buildings, structures, systems, and components be seismically designed and evaluated in accordance with Uniform Building Codes in place at the time the evaluations or design were taking place; however, even prior to 1980 some structures were evaluated using more stringent seismic criteria, based on case-by-case reviews of the structure's mission and its contents.

Following the Livermore earthquakes of January 1980, a more stringent seismic design policy was required for any new structure or modification to an existing structure (Tokarz, 1991a). This policy was formalized in 1984 with the issuance of the Earthquake Safety Program, UCAR 10129 (Freeland, 1984). It required that LLNL buildings, structures, systems, and components be seismically designed and evaluated within four safety classifications: high hazard, moderate hazard, low hazard, and no hazard conventional buildings. Guidelines for classification were provided by LLNL's Hazards Control Department.

Beginning in 1980 (Tokarz, 1991a), and later in accordance with the 1984 policy (Freeland, 1984), high hazard facilities required a two-step design or evaluation process. Step one involved dynamic response spectral analysis using response spectra corresponding to a peak horizontal ground acceleration of 0.50g and a peak vertical ground acceleration of 0.33g. The response was required to remain elastic and within Uniform Building Code working stress allowable limits. Connections were to be subjected to forces 1.5 times those due to the 0.50g horizontal and 0.33g vertical response spectra. The second step involved dynamic analysis with peak ground accelerations of 0.80g horizontal and 0.53g vertical with inelastic (post-yield) response permitted provided the structure remained functional during and after an earthquake. In both steps, the horizontal and vertical accelerations were to be applied simultaneously.

Moderate hazard facilities also required a two-step design or evaluation process. Step one was a dynamic response spectral analysis using response spectra corresponding to peak ground accelerations of 0.25g horizontal and 0.17g vertical. The response was required to remain elastic and within Uniform Building Code strength allowable limits. Connections were to be subjected to forces 1.5 times those due to the 0.25g horizontal and 0.17g vertical response spectra. Step two involved dynamic analysis with a peak horizontal ground acceleration of 0.50g and a peak vertical ground acceleration of 0.33g, and with inelastic response permitted provided functionality was maintained during and after the earthquake. In both steps, the horizontal and vertical accelerations were to be applied simultaneously.

Low-hazard and no-hazard (i.e., conventional building) facilities were subdivided based on the number of stories. One- and two-story structures were required to meet all Uniform Building Code requirements with an upgraded building seismic lateral load coefficient of 0.25 W (static), where W is the weight of the building. Connections were subjected to forces 1.5 times those due to the 0.25 W earthquake forces. Structures over two stories in height had the same requirements as for one- and two-story structures; in addition, they were evaluated using response spectra corresponding to peak ground accelerations of 0.50g horizontal and 0.33g vertical, acting simultaneously. Inelastic response was permitted provided the structure would not collapse during an earthquake.

The policy implemented since 1980 (Tokarz, 1991a) has been applied retroactively to all high hazard structures, but not all structures currently ranked as moderate hazard. Some structures designed prior to 1980, but not modified since, have not been reevaluated based on the 1980 earthquake policy. When modifications or additions to a structure did occur, only these additions or modifications were designed to meet the more stringent 1980 policy. Typically, the rest of the structure was not evaluated against that policy.

There are several notable exceptions to this, two of which are Buildings 332 and 251. When modifications were made to these buildings, the entire structures were evaluated using the more stringent 1980 policy; however, even in these cases, not all parts of the structure were actually upgraded in accordance with the policy. Only those portions identified as critical for the containment of radioactive and/or hazardous materials were upgraded. Consequently, individual structures at LLNL may be designed to several different criteria, corresponding to the various modifications and additions built over the years.

It should be noted that a number of other structures at LLNL have been seismically upgraded to meet more stringent criteria (e.g., Building 111). These will not be discussed further in this EIS/EIR as they cannot release any significant quantity of hazardous materials and they are not important for emergency response. Section I.3 describes the selection of structures requiring seismic response analysis.

In 1990 a new set of seismic design and evaluation guidelines was adopted for all DOE facilities (Kennedy et al., 1990). These guidelines also classify facilities into four usage categories: general use, important or low hazard, moderate hazard, and high hazard. Table I-9 describes those usage categories.

Under the Kennedy et al. (1990) guidelines described in section I.5 moderate- and high-hazard facilities are subjected to elastic response spectrum dynamic analyses which explicitly model the mass and stiffness distributions of the structures. Limited inelastic behavior of these facilities is permitted and accounted for by reducing their elastically computed seismic response. The amounts of reduction allowed for moderate and high hazard structures are less than the amounts allowed for general use and other facilities described below. The lower reductions introduce increased conservatism and a reduced probability of damage for the higher hazard facilities. The response spectra used as the seismic input to such analyses are median amplified curves corresponding to post-yield damping and whose zero period (or peak ground) acceleration values represent a probability of exceedence of 1×10^{-3} per year (or a 1000-year return period) for moderate hazard facilities, and a probability of exceedence of 2×10^{-4} per year (or a 5000-year return period) for high hazard facilities. The spectral shape is typically based on procedures proposed by Newmark and Hall (1982). The elastically computed seismic demand on the structural members of each facility, after reductions to account for limited inelastic behavior, is required to be less than each member's structural capacity, determined from code ultimate values.

General use and important or low hazard facilities are designed or evaluated based on normal building code (i.e., the 1991 Uniform Building Code) seismic provisions. These provisions express the lateral earthquake forces on a building in terms of the total base shear, V, according to the equation V = ZICW/RW where Z is a seismic zone factor equivalent to peak ground acceleration; I is a factor accounting for the importance of the facility; C is a spectral amplification factor; W is the total weight of the facility; and RW is a reduction factor to account for the energy absorption capability of the facility. General use, and important or low hazard facilities are subjected to equivalent static or dynamic analysis scaled to this Uniform Building Code–type base shear, with the exception that Z and C are determined from site-specific seismic hazard curves and 5 percent damped median response spectra, respectively. The Z factor for general use facilities is the maximum ground acceleration corresponding to a probability of exceedence of 2×10^{-3} per year or a 500-year return period, while the Z factor for important or low hazard facilities is the maximum ground acceleration corresponding to an annual exceedence probability of 1×10^{-3} per year, or a 1000-year return period. Demand forces and stresses on structural members are required to be less than the appropriate structural capacities, determined from code ultimate values when strength design is used or from allowable stress levels when allowable stress design is used.

It should be noted that DOE does not require that existing DOE facilities be evaluated to these newer guidelines (Kennedy et al., 1990).

I.7.2 LLNL Site 300

Before the recent reclassification of the Corral Hollow–Carnegie fault zone as active (see section I.4.3), the LLNL Site 300 seismic ground motion hazard was defined by the same active faults that defined the LLNL Livermore site and SNL, Livermore ground motion hazards. It was thought that the ground motion hazard would be less at LLNL Site 300 since it was farther from the active faults. (See also Table 4-4, in Kennedy et al., 1990.) When the 1984 Earthquake Safety Program (Freeland, 1984) requirements were adopted by LLNL, the same requirements were applied to the LLNL Site 300 structures. As at the LLNL Livermore site, these requirements were not applied retroactively; only those designs for new structures, additions, or modifications were required to utilize the newer policy.

The 1990 DOE guidelines (Kennedy et al., 1990) also apply to LLNL Site 300; however, with the Corral Hollow–Carnegie fault reclassified as active, it is not necessarily conservative to use the same ground motion acceleration response spectra as that used at the LLNL Livermore site and SNL, Livermore. For this reason, the studies described in section I.4.3 were performed in order to more rigorously define the ground motion at LLNL Site 300 based on the site's specific geologic setting. The studies concluded that it is still reasonable to utilize the acceleration response spectra developed for the LLNL Livermore site when evaluating structures at LLNL Site 300.

Due to the lack of any new construction at LLNL Site 300 since the issuance of DOE 1990 guidelines, and because none of the site's structures are ranked as high hazard, there has not been any evaluation of LLNL Site 300 structures utilizing the new guidelines.

I.7.3 SNL, Livermore

Before the issuance of the 1990 DOE seismic design and evaluation guidelines (Kennedy et al., 1990) SNL, Livermore did not institute a seismic safety program similar to that of LLNL (Freeland, 1984). In addition, formal classification of structures into four hazard categories (see section I.7.1) was not conducted at SNL, Livermore.

The only two structures at SNL, Livermore identified as needing a seismic response prediction (see section I.3 for a description of the selection process) were the Tritium Research Laboratory (Building 968) and the Emergency Communications Facility (Building 964). Consequently, the following discussion of design criteria utilized is limited to those two structures. Building 968 was most recently evaluated and upgraded in 1982. The seismic design evaluation criteria in place at that time for LLNL's critical facilities were specified for use on this facility at SNL, Livermore. The criteria required evaluation to a 0.8g peak ground acceleration earthquake. Building 964 was seismically designed using a static 0.25 W Uniform Building Code–type analysis, and has not been upgraded since then.

Following the January 1980 Livermore earthquakes, a number of other structures at SNL, Livermore were reevaluated to seismic criteria more stringent than those used in their original designs; however, discussions of the original or upgrade criteria are not relevant to this EIS/EIR and are not included. As described in section I.3, these other structures were not identified as being of concern for release of hazardous or radioactive materials, nor were they required to be operational for emergency response functions.

To date, none of SNL, Livermore's structures have been fully reevaluated to the newer 1990 DOE guidelines (Kennedy et al., 1990).

I.8 RESULTS OF EVALUATIONS

Table I-12 provides building and equipment loss-of-confinement potentials resulting from the postulated 0.8g earthquake. These results, along with Table I-13 results, which provide loss of function potentials described below, were used in developing the seismically initiated accident scenario in Appendix D and in describing the site's emergency response plan in Appendix J. Table I-14 provides building and equipment loss of confinement potentials, resulting from a postulated "Above Design Basis" earthquake of 0.9g, for those structures found unlikely in Table I-12 to sustain loss of function due to the 0.8g event. Structures important to emergency response shown as unlikely in Table I-13 to sustain loss of function due to the 0.8 event were not reevaluated. The results described in Table I-14 for the Above Design Basis earthquake were not used in an additional seismically induced accident scenario in Appendix D, because no additional failures were identified as a result of using the 0.9g event.

It should be noted that except for structures classified as high hazard, the 0.8g event already represents an "Above Design Basis" earthquake. This is because low and moderate hazard structures, according to DOE criteria (Kennedy et al., 1990) for LLNL and SNL, Livermore, are only required to be designed to 0.5g and 0.6g events.

When structural components or equipment did not meet the requirements of the evaluation criteria in section I.5, the potential for loss of building function or confinement was listed as "possible." Possible failures of building equipment such as cranes or other heavy overhead items which could impact hazardous and/or radioactive materials are included in either the program column or the safety system column, depending on whether the postulated failure could cause a release (e.g., an overhead crane falling on a glovebox) or prevent a safety system from operating (e.g., an overhead crane falling onto the diesel generator supplying backup power).

Table I-13 provides building damage potentials resulting from the postulated 0.8g earthquake for those facilities identified as important to emergency response (see section I.3). Rather than predicting loss of confinement of hazardous materials, failure to meet the evaluation criteria is assumed to result in the loss of function of this particular structure or its equipment. There were no formally issued functional requirements for equipment operability following an earthquake for these structures. Equipment evaluation results referred to in Table I-13 are typically limited to anchorage evaluations for backup emergency power equipment (i.e., engine generators and associated gas tanks, starting batteries, etc.), except as noted in "comments." Some of the potentials for loss of function due to equipment damage are listed as unlikely based on a combination of seismically adequate anchorages or doubly/triply redundant systems.

Evaluation results shown in Table I-13 for the Fire House (Building 323) were limited to that structure. The capability of the domestic water supply system, including hillside tanks, pump stations, underground piping, and valves to survive a 0.8g seismic event was not evaluated. However, based on the conclusions of the Mechanical Utilities Systems Master Plan for the Domestic Water System (CH2M-Hill, 1990), the main reservoir tanks would suffer damage even at lower level seismic events. Consequently, it should be assumed that domestic water would be generally unavailable for fire-fighting following a 0.8g event.

In Table I-12, an N/A (not applicable) in either column indicates that no programmatic equipment or safety equipment that must operate following an earthquake to either maintain confinement or maintain accident dose levels to the public below regulatory levels, was identified by Safety Analysis Reports (or other similar facility document) or by the lab personnel. In Table I-13, an N/A indicates that no equipment, other than that clearly not susceptible to seismic-induced damage (e.g., mobile engine generators, hand-held radio communications, etc.), was identified as necessary to operate in order for the facility to be considered operational following an earthquake.

In general, it should be noted that a conservative assumption is implicitly made in using the results from Tables I-12 to I-14 in modeling accident scenarios (Appendix D). A failure of a structure or equipment to meet the evaluation criteria is assumed not only to cause loss of confinement of any released hazardous and/or radioactive material, but to fail in such a way as to cause the release itself. An example would be in assuming a structural roof diaphragm failure drops building debris onto a laboratory space, rupturing a glovebox containing hazardous material. In reality, structural failures can occur without causing hazardous and/or radioactive material releases.

Table I-12 Potential for Loss of Confinement Due to Demand Criteria Postulated to Be a 0.8g PGA Earthquake

Building No.	Building Name	Site	Building Classifi-cation	Potential for Loss of Confinement			Location or Components Reviewed
				Due to Building Damage	Due to Program	Equipment Damage Safety Sys.	
166	Inertial Confinement Fusion Lab	LLNL	L	Unlikely	Unlikely	Possible	Southwest increment only
251	Diagnostic Chemistry	LLNL	H	Unlikely	Unlikely	Unlikely	Hardened portion increments 3 and 6
			L	Possible	Possible	Possible	Unhardened portion (all other increments)
321	Material Fab. Shop Area C	LLNL	M	Possible	Unlikely	Possible	Increment 4 only
331	Hydrogen Research Facility	LLNL	H	Possible	Possible	Possible	
332	Plutonium Facility	LLNL	H	Unlikely	Unlikely	Possible	
514	Waste Treatment	LLNL	M	N/A	Unlikely	N/A	Four 55-gallon drums & adjacent mixing tank structure
612	Waste Storage	LLNL	M	Unlikely	Unlikely	N/A	
614	Waste Storage	LLNL	M	Possible	Unlikely	N/A	East increment only
625	Waste Storage	LLNL	M	Possible[f]	Possible[a]	N/A	
131	Engineering	LLNL	M	Possible	Unlikely	N/A	Only sub-building II
141	Electrical Plating Shop	LLNL	L	Possible[a]	Possible[a]	N/A	
151	Nuclear Chemistry	LLNL	L	Possible	N/A	N/A	Only west wing
322	Plating Shop	LLNL	L	Possible	N/A	N/A	
493	Separator Support Facility	LLNL	L	---[b]	---[b]	---[b]	
298	Fusion Target Facility	LLNL	---	---[c]	---[c]	---[c]	
391	NOVA Laser Facility	LLNL	---	---[c]	---[c]	---[c]	
518	Gas Cylinder Dock	LLNL	L	Possible[a]	N/A	N/A	
622	Tank Area	LLNL	---[d]	N/A	Possible[a]	N/A	Only three propane

							tanks
693	Chemical Waste Storage	LLNL	M	Possible	N/A	Unlikely	
968	Tritium Research Laboratory	SNL, Livermore	---[e]	Unlikely	Possible	Possible	Laboratory Building
				Possible	N/A	Possible	Mechanical Room (adjacent to laboratory)

[a] No seismic documentation available for review.

[b] Building not evaluated. Hazardous and/or radiological materials cannot be dispersed by collapse of building or equipment due to seismic event.

[c] Building not evaluated. Future use expected to alter current structure.

[d] Building never classified.

[e] Building never classified. Evaluation criteria for Moderate Hazard (DOE, 1990) used.

[f] Limited seismic documentation available for review.

N/A = Not applicable because no programmatic equipment or safety equipment that must operate following an earthquake to either maintain confinement or maintain accident dose levels to the public below regulatory levels was identified by Safety Analysis Reports (or other similar facility documents) or by Laboratory personnel.

Table I-13 Potential for Loss of Function Due to Demand Criteria Postulated to Be a 0.8g PGA Earthquake

<table>
<tr><th rowspan="2">Bldg. No.</th><th rowspan="2">Building Name</th><th rowspan="2">Site</th><th rowspan="2">Bldg. Classification[a]</th><th colspan="2">Potential for Loss of Function Due to</th><th rowspan="2" colspan="2">Comments</th></tr>
<tr><th>Building Damage</th><th>Equipment Damage</th></tr>
<tr><td rowspan="2">271</td><td rowspan="2">Protective Force</td><td rowspan="2">LLNL</td><td>---[b]</td><td>Possible</td><td>Possible</td><td colspan="2">South increment</td></tr>
<tr><td>H</td><td>Unlikely</td><td>Possible</td><td colspan="2">North increment basement/diesel generator</td></tr>
<tr><td>313</td><td>Emergency Communications</td><td>LLNL</td><td>H</td><td>Unlikely</td><td>N/A</td><td colspan="2">Communications backed up by mobile units. No other equipment necessary.</td></tr>
<tr><td rowspan="2">323</td><td rowspan="2">Hazard Control Fire House</td><td rowspan="2">LLNL</td><td>---[b]</td><td>Possible</td><td>N/A</td><td>South Portion</td><td rowspan="2">Communications backed up by mobile units. No other equipment necessary.</td></tr>
<tr><td>M</td><td>Possible</td><td>N/A</td><td>North Portion</td></tr>
<tr><td>663</td><td>Health Services</td><td>LLNL</td><td>M</td><td>Unlikely</td><td>Unlikely</td><td colspan="2">Only back-up fresh water and diesel generator were evaluated. Other equipment unnecessary.</td></tr>
<tr><td rowspan="2">964</td><td rowspan="2">Security/Emergency Response</td><td rowspan="2">SNL, Livermore</td><td>L</td><td>Possible</td><td>N/A</td><td colspan="2">First floor</td></tr>
<tr><td>M</td><td>Unlikely</td><td>N/A</td><td colspan="2">Basement</td></tr>
</table>

[a]Buildings in this table were never classified. Documentation reviewed treats these facilities similarly to high–(H),

moderate–(M), or low–(L) hazard structures.
[b] No documentation available for review.
N/A = Not applicable because no equipment, other than those clearly not susceptible to seismic-induced damage (e.g., mobile engine generators, hand-held radio communications, etc.) was identified as necessary to operate in order for the facility to be considered operational following an earthquake.

Table I-14 Potential for Loss of Confinement Due to "Above Design Basis" Event Postulated to Be a 0.9g PGA Earthquake

Building No.	Building Name	Site	Building Classi-fication	Potential for Loss of Confinement			Location or Components Reviewed
				Due to Building Damage	Due to Program	Equipment Damage Safety Sys.	
166	Inertial Confinement Fusion Lab	LLNL	L	Unlikely	Unlikely	Possible	
251	Diagnostic Chemistry	LLNL	H	Unlikely	Unlikely	Unlikely	Hardened portion increments 3 and 6
			L	Possible	Possible	Possible	Unhardened portion (all other increments)
332	Plutonium Facility	LLNL	H	Unlikely	Unlikely	Possible	
514	Waste Treatment	LLNL	M	N/A	Unlikely	N/A	Four 55-gallon drums & adjacent mixing tank structure
612	Waste Storage	LLNL	M	Unlikely	Unlikely	N/A	
614	Waste Storage	LLNL	M	Possible	Unlikely	N/A	East increment only
968	Tritium Research Laboratory	SNL, Livermore	---*	Unlikely	Possible	Possible	Laboratory Building
				Possible	N/A	Possible	Mechanical Room (adjacent to laboratory)

* Building never classified. Evaluation criteria for Moderate Hazard (DOE, 1990) were used.
N/A = Not applicable because no programmatic equipment or safety equipment that must operate following an earthquake to either maintain confinement or maintain accident dose levels to the public below regulatory levels was identified by Safety Analysis Reports (or other similar facility documents) or by Laboratory personnel.

Conversion Equations

English Units to Metric Units–Lengths		
To Convert:	To:	Multiply By:
inches	centimeters	2.54
inches	millimeters	25.4
feet	centimeters	30.48
feet	meters	0.305
miles	kilometers	1.61
Metric Units to English Units–Lengths		
To Convert:	To:	Divide By:
millimeters	inches	25.4
centimeter	inches	2.54
meters	feet	3.05
meters	yards	0.915

APPENDIX I GLOSSARY

Active fault	In this EIS/EIR, a fault known to be recent because it has displaced materials 35,000 years old or younger. Alquist-Priolo Special Studies Zones Act of 1972 defines an active fault as one that has had surface displacement during Holocene time (the last 11,000 years).
Alluvial	Referring to alluvium, which is any stream-laid sediment deposit found in a stream channel and in low parts of a stream valley subject to flooding.
Anticline	A fold in rocks in which the strata dip outward from both sides of the axis, where the oldest strata are in the core of the fold. The opposite of a syncline.
Arcuate	Curved like a bow, curved or bowed.
Aseismic slip	A slip along an underground fault consisting of many small movements so that very little seismic energy is emitted.
Blind thrust fault	A thrust fault that does not intersect the surface of the earth; a buried thrust fault.
Clastic	Pertaining to a rock or sediment composed principally of broken fragments that are derived from preexisting rocks or minerals and that have been transported some distance from their places of origin.
Colluvium	A general term applied to loose and incoherent deposits, usually at the foot of a slope or cliff and brought there chiefly by gravity. Talus and cliff debris are included in such deposits.
Conjugate fault	A fault or set of faults that are of the same age and deformation episode.
Coseismic slip	A slip directly associated with a particular earthquake, as opposed to a later slip.
Decollement	A low-angle fault that forms the base of an overlapping series of thrust faults.
Demand criteria	Values of maximum ground acceleration that buildings should be able to withstand and remain operational.
Deterministic	With results determined by input assumptions and data, but without the probability of occurrence.
Dextral motion	Right-lateral motion on a strike-slip fault. If one stands on one side of the slip, the other moves to the right.
Dip	The angle at which a stratum or other planar feature is inclined from the horizontal.
Disconformity	An unconformity in which the bedding planes above and below the break are essentially parallel, indicating a significant interruption in the orderly sequence of sedimentary rocks, generally by a considerable interval of erosion (or sometimes of nondeposition), and usually marked by a visible and irregular or uneven erosion surface of appreciable relief. (An unconformity is a substantial break or gap in the geologic record where one rock unit is overlaid by another not next in the stratigraphic succession.)
En echelon	Parallel structural features that are offset like the edges of shingles on a roof when viewed from the side.
Epicenter	The point on the earth's surface directly over the point at which earthquake motion starts.
Exponential notation	A means of expressing large or small numbers in powers of ten. For instance, 4.3×10^{6} = 4,300,000 and 4.3×10^{-5} = 0.000043. This relationship is also sometimes expressed in the form $4.3E^{+6}$ = 4,300,000 and $4.3E^{-5}$ = 0.000043.
Fault	A fracture in the earth's crust accompanied by displacement of one side of the fracture with respect to the other and in a direction parallel to the fracture.
Fault creep	Slow ground displacement usually occurring without accompanying earthquakes. It may be of tectonic origin or result from oil or ground water withdrawal.

