APPENDIX H

Geology and Soils Data

EXISTING SETTING
Geologic Hazards

1.0 Introduction

The compilation of data related to geologic hazards in the EIR Study Area utilized a wide variety of resources. Numerous published maps and texts from the California Geological Survey and the United States Geological Survey, along with other publicly available materials, were reviewed for relevant information on the general setting of the site. These materials were particularly helpful in developing the regional setting of geologic and seismic factors influencing the hazards. Within the EIR Study Area, the primary tool utilized was the geotechnical-report database provided by the University. This data was supplemented by further materials supplied by the University, along with some additional published materials. All of the resources utilized are listed in the references at the end of this document.

2.0 Regional Setting

2.1 Regional Geology

The EIR Study Site is located on the western slope of the Berkeley Hills and the flatlands adjacent to these hills. It is situated east of San Francisco Bay, within the northern portion of the Coast Ranges geomorphic province of California. The region is characterized by northwest-trending mountain ranges and valleys that generally parallel the major geologic structures, such as the San Andreas and Hayward faults. The oldest widespread rocks in the region are highly deformed sedimentary and volcanic rocks of the Franciscan Assemblage, formed during the Mesozoic Age (the period from 225 million to 65 million years before present). These rocks are in fault contact with similar-age sedimentary rocks of the Mesozoic–Age Great Valley Sequence. The Mesozoic rocks are, in turn, overlain by a diverse sequence of sedimentary and volcanic rocks from the Tertiary Age (the period from 65 million to 1.8 million years before present). Alluvial materials, derived from these bedrock units, have been conveyed by streams draining the East Bay Hills and deposited in a broad alluvial plain. Since the deposition of the bedrock units, the Mesozoic and Tertiary rocks have been extensively deformed by repeated episodes of folding and faulting. In general, upland areas such as the Berkeley Hills have experienced some tectonic uplift over time, while the adjacent alluvial plains and lowlands have experienced some subsidence.

2.1.1 Regional Faulting

Seismic activity within the Coast Ranges is generally associated with active faults of the San Andreas system, which includes major active faults both east and west of the EIR Study Site. Over the width of the San Francisco Bay Region, approximately 1.5 inches/year of relative horizontal movement occurs between the North American and Pacific Plates (WGCEP, 2003, 2008, 2015). This movement is partially accommodated by earthquakes and creep occurring along several active faults. Locations of these active faults relative to the study site are shown on the San Francisco Bay Area Fault Map, Figure 1.

The approximate distances and directions to major, active Bay Area faults are indicated in the following table (Jennings and Bryant, 2010), while the other relevant data is generally taken from The United States Geological Survey's Working Group on California Earthquake Probabilities – WGCEP (Aagaard, et al., 2016). It should be noted that recent studies have indicated the Hayward fault connects with the Rodgers Creek fault below San Pablo Bay (Watt et al, 2016); this has resulted in the maximum magnitude of the combined Hayward–Rodgers Creek fault system being increased over the magnitudes previously attributed to the faults individually.

Table 1. Approximate Active-Fault Distances and Directions

Fault	Distance and Direction from Site	Rupture Length (Miles)	Maximum Magnitude	Slip Rate (Inches)
Hayward–Rodgers Creek (total length)	Through EIR Study Site	93	7.4	0.4
Calaveras (north of Calaveras Reservoir)	11.3 miles southeast	76	6.8	0.8
Concord–Green Valley	13.7 miles northeast	58	6.9	0.2
Greenville	18.1 miles northeast	36	6.9	0.2
San Andreas (1906 rupture)	18.8 miles southwest	293	7.9	0.9
West Napa	20.7 miles north	32	6.5	0.2
San Gregorio	23.5 miles southwest	109	7.3	0.3
Maacama	88 miles northwest	182	7.4	0.4

2.1.2 Historic Seismicity

The San Francisco Bay Region has experienced several large earthquakes during historical time. A summary of the more significant earthquakes in the region is given below.

2.1.3 The Hayward Earthquake of October 21, 1868

On October 21, 1868, an earthquake of about **M** 6.8 occurred on the southern segment of the Hayward fault, causing significant damage throughout the region. Surface ground rupture occurred over a length of approximately 30 miles. The northern limit of ground rupture was in the vicinity of Mills College. The epicenter of the 1868 earthquake was located in the Castro Valley area (Goter,1988).

2.1.4 The 1858 and 1911 Earthquakes

Two other earthquakes greater than **M** 6 are thought to have occurred on the Hayward fault (Steinbrugge et al., 1987). These occurred in 1858 (**M** 6.1) and 1911 (**M** 6.6). Both of these earthquakes were centered in or near the southern portion of the Hayward fault.

2.1.5 The San Francisco Earthquake of April 18, 1906

The largest historical earthquake in the region was the great San Francisco earthquake of April 18, 1906 (**M** 7.9), which occurred on the San Andreas fault near San Francisco. This earthquake caused strong-to-violent ground-shaking throughout much of west central California and caused widespread damage, including some damages in Berkeley.

2.1.6 The Loma Prieta Earthquake of October 17, 1989

On October 17, 1989, the **M-**7.1 Loma Prieta earthquake occurred near the San Andreas fault in the Santa Cruz Mountains. The earthquake resulted in 63 deaths and approximately $6 billion in damage over a wide area (McNutt and Sydnor, 1990). Moderate ground-shaking was felt in the Berkeley area (McNutt and Toppozada, 1990).

2.1.7 The Napa Earthquake Of August 24, 2014

A **M** 6.0 earthquake occurred on the morning of August 24, 2014, near the City of Napa. Although the earthquake was felt widely throughout the region, no fatalities occurred. Damage in the City of Napa was estimated at $36 million. Ground-shaking in the Berkeley area was relatively light.

2.2 Future Earthquake Probabilities

WGCEP has evaluated the probabilities of significant earthquakes occurring in the Bay Area over the next 30 years. The WGCEP report indicates that there is a 72-percent probability that at least one magnitude-6.7-or-greater earthquake will occur in the San Francisco Bay region before 2043. This probability is an aggregate value that considers seven principal Bay Area fault systems and unknown faults (background values). The findings of the WGCEP reports are summarized in Table 2.

Table 2. WGCEP (2016) Probabilities

Fault System	Probability of at Least One Magnitude-6.7-or-Larger Earthquake by 2043
Hayward–Rodgers Creek	33%
San Andreas	22%
Calaveras–Paicines	26%
San Gregorio	6%
Concord–Green Valley–Greenville	16%
Background	13%

The published background value indicates that between 2014 and 2043, there is a 13-percent chance that an earthquake with a magnitude of greater than 6.7 may occur in the Bay Area on a fault system not characterized in the study.

3.0 Site-Specific Data

3.1 Database

The primary tool utilized to develop site-specific information regarding the existing conditions within the boundaries of the EIR Study Site was the database of geotechnical information supplied to us by the University. The database listed 432 records regarding projects for the University, but only 248 of the records contained a pdf of the project report with detailed information. To review representative information, the records with a pdf report were placed into zones, using the five zones shown on the EIR Study Area. The City Environs Properties area was further divided into sub-areas for properties north, west, and south of the Campus Park (plus the one property at 1608 4th Street, although no pdf records were received for that site). Apparently, the geotechnical investigation reports for Housing Sites 1 and 2 are not yet available, so any new data from those sites was not included in the data entry.

