1. Introduction

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Lawrence Livermore National Laboratory (LLNL) is a premier research laboratory that is part of the National Nuclear Security Administration (NNSA) within the U.S. Department of Energy (DOE). LLNL is managed and operated by Lawrence Livermore National Security, LLC (LLNS); the LLNS management team includes Bechtel National, University of California, BWX Technologies, and Amentum. LLNS manages LLNL under NNSA Contract Number DE-AC52-07NA27344.

As a national security laboratory, LLNL is responsible for ensuring that the nation's nuclear weapons remain safe, secure, and reliable. The Laboratory also meets other pressing national security needs, including countering the proliferation of weapons of mass destruction and strengthening homeland security and conducting major research in atmospheric, earth, and energy sciences, bioscience and biotechnology, and engineering, basic science, and advanced technology. The Laboratory staff of approximately 8,500 serve as a scientific resource to the U.S. government and a partner to industry and academia.

1.1 Location

LLNL consists of two sites – an urban site in Livermore, California, referred to as the "Livermore Site," and a rural test site near Tracy, California, referred to as "Site 300". See **Figure 1-1.**

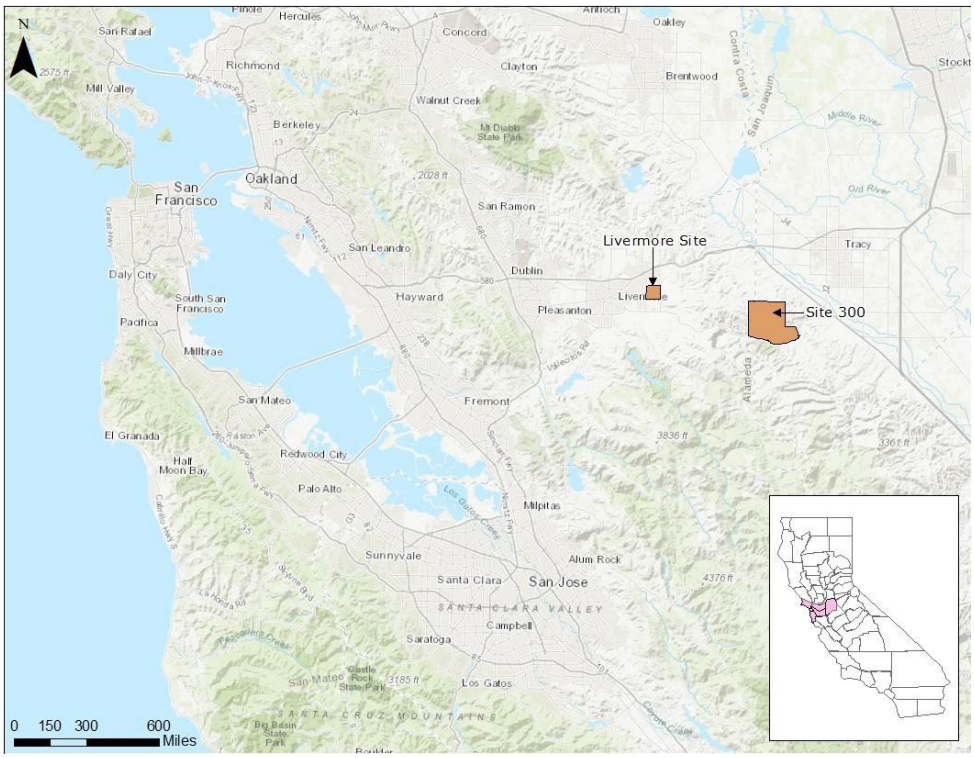

Figure 1-1. Locations of the two LLNL Sites – the Livermore Site and Site 300

The Livermore Site, LLNL's general research site, is within the eastern limits of Livermore, a city with a population of about 90,000 in Alameda County.

The Livermore Site occupies 1.3 mi^2, including the land that serves as a buffer zone along its north and west perimeters.

Within a 50-mi radius of the Livermore Site are cities such as Tracy and Pleasanton and the more distant (and more densely populated) cities of Oakland, San Jose, and San Francisco. Of the 8.6 million people within 50 mi of the Laboratory, only about 13% are within 20 mi.[1]

Site 300, LLNL's Experimental Test Site, is in the Altamont Hills of the Diablo Range in Central California and straddles the San Joaquin and Alameda County line. The site is 12 mi east of the Livermore Site and occupies 10.9 mi^2.