Fault plane solution	A determination of the underground plane on which a slip occurs in an earthquake; a determination of the focal plane. The distribution of first-motion compressional and dilatational waves from an earthquake calculated from many seismological stations.
Fault zone	The region of rock failure along a fault.
Focal depth	The depth from the earth's surface to the point of initial rupture of an earthquake.
Focal plane	The plane on which the initial rupture of an earthquake occurs.
Fold	A bend in strata or any other planar structure.
g notation	Accelerations measured relative to the acceleration of gravity at the earth's surface. Thus, 0.1g = 3.2 ft/sec^2 or 98.3 cm/sec^2.
Geodetic	Of, relating to, or determined by geodesy, which is a branch of applied mathematics that determines the exact positions of points and the figures and areas of large portions of the earth's surface, the shape and size of the earth, and the variations of terrestrial gravity and magnetism.
Geologic ages	The ages of rocks, formations, etc. The present age is the Holocene or Recent Age.
Ground acceleration	The intensity of the strong phase of ground shaking in units of g (earth's gravitational attraction).
Holocene	A standard epoch of geological time, from 10,000 years ago until the present.
Left-lateral	On a strike-slip fault, if one stands on one side of the slip, the other moves to the left.
Liquefaction	A type of soil failure where a mass of saturated soil is transformed from a solid to a liquid state.
Magnitude	A measure of the strength of an earthquake or the strain energy released by it; the logarithm of the amplitude of motion recorded on a seismograph.
Metamorphic rock	Any rock derived from preexisting rocks by mineralogical, chemical, and/or structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment, generally at depth in the earth's crust.
Microearthquakes	Very small earthquakes that can only be detected by seismometers.
Microseismicity	Weak seismic signals in an earthquake region that are too small to notice but which indicate continued slow slip.
Miocene	A standard epoch of geologic time between the Pliocene and Oligocene, from about 28 million to 5.3 million years ago.
ML	Local or Richter magnitude defined as the log10 of the maximum seismic-wave amplitude recorded on a standard seismograph at a distance of 100 km from the earthquake epicenter. The magnitude measures the strain energy released by an earthquake.
Modified Mercalli Scale	An earthquake intensity scale, with 12 divisions ranging from I (not felt by people) to XII (damage nearly total).
MS	Surface wave magnitude; magnitude determined from measurements of the amplitude of seismic surface waves.
Normal fault	A fault in which the block above appears to have moved downward relative to the block below.
Paleosol	A buried soil; a soil of the past.
Piercing point	A point at which an underlying structure penetrates to the earth's surface.
Plate tectonics	A theory of global-scale dynamics involving the movement of rigid plates of the earth's crust.
Pleistocene	A standard epoch of geological time, from about 1.6 million to 10,000 years ago.
Pliocene	A standard epoch of geological time, from about 5.3 million to 1.6 million years ago.
Plunge	The inclination of a linear geologic structure measured as the angle it makes with the horizontal.
Quaternary	The period of geologic time since the end of the Pliocene, comprising the Pleistocene and Holocene, from about 1.6 million years ago to the present.
Response spectra	Spectral content of earthquake accelerations for specified peak accelerations and damping factors.
Reverse fault	A fault dipping steeper than 45·, in which the block above appears to have moved upward relative to the block below.

Right-lateral motion	On a strike-slip fault, if one stands on one side of the slip, the other moves to the right.
Sedimentary rock	A rock resulting from the consolidation of loose sediment that has accumulated in layers.
Seeps	A spot where water or petroleum oozes from the earth, often forming the source of a small trickling stream.
Seiche	A wave oscillation of the surface of water in an enclosed basin (such as lake or bay) initiated by an earthquake or changes in atmospheric pressure.
Seismogenic source	A fault capable of producing earthquakes.
Shear	Force or motion tangential to the section on which it acts.
Slickensides	A smoothly striated surface that results from friction along a fault plane.
Slip	To move or displace; a movement dislocating adjacent blocks of crust separated by a fault.
Splays	Divergent small faults that comprise a fault zone.
Strata	Plural of stratum which is a single sedimentary bed or layer.
Stratigraphic offset	Displacement of a formerly continuous stratigraphic horizon.
Strike (of a fault)	The direction of the line of intersection of a horizontal plan with an uptilted geologic stratum.
Strike-slip fault	A fault in which the net slip is horizontal, parallel to the strike of the fault.
Surface faulting	As opposed to a thrust fault, a fault that does intersect the surface of the earth; the displacement of ground along the surface trace of a fault.
Syncline	A fold in rocks in which the strata dip inward from both sides of the axis, where the youngest strata are in the core of the fold.
Terraces	Relatively horizontal or gently inclined surfaces or deposit sometimes long and narrow, which are bounded by a steeper ascending slope on one side and by a steeper descending slope on the opposite side.
Tertiary	The period of geologic time between the Cretaceous and the Pleistocene, comprising the Pliocene, Miocene, Oligocene, Eocene, and Paleocene, from about 65 million to 1.6 million years ago.
Thrust fault	A fault dipping less than 45·, in which the block above appears to have moved upward relative to the block below.
Tonal contrast	A contrast in color value or hue in a photograph. Often referred to a change or contrast in color along a linear trend in aerial photographs of the earth's surface, suggesting the presence of a fault or structural boundary.
Trace	A line on one plane representing the intersection of another plane with the first one (e.g., a fault trace).
Trend (of a fault)	Its strike. If the fault intersects the surface, the direction of that intersection.
Tuff	A rock formed of compacted volcanic fragments, generally smaller than 4mm in diameter.
Volcanic rock	A generally finely crystalline or glassy igneous rock resulting from volcanic action at or near the Earth's surface, either ejected explosively or extruded as lava (e.g., basalt). The term also includes near-surface intrusions that form a part of the volcanic structure.

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APPENDIX J EMERGENCY PLANNING AND RESPONSE

The purpose of this appendix is to summarize emergency planning and response activities established to mitigate the consequences of major emergencies and natural disasters at the Lawrence Livermore National Laboratory (LLNL) and the Sandia National Laboratories, Livermore (SNL, Livermore). This summary covers four topics: Regulatory Background, which identifies the federal regulations upon which the emergency preparedness programs are based; Local, State, and Federal Emergency Response, which describes the responsibilities of government agencies as well as the LLNL and SNL, Livermore involvement with state and local emergency planning organizations; and LLNL Emergency Preparedness and SNL, Livermore Emergency Preparedness, which discuss planning and response, emergency management, functional response, emergency organization and responsibilities, mutual assistance (between the Laboratories and from outside entities), and training and exercises. Figure J-1 identifies the location of additional information on emergency response and related topics within the EIS/EIR.

J.1 REGULATORY BACKGROUND

Federal regulations require the establishment of emergency planning and response to radiological or hazardous incidents. These regulations include 40 C.F.R. sections 335, 265, and 302.6, and 29 C.F.R. section 1910.120, which deal with SARA Title III Emergency Planning and Notification, continuous planning, release reporting, and hazardous waste operation and emergency response. In addition, DOE provides specific direction in DOE Orders 5000.3A, 5500.2B, 5500.3A, 5500.1B, and 5500.10 (DOE, 1990a, 1991a, 1991b, 1991c, 1991d) for implementing emergency preparedness for a variety of events, including earthquakes.

To meet federal requirements, both LLNL and SNL, Livermore have developed sitewide emergency preparedness plans. These programs coordinate and integrate all aspects of response, including notification, protective actions, and mutual assistance; specify the methods employed; and provide the framework and support for ongoing maintenance of the emergency response programs.

J.2 LOCAL, STATE, AND FEDERAL EMERGENCY RESPONSE

The federal government has established a Federal Radiological Emergency Response Plan (50 Fed. Reg. 46,542, 1985) under the management of the Federal Emergency Management Agency for responding to incidents involving radioactive materials. For incidents involving other hazardous material, the EPA planning requirements of 40 C.F.R. (40 C.F.R. section 355, 1990) provide for National Response Teams to assist if needed.

The California State Office of Emergency Services is responsible for the development and implementation of state emergency preparedness plans. The City of Livermore and Alameda County also have developed plans and designated resources to respond to incidents. LLNL, SNL, Livermore, the State of California, Alameda County, and the City of Livermore have formed a local community emergency management planning group to coordinate the emergency response plans of these organizations. This group has been meeting on a quarterly basis and is discussing items such as Protective Action, Standard Notification Form, and Evacuation Route Planning. Emergency plans cover a wide range of incidents beyond hazardous material and radioactive material releases (such as explosions, fire, earthquake, and sabotage).

DOE is responsible for ensuring that emergency plans and procedures are in place for all nuclear facilities, operations, and activities under its jurisdiction (DOE, 1991b). For LLNL, DOE San Francisco field office ensures that an emergency plan has been developed and that the headquarters section responsible for emergency planning has reviewed and concurred with the plan. DOE Albuquerque field office has this responsibility for SNL, Livermore. In addition to overseeing the development of plans by the operators of LLNL and SNL, Livermore, these field offices are required to develop site-specific plans for response to incidents at LLNL and SNL, Livermore. Finally, these DOE field offices are required to determine and maintain the resources needed to operate their emergency preparedness programs.

J.2.1 General Responsibilities and Resources of Federal Agencies

The Director of the Federal Emergency Management Agency has "the responsibility for establishing federal policies for and coordinating, all civil defense and civil emergency planning, management, mitigation, and assistance functions of executive agencies" by Executive Order 12148, July 20, 1979. As a result of this Executive Order, the Federal Radiological Emergency Response Plan was published (50 Fed. Reg. 46,542, 1985). The following paragraphs describe agency responsibilities established by the Federal Radiological Emergency Response Plan.

DOE is responsible for conducting and managing federal onsite actions at LLNL and SNL, Livermore; monitoring, evaluating, advising, and providing assistance, if required; developing and/or evaluating recommendations for state, county, and local officials on public protective action measures; coordinating with the state the release of information to the public, Congress, and the Executive Branch; and initiating response activities with state concurrence. In conjunction with the Environmental Protection Agency, DOE is responsible for coordinating federal radiological monitoring and assessment. Jointly with the Federal Emergency Management Agency, DOE is responsible for recommending offsite public protective action measures to state, county, and local officials.

The EPA is responsible for providing intermediate and long-term response. The Federal Emergency Management Agency is responsible for coordinating federal assistance to state and local governments, and providing logistical support to federal agencies.

For accidents involving radioactive materials or wastes, DOE maintains Radiological Assistance Teams with the Radiological Assistance Program. There are eight regional offices established in the United States with Radiological Assistance Teams ready to support on-scene command and control maintained by state, tribal, or local agencies.

For nonradiological emergencies, DOE or the Federal Emergency Management Agency can procure and coordinate assistance for the appropriate federal agency, as required.

Federal Emergency Management Agency response teams will establish a joint operations center to coordinate activities of federal, state, and local agencies.

DOE resources, such as the Federal Radiological Monitoring and Assessment Center (FRMAC), would be available to provide assistance and support to state, county, and local officials as part of the Radiological Assistance Program. This assistance would include monitoring teams capable of evaluating the extent of offsite radiological contamination, the amounts of radioactive materials released to the environment, and the impact of plume exposure and ingestion pathway exposure to the population. In the event of a transportation incident, DOE may assist state or local authorities with identification of vehicle or property contamination, decontamination methods, and medical advice for contaminated injuries as part of the Radiological Assistance Program. If required, DOE's Atmospheric Release Advisory Capability can provide predictions for the potential downwind, offsite spread of airborne contaminants.

J.2.2 General Responsibilities of State and Local Government

The California State Office of Emergency Services is the lead agency responsible for the development and implementation of state emergency preparedness plans. If there is an offsite release of hazardous or radioactive materials from LLNL or SNL, Livermore, the state will assist Alameda and San Joaquin Counties. The California State

Office of Emergency Services has set up a local community emergency planning group to ensure coordination of emergency plans between LLNL, SNL, Livermore, Alameda and San Joaquin Counties, the City of Livermore, and the state.

The State Office of Emergency Services ensures that state agencies have trained personnel and resources in place to respond to emergencies.

Alameda and San Joaquin counties have developed emergency response plans for hazardous materials as required by SARA, Title III. Alameda County's plan also deals with the possible release of radioactive materials. The county emergency response organizations are the lead agencies in situations involving the offsite release of hazardous or radioactive material. They are responsible for coordinating state, county and city government responses to these situations.

The City of Livermore has developed and implemented an emergency plan for the accidental release of hazardous or radioactive material from LLNL or SNL, Livermore. The City of Livermore Civil Defense–Emergency Services is responsible for coordinating planning with the Alameda County Office of Emergency Services. It is also responsible for assisting other responding agencies in locating and providing needed equipment and resources.

Capabilities of State and Local Governments

The State Office of Emergency Services makes the resources of other state agencies available to affected counties as needed, in the event of an offsite release of hazardous or radioactive material. The California Highway Patrol assists in evacuations, notification, communications, and secures the site involved. The California State Department of Health Services can provide trained personnel capable of assisting staff members with monitoring and decontamination, the evaluation of the extent of any contamination, and ingestion pathway monitoring (SNL, Livermore, 1990a).

Alameda and San Joaquin counties can provide additional police to secure the site, alert nearby residents, and assist in evacuation. The counties can also request assistance from various city emergency teams.

The City of Livermore has fire and police services available to assist Alameda County in offsite response, and if requested can assist LLNL or SNL, Livermore. The City of Livermore Civil Defense-Emergency Services organization is capable of assisting other offsite agencies in procuring and placing needed equipment and resources, and in providing updates to city officials. The Civil Defense-Emergency Services Office can activate the Radio Amateur Civil Emergency System if primary communication links become unavailable (SNL, Livermore, 1990a).

J.3 LLNL EMERGENCY PREPAREDNESS

The LLNL Emergency Preparedness Plan and Emergency Preparedness Plan Implementing Procedures incorporate the LLNL Livermore site and LLNL Site 300, and include the organizational structure, response procedures, and functional roles of responding personnel. The focus of the plan is to provide a coordinated response to incidents involving more than one of the basic emergency service elements and to incidents that may be a threat to the health and safety of personnel and the general public. These incidents include, but are not limited to, earthquakes and other natural events, the inadvertent release of hazardous chemicals or radiation, fires, explosions, transportation-related offsite incidents involving LLNL, civil disturbances, and terrorism (LLNL, 1990a).

Emergency preparedness at LLNL relies upon the capabilities and resources of onsite organizations, the accessibility of emergency response equipment in multiple locations, and a communication system with multiple redundancy. Additionally, offsite support is available through mutual aid agreements with the local community.

J.3.1 Responsibilities and Authority for Planning

The Laboratory Director is ultimately responsible for emergency preparedness; however, responsibility for planning and implementing emergency preparedness is delegated to the Emergency Preparedness and Response Program Leader. The Program Leader ensures that the emergency response organization is prepared to perform the functions described in the Emergency Preparedness Plan and the Emergency Preparedness Plan Implementing Procedures, including those functions relating to ongoing planning and program maintenance.

The Program Leader also is responsible for ensuring that the LLNL Emergency Preparedness Plan and Emergency Preparedness Plan Implementing Procedures are appropriate and adequate for current LLNL operations. This is accomplished through review of Safety Analysis Reports, Building Safety Analysis Summaries, Facility Safety Procedures, Self-Help Plans, and annual internal hazard assessments or self-appraisals by persons not directly responsible for program administration. The Department of Energy also plays an oversite role in ensuring the adequacy of these documents and internal assessments.

Hazard assessments provide the basis for emergency planning requirements and prescribe the operational emergency strategies. The requirements for the hazard assessments are provided in the LLNL Health and Safety Manual (LLNL, 1990a). In response to these review findings, the Emergency Preparedness Plan and the Emergency Preparedness Plan Implementing Procedures are reviewed annually, changes are coordinated, revisions published, approvals acquired, and appropriate controlled distribution is carried out.

J.3.2 LLNL Emergency Response Resources

To support localized response capabilities, LLNL is divided into 22 self-help zones (15 at the LLNL Livermore site, and 7 at LLNL Site 300). Response is guided by implementation of Self-Help Plans that are consistent with the Emergency Preparedness Plan. These Self-Help Plans provide for personnel accountability, first aid response, locating and rescuing trapped or injured personnel, maintaining the safety and well-being of personnel, and locating and reporting damage to facilities.

Emergency equipment is maintained to perform search, rescue, and first aid, and to shut down utilities during an emergency. Personal protective equipment such as disposable coveralls, various types of gloves, face shields, head gear and shields, shoe covers, and head covers are maintained for personnel responding to incidents such as spills of hazardous materials. Equipment is inspected regularly and replaced when necessary.

LLNL has several systems for communicating emergency information. These systems include evacuation paging in buildings, telephones, two-way radios, radio pagers, an AM broadcast station (1610), siren/klaxons, portable loudspeakers, megaphones, and runners. In addition, these systems are supplemented by the Radio Amateur Civil Emergency System, a network of employees who are amateur radio operators.

J.3.3 Organizations and Interface

J.3.3.1 Emergency Management

Emergency Management Team

The organization responsible for managing response to a major emergency or disaster at LLNL is the Emergency Management Team. The Emergency Management Team includes a senior DOE representative (generally the San Francisco field office Livermore site office representative) and senior LLNL managers and staff from each basic emergency service organization. The structure of this team is shown in Figure J-2.

Activation of the Emergency Management Team and implementation of the elements of the Emergency Preparedness

Plan are initiated on recognition of the existence of an emergency condition and classification of the incident. Classification is based on a standardized scheme of escalating severity levels (Alert, Site Area Emergency, General Emergency). Emergency Action Levels (LLNL, 1990a), defined in the Plan, provide guidance in classifying the types of events that may be considered emergencies and thus require activation of the Emergency Management Team. Safeguards and Security emergencies are classified separately as are Radiological Assistance Program emergencies. During such emergencies, DOE may use trained personnel from LLNL to respond to emergencies at other locations.

Incident Commander

The Incident Commander is responsible for the initial classification of incidents, initiating the appropriate response functions, and making required initial notifications (LLNL, 1990a). The Incident Commander is also responsible for safety, rescue, fire control and extinguishment, spill control, containment, protection of classified matter, property conservation, and salvage operations. The Incident Commander retains on-scene operational control throughout the duration of the incident.

Emergency Manager

The Emergency Manager assumes management command and control (LLNL, 1990a) and may reclassify the emergency. The Emergency Manager is responsible for activating the Emergency Management Center and its organization, reviewing recovery operations, and reviewing documentation of the incident and the response. The Emergency Manager also may issue protective action orders for personnel, and may make protective action recommendations to state and local emergency service organizations for offsite protective actions.

Laboratory Emergency Duty Officer

The Laboratory Emergency Duty Officer, who is on call 24 hours a day, serves as the Emergency Manager until one of the designated Emergency Managers assumes that function. At LLNL Site 300, the Resident Manager fulfills a similar role.

J.3.3.2 Emergency Management Center

The Emergency Management Center is the focal point for emergency management and control. The facility provides a location for official liaison with local, state, and federal agencies and with the news media; a central location from which the Emergency Manager maintains continuity of operations and succession of authority; and a location for centralized information-gathering and dissemination by decision-makers while directing coordinated emergency response and protective actions (LLNL, 1990a).

The Emergency Management Center is located in Building 313. The alternative backup location is Building 111. The facility may be partially activated for an Alert classification and shall be fully activated for a Site Area or General Emergency. Full staffing includes representatives of those organizations indicated in solid boxes in Figure J-2, as well as support provided by the Information Display and Recording Team, Communications and Telephone Operators, Radio Amateur Civil Emergency System operators, and representatives of specific service groups and program management.

Communications are typically maintained by telephone between the Emergency Management Center and the Hazards Control Satellite Operations Center, the Field Operations Center, the Atmospheric Release Advisory Capability Center, and local, state, and federal officials. Radio Amateur Civil Emergency System capabilities are employed as a backup.

The release of public information is coordinated through and approved at the Emergency Management Center, with the participation of the senior DOE representative, who has primary responsibility for interfacing with DOE San Francisco Field Office and DOE Headquarters.

J.3.3.3 Functional Response

Organizational divisions (represented by dashed lines in Figure J-2) functionally respond to an emergency by dispatching personnel and equipment. These units are directed by the following seven organizations, which coordinate all activities with the Emergency Management Center and provide guidance to the units from the Hazards Control Satellite Operations Center via communication networks.

J.3.3.3.1 Hazards Control Department

The Hazards Control Department (shown in Figure J-3) consists of five divisions. During a sitewide emergency, the department head is responsible for establishing health and safety emergency control plans, utilizing resources, and developing emergency response teams. All department personnel respond to designated duties. Hazards Control activates its Satellite Operations Center in Building 253 to coordinate resources and relay information to the LLNL Emergency Management Center (LLNL, 1990a). The safety mission of each division within Hazards Control is described below.

Fire Safety Division

Fire personnel are on duty 24 hours a day at both the LLNL Livermore site and LLNL Site 300 (LLNL, 1990a). The Fire Safety Division operates under the "Incident Command System." The first fire officer to arrive at the scene assumes the Incident Commander position until relieved by the Fire Chief or a chief officer. The Fire Chief or a chief officer becomes the Incident Commander upon arrival at the emergency.

During a single emergency, the Incident Commander operates from a mobile command post located at the emergency scene. During multiple emergencies, the Incident Commander and staff operate from the Field Operations Center in Building 323 (the LLNL Fire Station). The Field Operations Center serves as a central clearinghouse for support requests from the Incident Commander, as a staging area for non-Laboratory resources such as mutual aid personnel and equipment, and as a major communications link to the Hazards Control Satellite Operations Center. From the Field Operations Center, command posts are set up at each emergency scene under the direction of an operations officer designated by the Incident Commander. All requests for personnel and equipment come through the field command post(s) to the Incident Commander. Run cards (informational cards) are maintained by the Fire Safety Division to advise fire officers regarding hazard information and special actions required for each facility.

The Field Operations Center is equipped with telephones, radios, chalkboards, a kitchen, sleeping quarters, and showers. The facility is a central assembly area for response personnel if radio communication is disrupted (LLNL, 1990a).

Safety Services Division

The Safety Services Division includes the Radiation Measurement Group and the Industrial Hygiene Services Group and is responsible for providing the Incident Commander with requested radiation measurements and industrial hygiene services through the Hazards Control Satellite Operations Center. The Radiation Measurement Group provides radioactive sample analysis and radiation survey instruments to support personnel in the field. The Industrial Hygiene Services Group provides analysis of toxic materials, industrial hygiene instruments, and personal protective equipment (LLNL, 1990a).

Operational Safety Division

The Operational Safety Division is responsible for providing onsite and offsite safety support. Operational Safety is composed of Teams 1–7, which provide field safety support to LLNL programs and support organizations and may assist Fire Safety's Emergency Operations Group. The Operational Safety Division Leader is assigned to the Hazards

Control Satellite Operations Center when it is activated and maintains radio communication with the Safety Team Leaders via a portable radio network.

Except for Team 7 (which is responsible for LLNL sitewide environmental, safety, and health assessment activities) each team is assigned to a specific area (five teams to the LLNL Livermore site, and one to LLNL Site 300). The team also is assigned to a program(s) at LLNL and provides knowledge and expertise during emergencies. One member of a team reports to one of the team's assigned areas, assesses the situation, and relays this information to the Safety Team Leader. The Safety Team Leaders, or a member of the Safety Team (depending on time-frame), in turn, relay this information to the programmatic command post and to the Operational Safety Division Leader at the Hazards Control Satellite Operations Center. When a command post is established at the scene of a specific emergency, the Safety Team Leader or other team member reports directly to the Incident Commander. If there are no problems at a safety team's assigned area, the Operational Safety Division Leader may direct the team leader to reassign personnel to another safety team (LLNL, 1990a).

Health and Safety Division

The Health and Safety Division is composed of the Industrial/Explosives Safety Group, the Health Physics Group, the Industrial Hygiene Group, and the Criticality and Safety Analysis Group. Health and Safety Division is responsible for supporting Fire Safety's Emergency Operations Group and for providing additional support, as directed, through the Hazards Control Satellite Operations Center.

When the Hazards Control Satellite Operations Center is activated, unassigned members of each group report to their assembly areas for briefings and instructions from the Division Leader. Group members, with safety team assignments, report to the Safety Team Leader at the field command post in their assigned geographical areas. Group members provide technical support in their areas of expertise, as follows:

- Industrial/Explosives Safety advises on high-pressure systems, electrical hazards, general physical hazards, and explosives.
- Health Physics deals with exposure to ionizing radiation and radioactive contamination.
- Industrial Hygiene advises on the control of chemical and physical agent exposures and their potential impacts on personnel, and conducts assessments of employee exposures to these agents.
- Criticality and Safety Analysis advises on fissile materials that may present a criticality concern.

Special Projects Division

The Special Projects Division is primarily responsible for research in areas related to fire, health physics, industrial hygiene, and analytical chemistry. Special Projects supports other department personnel during an emergency by providing technical information and specialized measurements in the fields of fire, radiation, and safety science (LLNL, 1990a).

Atmospheric Release Advisory Capability (ARAC)

The Atmospheric Release Advisory Capability (ARAC) group is an integration of professional staff, numerical models, and computer systems that provides emergency response support not only to LLNL but also to other installations worldwide. Its overall mission includes emergency planning, real-time emergency response and assessments, postaccident analysis, and training. During an emergency, ARAC provides real-time assessments of the consequences of an atmospheric release of radioactive material, and advisory services through analysis of hypothetical scenarios, routine assessments, and evaluations involving atmospheric release of toxic materials.

