SUNKEN CITY LANDSLIDE – PRELIMINARY FEASIBILITY STUDY

Task Order Solicitation GEO File No. 15-160
Point Fermin Park Area, San Pedro
Los Angeles, California

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EXECUTIVE SUMMARY

As requested by the City of Los Angeles Bureau of Engineering (LABOE), Amec Foster Wheeler Environment & Infrastructure, Inc., (Amec Foster Wheeler), has prepared the following report summarizing the completed preliminary engineering geologic feasibility study of the "Sunken City" landslide area. The subject landslide area is historically known as the Point Fermin landslide and a smaller, more active portion of that larger landslide area has locally become known as the "Sunken City" landslide (Figure 1). The purpose of the requested preliminary feasibility study is to evaluate the engineering geologic conditions that would potentially affect a decision to open the currently fenced off portion of the landslide area for controlled public use. As a part of this evaluation, LABOE and the Los Angeles Department of Recreation and Parks (LADRP), which has jurisdiction over the city-owned portion of the site, have also requested development of possible alternatives for public use of the area, including development of conceptual mitigation measures to improve the safety conditions.

This subject area was originally developed as residential housing along Paseo Del Mar in the 1920s, but the local residential improvements were damaged by landsliding that began in 1929 and were ultimately abandoned because of continuing landslide movement. The Sunken City portion of the landslide developed in 1940-41 and historical comparison of landmarks within this smaller, shallower area of landsliding suggests up to about 130 feet of horizontal movement and up to about 50 feet of vertical movement has occurred since 1929. Movement of the landslide(s) over almost 90 years has disrupted and displaced the ground and underlying bedrock structure, and in the case of the Sunken City landslide, has broken the slide mass into a myriad of unstable blocks. The most dangerous and unstable areas tend to be concentrated along the ocean shoreline where the displaced landslide blocks encroach on the intertidal zone and are continually being eroded away and undermined by wave action. The combination of seaward slide movement and wave erosion has created relatively high, over-steepened bluffs that are riddled with fractures and open fissures. Under these conditions there is a significant potential for rapid catastrophic failure to occur at any time.

On the basis of the compiled information, observations and evaluations, a ground failure hazard map was prepared to identify those areas of the landslide with the highest potential for hazardous ground failure. In addition to the ground failure hazards, each of the defined hazard areas includes pervasive uneven surfaces, open fissures and local steep to near-vertical slopes that represent significant slip, trip and fall hazards for pedestrians. The delineated hazard zones are shown on Plate 3.

It will not be possible to effectively mitigate hazards along the shoreline and in the vicinity of the ocean bluffs to the extent that they will be safe enough for public access. This conclusion is primarily a consequence of the height, steepness and bedrock conditions along the ocean shoreline, and also because of effects of wave erosion along the toe of the bluffs and associated continuing ground movement within the landslide area. However, significant mitigation of the ground failure and surface hazards can be accomplished in the inland portions of the Sunken City Landslide, but not to the degree that supports a recommendation allowing public access. A conceptual mitigation grading plan for the inland portion of the Sunken City landslide area was developed on the basis of Amec Foster Wheeler's recommendations and is attached as Appendix E.

The upper terrace area comprising the top of the Point Fermin Landslide mass in the inland areas away from the ocean shoreline and bluff top have not been identified as a significant ground failure hazard zone (Plate 3). Controlled public access to this area is, therefore, considered feasible, pending implementation of an appropriate monitoring program and other recommendations described in the following report.

SUNKEN CITY LANDSLIDE - PRELIMINARY FEASIBILITY STUDY

Task Order Solicitation GEO File No. 15-160
Point Fermin Park Area, San Pedro
Los Angeles, California

1.0 INTRODUCTION

As requested in the subject Task Order Solicitation (TOS) from the City of Los Angeles Bureau of Engineering (LABOE), dated December 15, 2015, Amec Foster Wheeler Environment & Infrastructure, Inc., (Amec Foster Wheeler), has prepared the following report summarizing the completed preliminary engineering geologic feasibility study of the “Sunken City” landslide area. The work was authorized in a letter from LABOE dated February 19, 2016, as Work Order E1907967 under Amec Foster Wheeler’s on-call services contract C-121567. The general scope of work and estimated costs are summarized in Amec Foster Wheeler’s proposal dated January 5, 2016 (2015IRV61p).

The subject landslide area is historically known as the Point Fermin landslide and a smaller, more active portion of that larger landslide area has locally become known as the “Sunken City” landslide. The Point Fermin landslide area adjoins the easterly end of Point Fermin Park and is located along the south-facing ocean bluffs between the current terminus of W Paseo Del Mar on the west, and the former intersection of Paseo Del Mar with Pacific Avenue on the east (Figure 1). This area was originally developed as residential housing along both the landward and seaward sides of Paseo Del Mar in the 1920s. These residential improvements and associated infrastructure were subsequently damaged and disrupted by landsliding that began in 1929, and the area was ultimately abandoned because of continuing landslide movement. The landslide-affected area along the previous alignment of Paseo Del Mar between Point Fermin Park and Pacific Avenue is now surrounded by a relatively high steel fence that is intended to restrict public access to the area. This area is understood to be under the jurisdiction of the City of Los Angeles Department of Recreation and Parks (LADRP). The purpose of the requested preliminary feasibility study is to evaluate the engineering geologic conditions that would potentially affect a decision to open the fenced off area for controlled public use. As a part of this evaluation, LABOE has also requested development of possible alternatives for public use of the area, including development of conceptual mitigation measures to improve the safety conditions. Amec Foster Wheeler’s work was performed in cooperation and collaboration with LABOE representatives, with additional direction provided by LADRP representatives.

2.0 SCOPE OF WORK

The scope of work performed as part of the requested feasibility study includes eight task elements. Although the bulk of the proposed work is engineering geologic/geotechnical, a smaller civil engineering component is also included in the proposed services to address requested conceptual grading design for implementation of possible grading mitigation measures. Each of the eight general task items comprising the subject feasibility study is briefly outlined below.

2.1 REVIEW AND COMPILATION OF PERTINENT BACKGROUND INFORMATION

Records, reports, maps and historic photographs available from research on the internet, from published references, and also to some extent from the City's files were reviewed and pertinent information was compiled for use in summarizing the geologic conditions and history of landsliding in the area. This information included: geologic mapping of the landslide area performed in 1929; survey monitoring of the landslide movement between 1929 and 1941; and local subsurface exploration and geologic mapping within and near the landslide area in the mid-1980s. Geologic information directly pertinent to the existing site conditions was compiled on Amec Foster Wheeler's geologic map. Scaled overlays of the previous geologic maps and historic topographic maps were prepared for comparison to the current topographic contours and site conditions to provide a better understanding of the landslide history and changes in the local conditions through time. Complete copies of the most pertinent reference reports are attached as Appendices A through D.

2.2 ENGINEERING GEOLOGIC REVIEW AND MAPPING

Geologic mapping of the landslide limits were performed, including delineation of the more active Sunken City portion within the larger Point Fermin landslide area. This mapping included approximate delineation of the major sub-blocks and internal bedding structure within the Sunken City portion of the landslide mass, which has been broken into a myriad of smaller pieces by movement over the last 75 years. The extended period of landslide activity has severely disturbed and disrupted the geologic structure within this complex of landslide blocks. The "in-place" geologic structure exposed in the intertidal zone beneath the landslide mass is, therefore, considered to be more representative of the geologic conditions that control local landsliding. The primary base of landsliding for each landslide is locally exposed along the shorefront in the easterly portion of the slide area and was mapped in detail, along with the associated nearby geologic structure exposed in the intertidal zone.

The approximate locations of displaced concrete slabs that comprised the previous Paseo Del Mar roadway pavement within the landslide area were also mapped, along with the general trend and location of primary trails within the site. The orthophoto topography provided by LABOE, vertical aerial photography available from the NavigateLA website, and reconnaissance photos taken throughout the site were used to supplement direct field observations and mapping. Previous geologic mapping and published geologic information regarding the local stratigraphy were referenced and, as appropriate, were incorporated in Amec Foster Wheeler's geologic map and general geologic model of the landslide conditions.

2.3 PREPARATION OF GEOLOGIC MAP AND CROSS-SECTIONS

The collected previous and recent geologic information are compiled and presented on the Geologic Map (Plate 1). Three geologic cross-sections were also prepared in an approximately north-south direction through the landslide mass, extending from offshore through the intertidal/bluff area and to the north beyond the mapped limits of the Point Fermin landslide to include Shepard Street (Plate 2). The projected landslide geometries illustrated along the geologic cross-sections were used to perform relative evaluations of the stability conditions along each profile/section.

2.4 GENERALIZED STABILITY ANALYSES AND RELATIVE STABILITY EVALUATIONS

Analyses of the generalized stability conditions were performed along each of the three geologic cross-sections, including "back analyses" of the projected/assumed landslide geometries to estimate appropriate strength parameters for the slide plane/rupture surface. The stability of the landslide was also analyzed using a suite of possible groundwater levels within the slide mass to generally assess the sensitivity of the stability conditions to variations in the assumed groundwater conditions. Review of available references indicates that observed/noticeable movement of the Point Fermin and Sunken City portion of the landslide has been observed approximately coincident with heavy or extreme rainfall years. As briefly discussed above, these analyses are based on limited available subsurface information and are, therefore, considered primarily useful for generalized evaluation of the relative stability conditions, and are not considered definitive of the actual conditions.

2.5 DELINEATION OF GROUND FAILURE HAZARD AREAS

On the basis of the compiled data, observations, and evaluations, ground failure hazard zones were delineated within the landslide area. Three hazard levels were defined specific to the exposed geologic conditions and the associated local history of landsliding, including "Extreme Hazard", "High Hazard" and "Hazard" zones. These hazard zone definitions were, in turn utilized to identify specific hazard zones within the landslide area.

2.6 PROJECT MEETINGS AND EVALUATION OF POTENTIAL MITIGATION ALTERNATIVES

The project status, observations and findings were routinely reviewed and discussed in telecom discussions and project meetings with representatives of LABOE and to a lesser extent with LADRP. In addition to the exchange of information regarding the landslide conditions, the principal value of these interactions has been review, discussion and input regarding potential mitigation alternatives for the existing hazards.

2.7 DEVELOPMENT OF CONCLUSIONS AND RECOMMENDATIONS

On the basis of the compiled data, observations, and evaluations, engineering geologic conclusions were developed regarding the landslide conditions and associated hazards within the landslide area. In cooperation and collaboration with LABOE representatives, and with additional direction provided by LADRP representatives, preliminary recommendations were also developed for potential mitigation measures to improve the safety of the site and to allow limited public access to some areas.

2.8 PREPARATION OF SUMMARY REPORT

This report was prepared to briefly summarize the compiled data, observations, evaluations, conclusions and recommendations outlined above.

3.0 LANDSLIDE CHROLOLOGY/HISTORY

Prior to 1929: Residential and commercial development of the local area began sometime prior to 1929, including construction of Paseo Del Mar, Carolina Street, and two unnamed alley ways that were all ultimately affected by landsliding in the area. The parcel map used as a base for geologic mapping in 1929 shows structures on approximately 14 of the lots within the landslide area.

1929: The first indication of landslide movement was recognized in January 1929 with the occurrence of water line and gas line breaks under the Ocean View Inn on Paseo del Mar, approximately 200 feet west of Carolina Street. Over the next several months, similar utility breaks and a line of pavement and ground cracks formed an essentially continuous arc that extended out to the ocean bluff at locations south of the Ocean View Inn and south of the intersection of Pacific Avenue and Paseo Del Mar.

The City of Los Angeles subsequently conducted a geologic study of what became known as the Point Fermin Landslide (Ransome, 5/7/1929, refer to Appendix B). This study included geologic mapping of the slide area, installation of monitoring points along 7 survey lines and also excavation of a “test well”. The test well was located in the west-central portion of the landslide, and reportedly extended to a depth of 140 feet. Groundwater observations and measurements at the site are relatively limited and are briefly summarized under Section 4.4 of the text.

A second geologic study of the landslide area was authorized by the City of Los Angeles in August 1929. This relatively brief study was conducted by three geologists, including

Mr. Ralph Arnold, a well regarded geologist with extensive experience in the San Pedro area. Their observations, conclusions and recommendations are summarized in a report dated August 29, 1929 and included summaries of survey data and mapping that documented continuing movement of the landslide (refer to Appendix D). These observations and measurements suggested at least two surfaces of movement along the seaward-dipping bedding planes in the bedrock, including a deep surface that extended well below sea level at the shoreline. This conclusion was reinforced by relatively deep dislocation of the casing in the test hole drilled by Ransome and also dislocation of the casing for an oil exploration borehole that had been drilled from a platform at the base of bluff sometime before 1921 (refer to Plate 1 and Appendices C and D). The primary recommendation from the report was "*The entire area should be abandoned as a place of human habitation and all persons forbidden to enter the same. This is particularly true of the beach below the high cliffs on account of the danger of falling rocks and the possibility of the precipitation of huge masses of rock falling into the ocean without warning.*"

1929 - April 1940: The Point Fermin Landslide continued to move slowly but consistently throughout this time. At the time of the apparently final set of survey measurements in April 1940, the total recorded horizontal displacements were about 15 to 17 feet, with maximum vertical displacements of about 5 to 7 feet (i.e., the ground within the landslide area moved toward the ocean and elevation of the ground surface dropped). Survey lines that were established in the intertidal zone parallel to the shoreline also located the apparent offshore edge of landsliding (refer to "dislocation points" along Survey Lines "F" and "H' on Plate 1 and Appendix D). Relatively slow movement of the translational landslide reportedly allowed most of the existing residential structures to relocate outside the slide area. A relatively abrupt increase in the rate of movement was recorded in April 1940 (Appendix C).

1940 – 1941: Survey monitoring apparently ended in 1941 after acceleration of the landslide was recorded in April 1940, which apparently destroyed or made many of the survey monitoring points inaccessible or too dangerous to access. Substantial acceleration of the southeasterly portion of the Point Fermin Landslide in 1940-41 created what has become known as the "Sunken City" landslide area, as shown in many historic photographs from that time period. The 1940-41 rainfall year was the wettest on record at that time, with an annual total of approximately 33 inches of rain. Bluff erosion due to heavy storm surf conditions likely also contributed to this acceleration, including landfall of a dissipating hurricane in September 1939 that reportedly destroyed the outer 300 feet of the Huntington Beach Pier.

1941 – 1986: No specific survey measurements are apparently available, but geologic review and investigation in the early 1980's indicated that noticeable slide movement continued to occur primarily in the "Sunken City" portion of the landslide. Noticeable movement was attributed to continuing erosion along the toe of the bluff and periodic acceleration associated with extended heavy rainfall.

The 1977-78 rainfall season was a record rainfall year with an annual total of approximately 33 inches (second only to the 2004-2005 total of nearly 38 inches). As reported in a professional paper about the Point Fermin Landslide in the mid-1980s prepared by Engineering Geologist Mike Scullin (Appendix A), nearly continuous movement was evident in the easterly (Sunken City) portion of the Point Fermin landslide after the heavy rains in 1978. As shown on Sculllin's geologic map, a relatively small new landslide apparently occurred during this period that produced a minor northeasterly enlargement of the slide area in the vicinity of the existing Pacific Avenue viewpoint parking area. A geologic report prepared by Munson in 1979 also mapped two small scarps a short distance to the west that extended about 20 to 25 feet north of the pre-existing slide limits. These areas of local landslide enlargement were believed to have occurred in response to the record 1977-78 rainfall (Munson, 1979, refer to Plate 1). Relatively little information is apparently available regarding local geologic conditions/observations and evidence of ground movement in the years following original publication of Scullin's geologic paper in 1986 by the Geological Society of America.

1987: The existing wrought iron/steel fence was reportedly installed around most of the Point Fermin Landslide by the City of Los Angeles in 1987 in response to safety concerns and also complaints about noise and vandalism from the surrounding residents (Waters, 8/17/1986).

2009: In July 2009, a chunk of the Sunken City cliff reportedly collapsed sending a large cloud of dust into the air, no one was hurt (Littlejohn, 11/29/11).

3.1 CURRENT OBSERVATIONS OF LANDSLIDE CONDITIONS

The original ground surface in the Point Fermin landslide area was an essentially level terrace with a slight seaward slope, similar to what exists in the adjoining Pt. Fermin Park area to the west. Displacement of the landslide originally occurred as a relatively coherent block or rock mass that moved seaward along weak strata/bedding in the underlying bedrock that are tilted towards the ocean (this is known as a translational landslide). Cracks and what were locally described as "crevices" developed around the edges of the block as the rock mass moved seaward. Most of the original terrace surface was preserved, but at a lower elevation and at a location that is about 20 to 25 feet further seaward (the ratio of the maximum horizontal and vertical displacements measured in the 1929 through 1941 survey monitoring is consistent with an overall seaward inclination of the underlying bedrock strata of about 18 to 22 degrees). The current ground surface of the greater Point Fermin landslide is somewhat undulatory, reflecting the presence of broad areas of extension and settlement along incipient slide block boundaries (Plate 1).

Comparison of available mapping and the 1929 - 1940 survey data indicates that relatively minor additional displacement has occurred in the northerly and westerly extremities of the greater Point Fermin landslide area since activation of the Sunken City portion of the landslide 75 years ago. Comparison of the distance between the north edge of the displaced Paseo Del Mar pavement/curb section to the original right-of way (R.O.W.) location in the area westerly of the Sunken City landslide indicates that approximately 20 to 25 feet of horizontal displacement has occurred in that area since 1929. This is about 5 to 10 feet more than was measured during the last available survey measurements 76 years ago in April 1940. This additional movement is equivalent to an average displacement rate of about 0.8 to 1.5 inches/year, although much of this additional movement may have occurred coincident with original development of the Sunken City portion of the landslide during the extreme 1940-41 rainfall season, or possibly during other extreme rainfall seasons.

Evidence of substantial displacement of the larger landslide area that post-dates 1987 construction of the existing wrought iron/steel fence would presumably be reflected in deformation/displacement of the fence or nearby fence foundations in the vicinity of the four locations where the fence crosses the mapped landslide boundary (refer to Plate 1). Although some local distress or damage to the fence was observed in the vicinity of these crossing areas, there was no apparent evidence of substantial landslide displacement of the fence. Previous experience in similar landslide areas suggests that sophisticated subsurface monitoring of the base of the landslide would likely show relatively minor, slow, creeping landslide movement and/or periodic minor movement associated with higher rainfall/groundwater conditions (e.g., inclinometers that extend down through the slide mass into undisturbed bedrock beneath the landslide would be capable of measuring displacements of as little as 0.001-inch). The rate and magnitude of this type of movement may take many years to manifest at the ground surface and the often subtle evidence of this deep movement is also easily obscured.

The Sunken City portion of the landslide initially developed in 1940 as a translational block. However, as the movement progressed, the slide mass broke into ever-smaller blocks that in some areas locally preserved only small isolated remnants of the original terrace surface. Breakdown of the rock mass has developed primarily as a consequence of a relatively large magnitude of apparently continuous very slow slide movement that has occurred over an extended period of time. Continuing movement created internal fractures in the blocks, reducing the strength of the rock to the extent that it could not support the near-vertical boundaries around the edges of the blocks. Differences in the shape and orientation of the underlying landslide slip surface, slight differences in the rate of movement within the blocks and the probable presence of pre-existing faults likely contributed to breakdown of the rock mass. Landslide movement that has occurred over the last 75 years has internally fractured, displaced and disrupted the structure/fabric of the rock mass. As such, portions of the existing slopes within the slide area, and also the steep bluff slopes along the shoreline are potentially unstable and subject rapid catastrophic failure.