The city of Tracy, with a population of about 85,000, is approximately 6 mi to the northeast of Site 300 (measured from the northeastern border of Site 300 to Sutter Tracy Community Hospital). Of the 8.3 million people who live within 50 mi of Site 300, 93% are more than 20 mi away in large metropolitan areas, which include Oakland, San Jose, and Stockton.[1]

1.2 Meteorology

The climate at both sites is characterized by mild, rainy winters and warm-to-hot, dry summers with strong seasonal wind and rainfall patterns. Wind patterns at both sites 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 during the warm season, increasing in intensity as the valley heats up. During the winter, the wind blows from the northeast more frequently as cold, dense air spills out of the San Joaquin Valley. The meteorological conditions at Site 300 are also strongly influenced by higher elevation and more pronounced topological relief. Approximately 55% of the rain at both sites falls in January, February, and March and approximately 80% falls in the five months from November through March, with very little rain falling during the warmer months. For a detailed review of rainfall at LLNL, see Bowen (2007). For a detailed review of the climatology at LLNL, see Gouveia and Chapman (1989).

Meteorological towers at both the Livermore Site and Site 300 continuously gather data including wind speed, wind direction, rainfall, humidity, solar radiation, and air temperature. Temperature, rainfall, and wind speed data from the Livermore Site and Site 300 towers during 2022 are summarized in **Table 1-1.** Annual wind data for the Livermore Site and Site 300 are shown in **Figure 1-2.**

[1] The population numbers were derived in using Oak Ridge National Laboratory LandScan data and ESRI ArcMAP software. See Wilson et al. (2023), Appendix C, for population file. The population numbers will be updated in the 2023 ASER.

Table 1-1. Summary of Temperature, Rainfall, and Wind Speed Data at the Livermore Site and Site 300 in 2022

	Livermore Site		Site 300	
Temperature	**°C**	**°F**	**°C**	**°F**
Mean daily maximum	23.0	73.4	22.2	71.9
Mean daily minimum	7.7	45.9	13.2	55.7
Average	14.7	58.5	17.3	63.2
High	44.1	111	41.6	107
Low	-3.9	25.0	0.5	32.8
Rainfall	**cm**	**in**	**cm**	**in**
Total	30.7	12.1	22.8[(c)]	9.0[(c)]
Climatological normal [(a)]	32.4[(b)]	12.8[(b)]	26.5[(b)]	10.4[(b)]
Wind	**m/s**	**mph**	**m/s**	**mph**
Average speed	2.1	4.8	5.8	13.1
Peak gust speed	20.9	46.8	40.2	90.0

(a) Climatological normal is based on a 30-year period (1991–2020).

(b) 1991–2020 (Mean re-calculated every 10 years).

(c) The Site 300 rain gauge failed on December 10 – December 28 and December 31. Rainfall for these days was estimated using Quantitative Precipitation Estimates from the National Weather Service (https://water.weather.gov/precip/index.php). Estimated rainfall is 4.61 inches (11.7 cm) for these days.

1.3 Topography

The Livermore Site is located in the southeastern portion of the Livermore Valley, a prominent topographic and structural depression, oriented east–west within the Diablo Range. The most prominent valley in the Diablo Range, the Livermore Valley, is bound on the west by the Pleasanton Ridge and on the east by the Altamont Hills. The valley is approximately 14 mi long and varies in width generally between 2.5 and 7 mi. The highest elevation of the valley floor is 720 ft above sea level along its eastern margin near the Altamont Hills; it descends gradually to 300 ft at the southwestern corner. The valley floor is covered primarily by alluvial and floodplain deposits consisting of gravels, sands, silts, and clays with an average thickness of about 325 ft. Ephemeral waterways flowing through the Livermore Site include Arroyo Seco along the southwestern corner and Arroyo Las Positas along the eastern and northern perimeters.

Site 300 consists of a series of steep hills and ridges separated by intervening ravines oriented in a generally northwest–southeast direction. 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 of Site 300 ranges from about 1,740 ft above sea level at the northwestern corner of the site to approximately 490 ft in the southeastern portion. Corral Hollow Creek, an ephemeral stream that drains toward the San Joaquin River Basin, runs along the southern and eastern boundaries of Site 300.