The Hazard Control Satellite Operations Center normally requests the services of ARAC. Information about an accident or potential accident is transmitted to the Atmospheric Release Advisory Capability System Center. The center provides calculations in the form of plots showing dose or air concentration and ground deposition of toxic materials. ARAC support computers are located in Building 253 at the LLNL Livermore site and Building 848 at LLNL Site 300. Communication with the Emergency Management Center is maintained through the Hazards Control Satellite Operations Center.

J.3.3.3.2 Environmental Protection Department

The Environmental Protection Department (shown in Figure J-4)

consists of four divisions. During a sitewide emergency, the department is responsible for providing environmental support to all LLNL programs and departments. With the exception of Environmental Restoration, which does not play a role in emergency response, the mission of each division within Environmental Protection is described below.

Operations and Regulatory Affairs Division

The Environmental Operations Group of the Operations and Regulatory Affairs Division provides environmental support to LLNL programs and departments during emergencies. The first member of the group to respond reports to the Incident Commander. The group assesses the incident and coordinates necessary cleanup and corrective measures; evaluates the incident and establishes whether the incident is reportable to external regulatory and emergency response agencies; coordinates reporting with the Emergency Manager; notifies the regulatory agencies; and prepares and submits the reports required by those agencies. In addition, Environmental Operations will assist the responsible LLNL program in evaluating the incident and in preparing Unusual Occurrence Reports under DOE Order 5000.3A (DOE, 1990a). The group also directs the sampling of environmental media to assess the extent of contamination, determines the level of cleanup needed, and verifies that cleanup is completed.

Hazardous Waste Management Division

The Hazardous Waste Management Division is responsible for providing equipment and personnel to contain and clean up spills in an environmental emergency (LLNL, 1989, 1990b, 1990c), and for maintaining a supply of emergency response equipment in a specially equipped response trailer. The Operations Group within the division has the primary responsibility for providing remedial support in an environmental emergency (Stein and Gancarz, 1985).

Environmental Surveillance Division

The Environmental Surveillance Division includes the Environmental Monitoring Group and two laboratories. The Environmental Monitoring Group determines if air releases have been detected by samplers used in the routine air-monitoring program and by portable air samplers deployed in response to the incident; performs air dispersion modeling to show potential air contaminant migration; responds to incidents involving the detection of contaminants in the sanitary sewer system; and samples water, soil, vegetation, and any other environmental media. This group has the primary responsibility for operating the sanitary sewer monitoring station at Building 196. If this system detects contaminants above acceptable levels, the diversion system, which is described in Appendix B, is activated. The Environmental Monitoring Group verifies that the event is real and, through the use of satellite monitoring stations, locates the vicinity of the spill (LLNL, 1990a); notifies the Livermore Water Reclamation Plant of the incident; and prepares any required reports.

The Environmental Analytical Sciences Laboratory is a California State–certified lab that can be used to analyze samples for certain contaminants to identify materials in a release or determine if cleanup has been completed.

The Radiation Analytical Sciences Laboratory, which is operated by the Nuclear Chemistry Program, can be used to analyze environmental samples for radioactive contamination.

J.3.3.3.3 Credibility Assessment

Credibility Assessment consists of a team of individuals knowledgeable in design and fabrication of improvised nuclear and non-nuclear explosive devices, in psycholinguistic or psychologic threat message analysis, and in adversarial behavioral analysis.

J.3.3.3.4 Health Services Department

The Health Services Department consists of a professional medical staff and Fire Safety Division Emergency Medical Technicians. Health Services is responsible for maintaining a detailed medical emergency response plan for providing medical care during emergencies, using both LLNL and offsite non-Laboratory capabilities. Both ground and air transportation are available to local hospital emergency facilities. Ambulances are radio equipped.

For emergencies involving the LLNL Livermore site, air transport of patients is provided by Alameda County under the Alameda County Medical Alert Plan. Memoranda of Agreement ensure availability of Valley Memorial Hospital in the City of Livermore and Eden Hospital (trauma center) in Castro Valley for treatment of radiologically contaminated personnel. At LLNL Site 300, air transport is provided by Modesto Medi-Flight. Tracy Community Hospital is available for treatment of patients who are not radiologically contaminated. Contaminated injured personnel will be transported to Valley Memorial Hospital (LLNL, 1990a) or Eden Hospital. The decision for air transport is normally made by Health Services Department personnel, but may be made by the Fire Safety Division, if warranted, through the Emergency Management Center. Notification is coordinated by the LLNL dispatcher.

In addition to medical supplies available at Buildings 663 (LLNL Livermore site) and 877 (LLNL Site 300), the Health Services Department maintains a mobile disaster supply trailer containing blankets, cots, limited medical and orthopedic supplies, bandages, respiratory equipment, radios, and documentation supplies. The trailer is supplied with an emergency generator and lights.

J.3.3.3.5 Plant Engineering Department

The Plant Engineering Department (shown in Figure J-2) is responsible for maintaining LLNL facilities and utilities. Personnel are on duty 24 hours a day. Maintenance and Operations Division personnel within this department are routinely called upon to correct malfunctions. In the event of an emergency, Plant Engineering will activate the Satellite Operations Center in Building 511 when the Emergency Management Center is activated, and will support the Incident Commander at the scene of the emergency. Plant Engineering will also activate Self-Help Plans.

J.3.3.3.6 Safeguards and Security Department

The Safeguards and Security Department consists of five divisions, two of which are responsible for responding to and assisting emergency service personnel.

Protective Force Division

The Protective Force Division protects LLNL property and personnel; maintains appropriate control of classified material and information; and controls personnel access, including site evacuations, during an emergency. Safeguards and Security also develops and executes security measures and mutual-aid agreements, provides 24-hour coverage of overall security resource management, provides advice to the Emergency Manager during an emergency, functions as liaison with outside law enforcement, and assesses tactical situations. The Protective Force Division will also provide support as requested if the Federal Bureau of Investigation assumes command and control of the emergency from the LLNL Emergency Manager. Additional information related to the Safeguards and Security Department is presented in section 4.16.2.

Materials Management Division

Materials Management personnel provide specialized advice on emergency activities during a threat to accountable nuclear materials, sealed radioactive sources, or classified weapon parts.

J.3.3.3.7 Public Information Office

The Public Information Office functions as the point of contact for the release of emergency-related information from LLNL. Before it is given out, information is gathered at the Media Center in Building 219. The Public Information Office Manager coordinates with DOE, University of California, and SNL, Livermore Public Affairs offices. The DOE representative in the Emergency Management Center reviews all public information statements and responses to queries regarding the emergency. The DOE representative is also the point of interface with DOE/SAN and DOE/HQ.

The Public Information Office is staffed on a 24-hour basis and is equipped with six walkie-talkies and a radio pager. The onsite Radio Amateur Civil Emergency System may be used as communications backup.

J.3.4 Mutual Assistance Agreements

Mutual aid agreements that cover fire, medical, rescue, and radiation emergencies are in place between LLNL and the following agencies: Alameda County (Medical Response), Alameda County (Fire Service Operational Plan), Valley Memorial Hospital (Radiation Emergency), State of California Office of Emergency Services, UC Davis (Applied Science Department–LLNL Building 661), City of Livermore (Automatic Aid Agreement), City of Tracy, UC and State of California (Master Mutual Aid Agreement), and Twin Valley Mutual Aid. These agreements are also discussed in section 4.16.

In addition, the Safeguards and Security Department has established agreements for nonreciprocal police assistance to LLNL with the following agencies: City of Livermore, California Highway Patrol, Alameda County Sheriff's Department, City of Tracy, and the San Joaquin County Sheriff's Department.

LLNL and SNL, Livermore maintain mutual assistance agreements for a range of emergency response actions including fire, chemical, medical, security and safeguards, radiological, and environmental monitoring and assessment emergency support. Specific responses provided to SNL, Livermore by LLNL are described below.

Upon arrival at the scene of a fire at SNL, Livermore, the LLNL fire Incident Commander assumes lead responsibility for all fire-fighting activities. (If requested, the SNL, Livermore Fire Extinguisher Team will support the LLNL fire Incident Commander and his personnel.) The LLNL fire department is qualified to respond to fires involving radioactive material and hazardous chemicals. LLNL also possesses a 24-hour response capability and has established mutual aid agreements with other local area fire departments as part of the Twin Valley Fire Incident Commanders Association.

On a 24-hour basis, the LLNL Hazards Control Fire Safety Division team, which is equipped with protective clothing and respiratory protection equipment, provides a first response to chemical emergencies, including spills and leaks. Upon arrival at the scene, the LLNL team assumes responsibility for responding to the chemical hazard and coordinates activities with the SNL, Livermore Chemical Hazards Supervisor, Building Emergency Team Leader, and on-scene environmental response team members.

LLNL also can provide trained emergency medical technician personnel and an ambulance for medical emergencies at SNL, Livermore on a 24-hour basis. During normal working hours, an occupational health physician is available for response to medical emergency situations. Ambulance personnel are trained to respond to injuries involving radioactive contamination and can treat injured personnel at the LLNL medical facility or deliver injured personnel to

Valley Memorial Hospital. When the injuries involve radioactive contamination, LLNL provides health physics monitoring and support to the hospital. Upon arrival at the scene, the LLNL medical team assumes responsibility for responding to the situation, and the SNL, Livermore first aid team provides support.

If requested, the LLNL Safeguards and Security Department will support the SNL, Livermore Security Department in responding to security-related situations, including security threats, hostage negotiations, and site evacuations. Several on-duty LLNL security officers can respond immediately, and additional support can be provided within one hour. In such instances, the LLNL security officers will function under the direction of the SNL, Livermore Security Supervisor.

Radiological and environmental evaluation support can be provided to SNL, Livermore by the LLNL environmental evaluation team. The LLNL team can assist with determining the extent of offsite consequences resulting from a release of tritium. Under the direction of the SNL, Livermore Radiological Hazards Supervisor, the LLNL team will augment the SNL, Livermore Environmental Response Team. Since neither the SNL, Livermore team nor the LLNL team is equipped with protective clothing capable of allowing extended entry into concentrated tritium plumes, radiological monitoring will be conducted at the plume edge and after the plume has dispersed. The LLNL team's support will be directed toward evaluating the extent of offsite contamination. Later, as available, ingestion pathway sampling and analysis support will be provided to DOE and state agencies.

The SNL, Livermore Radiological Response Team at the Tritium Research Laboratory or health physics professionals responding to radiological incidents at other buildings may request support from the LLNL emergency assistance team. Under the direction of the SNL, Livermore Building Emergency Team Leader, the LLNL team will be used in an advisory capacity in support of building reentry. If onsite contamination problems are widespread, the LLNL team may assist with personnel decontamination activities. If counting equipment is not available or onsite background levels are too high, SNL, Livermore may request assistance in counting samples.

LLNL also can provide radiological assessment support via operation of its Atmospheric Release Advisory Capability system.

J.3.5 Training, Drills, and Exercises

The LLNL Emergency Preparedness Plan requires initial training and annual retraining for key Emergency Management Organization personnel. The training program consists of performance-based modules that are specific to the requirements of emergency response organization positions. The training program may be revised as needed on the basis of changes to the Emergency Preparedness Plan or its procedures and to critiques following drills or exercises.

Drills and exercises are developed and conducted to provide practical training of the response organization and evaluation of its performance under various scenarios. Drills and exercises are conducted in coordination with appropriate federal, state, and local agencies. LLNL conducted its most recent full-scale exercise in December 1990.

J.4 SNL, LIVERMORE EMERGENCY PREPAREDNESS

The SNL, Livermore Emergency Preparedness Plan describes the program for responding to onsite emergencies and near-site emergencies that may affect activities onsite. The plan covers spills or releases of radioactive or hazardous materials, fires, explosions, natural disasters, security events, and declared states of national alert. The plan was developed to meet the intent of DOE Orders (See section J.1 for the specific Orders) and to provide guidance to assure the health and safety of personnel and the general public during emergencies.

The SNL, Livermore plan covers personnel roles and responsibilities, authority, and organizational interfaces; activation and augmentation of the emergency response organization; interfaces and coordination between the SNL, Livermore emergency response organization, LLNL, and offsite officials and agencies; emergency classification; notification and communications; assessment and mitigation of situations; facilities and equipment; medical treatment and first aid; release of information to the public and media; assembly, accountability, and evacuation of nonessential personnel; the Emergency Preparedness Training Program, including drills and exercises; and administration of the Emergency Preparedness Plan, including provisions for its review and update. Emergency Preparedness Plan Implementing Procedures have been developed from the commitments in the plan. These procedures are position-specific and include step-by-step checklists (SNL, Livermore, 1990a, 1990b).

Other plans that establish criteria or provide information pertaining to emergency preparedness and response are the SNL, Livermore Hazardous Waste Management Facility Contingency Plan, the Spill Prevention Control and Countermeasure Plan, the Radio Amateur Civil Emergency System Communications Plan, the Security Emergency Operations Procedures, the Emergency Organization Activation List, the Emergency Phone Directory, and Site Building Floor Plans.

J.4.1 Responsibilities and Authority for Planning

Development and implementation of the emergency response program is the responsibility of the Emergency Preparedness Review Committee, which is chaired by a Director-level individual assigned by the Vice President. Each SNL, Livermore directorate is represented on the committee. The Emergency Preparedness Coordinator serves as committee secretary.

The Emergency Preparedness Review Committee reviews and approves the plan; obtains Vice Presidential approval; periodically reviews the status of the program, including its associated training, drills, and agreement letters; ensures that sufficient resources are allocated for program support; recommends improvements; and ensures adequate implementation.

J.4.2 SNL, Livermore Emergency Response Resources

SNL, Livermore maintains both equipment and organizations sufficient to respond to most emergencies. SNL, Livermore response capabilities are enhanced by resources provided by LLNL, as established in letters of agreement (discussed in section J.2.4). This approach was developed because the only facility at SNL, Livermore with a significant inventory of radioactive material is the Tritium Research Laboratory in Building 968; thus, the majority of radiological emergency response is focused on that facility.

Emergency response equipment for radiological and hazardous material releases is maintained and routinely inventoried to ensure readiness for use. The emergency equipment includes full body protection with supplied air for reentry, supplies for decontamination of emergency response personnel, gloves, shoe covers, flashlights, and other supplies. The equipment is located in cabinets just outside the Tritium Research Laboratory, one cabinet outside the entrance to the laboratory monitoring room and a second cabinet inside the main entrance. A tritium monitor is maintained with the emergency equipment and additional monitors are available from the Tritium Research health physics office.

Two environmental response team kits are maintained for environmental monitoring, including supplies necessary for taking soil, vegetation, and water samples. Radiation monitors are available from the health and safety division. Kits also include protective clothing such as gloves, coveralls, and shoe covers. Several vehicles, available to the onsite team, are controlled by Security and the Center for Environment, Safety and Health and Facilities Management. Emergency equipment is audited on a quarterly basis and after each use, following a drill or an actual release.

J.4.3 Organizations and Interface

J.4.3.1 Emergency Management and Functional Response Areas

The emergency response organization shown in Figure J-5

identifies the organization that will be activated during an emergency. The organization's five main functional areas are discussed below.

J.4.3.1.1 Emergency Response Director

The Emergency Response Director is responsible for overall implementation of the resources needed to respond to, mitigate, and terminate an emergency. The Emergency Response Director has full decision-making authority to implement the necessary emergency response activities. The Emergency Response Director determines priorities and appropriate levels of response; declares the emergency classification based on the emergency action levels; issues protective action orders for onsite personnel; and approves emergency worker exposures above 5 rem. The Emergency Response Director also is responsible for ensuring that necessary personnel are obtained, for committing funds for critical resources, and for approving press releases.

J.4.3.1.2 Plant Engineering

The Plant Engineering Supervisor is responsible for coordinating engineering work response activities at the scene of the event. This supervisor directs the activities of the building emergency teams, assesses the extent of damage, recommends corrective actions to the Emergency Response Director, implements corrective actions, coordinates response activities with offsite organizations, and coordinates recovery planning. The Plant Engineering Supervisor is also responsible for evaluating the possible impact to nearby facilities requiring shutdown of gas and electrical systems or closure; and for obtaining resources needed for emergency response activities, including equipment, supplies, and personnel from resources already onsite, from other DOE facilities, or from vendors.

Plant Engineering maintains a list of essential personnel who will be available at a central point for various levels of emergencies. These individuals possess expertise in areas such as plant engineering and maintenance.

Building Emergency Teams

Every building at SNL, Livermore has an emergency team. Several emergency teams are assigned to each of the larger buildings at SNL, Livermore, including First Aid Teams, Fire Extinguisher Teams, Personnel Accountability Teams, and (for the Tritium Research Laboratory) a Radiological Response Team.

The Building Emergency Team Coordinator, who reports to the Plant Engineering Supervisor, is responsible for coordinating the activities of the Building Emergency Team Leaders (Figure J-6) and the response actions of activated Building Emergency Teams. These activities include completing accountability, checking the buildings, searching for and rescuing missing persons, and evacuating individual buildings or groups of buildings. If a site evacuation is ordered, the Building Emergency Team Coordinator works closely with the Security Supervisor. The Building Emergency Team Coordinator operates primarily from the Emergency Management Center but may proceed to the scene of an emergency if required. The coordinator can obtain help from the Plant Engineering staff for establishing barricades to minimize water damage or to control the spill of hazardous chemicals, for turning off gas and electric supplies, for providing emergency power sources, and for modifying building ventilation system operations.

The Building Emergency Team Leader is the primary person in charge at the scene of the emergency. This responsibility includes coordinating the teams' activities for building evacuation; first aid; initial use of fire extinguishers and other small hand-held, maintenance-type equipment; limited special actions for chemical or radiological hazards; and verification that classified information has been secured. In addition to the assigned teams, the Building Emergency Team Leader may receive assistance at the scene from the Protective Force, the Environmental Response Team, and other building emergency teams. The assigned Building Emergency Team Leader will maintain lead responsibility at the scene for the response effort except when the LLNL Fire Department is called. In those situations, the LLNL Fire Safety Division Incident Commander assumes lead authority, and the Building Emergency Team Leaders, if needed, pass instructions to evacuees and team members.

First Aid Team

The First Aid Team consists of persons qualified in basic first aid and cardiopulmonary resuscitation. In addition, an occupational physician and nurse are onsite during normal work hours. For injuries requiring medical attention beyond the qualifications of the First Aid Team, professional medical assistance is requested. The First Aid Team continues first aid activities until relieved by the medical professionals. If an individual needs to be taken to the medical clinic or an offsite medical facility, the SNL, Livermore First Aid Team supports the LLNL ambulance crew. For injuries involving radioactive contamination, help is obtained from the Radiological Response Team. For multiple injuries or a situation where building occupancy is precluded, a medically outfitted van is available to serve as an emergency medical station.

Fire Extinguisher Team

The Fire Extinguisher Team responds to fire alarms and, if there are no chemical, radioactive, or other hazardous materials involved, uses fire extinguishers when it appears that they would be effective. If radioactive material or hazardous materials are involved, assistance will be provided by the Environmental Response Team and, if necessary, an LLNL Hazards Control team. The Fire Extinguisher Team is also assisted by the SNL, Livermore Fire Marshal, as necessary. The Fire Marshal may serve as advisor to the Building Emergency Team Leader and assists LLNL Livermore site fire personnel who respond to emergencies under mutual assistance agreements with SNL, Livermore.

Accountability Team

The Accountability Team is responsible for verifying that personnel have evacuated the building area and that missing persons are identified. The team sweeps a building area to ensure that evacuation is underway and reports to the Building Emergency Team Leader when the evacuation is complete. If professional offsite responders are not enroute or available, the Accountability Team performs search and rescue activities with other team members, as needed. The Accountability Team also serves as security observers in the cleared assembly areas to ensure that uncleared personnel are escorted while in the cleared assembly areas and during building reentry.

Radiological Response Team

The Radiological Response Team is assigned solely to the SNL, Livermore Tritium Research Laboratory. (Limitations on radioactive material at buildings/areas other than the Tritium Research Laboratory make the possibility of a radiation problem at other facilities remote.) This team evaluates the radiological hazards and takes corrective actions under the direction of the Building Emergency Team Leader. If radiological material has been released, the Radiological Response Team assesses the extent of damage and the potential hazard to personnel. The Team may consult with the Radiological Hazards Supervisor in the Emergency Management Center, or may recommend that he come to the scene to assist with emergency response and/or cleanup activities. Additional support can be requested from LLNL. Health physics professionals respond to radiological incidents at buildings other than the Tritium Research Laboratory. Individuals who may be called upon to assist the health physics staff are building occupants familiar with activities in the building.

J.4.3.1.3 Security

The Security Supervisor coordinates onsite security activities in response to security threats and other emergency conditions. This responsibility includes overall site access control, provisions for expedient entry of emergency vehicles, security communications, implementation of site evacuation, and, if necessary, closure of the site. The Security Supervisor is responsible for ensuring access control to the security building, housing the Emergency Management Center and a Satellite Operations Center, and controlling access to buildings or areas of the site that are evacuated. The Security Supervisor is the primary interface with the Alameda County Sheriff's Department and the City of Livermore Police Department. The Security Supervisor also interfaces with the Federal Bureau of Investigation on matters relating to security and provides support, as requested, if the Federal Bureau of Investigation assumes command and control from the Emergency Response Director. Finally, the Security Supervisor interfaces with DOE and SNL, Albuquerque for issues relating to security.

J.4.3.1.4 Environment, Safety and Health

Radiological Hazards

The Radiological Hazards Supervisor is responsible for calculating doses from actual or potential radiological releases and coordinating offsite Environmental Response Teams. In addition, the supervisor recommends onsite protective actions, tracks and evaluates the radiological exposures of emergency response personnel, and notifies the Emergency Response Director if radiological exposure limits are being approached or exceeded. For decisions regarding reentry of the radiological response team into the Tritium Research Laboratory, the Building Emergency Team Leader tracks and evaluates radiological exposures of Tritium Research Laboratory emergency response personnel. The Radiological Hazards Supervisor also coordinates the activities and deployment of any field teams provided by LLNL.

Chemical Hazards

The Chemical Hazards Supervisor is responsible for assessing any potential chemical hazard that may result from an emergency. This supervisor updates the Emergency Response Director regarding the situation and recommends control and cleanup methods. The Chemical Hazards Supervisor may request the help of an LLNL Hazards Control team, serves as the primary interface with chemical support personnel, keeps the Emergency Response Director informed of EPA and State of California hazardous material reporting requirements, and assists in notifying these agencies.

Environmental Response Team

The Environmental Response Team, under the direction of the Radiological Hazards Supervisor and/or the Chemical Hazards Supervisor, is responsible for responding to emergencies that have the potential for hazardous material releases to the environment. In a radiological release, offsite monitoring for tritium is the primary function of the team. Its activities include evaluating radiological exposure to the public and ingestion pathway monitoring. In a chemical or other nonradiological hazardous material release, team members are responsible for assisting with hazards assessment, protective actions, control, and cleanup.

J.4.3.1.5 Public Information

The Public Information Officer is the official spokesperson for SNL, Livermore during an emergency. The Public Information Officer is responsible for issuing timely and accurate press releases, handling press briefings, and coordinating the release of information with DOE/AL, LLNL, and other offsite agencies as appropriate. The Emergency Response Director and DOE/AL review and approve all press releases prior to their release.

In order to assure timely issue, DOE/AL has preapproved the language to be used for the initial public press release so that only the approval of the Emergency Response Director (to assure the accuracy of the press release) need be obtained. Subsequent press releases with specifics and details of the emergency would be approved by both the

Emergency Response Director and DOE/AL. The official SNL, Livermore, source of information must be perceived as reliable and timely by the media to minimize misinformation and the use by the press of other sources of information that may not be as current as the information available directly from SNL, Livermore.

J.4.4 Mutual Assistance Agreements

LLNL and SNL, Livermore maintain mutual assistance agreements for a range of emergency response actions including fire, chemical, medical, security and safeguards, radiological and environmental monitoring, and assessment. For more detail on the mutual assistance agreements between LLNL and SNL, Livermore see section J.3.4.

