Tule Wind Project
San Diego County, California

Desktop Study

Prepared for
Iberdrola Renewables

November 2009

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Executive Summary

The following is based on published and other publically available information. The costs noted below are subject to the limitations enumerated in the report.

- The site is underlain by bedrock with potentially thin, if any, soil covering in some areas. This will not pose a hazard to the foundations, but will likely complicate, and increase the cost of, construction of roads, foundations, and buried collection and grounding systems.
- A combination of turbine foundation types may be the most economical approach. It is likely that a spread footing will be most economical at locations with soil greater than 3 ft thick, and a rock socket, rock anchor, or P&H-style will be most economical at sites with thin soil. Based on the USDA soil mapping, it appears that proposed turbine sites divide about 50 percent with thin soils and 50 percent with thick soils.
- Project area seismicity is high.
- The soils encountered across the site appear to be moderately corrosive to steel and concrete.
- Soil resistivity is likely to be >10,000 Ωcm in the dominantly silty sand soils and in areas where bedrock is shallow or at the surface.
- The anticipated the method for constructing the roads is to level and compact existing ground, areas with steep grades or high percentage of fines like dry stream crossings a layer of 4 to 6 inches of gravel would be desirable.
- A preliminary geotechnical investigation is strongly suggested because of the uncertainty of the need and cost-effectiveness of alternative turbine foundation designs. There are no appear significant geological hazards that need to be evaluated, but this can also be confirmed at least in part via preliminary investigation. The first phase of investigation would consist of reconnaissance and test pitting to evaluate soil thicknesses. This will cost on the order of $18,000 - $23,000. If indicated by the first phase, the second phase of preliminary investigation would consist of limited drilling to allow better comparison of alternative foundation types. This will cost on the order of $51,000 - $64,000.
- Following are the preliminary estimates of final investigation, turbine foundation engineering and construction costs. Table 4 contains additional detail.
    - Use of a single spread footing design throughout the project will incur the cost of the foundation design and about $3,700 per turbine in geotechnical investigation and engineering. The foundation size likely will be smaller than typical due to strong site subgrade. Construction costs may be higher than normal due to creating a level surface after excavation, the need to manufacture onsite backfill or transport significant amounts of fill to about half the turbine locations.
    - Use of a spread footing design and a rock anchor/socket design will incur the cost of two foundation designs, about $3,700 per turbine in geotechnical investigation at the spread footing sites and $4,600 to $8,500 per turbine in geotechnical investigation at the rock anchor/socket sites. The rock anchor option will require additional anchor testing at 2-5% of the anchors, costing about $20,000 per test. Construction costs would be typical for the spread footings and are assumed to be lower than a typical spread footing at the other sites where rock anchor/socket foundations are used. P&H would need to be contacted for the cost of a P&H style foundation design.

1.0 Description of Proposed Development

1. The proposed *Tule Wind Project* is located near *Live Oak Springs* in *San Diego County, California* (Figure 1).

2. The wind project is planned to consist of *66 wind turbines*. Figures 2 and 3 are maps of the proposed layout. The proposed wind turbine is a *Gamesa G87 2.0 MW*.

3. In November 2007 Barr completed site reconnaissance in order to evaluate road construction. The results of that work are summarized in this desk top study.

2.0 Purpose and Scope

The scope of the work is limited to review and assessment of readily available existing information.

The goals of this report are to:

- Review readily available existing information, such as geologic maps and reports, geophysical reports, topographic maps, wetlands maps, flood maps, proposed development maps/turbine layouts, and aerial photographs.
- Summarize geologic/geotechnical conditions.
- Identify and qualify geologic/geotechnical risks.
- Recommend a geotechnical investigation approach.
- Summarize soil conditions as it relates to electrical design parameters.
- Recommend whether or not a preliminary field investigation is warranted, and if so, recommend a scope.
- Identify appropriate foundation types and issues.
- Identify potential roadway issues.
- Provide conceptual-design level cost estimates.

3.0 Site Geology

This information is based largely on the El Cahon 30’ x 60’ Quadrangle geologic map and report (Todd, 2004) issued by the USGS.