A new spreadsheet was created using the representative database records with pdf report data for each of the zones utilized. If there were a series of reports for one project, only the final report was examined. Where there were reports scattered across the zone, a representative distribution of reports were incorporated. Reports for roadways (such as Centennial Drive) were not included. The reviewed reports were particularly useful in relation to describing the soils present, the bedrock depths, the groundwater depths, and the existing building-foundation types in the study site. The number of pdf reports included for each zone (and sub-area) is presented on Table 3 below.

Table 3 – Number of pdf Reports on Spreadsheet for Each Zone

Zone	Number of pdf Reports on Project Spreadsheet
Campus Park	56
Clark Kerr Campus	2
Hill Campus West	11
Hill Campus East	3
City Environs – North	2
City Environs –West (Includes Housing Site #1)	5
City Environs – South (Includes Housing Site #2)	9

3.2 Topography

The topography within the EIR Study Site generally consists of gentle, southwesterly descending slopes, with the exception of the Hill Campus East. The Campus Park varies in elevation from about 400 feet above Mean Sea Level (El 400) in the northeast corner to about El 210 feet in the southwest corner, with inclinations steepening in the northeast quadrant. The slopes are fairly uniform, except where Strawberry Creek flows westerly through the center of the campus. The City Environs Properties have similar slopes to the Campus Park, with the elevations of Housing Sites 1 and 2 being about El 200 and El 275 feet, respectively. 1608 4th Street is on an even more gently sloping area and is at an elevation of about El 20 feet. The Smyth–Fernwald Complex is the steepest of the City Environs Properties, with an elevation change from about El 650 feet in the highest area to about El 470 feet in the southwest corner; this relief of about 180 feet occurs over a distance of approximately 700 feet.

The developed portion of the Clark Kerr Campus is similar to the Campus Park topography, with gentle, southwesterly descending slopes that steepen in the northeast corner. These portions of the Clark Kerr Campus generally vary from about El 515 feet opposite the Smyth–Fernwald Complex to about El 390 feet in the southwest corner. The undeveloped canyon on the eastern boundary of this campus steepens considerably and has inclinations of about 2.5:1 (horizontal to vertical).

The Hill Campus East area typically consists of a series of southwest-trending, secondary ridges separated by intervening drainage swales. The two most prominent canyons are Strawberry Canyon, through the center of the area, and Claremont Canyon, near the southern boundary. The highest points within this area are along Grizzly Peak Boulevard, with elevations ranging between about El 1500 and El 1700 feet. The lowest portion of the area is by the entry gate to Lawrence Berkeley National Laboratory, with an elevation of about El 560 feet. The slopes typically have inclinations between about 2:1 and 3:1.

3.3 Geology

The geologic units present in the EIR Study Area are complex, so reference is made to the attached Geologic Map (Figure 2) to guide the reader through the following discussion. As noted earlier under Regional Geology, the hillside areas contain various sedimentary and volcanic bedrock units at the ground surface or at a shallow depth, while the areas downslope are within a broad alluvial plain. As seen on the Geologic Map, the Hill Campus East is located entirely within the bedrock area, while all of the other sectors of the Study Area have a mixture of bedrock units (toward the northeast) and alluvial units (toward the southwest).

Commonly in geologic discussions, the units are described from oldest to youngest; that framework will be used to provide information regarding the bedrock units. Materials belonging to the Franciscan Assemblage (KJfs and KJfm symbols on Figure 2) are present in the northeast corner of the Campus Park and adjacent areas. These materials were formed below an ocean where the Pacific Ocean is now present and a broad mixture of materials that were mixed together in a complex arrangement. Materials that were on the western crust of the Pacific Plate moved easterly and were subducted below the Great Valley Complex described below. KJfs material consists of sandstone, while KJfm is a mélange (or mixture) of about 14 bedrock types, sometimes in large blocks. These units were generally hard and competent where encountered in exploratory borings.

Slightly younger in age than the Franciscan Assemblage are the materials that belong to the Great Valley Complex; this Complex is divided into the Coast Range Ophiolite and the underlying Great Valley Sequence. With respect to the Coast Range Ophiolite, a small sliver of sc (silica-cabonate rock) is present by the northeast corner of Campus Park. This is a very hard bedrock, sometimes present in outcrops at the ground surface (such as Founder's Rock). Below the upper portions of the Smyth–Fernwald Complex and the Clark Kerr Campus, an elongate deposit of Jsv (keratophyre and quartz keratophyre) is present. This bedrock unit is also quite hard and present at a very shallow depth below the existing ground surface. The only unit belonging to the Great Valley Sequence present within the study site is Ku; this is a mixture of sandstone, siltstone, and mudstone. It is present below much of the Hill Campus West, as well as the lower portion of the Hill Campus East. Borings drilled in this material have encountered deep weathering and highly variable strengths.

The upper portion of the Hill Campus East is underlain by four different Tertiary–Age deposits: Tmb, Tor, Tcc, and Tsm. The limits of each material and the relationship to other units are complex, as seen on the Geologic Map. Tmb (Moraga Formation) is primarily basalt and andesite volcanic flow material, with some rhyolite tuff. Tor (Orinda Formation) is a non-marine, sedimentary deposit of conglomerate, sandstone, siltstone, and mudstone. Tcc (Claremont Chert) consists of chert, with small amounts of shale and sandstone. Tsm is an unnamed mudstone. Very few borings have been drilled in these materials, so site-specific data is not available; but published data and local experience indicate Tmb and Tcc are very competent, while Tor and Tsm are quite variable.

A broad alluvial plain is present southwest of the bedrock areas, and the three types of alluvium shown on the Geologic Map (Qhaf, Qhl, and Qpaf) within the study area are very similar, from an engineering standpoint. The depth of the alluvial materials over the bedrock becomes thicker in a southwesterly direction, and borings near the southwest corner of the Campus Park encountered bedrock at a depth of about 50 feet below the current ground surface. The building at 1608 4th Street is located in an area of fill material placed over the alluvium. Since no data is available for that structure, the thickness of the fill material could not be established.

3.4 Soils

The predominant soil type at the ground surface across all of the study site areas was silty clay, often sandy and sometimes gravelly. Laboratory testing of soil samples from borings for geotechnical investigations indicated the clay was generally stiff to hard. When the clay soils were at the ground surface and dried in the sun, they became very hard. The expansive characteristics of the soil materials were often evaluated in testing laboratories using swell tests, expansion index tests, and Atterberg Limits testing. These tests indicated the expansion potential of the clay soils varied from low to critically high.

Below the surface clay soils, layers of a wide variety of other soils were present. These soils included additional clays, silts, sands, and gravels, often in mixtures of soils due to the alluvial origin of most of these materials. The thickness of these soil layers varied widely and extended to the underlying bedrock.

3.5 Groundwater

The depth at which groundwater was encountered in borings provided in the geotechnical-report database indicated significant variability. In some cases, no groundwater was encountered within a boring if the boring was terminated before groundwater was reached, and in other cases, the drilling method precluded obtaining groundwater depths due to the placement of water into the boring. In most cases, the groundwater depth was provided from data at the time the boring was drilled and then backfilled; thus, the equilibrium level of groundwater may not have been established, and the groundwater may also vary with seasonal changes. Nonetheless, the depths can be useful, and typical depths are listed in the table below.