The SNL, Livermore Emergency Preparedness Plan also provides for assistance agreements with the City of Livermore Police Department, the Alameda County Sheriff's Department, the California Highway Patrol, and Valley Memorial Hospital.

J.4.5 Training, Drills, and Exercises

The SNL, Livermore Emergency Preparedness Plan requires initial training and annual retraining for emergency responders. The training program consists of performance-based modules that are specific to the requirements of emergency response organization positions. The training program may be revised as needed on the basis of changes to the Emergency Preparedness Plan or implementing procedures and to critiques following drills or exercises.

Drills and exercises are developed and conducted to provide practical training of the response organization and evaluation of its performance under various scenarios. Drills and exercises are conducted in coordination with state and local agencies. SNL, Livermore conducted its most recent full-scale exercise in February 1991.

J.5 TRANSPORTATION-RELATED EMERGENCY RESPONSE

Both LLNL and SNL, Livermore have emergency response plans and procedures for onsite transportation-related incidents involving hazardous and radioactive materials and wastes. Supplements to LLNL's *Health and Safety Manual* (LLNL, 1988) also address specific transportation concerns such as shipping of explosives and radioactive substances. In its *Transportation Safety Manual* (SNL, Livermore, 1991), SNL, Livermore includes additional guidance and procedures for responding to onsite transportation-related spills or releases.

These procedures detail specific activities for first response and evaluation of a hazardous spill, actual cleanup, records keeping, and subsequent follow-up to eliminate, if possible, repeat incidents. They also identify administrative roles and responsibilities, lines of authority for coordinating emergency response, and requirements for clean up after a transportation-related accident.

Packaging and Other Requirements

Compliance with U.S. Department of Transportation (DOT) and/or DOE requirements for packaging hazardous and radioactive materials reduces, if not eliminates, the impacts of any release of any hazardous or radioactive materials resulting from an accident. Packaging requirements for hazardous and radioactive shipments are detailed in DOT (49 C.F.R. 109–199) and Nuclear Regulatory Commission (10 C.F.R. 71) regulations. These requirements apply to shipments of hazardous and radioactive materials and wastes from LLNL and SNL, Livermore.

In addition, hazardous and radioactive material packages are labelled and the transport vehicle is placarded. Shipping papers and documentation requirements also provide necessary information for emergency response. These requirements are specifically identified in DOT regulations (49 C.F.R. 172.600).

J.6 TECHNICAL INFORMATION ASSISTANCE

In addition to the capabilities of LLNL and SNL, Livermore, further confirmation and advice are available from the National Response Center in Washington, DC, for emergencies involving spills of hazardous substances. CHEMTREC, a national information resource on hazardous substances, also provides such information and advice. Both the National Response Center and CHEMTREC are accessible 24 hours a day via a toll-free 800 telephone number.

Emergency response information involving radioactive materials and wastes is available from the Joint Nuclear Accident Coordinating Center. In conjunction with the Defense Nuclear Agency, DOE operates the Joint Nuclear Accident Coordinating Center to exchange and maintain information related to radiological assistance capabilities within the federal agencies and the military (DOE, 1990a). The Joint Nuclear Accident Coordinating Center also provides a focal point for requesting military assistance in connection with radiological accidents.

APPENDIX J GLOSSARY

Criticality	The state of a mass of fissionable material when it is sustaining a chain reaction.
Explosives	*See* High explosives.
Glovebox	A sealed box in which workers, while remaining outside and using gloves attached to and passing through openings in the box, can safely handle and work with radioactive materials, other hazardous materials, and nonhazardous air-sensitive compounds.
Hazardous waste	Any solid, semisolid, liquid, or gaseous waste that is ignitable, corrosive, toxic, or reactive as defined by RCRA and identified or listed in 40 C.F.R. part 261.
Health physics	The science and practice of radiation protection and management.
High explosives (HE)	Chemically energetic materials with the potential to react explosively; nuclear explosives are not included.
Packaging	In the NRC regulations governing the transportation of radioactive materials (10 C.F.R. section 71), the term "packaging" is used to mean the shipping container together with its radioactive contents.
Radioactive material	Any material having a specific activity greater than 0.002 microcuries per gram, as defined by 49 C.F.R. part 173.4-3(y).
Run card	A fire department folder that contains information on a building useful on a call, such as a response plan, building layout, location and nature of special hazards, and names of key people.

APPENDIX J REFERENCES

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APPENDIX K TRAFFIC AND TRANSPORTATION

K.1 INTRODUCTION

This appendix includes additional information supporting the impacts analyses in the traffic and transportation sections (see sections 4.13 and 5.1.11) of the EIS/EIR. It provides a more extensive and detailed discussion of traffic-related and transportation activities at LLNL and SNL, Livermore. It also addresses the general and specific requirements for moving hazardous and radioactive material and wastes both onsite and offsite (see sections 4.15 and 5.1.13). Figure K-1 describes the relationship between Appendix K and other portions of the EIS/EIR.

For the traffic analysis, section K.2 of the appendix provides additional information about existing roadway networks servicing the LLNL and SNL, Livermore sites; it also describes the analytical methodologies and modeling used to assess traffic conditions. The section also discusses the various modes of public transportation available in the region of LLNL and SNL, Livermore.

For the transportation analysis, section K.3 of the appendix describes the onsite and offsite movement, via ground and air, of hazardous and radioactive materials and wastes at LLNL and SNL, Livermore. It briefly discusses the regulatory environment for these activities, the organizations within LLNL and SNL, Livermore responsible for movement of these materials and wastes, the procedures followed to ensure safe movement of these materials and wastes, and quality assurance and quality control activities.

Because a number of related activities directly affect the safe transport of hazardous materials and wastes, this section includes a brief discussion of transportation packaging, labeling, marking, vehicle inspection and placarding, driver qualifications and training, and transportation routing for offsite shipment of hazardous materials and wastes.

K.2 TRAFFIC ACTIVITIES AT LLNL AND SNL, LIVERMORE

This section presents information from a traffic study conducted on LLNL and SNL, Livermore traffic activities for this EIS/EIR (TJKM Transportation Consultants, 1992). The study evaluated onsite and offsite traffic conditions for LLNL and SNL, Livermore, relevant local circulation policies, and existing and future traffic conditions in the project vicinity. This information was used to evaluate the EIS/EIR proposed action and its alternatives.

Due to the proximity of the two sites, and the fact that some LLNL Livermore site personnel park at SNL, Livermore, it was not considered feasible to conduct separate traffic analyses for the two sites. The respective increment of traffic (i.e., vehicle trips per day) contributed by each Laboratory was determined based on existing and projected personnel numbers at each facility. However, while it is acknowledged that the two Laboratories are distinct operations managed and operated by different contractors, the evaluation of Laboratory- related traffic effects on the local circulation network was conducted for the two Laboratories combined, due to the difficulty in distinguishing between LLNL- and SNL, Livermore-related traffic at a given intersection or roadway segment. A separate analysis was performed for LLNL Site 300 due to its distance from the other Laboratory sites.

For the traffic analysis, a.m. and p.m. peak-hour traffic conditions were examined at 16 key intersections and the Interstate 580 (I-580) interchanges at Vasco Road and Greenville Road near LLNL and SNL, Livermore, and at the I-580 interchange at Corral Hollow Road near LLNL Site 300. Intersections selected for study are those located in the vicinity of the facilities that are considered critical to the flow of peak-period traffic.

In addition, existing average daily traffic counts were conducted for 18 key roadway segments that provide direct or indirect access to the Laboratories. Traffic volumes on these key roadways could be affected by project activities. A description of the geometrics of the roadway segments evaluated is provided later in this section. The geometrics of the roadways include features of the roadway design, such as roadway alignment, intersections, and interchanges.

K.2.1 Existing Traffic Setting

The regional and local transportation setting is shown in Figure K-2.

LLNL Livermore Site and SNL, Livermore

Regional access to the LLNL Livermore site and SNL, Livermore is gained primarily from I-580 via the Vasco Road and Greenville Road interchanges. Interstate 580 runs in an east-west direction approximately 2 miles from the northern LLNL Livermore site boundary. Interstates 880 and 680 and State Highway Route 84 lie further west of the sites. Interstates 205 and 5 lie further to the east.

The LLNL Livermore site is accessed via security gates along Vasco Road, East Avenue, and Greenville Road. SNL, Livermore is accessed via security gates along East Avenue. Existing traffic volumes at the access gates along these three roadways are presented later in this section.

LLNL Site 300

Regional access to LLNL Site 300 is primarily from I-580 via the Corral Hollow Road interchange (see Figure K-2). West of LLNL Site 300, "Corral Hollow Road" is renamed "Tesla Road," and runs in an east-west direction south of SNL, Livermore, before changing to a northwest-southeast alignment named "South Livermore Avenue," then a north-south alignment named "North Livermore Avenue." LLNL Site 300 is accessed from a series of two security gates at the main entrance off Corral Hollow Road, which are discussed later in this section. An additional access, into a parking area only, is located to the west of the main entrance off Corral Hollow Road.

K.2.1.1 Relevant Local Circulation System Policies and Regional Transportation Improvements

This section describes relevant policies from the circulation elements of applicable jurisdictions in the project vicinity. These policies generally reflect their respective standards for acceptable traffic conditions and are considered by both LLNL and SNL, Livermore in their traffic planning decisions. This section also briefly discusses important regional transportation improvements currently under construction.

City of Livermore

The Circulation Element of the Livermore Community General Plan (1989) contains the following policy pertaining to this project:

> "For the purposes of development-associated traffic studies, road improvement design, and capital improvement priorities, the City shall consider a peak-hour volume-to-capacity (V/C) ratio of 0.85 for periods of 2 hours or more per average day to be the upper limit of acceptable service at major intersections in Livermore."

County of Alameda

The Traffic and Circulation Element of the Livermore-Amador Valley Planning Unit General Plan (County of Alameda, 1977) contains the following policy pertaining to this project:

> "Improve Safety and Reduce Congestion. To improve the safety of and reduce the congestion on roadways through capital improvements and promotion of alternative means of transportation."

County of San Joaquin

The San Joaquin County General Plan 1995 (1976) contains a standard regarding intersection levels of service that was defined by an unpublished San Joaquin superior court decision to be level of service (LOS) C. LOS describes the operating conditions that occur on a lane or roadway when accommodating various traffic volumes. In this study, LOS is described by a letter rating system from A to F, with LOS A indicating stable flow and little or no delays, and LOS F indicating jammed traffic conditions and excessive delays. A more detailed discussion of LOS categories and how they relate to V/C ratios is provided later in this appendix. The County is in the process of updating its General Plan to include a revised traffic standard of LOS D (Islas, 1991). The new General Plan is still in a draft stage, and hearings are pending.

Regional Transportation Improvements

There are currently two regionally important transportation projects underway. They are the extension of the Bay Area Rapid Transit District (BART) rail transit to Dublin/Pleasanton, and the Mid-State Tollway project (refer to Figure K-2). BART is extending rail transit from the existing BART rail system 12 miles from the Bayfair Station (in San Leandro) to the cities of Dublin and Pleasanton. Construction is underway on this BART extension and is anticipated to be completed in 1995. The Mid-State Tollway project involves a conceptual proposal for an 85-mile tollway connecting the Fremont area with the Interstate 80 corridor near Vacaville, and the Interstate 5 corridor, via I-580, with the Interstate 80 corridor near Vacaville. These connections are proposed to occur approximately midway between Interstate 680 and Interstate 5. The Mid-State Tollway construction is projected to begin in 1994 and be completed in the late 1990s. Although both the BART extension and the Mid-State Tollway project will have significant effects on Tri-Valley area traffic, neither is in the immediate vicinity of the LLNL and SNL, Livermore facilities, and so neither project is expected to have a significant effect on the key intersections or roadway segments studied in the traffic analysis. The traffic study does not include any assumptions in the analysis derived from these proposed projects.

K.2.1.2 Standards of Significance

A standard of significance is the limit of acceptable performance at a given intersection or roadway. Exceeding this limit would constitute a significant adverse effect on the traffic network. For purposes of this EIS/EIR analysis, an impact is considered to be significant if the increment of traffic contributed by the project is substantial in relation to the existing traffic load and capacity of the roadway network, and causes a change in the V/C ratio and/or corresponding LOS to an unacceptable level. The standard of significance for evaluating traffic conditions in the vicinity of the LLNL Livermore site and SNL, Livermore is that used by the City of Livermore: future intersection congestion conditions exceeding a peak-hour V/C ratio of 0.85 per average day at major intersections are considered to be significant.

As described later in this appendix, a V/C ratio of 0.85 corresponds to LOS D (LOS D includes the range of V/C ratios from 0.81 to 0.90). For evaluation of LLNL Site 300 traffic conditions in San Joaquin County, the existing LOS C standard is used. LOS C encompasses the range of V/C ratios from 0.71 to 0.80. Traffic congestion conditions exceeding LOS C (LOS D and worse) are considered to be significant. Section K.2.2 of this appendix contains additional discussion of the relationship between LOS and V/C ratios.

In addition, a significant impact would be identified if the proposed action resulted in inadequate provision of internal parking and circulation.

K.2.1.3 Project-Related Traffic Generation and Distribution

Existing 24-hour average daily traffic counts at all entrances to the project sites were collected (TJKM Transportation Consultants, 1992). Average daily traffic is defined as the total number of cars passing over a segment of roadway, in both directions, on a typical day. In this report, all average daily traffic volumes are two-way counts at the indicated locations. The estimated average daily traffic volumes generated by the LLNL Livermore site and SNL, Livermore are approximately 23,960 vehicles per day and 3100 vehicles per day, respectively (TJKM Transportation Consultants, 1992). The distribution of the total 23,960 trips at the LLNL Livermore site is as follows: 32 percent at Westgate Drive, 23 percent at Southgate Drive, 8 percent at West Perimeter Drive, 14 percent at Mesquite Way, 20 percent at East Gate Drive and 3 percent at the truck entrance on East Avenue. The SNL, Livermore trip distribution at the three access gates is as follows: 43 percent at the west gate, 29 percent at the east gate (Thunderbird Lane) and 28 percent at the main gate.

Since some LLNL Livermore site personnel park at SNL, Livermore, it is not possible to compute the number of trips per person for each Laboratory site. The average trips per person is computed based on the total trips per person for both sites. Based on the actual 24-hour average daily traffic counts conducted in 1991 to determine total personnel trips, the average is approximately two trips per person per day. In most employment centers, the average trip rate is approximately three trips per person. The reduction in vehicle trips is due to the utilization of ridesharing and transit, which more than offsets the trips created by delivery vehicles, visitors, and midday trips by Laboratory personnel.

Existing peak-hour traffic counts show that the LLNL Livermore site and SNL, Livermore traffic contributes a high proportion of the daily traffic in the vicinity in the a.m. peak hour. The existing trip distribution patterns show the Vasco Road corridor to be the most heavily utilized. The distribution of the a.m. peak hour traffic from the Laboratories is as follows: 38 percent on Vasco Road, 28 percent on Greenville Road towards the I-580 freeway, 30 percent on East Avenue, 2 percent on Patterson Pass Road, and 2 percent on Greenville Road (towards Tesla Road) (TJKM Transportation Consultants, 1992).

The average daily traffic volume at LLNL Site 300 is estimated to be approximately 700 vehicles per day. As with the LLNL Livermore site and SNL, Livermore, this traffic volume was derived from actual 24-hour average daily traffic counts conducted at the main entrance. Based on this daily traffic volume and the current number of personnel at LLNL Site 300, an average trip rate of approximately 3.5 trips per person per day is calculated. It should be noted that this trip rate differs from the trip rate calculated for the LLNL Livermore site and SNL, Livermore. As noted earlier, both average trip rates were calculated from actual traffic counts at the respective sites. The distribution of traffic on Corral Hollow Road is estimated at 60 percent towards Tracy and 40 percent towards Livermore.

K.2.1.4 Peak-Hour Conditions at Key Intersections

Intersection operations were evaluated using a method of intersection capacity analysis known as the Intersection Capacity Utilization method. This is a method for analyzing intersection operating conditions by calculating a V/C ratio for each governing "critical" movement during a traffic signal phase. The V/C ratio for each phase is summed with the others at the intersection to produce an overall V/C ratio for the intersection. The V/C ratio represents the percent of the intersection capacity utilized. A more detailed description of this methodology is provided later in this section. Peak-hour intersection conditions are reported as V/C ratios. The peak hour is defined as the four busiest consecutive 15-minute periods, in the morning and in the evening. These typically occur during the a.m. and p.m. commute periods. Levels of service are reported using a letter rating system and corresponding descriptions of intersection traffic flow, delay, and maneuverability. This rating system is also described later in this section. Calculation sheets for existing intersection conditions are presented in the traffic study prepared for this EIS/EIR (TJKM Transportation Consultants, 1992).

Selected study intersection locations in the vicinity of all three project sites (LLNL Livermore site, LLNL Site 300, and SNL, Livermore) are shown in Figure K-3 and are listed in Table K-1. Table K-1 presents existing a.m. and p.m. peak-hour V/C ratios and level of service ratings for each study intersection.

Vasco Road

Measures to improve current operating conditions along Vasco Road have been implemented recently in conjunction with other projects in the vicinity. For purposes of the traffic study, these and any other approved and funded improvements were considered to exist (as of September 1992) as part of the baseline conditions for evaluating intersection levels of service (TJKM Transportation Consultants, 1992). A discussion of the assumed improvements as of September 1992 is provided below.

Recent improvements to widen Vasco Road to three or four lanes (with appropriate turn lanes) between Patterson Pass Road and East Avenue have improved the volume-to-capacity ratios at the intersections of Vasco Road with Westgate Drive and East Avenue to acceptable city standards. These improvements were completed in 1991. Improvements at the four Vasco Road intersections (Patterson Pass Road, Westgate Drive, Mesquite Way, East Avenue) included widening the northbound approach to accommodate two through lanes with separate left- and right-turn lanes. Other improvements at these intersections that now exist include the following:

- Patterson Pass Road. Other than the northbound approach, all intersection approaches retain the existing lane configuration.
- Westgate Drive. The southbound approach was widened to accommodate two through lanes and two southbound-to-eastbound left-turn lanes, each 350 ft long, replacing a single 1000-ft-long left-turn lane.
- Mesquite Way. When development on the west side takes place, this intersection will become a full, four-way intersection with appropriate turn lanes. Recent interim improvements included the installation of a traffic signal and widening the southbound approach to include two southbound-to-eastbound left-turn lanes and one through lane.
- East Avenue. The southbound approach now includes two southbound-to-eastbound left-turn lanes.

I-580/Vasco Road Interchange

This interchange does not currently contain intersections involving either of the two ramps serving the major flow of Laboratories-related traffic—the northbound-to-westbound on-ramp and the eastbound-to-southbound off-ramp. These movements are currently served by a free-flowing loop on-ramp and a free-flowing diagonal off-ramp, respectively. The configuration of these ramps does not lend itself to conventional peak-hour intersection evaluation, due to the free-flowing nature of the traffic movements. The 1991 a.m. peak hour turning movement counts conducted at the I-580/Vasco interchange showed the eastbound to southbound movement at the intersection of I-580 eastbound off-ramp and Vasco Road to be approximately 1400 vehicles. Thus, the eastbound off-ramp is operating near capacity. The eastbound off-ramp is yield-controlled and is currently opposed by approximately 650 southbound vehicles near the intersection of Vasco Road and I-580 eastbound off-ramp in the a.m. peak hour. Field observations indicated that the eastbound to southbound off-ramp traffic is able to maneuver without much difficulty since the southbound traffic are utilizing the inner lane, thus leaving the curb lane free. Conversations with the City of Livermore engineer indicated that occasionally congestion does occur in this area, but only at the peak 15-minutes interval (TJKM Transportation Consultants, 1992). Overall, traffic operation is acceptable.

Observations at the I-580 westbound off-ramp were also made by TJKM Transportation Consultants. Currently, the existing traffic from the I-580 westbound loop off-ramp to southbound on Vasco Road is yield controlled. Field observations indicate that the westbound loop off-ramp traffic is able to execute the movement without undue delays.

In the future, in order to accommodate growth in industrial areas north of the Laboratories, in residential areas north of I-580, and general growth in eastern Contra Costa County to the north, the Vasco Road interchange may need to be improved. Although no specific improvement project is currently planned or funded, such improvements would likely involve the construction of signalized westbound and eastbound off-ramps and the provision of loop on-ramps in the northeast and southwest quadrants of the interchange.

I-580/Greenville Road Interchange

Currently, the City of Livermore is in the process of modifying the intersection of I-580 westbound off-ramp and Southfront Road to be a three-way stop sign–controlled intersection. Traffic safety and operations will improve when this modification is completed. The intersection of I-580 westbound off-ramp and Northfront Road would remain the same in the short term. Field observations by TJKM Transportation Consultants indicate that traffic has no difficulty utilizing these two intersections.

First Street

Three intersections with First Street were evaluated in the traffic study. Little of the existing First Street traffic is related to the LLNL Livermore site or SNL, Livermore; however, in the future, when North Mines Road is completed between First Street and Vasco Road, some Laboratory-related traffic may use portions of First Street. As shown in Table K-1, two First Street intersections currently operate at levels of service that exceed a standard of significance V/C ratio of 0.85 (LOS D) in the p.m. peak hour. It should be noted that a design study is currently underway for the First Street area in the City of Livermore to widen First Street from the existing two lanes to four or six lanes (from north of North Mines Road to the I-580 eastbound on-/off-ramps). This first phase of the widening is expected to be completed by 1996. The second phase is to modify the existing First Street/I-580 interchange from the existing loop off-ramps in the northwest and southeast quadrants to loop on-ramps in the northeast and southwest quadrant. The second phase improvements are designed to accommodate the buildout of the City's General Plan land uses. It is likely that these improvements would improve the LOS of study intersections along First Street at Las Positas Road and North Mines Road to acceptable City standards, as well as further improve the LOS at First Street and Southfront Road (TJKM Transportation Consultants, 1992).

Table K-1 Existing Levels of Service at Key Intersections

Intersection ID Number (Refer to Figure K-3)	Intersection Location	A.M. Peak Hour		P.M. Peak Hour	
		V/C	LOS	V/C	LOS
1	I-580 SB Off-Ramp at Corral Hollow Road	0.20	A	0.24	A
2	I-580 NB Off-Ramp at Corral Hollow Road	0.23	A	0.18	A
920	I-580 WB Off-Ramp at Springtown Boulevard	0.85	D	0.84	D
922	I-580 EB Off-Ramp at First Street	0.75	C	0.84	D
894	First Street at Southfront Road	0.84	D	0.67	B
684	First Street at Los Positas Road	0.84	D	0.89	D
615	First Street at North Mines Road	0.82	D	0.87	D
655	East Avenue at S. Livermore Avenue	0.57	A	0.66	B
588	East Avenue at North Mines Road	0.58	A	0.69	B
617	East Avenue at Vasco Road	0.61	B	0.62	B
671	East Avenue at Greenville Road	0.34	A	0.42	A
924	I-580 WB Off-Ramp at Vasco Road	NA	NA	NA	NA
926	I-580 EB Off-Ramp at Vasco Road	NA	NA	NA	NA
575	Vasco Road at Preston Avenue	0.62	B	71	C
583	Vasco Road at Patterson Pass Road	0.70	B	0.62	B
616	Vasco Road at Westgate Drive	0.47	A	0.53	A

591	Vasco Road at Mesquite Way	0.41	A	0.47	A
16	I-580 EB Off-Ramp at Southfront Road	NA	NA	NA	NA
15	I-580 WB Off-Ramp at Northfront Road	NA	NA	NA	NA
928	Greenville Road at Altamont Pass Road	0.70	B	0.35	A
931	Greenville Road at Southfront Road	0.70	B	0.43	A
581	Greenville Road at Patterson Pass Road	0.75	C	0.60	A

NB = northbound; WB = westbound; EB = eastbound; SB = southbound.
V/C = volume-to-capacity ratio.
LOS = level of service, ranging from A (stable flow-very slight or no delay) to F (forced flow-excessive delay).
NA = not applicable; no intersections exist at this interchange at the present time.

V/C	LOS	V/C	LOS
0.00–0.60	A	0.81–0.90	D
0.61–0.70	B	0.91–1.00	E
0.71–0.80	C	1.00+	F

Source: TJKM Transportation Consultants, 1992.

