1

Site Overview

Introduction

Meteorology and geography play primary roles in how the environment is affected by human actions. Dispersal of particles in air, for example, is influenced by the wind and rain, which in turn are influenced by geographical characteristics. Similarly, the movement of ground water is constrained by the particular geology of a site. Thus, knowledge of wind, rainfall, geology, and geographical characteristics is used to model the effects that operations at Lawrence Livermore National Laboratory might have on the surrounding environment. Some history and a description of these characteristics help us understand the importance of the Laboratory's meteorological and geographic setting.

Operations

Lawrence Livermore's mission is to apply science and technology in the national interest, with a focus on global security, global ecology, and bioscience. Laboratory employees are working with industrial and academic partners to increase national economic competitiveness and improve science education. The Laboratory's mission is dynamic and has changed over the years to meet new national needs.

LLNL is a full-service research laboratory with the infrastructure—engineering, maintenance, and waste management activities, as well as security, fire, and medical departments—necessary to support its operations and about 8700 personnel.

Location

LLNL consists of two sites—the main laboratory site located in Livermore, California (Livermore site) in Alameda County, and the Experimental Test Site (Site 300) located near Tracy, California, in San Joaquin and Alameda counties (**Figure 1-1**). Each site is unique, requiring a different approach for environmental monitoring and protection.