The project site is in the Peninsular Ranges physiographic province. In this area, volcanic and marine sedimentary rocks ranging in age from Paleozoic to Mesozoic were intruded by granitic rocks in late Mesozoic to Cenozoic time. There were many granite intrusions, to the extent that the aggregate is classified as what is known as a batholith. These intrusions distorted and metamorphosed the earlier sedimentary rocks, and later intrusions deformed earlier intrusions. The intrusions and deformation were driven by the subduction to the west, where oceanic crust was thrust under the North American plate. Eventually, this subduction ended, and the relative motion of the Pacific plate and the North American plate transitioned into the San Andreas fault zone, which is several miles east of the site. This introduced new stress and deformation to the region. As a result of the intrusions and deformation, many of the rocks at the site have undergone metamorphism and exhibit internal fabrics and foliations.

Based on the USGS on-line gis data base, three geologic units underlie the site: gr-m and sch under the western ¼ and grMz under the eastern ¾ of the project area (Figure 3). Note that the descriptions and notations vary between the published version of the El Cajon quadrangle and the USGS on-line gis data base. The quadrangle shows more detail and more units than the on-line database. The following descriptions are taken from the quadrangle, and the approximate equivalencies to the on-line units shown on Figure 3 are noted:

> **grMz approximates Klp on the quadrangle.** Klp is Tonalite of La Posta (Early and Late Cretaceous)—Hornblende-biotite trondhjemite in western part, and biotite trondhjemite and granodiorite in eastern part. Unit is leucocratic, homogeneous, largely undeformed, and inclusion-free, but locally, pluton margins are moderately to strongly foliated. Color index from 6 to 15.

> **grm approximates Kgm on the quadrangle.** Kgm is Tonalite of Granite Mountain (Early Cretaceous)—Biotite-hornblende tonalite; hornblende-biotite tonalite, lesser granodiorite; and minor quartz diorite. Medium- to coarse-grained; weak to very strong foliation. Color index from 17 to 27.

Sch approximates JTrm on the quadrangle. JTrm is Metasedimentary and metavolcanic rocks (Jurassic and Triassic)—Interlayered semi-pelitic, pelitic, and quartzitic schists; calcsilicate-bearing feldspathic metaquartzite; and minor small-pebble metaconglomerate. Includes layers of sandstone, quartz-pebble conglomerate, mudstone, and amphibolite. Interpreted to be metamorphosed submarine fan deposits and intercalated volcanic rocks; equivalent to the Julian Schist of Hudson (1922)

Based on these descriptions, some of the rocks may be massive and relatively structureless and some may have internal structure and foliation. Much of the rock may be very strong and shallow to the point that excavation may be difficult and require blasting. As such, foundation types such as the rock socket and the rock anchor can be considered. One issue in evaluating these foundations will be anisotropy in the rock. Because of internal fabric, some rocks may have anisotropic strength characteristics. These anisotropies will also need to be considered and evaluated along cut slopes. Each proposed turbine location will need to be evaluated because of the variations in the bedrock across the site.

Figure 4 shows the mapped soil types. Figure 5 shows the USCS soil classifications. The vast majority of the area is underlain by silty sand (SM). Figure 6 shows the approximate thickness of the site soils. Soils across much of the project area are thin, less than 1 meter, indicating that excavation for foundations and collection systems and roads may be difficult.

Given the thin and well-drained soils, crystalline bedrock, and high and steep relief, groundwater should not be an issue at the site. This is supported by the soil mapping which generally indicates the water table is greater than 80-inches deep.

4.0 Geologic/Geotechnical Risks

4.1 General Summary of Geologic and Geotechnical Risks

Table 1 is a summary of geologic and geotechnical hazards for the site.

Table 1 Summary of Geologic Hazards

Hazard	Present at Site?	Comment
Flooding/High groundwater	No	The proposed turbine sites are on high ground between drainages, and soils are generally well drained.
Landslides	Possibly in some areas	The site has high relief and generally thin and granular soils. Many of the bedrock units contain internal foliations and so have plains of weakness. These will need to be considered when designing cut slopes.
Subsidence – Pumping	No	Project site is underlain by bedrock with a framework capable of resisting subsidence due to production of oil, gas or water. There are no known oil or gas fields and no large volume extraction of water.
Subsidence – Mining	No	There is no mining activity in the area.
Subsidence – Caves/Karst	No	The bedrock is not susceptible to dissolution.
Earthquake/Seismicity	Yes	The site is in a high seismicity area.
Earthquake/ground rupture	No	There are no mapped faults in the project area.
Liquefaction	Unlikely	Seismicity is high and soils are sandy. However, soils tend to be thin and rocky with a relatively low regional water table.
Swelling/shrinking soil	No	High shrink/swell soils are not present.
Corrosive soil	Possibly	The soil survey reports generally moderate concrete corrosion and moderate steel corrosion.
Made ground	Unlikely	There is very low potential for filled areas associated with rural living practices.
Collapsible soil	No	There are no collapsible deposits at the site.
Volcanic activity	No	No current volcanic activity exists in the region.
Quick clay	No	Quick clay conditions are not known or likely to be present.