K.2.1.5 Average Daily Traffic Volumes

Existing average daily traffic volumes and machine count locations for the 18 key roadway segments are shown on Figure K-4 (TJKM Transportation Consultants, 1992). Machine counts are traffic counts conducted by using an automatic counting machine that tallies vehicles as they pass over a pressurized hose laid across a vehicle path. As described previously, all average daily traffic volumes presented in this appendix are two-way counts at the indicated locations. A description of the geometrics of the roadway segments evaluated is provided below.

First Street

First Street is a two-lane arterial street that widens to three lanes (one southbound and two northbound) between Southfront Road and the eastbound I-580 on-ramp. First Street is a State Highway, designated as Route 84. The interchange of First Street with I-580 is a partial clover-leaf with looped off-ramps in the northwest and southeast quadrants. The intersection of First Street at North Mines Road is currently signalized. The average daily traffic on First Street north of North Mines Road is approximately 27,300 vehicles per day. The design capacity of First Street north of North Mines Road is approximately 20,000 vehicles per day. Between I-580 and Southfront Road, the capacity is 22,500 vehicles per day. The existing volumes on First Street exceed capacity by approximately 5000 to 7000 vehicles per day.

Vasco Road

Vasco Road is a major arterial street south of I-580. It functions as the primary access route to LLNL Livermore site and SNL, Livermore from I-580. The interchange of Vasco Road at I-580 is a partial clover-leaf design with looped off-ramps in the northwest and southeast quadrants and a looped on-ramp in the northeast quadrant.

Between I-580 and Patterson Pass Road, Vasco Road has two lanes in both the northbound and southbound directions, separated by a raised median. There are striped bike lanes designated in each direction. Both sides of the road are posted for no parking. Separate left-turn lanes are provided at all intersections. The average daily traffic on Vasco Road north of Patterson Pass Road is approximately 17,600 vehicles per day. North of Patterson Road, capacity on Vasco Road is approximately 30,000 vehicles per day. Existing average daily traffic is within the capacity of the roadway. Improvements to widen Vasco Road between Patterson Pass Road and East Avenue were recently completed. The east side (adjacent to LLNL Livermore site) of Vasco Road was improved to its ultimate width, consisting of two northbound lanes and a raised median. Between Patterson Pass Road and Mesquite Way, there are two southbound through lanes. South of Mesquite Way, there is a single southbound through lane. This single southbound lane is an interim configuration until west-side development takes place and facilitates final widening improvements. Designated bike lanes are provided in both directions. The average daily traffic is approximately 13,000 vehicles per day south of Westgate Drive. The intersection of Vasco Road at East Avenue is signalized. When four-lane improvements to Vasco Road are completed, capacity south of Westgate Drive will be approximately 30,000 vehicles per day. Existing average daily traffic is within capacity. South of the East Avenue intersection, Vasco Road becomes a two-lane rural road. The average daily traffic in this section is approximately 4000 vehicles per day. It is estimated that the capacity of this section is approximately 10,000 to 12,000 vehicles per day.

Greenville Road

Greenville Road also provides access to the LLNL Livermore site and SNL, Livermore from I-580. There is no direct interchange between Greenville Road and I-580. Freeway access is west of Greenville Road at on- and off-ramps on Northfront Road and Southfront Road. Both Northfront Road and Southfront Road connect with Greenville Road. The Southfront connection is currently being widened and relocated as a part of improvements for a new business park in this area. North of Vaughn Avenue, Greenville Road has two lanes in both the northbound and southbound directions, separated by a raised median. Between Vaughn Avenue and Marathon Drive, Greenville Road narrows to two lanes with no median. There is an irregular gravel shoulder, and there are no bike lanes. Both sides of the road are posted for no parking. The road becomes very narrow at the Union Pacific Railroad underpass. Average daily traffic on Greenville Road north of Marathon Drive is currently 5630 vehicles per day. Capacity of Greenville Road is 17,500 vehicles per day. The existing average daily traffic is within capacity.

In the vicinity of Marathon Drive, Greenville Road widens as it approaches the stop-sign controlled intersection at Patterson Pass Road. This allows the provision of separate turn lanes at Marathon Drive and Patterson Pass Road. The west side of Greenville Road is improved in this area with a concrete curb and gutter.

South of Patterson Pass Road, Greenville Road returns to a two-lane configuration, and average daily traffic is approximately 5000 vehicles per day. There is a gravel shoulder in most areas, except on the west side in the vicinity of the east gate (Eastgate Drive) at LLNL Livermore site (where curbs are constructed). Both sides of the road are posted for no parking. Bike lanes are indicated by stripes in most areas but are not designated with signs. Currently, there is no traffic signal at the intersection of Greenville Road with Eastgate Drive, and traffic volumes do not warrant a signal at this time. At such time as traffic signal warrants are met, a signal may be necessary at this intersection. South of East Avenue, the average daily traffic is approximately 1700 vehicles per day. Greenville Road becomes a narrow rural road south of Tesla Road. Capacity of Greenville Road is 17,500 vehicles per day. The existing average daily traffic is within capacity.

East Avenue

East Avenue is a cross-town arterial that carries traffic between South Livermore Avenue and Greenville Road. East Avenue west of Vasco Road has two lanes in both the westbound and eastbound directions. There is no median, but separate left-turn lanes are provided at all intersections. There are designated bike lanes in both directions. Several major streets along East Avenue are controlled by traffic signals. Stop signs control East Avenue at its intersection with Dolores Street, causing some delay for East Avenue motorists. Average daily traffic on East Avenue west of Vasco Road is approximately 18,000 vehicles per day west of North Mines Road and 13,300 vehicles per day east of North Mines Road. Capacity of East Avenue west of Vasco Road is approximately 25,000 vehicles per day. The existing volumes are within capacity.

East Avenue east of Vasco Road provides access to the south gates of the LLNL Livermore site and provides the sole access to all gates at SNL, Livermore. Traveling east from Vasco Road, East Avenue has two lanes in both the eastbound and westbound directions. Bike lanes are provided on the north and south sides of East Avenue and are separated from traffic by asphalt curbs. There are several pedestrian crossings linking the LLNL Livermore site and SNL, Livermore, including one just west of the LLNL Livermore site south gate entrance, where East Avenue narrows to a two-lane road. Here, striped bike lanes are provided, but asphalt curb separations are not provided. East Avenue between Vasco Road and Greenville Road is posted on both sides for no parking. Average daily traffic in the area west of the Laboratory entrances in the four-lane section is approximately 10,830 vehicles per day. This street forms a T-intersection with Greenville Road. Capacity on the four-lane portion of East Avenue east of Vasco Road (between Vasco Road and the LLNL Livermore site south gate entrance) is approximately 25,000 vehicles per day. The two-lane portion of East Avenue east of Vasco Road has a capacity of approximately 15,000 vehicles per day. The existing volumes are within capacity.

North Mines Road

North Mines Road runs generally in a north-south direction between First Street and East Avenue. It is a four-lane road and is signalized at its intersection with First Street. Currently, North Mines Road is discontinuous at the railroad tracks north of Patterson Pass Road. North Mines Road was selected as a key roadway in this study because it is planned to be a through street between First Street and East Avenue. It might then become an access route to the LLNL Livermore site and SNL, Livermore via Patterson Pass Road and East Avenue. Currently, the northern section of North Mines Road serves industrial traffic, while the southern section serves residential traffic. The intersection of North Mines Road with East Avenue is signalized. North of East Avenue, the existing average daily traffic is approximately 2700 vehicles per day. The capacity of North Mines Road is approximately 25,000 vehicles per day. The existing volumes are within capacity.

Patterson Pass Road

Patterson Pass Road runs generally in an east-west direction just north of the LLNL Livermore site and terminates at North Mines Road. Patterson Pass Road east of Greenville Road is a two-lane rural road. Between Greenville Road and North Mines Road, Patterson Pass Road is improved with two lanes in each direction, a raised median, bus turnouts, and separate left-turn lanes. Both sides of the street are signed for no parking, and striped bike lanes are provided in both directions. There is no direct gate access to LLNL Livermore site from Patterson Pass Road. The existing average daily traffic between Vasco Road and Greenville Road is approximately 1000 vehicles per day. Capacity of Patterson Pass Road between Vasco Road and Greenville Road is approximately 30,000 vehicles per day. The existing average daily traffic is within capacity.

Tesla Road/Corral Hollow Road

Tesla Road is a two-lane rural road south of SNL, Livermore. This road does not provide direct gate access to either the LLNL Livermore site or SNL, Livermore. Tesla Road runs in a generally east-west direction between the City of Livermore and I-580 in San Joaquin County. Tesla Road east of Greenville Road is a winding road with several hairpin turns. The road's name changes to Corral Hollow Road at the Alameda County/San Joaquin County line. Tesla Road/Corral Hollow Road is the only access to LLNL Site 300.

Average daily traffic on Tesla Road west of Vasco Road is approximately 6200 vehicles per day. Tesla Road east of Vasco Road currently experiences average daily traffic of approximately 2500 vehicles per day. In the vicinity of LLNL Site 300, average daily traffic on Corral Hollow Road is approximately 700 vehicles per day west of LLNL Site 300 and 850 vehicles per day east of LLNL Site 300. Capacity on Tesla/Corral Hollow Road is approximately 10,000 vehicles per day. The existing volumes are within capacity.

K.2.1.6 Study Area Traffic Accident History

A review of Statewide Integrated Traffic Records System accident reports was made for 1988, 1989, and 1990 to determine the accident history at the LLNL Livermore site and SNL, Livermore study intersections and in the vicinity of LLNL Site 300. A tally of accidents by year was made, and a 3-year accident rate was calculated for study intersections.

The results of the analysis indicated that three Vasco Road intersections (at Preston Avenue, Brisa Street, and Vaughn Avenue) and First Street intersections between North Mines Road and Southfront Road have experienced relatively high accident rates and have already been targeted by the City of Livermore for safety improvements. Traffic studies and planned improvements (in conjunction with other projects in the area) are underway to mitigate traffic conditions in these areas; therefore, no further analysis has been conducted for this EIS/EIR for the identified accident areas. The recent improvements along Vasco Road and those planned for First Street have been described in section K.2.1.4. In addition, the intersection of Vasco Road at Preston Avenue was modified during 1990 to prohibit left turns from Preston Avenue onto Vasco Road. According to the City of Livermore, this mitigation has virtually eliminated accidents at this location. There is a new traffic signal at the intersection of Vasco Road at Brisa Street, and an additional signal is planned for the intersection of Vasco Road at Vaughn Avenue. Vasco Road is currently being widened between Brisa Street and Vaughn Avenue with two through lanes in the north- and southbound directions and separate right-turn lanes.

Accidents in the vicinity of LLNL Site 300 occur between I-580 and the Alameda/San Joaquin County Line at a rate of approximately four accidents per year. There is no recurring location for these accidents, which consist primarily of property damage caused by single-driver run-offs. No further review was warranted.

K.2.1.7 Onsite Circulation

LLNL Livermore Site

External Access

Vehicle access to the LLNL Livermore site is currently provided at six locations. Westgate Drive and Mesquite Way entrances are on the western periphery of the site and provide access from Vasco Road. To the south, adjacent to East Avenue, are the Southgate Drive and Southwest Gate entrances. From Greenville Road, the Eastgate Drive entrance provides access to the east side of the LLNL Livermore site. An additional entrance to the LLNL Livermore site from Greenville Road is located south of the Eastgate Drive gate entrance. This entrance, which accesses the East Badge Office, Visitor's Center, and Credit Union, is not a formal gate entrance and no vehicular traffic can access the remainder of the LLNL Livermore site from this location. A shipping and receiving gate is on the north side of East Avenue between Greenville Road and the Southgate entrance. The existing (1991) inbound and outbound traffic volumes at these gates are shown in Figure K-5. As shown on Figure K-5, the LLNL Livermore site pedestrian gates are on East Avenue between the Southwest Gate and Southgate Drive. Although no pedestrian counts were made at these locations, these gates provide access between the two Laboratories as well as access for LLNL Livermore site personnel who park at SNL, Livermore.

Onsite Street Network

The existing internal circulation network is depicted in Figure K-6. Primary internal circulation roads are Inner Loop Road, Outer Loop Road, Eastgate Drive, Southgate Drive, Westgate Drive, Avenue A, and Mesquite Way. Newer sections of the LLNL Livermore site are served by streets that extend outward from the two main loop roads. There is no major circulation road through the southwest quadrant. Streets in this older section of the facility form a grid pattern. This quadrant is the most densely populated of the entire site, and is a limited access area. This security rating affects the feasibility of including the southwest quadrant in the overall circulation network because there is not the same free flow of traffic movement through this quadrant.

Although not all internal streets are depicted on Figure K-6, the LLNL Livermore site street network is currently designated by a usage hierarchy of major, minor, service, and fire categories (LLNL, 1989b). Major roads serve as arterials between quadrants. Minor roads function as collectors and link major roads to specific facilities. Service roads are typically short and are limited to serving only a few destinations. Fire roads are designated for emergency service.

A traffic circulation and access study was conducted for LLNL that identified and recommended mitigations for onsite access and circulation problems (TJKM Transportation Consultants, 1986). The study evaluated 1986 and future year 2000 traffic conditions. The Planning and Development Department at the LLNL Livermore site continues to utilize the 1986 study as a guide for onsite traffic improvements.

The key recommendations of that study were to provide additional inbound access lanes at the Eastgate portal, to increase capacity at the intersection of Mesquite Way and Vasco Road, and to develop two new gate facilities at Westgate Drive and Patterson Pass Road. In response to those recommendations, a new Westgate Drive portal has been constructed. A third westbound (inbound) lane has been added to the Eastgate portal, and a traffic signal and street improvements are under construction at the Mesquite Way intersection at Vasco Road. The installation of a Patterson Pass Road gate is part of the long range planning at LLNL Livermore site, but is not being considered as part of the EIS/EIR proposed action.

In recent discussions with LLNL Livermore Facilities Planning staff, two existing onsite circulation problems were identified (TJKM Transportation Consultants, 1992): (1) a.m. peak-hour queuing and delays at the intersections of Westgate Drive and Avenues A and B; and (2) p.m. peak-hour queuing in the eastbound exiting lanes at Eastgate Drive.

Peak-hour turning movement counts were taken at all three intersections. Based on these counts and on field observation, traffic currently has no difficulty moving through the Westgate Drive intersections during the a.m. peak period and queuing is minimal (TJKM Transportation Consultants, 1992). No mitigation is warranted at this time, although growth in the northwest quadrant may create poorer conditions in the future. Based on a recent p.m. peak-hour turning movement count, the intersection of Greenville Road at Eastgate Drive/Lupin Way is approaching design capacity. This results in long delays for the eastbound-to-northbound left-turn movement out of the LLNL Livermore site. The reserve capacity for this movement is 24 vehicles. Reserve capacity is the unused capacity of a vehicle travel lane (i.e., the number of additional vehicles that could make a particular turning movement before that movement reaches capacity). Although the intersection does not yet meet peak-hour traffic signal warrants, future traffic conditions may create a need for traffic signals at this location.

Onsite Parking

It has been the practice at LLNL to provide personnel parking close to the work places. The latest parking demand evaluation was conducted by LLNL in 1988 in their Parking Master Plan (LLNL, 1988). At that time the reported LLNL Livermore site population was 10,458, including regular and contract personnel. The net demand for personnel parking was determined to be 0.71 stall per person. The required personnel parking need was calculated to be 7425 parking stalls.

When calculating the parking supply, the LLNL Livermore site takes into consideration the number of marked parking spaces both in parking lots and on streets. The 1988 LLNL analysis also considered the availability of safely parked vehicles in unmarked areas. As described in the Parking Master Plan, these are vehicles not in marked parking lots or roadside stalls, but that are parked safely and orderly on paving, neither causing a security problem, nor blocking moving traffic. In 1988, there were approximately 5576 marked personnel parking stalls and 539 available unmarked parking stalls.

Using number of personnel by site location, the deficit of personnel parking was determined in the Parking Master Plan to be 1310 stalls. In calculating 1991 parking demand, 1988-approved or 1988-funded improvements for 913 parking stalls are considered to exist, resulting in a net deficit of 397 parking stalls before taking personnel increases into consideration.

The 1991 number of LLNL Livermore personnel is reported to be approximately 11,200 persons. This equates to an increase of 742 persons and an increase in parking demand of 527 stalls (742×0.71). When added to the 1988 deficit of 396 stalls, the revised parking stall deficit is 923 onsite personnel parking stalls.

There are also 962 assigned government vehicles located onsite, including those assigned to the Protective Force Division. As of 1988, there were a total of 844 government vehicle parking stalls located both within and outside of parking lots onsite, with a resulting deficit of 118 government vehicle stalls. Planned improvements included 11 government vehicle stalls, which would reduce the deficit by nine percent to 107 government vehicle stalls (LLNL, 1988).

Onsite Accident History

The traffic study (TJKM Transportation Consultants, 1992) did not review any accidents or Statewide Integrated Traffic Records System reports for onsite traffic accidents, but, according to the LLNL Planning and Development Department and the Protective Force Division, the majority of onsite accidents take place in the LLNL Livermore site parking lots. Parking lot accidents are not typically mitigated by physical street improvements. It should be noted that the security division has stated that there have been approximately seven serious onsite traffic accidents during the 3-year evaluation period; however, the number of onsite accidents was not considered substantial enough to allow further analysis for accident trends (i.e., there are not enough accidents at any one location to facilitate a trend analysis).

SNL, Livermore

SNL, Livermore personnel are restricted from driving through the SNL, Livermore facility grounds and are required to park in lots adjacent to East Avenue or near the Combustion Research Facility on Thunderbird Lane. Existing 1991 parking lot driveway counts for SNL, Livermore are shown on Figure K-5. It should be noted that LLNL Livermore site personnel may park in the SNL, Livermore parking areas if they have been issued a parking identification sticker for those lots. Although LLNL utilizes Parking Lot B99 on the south side of East Avenue, this lot is interconnected with the other SNL, Livermore parking lots. Personnel from both facilities may park in either lot. There are a total of 2000 parking stalls in these lots. Additional parking stalls for government vehicles are provided within the SNL, Livermore grounds. No parking stall deficiencies are currently identified at SNL, Livermore.

As a result of the onsite driving restrictions at SNL, Livermore, there was no evaluation of onsite circulation or traffic accident history.

LLNL Site 300

Site access to LLNL Site 300 is primarily provided from a series of two security gates at the main entrance on the north side of Corral Hollow Road, approximately 8 miles west of the City of Tracy. An additional access, into a parking area only, is located to the west of the main entrance off Corral Hollow Road. A daily volume count at the main access is shown on Figure K-7. Vehicular access around LLNL Site 300 is, for the most part, limited to parking lots and roadways in the southeast corner of the site near the General Services Area. There are 185 parking stalls designated at LLNL Site 300, including those used by government vehicles. On an average day, there are 50 to 60 empty stalls; therefore, adequate parking is available. Access to roadways in the northern limited area is restricted.

Access problems have been identified at the LLNL Site 300 main gate area. The existing design is operationally poor, and vehicle queuing areas are inadequate. In conjunction with the LLNL Site 300 facilities revitalization efforts, a study is in final design that includes a new main gate with associated roads, guard kiosk, and other amenities. The main site entrance will be relocated slightly to the west of its present location. The project will involve a complete appraisal of the needs of LLNL Site 300 users and the site infrastructure. New roads in the limited area will be considered to replace some existing roads with steep grades.

K.2.2 Traffic Analysis and Modeling Methodologies

This section provides a more detailed description of the intersection capacity utilization method that was used to evaluate traffic congestion at study intersections. The volume-to-capacity ratios and level of service ratings that quantify the amount of congestion at a given intersection are described. This section also describes the transportation modeling process used to project and evaluate future traffic conditions in the vicinity of the project sites.

K.2.2.1 Description of Intersection Capacity Analysis and Level of Service Ratings

The traffic study (TJKM Transportation Consultants, 1992) uses a method of intersection capacity analysis known as the Intersection Capacity Utilization method. A variation (and derivation) of the TJKM method, known as the critical movement analysis, is described in the 1985 Highway Capacity Manual, Special Report 209, published by the Transportation Research Board of the National Academy of Sciences.

The Intersection Capacity Utilization method sums the V/C ratios of all governing (or critical) signal phases at an intersection to produce an overall intersection V/C ratio. When the ratio of V/C reaches unity (1.00), the intersection is "at capacity" and is described as operating at LOS E and approaching LOS F conditions. Table K-2 provides a description of the relationship between the level of service rating and the V/C ratio.

A sample calculation is shown on the accompanying computer printout (Figure K-8). This example describes a hypothetical intersection at A Street and B Street, which is regulated by three-phase traffic signals, indicating separate signal phases for northbound, southbound, and east-west traffic. The first phase (illustrated in Figure K-8 at top of sample and defined in second, southbound set of directional figures) is for southbound traffic only and contains three lanes. Right-turn movements in the right lane (189 vehicles) have a smaller per-lane volume than in the two remaining lanes (225 and 227 vehicles). Therefore, the length of the signal phase is governed by the traffic in the two left lanes (through plus left). The capacity of Phase 1 is 2970 vehicles per hour of green, the volume is 452 vehicles, and the resulting V/C ratio is 0.1522. Phase 2, for the northbound movements, has two sets of combined governing lanes and a final V/C ratio of 0.1706. For Phase 3, the westbound through-plus-right traffic cannot proceed through the intersection at the same time as the eastbound left-turn movement, even though they are on the same signal phase. Practically, the left-turn vehicles and opposing through traffic alternate as gaps in traffic allow. The total Phase 3 capacity requirement is the sum of the combined westbound through and right, 0.2041, and the eastbound left, 0.0818. The critical movement V/C ratios are summed, then rounded to two decimal places. An allowance for yellow time (see Table K-3), assumed to be lost time for vehicle movement, is added to obtain the overall intersection V/C rating. In the example, the intersection total V/C ratio of 0.71 equates to a LOS C designation. The number of lanes and the use of the lanes is denoted with special nomenclature, as described in Figure K-9.

The advantage of this method of capacity calculation is its direct relationship to actual intersection operations and the ease with which changes in volume and capacity can be analyzed. In addition, the level of accuracy of this method is comparable to that of the traffic projection process used to determine future traffic volumes.

Table K-2 Summary of Levels of Service for Intersections

Level of Service	Type of Flow	Delay	Maneuverability	V/C Ratio
A	Stable Flow	Very slight or no delay. If signalized, conditions are such that no approach phase is fully utilized by traffic and no vehicle waits longer than one red indication.	Turning movements are easily made, and nearly all drivers find freedom of operation.	0.00–0.60
B	Stable Flow	Slight delay. If signalized, an	Vehicle platoons are formed. Many	0.61–

		occasional approach phase is fully utilized.	drivers begin to feel somewhat restricted within groups of vehicles.	0.70
C	Stable Flow	Acceptable delay. If signalized, a few drivers arriving at the end of a queue may occasionally have to wait through one signal cycle.	Back-ups may develop behind turning vehicles. Most drivers feel somewhat restricted.	0.71–0.80
D	Approaching Unstable Flow	Tolerable delay. Delays may be substantial during short periods, but excessive back-ups do not occur.	Maneuverability is severely limited during short periods due to temporary back-ups.	0.81–0.90
E	Unstable Flow	Intolerable delay. Delay may be considerable (up to several signal cycles).	There are typically long queues of vehicles waiting upstream of the intersection.	0.91–1.00
F	Forced	Excessive delay.	Jammed conditions. Back-ups from other locations restrict or prevent movement. Volumes may vary widely, depending principally on the downstream back-up conditions.	Varies*

* In general, volume-to-capacity ratios cannot be greater than 1.00, unless the lane capacity assumptions are too low. Also, if future demand projects are considered for analytical purposes, a ratio greater than 1.00 might be obtained, indicating that the projected demand would exceed the capacity.

Source: Transportation Research Board, 1985; Highway Research Board, 1965; TJKM Transportation Consultants, 1992.