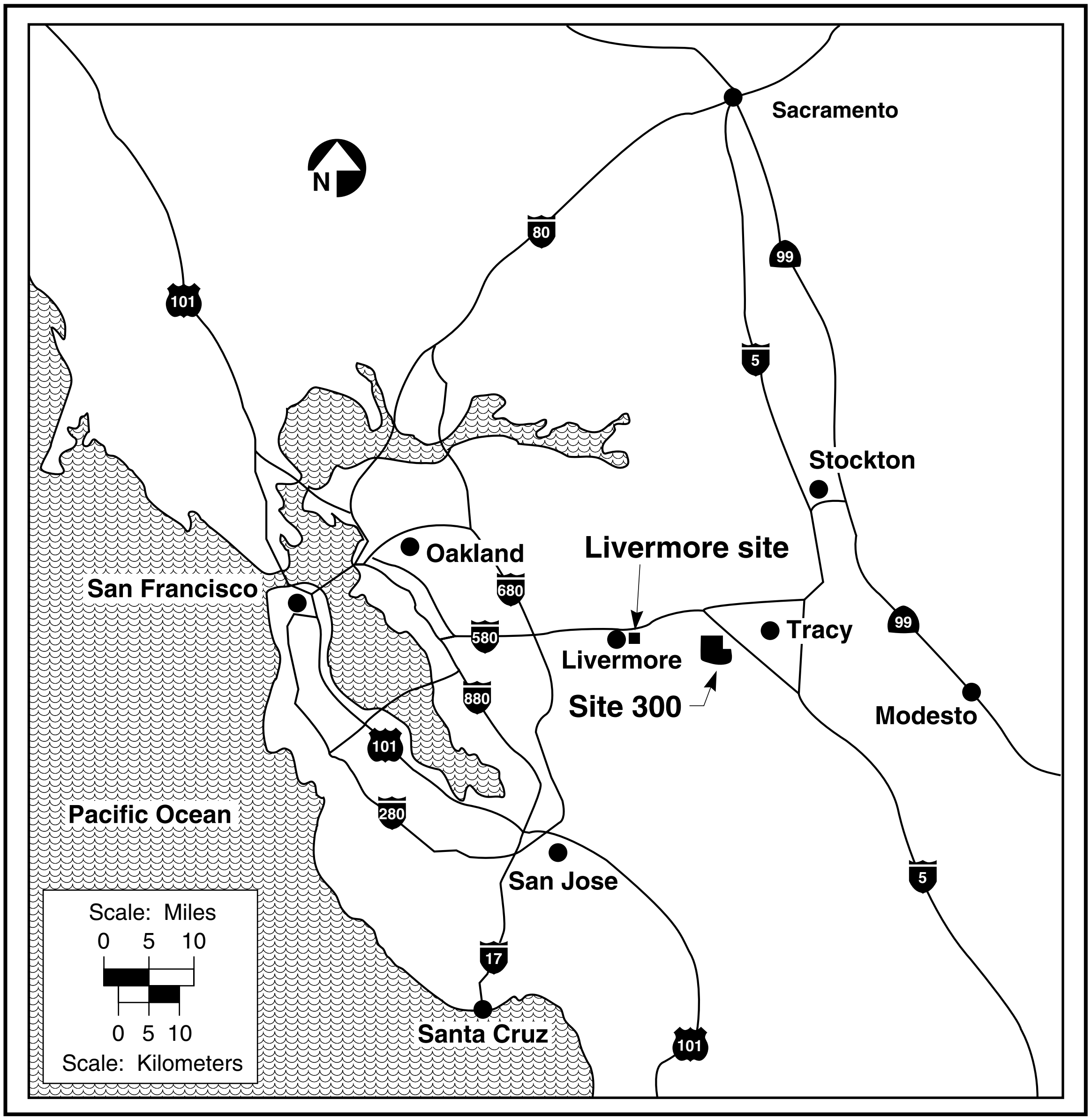

Figure 1-1. Locations of LLNL Livermore site and Site 300.

LLNL was founded at the Livermore site in 1952 at a former U.S. Navy training base. At that time the location was relatively isolated, being approximately 1.6 km from the Livermore city limits. Over time, Livermore evolved from a small town of fewer than 7000 people when the Laboratory began to its present population of about 74,300. The economy, which had been primarily agricultural, diversified to include light industry and business parks. Within the last few years, low-density, single-family residential developments have begun to fill the formerly vacant fields. Livermore residences are now near LLNL's western boundary.

LLNL's Livermore site occupies an area of 3.28 km^2, including the land that serves as a buffer zone around the site. Immediately to the south is Sandia National Laboratories/ California (Sandia/California), operated by Lockheed-Martin under Department of Energy (DOE) contract. Sandia/California engages in research and development associated with nuclear weapons systems engineering as well as related national security tasks. Although their primary missions are similar, LLNL and Sandia/California are separate entities, each with its own management and each reporting to a different DOE operations office.

To the south of LLNL, there are also some low-density residential areas and agricultural areas devoted to grazing, orchards, and vineyards. A business park lies to the southwest. Farther south, property is primarily open space and ranchettes, with some agricultural use. High-density residential development lies to the west. A very small amount of low-density residential development lies to the east of the Livermore site, and agricultural land extends to the foothills that define the eastern margin of the Livermore Valley. A business park is located to the north, and a 200-hectare parcel of open space to the northeast has been rezoned to allow development of light industry.

Site 300, LLNL's Experimental Test Facility, is located 20 km east of the Livermore site in San Joaquin and Alameda counties in the Altamont Hills of the Diablo Range; it occupies an area of 30.3 km^2. It is in close proximity to two other testing sites: PRIMEX/Physics International operates a testing site that is adjacent and to the east of Site 300, and SRI International operates another site, located approximately 1 km south of Site 300. The Carnegie State Vehicular Recreation Area is located south of the western portion of Site 300, and wind turbine generators line the hills to the northwest. The remainder of the surrounding area is in agricultural use, primarily as grazing land for cattle and sheep. The nearest residential area is the town of Tracy (population 54,200), located 10 km to the northeast.

Meteorology

Meteorological data (including wind speed, wind direction, rainfall, humidity, solar radiation, and air temperature) are continuously gathered at both the Livermore site and Site 300. Mild, rainy winters and warm, dry summers characterize the climate. A detailed review of the climatology for LLNL can be found in *Climatology of Lawrence Livermore National Laboratory* (Gouveia and Chapman 1989). The mean annual temperature for both sites in 1999 was 15°C. Temperatures range from 5°C during some predawn winter mornings to 40°C during some summer afternoons.

Both rainfall and wind exhibit strong seasonal patterns. These wind patterns tend to be dominated by the thermal draw of the warm San Joaquin Valley that results in wind blowing from the cool ocean toward the warm valley, increasing in intensity as the valley heats up. The wind blows from the northeast primarily during the winter storm season. Most precipitation occurs between October and April, with very little rainfall during the warmer months.

Annual wind data for the Livermore site are given in **Figure 1-2** and **Table 1-1**. These data show that greater than 50% of the wind comes from the south-southwest to westerly direction. Based on a ten-year record, the highest and lowest annual rainfalls were 541 and 211 mm, and the average annual rainfall was 360 mm. In 1999, the Livermore site received 245 mm of rain.