Table 4 – Groundwater Depths

Zone	Typical Depth to Groundwater (Feet)
Campus Park	5–35
Clark Kerr Campus	8–10
Hill Campus West	15–50
Hill Campus East	10–15
City Environs – North	10–20
City Environs – West (Includes Housing Site #1)	10–20
City Environs – South (Includes Housing Site #2)	10–25

3.6 Fault Rupture

As shown on the Geologic Map, the active Hayward fault passes through each of the broad areas being considered in this study. Faults are considered to be active when they exhibit one or more of the following:

- Evidence of Holocene–Age displacement (within about the past 11,000 years);
- Measurable tectonic creep along fault lines; and/or
- Close proximity to linear concentrations or trends of earthquake epicenters.

As described below, the Hayward fault possesses each of these characteristics.

During historical times, well-documented surface creep has occurred along the Hayward fault at average rates ranging from about 0.2 to 0.4 inches per year (Lienkaemper et al., 1991). However, variability in creep rates—both spatially along the fault trace and temporally—are present along the fault. As a result of the fault activity, an Earthquake Fault Zone (formerly called an Alquist–Priolo Special Study Zone) has been created along the fault, including through the study area. Studies for the Memorial Stadium retrofit project concluded that fault rupture might be about 3 to 4 feet horizontally and 0.5 to 1 foot vertically for an earthquake with a 10% probability of exceedance in 50 years (Maffei et al, 2009; Vignos et al, 2009). More recently, a characterization of the southern portion of the Hayward fault estimated a surface rupture of 2.7 to 5.5 feet for an earthquake with a 10% probability of exceedance in 50 years (Wells and Kulkarni, 2014). Applying probable increases for the northern section of the Hayward fault (compared to the southern section) and for the magnitude increase from the connection to the Rodgers Creek fault, it is believed these rupture magnitudes might be increased by approximately 50%.

The total length of the Hayward–Rodgers Creek fault system is nearly 100 miles, as seen in the San Francisco Bay Area Fault Map. Table 3 indicates the Hayward–Rodgers Creek fault has a 33% probability of causing a magnitude-6.7-or-greater earthquake by 2043—the highest probability of any Bay Area fault. The location of the Hayward fault as it passes through the study area is illustrated on Figure 5, Hayward Fault Close-Up. Given the likelihood of occurrence and potential rupture magnitude, the hazard associated with surface rupture on this fault is one of the three most serious geologic hazards that exist in the study area (the other serious geologic hazards are earthquake ground shaking and landsliding in the Hill Campus East).

Although the University is exempt from the State Earthquake Fault Zone requirements concerning fault-evaluation studies, the University has routinely conducted fault-assessment evaluations in the vicinity of the fault; more than a dozen fault-study reports were present in the database of reports provided by the University. A figure illustrating plates from two recent fault-evaluation studies are presented on Figure 6, Hayward Fault Study Examples.

3.7 Earthquake Ground Shaking

During large earthquakes, strong ground shaking will be produced. The magnitude of shaking is generally a function of the size and type of the earthquake, the distance of the site from the earthquake epicenter, and the geologic materials that are present at the site. Historically, ground motions in earthquake studies were calculated for the maximum event on a specific fault; this was termed a deterministic analyses. However, because of the large number of variables that influence the level of ground shaking, a more common current practice is to estimate the earthquake shaking in terms of the probability that it will be exceeded annually (the annual exceedance probability) or the time period between an event (return period); this is called a probabilistic analyses. To provide consistency in providing the design input across the Campus Park, a *Site-Specific Seismic Hazard Analyses and Development of Seismic Design Ground Motions* has been developed for the University and is routinely updated as new data becomes available. The most recent update was performed in 2015 by URS and provided both deterministic and probabilistic design information. The criteria provided in this series of reports have been utilized by incorporating the recommended response spectrums into the design of new structures on Campus Park and the surrounding environs, using the most recent version of the seismic design input. As an example of the data in the 2015 update, the mean peak ground-surface accelerations were approximately 0.35g, 1.11g, and 1.25g for return periods of 476, 975, and 2475 years, respectively. Given the very high level of ground shaking that will occur during a major earthquake, ground shaking is the second of the three serious geologic hazards present at the study site and is by far the most pervasive.

3.8 Liquefaction and Related Ground Failure

During strong earthquakes, various forms of ground failure can occur, such as liquefaction, lateral spreading, and seismic densification. Liquefaction is a condition where soils undergo a sudden loss of strength related to a rise in excess pore pressure generated during strong earthquake ground shaking. Soils that are susceptible to liquefaction include loose-to-medium-dense sand and gravel, low-plasticity silt, and some low-plasticity clays when any of these soils are below groundwater. Figure 3 indicates the areas that may be susceptible to liquefaction, according to analysis by the California Geologic Survey. They recommend that a site-specific study be performed for projects in the mapped areas. However, other than the site at 1608 4th Street (for which not data has been provided), the only possible areas that may be subject to liquefaction, according to this map, are the soils within Strawberry Creek and immediately uphill of Memorial Stadium. Site-specific borings across the study site have not identified the presence of any significant liquefiable deposits.

Lateral spreading occurs when liquefied soils are present near a free face (such as a stream channel), and the materials move in a horizontal fashion toward the open area. It is possible that localized lateral spreading could occur in the immediately vicinity of Strawberry Creek, but it is unlikely the ground movement would extend much beyond 10 feet from the top of the creek bank.

Seismic densification can occur when loose soils above the level of the groundwater are subject to strong ground shaking and densify. Such loose soils are not common in any portions of the study site, although a few local areas with some significant densification were identified in the site-specific reports that were reviewed. These areas included portions of Evans Diamond, Hellman Courts, and the field-hockey field on the Clark Kerr Campus.

3.9 Landslides

Natural landslides occur when soils or bedrock lose strength in a sloping area (often during heavy rains or an earthquake), and gravitation forces cause the materials to slide downhill. Human activities can also cause landslides to occur; these activities include undercutting a hill, placing a heavy weight like fill at the top of a slope, or substantially increasing the amount of water in a hillside. However, since only very gentle slopes are present the Campus Park (except for the banks along Strawberry Creek) and the City Environs Properties, these areas are not subject to landslides. A similar condition is present for nearly all of the Hill Campus West and the Clark Kerr Campus (except for the most uphill edge), so these areas are also not subject to landslides. Small, localized slides could occur in the Strawberry Creek bank areas or the eastern edges of Hill Campus West and the Clark Kerr Campus; there is a significant landslide that is impacting the bridge to Lawrence Berkeley National Laboratory over Centennial Drive. The major area that may be subject to landslides is the Hill Campus East. A portion of a landslide map of the Berkeley–Oakland area developed by the California Geologic Survey is presented on Figure 4, Landslide Map. This map indicates that a number of landslides are present in the Hill Campus East area, although nearly all of the landslides are considered dormant. It should be noted that these landslides may fail in the future during large earthquakes, and Figure 3 illustrates the areas that the California Geologic Survey considers may be susceptible to earthquake-induced landsliding on their Seismic Hazard Map of the area: they recommend a site should be evaluated for such a hazard before development. This is the third significant geologic hazard in the study area, but it is only a concern in the Hill Campus East.