Table K-3 TJKM Yellow Time Adjustment for Calculating V/C Ratios for V/C Calculations

Green Time	Add Yellow (Lost) Time	Total
0.71	0.10	0.81
0.72	0.10	0.82
0.73	0.10	0.83
0.74	0.10	0.84
0.75	0.09	0.84
0.76	0.09	0.85
0.77	0.08	0.85
0.78	0.08	0.86
0.79	0.07	0.86
0.80	0.07	0.87
0.81	0.06	0.87

0.82	0.06	0.88
0.83	0.05	0.88
0.84	0.05	0.89
0.85	0.04	0.89
0.86	0.04	0.90
0.87	0.03	0.90
0.88	0.03	0.91
0.89	0.02	0.91
0.90	0.02	0.92
0.91	0.01	0.92
0.92	0.01	0.93
0.93	0.00	0.93
Lane Capacities[a]		
Designation	**Through Capacity**	**Turn Capacity**
1.0	1725	1650
1.1	1650	1650
2.0	3450	2970
2.1	3375	2970
2.2	3300	---
3.0	5175	4290[b]
3.1	5100	4290
3.3	5550	---
4.0	6900	---
4.1	6825	---

V/C	LOS	V/C	LOS
0.00–0.60	A	0.81–0.90	D
0.61–0.70	B	0.91–1.00	E
0.71–0.80	C	1.00+	F

[a] The assumed capacities of the most common types of lanes.
[b] 80 percent each of second and third lanes. Source: TJKM Transportation Consultants, 1992.

K.2.2.2 Traffic Modeling Process

Traffic forecasting models are frequently used in transportation planning. A model is a mathematical way of describing the structure, performance, and behavior of the physical transportation system. It allows transportation engineers and planners to simulate and evaluate the interactions among various components of the transportation system, both present and future, by replicating as nearly as possible what exists in the real world and forecasting different levels of transportation and land use growth. Transportation demand estimation quantifies the amount of travel on the transportation system.

By using a model to represent the existing transportation system, future demand for travel can be analyzed given a specific set of projected land use developments and transportation plans. The demand for transportation is created by resident activity and commercial and employment centers; and the supply, which limits the amount of movement to and from activity centers, is represented by the service characteristics of the highway and transit systems.

Modeling involves many detailed tasks that evolve into a description of travel patterns in and around a study area. Before forecasting travel, an inventory of data is performed to establish relationships among travel choices and other variables in the existing transportation system. The first step in the modeling process involves choosing a model type and specifying variables. Second, the model is calibrated to reproduce the current observed travel behavior as accurately as possible. Finally, the projected travel demand is forecasted. The types of input data needed for modeling include current data and future projections of such variables as number of dwelling units and land use floor-area totals. Also included are current data and future projections of transportation system performance variables such as average vehicle speeds, roadway length, roadway capacity, and travel time. Information is collected about the current level of activity and the current transportation network to predict travel patterns on the future transportation network.

The travel demand model used in the traffic study (TJKM Transportation Consultants, 1992) is MINUTP. It has been used throughout the United States, including cities and counties in northern California. The model is run on a micro-computer. (It should be noted that the evaluation of LLNL Site 300 traffic impacts did not utilize a traffic model).

Transportation Network Assumptions

A transportation system consists of networks that represent available modes of travel. The networks are defined by numbering key intersections, called nodes, and identifying the segments between them, called links. The result is a geometric interpretation of the transportation system identifying travel routes in the study area. The Livermore traffic model utilized in the traffic analysis for LLNL Livermore site and SNL, Livermore is a vehicle model only (TJKM Transportation Consultants, 1992). Mass transit networks were not included in the modeling effort. During the modeling process, the trip generation produces individual person trips and, for the purposes of trip assignment, vehicle trips are used. The person trips must first be split into the public transit and the auto person trips. Then the auto person trips are converted to auto vehicle trips by the application of the auto occupancy factors (Metropolitan Transportation Commission, 1981).

Traffic Zones

The study area is separated into smaller areas called traffic zones. The zones vary in size depending on the intensity of activity, the nature of the land use within the zones, and the level of detail required in the analysis. Generally, the zonal borders are defined by homogeneous urban activities and follow natural boundaries (e.g., ridges, creeks), or man-made boundaries (e.g., streets, railroad tracks). More than 258 traffic zones were developed for the Livermore traffic model. Specifically, there are 69 traffic zones that represent the City of Livermore. A map showing the location of each City of Livermore traffic zone is presented in Figure K-10.

Nodes and Links

The transportation system is described in terms of nodes (intersections) and links (street segments). The type of data used to describe each link are node identification, average vehicle speed, link capacity, travel direction, link length, directional volume counts, number of lanes, and other information depending on the intended use. Not every street segment or intersection is represented in the model. Traffic zone centroids represent the centers of activity, rather than the geometric centers of the zones. A centroid, as used in the modeling process, is an assumed point within a traffic zone from which traffic generated by the land uses in that zone can be connected to the roadway system. Centroids are connected to nodes by imaginary links called centroid connectors. These connectors may represent entry streets into subdivisions and major driveways into office, industrial, and commercial sites. In the network, zone centroids are points where vehicle trips either begin or end. The model loads the vehicle trips onto the network from these zone centroids via the centroid connectors.

The Livermore traffic model consists of a series of nodes and links. Links are coded by facility type. This coding process permits flexibility in the presentation of results. The I-580 freeway and interchange ramps are also represented on the network by links and nodes. Following the network coding process, the network can be plotted with the aid of a computer. The ability to plot with computers ensures more accurate and reliable base networks.

Modeling Steps

Link data and land use data are used as inputs in the modeling process. The steps in the modeling process include network building, trip generation, path building, trip distribution, trip matrix adjustments, mode choice, trip matrix balancing, and trip assignment. These terms are defined in the Glossary. An iterative loop between the end of the trip-assignment phase and the beginning of the path-building phase is included in the modeling process to provide more stable and accurate trip tables.

The sequence of the steps used to model trip-making behavior depends on the type of area being studied and what sequence of steps is most applicable to the analysis and modeling procedures being used. The order of the steps should reconstruct the trip-making behavior of the traveler. The following sequence is used in this study: the trip maker decides to make a trip (generation), then where to go (trip distribution), then how to go (mode choice), and finally, which route to take (trip assignment).

K.2.2.3 Traffic Model Assumptions

LLNL Livermore Site and SNL, Livermore

The description of existing traffic conditions presented earlier in this appendix is based on actual traffic counts conducted by TJKM Transportation Consultants (1992). Evaluation of the existing plus proposed action scenario involves the distribution of the new vehicle trips anticipated in conjunction with the proposed action onto the existing roadway network in the same proportion as the existing Laboratories-related traffic.

Future (i.e., cumulative) traffic conditions (which assume an approximate year 2010 buildout of the General Plan land uses within the study area and, therefore, are also considered to represent cumulative conditions) were analyzed using the MINUTP travel forecasting model of the Tri-Valley area developed by TJKM Transportation Consultants (1992) and described in more detail in section K.2.2.2. This Tri-Valley traffic model consists of a detailed transportation network and traffic zone system for the entire Tri-Valley area (defined as the incorporated cities of Livermore, Pleasanton, Danville, San Ramon, and Dublin as well as adjacent portions of unincorporated Alameda and Contra Costa Counties). The model also incorporates assumptions for the balance of the nine-county Bay Area Region and key external stations such as San Joaquin County.

The land use data for Tri-Valley cities are based on the general plans of the individual jurisdictions while the data for the rest of the nine Bay Area counties are based on the Association of Bay Area Governments *Projections '90* (Association of Bay Area Governments, 1989). The Association of Bay Area Governments, in its role as the metropolitan council of governments, prepares projections of Bay Area employment and household growth and allocates this growth to various jurisdictions within the Bay Area.

Cumulative analyses for the proposed action and the no action alternative included the distribution of Laboratory traffic and general plan buildout traffic onto the existing roadway network. (The existing roadway network includes any approved but not yet constructed roadway improvements that would be completed in FY 1992). In addition, model runs were conducted for the no action and proposed action scenarios assuming various roadway improvements in the model area that are not yet, but which are expected to be, approved and funded. The purpose of these analyses was to demonstrate how traffic conditions would be improved with implementation of these improvements. The following anticipated improvements that affect the operations of study intersections were assumed for the no action and proposed action "cumulative (planned roadway network)" scenarios:

- Extension of Concannon Boulevard from Isabel Avenue to Telsa Road.
- Extension of Las Positas Road from First Street to Vasco Road.
- Extension of Brisa Street from Vasco Road to Greenville Road.
- Extension of North Mines Road from East Avenue to First Street.
- A standard partial cloverleaf interchange configuration was assumed for interchanges along I-580 at North Livermore Avenue, First Street, Vasco Road, and Greenville Road in the City of Livermore.
- Widening of First Street from the existing two lanes to six lanes from north of North Mines Road to the I-580 eastbound on-/off-ramps.

It should be noted that evaluation of the modification of operations alternative utilized the proposed action traffic analysis as a base, due to the fact that personnel increases and, thus, traffic generation, are assumed to be the same for both scenarios. Evaluation of the shutdown and decommissioning alternative did not utilize a traffic model.

LLNL Site 300

The traffic projections on Corral Hollow Road near LLNL Site 300 are based on information provided by the County of San Joaquin. The county is in the process of updating the County General Plan; therefore, the projected traffic volumes are preliminary. Intersection capacity utilization analysis was conducted for existing conditions at the intersections at the I-580/Corral Hollow Road interchange, and future traffic volumes along Corral Hollow Road were projected.

K.2.3 Alternate Modes of Transportation

Transit service is available directly to the LLNL Livermore site and SNL, Livermore by the local Wheels bus service and by BART (Bay Area Rapid Transit) Express. BART Express is a bus service with direct freeway routes between the Tri-Valley and BART train stations in the cities of San Leandro and Hayward. There are four BART Express routes serving the Tri-Valley.

Wheels Route 10 is a local, cross-valley bus route that provides service from Stoneridge Mall in Pleasanton to the LLNL Livermore site and SNL, Livermore. There are two BART Express transfer stations along this route. Wheels Route 12 provides local service between Las Positas College and the Triad business park in northwest Livermore, through downtown Livermore, to the LLNL Livermore site. There are also two BART Express transfer stations along Route 12.

It is estimated that the existing direct transit service to the LLNL Livermore site and SNL, Livermore by the local Wheels bus service and by Bay Area Rapid Transit (BART) Express would not be unduly impacted by the projected personnel increase under the proposed action.

K.2.3.1 LLNL Livermore Site

LLNL Livermore site conducts a ridesharing program as part of its in-house energy management program. The program began in 1976. One goal of the ridesharing program is to reduce onsite traffic and parking problems at the LLNL Livermore site. There is a designated onsite rideshare coordinator who maintains a database of individuals participating in the program. There are currently more than 474 carpools (estimated 700 riders) and 43 vanpools (estimated 565 riders) participating in the rideshare program (LLNL, 1991a).

The Stockton Metropolitan Transit District also supplies four buses, driven by LLNL drivers, which provide ridesharing opportunities to LLNL Livermore site and SNL, Livermore personnel from outlying cities (three from Manteca, two from Stockton, and one from Tracy).

Onsite transportation alternatives are also provided within the LLNL Livermore site. There are taxis (i.e., on-call shuttle vans) and energy-efficient carts available for onsite trips. As of 1991, the taxi fleet consisted of nine taxis (12 to 15 passengers), three buses (27 to 37 passengers), two station wagons, and a van. More than 700 laboratory bicycles are present throughout the facility for onsite travel. It is estimated that collectively these bicycles are ridden more than 500 miles per day (LLNL, 1991a).

LLNL is currently developing an expanded Transportation Systems Management Program to promote more efficient use of the transportation network and help reduce traffic congestion. This program would be an extension of the current ridesharing and transit opportunities available to Laboratory employees. In addition to reducing traffic congestion, this program would aid LLNL in complying with federal and state mandates related to vehicle emissions reductions. The program would include such elements as carpools, vanpools, transit, bicycles, telecommuting, emergency ride home, guaranteed ride home, and flexible work schedules.

K.2.3.2 LLNL Site 300

There are currently 26 carpools and two vanpools operating at LLNL Site 300. Parking stalls are reserved for these vehicles onsite. There are an estimated 49 carpool riders and 14 vanpool riders participating at the present time. There are also 155 government vehicles assigned to LLNL Site 300. Currently, there is no bus service to the site.

K.2.3.3 SNL, Livermore

There is no formal rideshare program at SNL, Livermore. There are two vanpools (estimated 19 riders) and 20 carpools (estimated 60 riders) known to be active at the site. SNL, Livermore personnel can also participate in the ridesharing opportunities provided by the Stockton Metropolitan Transit District buses discussed in section K.2.3.1. Informal rideshare matching is facilitated through a weekly newsletter.

Personnel at SNL, Livermore are restricted from driving on SNL, Livermore facility grounds; vehicle access is limited to parking areas adjacent to East Avenue. Onsite transportation is provided via approximately 200 bicycles and 131 gasoline- and electric- powered carts. Fifty government vehicles are assigned for use by specific SNL, Livermore departments onsite, including Protective Services.

As discussed previously, transit service is available at SNL, Livermore via Wheels and BART Express bus services. A bus stop turnaround is provided onsite.

K.3 TRANSPORTATION OF HAZARDOUS, RADIOACTIVE AND MIXED MATERIALS OR WASTES

This section discusses the procedures that LLNL and SNL, Livermore follow in receiving hazardous and radioactive materials, in safely moving these materials and wastes onsite, and in preparing them for offsite shipment. The discussion focuses particular attention on the organizational responsibility for implementing these procedures. Table K-4 lists the transportation-related definitions of hazardous, radioactive, mixed, and medical materials or wastes received and transferred onsite at LLNL and SNL, Livermore or prepared for shipment offsite.

In describing the transportation of hazardous, radioactive, mixed, and medical materials or wastes at LLNL and SNL, Livermore, the terms "transfer" and "transferring" refer to the intrasite movement of hazardous materials, while the terms "shipment" or "shipping" indicate the movement of materials or wastes offsite on public roads and highways (LLNL, 1991c). Under these definitions, the movement of materials or waste between the LLNL Livermore site and LLNL Site 300, or between the LLNL Livermore site and SNL, Livermore is considered a shipment.

Consistent with U.S. Department of Transportation (DOT) regulations, hazardous, radioactive, mixed, and medical materials and wastes are considered to be included within the hazardous materials and wastes classifications in the discussions in this appendix. For consistency with other parts of the EIS/EIR, material-specific details of the transportation requirements for the various materials will be highlighted separately. Medical wastes are only considered hazardous during onsite transfer because they must be sterilized before they are shipped offsite to a sanitary landfill. Medical wastes categorized as sharps waste (e.g., needles, blades, glass slides) are incinerated onsite.

Table K-4 Transportation-Related Definitions of Types of Hazardous, Radioactive, Mixed, and Medical Materials or Wastes

Types of Materials or Wastes	Definition
Hazardous Materials	"A substance or material, including a hazardous substance, which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated" (49 C.F.R. 171; DOE, 1986).
Hazardous Wastes	Wastes designated hazardous by Environmental Protection Agency (EPA) regulations (40 C.F.R. 261) and by the State of California (Title 22 of the California Code of Regulations). As used throughout this appendix, the term "hazardous waste" refers to nonradioactive, hazardous wastes.
Radioactive Materials	Any material having a specific activity greater than 0.002 microcuries per gram (49 C.F.R. 171.403; DOE, 1986).
Radioactive Wastes	"Solid, liquid, or gaseous material that contains radionuclides regulated under the Atomic Energy Act of 1954, as amended and of negligible economic value considering costs of recovery" (DOE Order 5820.2A). (See Appendix B for definitions of low level wastes and transuranic wastes.)
Mixed Wastes	Wastes that contain both radioactive and hazardous components as defined by the Atomic Energy Act and the RCRA (DOE Order 5820.2A; DOE Order 5400.3).
Medical Wastes	Wastes that consist of biohazardous waste and sharps (e.g., needles, blades, and glass slides) waste, managed in accordance with Chaptaer 6.1 of the California Health and Safety Code, are sterilized before shipment and, therefore, are not considered hazardous waste.

K.3.1 Transportation Regulatory Environment

This section provides a brief summary of the regulatory requirements for transporting hazardous and radioactive materials and wastes outside the boundaries of LLNL and SNL, Livermore. Hazardous materials arriving at LLNL and SNL, Livermore and hazardous materials and wastes shipped from the sites must comply with these regulations. Although the transfer of hazardous, radioactive, mixed, and medical materials or wastes onsite is subject primarily to DOE requirements, as a minimum these requirements provide safety equivalent to the DOT regulations for offsite shipments (e.g., placarding and packaging requirements).

The section also identifies and discusses the responsibilities of the federal and state agencies responsible for administering and enforcing these regulations. Table K-5 lists major regulatory requirements and responsible agencies affecting the movement of hazardous materials and wastes.

Table K-5 Regulations or Guidance for the Transportation of Hazardous, Radioactive, and Mixed Materials or Wastes

Regulations or Guidance	Responsible Agency
Title 10 Code of Federal Regulations section 71 (10 C.F.R.)	Nuclear Regulatory Commission
Title 49 Code of Federal Regulations sections 171–177 (49 C.F.R.)	U.S. Department of Transportation
Title 40 Code of Federal Regulations sections 260–263 (40 C.F.R.)	U.S. Environmental Protection Agency
Title 13 California Code of Regulations article 1–6.5	California Highway Patrol
Title 22 California Code of Regulations section 30	California Department of Health Services
DOE Order 1540.1 "Materials Transportation and Traffic Management"	U.S. Department of Energy
DOE Order 1540.2 "Hazardous Material Packaging for Transport—Administrative Procedures"	U.S. Department of Energy
DOE Order 1540.3 "Base Technology for Radioactive Material Transportation Packaging Systems"	U.S. Department of Energy
DOE Order 5400.3 "Hazardous and Radioactive Mixed Waste Program"	U.S. Department of Energy
DOE Order 5480.1B "Environmental Safety and Health Program for Department of Energy Operations"	U.S. Department of Energy
DOE Order 5480.3 "Safety Requirements For Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes"	U.S. Department of Energy
DOE Order 5480.4 "Environmental Protection Safety, and Health Protection Standards"	U.S. Department of Energy
DOE Order 5610.1 "Packaging and Transportation of Nuclear Explosives, Nuclear	U.S. Department of

Components, and Special Assemblies"	Energy
DOE Order 5820.2A "Radioactive Waste Management"	U.S. Department of Energy
"DOE Explosive Safety Manual" (DOE/EV/06194-3)	U.S. Department of Energy

K.3.1.1 Federal Regulatory Role

The DOT takes the lead in establishing transportation regulations, but shares the enforcement of these regulations with other federal agencies, such as the Federal Highway Administration, the Federal Aviation Administration, the National Highway Traffic Safety Administration, and the states or Native American tribes (Office of Technology Assessment, 1986). The Nuclear Regulatory Commission (NRC), the Environmental Protection Agency (EPA), and the Occupational Safety and Health Administration (OSHA) regulate other aspects of hazardous, radioactive and mixed materials or wastes transportation. The EPA has responsibilities for hazardous wastes including the hazardous waste component of mixed wastes (i.e., wastes that include both are hazardous and radioactive components), and OSHA is concerned with worker safety. The Federal Emergency Management Agency (FEMA) is responsible for coordinating federal assistance, planning, and training for all types of emergency response with state, tribal, and local governments (Office of Technology Assessment, 1986). (See Appendix J for additional information on emergency response to hazardous materials transportation accidents.)

K.3.1.2 State Regulatory Role

In California, the transportation of highway route controlled quantity shipments of radioactive hazardous materials and wastes is regulated by the California Highway Patrol pursuant to 13 California Code of Regulations (C.C.R.) sections 1 to 6.5. Portions of the DOT regulations (49 C.F.R. sections 107, 171–179, 393) have been incorporated by reference into the C.C.R. and are enforced by the California Highway Patrol. In addition, under the California Hazardous Waste Control Law, the California Department of Health Services (now known as Department of Toxic Substances Control) monitors compliance with the proper hazardous waste materials packaging, labeling, manifesting, transportation, and disposal requirements. Anyone who transports hazardous waste or hires a transporter in the state must comply with these requirements. The state also requires that vehicles used to ship hazardous waste must be inspected annually by the California Highway Patrol; vehicle owners must also carry insurance against accidents involving hazardous materials.

The C.C.R. lists regulatory requirements for hazardous, radioactive, and mixed materials or wastes transportation specifically related to shipping papers, shipping certification, hazard labels, marking, placards, vehicle safety equipment, shipment preparation, vehicle loading, and similar requirements. The California Highway Patrol, under 13 C.C.R. article 6.5, also has designated highway routes, safe stopping places, and inspection stops for the transportation of certain explosive materials. State laws also allow the California Highway Patrol to conduct en route inspections of vehicles transporting these hazardous materials.

K.3.2 Transportation Packaging and Other Requirements

The federal regulatory standards for containers used to ship hazardous, radioactive, and mixed materials or wastes are comprehensive, requiring that the packaging be adequate to prevent release of its contents during transportation. Both LLNL and SNL, Livermore must comply with these requirements. (The law (25168, Health and Safety) that required training for hazardous waste drivers was repealed in 1990; the 13 C.C.R. section 1176, article 4.5 is no longer valid).

The DOT regulations apply to containers of all sizes, although different requirements apply to whether a material is shipped in small packages or in bulk (49 C.F.R. section 173).

The DOT and NRC cooperate to regulate containers for radioactive materials or wastes. The NRC, under its own authority, is responsible for regulating, reviewing, and certifying very secure packaging called Type B containers. The DOT sets regulations for all other packaging for radioactive materials in consultation with the NRC. DOE has authority, under DOT regulations (49 C.F.R. section 173.7), to approve the packaging and certain operational aspects of its research, defense, and contractor-related shipments of materials requiring Type B containers. DOE, however, must use standards and procedures equivalent to those of the NRC.

In reviewing more than 40 years of available records, DOE has determined there have been no documented deaths or significant injuries associated with the shipping of radioactive materials or wastes (DOE, 1990a). Nonetheless, transport of radioactive materials is subject to stringent regulations addressing the design and manufacture of transport packaging, shipment identification, including labeling, marking, placarding, and shipment papers, package and vehicle inspections, and routing and driver training (DOE, 1990a). It is DOE policy to ensure that all packaging approved in transporting radioactive and other hazardous material meet all applicable safety requirements (DOE, 1986).

K.3.2.1 Packaging for Hazardous, Radioactive, and Mixed Materials or Wastes

Proper packaging of hazardous, radioactive, and mixed materials and wastes for transportation is an important safeguard against accidental spills and releases (LLNL, 1989a). Table K-6 shows examples of how LLNL matches hazardous materials with appropriate packaging for transport. Table K-7 shows examples of packaging guidelines for transporting radioactive materials at SNL, Livermore.

Both LLNL and SNL, Livermore receive shipments of hazardous and radioactive materials in packaging that already complies with DOT and/or DOE requirements. Onsite transfer of these materials is accomplished, where feasible and appropriate, using the original packaging. Where hazardous or radioactive materials are received and stored in bulk quantities and dispersed to locations onsite, these transfers are done with packaging and procedures equivalent to DOT safety regulations. Packaging to be used for offsite shipments of hazardous, radioactive, and mixed materials or wastes must meet DOT and DOE requirements (49 C.F.R. sections 171–179 and DOE Orders 1540.1 and 1540.2).

For shipments of radioactive wastes, DOE has tested all types of containers used for offsite shipments of radioactive materials in accordance with DOT's "Spec 7A Type A" standards (designed for normal shipping conditions per 49 C.F.R. section 173.403) and has developed an overall quality assurance plan covering radioactive material packaging (LLNL, 1990a). Before Type B packaging can be certified for the shipping of radioactive materials at any DOE site, it must pass a series of tests simulating or reproducing possible accident conditions of transport (specified in 10 C.F.R. section 71 and DOE Order 5480.3).

Table K-6 Matching Hazardous Waste Type with Packaging Requirements

Waste Types	Packaging Requirements
Large Volumes of Liquid Wastes	Carboys (less than 110 gal) or metal drums meeting DOT specifications
Small Volumes of Liquid Wastes	Strong, tight, compatible containers or specific containers required for specific liquid waste
Solid Wastes	Original containers, plastic bags, or in appropriate strong, tight containers

Radioactive Tritiated Wastes	DOT 7A or DOT 2R (Type A) container (to storage facility)
Higher Level Tritiated Water	DOT 6M container (Type B)*
SRD Classified U-238 Wastes	DOT 7A box or DOT 7A drum
Mixed Wastes	Strong, tight, compatible (Type A) containers (prior to transfer to waste facility)
Transuranic Wastes	DOT Type B containers

* Not used for offsite shipments from LLNL.