The meteorological conditions at Site 300, while generally similar to those at the Livermore site, are modified by higher elevation and more pronounced topological relief. The complex topography of the site significantly influences local wind and temperature patterns. Annual wind data are presented in **Figure 1-3** and **Table 1-2**. The data show that winds are more consistently from the west-southwest and reach greater speeds than at the Livermore site. The increased wind speed and elevation of much of Site 300 result in afternoon temperatures that are typically lower than those for the Livermore site. Rainfall for 1999 was 198 mm at Site 300.

Topography

The Livermore site is located in the southeastern portion of the Livermore Valley, a topographic and structural depression oriented east-west within the Diablo Range of the California Coast Range Province. The Livermore Valley, the most prominent valley in the Diablo Range, is an east-west trending structural and topographic trough that is bounded on the west by Pleasanton Ridge and on the east by the Altamont Hills. The valley floor is covered by alluvial, lake, and swamp deposits consisting of gravels, sands, silts, and clays, at an average thickness of about 100 m. The valley is approximately 25-km long and averages 11 km in width. The valley floor is at its highest elevation of 220 m above sea level along the eastern margin and gradually dips to 92 m at the southwest corner. The major streams passing through the Livermore Valley are Arroyo del Valle and Arroyo Mocho, which drain the southern highlands and flow intermittently. Major arroyos are depicted in Chapter 7 (**Figure 7-1**).