Comparison of the distance between the north edge of the displaced Paseo del Mar pavement/curb section to the original Paseo Del Mar R.O.W. suggests that between about 30 and 130 feet of horizontal movement and about 25 to 50 feet of vertical movement have occurred in the Sunken City portion of the landslide. The greatest horizontal displacements have occurred in the westerly portion of the smaller slide area. Along the westerly edge of the slide mass, the existing ground elevations are about 55 to 65 feet lower than the original terrace level. Comparison of the 1972 topographic base map used by Scullin for his geologic mapping in the 1980s to the current topographic base provided by LABOE (circa 2014) suggests that about 35 to 40 feet of seaward displacement has occurred in the westerly portion of the Sunken City landslide since 1972. Similar comparisons in the easterly portion of the landslide suggest about 25 to 30 feet of seaward displacement over that same time period, including enlargement of the slide boundary to the northeast over an area of about 3,000 square feet (i.e., towards the existing parking area/overlook at the south end of Pacific Avenue). These comparisons indicate an average displacement rate of about 10 to 11 inches/year in the westerly portion of the slide and about 7 to 8 inches/year in the easterly portion of the slide since 1972. However, the actual rate of movement is likely to be highly variable within the slide mass and has been observed to accelerate in response to heavy rainfall (i.e., increased groundwater pressure), and also in response to wave erosion and removal of the landslide toe along the shoreline. Rapid acceleration and catastrophic failure is most likely to occur in the steep bluff slope area along the ocean shoreline.

Comparison of data between the 1929 geologic map and the current topographic base suggests up to about 50 to 80 feet of bluff retreat has occurred in conjunction with displacement of the landslide. Similar comparisons between Scullin's geologic map, which used a topographic base map prepared in 1972, and the current topography suggests bluff retreat from a few feet up to about 50 feet. These estimates are, however, just snapshots in time because the landslide has been moving or creeping incrementally seaward since original activation of movement in 1929 and is continually being eroded away by wave action. It is interesting to note that the 1929 location of the oil exploration well the was drilled on the beach in the early 1920s is currently about 35 to 40 feet behind the toe of the existing bluff and is overlain by remnants of the northerly edge of the Paseo Del Mar roadway (refer to Plate 1).

4.0 GEOLOGIC CONDITIONS

4.1 TOPOGRAPHY AND GEOLOGIC SETTING

The project site is located along the ocean shoreline in the southeasterly extremity of the Palos Verdes Peninsula and is bounded on the south by a steep bluff slope (Figure 1). The uplifted remnant of an ancient wave-cut terrace in the top of the bedrock forms the relatively level area of residential development and adjoining park areas that surround the landward side of the Point Fermin landslide. The modern equivalent of this bedrock erosion platform is present extending seaward at a relatively shallow gradient from the base of the existing ocean bluff. Outside of the landslide area, the top of the nearby bluffs has an elevation of about 110 feet and the adjoining terrace surface ascends at gentle gradient to the north. The terrace surface is typically underlain by several feet of dark adobe topsoil and minor local intervals of terrace deposits.

Bedrock underlying the site is assigned to the Monterey formation, which was deposited in deep ocean basins during the Miocene, about 4 to 16 million years ago (Conrad and Ehlig, 1983). This deposition occurred on much older (Mesozoic age), metamorphic basement rock known as the Catalina Schist, which is typically characterized by an abundance of blue and green schist. During the older portion of this sedimentation process, local layers and irregular bodies of basalt were emplaced by volcanic activity, which also deposited thin layers of volcanic ash in the sedimentary section that through time have been altered to relatively weak bentonitic clay beds. Following deep burial and partial lithification of these deep-sea deposits, tectonic compression along bounding faults on the southwesterly and northeasterly sides of what is now the Palos Verdes Peninsula began to uplift and deform the bedrock into a broad dome-like fold or anticline. The central axis of this anticlinal fold is located near the center and highest point of the Peninsula and plunges or bends downward to the northwest towards Palos Verdes Estates and to the southeast towards San Pedro. Uplift of the Peninsula over about the previous 1.5 million years is reflected in at least thirteen (13) wave-cut marine terrace platforms that extend between elevations of about 50 feet at a few locations near the ocean shoreline, and up to about 1,300 feet near the crest of the Peninsula (Woodring, et al, 1946). Uplift and folding of the bedrock strata has imparted a pervasive seaward dip or inclination to the sedimentary layers on the southwest side of the Peninsula, including the subject area. The seaward inclination of the bedrock strata at low to moderate angles, and also the presence of relatively weak bentonite clay beds within the bedrock, are the principal controlling factors for large translational landsliding that has occurred at many locations along the southerly side of the Peninsula.

4.2 STRATIGRAPHY

The earth materials in the vicinity of the project site can be divided into five (5) primary stratigraphic units with an associated geologic map symbol (Plate 1). In generally decreasing age of deposition or occurrence, they are: 1) Monterey formation bedrock, Altamira Shale member (Tma); 2) non-marine terrace deposits (Qtn); 3) beach deposits (Qbd); 4) landslides (Qls) and artificial or man-made fill (af). Stratigraphic nomenclature for the project is taken primarily from USGS Professional Paper 207 (USGS, 1946) and from a professional paper prepared by Conrad and Ehlig (1983). The geologic map symbols referenced above utilize standard geologic practice wherein naturally deposited Quaternary-age geologic units (i.e., from the present to about 2.6 million years old [USGS, 2010]) are labeled with a capital “Q”, including appropriate subscripts, and Tertiary-age geologic units/bedrock (i.e., from about 2.6 million to 65 million years old [USGS, 2010]) are labeled with a capital “T”. Manmade or artificial fill is not labeled with a time period and is identified only with appropriate subscripts. Brief summary descriptions of each of these units are provided below.

4.2.1 Monterey Formation Bedrock (Tma)

Monterey formation bedrock is well exposed in the ocean bluffs and adjoining intertidal zone to the east and west of the Point Fermin landslide area. Much of the intertidal zone extending seaward from beneath the easterly portion of the Point Fermin Landslide also appears to consist of in-place Monterey formation bedrock (Plate 1). On the basis of the age, stratigraphic position and character of the local bedrock, it has been assigned to the Altamira Shale member of the Monterey formation, and an “a” has been added to the map symbol to reflect this classification (Woodring, et al, 1946). The local bedrock is composed of two (2) dominant rock types: 1) laminated to thinly bedded porcelaneous shale, silty shale, diatomaceous shale and dolostone with minor thin interbeds of blue-schist sandstone and altered bentonitic tuff that are present in the area immediately east of (and also beneath) the landslide area; and 2) moderately to very thickly bedded blue schist sandstone with intervals, interbeds and inclusions of thinly bedded to laminated, porcelaneous, silty and diatomaceous shale that comprise much of the exposures immediately west of the landslide area.

Sea cliff exposures beneath Point Fermin about 700 to 800 feet to the west of the landslide, consist primarily of thickly to very thickly bedded blue schist sandstone with an intervening section of abundant shale at about mid-height. These locally unique deposits of abundant blue-schist sandstone are believed to be the result of submarine fan deposition from an uplifted block of the Catalina Schist basement rock during the Miocene that was located to the north (Russell, 1987). The sandstone reportedly fines and becomes more thinly bedded in the upper portion of the sequence and appears to grade laterally to the east, interfingering with shale and with an increasing occurrence of shale inclusions within the sandstone, thus suggesting a transition near the edges of the fan complex. The available exposures suggest this local transition occurs within or beneath the westerly portion of the landslide area.

4.2.2 Non-marine Terrace Deposits (Qtn)

Limited observations near the bluff and within the landslide suggest that the naturally deposited surficial soil cover (primarily residual soil) on the top of the remnant bedrock erosion platform consists primarily of several feet of dark brown, adobe topsoil. However, subsurface exploration logged by Munson (1979) in the area northeast of slide recorded a relatively consistent ~2-foot thick interval of light-colored silt and clay with abundant shale fragments beneath the topsoil, and at one location, fine sand was logged on the top of the bedrock that may be the erosional remnant marine terrace deposits. These limited local exposures did not warrant addition of this unit to the geologic map.

4.2.3 Beach Deposits (Qbd)

A relatively thick apron of reworked landslide rubble is present along the shoreline at the base of the bluff in the subject area. Although there is some fine to coarse sand matrix material exposed in some local areas, most of the exposed beach deposits consist of typically tabular-shaped, sub-rounded, cobble and boulder-size rock fragments. The high tide line appears to coincide with the base of the bluff in most areas, so wave action immediately begins reworking detritus shed during erosion and failure of the bluff slope. The most recent failure areas can be identified by large piles, or coarse talus cones of tabular boulders with locally higher angularity, and in some cases also including finer soils and angular sand and gravel clasts near the crest of the pile against the bluff face that have not yet been washed away by the wave action. The lowermost portion of the beach deposits likely includes fine to coarse sand and gravel matrix material between primarily clast-supported cobbles and boulders. The thickness of the beach deposits is unknown, but the local presence of erosion resistant bedrock outcrops in many areas of the intertidal zone suggests that a thickness of about 4 to 8 feet would be typical.

4.2.4 Landslides (Qls)

The occurrence of landsliding in the subject area is primarily controlled by the presence of unsupported, or inadequately supported seaward-dipping bedding or strata in the bedrock that contains relatively weak, laterally extensive bentonitic clay beds. These weak clay beds have low frictional resistance and under the right conditions can form failure or slip surfaces that allow the overlying bedrock blocks to slide down the inclined surface of the bedding or strata. This type of landsliding is known a translational block failure and can extend over a large area, as demonstrated by the Point Fermin landslide and also by the Portuguese Bend landslide about 5 miles to the northwest, which has been moving continuously since 1956.

As discussed above, landsliding in the subject area can be divided into two distinct areas: the Point Fermin landslide that encompassed essentially the entire area of landsliding at the site, and a secondary failure of that original landslide mass that is known as the Sunken City landslide. In the early 1980s, downhole geologic logging in two large diameter bucket auger borings within, and a short distance to the north of the Point Fermin landslide identified two bentonite clay beds that are vertically spaced about 20 to 25 feet apart (Scullin, 1987, Appendix A).

Projection of these weak bentonite beds to the head or back of the landslide area, and to the bottom of the existing bluff in the east-central portion of the slide area, strongly suggest that these clay beds represent the base of landsliding for the Sunken City landslide (i.e., along the upper clay bed) and the encompassing Point Fermin landslide (i.e., along the lower clay bed). These clay beds have been mapped along the lower portion of the bluff in the eastern portion of the landslide area, and can be seen to intersect with a fault/displacement surface that forms the easterly edge/boundary of the landslide area (refer to Plate 1). Seaward projection of the mapped bentonite bed at the base of the Point Fermin landslide also approximately coincides with the “dislocation point” identified in the intertidal zone by 1929 survey measurements (refer to “dislocation point” along Survey Line “H” on Plate 1). The geologic structure or strata exposed in that portion of the bluff gradually rise in elevation to the east, and farther to the west, the exposures of the mapped clay beds descend below the beach deposits and are believed to be below sea level at the shoreline in the central and westerly portions of the landslide area (Plates 1 and 2).

As briefly discussed above under Section 4.2.1, the character of the bedrock comprising the westerly portion of the landslide consists of moderately to very thickly-bedded blue schist sandstone, interbedded with intervals of porcelaneous, silty and diatomaceous shale. This rock is relatively resistant to erosion and has formed relatively high, very steep to essentially vertical cliff faces along much of the ocean shoreline, where it is exposed to continual wave erosion during higher tides. Movement of both the Sunken City and to a lesser extent the Point Fermin landslides has broken the slide masses into steep-sided blocks that are subject to sudden catastrophic failure, particularly during or after heavy rainfall and/or large storm surf events. Detritus produced by failure of the bluff face in this westerly area tends to be composed of large blocks and tabular pieces of bedrock.

The easterly portion of slide area (i.e., in the area where the base of both landslide masses is exposed in the bluff face) is composed primarily of thinly bedded porcelaneous, silty and diatomaceous shale with minor thin interbeds of sandstone. This rock tends to be less resistant to erosion and typically forms moderately steep slopes with aprons of soil and rock detritus along the ocean shoreline. In areas of active wave erosion, a steep to near-vertical exposure of displaced and/or in-place bedrock (i.e., below the base of the Point Fermin slide mass) is locally present along the back of the beach deposits. These steep slopes range in height from a few feet up to a maximum of about 20 feet. Detritus shed from shallow failures and erosion of this portion of the landslide area tends to consist primarily of soil and gravel to cobble-size rock fragments, with some local boulder-size blocks of relatively hard dolostone. A portion of the steep slope along the back of the beach deposits has been locally undermined by wave erosion in the area where the base of the Point Fermin landslide crosses the bottom of the bluff. This differential erosion is primarily a consequence of the softer bentonitic materials and associated shearing deformation that is present along the base of the landslide (Plate 1).

4.2.5 Artificial or Manmade Fill (af)

No records documenting construction/placement of artificial fill within the landslide area are known to be available, but descriptions by Arnold (1929) indicate that the "crevices" that formed around the head/perimeter of the landslide were filled to reduce the safety hazard (Appendix D). The limits of these fills are not known, but have been locally inferred on the geologic map (Plate 1).

4.3 Geologic Structure

In general, bedding or stratification of the Monterey formation bedrock materials that underlie the landslides and surrounding area are inclined shallowly (i.e., about 5 to 25 degrees) towards the shoreline. However, geologic mapping of the base of the landslides in the easterly portion of the slide area indicate these beds gradually rise in elevation to the east, and the overall inclination of the bedding in that area has a component to the west. This westerly dip component in the underlying bedding appears to be most pronounced in the easterly extremity of the slide area and decreases to the west. Displacement of a bedrock block that occurred near the terminus of Pacific Avenue in the late 1970s - early 1980s (refer to Section 3.0) appears to have moved in a southwesterly direction, oblique to the shoreline, reflecting the more westerly component of bedding dip in that area (Plate 1). Bluff exposures of individual beds within displaced bedrock comprising the westerly half of the slide area show relatively minor variations in elevation, suggesting the primary component of dip in the underlying bedding in that area is directly south toward the ocean.

Geologic mapping of the base of both the Point Fermin and shallower Sunken City landslides indicate these failure surfaces extend below sea level along the shoreline in the westerly portion of the slide area. The relatively weak, seaward-dipping, bentonitic clay beds that control the landsliding are, therefore, covered by the rubbly beach deposits in this area and also by overlying bedrock layers, particularly in the areas further seaward. Available exposures along the westerly shoreline and offshore areas suggest that seaward displacement of the slide masses has been accommodated at some locations by uplift and buckling of these overlying bedrock layers, thus allowing the base of landsliding to “daylight” (i.e., extend upwards to break out at the submerged ground surface). The best example of this uplift and buckling along the shoreline is present in the area between Geologic Cross Sections 2-2’ and 3-3’ on the attached Geologic Map (Plate 1). At that location, a line of outcropping bedrock strata in the intertidal zone was measured with inclinations at moderate angles (40 to 45 degrees) to the north, back towards the bluff face. This apparent “ramping up” of the landslide slip surface is also reflected in the nearby portion of the bluff face, where the remnant bedding in the displaced bedrock is also inclined to the north, apparently in response to local, “along-bedding” rotational failure of the bluff face. A local area of similarly “back-rotated” blocks appears to be present in the shoreline area at the westerly edge of the Sunken City landslide.

A possible explanation for the apparent “back-rotated” conditions observed at these two local areas along the shoreline is that original buckling failure along the ocean shoreline during development and displacement of the deeper Point Fermin Landslide produced displaced bedrock structural conditions that were favorable for development of “along-bedding” failures in the overlying stratigraphy. Development of the Sunken City landslide approximately 20 years later may, therefore, have been accommodated by uplift and buckling produced by the deeper landslide. The “ramped up” geologic structure produced by the original landslide failure could reasonably have “daylighted” the shallower bentonite bed, thus allowing the Sunken City landslide to develop and fail almost entirely along that weak bedding plane. This hypothesized failure mechanism would also make the Sunken City portion of the landslide potentially more susceptible to rapid failure in response to significant bluff retreat during heavy storm surf, as was recorded in September 1939, prior to relatively rapid development of that shallower landslide in 1940-41 (Section 3.0).

Original displacement along the westerly edge of the Point Fermin landslide appears to have occurred along a pre-existing fault in the bedrock that crossed down the face of the bluff and across the adjoining intertidal zone along a trend that is slightly east of due-south (Plate 1). The westerly edge of the landslide in Arnold’s 1929 geologic report is described as a fissure where it crosses the intertidal zone, and his report includes a picture of a large group of men reviewing the fissure in the beach area (Appendix D). Descriptions in 1929 and comparison with the current exposures suggest that several feet of uplift has occurred through time on the easterly side of that fissure. 1929 survey measurements along a line parallel to the shoreline also identified the apparent offshore edge of landsliding, which coincides with this fault feature in the intertidal zone (refer to “dislocation point” along Survey Line “F” on Plate 1).

As shown on Scullin’s 1987 geologic map (Appendix A), minor westerly enlargement of the slide occurred sometime after the original failure. Scullin’s map is consistent with the recent geologic mapping (Plate 1), and the edge of the landslide now follows a second pre-existing bedrock fault surface that crosses the bluff face in a more southwesterly direction and is coincident with an existing erosion/drainage gully. Although this second fault is clearly visible crossing the intertidal zone, the geometry of the landslide suggests that the edge of the landslide bends to the southeast in the beach area and likely merges with the original slide boundary somewhere offshore (Plate 1).

4.4 GROUNDWATER

The presence of groundwater is an important consideration in assessing the stability of landslides because it generally reduces the strength of the bedrock, particularly the weak bentonite clay beds that form the base of these landslides. However, more importantly, the hydrostatic pressure of the groundwater reduces the frictional resistance along the base of the landslides and also other weak bedding planes discontinuities within the bedrock by producing an uplift force on the overlying earth materials.

Ransome's 1929 geologic study (Appendix B) included excavation of a "test well". The test well was located in the west-central portion of the landslide at an elevation of 112 feet, and reportedly extended to a depth of 140 feet. Groundwater seepage was observed between depths of 70 to 90 feet and a water surface was measured during drilling at a depth of 100 feet. Subsequent measurements reportedly indicated that the water level rose to 80 feet below the ground surface (~elev. 32 feet) sometime after completion of drilling. It is interesting to note that measurements about three months after installation of the well indicated that it was open only to a depth of about 101 feet, likely marking the base or possibly the uppermost surface movement in the landslide (MacNaughton Library, 1940, refer to Appendix C).

Scullin's 1987 geologic publication (Appendix A) referenced the occurrence of seepage at a depth of 48 feet (~elev.72 feet) in his exploratory boring B-1, which was located about 20 feet north of the slide boundary (Plate 1). Ransome's and Scullin's observations and measurements are the only information that are known to be available regarding groundwater levels within the landslide mass. Observations during recent geologic mapping suggest that seepage has locally occurred a few feet above the exposed base of the existing bluff, but no active seepage was observed during the recent field work.