Table K-7 Guidelines for SNL, Livermore Packaging of Radioactive Materials

Packaging Types of Radioactive Material	Guidelines for Packaging
Limited Quantity/Instruments and Articles	Packaged in strong, tight packages that will not leak any of the radioactive contents during normal transportation.
Type A Quantity of Radioactive Material (Derived following requirements specified in DOT regulations, 49 C.F.R. section 173.433)	Packaged in appropriate inner containers to prevent leakage of the contents with the inner containers overpacked in one of the following containers: • strong fiberboard box • tightly sealed metal can or drum • strong wooden box • approved DOT-7A equivalent packaging • original containers received from manufacturer, if in good condition Materials shall be properly cushioned to prevent movement. Container shall be securely closed.
Type B Quantity of Radioactive Materials (Derived following requirements specified in DOT regulations, 49 C.F.R. section 173.433)	Packaged in a DOT-, DOE-, or NRC-certified container in accordance with provisions of the certificate of compliance.

Source: Yourick et al., 1989.

K.3.2.2 Other Requirements

Shipping papers must accompany shipments of hazardous, radioactive and mixed materials and wastes. These papers must describe the material or waste and certify that the shipment meets applicable DOT and/or DOE requirements. Hazardous waste must be accompanied by a specific shipping document called the Uniform Hazardous Waste Manifest, listing EPA identification numbers (also required by California Department of Health Services) of the generator, transporter, and designated treatment, storage, or disposal facility. The method for describing hazardous materials and wastes is provided in DOT regulations (49 C.F.R. section 172).

The DOT has also established requirements for marking and labeling hazardous radioactive, and mixed radioactive materials packages and containers. There are also requirements for the placarding of transport vehicles. This is done so the contents of a package can be identified if it becomes separated from the shipping papers. In addition, the EPA also requires special markings for packages of hazardous wastes.

Shippers, in this case LLNL and SNL, Livermore, must affix labels, as required by DOT (49 C.F.R. section 172.400), to hazardous materials packages which specifically identify the hazards classification of the package. Both the shipper and the carrier, however, share responsibility that transport vehicles display appropriate placards identifying the hazards of the cargo. Placards are important to emergency response personnel in the event of an accident. The DOT has developed placarding tables (49 C.F.R. section 172) to provide guidance to shippers and carriers for proper placarding.

K.3.3 Hazardous and Radioactive Materials and Wastes Transportation at LLNL and SNL, Livermore

This section briefly discusses the onsite and offsite transportation settings for transfer and shipment of hazardous, radioactive, and mixed materials or wastes at LLNL and SNL, Livermore. The regional and local transportation setting is described in section 2.1 and shown in Figure K-2, including the locations of the Livermore and Tracy municipal airports. (To simplify terminology for this discussion, the Department of Transportation designation of *hazardous materials and wastes* is used; this designation includes hazardous, radioactive, and mixed materials and/or wastes.

K.3.3.1 Highway Transportation

Interstate 580 is the major highway providing access to the LLNL and SNL, Livermore sites from the major metropolitan areas of Oakland and San Francisco to the west and from the California Central Valley and Interstate 5 to the east. Shipments of hazardous materials and wastes arrive and are shipped via these access corridors.

K.3.3.2 Air Transportation

LLNL and SNL, Livermore shipments of materials move through both the Livermore Municipal Airport (primarily to and from the LLNL Livermore site). LLNL also ships and receives shipments via the Tracy Municipal Airport (primarily to and from LLNL Site 300).

Livermore Municipal Airport

The Livermore Municipal Airport is located within the western boundary of the City of Livermore and south of Interstate 580 and encompasses approximately 400 acres. The city has been involved in operating an airport since it leased a former Naval Auxiliary Air Field from the Navy in 1942. Operations were moved to the current site in 1965. Based on air traffic counts taken in the early 1970s, the city constructed a Federal Aviation Administration air traffic control tower in 1973; and installed an instrument landing system in 1979. More recently, the City of Livermore established a "protection zone" 5000 ft to the north, south, and east of the airport, and 7000 ft to the west. No new residential land use designations or intensification of existing land use designations would be allowed within this zone (City of Livermore, 1991).

The Livermore Municipal Airport is classified as a General Transport Airport (i.e., "all civil aircraft activity by other than commercial aviation"). Contract air operations began with LLNL (known then as Lawrence Radiation Laboratory) in March 1954, using a Beech D-18 aircraft and a temporary facility at the airport (City of Livermore, 1975).

A 40-passenger LLNL aircraft (Fairchild F-27) is now housed and serviced at the Livermore Municipal Airport. The aircraft usually makes one round trip per weekday carrying passengers between Livermore and the Nevada Test Site. Whenever LLNL plans to ship hazardous materials on the LLNL aircraft via the Livermore Municipal Airport, LLNL notifies airport authorities as much as 24 hours ahead of time. In addition, although airport authorities allow some exceptions, an informal policy exists that LLNL will not receive or ship Class A or B (defined in 49 C.F.R. sections 173.88 and 173.53) explosives from the Livermore Municipal Airport (Maestas, 1991). Any hazardous materials transported together with passengers must meet restrictions established by DOT regulations. In addition to flights by the LLNL aircraft, Ross Aviation, contracted to DOE, also transports LLNL-related cargo via the Livermore Municipal Airport.

For the 12 months preceding February 1991, the airport logged a total of 233,405 flight operations (takeoffs and landings), which compares to 227,952 operations from February 1989 to February 1990; and 209,391 operations for the previous 12 months (Maestas, 1991). The number of LLNL-related flight operations (takeoffs and landings) made by the LLNL plane via the Livermore Municipal Airport is conservatively estimated to be 520 annually. Of the 233,405 flight operations logged at the airport for the 12 months preceding February 1991, the percentage of total operations associated with the LLNL plane is approximately 0.2 percent. Only about one flight a month is involved in transporting hazardous materials; the remaining flights involve transportation of LLNL personnel. In 1990, Ross Aviation flights via the Livermore Municipal Airport involving LLNL-related materials numbered four flights, not enough to substantially increase the percentage of LLNL-related flights using the airport.

Tracy Municipal Airport

Located approximately 3 miles southwest of the City of Tracy, the Tracy Municipal Airport occupies about 309 acres, of which less than half has been developed for aviation use (City of Tracy, 1975). The facility was first constructed by the U.S. Army Air Corps in 1943 on city property and was used as a training base in World War II; it reverted to civilian use in 1946 (City of Tracy, 1975).

The total annual operations (takeoffs and landings) at the airport, estimated from fuel sales and observations of based aircraft, are approximately 56,750. The airport is being considered by the FAA as a "reliever" airport for air traffic from the Bay Area. If this were to occur, certain upgrades to the airport would probably follow (e.g., a permanent control tower).

As might be expected, the airport's busiest days of the week are Friday, Saturday, and Sunday. The busiest months are April through October. At certain times of the year the California National Guard sets up a portable tower and operates the airport as a controlled airport (primarily a training opportunity for national guard staff). These training periods generally last for only a few weeks (Pellegrino, 1991).

The LLNL plane flies hazardous materials via the Tracy Municipal Airport approximately once a month. Ross Aviation also occasionally flies LLNL-related materials via the Tracy Municipal Airport and, in 1990, there were 20 LLNL-related shipments via Ross Aviation into the Tracy Municipal Airport, making the percentage of LLNL-related flights at the airport less than 0.04 percent of total annual operations.

Tracy Municipal Airport authorities have a verbal agreement with LLNL that its shipments will be "transferred" from ground transportation to and from aircraft at the north end of runway #11, away from the terminal and fueling facilities (Pellegrino, 1991). The only flight path restrictions are largely due to weather (the prevailing wind is from the northeast so nearly all takeoffs and landings proceed in that direction) and apply to all aircraft using the airport.

Tracy Municipal Airport personnel informally monitor LLNL-related flight activity and periodically check the shipment loading area for spills or other unusual conditions. There is no record of any problems with LLNL-related flights at the airport (Pellegrino, 1991). LLNL officials have met with Tracy Municipal Airport authorities, providing them with emergency response information about LLNL-related flights.

Other Air Transport Facilities

When LLNL or SNL, Livermore programs require specific deliveries to support schedules, occasional use is made of regularly scheduled DOE-contracted air shipments via the Alameda Naval Air Station near Oakland. In addition, in 1990 LLNL completed an interservice support agreement with Castle Air Force Base (AFB) at Merced, CA, permitting DOE-contracted aircraft to use this facility if required by weather or schedule constraints. The agreement covers shipments of classified materials, nonhazardous and hazardous materials, radioactive materials, and explosive materials meeting DOT packaging and loading requirements. In 1990, LLNL shipments amounted to 25 shipments from the Alameda Naval Air Station and 12 shipments from Castle AFB. SNL, Livermore has a similar agreement with Castle AFB citing the benefit of reducing the transportation of hazardous materials through more densely populated areas.

K.3.4 LLNL Organization for Transport of Hazardous and Radioactive Materials and Wastes

In 1990, LLNL established the Hazardous Material Packaging and Transportation Committee to improve the Laboratory's integration and coordination of hazardous material transportation (LLNL, 1990a). Made up of representatives from the Materials Management Division, Hazardous Waste Management Division, and Materials Distribution Division, the committee has taken a number of actions to enhance transportation operations:

- Independent review of all shipping papers associated with offsite hazardous material shipping.
- Coordinated review of existing quality assurance plans.
- Review of LLNL's compliance with DOE Orders 1540.1, 5480.1B, and 5480.3 (see Table K-5).
- Identification of a number of interim measures to enhance transportation safety (e.g., improved tie-down practices, vehicle and loading checklists, and safety modifications to forklifts used for onsite transfer of hazardous materials).
- Centralization of all offsite shipping records.

In addition to assuring improved integration and coordination of hazardous material transportation at LLNL, the committee is responsible for initiating internal reviews of LLNL transportation activities. In June 1990, to facilitate this activity, LLNL entered into an agreement with Los Alamos National Laboratory in Los Alamos, New Mexico, to provide reciprocal annual independent reviews of each Laboratory's transportation programs (LLNL, 1990a).

LLNL has also established a central records system for all offsite shipments of hazardous materials and wastes. This system provides verification that these shipments comply with applicable regulations and DOE orders. LLNL's quality assurance planning requires that internal and external audits be conducted regularly to review all hazardous material and waste management, including onsite and offsite transportation. The audit procedures require responsible organizations to identify environmental, health, and safety concerns; determine causes; and monitor corrective actions.

Specifically for transportation, LLNL has developed a series of checklists and oversight checks for all offsite hazardous material shipments to ensure that shipping documentation and transportation practices meet all applicable DOT and EPA regulations. Involving both onsite and offsite transportation activities, the checklists have been coordinated among the three organizations involved with transportation and the Hazardous Materials Packaging and Transportation Committee. Table K-8 summarizes these checklists and their functions. Figure K-11 shows an example of the Hazardous Materials Shipping Checklist used by the Traffic Management Section to verify shipments leaving LLNL.

The Hazardous Materials Packaging and Transportation Committee has coordinated the development of *LLNL Onsite Hazardous Materials Packaging and Transportation Safety Manual* (LLNL, 1991c) to provide a comprehensive approach to all transportation-related activities at LLNL. Figure K-12 illustrates how the management of hazardous materials and wastes is organized at LLNL.

At LLNL, hazardous materials and wastes, including radioactive materials and wastes, are divided into three categories corresponding to an assigned organization area of responsibility:

- Category 1 hazardous materials are "DOE-controlled materials" which include radioactive, hazardous, and classified materials, materials of national interest, and materials of high monetary value, such as precious metals used at LLNL (plus certain hazardous materials defined by DOT regulations, 49 C.F.R. section 171.8). The LLNL Materials Management Division is responsible for control and accountability for onsite transfer, receipt, and preparation for offsite shipment of these materials.

- Category 2 hazardous materials are all unclassified materials of negligible economic value, including hazardous, radioactive, and mixed wastes. These materials are the responsibility of the LLNL Hazardous Waste Management Division.
- Category 3 hazardous materials include all other hazardous materials (not included in Categories 1 and 2). These materials are the responsibility of the LLNL Materials Distribution Division.

Table K-8 Transportation Activity Checklists

Checklist	Function
Hazardous Materials Loading Checklist	Implemented for all onsite transfer of hazardous materials by Materials Management Division, Hazardous Waste Management Division, and Material Distribution Division.
Daily Vehicle Inspection Checklist	Safety and equipment checklist for all vehicles that transfer hazardous materials onsite.
Receiving/Shipping Checklist	Specific requirements for all industrial gas cylinders received at or shipped from LLNL.
Issuing Checklist	Must be implemented prior to issuance of any industrial gas cylinders to users.
Hazardous Material Shipping Checklist	Provides a secondary review by the Traffic Management Section of all hazardous material shipped offsite.

Source: LLNL, 1990a.

K.3.4.1 Materials Management Division

As part of the Safeguards and Security Department, the Materials Management Division is responsible for the receipt, transfer, packaging and shipment of Category 1 controlled hazardous materials, including nuclear and classified materials, mock and actual high explosives, precious metals, and other controlled materials as directed by DOE (LLNL, 1990c). The organization's activities which are key to onsite and offsite transportation of hazardous materials include:

- Preparing shipments of accountable nuclear material and preparing the required documentation for disposal of these materials (Hazardous Waste Management prepares documentation for Materials Management Division review).
- Ensuring that all Category 1 hazardous materials are safely handled, transferred, and stored onsite.
- Ensuring that all packaging and documentation for Category 1 materials meets DOE as well as applicable DOT and NRC regulations for shipping controlled materials, as appropriate.

K.3.4.2 Hazardous Waste Management Division

As part of the Environmental Protection Department, the Hazardous Waste Management Division is responsible for the transfer, treatment, packaging, storage, and shipment of all Category 2 hazardous wastes, radioactive wastes, and mixed wastes generated at LLNL (LLNL, 1989a). The organization's responsibilities, which are key to onsite and offsite transportation, include:

- Packaging and preparing wastes for shipment and disposal.
- Tracking and documenting the onsite and offsite movement of (Category 2) hazardous, radioactive, and mixed wastes from the waste accumulation areas to final disposal.
- Ensuring that containers used for shipping wastes meet DOT and other regulatory requirements.
- Responding to emergencies (secondary response only) and participating in cleanup of hazardous and radioactive spills that may occur at LLNL.

K.3.4.3 Materials Distribution Division

Within the Supply and Distribution Department, the Materials Distribution Division is responsible for receiving, storage, packaging, transfer, and shipping much of the materials used in LLNL programs and facilities including Category 3 hazardous materials at the LLNL Livermore site and LLNL Site 300.

Those Materials Distribution Division responsibilities key to onsite and offsite transportation include:

- Ensuring that all packaging used for shipping for Category 3 hazardous materials meets appropriate DOT specifications.
- Ensuring that all packages of Category 3 hazardous materials received at LLNL comply with regulatory and safety requirements.
- Ensuring that all packages of Category 3 hazardous materials released for offsite commercial or DOE shipment meet regulatory and safety requirements.

K.3.4.4 Traffic Management Section

To improve overall management and coordination of offsite transportation operations, LLNL established the Traffic Management Section within the Supply and Distribution Department as a focal point for all internal and external audits, inspections, and reviews related to hazardous materials and wastes transportation. The traffic management section is specifically responsible for:

- Verifying that all shipments of Category 1, 2, and 3 hazardous materials are properly packaged (including correct labeling and markings).
- Ensuring that proper shipping documentation is complete.
- Ensuring that the carrier is properly certified to transport hazardous materials.

The Traffic Management Section has also completed a review of actions necessary for LLNL to participate fully in DOE's Shipment Movement Accountability Collection (SMAC) system and intends to implement participation during FY 1992. The review assisted in ensuring that LLNL's procurement, accounting, and receiving information system is modified to provide the data required by SMAC.

K.3.4.5 LLNL Onsite Transfer of Hazardous Materials and Wastes

As discussed in section K.3.4, LLNL assigns responsibility for the receipt and onsite transfer of hazardous material and waste depending on whether it falls into Categories 1, 2, or 3 hazardous materials. The LLNL Livermore site receives hazardous wastes from its facility at the Livermore Municipal Airport and from LLNL Site 300. Regardless of which LLNL organization has lead responsibility for managing hazardous materials and wastes, the Laboratory must meet DOE safety requirements for transfer of these materials onsite.

The LLNL onsite packaging and transportation activities are organized to ensure health, safety, and environmental protection. This is accomplished by focusing on three important areas of management, specifically containment, communication, and control of hazardous materials (LLNL, 1991b).

Containment. Providing adequate containment of hazardous materials and wastes during each transfer to ensure no hazardous materials are released during normal onsite transport operations.

Communication. Providing adequate communication to provide sufficient information to personnel handling hazardous materials and (if needed) to emergency responders.

Control. Adherence to documental procedures and other administrative and/or physical control requirements appropriate for the level of containment and communication.

Specific requirements for these areas of activity are applied to the various categories of hazardous materials.

Specific Requirements for Hazardous Materials and Wastes

All three organizations, Materials Management Division, Hazardous Waste Management Division, and Materials Distribution Division, have significant roles in the management and movement of hazardous materials and wastes at LLNL.

Category 1 hazardous materials that arrive onsite are under the jurisdiction of the Materials Management Division which monitors the transfer of these materials to LLNL's programs and facilities. Vehicles and drivers used in transferring Category 1 materials from receiving areas to LLNL facilities must meet LLNL safety requirements including vehicle safety inspections and driving safety training.

All waste materials resulting from the use of Category 1 hazardous materials remain under the jurisdiction of the Materials Management Division. Following inspection and assaying, some of these materials are reassigned to the Hazardous Waste Management Division (e.g., transuranic wastes [see Appendix B], some high explosive wastes, some sealed sources) and become Category 2 materials.

Category 2 hazardous wastes are generated almost entirely at the LLNL Livermore site, although LLNL Site 300 and the LLNL facility at the Livermore Municipal Airport (mainly waste from solvents and similar materials used in servicing the LLNL aircraft) ship hazardous wastes to the LLNL Livermore site for storage or treatment before offsite disposal. (Appendix B discusses the management of hazardous wastes in more detail.)

Hazardous wastes (except medical wastes) are collected and stored temporarily at satellite waste accumulation areas located within work areas. Wastes from a number of satellite waste accumulation areas are collected at larger waste accumulation areas. Table K-9 summarizes the sequence of steps taken at the waste accumulation areas in preparation for onsite transfer and subsequent offsite shipment of hazardous wastes.

The Hazardous Waste Management Division accepts responsibility for transferring hazardous wastes from waste accumulation areas to treatment and storage facilities onsite, providing Waste Technicians to ride in vehicles with drivers provided by the Materials Distribution Division.

The waste technicians are responsible for verifying that wastes in the waste accumulation areas are properly segregated, packaged, and documented before they are transferred to interim storage or treatment. The Hazardous Waste Management Division also is responsible for packaging and preparing shipping papers for the shipment of hazardous wastes (except Controlled Materials waste) for offsite storage, treatment, recycling, or disposal.

Category 3 hazardous materials are primarily those materials used at LLNL that are not "controlled" as in Category 1 or are not waste materials in Category 2. Examples of these materials include flammable and nonflammable compressed gases, corrosives, poisons, and combustible liquids. These materials are usually received at LLNL transported by commercial carriers in DOT-approved packages.

Some users can transfer small quantities of Category 3 hazardous materials from receiving areas to programs and facilities where these materials are used. However, even if users transfer these materials onsite, they must meet LLNL requirements for securing loads, proper packaging and knowledge for proper response in case of an accidental spill. Medical wastes are managed according to procedures in LLNL's Procedure for Handling Medical Waste (LLNL, 1991b).

The Hazards Control Department provides advisory services to LLNL personnel through consulting training, monitoring, and auditing. Hazards Control also provides emergency control services through the Laboratory Fire Department.

Vehicles used in transferring hazardous materials onsite must be equipped with general safety equipment, such as fire extinguishers, "spill kits," and in the case of special hazards such as radioactive materials, with radiation detection equipment. The LLNL motor pool inspects and maintains these vehicles on a regular schedule.

Onsite, LLNL transports containers of solid wastes primarily on flatbed trucks which must pass daily vehicle inspection. Trucks with self-contained pumps are used to pump out temporarily stored liquid wastes in sumps or tanks. Bulk liquids are transported in 350-gal "tuff" tanks or 5000-gal stainless steel or lined steel tank trucks. Smaller liquid containers and tanks are transported on flatbed trucks.

The movement of explosives at LLNL is handled by the Materials Management Division or by LLNL Site 300 Transportation. For onsite movement of explosives at LLNL Site 300, each operating group is responsible for transporting the explosives under its control in approved packaging and vehicles. Hand-carrying of explosives is permitted only when authorized by a safety procedure (Prokosch and Guarienti, 1988).

Specific Requirements for Radioactive Materials and Wastes

Specific procedures for packaging and transporting hazardous wastes are provided in *Guidelines for Waste Accumulation Areas* (Hirabayashi, 1989). The Hazardous Waste Management Division will only accept wastes that meet the conditions set forth in these guidelines which cover storage functions, including waste segregation, identification, packaging, transportation and spill prevention. Each of these components is an important link in the chain of safe and efficient hazardous waste management.

Radioactive wastes may also be subject to additional packaging and certification requirements for acceptance at an approved DOE disposal site. An example of the certification process is described in the LLNL Transuranic Waste Certification Program (LLNL, 1987), which describes how transuranic wastes would be certified as meeting the requirements for acceptances at the Waste Isolation Pilot Plant in New Mexico, when that facility becomes operational and begins accepting wastes. The plan includes descriptions of the waste certification organization, personnel responsibilities, packaging requirements, data collection needs, and various waste form descriptions (e.g., solidified liquid waste).

Figure K-13 provides a diagram illustrating the onsite transfer of Categories 1, 2, and 3 hazardous materials and wastes at LLNL.

Table K-9 Waste Management Activities at Waste Accumulation Areas Relevant to Transportation

Waste Preparation Functions	Associated Activities

Waste Segregation	Segregation is required because some chemicals may be highly reactive if mixed with others; also, improper mixtures may require special analysis and disposal procedures, which are costly. Radioactive wastes must be segregated from nonradioactive wastes.
Waste Identification	Waste generators are responsible for identifying (sampling and analyzing if necessary) wastes before they are picked up by Hazardous Waste Management Division Staff. The identity of waste components must be recorded on a hazardous waste label and attached to each waste container.
Waste Packaging	Waste generators are responsible for packaging waste so that it may be safely transported and stored pending disposal. Hazardous Waste Management Division Staff will remove waste from waste accumulation areas only if it is packaged in tightly closed, approved containers that show no signs of damage, deterioration, or leaking.
Waste Transportation	Transportation of hazardous waste from the point of generation to the Waste Accumulation Area must be by a method agreed upon between the generator and the Hazards Control Safety Team Leader. Onsite transfer of hazardous waste from Waste Accumulation Areas is done by the Materials Distribution Division with supervision by the Hazardous Waste Management Division. Offsite shipment is provided by DOE or by carriers licensed by the State of California.

Source: Hirabayashi, 1989.

K.3.4.6 LLNL Offsite Shipment of Hazardous Materials and Wastes

The transport of hazardous materials and wastes offsite must meet federal, state, and local regulations and requirements for packaging; vehicle and driver qualifications; and, in some cases, routing.

Coordination of the offsite shipment of hazardous materials and wastes is the responsibility of the Hazardous Waste Management Shipping Coordinator, who works with the Traffic Management Section to ensure that all packaging and shipments of hazardous material and waste is in compliance with appropriate regulations and DOE orders (LLNL, 1990b). The Coordinator must also:

- Prepare manifests and related shipping documents.
- Prepare reports as required.
- Maintain records as required.