3.10 Expansive Soils

Expansive soils are silts and clays that swell and shrink as the amount of water in the soil increases and decreases, respectively. This change in water content primarily occurs in the near-surface environment, as deeper soils may undergo much less change in water content; also, the weight of overlying soils minimizes swelling uplift. As noted earlier under Section 3.4, Soils, laboratory tests on soils throughout the study site indicate a broad range of swelling potential, from virtually none to quite large.

3.11 Graded Areas

There are very limited locations of significant graded areas within the study site, because most of the area consists of gentle slopes where minimal grading was needed for development. Some small amount of grading may have been performed in the past to create a level building pad for a large building, and/or to excavate below a proposed structure for a basement. The most obvious exceptions to this general trend of minimal grading are the broad level areas needed for athletic fields, which are scattered throughout the Campus Park and the Clark Kerr Campus. It should be noted that major grading was required when Memorial Stadium was initially constructed, but these graded materials were substantially altered and strengthened during the seismic-retrofit work.

Since most of the Hill Campus East consists of sloping terrain, grading would typically be necessary for developing structures and facilities. However, with the exception of the Space Sciences Laboratory, the Mathematical Sciences Research Laboratory, and some scattered research facilities just downhill of Grizzly Peak Boulevard, there has been little development to date, and therefore little grading has occurred.

3.12 Erosion

Erosion can occur when rainfall or other sources result in the placement of a significant amount of water on a sloping, bare-earth surface. Eroded soils can cause damage if they enter a waterway (like Strawberry Creek) or a storm-drain facility that deposits the collected water and entrained sediment into San Francisco Bay. However, other than during construction or immediately after building demolition, soils throughout the study area are already vegetated, leading to minimal erosion. During demolition and construction activities, special products are routinely placed at the perimeter of the work area and at storm-drain inlets to capture any eroded soils before damage occurs.

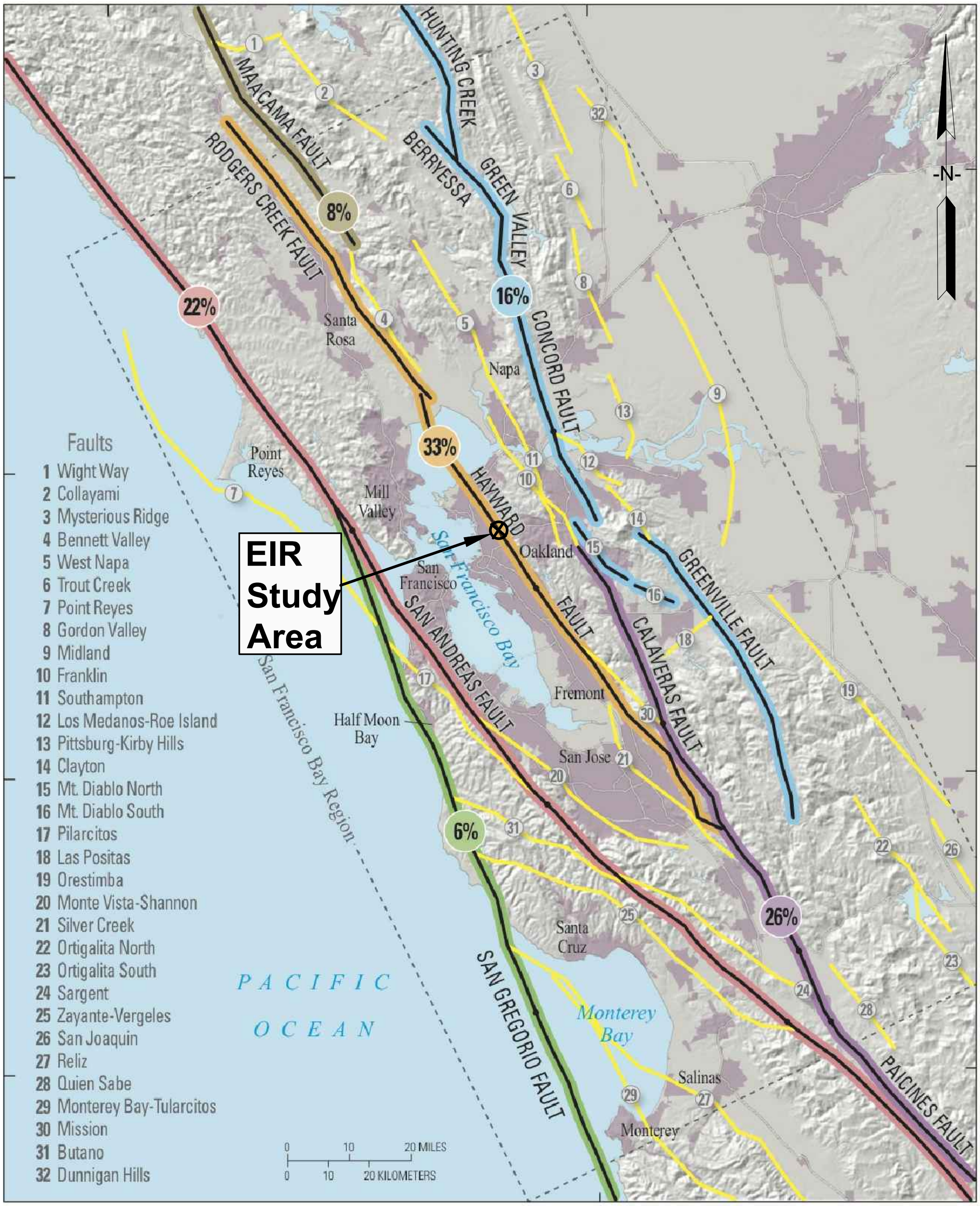
3.13 Existing Building Assessments

The geotechnical database indicates the earliest buildings on campus were typically supported by footing foundations; about 50–60 years ago, drilled piers came into use for some structures. More recently, mats and micropiles have been used widely, especially to accommodate heavy building loads and overturning concerns. All of these foundation types are commonly used throughout the Bay Area, where relatively good subsurface-support conditions are present for static loads. The reports in the database did not indicate many structures with settlement cracks or other foundation-movement problems.

As a result of concerns that strong seismic shaking would impact existing structures, the University has adopted a Seismic Safety Policy. All University buildings are evaluated in accordance with the American Society of Civil Engineers Standard *Seismic Rehabilitation of Existing Buildings* (ASCE-41). The University has Expected Seismic Performance Level criteria, which rank the buildings on a scale of I to VII, with I being good and VII being very poor. Structures with ratings of VII have been removed, as have most buildings with a rating of VI. There is a current three-phase program to eliminate the remaining buildings with a rating of VI and reduce the number of buildings with a rating of V.