While not necessarily a geologic hazard, parts of the area may have shallow bedrock which could complicate excavations for foundations, collection system cables, and roads.

4.2 Soil Conditions

The project site has surficial soils of colluvial and alluvial origin, consisting primarily of sand and gravel. The fairly dry conditions coupled with generally well drained soil conditions should provide for a favorable construction environment. However, low areas and drainage swales should be avoided or mitigated when laying out proposed access roads and turbine locations. In addition, shallow bedrock is present at the project site, which may complicate excavations for foundations, collection system cables, and roads.

4.3 County of San Diego Guidelines

The County of San Diego provides Guidelines for Determining Significance of various issues (**http://www.sdcounty.ca.gov/dplu/procguid.html#guide)**. The geologic hazards focus on the following issues:

- Fault rupture
- Ground shaking
- Liquefaction
- Landslides
- Expansive soils

The hydrology hazards focus on the following issues:

- Flash floods and debris flows
- Alluvial fan floods
- Urbanization
- Landform modification
- dam failure
- Faulty drainage facilities

The County also lists tsunamis and seiches as possible issues in both the geologic and hydrologic hazards, but as the site is far inland and not adjacent to any large water bodies, these are not risks.

4.3.1 Fault Rupture

The information on mapped faults presented by the County and the USGS and CGS on-line databases indicates that there are no mapped faults in the development area. The closest mapped fault is just southeast of proposed turbine Q2. All of the mapped faults in the area of the project site are likely Quaternary in age. There are no adjacent historic, Holocene, or Late Quaternary faults, indicating that the faults have not experienced rupture in the last 100,000 years. The Elsinor Fault zone is approximately 5 miles to the northeast.

Most of the proposed project structures (turbines, substation, met tower) are not designed for human occupancy. Only the O&M building is designed for human occupancy. None of the proposed turbine locations are within 50 ft of the trace of an Alquist-Priolo fault or a County special study fault. Therefore, fault rupture does not appear to be a significant risk to the project.

4.3.2 Ground Shaking

All of San Diego County is located within Seismic Zone 4, which is the highest seismic zone and is subject to ground shaking. Appendix A contains seismic design parameters derived from the USGS earthquake hazards program accessed November 11, 2009 (http://earthquake.usgs.gov/hazards/products/conterminous/2008/software/).

Load factoring for wind turbines allows for the use of the greater of the wind load or the seismic load. Invariably, the wind load is greater, and so the seismic loading is not a factor for wind turbines. However, ground shaking will need to be evaluated as part of the design of other project structures.

4.3.3 Liquefaction

Liquefaction is a potential risk where loose, saturated sandy soils may be subjected to seismic energy. The County has identified specific soil units that are susceptible to liquefaction risk, including the Mottsville loamy coarse sand (MxA) 0-2 percent slopes. The site contains a Mottsville soil unit (MvC) that is a loamy coarse sand, 2 to 9 percent slopes, with depth to water table more than 80 inches (http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx). This is a well-drained soil. It does not appear that any of the currently proposed turbine locations are on the Mottsville soil, but proposed site C4 is close to an area of Mottsville soil. It should be noted that this general description – loamy coarse sand with depth to water table more than 80 inches, applies to virtually all of the site soil types. However, many of the other soil types are less than 80 inches thick over rock and weathered rock.

In summary, the site contains a soil type that is close to but does not exactly match the County's descriptor of potential risk areas. Many of the site soils have similar general descriptions. However, the soils do not appear to be saturated, so overall the risk of liquefaction appears to be low. Still, this should be further evaluated as the project moves forward and site-specific information is generated, including the locations of other project structures like met towers, O&M building, substation, and collection system.