5.0 GENERALIZED STABILTY ANALYSES

The three geologic cross-sections illustrate subsurface projections of the geologic structure/landslide base that are based on the available/collected geologic data. Subsurface data are essentially limited to previous observations and measurements from two bucket auger borings within and adjacent to the central portion of the landslide (Scullin, 1987, Appendix A and Plate 1). This exploration information and mapping of the bentonite beds/base of the landslides along the shoreline in the easterly portion of the landslide area provide the only data available for subsurface projection of the landslide geometries. The location of Geologic Section 2 - 2' includes the data from Scullin's exploratory borings and is, therefore, considered the best representation of the Point Fermin and Sunken City landslide geometries (Plate 2). Analyses of the generalized stability conditions were performed along each of the three geologic cross-sections (Plate 2), including "back analyses" of the projected/assumed landslide geometries to estimate appropriate strength parameters for the slide plane/rupture surface. These analyses are considered generalized because of the limited extent of information available for delineating and projecting the landslide conditions.

Using an estimated existing groundwater surface based on the limited available data (Section 4.4 above), stability analyses were performed for each of the projected landslide geometries shown on the geologic sections (i.e., a total of five landslide geometries because the Sunken City landslide is not present along Section1-1'). The purpose of these analyses was to determine what uniform strength parameters are required to maintain marginal stability (i.e., F.S. of ~1.0) along all of the projected landslide geometries (the assumption being that the composition/strength of the bentonite comprising much or most of the length of each failure surface is about the same). On the basis of these analyses, a uniform strength of phi (ϕ) = 13 degrees and cohesion (c) = 0 was estimated, which is generally in the range of other calculated values in the Palos Verdes area. Factors of safety for the projected/estimated existing near-equilibrium conditions of the landslides using these estimated strength parameters ranged from 0.97 to 1.1 (refer to Appendix E). Using these projections, estimates and assumptions, the average factor of safety of the Sunken City landslide is about 1.0 and average factor of safety of the underlying and encompassing Point Fermin landslide is about 1.1.

The stability of the landslide was also analyzed using the estimated strength parameters and a suite of possible groundwater levels within the slide mass to generally assess the sensitivity of the stability conditions to variations in the assumed groundwater conditions. Review of available references indicates that observed/noticeable active movement of the Point Fermin and Sunken City portion of the landslide has occurred approximately coincident with heavy or extreme rainfall years.

The assumed/projected groundwater levels that were estimated for the existing conditions were used as a baseline and essentially uniform rises of 10, 20 and 30 feet above those baselines were assumed for the purposes of these sensitivity analyses. As would be expected, the factors of safety for the landslides (i.e., the stability) decrease with increasing water levels. Along Section 2 - 2', which is considered the most representative of the overall landslide conditions, the relative analyses indicate the Sunken City portion of the landslide tends to be more sensitive to rising groundwater than the underlying Point Fermin slide mass. An attached graphic summary of the analytical results shows a 7%, 17% and 27% reduction in the factor of safety of the Sunken City landslide for the assumed respective rises in groundwater of 10, 20 and 30 feet (refer to Appendix E). By comparison, these same assumed groundwater rises reduced the factor of safety of the underlying point Fermin landslide by 6%, 12% and 19%, respectively. Using these projections, estimates and assumptions, the average factors of safety of both the Sunken City landslide and the Point Fermin landslide are less the 1.0 (i.e., unstable or actively moving) for an assumed groundwater rise of 10 to 20 feet (Appendix E).

6.0 GROUND FAILURE HAZARD ZONES

On the basis of the compiled information, observations and evaluations, a ground failure hazard map was prepared to identify those areas of the landslide with the highest potential for hazardous ground failure. Three hazard levels were defined specific to the exposed geologic conditions and the associated local history of landsliding, including “Extreme Hazard”, “High Hazard” and “Hazard” zones. These hazard zone definitions were, in turn utilized to delineate specific hazard zones within the landslide area. In addition to the ground failure hazards, each of the defined hazard areas includes pervasive uneven surfaces, open fissures and local steep to near-vertical slopes that represent significant slip, trip and fall hazards for pedestrians. The delineated hazard zones are shown on Plate 3.

“Extreme Hazard” zones were identified by the presence of pervasive dilated fracturing within the bedrock comprising relatively high, very steep slopes/cliffs. Locally extensive open fracture systems have developed in the area as a consequence of continuing long-term displacement of the landslides, and the associated height and steepness of the slopes/cliffs in the “Extreme Hazard” zone area produces a potential for life-threatening catastrophic failure that could occur at any time. These catastrophic failures would affect both the area above/behind the slope, and also to a much more dangerous degree, the area below the slope. Relatively minor rockfalls in these areas could have life-threatening consequences, and are most likely to occur along the ocean shoreline, which is affected by essentially continuous wave erosion. Waves and ocean tides also typically restrict access along the shoreline to a relatively narrow zone along the base of the cliffs, within the influence of even minor rockfalls.

As shown on Plate 3, most of the “Extreme Hazard” zones are located along the shoreline near the westerly boundary of the Sunken City landslide where the erosion resistant, blocky sandstone supports relatively high, very steep sea cliffs and local pinnacles of rock bounded by open fractures. A similar pinnacle area is also present away from the shoreline, near the center of the Sunken City landslide. At that location, the near-vertical rock face appears to be leaning slightly seaward, suggesting a potential for catastrophic toppling failure.

“High Hazard” zones were also identified by the presence of pervasive dilated fracturing within bedrock comprising relatively high, steep slopes/cliffs. However, the steepness of the slopes in these areas tends to be less, and potential ground failure in these areas is more likely to consist of shallow slabs and rockfalls rather than catastrophic failure or toppling of large blocks or areas of the slope face. Similar to the “Extreme Hazard” zones, most of the “High Hazard” zones tend to be located along the actively eroding shoreline and similar life-threatening exposure to even minor rockfall is present along the base of the bluff slopes/cliffs in these areas (Plate 3).

“Hazard” zones were also delineated primarily on the basis of extensive fracturing of the slide masses/ground that has occurred as a consequence of continuing long-term displacement of the landslides. Relatively large horizontal and vertical ground displacements within these portions of the landslides have broken the slide masses into a myriad of blocks with intervening ground cracks and extensional zones. These ground cracks and extensional zones are subject to local ground collapse, and the slide debris is subject to shallow failure and rockfall in areas with significant slope gradients. As shown on Plate 3, the “Hazard” zones encompass all of the remaining areas of the Sunken City landslide and the shorefront slope that descends from the terrace level in the westerly portion of the Point Fermin landslide. In many of these areas, there are remnants of previous infrastructure improvements (primarily concrete slabs, along with local steel rails, abandoned pipes, etc.) that represent tripping, falling and local collapse hazards, in addition to, or associated with the local ground collapse and shallow failure potential.

As requested, primary trails within the landslide area are also delineated on Plate 3. However, evidence at the site suggests that, with the exception of most of the cliff faces, there is very little of the slide area that has not been accessed by the public by walking, crawling and/or climbing.

7.0 FEASIBILITY OF MITIGATION MEASURES FOR GROUND FAILURE HAZARDS

In general, the existing ground failure hazard zones along the ocean shoreline and bluff top are the areas where the hazardous conditions are most extreme. It will not be possible to effectively mitigate hazards in those areas to the extent that they will be safe enough for public access. Although some removals could marginally reduce the hazard potential in local areas, the only practical mitigation measure for the hazard zones along the ocean shoreline is avoidance. This conclusion is primarily a consequence of the height, steepness and bedrock conditions along the ocean shoreline, and also because of effects of continuous erosion along the toe of the bluffs and associated continuing ground movement within the landslide area.

Significant mitigation of the ground failure hazards can be accomplished in the inland portions of the Sunken City Landslide, but not to the degree that supports a recommendation allowing public access. The longevity of these mitigation measures would be limited by the effects of continuing wave erosion and landslide movement. Coastal permitting issues may also severely constrain or possibly prohibit mitigation grading in the slide area, particularly in the vicinity of the existing bluff slopes. Potential liability associated with grading modification of a hazardous landslide area should also be considered.

The upper terrace area comprising the top of the Point Fermin Landslide mass in the inland areas away from the ocean shoreline and bluff top have not been identified as a significant ground failure hazard zone, and controlled public access to this area is considered feasible, pending implementation of an appropriate monitoring program (Section 8.2) and other safety measures.

8.0 GENERAL RECOMMENDATIONS

8.1 MITIGATION GRADING OF THE INLAND PORTIONS OF THE SUNKEN CITY LANDSLIDE

Recommended general grading mitigation measures for this area would primarily consist of regrading locally steep slope areas to gradients or slope ratios (H:V) shallower than 1:1 (bedrock cuts) or 1.5:1 (soil cuts or compacted fills). These areas should also be graded with drainage gradients that minimize infiltration of incident rainfall and other potential surface flow across the area. Any proposed drainage structures and/or other drainage improvements should consider the occurrence of continuing/future landslide movement and should consist of flexible components that are easily maintained. Remnant infrastructure improvements from previous development of the area should be removed to facilitate implementation and future maintenance of the grading/drainage plan.

8.2 LANDSLIDE MONITORING

Considering the potential for public use of the landslide area, some provisions should be made to monitor current and future landslide movement. Survey monitoring points should be established within the landslide area to monitor their position/location relative to “no movement” datum monuments well beyond the limits of the mapped landsliding. Monitoring points should also be established around the perimeter of the landslide area, both within and beyond the surface projection of the bentonite bed that forms the base of the Point Fermin Landslide (see Geologic Cross-Sections). Some consideration should also be given to installation of inclinometers to monitor subsurface movement along the base of both the upper and lower landslide slip surfaces, and also piezometers to monitor the groundwater pore pressure affecting the landslides.

8.3 MITIGATION OF THE RATE AND SEVERITY OF FUTURE LANDSLIDE MOVEMENT

It should be recognized that the subject site is an active landslide area. Although the rate of movement may not be noticeable in the short term, there is no physical mechanism for this landslide area to stabilize itself, particularly in consideration of continual wave erosion that is occurring along the ocean shoreline. Specific provisions should be developed and implemented to enhance drainage conditions within and surrounding the landslide area to minimize infiltration of rainfall and surface water runoff. To the extent possible, uncontrolled runoff over the bluff edge, or over the scarps that form the boundaries of the slide areas should also be eliminated. Uncontrolled runoff from the upland areas northerly of the slide area and/or leakage from existing storm drains or utilities is of particular concern. Specific provisions should be developed for routine monitoring and maintenance of the water, sewer and storm drain lines in the areas within a radius of about 200 to 300 feet surrounding the boundaries of the slide area. Any existing lines within the slide area or any that are no longer in the area near the perimeter of the landslide should be removed or appropriately sealed and abandoned.

9.0 GRADING MITIGATION CONCEPT

At the initial site meeting for the project, representatives of the Los Angeles Department of Recreation and Parks (LADRP) expressed a goal to improve the safety conditions of the site in preparation for possible controlled public access to the area. A conceptual mitigation grading alternative has been developed by Wagner Engineering & Survey, Inc (WES) under Amec Foster Wheeler's direction to clean up and improve the drainage conditions in the Sunken City portion of the landslide area, and to the extent considered feasible, to also improve the site safety conditions. A copy of the plans illustrating the details of this grading concept is attached as Appendix F.

The primary features or advantages of this grading concept are:

- Smoothes the topography on the top and upper portion of the landslide, removing locally over-steeped slopes (i.e., "Extreme" and "High Hazard" areas);

- Reconfigures the topography to provide positive drainage gradients to a large drainage swale that runs the length of the landslide to collect and discharge incident rainfall and other surface runoff;

- In addition to those drainage improvements, the mitigation grading will fill existing ground cracks (at least temporarily) and will generally densify the surface materials, which will also tend to reduce infiltration of surface water into the slide mass;

- Removes concrete, pipes and other debris from the Sunken City portion of the landslide that represent local safety hazards and may also provide local conduits for rapid infiltration of surface water into the slide mass;

Possible drawbacks or disadvantages of this grading concept are:

- Does not provide significant mitigation of "Extreme" and "High Hazard" areas along the shoreline, including the top of the bluffs along the seaward edge of the grading area;

- Locally directs some sheet-flow drainage towards the top of the bluff/shorefront slope in the Sunken City landslide area;

- Creates the false impression that the Sunken City portion of the landslide is now safe, possibly increasing the potential for injuries and life threatening accidents in the vicinity of the extremely hazardous bluff slope areas, including potential catastrophic failure of the bluff.

10.0 CLOSURE AND GENERAL CONDITIONS

This report is based on the project as described and the geologic/geotechnical data obtained from Amec Foster Wheeler's engineering geologic review and mapping of the site conditions and research of the referenced documents. The conclusions and interpretations do not reflect possible undetected variations that may occur between the reported exploration locations or other data points. Amec foster Wheeler should be notified of any pertinent change in the site conditions, or if geologic conditions are found that differ from those described in this report.

This report has not been prepared for use by parties other than the City of Los Angeles Bureau of Engineering and City of Los Angeles Department of Recreation and Parks, or their designated representatives, or for projects or locations other than that described herein. This document may not contain sufficient information for other parties or other purposes. This report has been prepared in accordance with generally accepted geologic/geotechnical practices and makes no other warranties, either express or implied, as to the professional advice or data included.

We appreciate the opportunity to be of service. Should you have any questions or require additional information, please contact Scott Kerwin at your earliest convenience.

11.0 REFERENCES

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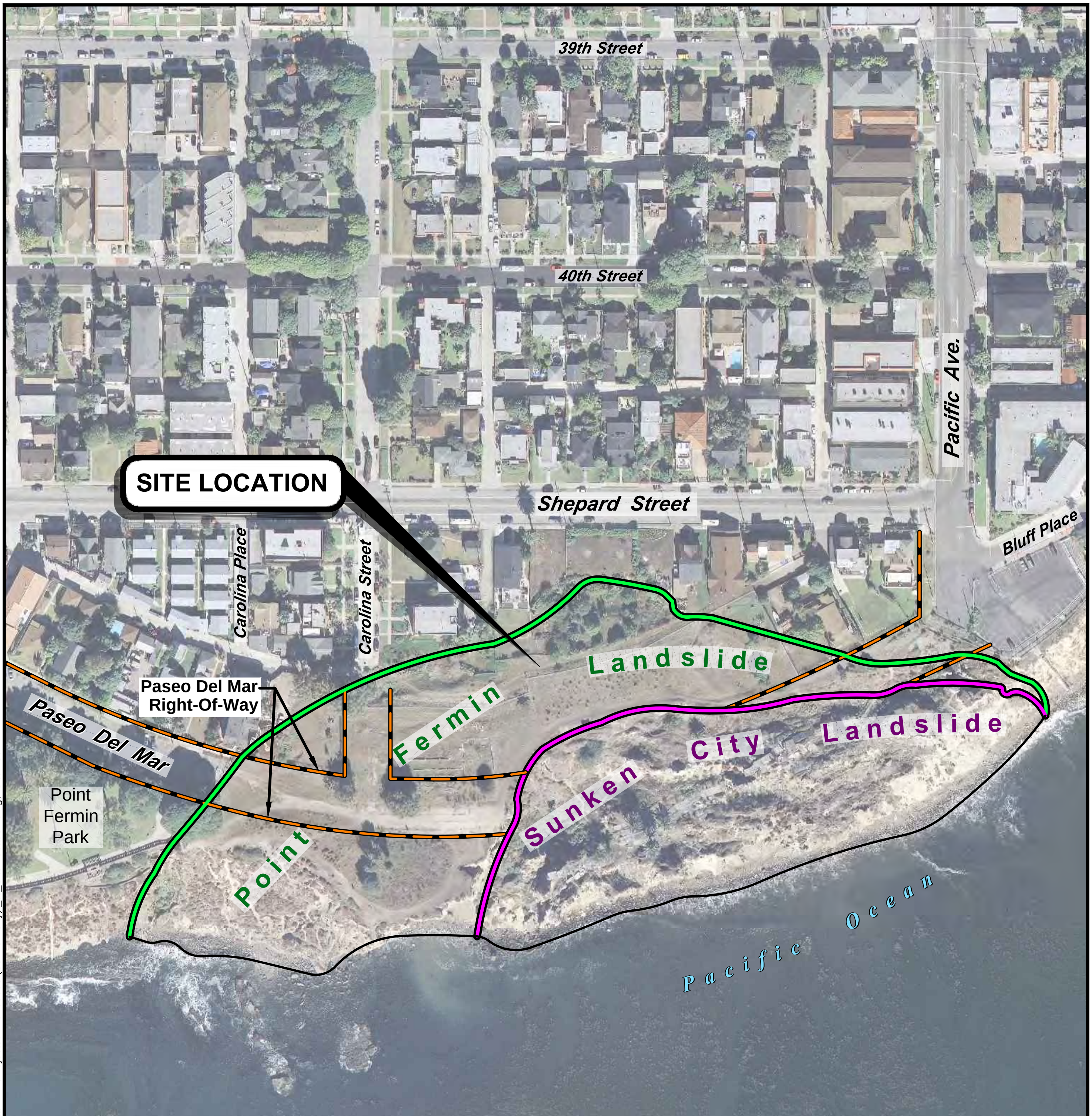
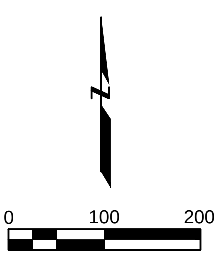
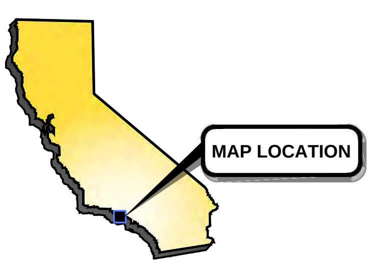
FIGURE

Plot Date: 11/21/2016 9:15:13 AM, Plotted by: joanna.worker Drawing Path: W:\Projects\IR16166090 (Sunken City)_tb_Site Location.dwg, Site Loc



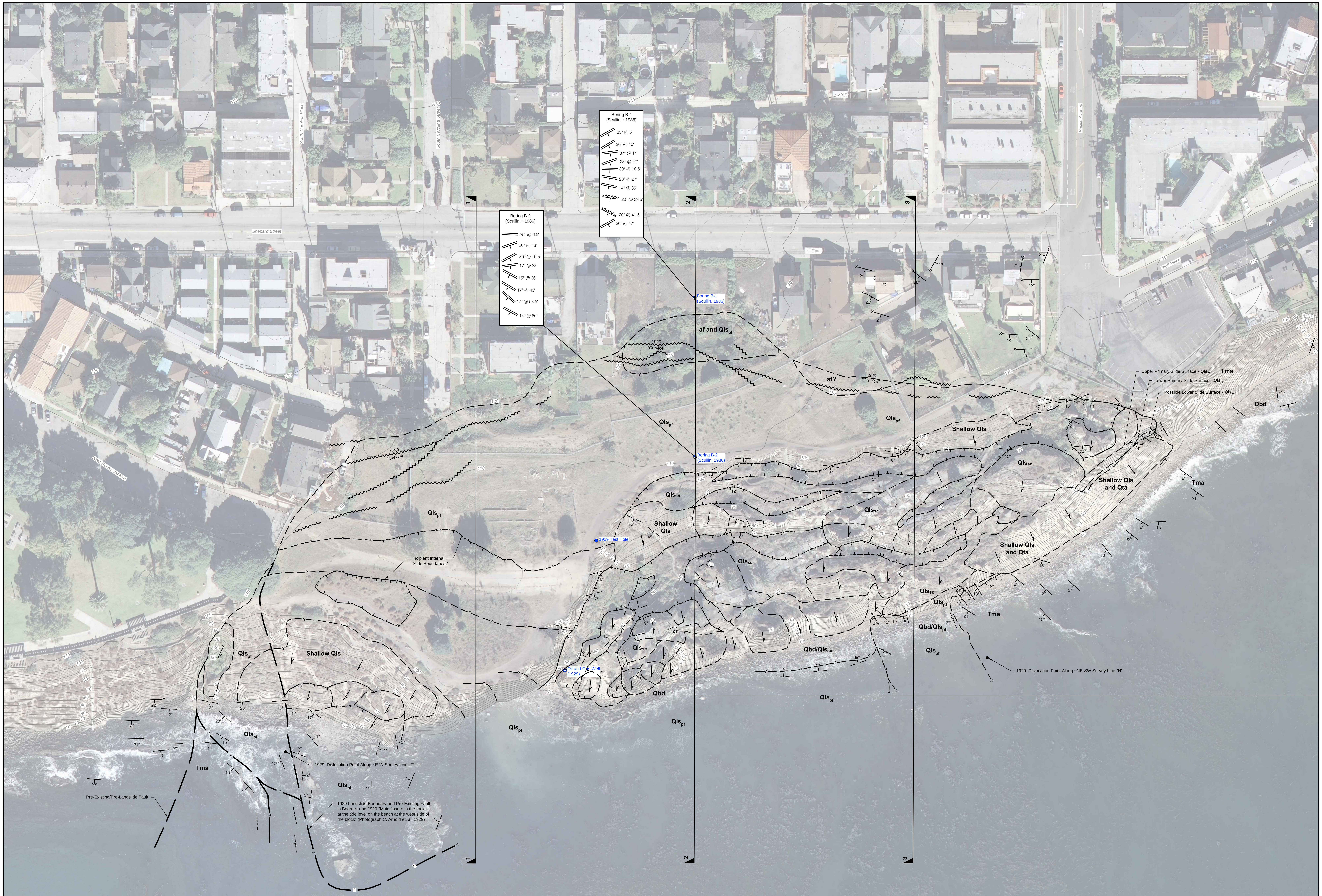




Basemap modified from topographic CAD file and aerial photo provided by City of Los Angeles, Department of Public Works.