3.14 Sites 1 and 2

Sites 1 and 2 are very similar from a geotechnical/geologic perspective and share the same geologic hazard profile. Sites 1 and 2 are likely to be underlain by 30–40 and 50–60 feet, respectively, of relatively competent soils. The groundwater is likely to be present at a depth of 10–20 feet at both sites. The sites will not be subject to fault rupture or landslide hazards, and only minor expansive-soil or liquefaction-settlement concerns are likely to be present. The only significant geologic hazard that will likely impact these sites is strong ground shaking during a major earthquake.



Base: "Map of Known Active Geologic Faults in the San Francisco Bay Region," USGS, Fact Sheet 2016-3020, 2016.

Original figure produced in color.

Detailed Description from USGS

Map of known active geologic faults in the San Francisco Bay region, California, including the Hayward Fault. The 72 percent probability of a magnitude (M) 6.7 or greater earthquake in the region includes well-known major plate-boundary faults, lesser-known faults, and unknown faults. The percentage shown within each colored circle is the probability that a M 6.7 or greater earthquake will occur somewhere on that fault system by the year 2043. The dark, thick lines outlined in various colors represent major plate boundary faults; the thinner, yellow lines mark lesser-know, smaller faults.

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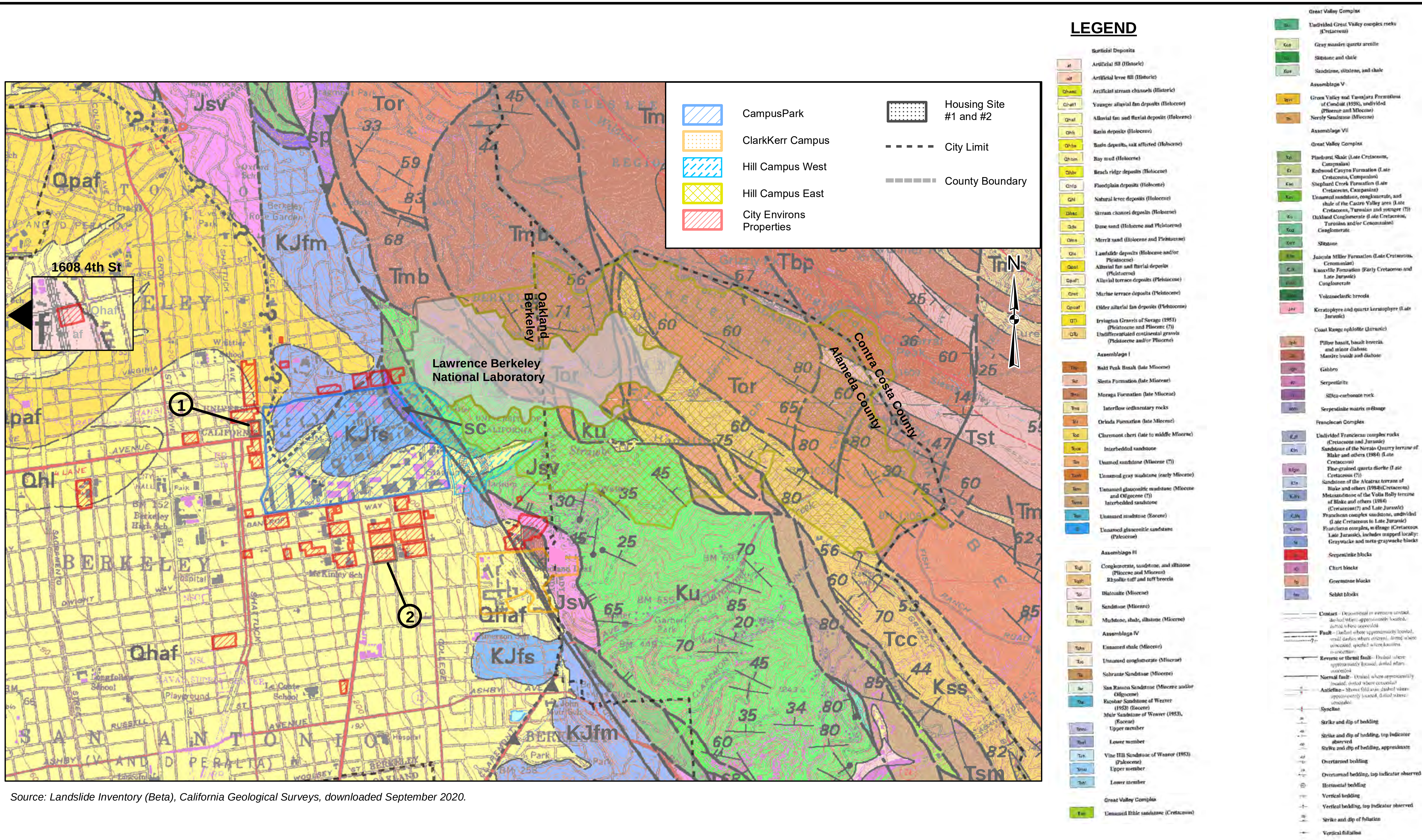
SAN FRANCISCO BAY AREA FAULTS		
UC BERKELEY - LRDPCMP EIR Berkeley, California		
PROJECT NO. **2500-18**	DATE **September 2020**	FIGURE **1**



Source: Landslide Inventory (Beta), California Geological Surveys, downloaded September 2020.

Original figure produced in color.

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APPROXIMATE SCALE FEET

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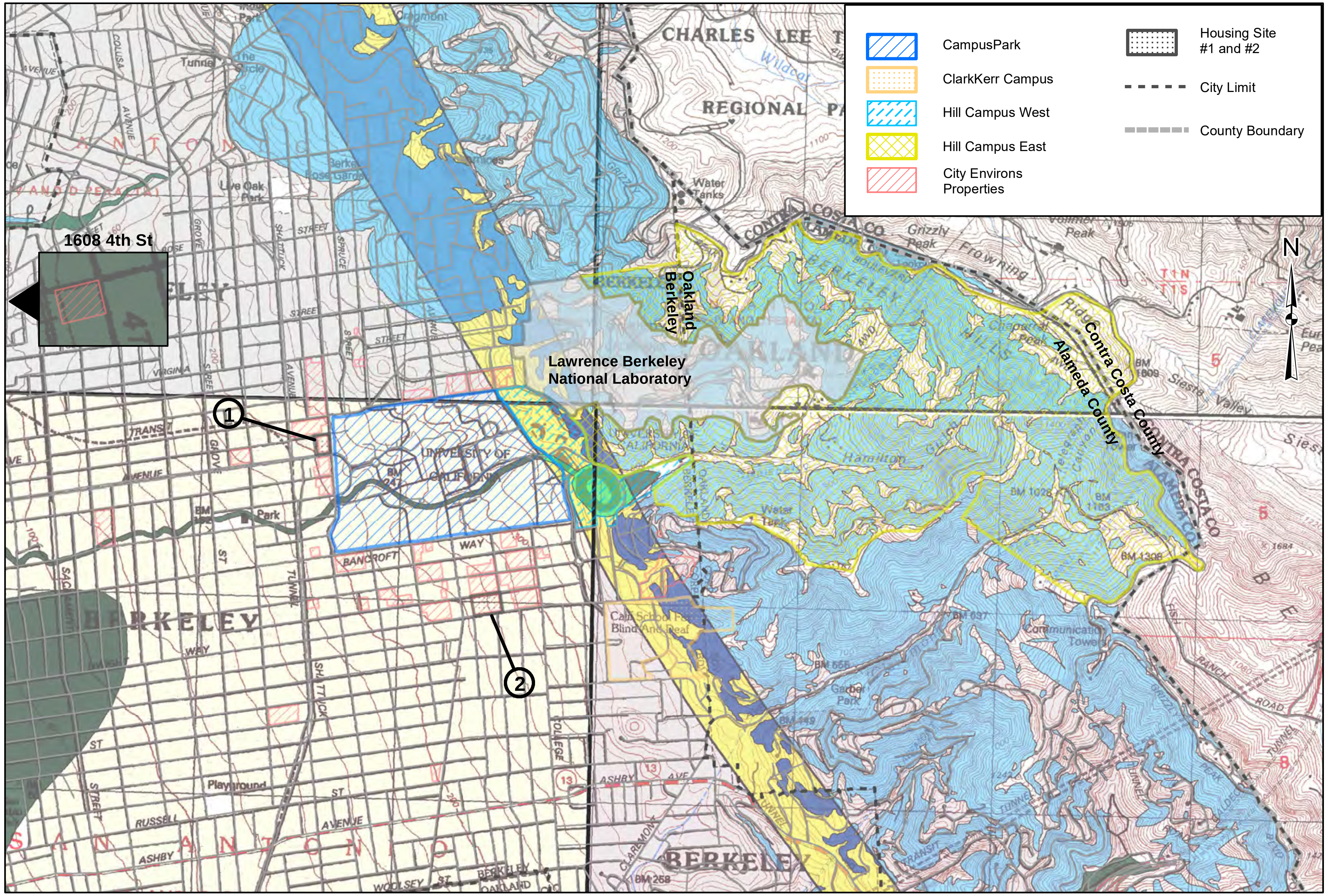
GEOLOGIC MAP		
UC BERKELEY - LRDPCMP EIR Berkeley, California		
PROJECT NO.	DATE	FIGURE 2
2500-18	September 2020	