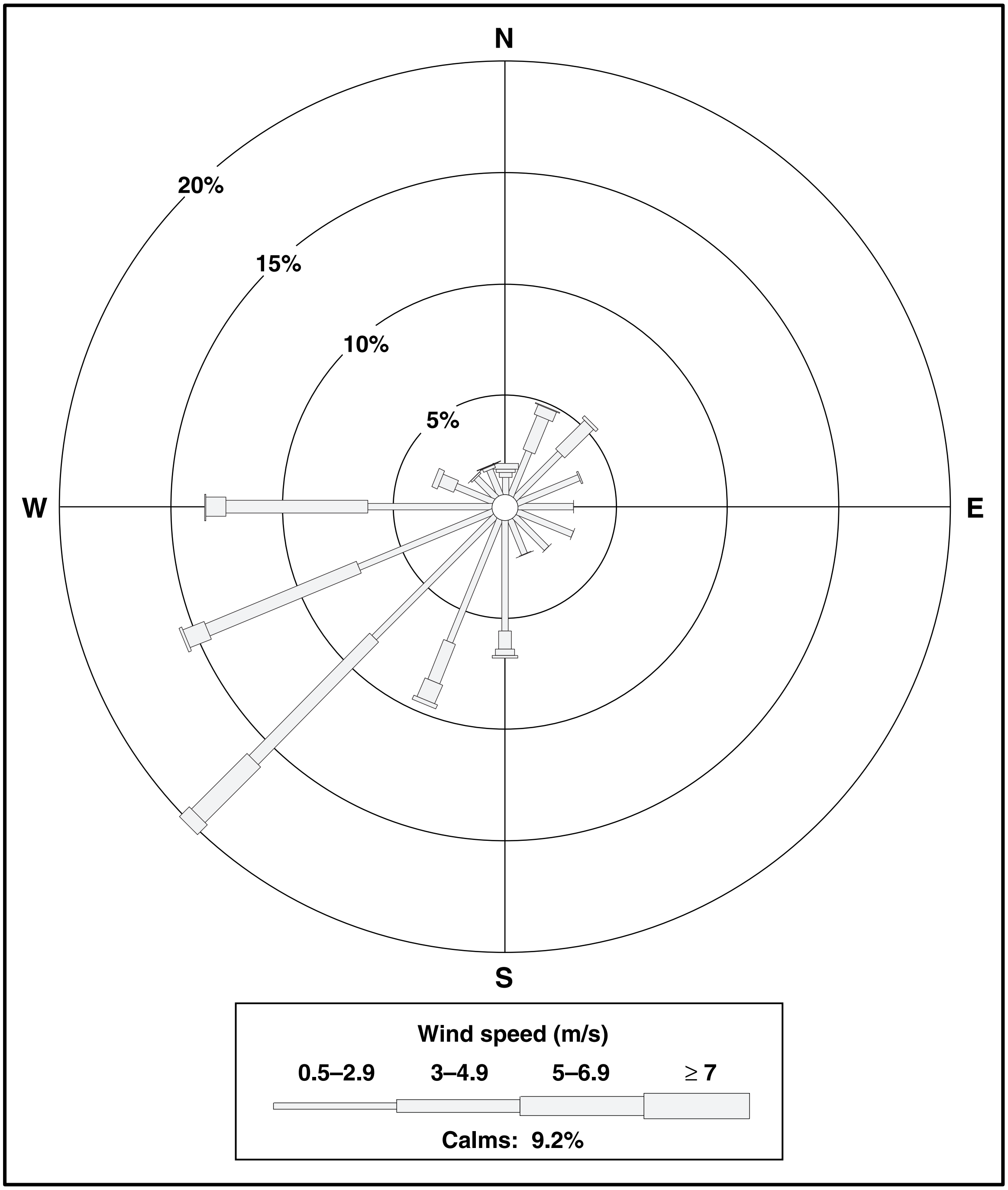

Figure 1-2. Wind rose showing the frequency of occurrence for wind speed and direction at the Livermore site, 1999.

Table 1-1. Wind rose data for LLNL's Livermore site at the 10-m level for 1999. Values are frequency of occurrence (in percent). Columns and rows may not exactly sum to the listed totals because of rounding.

Direction	Wind speed range (m/s)					
	0.0–0.4	**0.5–2.9**	**3.0–4.9**	**5.0–6.9**	**≥7.0**	**Total**
NNE	0.58	2.11	1.66	0.46	0.05	4.9
NE	0.58	2.84	1.83	0.14	0.00	5.4
ENE	0.58	2.92	0.08	0.00	0.00	3.6
E	0.58	2.41	0.03	0.00	0.00	3.0
ESE	0.58	2.61	0.02	0.00	0.00	3.2
SE	0.58	2.00	0.00	0.00	0.00	2.6
SSE	0.58	1.65	0.00	0.03	0.00	2.3
S	0.58	4.95	0.81	0.29	0.11	6.7
SSW	0.58	5.96	1.89	0.90	0.23	9.6
SW	0.58	7.71	7.72	3.51	0.65	20.2
WSW	0.58	8.44	5.48	0.97	0.16	15.6
W	0.58	5.43	6.52	0.96	0.05	13.5
WNW	0.58	1.86	0.74	0.26	0.00	3.4
NW	0.58	1.31	0.09	0.02	0.00	2.0
NNW	0.58	1.26	0.14	0.03	0.03	2.0
N	0.58	0.76	0.23	0.14	0.27	2.0
Total	**9.3**	**54.2**	**27.2**	**7.7**	**1.6**	**100**