SITE LOCATION MAP Sunken City Project Point Fermin San Pedro, California		amec foster wheeler
Date: Dec. 2016	Project No. IR16166090	Figure
Submitted By: stk	Drawn By: jrw	1

PLATES



Explanation

- Boring location (Scullin, 1986)
- Oil and gas well (Arnold, 1929)
- Test boring (Arnold, 1929)
- Geologic contact; solid where exposed or well-located; dashed where approximately located, queried (?) where uncertain
- Fault; dashed where approximately located, queried (?) where uncertain
- Approximate extent of closed depression or down-dropped landslide block(s)
- Approximate direction of landslide movement
- 3 3' Geologic cross section location
- 38° Strike and dip of bedding (bedrock)
- 9° Strike and dip of shear surface
- Approximate strike showing dip direction of bedding (bedrock)
- 7° Strike and dip of bedding (landslide)

Geologic Mapping/Data by Others

- 22° S Strike and dip of bedding (bedrock, Scullin 1986)
- 30° @ 47' Subsurface strike and dip of bedding, showing depth of measurement (Scullin 1986)
- 20° @ 41.5' Subsurface strike and dip of shear surface, showing depth of measurement (Scullin 1986)
- Tension cracks, small scarps and/or fissures mapped in 1929 (Arnold, et al, 1929)

af Artificial/man-made fill
Qbd Beach deposits
Qta Talus deposits
Qls_{sc} Landslide (Sunken City)
Qls_{pf} Landslide (Point Fermin)
Tma Monterey Formation - Altamira Shale Member

N

40 20 0 40
Approximate Scale in Feet

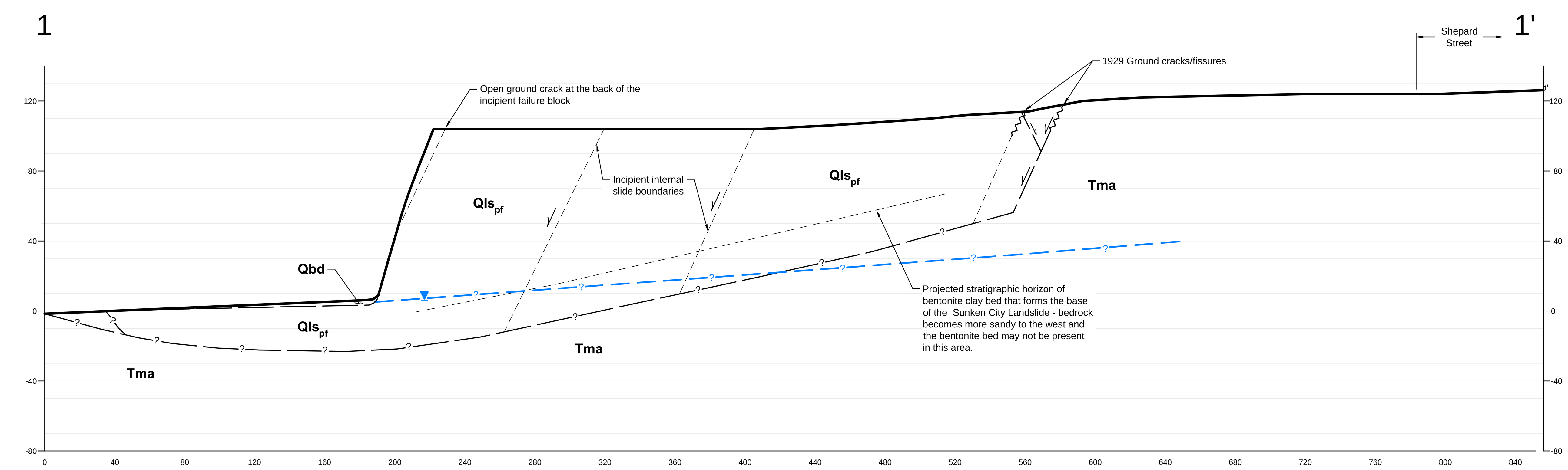
Basemap modified from topographic CAD file and aerial photo provided by City of Los Angeles, Department of Public Works.

GEOLOGIC MAP
Sunken City Project
Point Fermin
San Pedro, California

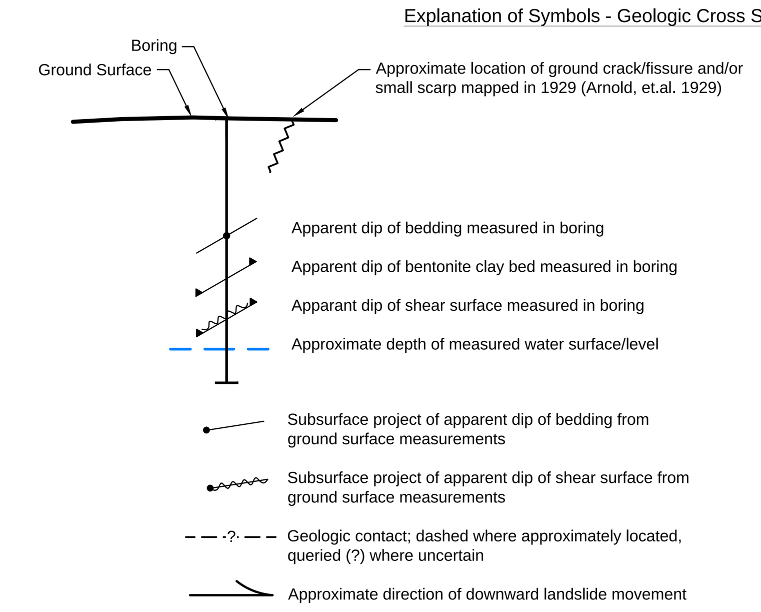
amec foster wheeler

Date: December 2016	Project No. IR16166090	Plate
Submitted By: stk	Drawn By: pah	1

Plot Date: 5/09/2016 4:11:54 PM, Plotted by: pat.herring
Drawing Path: Y:\IR16166090\ACAD_TB_001-GEOLOGY.DWG, Plate 1-Geology Map

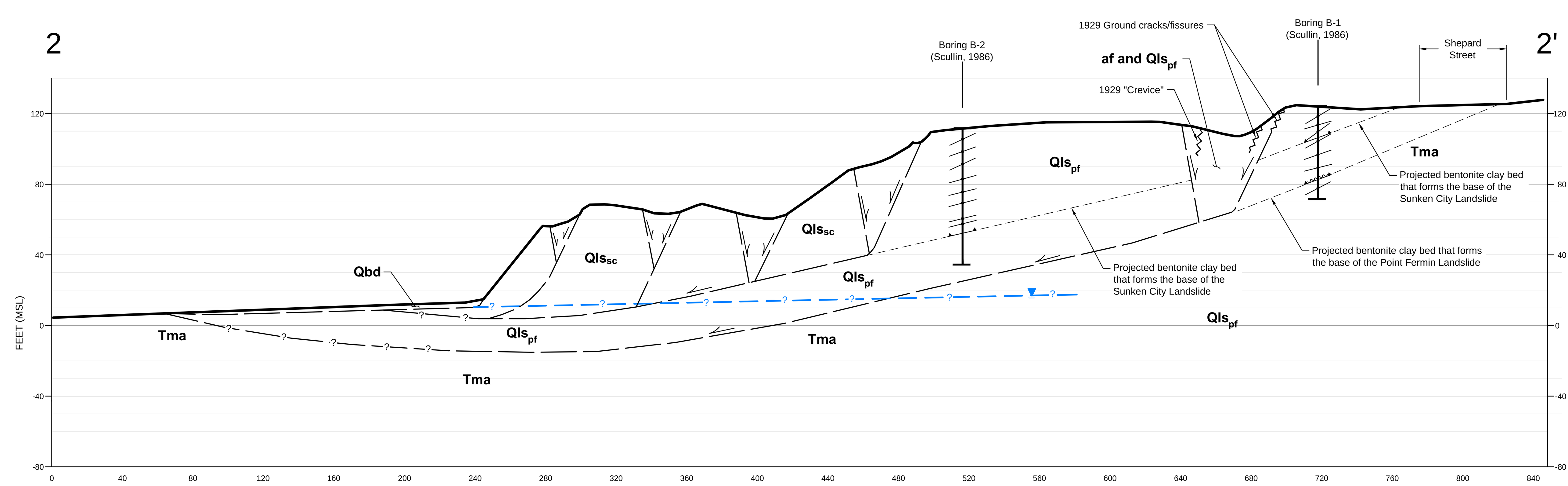


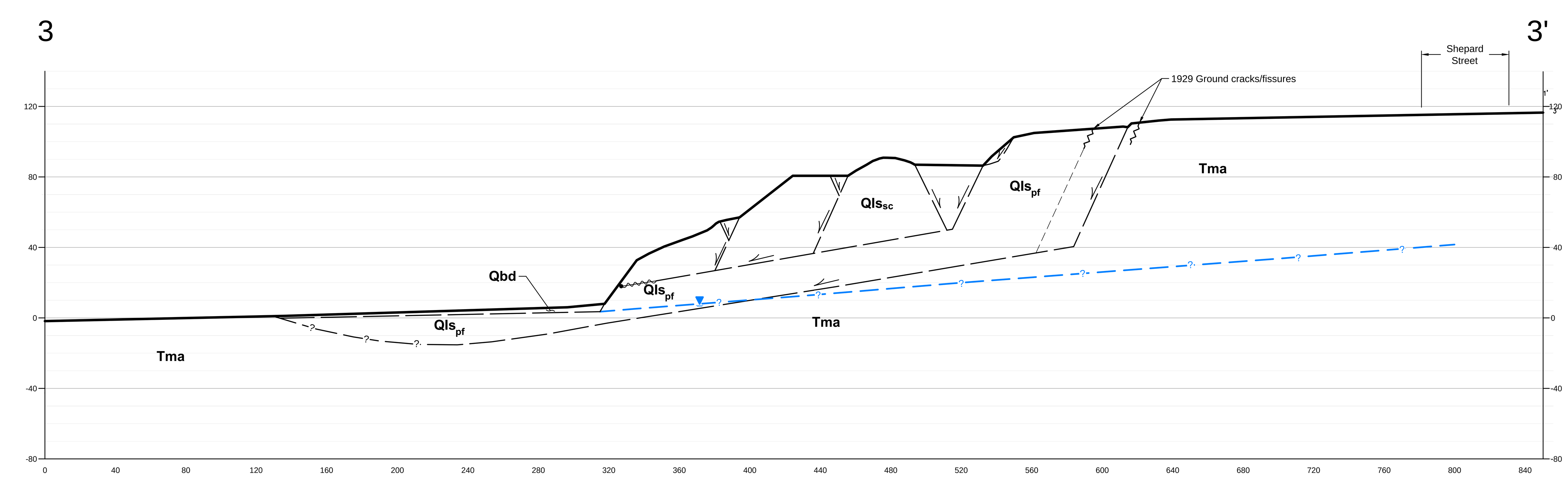
Explanation of Symbols - Geologic Cross Sections

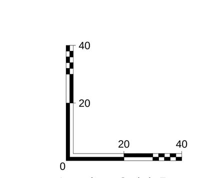


af Artificial/man-made fill
Qbd Beach deposits
Qls$_{sc}$ Landslide (Sunken City)
Qls$_{pf}$ Landslide (Point Ferman)
Tma Monterey Formation - Altamira Shale Member

Note: Unless otherwise noted, projection of map and boring data is perpendicular to the line of section.







GEOLOGIC CROSS-SECTIONS
Sunken City Project
Point Fermin
San Pedro, California

amec foster wheeler

Date: December 2016	Project No. IR16166090	Plate
Submitted By: skt	Drawn By: pah	2

OINT FERMIN LANDSLIDE AREA - GROUND FAILURE HAZARD ZONES

Explanation

Approximate location of primary existing trail

Approximate location of remnant concrete slabs from Paseo Del Mar roadway

North side of Paseo Del Mar roadway Right-of-Way

EXTREME HAZARD ZONE - the presence of pervasive dilated fracturing within the bedrock comprising these relatively high, very steep slopes indicates a potential for life-threatening catastrophic failure that could occur at any time, affecting both the area above/behind, and also below the slope.

HIGH HAZARD ZONE - disturbance of the bedrock fabric from the extended period of ground movement within the landslide makes these relatively steep slope areas highly susceptible to shallow failure and/or rockfalls, primarily affecting areas on or below the slope.

HAZARD ZONE - relatively large horizontal and vertical ground displacements within these portions of the landslide have broken the slide mass into a myriad of blocks with intervening ground cracks and extensional zones, thus reducing much of the bedrock to rocky or blocky debris; these ground cracks and extensional zones are subject to local ground collapse and the slide debris is subject to shallow failure in areas with significant slope gradients.

N

40 20 0 40

Approximate scale in feet

Basemap modified from topographic CAD file and aerial photo provided by City of Los Angeles, Department of Public Works.

GROUND FAILURE HAZARD ZONES
Sunken City Project
Point Fermin
San Pedro, California

amec foster wheeler

Date: December 2016	Project No. IR16166090	Plate
Submitted By: stk	Drawn By: jrw/pah	3

APPENDIX A

Point Fermin Landslide, Scullin, 1987

POINT FERMIN LANDSLIDE
San Pedro Area, City of Los Angeles, California

Michael Scullin
Robert Stone & Associates, Inc.
15414 Cabrito Road, Unit A
Van Nuys, CA 91406-1439

ABSTRACT

The historical Point Fermin Landslide comprises approximately 10.5 ± acres. The original landslide took place in 1929 with activation of the easterly portion in 1940-41, 1950 and with continuous movement since 1978. The slide started as a simple block slide. The eastern part is broken into numerous subblocks, some of which rotate backwards as they move seaward. The slide was caused by wave erosion undercutting thin seaward-dipping bentonite clay beds in the Altamira Shale. Stabilization for development is considered impractical at the present time. The extensive earthwork required to remove and support the existing active landslide cannot be justified without a large density development or high rise hotel, restaurant and so forth.

GENERAL SETTING

The Point Fermin Landslide is located along the coastal area of the City of Los Angeles, California, 2-1/4 miles south of the Palos Verdes Peninsula. The subject landslide is located on top of a marine terrace with a south facing slope. The head scarp and graben pass through the northerly portion of the overall site. Site drainage is into the slide grabens or south into the ocean.

Review of the City of Los Angeles records of the Point Fermin Landslide provided little previous records relative to geotechnical inspection or investigation, geologic or soil reports regarding instabilities within the site area. Researching the files of the City of Los Angeles produced several reports of the original slide activity, but nothing recent. Table I, table of survey lines "A" to "H" inclusive is attached; it shows the downward and outward movement of the original sliding between April 23, 1929 and October 31, 1929. Search of the City Survey records revealed no additional lines, no resurveys of the same lines, not even the records of the original surveys indicating that these surveys may have been let out to private surveyors without recent follow-up nor maintenance of the field books as public record.

The City of Los Angeles, Department of Recreation and Parks has taken over the Point Fermin Landslide. A nature trail was dedicated October 4, 1975. The 16-acre Point Fermin bluff area is covered with a variety of plants and more than 200 species of birds have been sited. Whales, seals and sea lions can be seen from the trail. There are 10 information stops along the trail for field trip groups and numerous geology classes visit the site area.

POINT FERMIN LANDSLIDE - HISTORICAL RECORD

The first report on the Point Fermin Landslide was by Ransome (1929). He indicated that the landslide was first noticed on January 2, 1929, when a water line broke under the Ocean View Inn on Paseo del Mar, about 200 feet west of Carolina Street. On January 10, 1929, a gas line broke in the same building. Breaking of water lines, street improvements, and dislocation of residences and garages continued through most of 1929. Survey line "C" appears to be through the vacant lot near the center of the landslide. Miller (1931) stated that it was found that, to June 18, 1930, the middle portion of the sliding block had moved seaward 7.66 feet. During the same time, the western portion of the block had moved seaward 8.11 feet and the eastern portion had moved seaward 7.52 feet. The original outward or seaward movement of the slide block was accompanied by much less downward movement, ranging from less than a foot to about 2-1/2 feet.

A subsequent geologic report to the City of Los Angeles by Arnold and others (1929) shows the original crevices and deep cracking and the geologic structure in relation to the city survey lines "A" through "H". Their geologic map is Figure 2. It also shows the residences and buildings dislocated by the slide. The original historical slide encompassed approximately 10.5± acres. It was 1,150 feet long in a southwesterly direction and 400 to 500 feet wide in a north-south direction.

The geologic environment of the Point Fermin Landslide described by Arnold and others (1929) indicates the presence of a plunging anticline along the eastern edge of the block and a syncline along the western end. This indicates that the movement takes place on the west flank of the anticline. The dips generally range from 10 to 25 degrees and average 15 degrees. The dip is generally seaward with variations within the slide blocks. Arnold and others (1929) indicate that a Coast and Geodetic Survey chart shows a shallow area extending southward from the region of the slide block for a distance of 2,000 feet. This block lies only 3 feet below mean low tide at a distance of 1,500-2,000 feet from shore line. It appears to be a part of a fault block of which the landslide is a part.