LEGEND

QUADRANGLE BOUNDARY

EARTHQUAKE FAULT ZONES

Earthquake Fault Zones
Zone boundaries are delineated by straight-line segments; the boundaries define the zone encompassing active faults that constitute a potential hazard to structures from surface faulting or fault creep such that avoidance as described in Public Resources Code Section 2621.5(a) would be required.

Active Fault Traces
Faults considered to have been active during Holocene time and to have potential for surface rupture: Solid Line in Black or Red where Accurately Located; Long Dash in Black or Solid Line in Purple where Approximately Located; Short Dash in Black or Solid Line in Orange where Inferred; Dotted Line in Black or Solid Line in Rose where Concealed; Query (?) indicates additional uncertainty. Evidence of historic offset indicated by year of earthquake-associated event or C for displacement caused by fault creep.

1906 C ? ?

SEISMIC HAZARD ZONES

Liquefaction Zones
Areas where historical occurrence of liquefaction, or local geological, geotechnical and ground water conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

Earthquake-Induced Landslide Zones
Areas where previous occurrence of landslide movement, or local topographic, geological, geotechnical and subsurface water conditions indicate a potential for permanent ground displacements such that mitigation as defined in Public Resources Code Section 2693(c) would be required.

OVERLAPPING EARTHQUAKE FAULT AND SEISMIC HAZARD ZONES

Overlap of Earthquake Fault Zone and Liquefaction Zone
Areas that are covered by both Earthquake Fault Zone and Liquefaction Zone.

Overlap of Earthquake Fault Zone and Earthquake-Induced Landslide Zone
Areas that are covered by both Earthquake Fault Zone and Earthquake-Induced Landslide Zone.

Note: Mitigation methods differ for each zone – AP Act only allows avoidance; Seismic Hazard Mapping Act allows mitigation by engineering/geotechnical design as well as avoidance.

Source: Earthquake Zones of Required Investigation Oakland West, Oakland East, Richmond and Briones Valley Quadrangles, California Geological Surveys, 2016.

Original figure produced in color.

0 2,000 4,000
APPROXIMATE SCALE FEET

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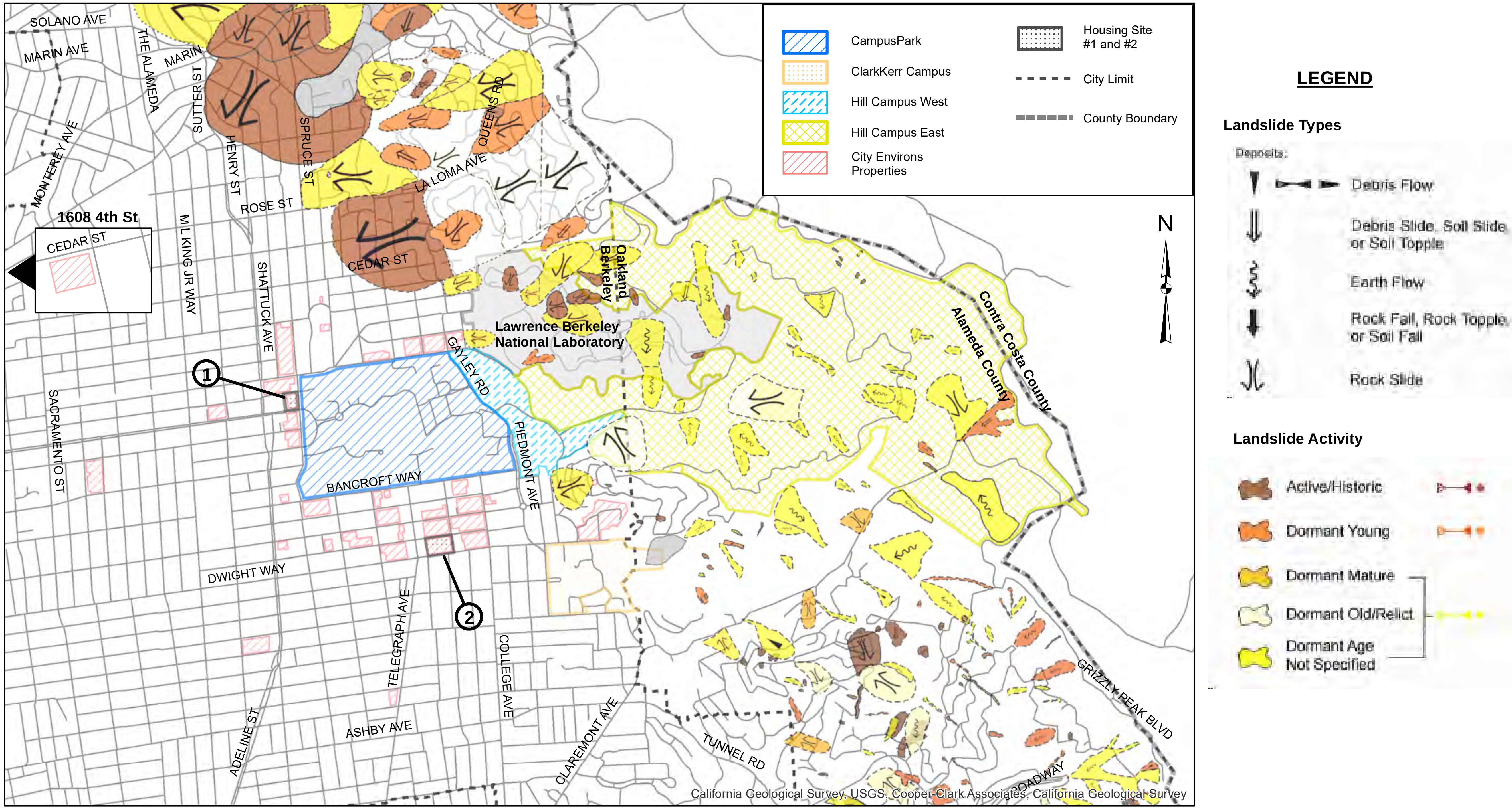
GEOLOGIC HAZARDS
UC BERKELEY - LRDPCMP EIR
Berkeley, California

PROJECT NO.	DATE	FIGURE 3
2500-18	**September 2020**	



Source: Landslide Inventory (Beta), California Geological Surveys, downloaded September 2020.