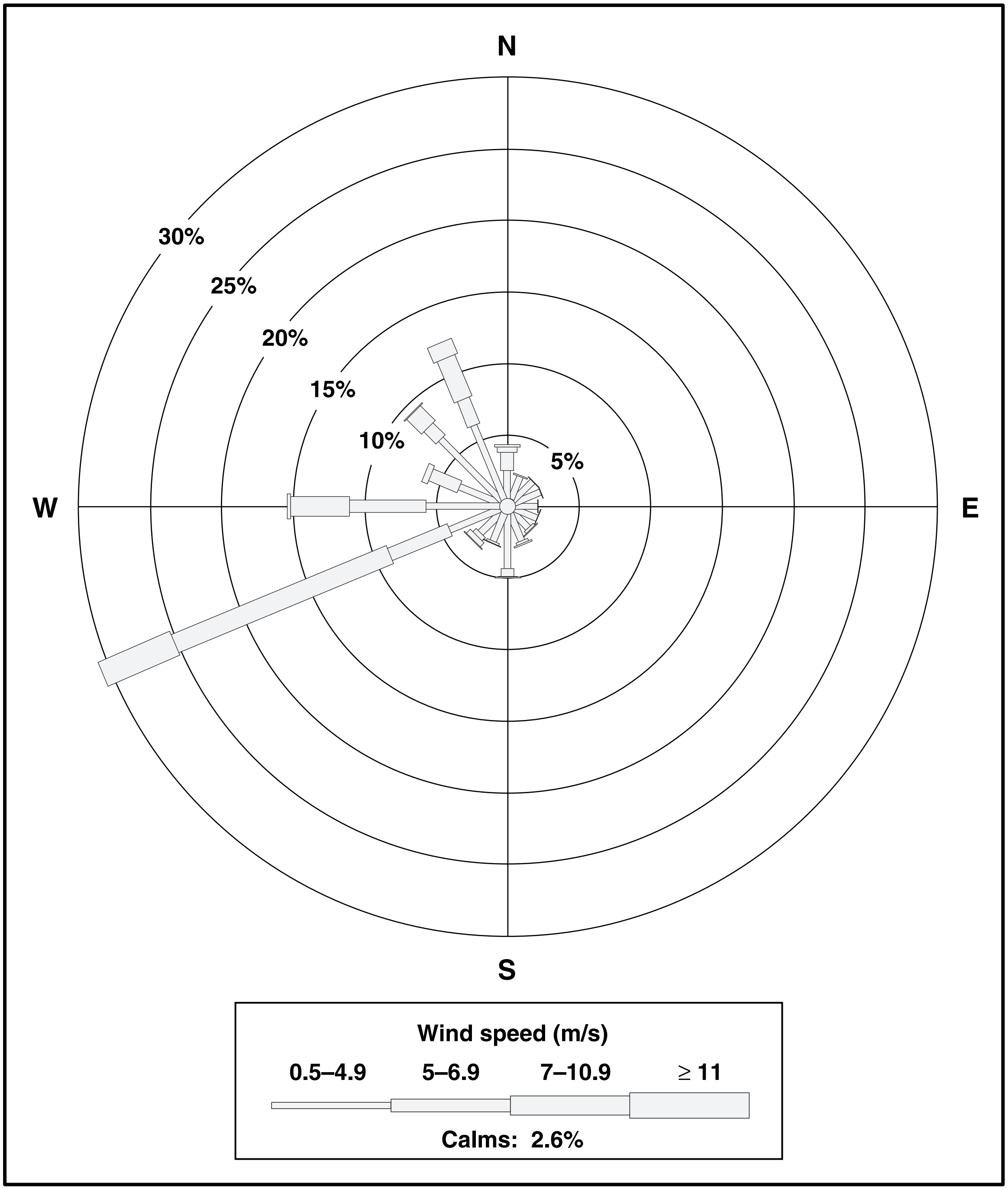

Figure 1-3. Wind rose showing the frequency of occurrence for wind speed and direction at Site 300, 1999.

Table 1-2. Wind rose data for LLNL's Site 300 at the 10-m level for 1999. Values are frequency of occurrence (in percent). Columns and rows may not exactly sum to the listed totals because of rounding.

Direction	Wind speed range (m/s)					
	0.0–0.4	**0.5–4.9**	**5.0–6.9**	**7.0–10.9**	**≥11.0**	**Total**
NNE	0.16	1.69	0.05	0.00	0.00	1.9
NE	0.16	1.91	0.03	0.00	0.00	2.1
ENE	0.16	1.91	0.00	0.00	0.00	2.1
E	0.16	1.53	0.05	0.00	0.00	1.7
ESE	0.16	1.62	0.03	0.03	0.00	1.8
SE	0.16	1.50	0.19	0.07	0.00	1.9
SSE	0.16	2.04	0.17	0.10	0.00	2.5
S	0.16	3.77	0.56	0.06	0.00	4.6
SSW	0.16	2.06	0.16	0.03	0.00	2.4
SW	0.16	2.09	0.33	0.38	0.05	3.0
WSW	0.16	3.78	4.56	16.2	5.46	30.2
W	0.16	5.20	5.33	4.09	0.25	15.0
WNW	0.16	4.04	1.21	0.45	0.00	5.9
NW	0.16	6.08	1.20	1.46	0.06	9.0
NNW	0.16	5.65	2.56	2.47	1.12	12.0
N	0.16	1.94	1.29	0.37	0.17	3.9
Total	**2.6**	**46.8**	**17.7**	**25.8**	**7.1**	**100**

The topography of Site 300 is much more irregular than that of the Livermore site; a series of steep hills and ridges is oriented along a generally northwest-southeast trend and is separated by intervening ravines. The Altamont Hills, where Site 300 is located, are part of the California Coast Range Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. The elevation ranges from approximately 538 m above sea level at the northwestern corner of the site to approximately 150 m in the southeast portion.