4.3.4 Landslides

The project site has areas of steep slopes, greater than 25%. Some bedrock units have foliation and other plains of weakness that could contribute to instability. There are areas mapped as talus deposits indicating past mass wasting. The project development will include cut slopes and grading that could affect slope stability. Therefore, this is an issue that will need to be further addressed as the project moves forward.

4.3.5 Expansive Soils

Certain types of clayey soils ("fat" clays) have a tendency to absorb water and swell and then shrink as they dry. This can exert considerable pressure on structures, leading to cosmetic and structural damage. The County has identified specific soil units that are susceptible to expansion (shrink-swell) risks. None of these specifically named soils are present at the site. In addition, the site soils are silty sands (SM), not fat clays (CH or MH) (Figure 5). Therefore, the risk of expansive soils is not significant.

4.3.6 Flash Floods and Debris Flows

Debris flows, also known as mudflows, are shallow water-saturated landslides that travel rapidly down slopes carrying rocks, brush, and other debris. The path of a mudflow is determined by local topography, and will typically follow existing drainage patterns. Project facilities will be constructed on high ground and are not expected to be susceptible to debris flows or flash floods.

4.3.7 Alluvial Fan Floods

Alluvial fans are a desert phenomenon where streams emerge from canyons and deposit sand and rock in a cone-shaped formation fanning out from the canyon mouth. Alluvial fans form in arid and semi-arid environments where steep mountain fronts meet flatter valley floors. The infrequent but intense storms in these environments produce flash floods that can carry heavy debris and sediment loads. No alluvial fans have been identified on the project site.

4.3.8 Urbanization

The conversion of undeveloped, natural areas to urbanized uses throughout San Diego's watersheds can contribute to increased potential for flooding, by increasing the rate and amount of runoff in a watershed and altering drainage patterns. The proposed wind farm will result in a negligible change to the impervious area.

4.3.9 Landform Modification

Any alteration to natural drainage patterns by modifying landforms that control the conveyance of surface water can increase the potential for flooding. The proposed wind farm will not alter the drainage patterns.

4.3.10 Dam Failure

Dam failure inundation is flooding caused by the release of impounded water from failure or overtopping of a dam. The failure of a dam occurs most commonly as a result poor design, neglect, or structural damage caused by earthquakes. There are no dams identified in the project area.

4.3.11 Faulty Drainage Facilities

Drainage facilities including storm drains, culverts, inlets, channels or other such structures are designed to prevent flooding by collecting stormwater runoff and directing flows to either the natural drainage course and/or away from urban development. The capacity of a drainage structure can typically be adequately determined by a hydrology and drainage study; however if drainage facilities are not adequately designed or built, or properly maintained, the facilities can overflow or fail, resulting in flooding.

The drainage facilities in the project site are limited to small culverts on intermittent streams.

5.0 Feasible Foundation Types

Feasible foundation types for the Tule Wind Project are in part selected based upon a combination of critical geotechnical, climatological, and mechanical factors which drive the design selected.

1. **Geotechnical Factors.** The project site geology consists of shallow bedrock overlain by mostly sand and gravel. The site has high seismicity but is of a magnitude that would not supercede design loads due to wind (IBC, 2006). The water table is likely to be relatively deep across most of the project area.

2. **Climatological Factors.** As stated in Section 4.2, flooding will be of short duration.

3. **Mechanical Factors.** The proposed turbine for the project is the Gamesa G87.

The following foundation types are not feasible or are not recommended based on the combination of critical geotechnical, climatological, and mechanical factors identified:

1. **Deep Foundations.** Due to the predicted competency of the soil deposits, deep foundations will likely not be required. Less expensive foundation options are suitable for the site.

2. **Stone Columns Supporting Spread Footing.** Soils and rock at the project site likely do not need this type of soil improvement technique.

The following foundation types are feasible based on the combination of critical geotechnical, climatological, and mechanical factors identified:

1. **Spread Footing.** The soil deposits and bedrock are typically suitable for support of a spread footing. A level foundation subgrade is difficult to achieve in bedrock, and the use of lean concrete and engineered fill is often needed to level the bedrock subgrade.