Contractors transporting hazardous wastes from LLNL must be licensed by the state. Trucks carrying hazardous wastes in California are subject to inspections by the California Highway Patrol, both on the highway and at the shipping terminal. Table K-10 provides a summary of the annual number of LLNL offsite shipments of hazardous materials and wastes for the years 1987 through 1990.

Specific Requirements for Explosive Materials

LLNL has designated two areas for receiving and dispatching shipments of explosives between the LLNL Livermore site and LLNL Site 300: Building 191, the High Explosives Applications Facility (HEAF) at the LLNL Livermore site, and Building 818 at LLNL Site 300. All explosives to be shipped offsite are packaged in containers as specified by DOT regulations except when DOE has an approved exemption from the DOT to use different packaging. Shipping containers must also have the appropriate DOT labels affixed.

Only authorized persons may transport explosives and only in approved vehicles. All drivers of explosives-carrying vehicles must have received proper training in the general safety precautions for explosives handling and specialized training for explosives transportation, following the requirements of 49 C.F.R. sections 390–397. In addition, drivers must receive special training that emphasizes caution, road courtesy, and defensive driving (Prokosch and Guarienti, 1988).

Table K-11 summarizes the various controls that drivers must meet in transporting explosive materials. Before vehicles loaded with explosive materials can leave the LLNL Livermore site or LLNL Site 300, drivers must be informed about both the nature of their cargo and methods of fighting vehicle- or cargo-related fires.

In addition, before any motor vehicle may be loaded with explosives (Class A, B, or C) for shipments on public highways, the vehicle must be inspected and approved by a qualified inspector using an approved inspection checklist which is then carried by the driver. Each vehicle transporting explosives is required to carry specialized equipment, such as fire extinguishers and two-way radios. Drivers must also complete the appropriate inspection records to document compliance with these regulatory requirements.

Transportation of explosives on public highways is under the jurisdiction of the California Highway Patrol, which has established approved routes, stopping places, and rules of the road (California Highway Patrol, 1988; 13 C.C.R. sections 1150.1 et seq.). Currently two approved explosives routes exist between the LLNL Livermore site and LLNL Site 300. The first is by way of Corral Hollow Road (west), Tesla Road, and Greenville Road. The second is by way of Corral Hollow Road (east), Interstate 580, and Greenville Road. Because the first route is less congested with traffic, it is the preferred route.

Specific Requirements for Radioactive Materials and Wastes

For offsite transport, radioactive materials and wastes must comply with DOE and DOT packaging requirements (DOE Order 5480.3 and 49 C.F.R. section 173). Transuranic (TRU) wastes are subject to the additional packaging and certification requirements to qualify them for long-term storage and eventual disposal at a DOE-licensed facility. This certification program plan is described in the LLNL Transuranic Waste Certification and Quality Assurance Plan (LLNL, 1990b).

All waste shipments expected to be consigned to the Nevada Test Site will be made in accordance with applicable DOT, EPA, state, and local hazardous materials regulations and with DOE requirements contained in the Nevada Test Site waste acceptance criteria (DOE, 1988). These requirements include DOT placarding requirements (49 C.F.R. section 172). Also, all mixed-waste shipments will be in accordance with the DOT's "Standards Applicable to Transporting of Hazardous Waste" (40 C.F.R. section 263).

DOE safe, secure transports (SSTs) are used for offsite shipment of classified special nuclear materials, including classified device parts when required. The SSTs are a ground transportation system with "built-in deterrent and disabling devices and special electronically coded locks set in vault-like doors" (DOE, 1990b). These systems are operated by specially selected and trained personnel. The transport systems must comply with DOE requirements and appropriate DOT regulations (49 C.F.R. sections 170–179).

Table K-10 Annual Number of LLNL Offsitea Hazardous and Radioactive Materials and Wastes Shipments for 1987–1990b

Hazardous Materials Land Wastes	1987 Shipments	1988 Shipments	1989 Shipments	1990 Shipments
Explosives	8	53	47	12
Nonflammable Gas	23	41	47	66
Flammable Gas	3	5	10	8
Flammable Solid	8	25	27	5
Oxidizer	1	0	5	2

Poison	1	3	14	9
Corrosive Materials	1	14	15	8
Hazardous Wastes	9	49	70	175
Combustible Liquids	0	0	0	2
Flammable Liquids	3	22	22	10
Radioactive Materials Empty Packaging	32	42	28	29
Radioactive Materials—Other	82	114	132	95
Radioactive Waste for Burial	12	0	2	0
Highway Route Controlled Radioactive Materials	2	5	9	7
Total:	181	373	428	426

[a] Includes shipments to and from LLNL Site 300.

[b] Does not include vendor pickups of hazardous materials (e.g., compressed gases), which LLNL estimates to be approximately 250 shipments annually. Source: LLNL, 1991d.

Table K-11 Safety Controls on Drivers of Vehicles Carrying Explosive Materials

Driver Controls:
• Obey posted speed limits, but do not exceed speeds of 25 mph onsite and 55 mph offsite.
• Be familiar with the emergency procedures for accident or fire involving a vehicle carrying explosive materials.
• Do not load vehicle in excess of rated weight limit.
• Do not smoke or permit a flame within 50 ft of a vehicle carrying explosives.
• Do not leave a vehicle transporting explosives without stopping the motor and setting the parking brake; if the vehicle is on a grade, one wheel must be chocked.
• Do not transport explosives if bad weather limits the driver's safe control of the vehicle.
• Do not exceed the normal passenger capacity of the vehicle.

Source: Derived from Prokosch and Guarienti, 1988.

K.3.5 SNL, Livermore Organization for Transport of Hazardous Materials and Wastes

In 1990, SNL, Livermore reorganized its administration of packaging and transportation of hazardous materials and wastes, creating several new divisions with responsibilities to ensure adequate self-assessments and independent oversight to meet the requirements of DOE Orders 5480.1 and 5482.1B. In addition, SNL, Livermore has instituted an oversight program to ensure that line organizations comply with DOE and SNL, Livermore hazardous material policies and procedures. SNL, Livermore also requires its vendors and/or suppliers to adhere to all relevant onsite health and safety regulations; for example, the labeling of cryogenic (i.e., very low temperature) storage tanks onsite (SNL, Livermore, 1991b).

SNL, Livermore has also instituted a comprehensive training program for hazardous materials packaging and transportation, which provides job task analysis, individual training records, performance measures, and frequency of training requirements. Personnel are scheduled to attend training sessions to support the program requirements. In addition, a training database has been developed to track past and future training session attendance and to identify future training needs (SNL, Livermore, 1991b).

For improved safety, SNL, Livermore has revised its Spill Prevention, Control and Countermeasures plan and program to meet the requirements of DOE Orders 5480.1B and 5480.4, and federal regulations contained in 40 C.F.R. section 112. The plan includes specific procedures, forms, and checklists for use by maintenance personnel and has been used in developing a training program for fire-fighting personnel. SNL, Livermore has also prepared a hazardous materials quality assurance plan to address the onsite transportation and handling of hazardous materials. The plan references procedures such as proper grounding of flammable liquid drums and cargo loading and securing procedures (SNL, Livermore, 1991b).

To ensure compliance with DOE Order 5480.3, including procedures for preparing, packaging, and transporting offsite shipments of hazardous materials, SNL, Livermore has developed the *Transportation Safety Manual* identifying responsibilities, lines of authority, and program approval procedures. The manual further defines minimum safe packaging and training requirements and provides for compliance of regulatory vehicle standards and driver qualifications for the transport of hazardous materials. The manual also provides information about emergency response procedures (SNL, Livermore, 1991d).

Periodic training is coordinated with the security inspector force to raise awareness of hazardous material movements onsite. Vehicles moving hazardous materials onsite are equipped with driver-side door pockets that display the hazard class cards applicable to the hazards on board the vehicle. When transferring hazardous materials, the driver selects an appropriate hazard class card from the door pocket and attaches it to a clipboard kept in the vehicle. In case of an emergency, this card provides readily available information on the nature of the hazardous materials being transferred. SNL, Livermore has revised its quality assurance plan along with the supporting procedures to include offsite and onsite packaging and shipping. This process would be supported by a series of internal audits of the packaging and transportation programs (SNL, Livermore, 1991b).

In support of transportation emergency response capacity, the telephone system at SNL, Livermore's Security Control Center has been upgraded to accommodate up to six callers conferenced at one time. SNL, Livermore has also revised its incident response procedures to ensure its communication capabilities to respond to a transportation emergency involving hazardous materials.

K.3.5.1 SNL, Livermore Onsite Transfer of Hazardous Materials and Wastes

SNL, Livermore's onsite transportation manual (SNL, Livermore, 1991a) and *Transportation Safety Manual* (SNL, Livermore, 1991d) include procedures for managing the transfer of hazardous materials and wastes. These procedures are consistent with federal regulations and DOE Orders for offsite shipment of hazardous materials and wastes, including:

- Marking the outside of the packaging.
- Labeling the outside of the packaging, whenever possible, with a proper DOT label.

- Packaging the materials or wastes properly.
- Documenting the movement with proper records.
- Placarding transport vehicles following procedures outlined in the manual.

Hazardous materials, with the exception of explosives, are received onsite through the Property Management Division which has responsibility for transferring these materials to onsite programs and facilities. Handlers and delivery personnel responsible for moving hazardous materials must undergo training in the hazards and safety procedures related to the types of materials they work with (Yourick et al., 1989). A summary of these training requirements is presented in Table K-12.

Hazardous wastes generated at SNL, Livermore become the responsibility of the Environmental Protection Department. There are several classes of wastes managed at SNL, Livermore (see Appendix B for a more detailed discussion of hazardous wastes) (SNL, Livermore, 1991d):

- Hazardous chemical wastes, which include RCRA, Toxic Substance Control Act, and California Regulated Wastes.
- Radioactive wastes, which include predominately low-level tritiated (contaminated with tritium) waste (e.g., paper, oil absorbed into clay, or liquid oil) and depleted uranium.
- Mixed wastes, which include a combination of hazardous and radioactive wastes (see Table K-6).
- Medical wastes, which include biohazardous waste and sharps waste (e.g., needles, blades and glass slides).
- Nonsewerable industrial waste water, which is not designated as either hazardous or radioactive waste but is managed as hazardous waste.

Once hazardous wastes are properly identified packaged, marked, and labeled (according to 49 C.F.R. sections 100–177 and 40 C.F.R. sections 260–268), a trained hazardous waste technician loads, secures, and transfers the wastes in a qualified vehicle, specifically designed for this work. The wastes are stored in a secure EPA-permitted waste management facility. The vehicle used to transport waste onsite is equipped with a CB radio tuned to the site security communication center. At no time does the vehicle carrying waste use a public road for these onsite transfers (SNL, Livermore, 1991d). Figure K-14 shows the flow of hazardous materials and wastes onsite at SNL, Livermore.

Specific Requirements for Explosives

Class A explosives are received by the Health and Safety Division at one onsite location (Building 981) by qualified explosives handlers. Class B and C type explosives may be received at an alternative building location (Building 928) for later transfer by qualified explosives handlers. All explosives are packaged for shipment by explosives handlers only in authorized explosives areas. Bulk compressed gas is also received at a single onsite location (Raw Stock in Building 918) from which it is distributed to a requesting organization. Outbound compressed gas must also go through this facility.

Specific Requirements for Radioactive Materials

At SNL, Livermore, only designated persons are authorized to transport radioactive materials onsite (Yourick et al., 1989). The extent of packaging for radioactive materials depends on the quantity of material involved and the radiation level at the external surface of the package. Packaging varies with the particular radionuclides to be transported, and determination of packaging type for a particular radioactive material shipment follows a detailed process of matching radionuclide activity levels with the appropriate shielding and safety requirements.

Table K-12 SNL, Livermore Hazardous Materials Training Requirements

Training Requirements:
• DOT and EPA regulatory requirements.

• Identification of materials and hazard classes.
• Onsite transfer and movement procedures.
• Use and identification of labels, markings, and placards for onsite transfers and movements.
• Packaging requirements for onsite transfers and movements.
• Storage and vehicle cargo compatibility.
• Loading and unloading procedures.
• Maintenance and use of packaging.
• Onsite transfer and movement documents.
• Emergency response procedures.
• Vehicle standards and operation.
• Other requirements as necessary.

Source: Yourick et al., 1989.

K.3.5.2 SNL, Livermore Offsite Shipment of Hazardous Materials and Wastes

With the exception of explosives and bulk compressed gas, outbound hazardous materials and wastes are picked up by shipping personnel and delivered to a single onsite location for packaging for offsite shipment. Occasionally, for security reasons, Nuclear Explosive–Like Assemblies are prepared for shipment (collected, placed in containers, marked and labeled) at Test Assembly Group locations. All shipments of hazardous materials and waste offsite must comply with DOT regulations.

SNL, Livermore prepares hazardous, radioactive, and mixed wastes for offsite transportation at the Waste Management Facility (Buildings 961 and 9622) where wastes are properly packaged, marked, and labeled according to DOT and EPA regulations. Table K-13 lists the number of hazardous and radioactive materials and wastes shipments offsite from 1987 to 1990. Before waste containers are shipped offsite, they are further inspected by Hazardous Waste Management staff for compliance with closure, strength, handling, devices, size, and weight requirements by DOT and disposal-site waste acceptance criteria.

Specific Requirements for Explosives

The shipping of explosives is monitored by the California Highway Patrol (see section K.3.3). In addition, as required by DOE orders, all packaging, labeling, applicable shipping documents, and transportation requirements must comply with DOT regulations (49 C.F.R. sections 100–179). Only designated personnel are authorized to transport explosive materials. The proper packaging according to DOT requirements along with the marking, labeling, vehicle placarding, and records documentation must be followed.

Specific vehicles are dedicated for transporting explosives and are equipped according to DOE Explosives Manual requirements. Each vehicle must be inspected daily before use by the operator and inspected monthly by the section supervisor. Records must be kept of these inspections. In addition, materials to be transported on the same vehicle must be compatible.

Table K-13 Annual Number of SNL, Livermore Offsite Hazardous, Radioactive, and Mixed Material or Waste Shipments for 1987–1990*

Hazardous Radioactive,and Mixed Materials or Wastes	**1987 Shipments**	**1988 Shipments**	**1989 Shipments**	**1990 Shipments**
Explosives	110	120	91	44
Nonflammable Gas	55	37	81	82
Flammable Gas	19	49	21	34
Flammable Solid	23	31	22	8
Oxidizer	0	0	1	1
Poison	10	11	8	18
Corrosive Materials	7	17	51	68
Flammable Liquids	7	6	9	10
Radioactive Materials (No Label Required)	30	56	42	28
Radioactive Materials (White Label Required)	7	7	8	11
Radioactive Materials (Yellow Label Required)	17	23	26	13
Otherwise Regulated Materials (ORM) A, B, D, and E	10	13	3	5
Hazardous Waste	10	12	22	39
Radioactive Waste	1	0	0	1
Mixed Waste	0	0	0	2
Total:	306	382	385	364

* SNL, Livermore shipment data includes hazardous materials shipments picked up by vendors (e.g., compressed gas cylinders). Source: SNL, Livermore, 1991c.

APPENDIX K GLOSSARY

Centroid	A point within a traffic zone that represents the assumed focal point of the land use activity. For modeling purposes, a centroid is a point in the zone from which traffic generated by the zone can be connected to the surrounding roadway system.
Geometrics	In traffic studies, the features of roadway design, roadway alignment, grade, cross-section, access control, intersections, and interchanges.
Intersection Capacity Utilization method	In traffic studies, a method for analyzing intersection operating conditions by calculating a volume-to-capacity (V/C) ratio for each governing "critical" movement during a traffic signal phase. The V/C ratio for each phase is summed with the others at the intersection to produce an overall V/C ratio for the intersection as a whole. The V/C ratio represents the percentage of intersection capacity utilized. For example, a V/C ratio of .85 indicates that 85 percent of the capacity is being used.
Level of Service (LOS)	In traffic studies, the different operating conditions that occur in a lane or roadway when accommodating various traffic volumes. A qualitative measure of the effect of traffic flow factors such as special travel time, interruptions, freedom to maneuver, driver comfort, convenience, and (indirectly) safety and operating cost. In this study, levels of service are described by a letter rating system of A through F, with LOS A indicating stable traffic flow with little or no delays and LOS F indicating excessive delays and jammed traffic conditions.
Machine count	A traffic count made using an automatic counting machine that tallies vehicles as they pass over a pressurized hose laid across a vehicle path.
Mode choice	A choice of means of travel (e.g., car, public transit, walking, cycling).
Network building	In traffic studies, redrawing the roadway system in a format that can be understood by the model program. The extent of the network developed to accurately study an area must take into account traffic expected to be generated locally and from the surrounding region. A network looks like a simplified and stylized version of a roadway map, with a series of straight lines (links) used instead of curves. Links are coded with data such as their distance, speed of travel, roadway capacity, and number of travel lanes.
Path building	The development of travel paths for traffic. The model determines the minimum impedance path from a selected origin to its destination. This would depend on the variables related to the various possible routes, such as distance and travel time or speed.
Reserve capacity	The unused capacity of a vehicle travel lane. The number of additional vehicles that could make a particular turning movement before that movement reaches capacity.
Special nuclear material	Plutonium, uranium enriched in the isotope U-233 or in the isotope U-235, and any other material which, pursuant to the provisions of Section 51 of the Atomic Energy Act of 1954, as amended, has been determined to be special nuclear material, but does not include source material, or any other material enriched by any of the foregoing.
Standard of significance	The limit of acceptable performance of the traffic network. Exceeding this limit would constitute a significant adverse effect in terms of traffic conditions.
Trip assignment	The allocation of vehicle trip ends to available routes between locations in a traffic study area.
Trip distribution	The allocation of vehicle trips onto the surrounding roadway network from a specified location.
Trip generation	The number of vehicle trip ends associated (produced) by a particular land use of a traffic study site.
Trip matrix adjustment	This process factors the person trips generated to vehicle trips. The vehicle occupancy factor is typically 1.5.
Trip matrix balancing	This process converts a production-attraction matrix to an origin-destination trip table.

Type A pTrip matrix balancingackaging	"A packaging designed to retain the integrity of containment and shielding . . . under normal conditions of transport as demonstrated by" a water spray test, a free-drop test, a compression test, and a penetration test (40 C.F.R. parts 173.403(gg), 173.465).
Uranium hydride	A bed of the porous form of the material used to transport and store tritium.
V/C ratio	Volume-to-capacity ratio.
Vehicle trip ends	A single or one-directional vehicle movement with either the origin or destination inside a traffic study site.
Waste Isolation Pilot Plant (WIPP)	A facility in southeastern New Mexico being developed as the disposal site for transuranic and transuranic mixed waste, not yet approved for operation.

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APPENDIX L PUBLIC INFORMATION AND INTERGOVERNMENTAL AFFAIRS

Council on Environmental Quality (CEQ) Regulations (42 U.S.C. 1506.6) implementing the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA) Guidelines (California Administrative Code, Title 14, section 15201) compel public participation and involvement in the EIS/EIR process. Further, Department of Energy (DOE) guidelines (57 Fed. Reg. 80.15124, 1992) for implementing NEPA, and University of California (UC) Handbook (UC, 1991) for implementing CEQA, stipulate requirements for public notice during the EIS/EIR process. These guidelines also describe the requirements for a formal public hearing and comment period after the release of the Draft EIS/EIR. In response to these requirements, DOE and UC have prepared a project community relations plan (DOE and UC, 1991a), which describes the EIS/EIR process and the opportunities for public input and involvement in this process.

In addition, the EIS/EIR process includes intergovernmental affairs activities designed to keep government agencies and officials informed of the issues and the status of the EIS/EIR project. These activities include opportunities to participate in the scoping process, consultations during data collection, and opportunities to comment on the Draft EIS/EIR. The process also involves briefings and, when appropriate, consultation with government agency representatives and officials.

This appendix summarizes public information and intergovernmental affairs activities conducted before and during the preparation of the Draft and Final EIS/EIR.

APPENDIX L REFERENCES

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APPENDIX M INFORMATION DEPOSITORIES

Copies of the Draft EIS/EIR, as well as pertinent supporting documents, have been placed in the nine reading rooms and libraries listed below. Two of the nine locations, the Livermore Public Library and UC Berkeley Library, are reference libraries that contain expanded document collections. These two reference libraries contain copies of all documents cited in the EIS/EIR and copies of relevant studies and reports reviewed by the contractor during the preparation of the EIS/EIR. Document indices have been placed in each location. Check with the individual facility for current hours of operation.

Facility	Address
DOE Headquarters Reading Room	1000 Independence Ave. SW Room 1E-190 Washington, DC 20585 (202) 586-5955
DOE Reading Room	San Francisco Operations Office 1333 Broadway—6th Floor Oakland, CA 94612 (510) 273-4429
Livermore Public Library*	1000 So. Livermore Avenue Livermore, CA 94550 (510) 373-5500
LLNL Visitor Center	East Entrance, Greenville Road Livermore, CA 94550 (510) 422-9797
Tracy Public Library	20 East Eaton Avenue Tracy, CA 95376 (209) 835-2221
UC Berkeley* Charles F. Doe Library	Government Documents Section 350 Main Library Annex Berkeley, CA 94720 (510) 642-2569
Facility	**Address**
Sandia National Laboratories, Livermore	Livermore Reading Room 7011 East Avenue Building 911 Lobby Livermore, CA 94551 (510) 294-2447
Dublin Library	7606 Amador Valley Blvd. Dublin, CA 94568 (510) 828-1315
Pleasanton Public Library	400 Old Bernal Avenue Pleasanton, CA 94566 (510) 462-3535

* Indicates reference library with expanded document collection.

APPENDIX N MITIGATION MONITORING PROGRAM

The California Environmental Quality Act (CEQA) requires a document called a Mitigation Monitoring Program "for changes to the project which it has adopted or made a condition of project approval in order to mitigate or avoid significant effects on the environment. The reporting or monitoring program shall be designed to ensure compliance during project implementation" (California Public Resources Code, section 21081.6). In addition, DOE has a policy (DOE, 1990) of preparing Mitigation Action Plans, when it commits to mitigate adverse environmental impacts associated with the selected action. This Mitigation Action Plan is issued after the Record of Decision is published (DOE 1991).

The CEQA-required Mitigation Monitoring Program, which is a UC document, will cover only LLNL. The DOE plan will be prepared to cover both LLNL and SNL, Livermore.

The LLNL Mitigation Monitoring Program will be published concurrently with the Final EIS/EIR. The Mitigation Action Plan for LLNL and SNL, Livermore will be published after the Record of Decision. An annotated outline that will form the basis for the Mitigation Action Plan and the Mitigation Monitoring Program is presented here to indicate the planned content and organization of the documents:

N.1.0 BACKGROUND AND DESCRIPTION OF THE PROPOSED ACTION

N.1.1 Background

[This section will provide a summary of any pertinent background information (e.g., the facilities, location, and chronology of events leading to the EIS/EIR).]

N.1.2 Summary

[A summary of the proposed action and the impacts that are to be mitigated.]

N.2.0 PROPOSED MITIGATION MEASURES

N.2.1 Environmental issues 1 to 9

[Each environmental issue (such as Air Quality) will be taken up in turn. Significant adverse impacts will be summarized and feasible measure(s) to mitigate them will be briefly described. The following questions will be addressed:

1. Feasibility. Can it be done in the state of the art?

2. Effectiveness. What will be the level of significance afterwards?

3. Cost/benefit. Does the improvement warrant the effort?

4. Regulatory. What are the statutory and regulatory constraints on the measure? Is the measure subject to possible *changes in federal or state regulations? What contingency measures are there for adapting to a change?*

5. Schedule. When will the mitigation measure be started and how long will it take?

6. Who will be responsible for implementing the measure?

7. What kind of monitoring is required during the implementation of the measure and afterwards?

8. Who will be responsible for monitoring the progress of the mitigation and evaluating whether modifications to the procedures need to be made?

9. Who is responsible for monitoring and reporting?]

N.3.0 SUMMARY OF PLAN REQUIREMENTS

N.3.1 Summary

[This section will provide a summary of the proposed mitigation measures. It will provide an overall view of the feasibility of the mitigation measures proposed.]

N.3.2 Schedule

[A summary table will be provided that lists each mitigation measure, the schedule for completion, the responsible entity, and any other pertinent facts. A sample table (Table N-1) is included.]

APPENDIX M & N REFERENCES

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