Hydrogeology

Livermore Site

The hydrogeology and movement of ground water in the vicinity of the Livermore site have been the subjects of several investigations (Stone and Ruggieri 1983; Carpenter et al. 1984; Webster-Scholten and Hall 1988; and Thorpe et al. 1990). This section has been summarized from the reports of these investigations and from data supplied by Alameda County Flood Control and Water Conservation District Zone 7, the agency responsible for ground water management in the Livermore Valley basin (San Francisco Bay Regional Water Quality Control Board 1982a and b).

The Livermore Formation (and overlying alluvial deposits) contains the aquifers of the Livermore Valley ground water basin, an important water-bearing formation. Natural recharge occurs primarily along the fringes of the basin and through the arroyos during periods of winter flow. Artificial recharge, if needed to maintain ground water levels, is accomplished by releasing water from Lake Del Valle or from the South Bay Aqueduct into arroyo channels in the east. Ground water flow in the valley generally moves toward the central east-west axis of the valley and then westward through the central basin. Ground water flow in the basin is primarily horizontal, although a significant vertical component probably exists in fringe areas, under localized sources of recharge, and in the vicinity of heavily used extraction (production) wells.

Beneath the Livermore site, the water table varies in depth from the surface from about 10 to 40 m. **Figure 1-4** shows a contour map of water table elevations (meters above mean sea level) for the Livermore site area. Although water table elevations vary slightly with seasonal and year-to-year differences in both natural and artificial recharge, the qualitative patterns shown in **Figure 1-4** are generally maintained. At the eastern edge of the Livermore site, ground water gradients (change in vertical elevation per unit of horizontal distance) are relatively steep, but under most of the site and farther to the west, the contours flatten to a gradient of approximately 0.003.