2. **Rock Socket Foundation.** At sites where bedrock is encountered at very shallow depths, i.e,. within 1-3 feet of the ground surface, a rock socket foundation may be appropriate. This foundation type may be feasible at some locations. This type of foundation is constructed by blasting an excavation approximately 20’x20’x20’ into the bedrock, placing an anchor bolt cage and reinforcing in the excavation, and filling the excavation with concrete. The success of this foundation type is highly dependent on the rock strength, rock conditions and blasting

techniques. Each site needs to be evaluated accordingly. There is more uncertainty associated with a rock socket foundation than with a conventional spread footing.

3. **Rock Anchor Foundation.** At sites where strong, massive bedrock is encountered at very shallow depths, i.e. within 1-3 feet of the ground surface, a rock anchor foundation may be appropriate. This foundation type may be feasible at some locations. This type of foundation is constructed by blasting an excavation approximately 25'-35' in diameter by 7'-9' into the bedrock, drilling anchors to an approximate depth of 20'-50', placing an anchor bolt cage and reinforcing in the excavation, and pouring a concrete cap. This type of foundation is also dependent on the rock strength and condition. There is also more uncertainty associated with a rock anchor foundation than with a conventional spread footing.

4. **Patrick and Henderson Style Foundation.** P&H style caissons have been constructed in similar soil and rock conditions found at the project site. The P&H style foundation is known to occasionally have issues with foundation movement and stiffness, but is feasible to construct at this project.

Based on the site characteristics discussed in this report, it is likely that all of these foundation types may be cost competitive. The site is underlain by bedrock with potentially thin, if any, soil covering in some areas. This will not pose a hazard to the foundations, but will likely increase the cost of the foundation construction. Rock removal may be required for turbine locations with shallow bedrock in order to achieve a typical 7 foot embedment for a spread footing foundation. An alternative to using a spread footing foundation at turbine locations with shallow bedrock (<3 feet of soil) is to use a rock socket, rock anchor or P&H style foundation. This would require a more intensive geotechnical investigation and foundation engineering effort. These foundation types may reduce costs due to reduced quantities of steel and concrete, but these savings are offset to some degree by the cost of blasting or installing rock anchors. Alternatively, a spread footing may work at all proposed locations, but the costs of excavation, supplemental lean concrete with engineered fill needed to level the bedrock, and crushing rock for backfill or importing backfill over the foundation will add to the costs of construction. Barr recommends preparing detailed designs based on site-specific conditions to better estimate the cost of constructing these foundations. It may be useful to include a contractor in preparing the cost estimate, as they tend to have a better understanding of the difficulties associated with blasting and other construction issues. A spread footing would be most feasible in locations with soil thicknesses greater than 3 feet, which based on the soil mapping is about 50 percent of the proposed turbine locations.

6.0 Electrical Design

6.1 Soil Electrical Resistivity

The soil, bedrock, and groundwater conditions of the site indicate generally high resistivity subsurface conditions throughout the project site located in San Diego County, California. Based on a summary of the soil properties from the USDA NRCS-NCGC SSURGO Soil Database of about 2,200 acres within a 500-feet radius of each proposed structure, the general soil types relevant to the Tule Wind Project are the La Posta, Sheephead, Tollhouse, Kitchen Creek, and Holland, all of which consist of silty sand. These soils have relatively low clay contents, from 7.5 to 11.5 percent. Bedrock is present near the surface across the entire project site. Resistivity will likely be higher where soil cover is thin or not present. The site has thin and well-drained soils, crystalline bedrock, and high and steep relief, thus groundwater should not affect resistivity.

For most engineering applications in soils, the motion of ions in the interstitial formation water is the dominant factor affecting the electrical resistivity. Ions in the formation water come from the dissociation of salts such as sodium chloride, magnesium chloride, etc. (Mooney, 1980). For water-bearing earth materials, the resistivity decreases with increasing:

1. Fractional volume of the material occupied by water
2. Salinity or free-ion content of the water
3. Interconnection of the pore spaces (permeability)
4. Temperature

The presence of clay minerals tends to decrease the resistivity because: (a) the clay minerals can combine with water, (b) the clay minerals can adsorb cations in an exchangeable state on the surface, and (c) the clay minerals tend to ionize and contribute to the supply of free ions.