The deep-seated character of the movement is also indicated by gas seepages which occurred in the crevices in the sea beach along the axis of the anticline. This gas was apparently natural and in connection with the many veins of asphalt

CITY OF LOS ANGELES SURVEY MEASUREMENTS

POINT FERMIN LANDSLIDE

Out means horizontal - Down means vertical

Measurements in hundredths of a foot

1929	Line A		Line B		Line C		Line D		Line E		Line F		Line H	
	OUT	DOWN	OUT	DOWN	OUT	DOWN	OUT	DOWN	OUT	DOWN	OUT	DOWN	OUT	DOWN
Apr. 23	.66	.12	.66	.12	.66	.12	.66	.12	.66	.12				
May 15	.04	.00	.12	.03	.11	.04	.11	.05	.16	.05				
Total	.70	.12	.78	.15	.77	.16	.77	.17	.82	.17				
May 24	.03	.00	.06	.02	.09	.02	.08	.03	.07	.01				
Total	.73	.12	.84	.17	.86	.18	.85	.20	.89	.18				
June 3	.03	.00	.04	.02	.05	.02	.07	.01	.07	.03				
Total	.76	.12	.88	.19	.91	.20	.92	.21	.96	.21				
June 12	.07	.01	.07	.01	.05	.00	.05	.01	.10	.01				
Total	.83	.13	.95	.20	.96	.20	.97	.22	1.06	.22				
June 19	.03	.02	.06	.01	.09	.02	.05	.03	.06	.01	.20			
Total	.86	.15	1.01	.21	1.05	.22	1.02	.25	1.12	.23	.20			
June 26	.05	.01	.05	.03	.05	.02	.12	.04	.08	.03	.10	.01		
Total	.91	.16	1.06	.24	1.10	.24	1.14	.29	1.20	.26	.30	.01		
July 2	.05	.00	.04	.00	.09	.03	.06	.03	.07	.06	.08	.01		
Total	.96	.16	1.10	.24	1.19	.27	1.20	.32	1.27	.32	.38	.02		
July 8	EARTHQUAKE													
July 10	.08	.03	.12	.05	.15	.06	.16	.02	.19	.04	.17	.01		
Total	1.04	.19	1.22	.29	1.34	.33	1.36	.34	1.46	.36	.55	.03		
July 17	.09	.00	.11	.05	.14	.03	.16	.10	.13	.06	.17	.05	.10	
Total	1.13	.19	1.33	.34	1.48	.36	1.52	.44	1.59	.42	.72	.08	.10	
July 24	.13	.06	.19	.06	.18	.09	.18	.11	.24	.08	.23	.01	.18	.03
Total	1.26	.25	1.52	.40	1.66	.45	1.70	.55	1.83	.50	.95	.09	.28	.03
July 31	.13	.02	.19	.05	.19	.02	.19	.04	.15	.08	.17	.04	High Water	
Total	1.39	.27	1.71	.45	1.85	.47	1.89	.59	1.98	.58	1.12	.13		
Aug. 7	.14	.04	.26	.09	.24	.09	.25	.10	.27	.04	.28	.03	High Water	
Total	1.53	.31	1.97	.54	2.09	.56	2.14	.69	2.25	.62	1.40	.16		
Aug. 14	.24	.04	.19	.14	.30	.10	.33	.12	.39	.13	.30	.04	High Water	
Total	1.77	.35	2.16	.68	2.39	.66	2.47	.81	2.64	.75	1.70	.20		
Aug.21	.29	.06	.41	.18	.50	.13	.47	.18	.47	.21	.60	.04	1.57	.10
Total	2.06	.41	2.57	.86	2.89	.79	2.94	.99	3.11	.96	2.30	.24	1.85	.13
Aug. 28	.15	.05	.28	.09	.21	.08	.22	.12	.19	.13	.13	.03	High Water	
Total	2.21	.46	2.85	.95	3.10	.87	3.16	1.11	3.30	1.09	2.43	.27		
Sep. 5	.22	.04	.31	.23	.32	.09	.31	.12	.46	.16	.46	.05	.26	.10
Total	2.43	.50	3.16	1.18	3.42	.96	3.47	1.23	3.76	1.25	2.89	.32	2.11	.23
Sep. 11	.45	.10	.60	.09	.47	.21	.58	.27	.53	.31	.57	.05	High Water	
Total	2.88	.60	3.76	1.27	3.89	1.17	4.05	3.50	4.29	1.56	3.46	.37		
Sep. 13	EARTHQUAKE													
Sep. 18	.26	.06	.31	.12	.35	.09	.38	.16	.36	.25	.58	.06	.88	.16
Total	3.14	.66	4.07	1.39	4.24	1.26	4.43	1.66	4.65	1.81	4.04	.43	2.99	.39
Sep. 25	.20	.04	.38	.06	.24	.06	.30	.07	.30	.10	.20	.03	High Water	
Total	3.34	.70	4.45	1.45	4.48	1.32	4.73	1.73	4.95	1.91	4.24	.46		
Oct. 2	.11	.00	.07	.03	.13	.03	.11	.06	.11	.08	.20	.03	.34	.09
Total	3.45	.70	4.52	1.48	4.61	1.35	4.84	1.79	5.06	1.99	4.44	.49	3.33	.48
Oct. 9	.04	.03	.08	.05	.08	.02	.03	.03	.08	.05	High Water			
Total	3.49	.73	4.60	1.53	4.69	1.37	4.87	1.82	5.14	2.04				
Oct. 16	.06	.01	.09	.03	.08	.02	.07	.00	.06	.03	.20		.14	
Total	3.55	.74	4.69	1.56	4.77	1.39	4.94	1.82	5.20	2.07	4.64		3.47	
Oct. 23	.06	.02	.08	.02	.08	.05	.07	.06	.08	.04	High Water			
Total	3.61	.76	4.77	1.58	4.85	1.44	5.01	1.88	5.28	2.11				
Oct. 30	.02	.01	.09	.03	.05	.02	.09	.02	.06	.03	.13	.02	.13	.03
Total	3.63	.77	4.86	1.61	4.90	1.46	5.10	1.90	5.34	2.14	4.77	.51	3.60	.51

TABLE 1: Measurements of ''downward'' and ''outward'' movement of the Point Fermin landslide during 1929. Lines A to H are shown on Figure A.

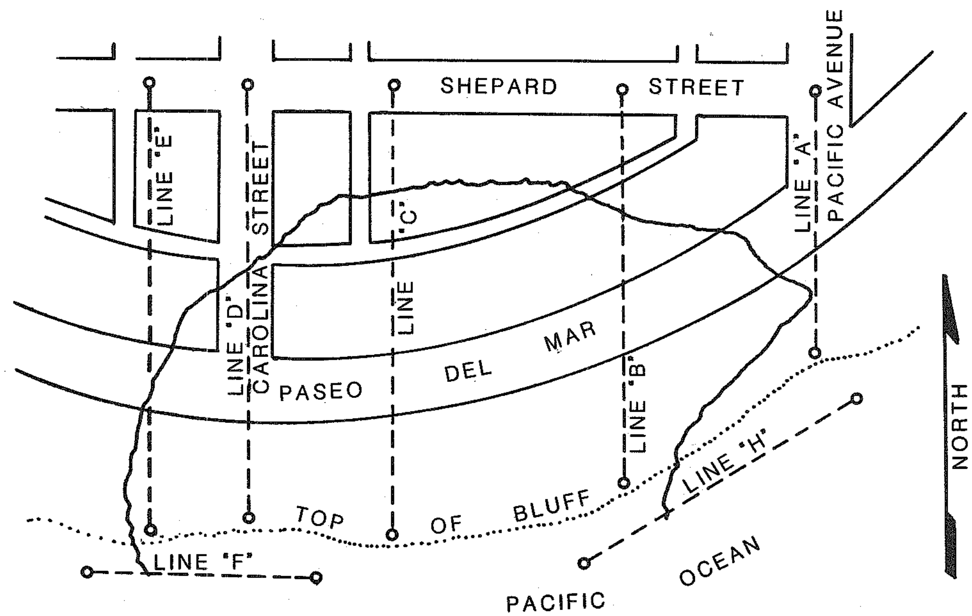


FIGURE A: 1929 Survey lines A-H, City of Los Angeles.

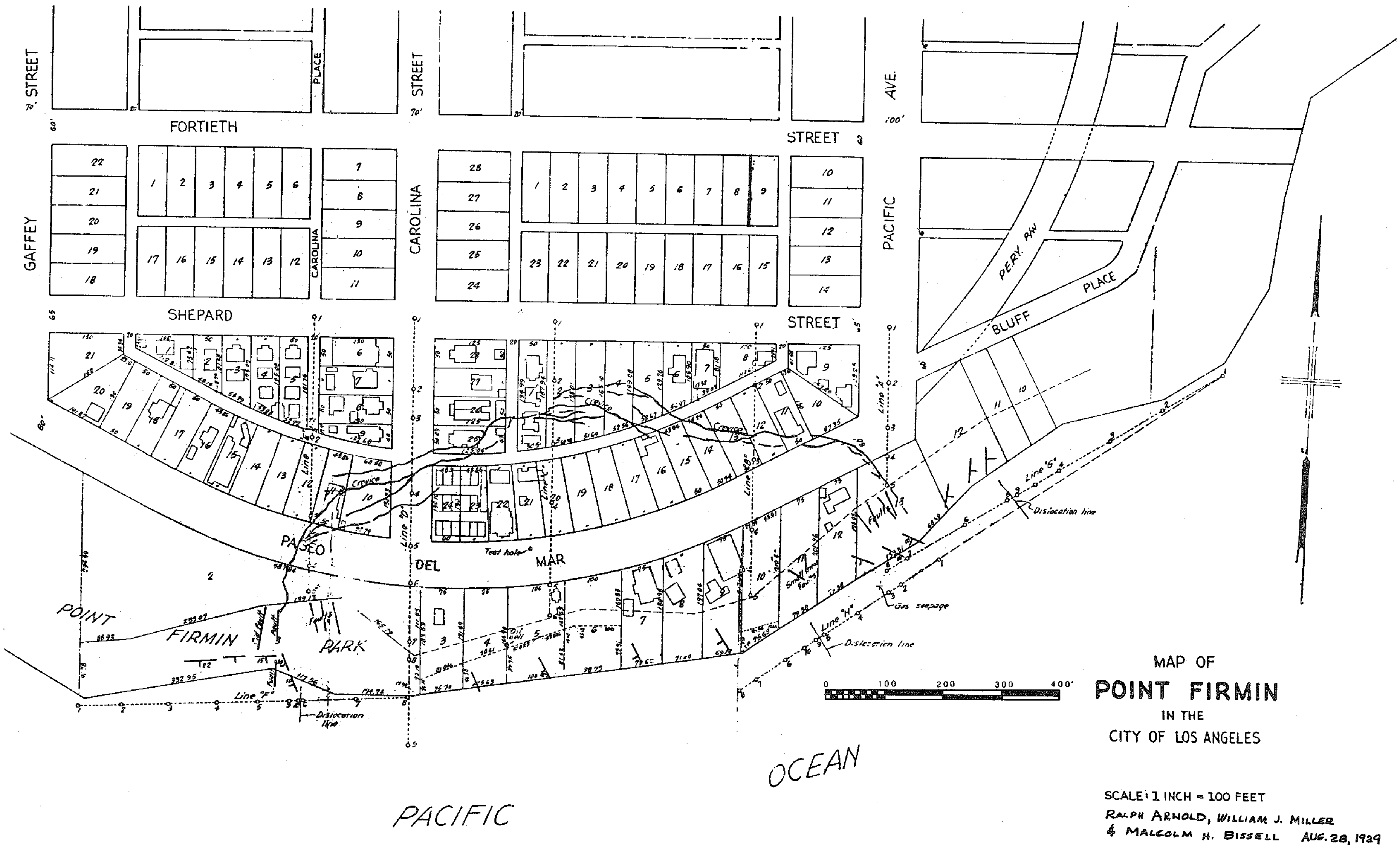


FIGURE 1: Point Fermin landslide as mapped by Arnold and others in 1929. (Note error in spelling of name).

penetrating the beds clearly shows the profound character of the fissures bringing the asphalt and gas to the surface. Tar of natural origin along joints in the Altamira Shale is common along the south coast of the Palos Verdes Hills.

Ransome (1929) also indicated the presence of moisture in the rocks, as shown by a belt of dampness and water seepage along the lower portion of the sea cliff in front of the disturbed area. Both Ransome (1929) and Arnold and others (1929) inferred that the faulting and broken character of the ocean bluff in front of the Point Fermin slide suggests that some movement took place before the area was inhabited and consequently that the movement recorded in cracked pavements and displaced foundations is merely a resumption of an older movement that has not been as large.

Ehlig and Ray (1982) indicated that the seaward movement of the landslide created a fissure 5 to 10 feet wide along the head which was filled with fossiliferous San Pedro Sand from Second and Beacon Streets. The slide reactivated in 1940 and 1941. Since about 1950, the eastern half of the slide has experienced frequent reactivation as wave erosion continues to remove the toe. Since the 1978 rains, the eastern portion appears to have undergone nearly continuous movement. Although the slide started as a simple block glide, the eastern part is broken into numerous subblocks, many of which rotated backward as they moved seaward. The slide was caused by wave erosion which undercut a thin seaward-dipping bentonite bed in the Altamira Shale. When wave erosion has removed debris, the bentonite bed can be seen along the easterly edge of the slide where it cuts diagonally across the face of the cliff.

The bentonite bed underlies sandstone beds which are resistant to development of shear surfaces across them and therefore have been buckled upward at the southwest corner of the slide. Most of the slide mass is composed of sandstone derived from a glaucophane schist source to the east and siliceous shale. Although bedding has an average seaward dip of about 15 degrees in this area, the sandstone and shale have sufficient strength to support the nearly vertical sea cliff. Ehlig and Ray (1982) state that a thick sandstone bed containing slump blocks and "rip-up" clasts forms a distinctive stratigraphic horizon several feet above the base of the landslide. This was probably formed by turbidite deposits on a submarine fan. Such features are unrelated to modern sliding.

POINT FERMIN LANDSLIDE
LOTS 3 AND 4, PECKS OCEAN VIEW TRACT

Lots 3 and 4 are located at the northerly extension of the head-scarp and at the approximate center of the original sliding (Figure 6). The crown head-scarp of the Point Fermin slide passes through the middle of lots 3 and 4. It is understood that the graben fissures were filled in 1929 to reduce surface water infiltration into the subsurface. No trenches or drill-holes were excavated in this area due to poor access. The slide-scarp bluff is a steep 1/2:1 or 1:1 slope with timbers holding the soils together. A wood timber stairway has been constructed for access into the graben area. This area has been landscaped into a garden with fruit trees, shrubs, flowers, and evergreen trees.

Boring B-1 was located on a pad area near the head-scarp slope. It was drilled to 53 feet depth and penetrated the landslide plane at 39.5 feet to 41.5 feet depth. Boring B-2 was located in the City of Los Angeles Department of Recreation and Parks property directly south of the subject site and Boring B-1. It is adjacent to the active eastern landsliding. Boring B-2 was terminated at 77 feet depth due to hard drilling. It did not penetrate the slide plane; however, it did extend through the tuffaceous sandstone with lapilli marker bed that is 17 feet to 19 feet above the bentonitic clay slide plane. The lithology of the stratigraphic section is similar in Borings B-1 and B-2 and also to the landslide blocks exposed in the bluffs southerly of Pacific Avenue. A copy of the lithology described by Cathy L. Conrad, Department of Geology, California State University Los Angeles, California 90032, is attached (Figure 4) for comparison with the stratigraphic units described on our Cross-Section A-A' (Figure 8) and our drilling logs (Figures 7A and 7B). Based upon the correlation of the above, we assume that the landslide plane is at 85 feet to 87 feet depth at the Boring B-2 location. Another marker bed is a 1/2 inch to 1 foot bentonitic clay interbed located 25 feet to 26.5 feet above the slide plane. These marker beds, particularly the tuffaceous sandstone with lapilli are well exposed in the sea bluff above the slide plane and above the beach at the toe of the slide. The slide plane beneath the subject property varies from 10 feet ± depth at the front property line to approximately 50 feet ± depth at the rear property line. There is approximately 380 feet ± length of landslide mass, 75 feet to 80 feet ± thick between the rear property line of Lots 3 and 4 and the ocean. The slide plane extends up toward Shepard Street at a 20° angle and would daylight near the center line of the street if it surfaced at that angle.

EARTH MATERIALS

The site area is underlain by a thick topsoil (ts), landslide debris, porcelanite, dolostone, siltstone, and shale of the Altamira Shale member of the Monterey Formation of Middle Miocene Age.

TOPSOIL (ts)

Topsoil composed of clayey silt and silty clay overlies the site. These soils are dark brown to gray brown, contain shale fragments and siltstone chips. They are massive, moist to wet and firm. Desiccation cracks indicate the expansive potential. Soil tests indicated an expansive index of 104 and is classified as high according to the U.B.C. Expansive Index Test; U.B.C. Standard 29-2.

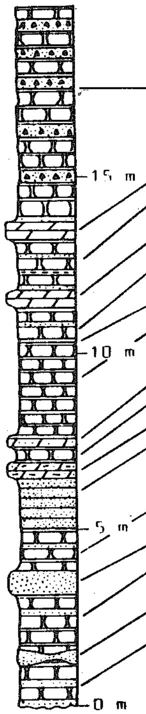
ALTAMIRA SHALE (Tma)

The site is underlain by the Altamira Shale member of the Monterey Formation. Within the site area, the bedrock is composed of clayey siltstone, sandy siltstone, cherty shale, porcelanite, dolostone, silty sandstone, tuffaceous sandstone with lapilli, sandstone derived from glaucophane schist and minor bentonitic clay. The weathered bedrock is light gray, tan and rust. The unweathered is gray, bluish gray, dark gray-black, dark gray blue and gray brown. It is moist to wet,

Figure 2. The active eastern portion of the Point Fermin Landslide. The photograph was taken from 500' elevation, looking north at 08:10 on November 24, 1959. The photograph (#3172) is courtesy of John S. Shelton of La Jolla, California.

Figure 3. The photograph is looking westerly at the overall Point Fermin Landslide showing the active easterly portion. Shepard Street northerly of the landslide and the southerly end of Pacific Avenue and parking lot is in the right hand portion of the photograph. The photograph (#74311, 1974) is by John Shadle, photographer; courtesy of the City of Los Angeles, Department of Building and Safety.