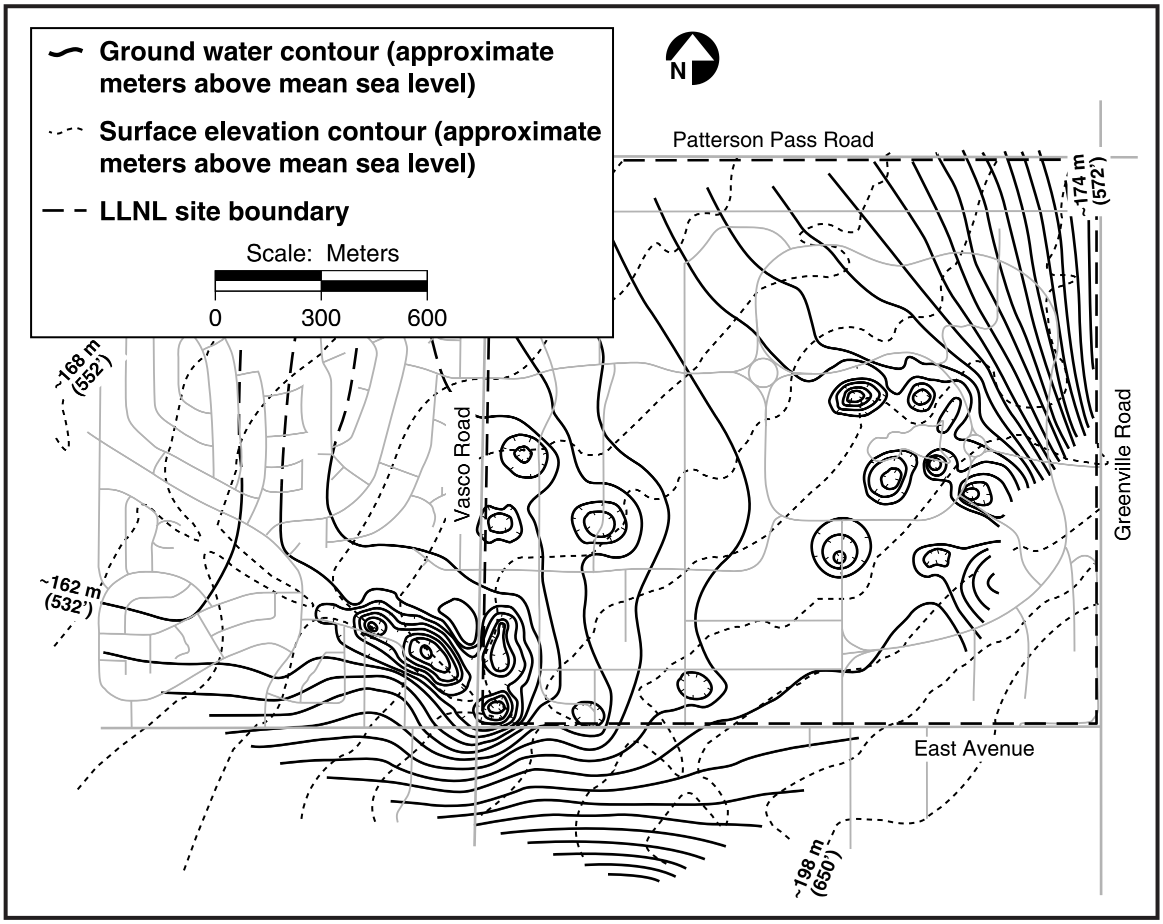

Figure 1-4. 1999 approximate ground water and surface elevation contours, Livermore site and vicinity.

Ground water flow under most of the site is southwesterly. This flow direction diverges from the generally westward regional flow and from flow patterns demonstrated for the site in the 1980s. This shift in flow direction is a consequence of ground water recovery and remediation in the southwest portion of the site and agricultural pumping. Aquifer tests on monitoring wells in the vicinity of the Livermore site indicate that the hydraulic conductivity (a measure of the rate of flow) of the permeable sediments ranges from 1 to 16 m/day (Isherwood et al. 1991). This, in combination with the observed water table gradients, yields an estimated average ground water velocity of 20 m/y (Thorpe et al. 1990). The range in these values reflects the heterogeneity typical of the more permeable alluvial sediments that underlie the area.

Site 300

Gently dipping sedimentary bedrock dissected by steep ravines generally underlies Site 300. The bedrock is made up primarily of interbedded sandstone, siltstone, and claystone. Most ground water occurs in the Neroly Formation upper and lower blue sandstone aquifers. Significant ground water is also locally present in permeable Quaternary alluvium valley fill. Much less ground water is present within perched aquifers in the unnamed Pliocene nonmarine unit. Perched aquifers contain unconfined water separated from an underlying main body of water by impermeable layers; normally they are discontinuous and highly localized. Because water quality generally is poor and yields are low, these perched water-bearing zones do not meet the State of California criteria for aquifers that are potential water supplies.

Fine-grained siltstone and claystone interbeds may confine the ground water and act as aquitards, confining layers, or perching horizons. Ground water is present under confined conditions in parts of the deeper bedrock aquifers but is generally unconfined elsewhere.

Ground water flow in most aquifers follows the attitude of the bedrock. In the northwest part of Site 300, ground water in bedrock generally flows northeast except where it is locally influenced by the geometry of alluvium-filled ravines. In the southern half of Site 300, ground water in bedrock flows roughly south-southeast, approximately coincident with the attitude of bedrock strata.

The thick Neroly lower blue sandstone, stratigraphically near the base of the formation, generally contains confined water. Wells located in the western part of the General Services Area (GSA) (see **Figure 8-8**) are completed in this aquifer and are used to supply drinking and process water.

Figure 1-5 shows the elevation contours for ground water in the regional aquifer at Site 300. This map of the piezometric surface (the elevation at which water stabilizes in a well that penetrates a confined or unconfined aquifer) is based primarily on water levels in the Neroly lower blue sandstone aquifer.

Recharge occurs predominantly in locations where saturated alluvial valley fill is in contact with underlying permeable bedrock or where permeable bedrock strata crop out because of structure or topography. Local recharge also occurs on hilltops, creating some perched water-bearing zones. Low rainfall, high evapotranspiration, steep topography, and intervening aquitards generally preclude direct vertical recharge of the bedrock aquifers.