0 2,000 4,000
APPROXIMATE SCALE FEET

Original figure produced in color.

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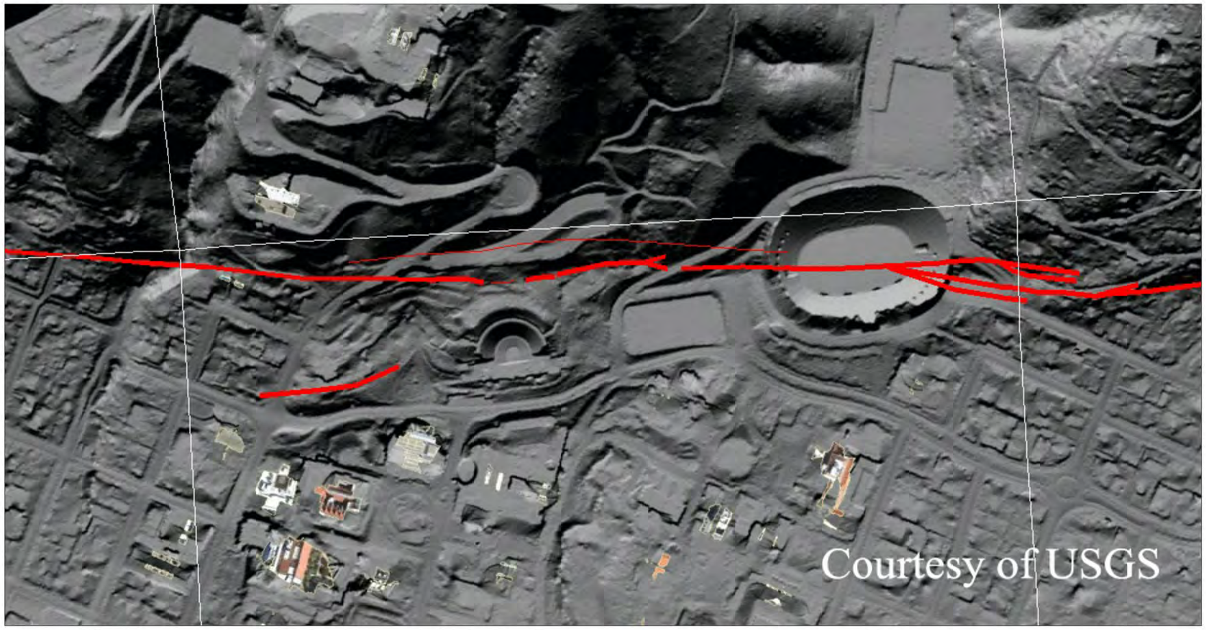
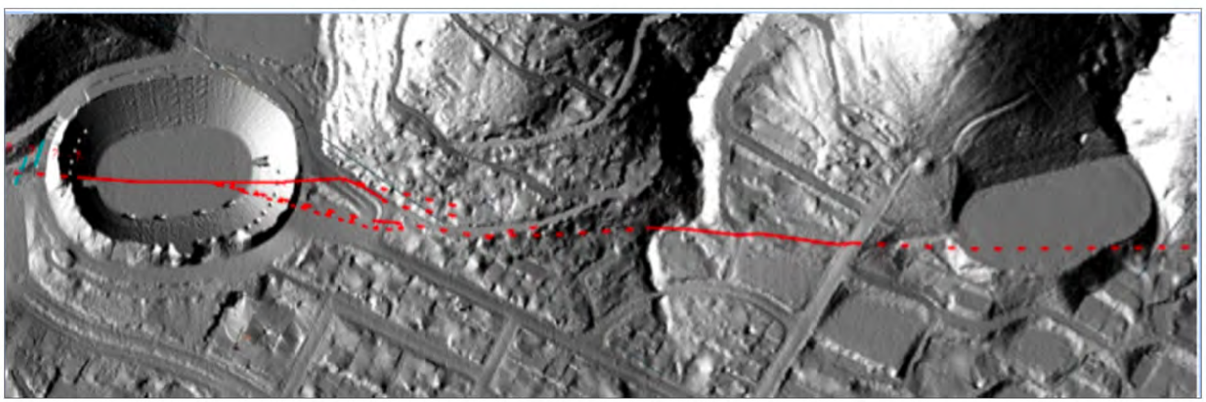
LANDSLIDE MAP		
UC BERKELEY - LRDPCMP EIR Berkeley, California		
PROJECT NO.	DATE	FIGURE 4
2500-18	September 2020	