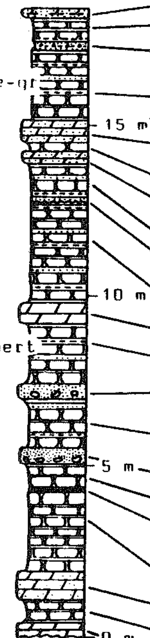
POINT FERMIN LITHOFACIES



Tuffaceous(?) Lithofacies
West side of Point Fermin

Thickness in meters	Lithology
6.10	porcelanite, light gray, interbedded with tuffaceous sandstone
.49	laminated dolostone
1.44	siltstone, porcelanite, sandstone, gray, coarse-gr
.43	laminated porcelanite, dolostone
.85	laminated porcelanite and poorly consolidated sandstone
.10	sheared bentonite, thickens to 30 cm
2.62	porcelanite
.30	sandstone, dolomitic sandstone
.43	porcelanite
.52	siltstone, dolomitic siltstone
1.41	sandstone and conglomerate, contains clasts of glaucophane schist, vein quartz, and metachert derived from Catalina Schist.
1.12	porcelanite and sandstone
.69	sandstone, forms ledge
1.57	porcelanite, minor sandstone
.43	sandstone, contains clasts of Catalina Schist origin, pinches and swells
1.21	porcelanite, sandstone, dolostone

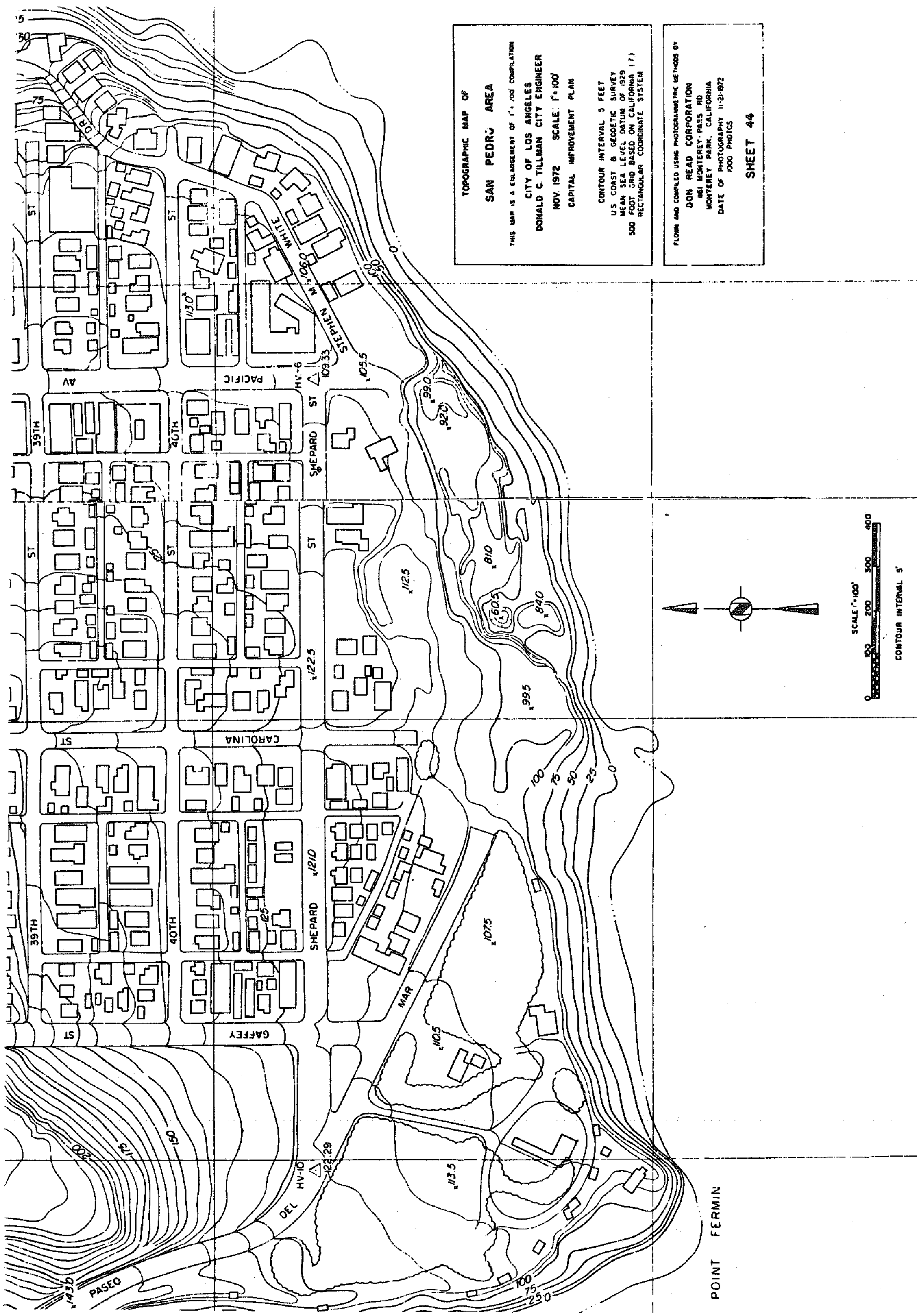
base of exposed section



East side of Point Fermin

Thickness in meters	Lithology
.26	dolomitic siltstone, laminated, yellow-brown
.66	laminated porcelanite, siltstone
.23	tuffaceous sandstone, granule layers at top and bottom with fine-grained sandstone near center
2.07	laminated porcelanite, siltstone, minor sandstone containing clasts of Catalina Schist origin.
.62	dolomitic siltstone, laminated, breaks into flagstone-like pieces
.26	porcelanite
.33	dolomitic siltstone
1.08	porcelanite, siltstone
.03	bentonite, slide plane base of Point Fermin landslide
2.95	porcelanite
.59	blocky dolostone
1.77	porcelanite
.39	sandstone containing rounded shale clasts up to .3 meters in length
1.41	laminated porcelanite with thin interbeds of sandstone containing clasts of Catalina Schist origin.
.46	sandstone containing rip-up clasts of shale
.75	porcelanite
.03	bentonite seam, light cream, overlain by 12 cm thick orange-brown stained zone
2.36	porcelanite
.75	laminated dolomitic siltstone
.62	porcelanite, honey-brown where fresh
.43	dolomitic siltstone, weathers yellow-brown

FIGURE 4: Lithofacies of the west and east sides of Point Fermin (Conrad, *in* Scullin, 1986). Compare boring logs B-1 and B-2 (Figure 7) with "east side" lithofacies.


TOPOGRAPHIC MAP OF
SAN PEDRO AREA
THIS MAP IS A ENLARGEMENT OF 1" = 200' COMPILATION
CITY OF LOS ANGELES
DONALD C. TILLMAN CITY ENGINEER
NOV. 1972 SCALE: 1" = 100'
CAPITAL IMPROVEMENT PLAN
CONTOUR INTERVAL 5 FEET
U S COAST & GEODETIC SURVEY
MEAN SEA LEVEL DATUM OF 1929
500 FOOT GRID BASED ON CALIFORNIA (7)
RECTANGULAR COORDINATE SYSTEM
FLOWN AND COMPILED USING PHOTOGRAMMETRIC METHODS BY
DON READ CORPORATION
1161 MONTEREY PASS RD
MONTEREY PARK, CALIFORNIA
DATE OF PHOTOGRAPHY 11-21-1972
1000 PHOTOS
SHEET 44
SCALE 1" = 100'
CONTOUR INTERVAL 5'
39TH ST
40TH ST
SHEPARD ST
PACIFIC AV
CAROLINA ST
GAFFEY ST
STEPHEN M WHITE DR
PASEO DEL MAR
POINT FERMIN
HV-6
HV-10
109.33
122.29

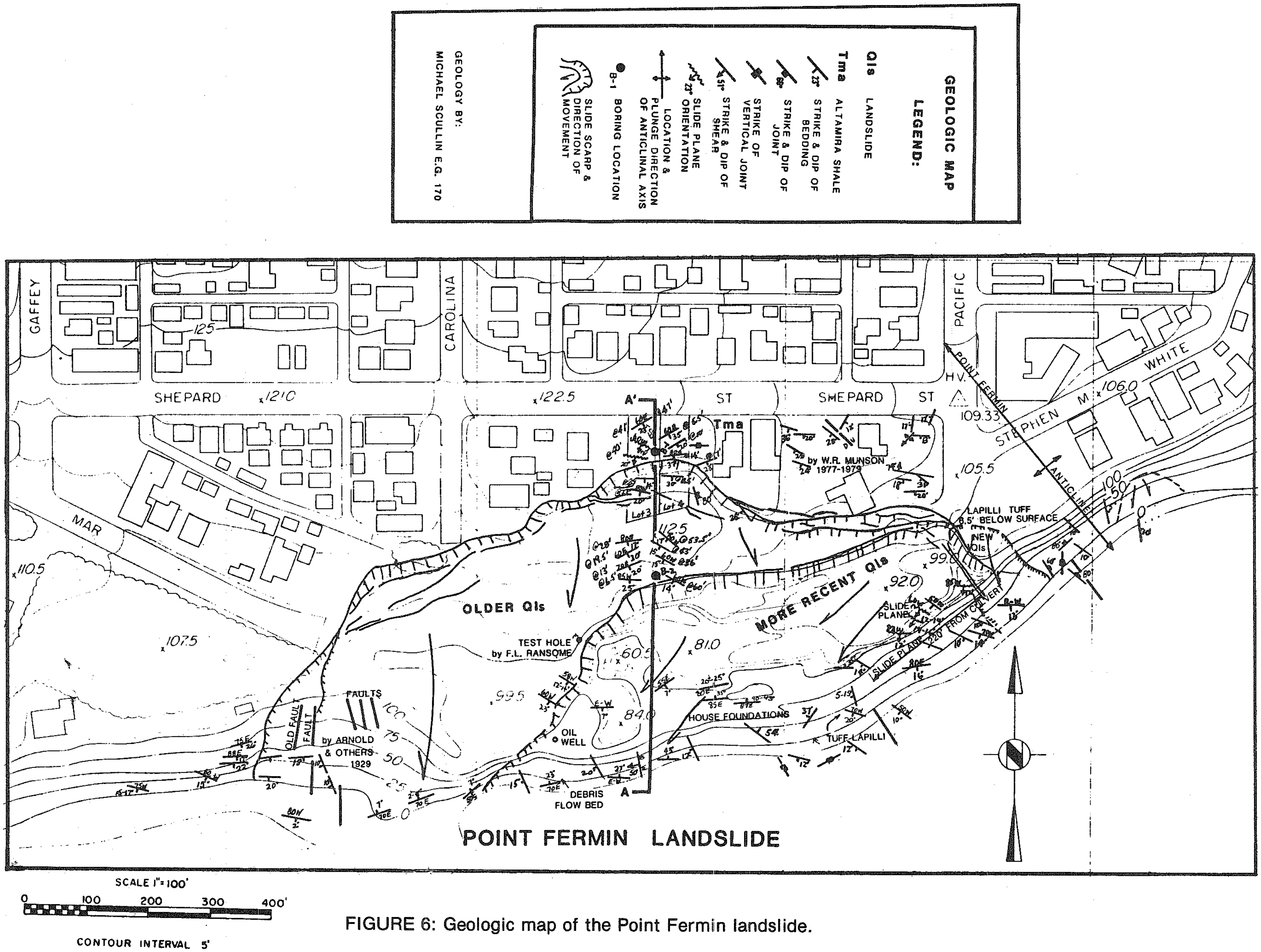
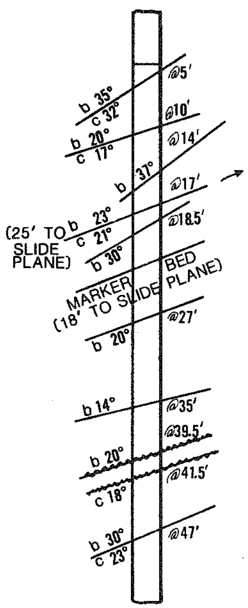


FIGURE 6: Geologic map of the Point Fermin landslide.

BORING B - 1



to 5' ts, Adobe, Silty Clay, dark gray-brown, moist.

@ 5' Clayey Siltstone, gray-dark brown with tan interbeds

Gray sandstone interbeds
Slickensided silty clay beds, highly fractured

@ 12' Yellow-rust Clayey Sand
1/2" Bentonitic Clay - marker bed

Tuffaceous Clay; gypsum crystals

Porcelanite; laminated , cherty siltstone, white sandstone interbeds, gray and rust-brown, tan

@ 20' Dolostone interbed

@ 22' Tuffaceous Siltstone and Lapilli Sandstone - marker bed

Porcelanite with siltstone and gypsum

@ 25' Gray and rust Clayey Siltstone, soft clay interbeds, tar, thin bedded, well bedded

@ 28.5' Dolostone

@ 30' Broken Clayey Silt, crushed siltstone and dolostone fragments, broken siltstone

@ 37' Dolostone

@ 39.5' Bentonitic Clay; light tan, slickensided, landslide plane

@ 42' Dolostone, black cherty shale and gypsum

@ 43' Clayey Siltstone, crushed silty clay, blue silty sandstone

@ 46' Porcelanite, blue gray, tight
Blue gray/black with blue sandstone interbeds

@ 48' Seepage easterly side of hole

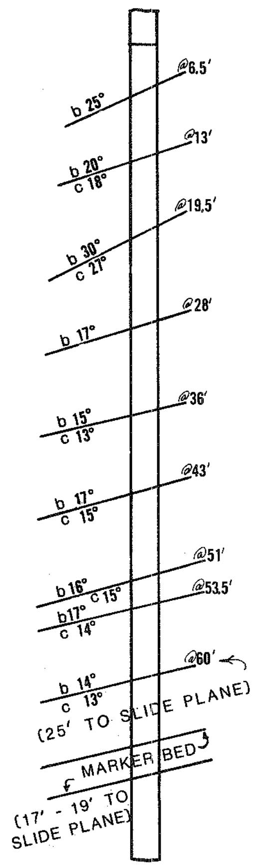
Porcelanite, blue gray, tight with blue sandstone interbeds

T.D. 53'

SCALE: 0 5' 10' 15' 20'

GEOLOGY BY: MICHAEL SCULLIN C.E.G. 170

BORING B - 2



@ 3' ts, Adobe, Silty Clay, dark gray-brown, moist-wet

@ 6.5' Clayey Siltstone, light gray silty fine sandstone interbeds with gravel, occasional cobbles & clay interbeds

Sandy Siltstone, rust with silty sandstone interbeds, very tight, massive with caliche

@ 13' Clayey siltstone, gray sandstone interbeds, thin bedded with caliche

@ 20' Dolostone
Cherty shale

@ 22' Porcelanite, oil residue and tar on joints, very tight gypsum and cherty

@ 26' Sandy Siltstone, oil residue and tar on joints, very tight

@ 30' Clayey Siltstone, calcium veins & caliche bentonitic clay interbed slightly crushed sandy siltstone, tight

@ 34' Porcelanite, bluish gray, tight

@ 38' Dolostone, very hard & tight

@ 39' Porcelanite with chert, dark gray, very tight

@ 43' Siltstone/Claystone, gray & brown, well bedded, thin bedded, gypsum, very tight
dark gray & black, white caliche & gypsum

@ 48' Porcelanite with siltstone interbeds, dark gray, very tight, thin bedded, caliche
sandstone interbed, gray

@ 56' Claystone interbed, dark gray siltstone, rust-brown

@ 60' Bentonitic Clay interbed - marker bed
Porcelanite, blue-gray, very tight

@ 66' Tuffaceous sandstone with lapilli - marker bed

@ 67' Dolostone interbed

@ 69' Tuffaceous sandstone with lapilli - marker bed

@ 71' Dolostone

@ 72' Porcelanite, dark gray & blue with siltstone interbeds, very tight, very hard

T.D. - 77'

SCALE: 0 5' 10' 15' 20'

GEOLOGY BY: MICHAEL SCULLIN C.E.G. 170

FIGURE 7: Geologic logs of borings from the Point Fermin landslide. Locations of borings B-1 and B-2 are shown on geologic map (Figure 6) and section (Figure 8).

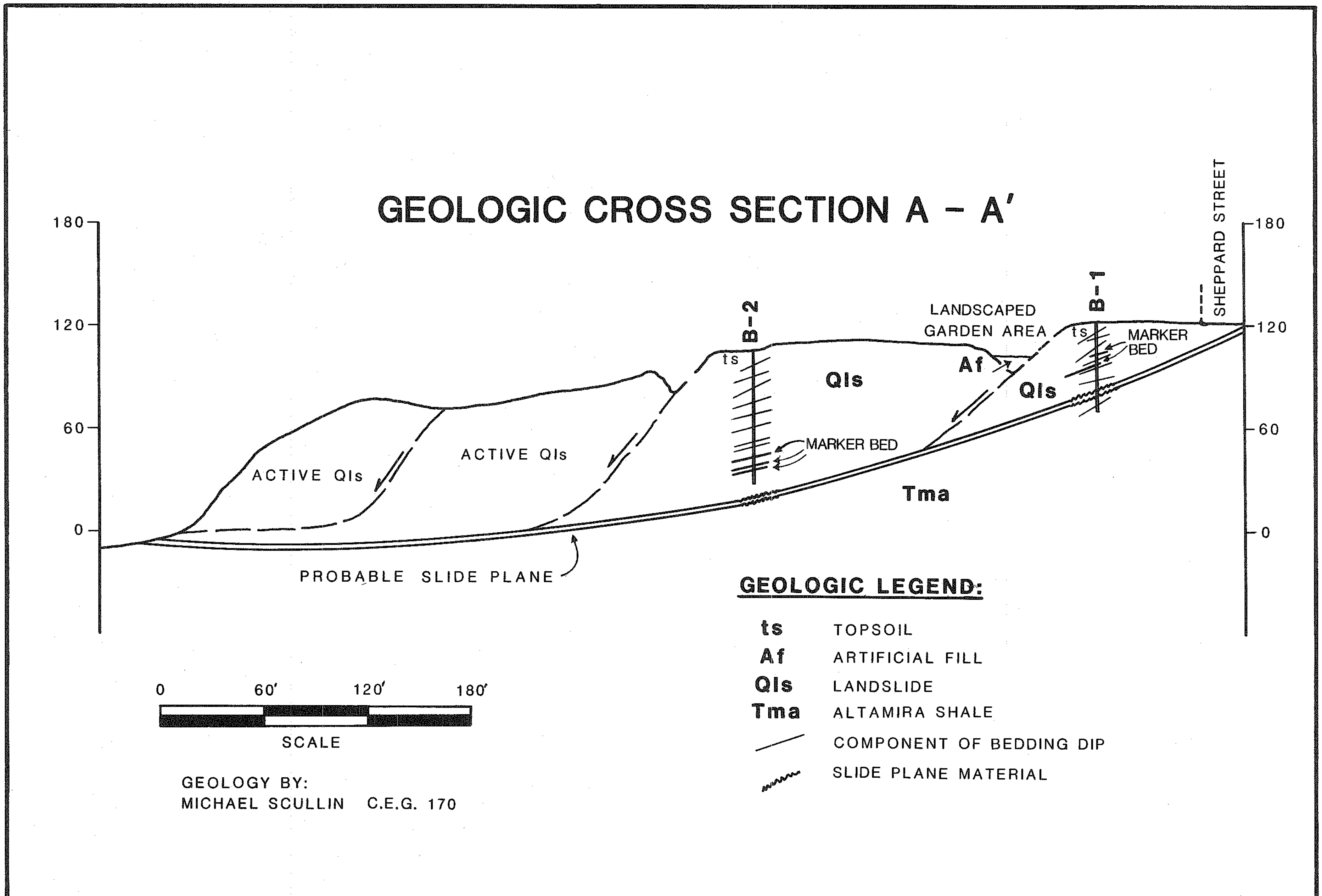


FIGURE 8: Geologic cross section A-A' of Point Fermin landslide. Location of section is shown on map (Figure 6).

tight to very tight and normally thin bedded, well bedded, and contains tar, gypsum, and caliche throughout the upper portions and within the joints in the unweathered portions. Within the borings, the primary bedrock is the clayey siltstone, sandy siltstone, porcelanite and dolostone. In this investigation, the bentonitic clay interbeds were determined to have a shear strength of C = 220 psf and $\phi = 17^{o}$. Tests in other areas nearby exhibit strengths of C = 200 psf and $\phi = 6^{o}$.