The general range of electrical resistivities for alluvium and sands is from 1,000 to 80,00 ohm-centimeters (Ωcm) or 10 to 800 ohm-meters (Ωm). Values can range from 100 to 10,000 Ωcm (1 to 100 Ωm) for clays. The general range of electrical resistivities for schist, gneiss, and granite are from 2,000 to 1E6 Ωcm (20 to 1E4 Ωm), 6.8E6 to 3E8 Ωcm (6.8E4 to 3E6 Ωm), and 4.5E5 to 1.3E8 Ωcm (4.5E3 to 1.3E6 Ωm), respectively (Telford, 1976).

The predominant factor affecting the electrical resistivity of the soil throughout the Tule Wind Project area appears to be the presence of thin, silty sand soils overlying shallow igneous (granite) and metamorphic (schist and gneiss) bedrock. The soil survey from San Diego County, California, indicates the soils consist of mostly silty sand, and thus are likely to have soil resistivities >10,000 Ωcm. Shallow bedrock will likely have resistivity >10,000 Ωcm.

Climatic variables, including fluctuating average low and high air temperatures of 28°F to 84°F, are important to note when comparing shallow soil electrical resistivity values to studies from other climates (IEEE, 1983). The electrical resistivity of surficial soils will decrease when the soils are warm, increase when cold, and will be notably higher when soils are frozen. However, the bulk resistivity of soils through the depth of construction is not likely to be impacted by air temperature fluctuations. High soil moisture will decrease resistivity.

Table 2 shows the soil types listed in the USDA NRCS-NCGC SSURGO database with resistivity categories assumed on the basis of soil characteristics and clay content provided for each soil type.

Table 2 Soil Type and Assumed Electrical Resistivity

Soil Series Name	Soil Symbol	Taxonomic Description	USCS	Clay Content (%)	Site Coverage (%)	Assumed Electrical Resistivity Ωcm
La Posta	LcE2	Entic haploxerolls, sandy, mixed, mesic	SM	7.5	23.1	>10,000
Sheephead	SpG2	Entic ultic haploxerolls, loamy, mixed, mesic	SM	10.0	17.4	>10,000
La Posta	LaE2	Entic haploxerolls, sandy, mixed, mesic	SM	7.5	15.1	>10,000
La Posta	LdG	Entic haploxerolls, sandy, mixed, mesic	SM	7.5	11.9	>10,000
Tollhouse	ToE2	Entic haploxerolls, loamy, mixed, mesic, shallow	SM	11.5	11.2	>10,000
Kitchen Creek	KcD2	Ultic argixerolls, coarse-loamy, mixed, mesic	SM	7.5	9.3	>10,000
Holland	HnE	Ultic haploxeralfs, fine-loamy, mixed, mesic	SM	11.0	4.1	>10,000
La Posta	LdE	Entic haploxerolls, sandy, mixed, mesic	SM	7.5	2.6	>10,000
Tollhouse	ToG	Entic haploxerolls, loamy, mixed, mesic, shallow	SM	11.5	2.1	>10,000
Holland	HnG	Ultic haploxeralfs, fine-loamy, mixed, mesic	SM	11.0	1.9	>10,000

Note: Soils comprising <1% of the project area were not included in this table.

The American Petroleum Institute (API) provides guidance for the potential corrosivity of materials based upon resistivity measurements (API-651, Cathodic Protection of Aboveground Petroleum Storage Tanks, 1996). Following Table 3 lists the General Classification of Resistivity (adapted from API 651, Chapter 5.3.1.2, Table 1).

Table 3 Classification of Resistivity

Resistivity Range, Ωcm	Resistivity Range, Ωm	Resistivity Range, Ω feet	Potential Corrosion Activity
<500	<5	<16	Very Corrosive
500 – 1000	5 – 10	16 – 33	Corrosive
1000 – 2000	10 – 20	33 – 66	Moderately Corrosive
2000 – 10,000	20 – 100	66 – 330	Mildly Corrosive
> 10,000	> 100	> 330	Progressively Less Corrosive

Based on this reference, the Tule Wind Project soils and bedrock appear likely to have very low corrosivity. This is somewhat in contrast to the soil descriptions which indicate most site soils near the proposed turbine locations are mildly corrosive to steel and concrete. More corrosive soil conditions might be encountered where there are localized increases in clay content and increased moisture conditions. More corrosive bedrock conditions might be encountered where there are localized increases in weathering, fracturing, and/or moisture content.