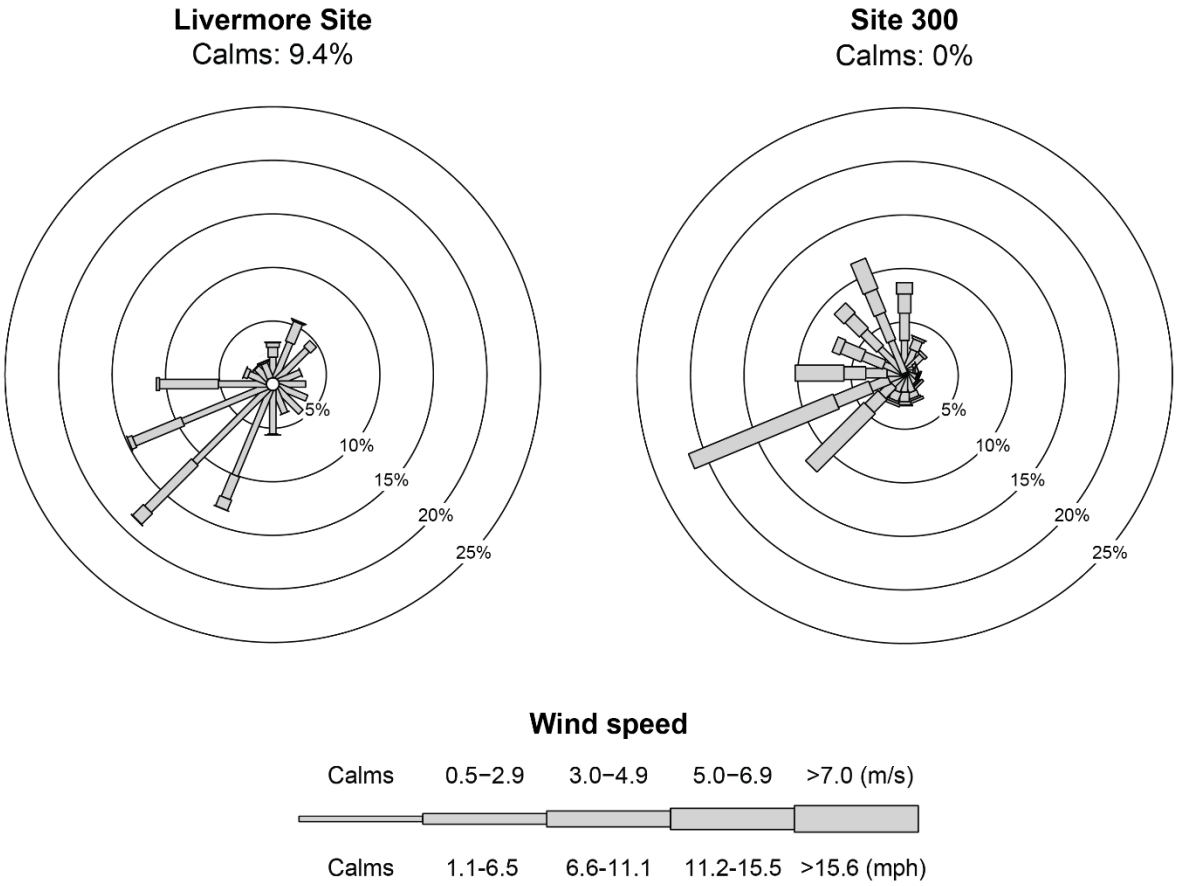

Figure 1-2. Wind Roses Showing Wind Direction and Wind Speed Frequencies at the Livermore Site and Site 300 in 2022

Note: The length of each spoke is proportional to the frequency at which the wind blows from the indicated direction. Different line widths of each spoke represent wind speed classes.

1.4 Hydrogeology

Geologically the Livermore Formation and overlying alluvial deposits contain the primary aquifers of the Livermore Valley groundwater basin. Natural recharge occurs primarily along the basin margins and arroyos during wet winters. In general, groundwater flows toward the central east–west axis of the valley and then westward through the central basin. Groundwater flow in the basin is primarily horizontal, although a significant vertical component probably exists along the basin margins under localized sources of recharge and near heavily used extraction or water production wells. Beneath the Livermore Site, the depth to the water table varies from about 35 to 125 ft below the ground surface. See Thorpe et al. (1990) for a detailed discussion of Livermore Site hydrogeology.

Site 300 is generally underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock primarily consists of interbedded sandstone, siltstone, and claystone. Groundwater occurs principally in the Neroly Formation upper and lower blue sandstone units and in the underlying Cierbo Formation. Significant groundwater is also locally present in permeable

Quaternary alluvium valley fill and underlying decomposed bedrock, especially during wet winters. Minor quantities of groundwater are present within perched aquifers in the unnamed Pliocene nonmarine unit. Perched aquifers contain unconfined groundwater separated from an underlying main body of groundwater by impermeable layers; normally these perched zones are laterally discontinuous. Recharge occurs predominantly in locations where saturated alluvial valley fill is in contact with underlying permeable bedrock or where permeable bedrock strata crop out along the canyon bottom because of structure or topography. The thick Neroly Formation lower blue sandstone unit, stratigraphically near the base of the formation, generally contains unconfined groundwater. Wells located in the southern part of Site 300 that historically pumped water from this aquifer for on-site drinking and process supply are available for backup purposes. In this area in southern Site 300, the Neroly Formation lower blue sandstone is confined. See Webster-Scholten et al. (1994) and Ferry et al. (2006) for a detailed discussion of Site 300 hydrogeology.

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