GEOLOGIC STRUCTURE

The Palos Verdes Fault is approximately three and one half miles north of the site and the Cabrillo Fault is less than one mile northeasterly of the site. The Point Fermin Anticline is one quarter mile easterly of the site. According to Ransome and Arnold and Others (1929), a syncline borders the westerly portion of the Point Fermin slide. The property is involved within a south-southwesterly dipping block. The trends are consistently N70E to N60W and dip southerly at 15 degrees to 25 degrees. The area geologic map by Woodring and others (1946) indicates south-southwesterly dips adjacent to the site. Bedding planes within the landslide blocks are also oriented N60E to N60W and east-west with dips of 13^{o} - 30^{o} southerly. Strong joints appear to be oriented near north-south and near east-west with steep dips of 70^{o} - 90^{o}.

The original Point Fermin Landslide was a block glide above southerly dipping bentonite clay. The more recent sliding in the easterly portion of the slide is a glide block with the seaward blocks rotating inland. The bentonitic clay slide plane exposed in the sea bluff southerly of Pacific Avenue terminus exhibits orientations of N60-85W, with dips of 12^{o} - 16^{o} southwesterly.

Seepage water was noted along and above the bentonitic clay slide plane on the sea-cliff. Seepage was also noted during our past investigation at 48 feet depth in Boring B-1. No seepage in Boring B-2.

CONCLUSIONS

The Point Fermin Landslide is not considered geotechnically feasible for development without further extensive investigation, evaluation and analysis. Stabilization for development is considered impractical at the present time. The extensive earthwork required to remove and support the existing active landslide cannot be justified without a large density development or highrise hotel, restaurant and so forth, that could financially support it.

GEOTECHNICAL GUIDELINES AND CONSIDERATIONS

1. Although bedding planes dip seaward at an average of $15^{o} \pm$ in the old landslide area, (westerly portion), the sandstone and shale within the westerly Point Fermin park and recreation area appear to have sufficient strength to support the near vertical sea cliff in that area. This sandstone forms a buttress that appears to support the westerly portion of the original landslide.

2. Surface water control, dewatering wells and horizontal drains can increase the stability considerably. It would not be cost effective if only a few single family dwellings were to be built along Shepard Street.

3. Liquefaction hazard potential is considered low in the subject site area. However, it is interesting to note that Miller (1931) indicated that the July 8, 1929 earthquake was followed by a distinctly accelerated movement lasting about two months and reaching a maximum of over five tenths of a foot during the week ending August 21, 1929. Earthquakes and heavy rainy seasons accelerate movement.

4. Earth materials can be excavated with modern earth-moving equipment.

5. There are several vacant lots along Shepard Street. The head-scarp graben is either southerly of or passes through these lots. Shear key buttressing in the graben area would require more than 50 feet depth of removal, recompaction and subdrainage and probably some soldier piles along the street area. This would not be cost effective for single family dwellings.

6. Low to moderate ground shaking is anticipated during the lifetime of future structures and maximum code values should be considered for seismic design.

ACKNOWLEDGEMENTS

I extend my gratitude to Ofra Stauber, Staff Geologist with Robert Stone & Associates, Inc., for typing the manuscript and for geologic drafting. I also thank David Simon and Mark Oborne for reviewing this paper. I am thankful to Ms. Bunny Kussman for review of newspaper articles regarding the Point Fermin Landslide. I am also grateful to Dr. Perry Ehlig for his consultation, both in the field and office, and in sharing his abundant knowledge of the area with us.

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1986 GSACS Guidebooks, Martin L. Stout
Department of Geology
California State University, Los Angeles
Los Angeles, California 90032

APPENDIX B

Report on the Point Firmin [sic] Landslide, Ransome, 1929

Report on the

POINT FIRMIN LANDSLIDE

By

F. L. Ransome.

Contents.

Pasadena, Cal., May 7, 1929.

Mr. John C. Shaw,
City Engineer,
Los Angeles, California.

My dear Mr. Shaw:

I submit herewith my report on the geological conditions near Point Firmin, San Pedro District, Los Angeles, California.

Very truly yours,

F. L. Ransome

Consulting Geologist.

Report on the geological conditions near Point Firmin, San Pedro District, Los Angeles, California.

By F. L. Ransome

Professor of Economic Geology, California Institute of Technology,

Pasadena, Cal.

-.-.-.-.-

The conditions that called for the present examination are certain land movements that are taking place on the ocean front at the south end of San Pedro, a short distance east of the Point Firmin lighthouse. The area involved is shown in the accompanying map.

The Point Firmin suburb of San Pedro is situated principally upon an uplifted sea terrace which, from an elevation of about 150 feet at its northern margin, slopes gently southward to the crest of the present sea-cliff, with an elevation of about 105 feet. The general width of the terrace, from the steeper slope at its rear to the verge of the present sea-cliff, is about 1200 feet. The average slope is accordingly about 1 to 25.

The surface of the terrace is covered with stiff, dark adobe soil, apparently rarely over 4 or 5 feet in thickness, which rests on generally light-colored shales, with interbedded dark-gray sandstones, belonging probably to the Modelo formation, of Miocene age. The dip of these beds, altho variable, is generally southward, at angles between 20 and 25 degrees. In the cliffs, south of Carolina Street, it appears that light-colored, thin-bedded shale is underlain, about half-way down the cliff, by more massive, dark-gray sandstone, which contains occasional lenticular layers composed of irregular blocks of hard calcareous shale, up to 2 feet in diameter. At this locality, the sandstones extend below low-water mark, but as shown in the cliffs west of the lighthouse, they are in turn underlain by more shale, similar in general character to that in the upper part of the cliff, south of Carolina Street.

The area affected by the recent earth movement lies south of the curved line shown in red on the accompanying map. This line is sketched from the results of a detailed survey, represented on a much larger-scale map, prepared by the Engineering Department of the City of Los Angeles. In general, the ground between this curved line and the ocean has moved seaward along the line of Carolina Street, for a distance of approximately 8 inches and downward, at the intersection of Paseo del Mar and Carolina Street, about 2.5 inches.

The first indication of movement was apparently furnished, on January 2, of this year, by the breaking of a water pipe in or under the Ocean View Inn, a small frame structure on the north side of the Paseo del Mar, about 200 feet west of Carolina Street. On January 10, a gas pipe broke in the same building. About the same time cracks were noted in the pavement at various points along the general course of the curved line shown on the map. On March 9, the water main on Carolina Street was pulled apart at a joint for a distance of 1.5 inches. On April 3, it broke again and from 4 to 5 similar breaks have been reported since April 3 to date (April 25). A survey by the Engineering Department, completed on April 8, showed that the center line of Carolina Street, between Shepard Street and the Paseo del Mar, had been extended 0.66 foot (about 8 inches). Surveys at this time showed that the benchmark at Paseo del Mar and Carolina Street had dropped 0.2 foot. On April 19, another survey showed a further extension along Carolina Street of 0.05 foot and an additional lowering of the benchmark by 0.05 foot.

In addition to the damage to water pipes, gas pipes, and pavement, buildings situated on or close to the curved line of fractures, practically all of them small frame dwellings and garages, have been damaged by the pulling apart of their foundations and the cracking of concrete walks and steps.

Altho there has unquestionably been movement of all of the ground between the curved fracture line and the top of the cliffs, this ground has apparently moved as a whole and the displacement has not been sufficient to cause appreciable damage.

On the ocean front the most obvious evidence of disturbance is registered in the cracking and displacement of a concrete stairway that gives access from the public park, along the upper part of the cliffs, to the beach below. This stairway, which runs parallel with the cliff and is built against it, has clearly been thrust seaward by movement of the rock of which the cliff is composed. The bottom of the stairway, which rests on sandstone, does not appear to have been displaced. The region of disturbance lies above the bottom of the flight and the rocks involved are the upper part of the gray sandstone and the overlying shale. That these rocks have recently moved, and probably are still moving, is indicated by numerous gaping fractures and by the dropping of loose fragments onto the stairway.

The rocks exposed along the beach, from the lighthouse to the eastern end of 40th Street are fairly hard sandstone with some layers of hard shale. There is no evidence whatever to indicate that these rocks have had any part in the recent disturbance. They are traversed by some fractures but none of these is an important fault. The maximum displacement along any of them can not exceed 3 inches, and there apparently has been no movement along them for centuries.

The facts observed indicate clearly that the disturbance is a landslide. The entire segment enclosed within the concavity of the fracture line shown on the accompanying map is slipping slowly seaward. The lower limit of disturbance is probably a concave surface that attains a maximum depth of 50 to 60 feet in the face of the sea-cliff and slopes up to the surface along radial lines to its emergence along the visible line of fracture. The curved line of fractures which appear at the surface is a zone of tension cracks which show where the moving mass has separated from the undisturbed ground. If these fractures were followed down they would be found to flatten towards the south and become smaller.

A number of factors have probably contributed to the movement. Among these may be mentioned (1) the generally thin-bedded, fragile character of the shale; (2) additional weakness due to folding and probably earlier faulting of the beds; (3) the prevailing dip of the beds towards the ocean; (4) wave erosion which, by cutting a cliff over 100 feet high brought about a condition under which the softer rocks of the cliff are unstable; (5) the presence of moisture in the rocks, as shown by a belt of dampness and seepage along the lower portion of the sea-cliff in front of the disturbed area; (6) the rather abundant occurrence of gypsum (a readily soluble mineral) as small seams between the layers of the shale and as small veinlets that cut across the shale layers.

Landslides in the Miocene shale have taken place elsewhere along the coast, a notable example being the large slide which extends for a mile along the shore in the vicinity of Portuguese and Inspiration points, about 5 miles northwest of Point Firmin. Here the characteristic hummocky, irregular surface of a typical landslide is plainly recognizable in the topography of the San Pedro Hills sheet (1 to 24000 scale) of the U. S. Geological Survey. The Point Firmin slide has not this broken character. It is still an incipient slide, in which the movement has been too slight to cause any conspicuous modification of the general land surface.

The broken character of the ocean bluff in front of the Point Firmin slide suggests that some movement took place before the district was inhabited and consequently that the movement recorded in cracked pavements and displaced foundations is merely a resumption of an older movement. Nevertheless, the total movement has not been large.

The cause of this renewed creep can probably not be definitely ascertained. It may be that the visible effects represent the culmination of gradually increasing stresses and minute adjustments in an unstable rock mass. The presence of water in such a mass by increasing its weight, by softening the clayey constituents, by decreasing cohesion, and by dissolving soluble constituents such as gypsum, unquestionably diminishes stability. The seepage along the cliffs shows that considerable water is present in the mass. Some of this water may come from the irrigation practiced on the affected area, some may come from leaky water pipes or sewers, and some may represent natural drainage. Should a heavy rainfall occur in the immediate future, considerable water would probably find its way into the open tension cracks and might cause further movement.

It is believed that the principal movement is confined to the shale which is exposed in the upper part of the cliff and that the disturbance observable in the sandstone as exposed in the cliff, beneath the shale, is relatively superficial and represents a spalling off along the cliff face under the weight and thrust of the more mobile shale.

It is entirely conceivable that a mass of rock in a condition of unstability might be set in motion by an earthquake or by the concussion of a heavy explosion. There is no evidence, however, to indicate that faulting, earthquakes or the firing of heavy guns are in any way responsible for the present condition at Point Firmin.

The Point Firmin slide presents two rather puzzling features. The first of these is the rather low angle upon which the slide appears to have taken place. Notwithstanding the general fragility of the shale, the proximity to a high sea-cliff, and other conditions mentioned in the preceding pages, it would scarcely have been expected that the observed movement would occur. The second feature is the apparent absence in the cliffs of any definite surface of movement between the rock in place and the mass that has moved. This last is probably explainable by the supposition that the movement has been distributed thru the fractured rock and the total slip has not proceeded far enough to produce a definite gouge or slip surface at the base of the moving mass.

An interesting feature of the sandstone exposed in the lower part of the sea-cliff, in front of the disturbed area, is the occurrence of asphalt rather generally distributed in small seams or veinlets thru the rock. In some places the asphalt is oozing out of these seams and dropping to the beach. Where cracks have recently been opened by movement of the rock, the asphalt can be seen in the process of viscous flowage into these cracks. The presence of this asphalt probably tends to facilitate movement in the mass, under slowly acting stress. It does not appear probable, however, that there is enough asphalt in the rock to justify the conclusion that its presence is the principal cause of the observed rock movement.

In the slight hope that some significant information might be obtained, a churn-drill hole was put down in the north parking of the Paseo del Mar, about 100 feet east of Carolina St., at an elevation of 112 feet above sea level. The driller's log on May 6, was as follows:

0 - 3 feet	----------	Adobe.
3 - 8 "	----------	Conglomerate.
8 - 21 "	----------	Yellow shale. - Hard.
21 - 37 "	----------	Brown sandy shale.
37 - 56 "	----------	Gray shale.
56 -102 "	----------	Brown shale.

A little seepage of water overnight between 70 and 90 feet. Water at 100 feet.

102 - 122 feet	---------	Coffee-colored shale.
122 - 140 "	---------	Light brown shale.

As there appeared to be no object in drilling deeper, the hole was stopped at 140 feet and the casing plugged so as to permit of future observations on water-level.

The log is not particularly illuminating. The "brown sandy shale" at 21 feet may possibly be the sandstone of the lower part of the cliff. The material from 102 feet down, while showing abundant flakes of shale, also contains a considerable proportion of sand grains. The drillers were unable to recognize any soft clayey seam such as might be interpreted as a surface of movement.

Conclusions.

1. The conditions at Point Firmin are the consequence of a landslide in an early stage of development.

2. Movement is likely to continue altho the rate will probably be slow and intermittent.

3. The access of large quantities water to the landslide area would probably accelerate the movement and might produce

disastrous changes on the surface of the area.

4. The area is not suitable for the erection of large permanent structures.

Recommendations.

It is difficult for the geologist to make recommendations without invading the province of the engineer. The following suggestions, however, are offered for the consideration of the Engineering Department.

1. Surveys should be made at regular intervals to determine the rate of movement.

2. Any open cracks should be filled and protected from the inflow of surface water.

3. A system of drainage should be installed to carry off any water that might otherwise sink deeply into the disturbed area.

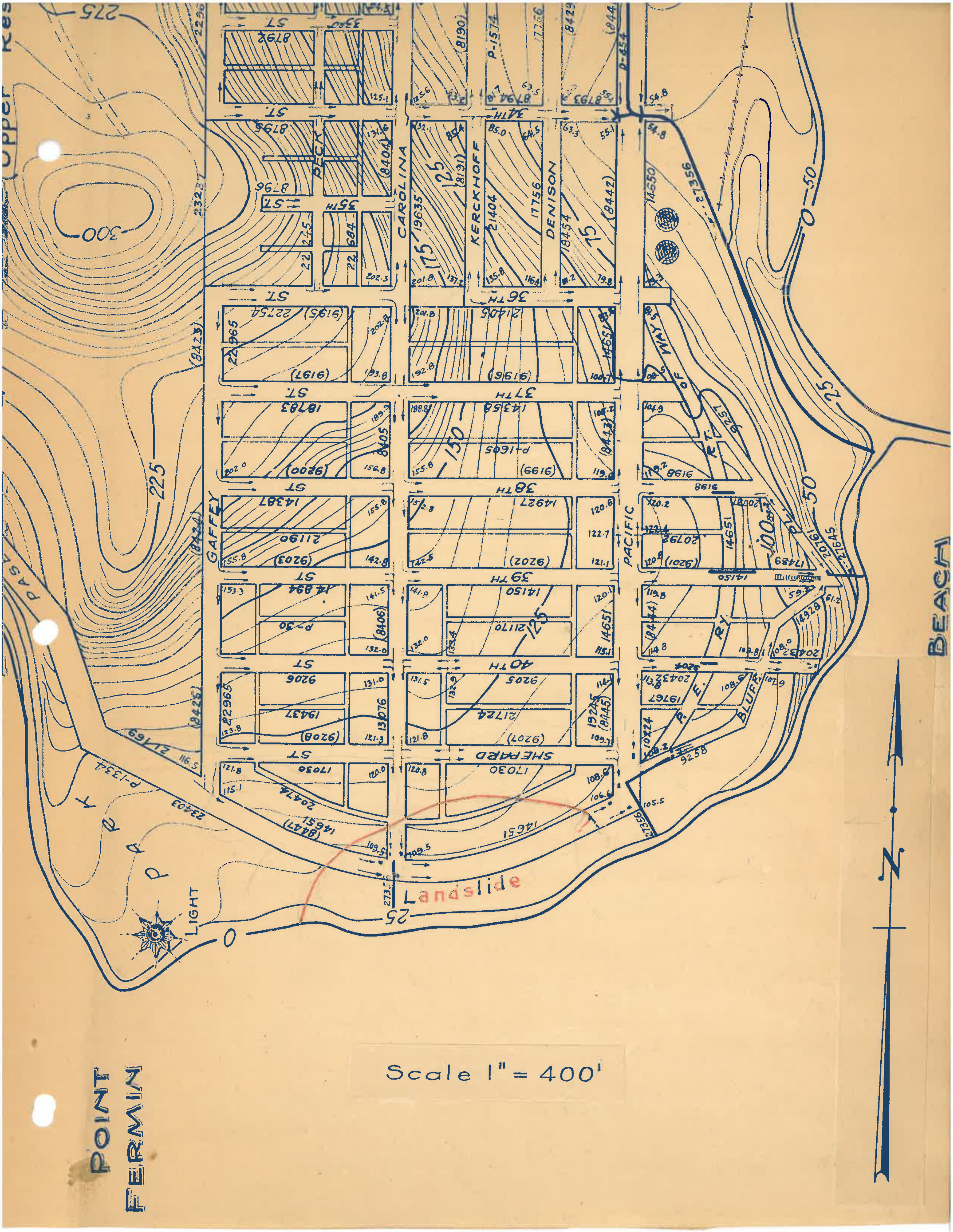
4. As it probably would be unwise to construct large permanent buildings on the affected area or in close proximity to it, the policy of converting the area south of Shepard Street into a public park appears to be worthy of some consideration.

Respectfully submitted

F. L. Ransome

Consulting Geologist.

May 7, 1929.