Hayward Fault- Northern Portion of Study Area



Source: http://seismo.berkeley.edu/hayward/index.html

Hayward Fault- Southern Portion of Study Area



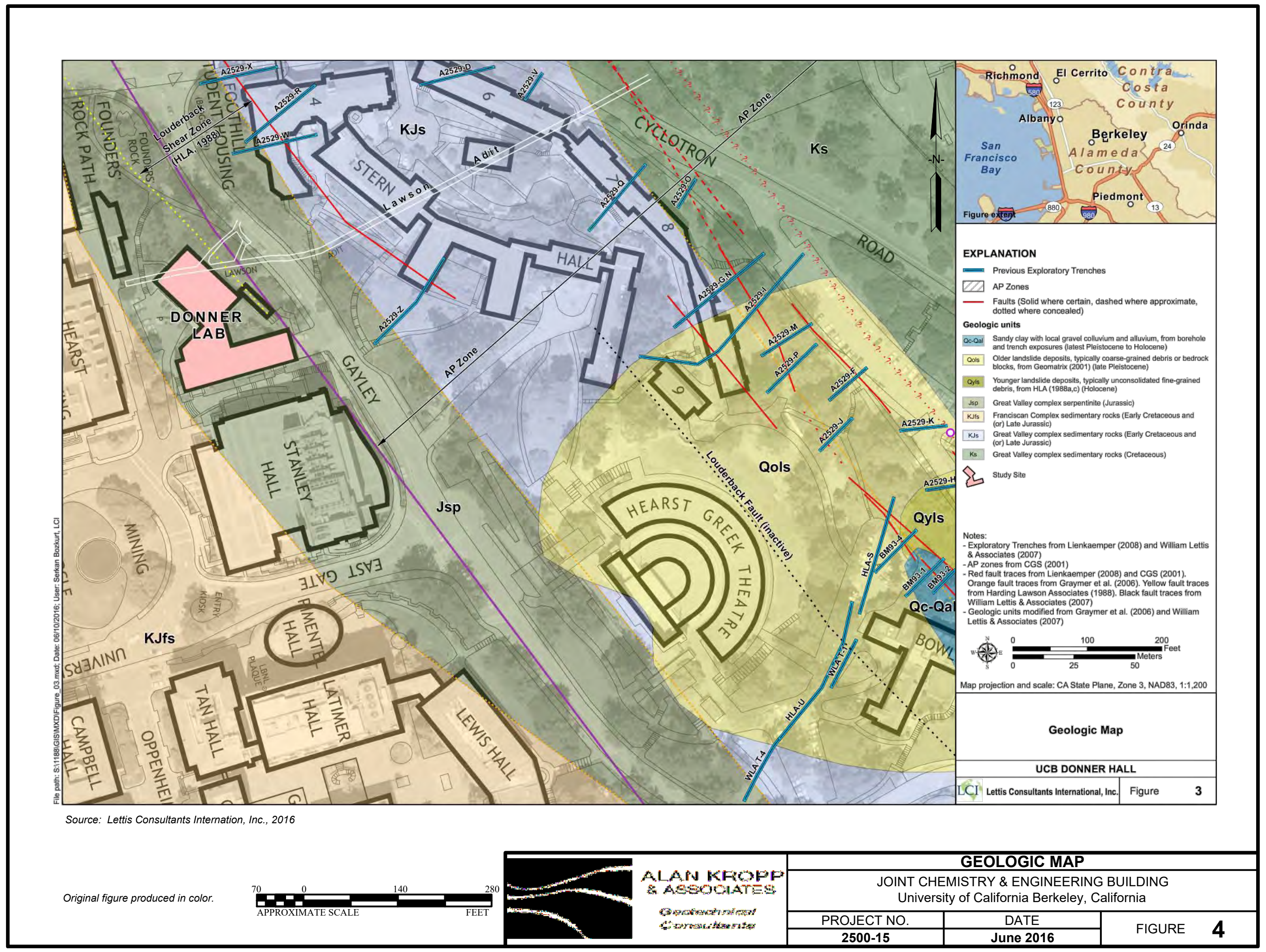
Source: https://haywardfaultucberkeley.pressbooks.com/front-matter/cover-picture/

NOTES:

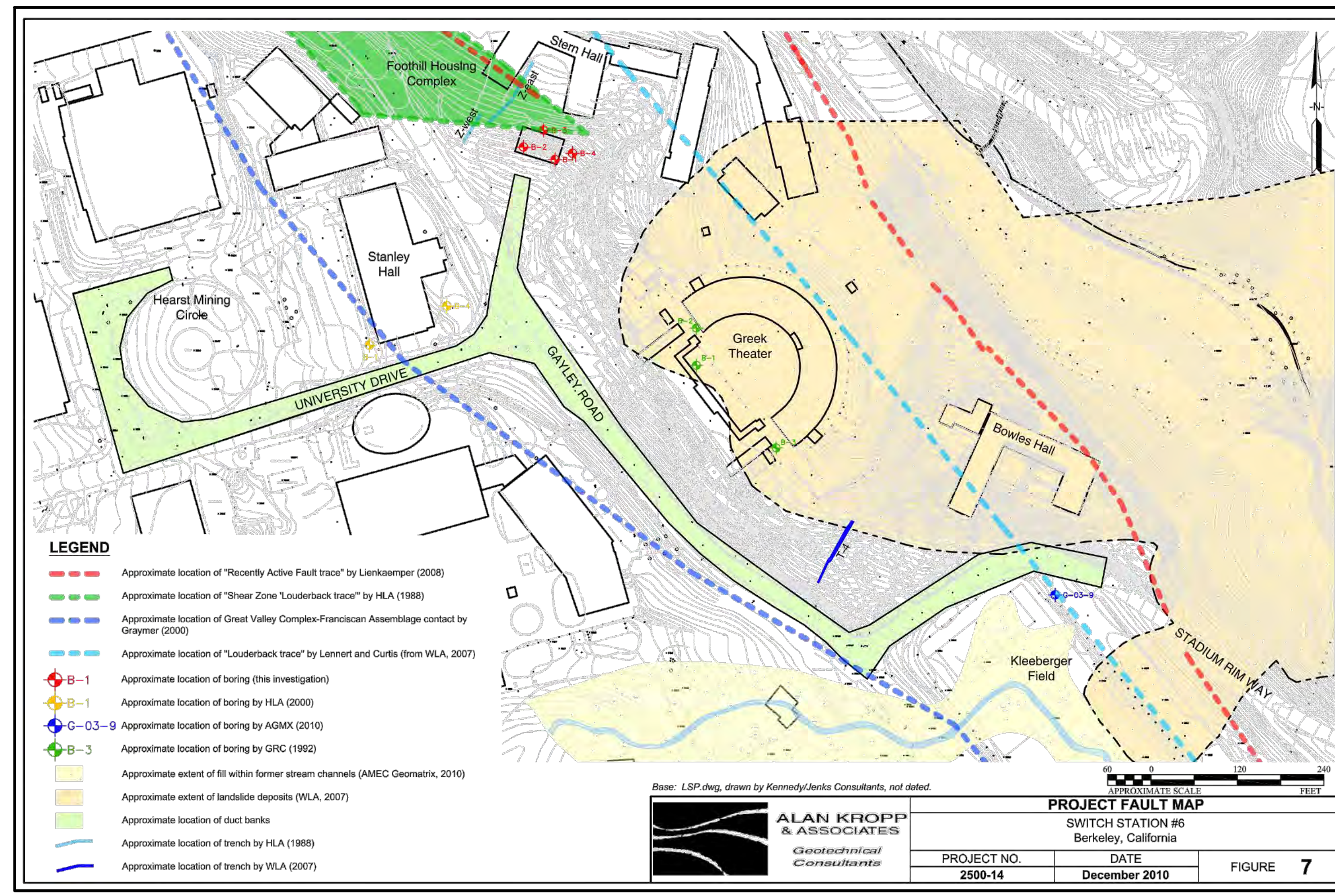
1. These images illustrate the active Hayward fault traces from Lienkaemper, 2006 on a hillshade output from LiDAR data
2. Original figure produced in color.

ALAN KROPP & ASSOCIATES
Geotechnical Consultants

HAYWARD FAULT CLOSE-UP		
UC BERKELEY - LRDPCMP EIR Berkeley, California		
PROJECT NO.	DATE	FIGURE 5
2500-18	September 2020	



Hayward Fault- Foothill Housing Complex to Hearst Greek Theatre



Hayward Fault- Hearst Greek Theater to Maxwell Family Field and Stadium Garage (Formerly Kleeberger Field)

Original figure produced in color.

ALAN KROPP & ASSOCIATES *Geotechnical Consultants*	HAYWARD FAULT STUDY EXAMPLES		
	UC BERKELEY - LRDPCMP EIR Berkeley, California		
	PROJECT NO. **2500-18**	DATE **September 2020**	FIGURE **6**