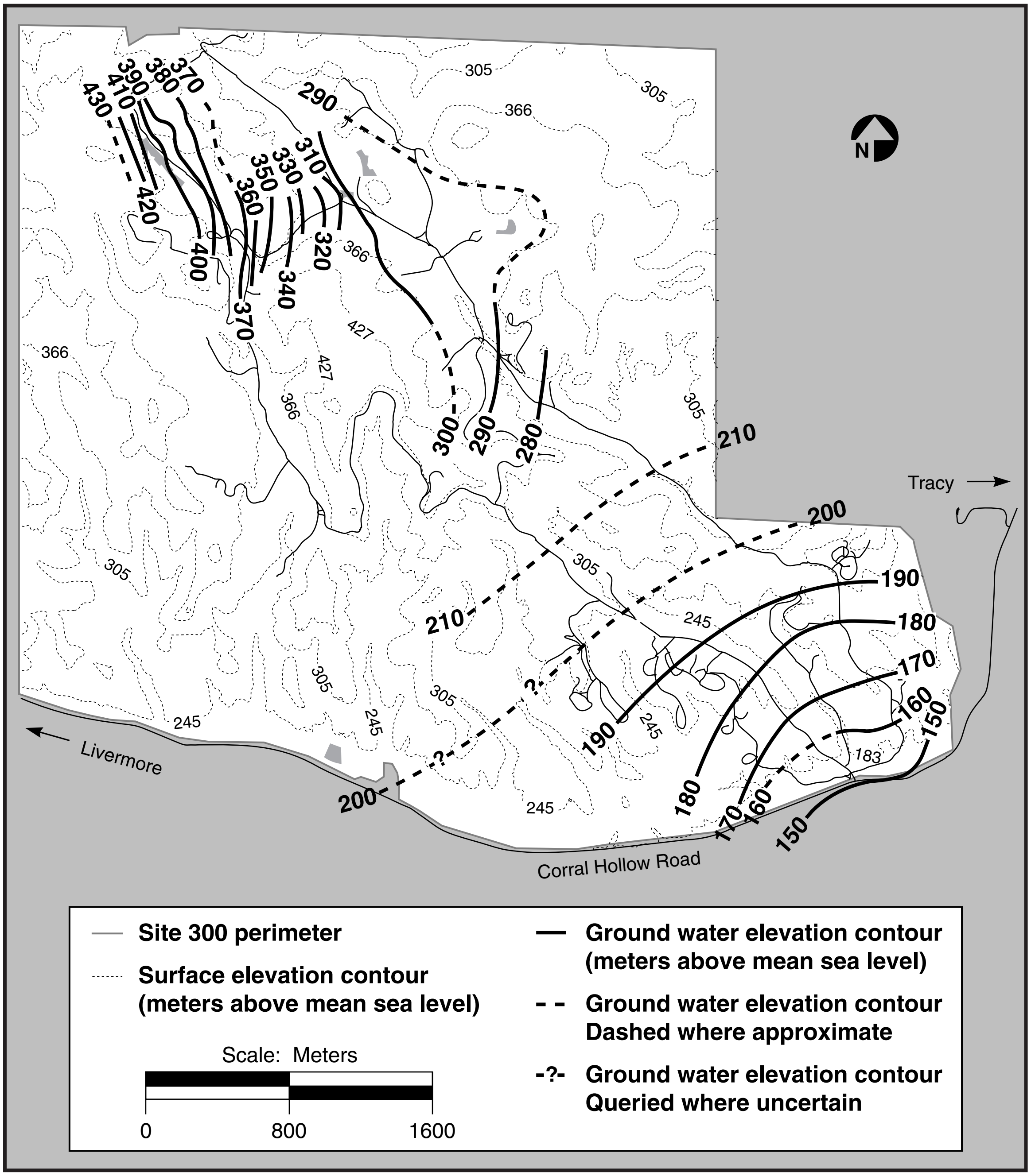

Figure 1-5. 1999 approximate ground water elevations in the principal continuous water-bearing zone at Site 300.

Further information on the hydrology of both the Livermore site and Site 300 can be found in the ground water protection information in Chapters 8 and 9.

Summary

LLNL recognizes the importance of our geology, hydrogeology, climate, and geographical relationships with our neighbors in assessing potential impacts of operations at the Livermore site and Site 300. Each year we gain additional information that allows us to better predict, interpret, and avoid potential impacts. Each environmental medium that is discussed in this document—air, soil, water, vegetation, and foodstuff—may be affected differently. The environmental scientists at LLNL take into account the unique locations of the Livermore site and Site 300 to tailor sampling and analysis programs for each method used to monitor the environment.

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