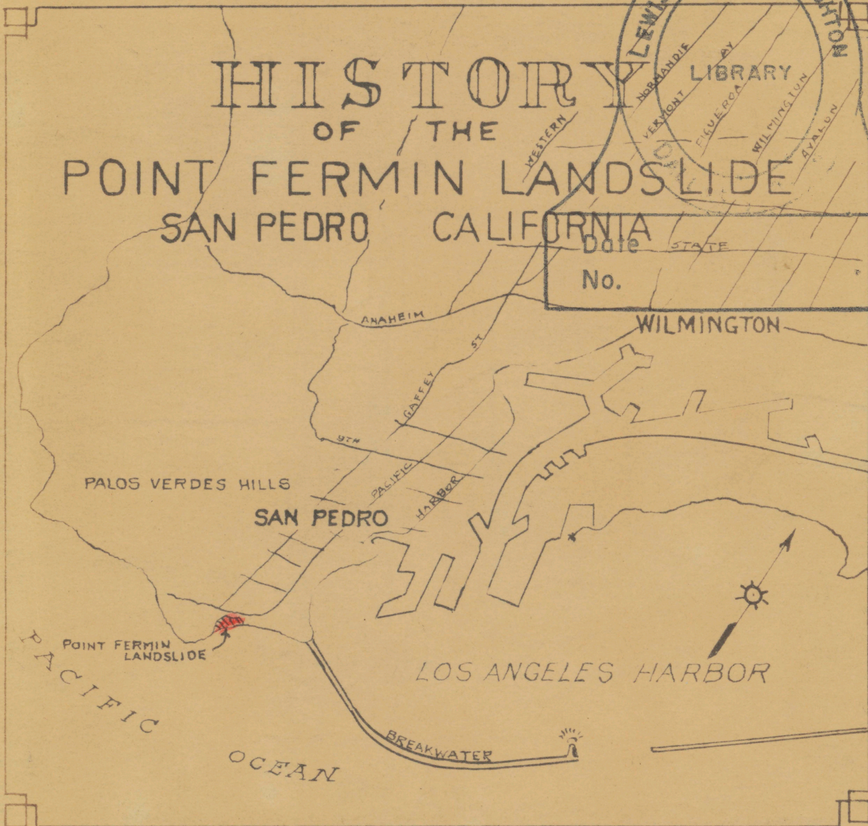

Upper Res
300
275
225
PASEO
PARK
LIGHT
GAFFEY
PECK
CAROLINA
KERCKHOFF
DENISON
PACIFIC
34TH
35TH ST
36TH ST
37TH ST
38TH ST
39TH ST
40TH ST
SHEPARD ST
WAY OF RT.
P. E. RY.
BLUFF PL.
Landslide
BEACH
N
POINT FERMIN

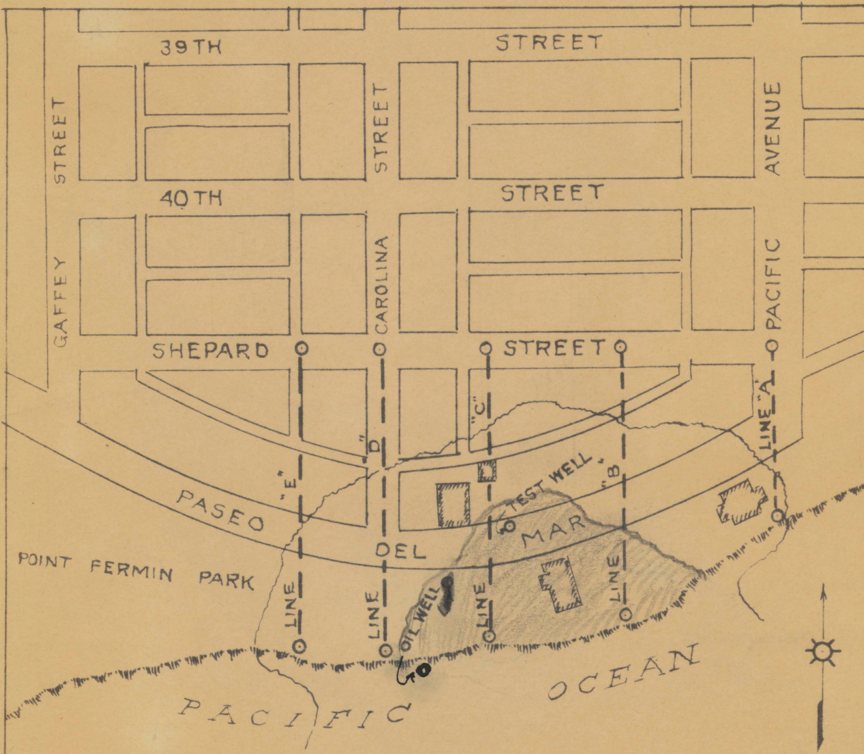
Scale 1" = 400'

APPENDIX C

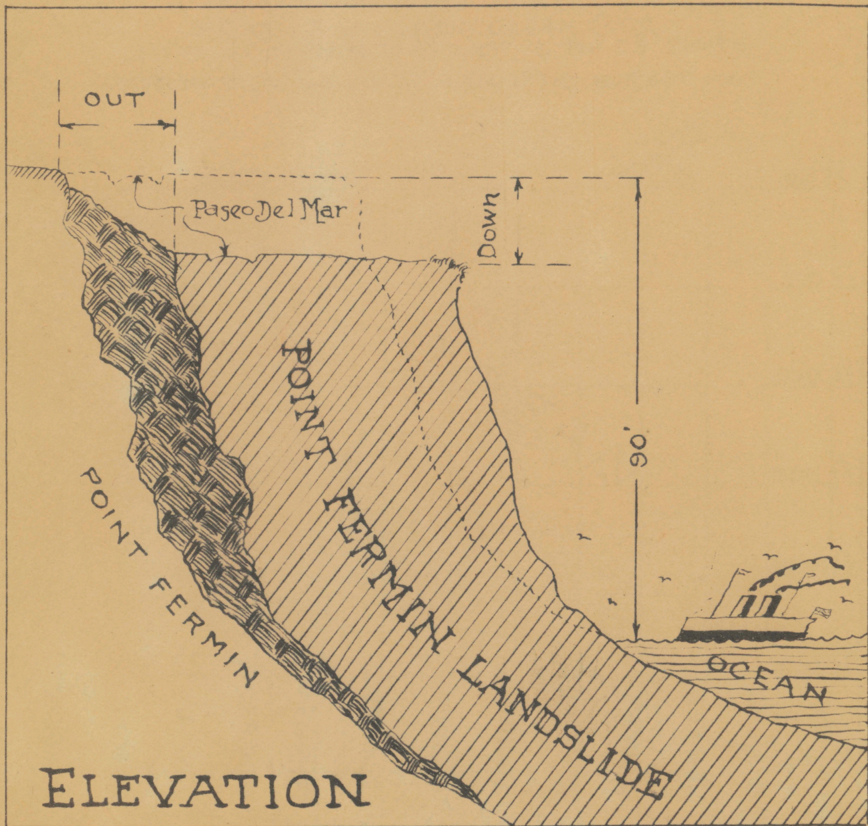
History of the Point Fermin Landslide,
MacNaughton Library, 1940

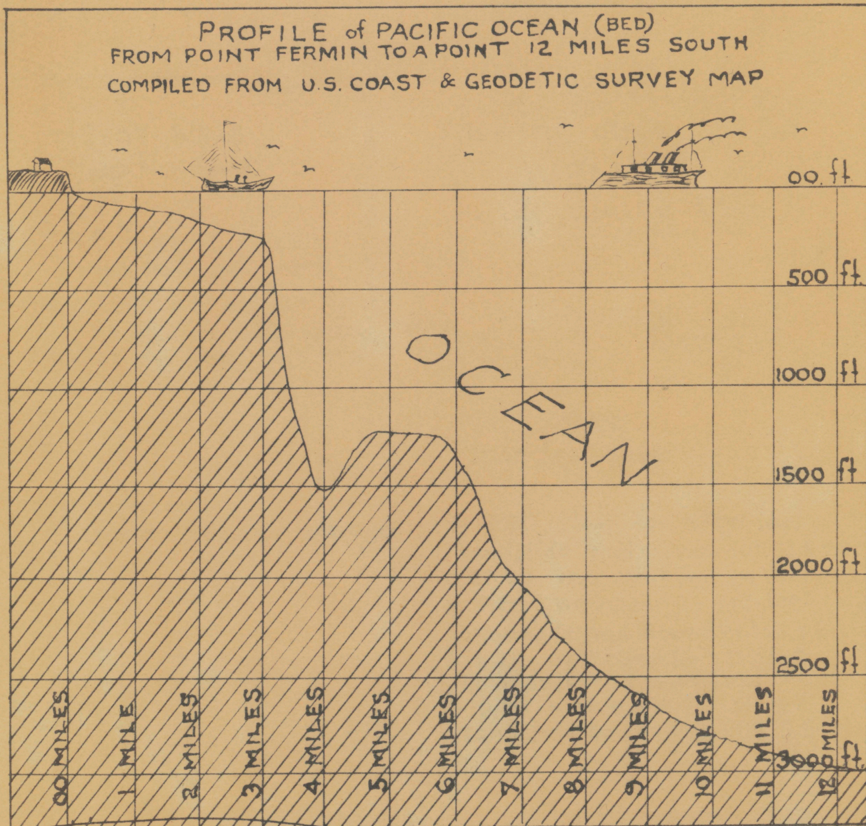
HISTORY
OF THE
POINT FERMIN LANDSLIDE
SAN PEDRO CALIFORNIA




39TH
STREET
40TH
STREET
SHEPARD
STREET
GAFFEY
STREET
CAROLINA
STREET
PACIFIC
AVENUE
PASEO
DEL
MAR
TEST WELL
OIL WELL
POINT FERMIN PARK
LINE "E"
LINE "D"
LINE "C"
LINE "B"
LINE "A"
PACIFIC
OCEAN

PLAN


OUT
Paseo Del Mar
Down
90'
POINT FERMIN LANDSLIDE
POINT FERMIN
OCEAN
ELEVATION


PROFILE of PACIFIC OCEAN (BED)
FROM POINT FERMIN TO A POINT 12 MILES SOUTH
COMPILED FROM U.S. COAST & GEODETIC SURVEY MAP
00. ft
500 ft.
1000 ft
1500 ft
2000 ft
2500 ft
3000 ft.
OCEAN
00 MILES
1 MILE
2 MILES
3 MILES
4 MILES
5 MILES
6 MILES
7 MILES
8 MILES
9 MILES
10 MILES
11 MILES
12 MILES

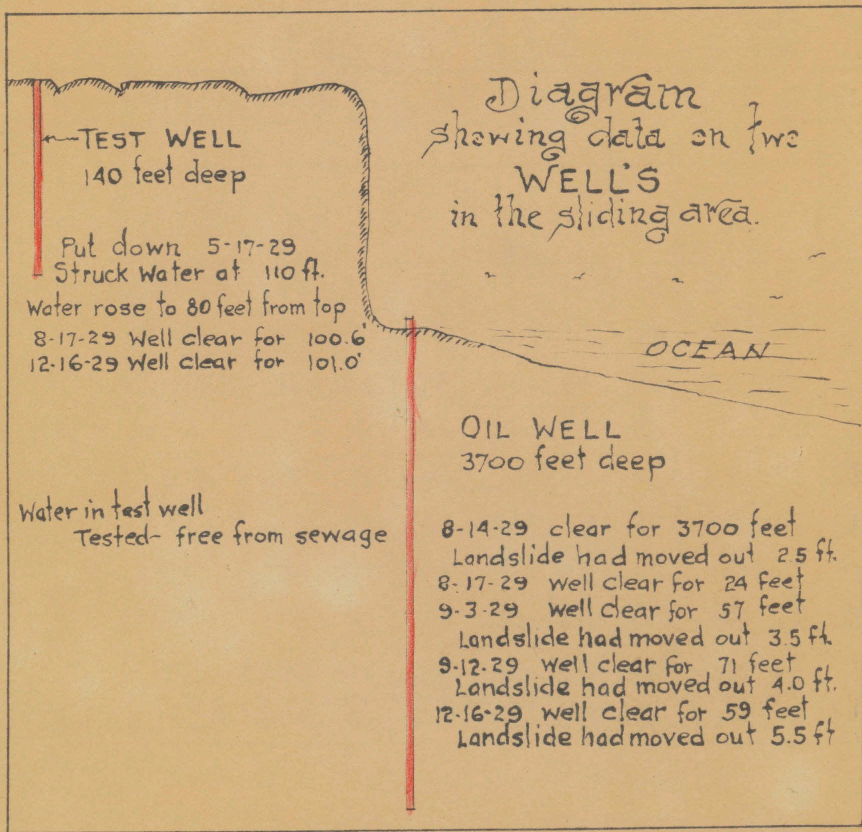


Diagram
showing data on two
WELL'S
in the sliding area.
TEST WELL
140 feet deep
Put down 5-17-29
Struck water at 110 ft.
Water rose to 80 feet from top
8-17-29 Well clear for 100.6'
12-16-29 Well clear for 101.0'
Water in test well
Tested- free from sewage
OCEAN
OIL WELL
3700 feet deep
8-14-29 clear for 3700 feet
Landslide had moved out 2.5 ft.
8-17-29 well clear for 24 feet
9-3-29 well clear for 57 feet
Landslide had moved out 3.5 ft.
9-12-29 well clear for 71 feet
Landslide had moved out 4.0 ft.
12-16-29 well clear for 59 feet
Landslide had moved out 5.5 ft

YEAR	MONTH	LINE "A"		LINE "B"		LINE "C"		LINE "D"		LINE "E"	
		Out	Down	Out	Down	Out	Down	Out	Down	Out	Down
	Apr. 23	.66	.12	.66	.12	.66	.12	.66	.12	.66	.12
	May	.07	.00	.18	.15	.20	.06	.19	.08	.23	.06
	June	.18	.04	.22	.07	.24	.06	.29	.09	.31	.08
1929	July	.48	.11	.65	.21	.75	.23	.75	.30	.78	.32
	Aug	.82	.19	1.14	.50	1.25	.40	1.27	.52	1.32	.51
	Sept	1.13	.24	1.60	.50	1.58	.45	1.57	.62	1.65	.82
	Oct	.29	.07	.43	.16	.42	.14	.37	.17	.39	.23
	Nov.	.22	.05	.23	.09	.28	.08	.24	.14	.27	.13
	Dec.	.20	.04	.28	.10	.25	.11	.30	.10	.24	.13
Total for 1929		4.05	.86	5.37	1.80	5.43	1.65	5.64	2.14	5.85	2.40

YEAR	MONTH	LINE "A" Out	LINE "A" Down	LINE "B" Out	LINE "B" Down	LINE "C" Out	LINE "C" Down	LINE "D" Out	LINE "D" Down	LINE "E" Out	LINE "E" Down
1930	Jan	.21	.08	.43	.12	.30	.13	.29	.17	.31	.14
	Feb	.21	.07	.23	.10	.26	.09	.23	.14	.26	.09
	March	.36	.11	.42	.17	.42	.15	.41	.18	.46	.17
	April	.49	.15	.69	.19	.62	.20	.64	.26	.61	.27
	May	.31	.10	.43	.12	.38	.13	.38	.23	.35	.20
	June	.29	.09	.39	.12	.31	.16	.33	.14	.24	.08
	July	.34	.13	.43	.15	.37	.15	.41	.18	.40	.17
	Aug	.04	.01	.00	.01	.03	.02	.02	.05	.04	.05
	Sept	.17	.07	.41	.09	.28	.07	.28	.09	.31	.11
	Oct	.17	.10	.13	.07	.20	.08	.23	.11	.15	.12
	Nov	.15	.50	.36	.10	.29	.12	.21	.15	.31	.12
	Dec.	.25	.03	.29	.06	.22	.08	.25	.10	.24	.08
Total for 1930		2.99	1.44	4.21	1.30	3.68	1.38	3.68	1.80	3.68	1.60
GRAND TOTAL		7.04	2.30	9.58	3.10	9.11	3.03	9.32	3.94	9.53	4.00

YEAR	MONTH	LINE "A"		LINE "B"		LINE "C"		LINE "D"		LINE "E"	
		Out	Down	Out	Down	Out	Down	Out	Down	Out	Down
	Jan	.32	.04	.33	.12	.41	.10	.33	.15	.35	.15
	Feb	.22	.06	.34	.08	.25	.07	.24	.10	.20	.07
	March	.18	.01	.18	.05	.17	.05	.16	.06	.19	.07
	April	.22	.00	.21	.07	.16	.08	.23	.10	.22	.12
	May	.31	.19	.32	.10	.29	.10	.21	.14	.31	.13
	June			.32	.06	.30	.10	.24	.12	.29	.13
1931	July			.35	.08	.36	.12	.40	.17	.36	.14
	Aug										
	Sept			.49	.11	.45	.12	.47	.11	.48	.17
	Oct			.16	.02	.08	.07	.08	.10	.04	.10
	Nov			.20	.05	.22	.04	.27	.05	.24	.05
	Dec			.22	.01	.20	.04	.20	.07	.23	.15
Total for 1931				3.12	.75	2.89	.89	2.83	1.17	2.91	1.28
GRAND TOTAL				12.70	3.85	12.00	3.92	12.15	5.11	12.44	5.28

YEAR	MONTH	LINE "A"		LINE "B"		LINE "C"		LINE "D"		LINE "E"	
		Out	Down	Out	Down	Out.	Down	Out	Down	Out	Down
	Jan.			.24	.07	.27	.08	.22	.12	.21	.03
	Feb			.25	.03	.21	.03	.26	.06	.17	.10
	March			.40	.09	.24	.07	.27	.06	.36	.13
	April			.24	.17	.26	.05	.33	.10	.21	.16
	May			.30	.04	.16	.07	.17	.05	.31	.12
	June			.16	.02	.33	.03	.13	.04	.10	.06
	July			.02	.01	.01	.02	.01	.01	.04	.04
1932	Aug			.04	.02	.05	.01	.07	.01	.07	.01
	Sept			.02	.00	.00	.03	.00	.01	.00	.02
	Oct										
	Nov			.07	.01	.09	.02	.02	.03	.04	.01
	Dec										
Total for 1932				1.74	.38	1.62	.35	1.44	.49	1.43	.66
GRAND TOTAL				14.44	4.23	13.62	4.27	13.59	5.60	13.87	5.94

○ Indicate reverse measurements.

YEAR	MONTH	LINE "A"		LINE "B"		LINE "C"		LINE "D"		LINE "E"	
		Out	Down	Out	Down	Out	Down	Out	Down	Out	Down
1933	Feb.			.06	.00	.03	.01	.09	.01	.10	.06
	March			.06	.02	.03	.02	.05	.00	.06	.01
	Aug			.05	.00	.03	.02	.08	.03	.02	.01
	Dec.			.08	.01	.02	.04	.11	.02	.04	.05
Total for 1933				.25	.03	.11	.09	.33	.06	.22	.13
1934	Apr			.02	.01	.00	.04	.00	.02	.00	.03
1935											
1936	May			.23	.00	.27	.03	.16	.02	.17	.08
	July			.21	.06	.19	.06	.18	.06	.21	.14
	Aug			.11	.03	.07	.04	.12	.03	.06	.05
	Oct			.22	.06	.19	.03	.20	.06	.21	.12
	Nov			.13	.02	.16	.04	.18	.02	.15	.02
Total for 1936				.90	.17	.88	.20	.84	.19	.80	.41
GRAND TOTAL				15.61	4.44	14.61	4.60	14.76	5.87	14.89	6.51

○ Indicate reverse measurements.

YEAR	MONTH	LINE "A" Out	LINE "A" Down	LINE "B" Out	LINE "B" Down	LINE "C" Out	LINE "C" Down	LINE "D" Out	LINE "D" Down	LINE "E" Out	LINE "E" Down
1937	June			.44	.10	.25	.05	.29	.11	.23	.18
	Nov.			.09	.02	.15	.03	.09	.02	.11	.01
Total for 1937				.53	.13	.40	.08	.38	.13	.34	.19
1938	Apr.			.19	.03	.14	.02	.14	.04	.19	.04
	Nov.			.26	.08	.21	.09	.11	.08		
Total for 1938				.45	.11	.35	.11	.25	.12		
1939	Apr			.12	.03	.09	.00	.01	.04		
	Nov			.14	.11	.19	.13	.00	.01		
Total for 1939				.26	.14	.28	.13	.01	.05		
1940	Apr			.84	.20	.79	.19	.27	.05		
GRAND TOTAL				17.69	5.02	16.43	5.11	15.67	6.22