Barr recommends an electrical resistivity survey be conducted in order to confirm grounding and cathodic protection design parameters. The work should be performed in accordance with ASTM method G57-06 "Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method" (equivalent to IEEE Std. 81-1983). Testing should be conducted at each construction site or at a representative number of sites for each soil type and topographic setting.

High soil resistivity and thin soil cover can affect the design of the wind turbine ground grid. The soil conditions necessary for acceptable grounding are compromised due to the conditions listed in the preceding paragraphs. Options to address poor soil conditions can include reduced spacing between grounding conductors and a ground grid with a larger area to reduce the ground resistance. The reduced spacing can also address issues related to touch and step potentials. The potential for higher ground potential rise can also require the installation of isolation equipment on copper based communication circuits, and can result in power conductors with increased insulation resistance.

Collector circuits generally operate at 35 kV (nominal). The National Electrical Code requires a burial depth of 36” for direct buried circuits. The burial depth can be reduced to 24” when the circuits are installed in rigid non-metallic conduit, or 6” when installed in intermediate metallic conduit or rigid steel conduit. San Diego County may also require ‘wrapping’ of metallic conduit for corrosion resistance. If thinner soil conditions are encountered, cutting channels in the rock or surface mounted conduit may be options. These electrical system requirements, which are unusual for most wind projects, can significantly affect the price of the project.

6.2 Soil Thermal Resistivity

The best approach is to determine site specific values during the geotechnical investigation phase.

6.3 Recommended Testing

When Iberdrola Renewables completes the next phase of geotechnical investigation (Section 8), it is assumed that the number of tests for the electrical design will be equal to about 10 percent of the number of turbines:

- Complete in situ soil electrical resistivity tests
- Collect and test soil samples for thermal resistivity
- Test and sample locations should be selected by the electrical designer.

7.0 Civil Design

The construction of access roads to the turbines was reviewed with respect to the subgrade, availability of construction materials, and the topography of the project site.

There are two types of road construction. One on the western edge of the site where turbines are on the mountain ridges, and the second in the lower elevations were the turbines will be placed on the crests of the hills and knobs.

The anticipated method for constructing the lower elevation roads is to clear the vegetation, move boulders, level and compact the ground. The granular character of the area is expected to be suitable for the road surface. Areas with very high fines such as dry stream beds may require a layer of gravel.

The roads climbing the mountains and on the mountain ridges will likely be cut into the side slopes in most cases. A 4 to 6 inch gravel layer would likely be desirable for vehicle traction and durability. The roads in this section will be steep with long stretches at 10 %.

Production of gravel on site is the likely source of road building materials. Sand is likely available in dry stream beds and rock can be blasted. This same process can produce aggregate for the concrete foundations.

8.0 Recommended Field Investigation

Based on Barr's experience with similar geological terrains, the site may be suitable for support of a typical spread footing, and either a rock socket, rock anchor, or P&H type foundation. A preliminary geotechnical investigation is recommended to gather site data to assist in determining the most economical turbine foundation type or combination of turbine foundation types. A spread footing is likely feasible at most if not all locations. However, if there are large areas with very thin soils and very strong rock, then the cost of excavation followed by supplemental lean concrete with engineered fill needed to level the bedrock, and crushing rock for backfill over the foundation or importing backfill may justify use of another foundation type. If a second foundation type is suggested, then evaluation of the rock properties and construction economics will be needed to determine whether a rock socket, rock anchor or P&H style foundation is economical.

8.1 Preliminary Geotechnical Site Investigation

The goals of a preliminary geotechnical site investigation are to (1) assess the magnitude of site hazards and (2) aid in determining the most economical style of foundation. This should be done ahead of the final geotechnical investigation such that time and money are best utilized to minimize costs associated the final geotechnical investigation. The preliminary geotechnical site investigation consists of a reduced scope aimed at factors that have the greatest potential to influence the project schedule and cost. At this site, there does not appear to be any significant geologic hazards, but site reconnaissance by a qualified geotechnical engineer or engineering geologist could confirm this.

A preliminary geotechnical site investigation may be done in phases:

- **Phase 1—**Conduct site reconnaissance at all proposed turbine locations. Identify locations susceptible to short duration and high intensity localized flooding. Evaluate risk of other possible geological hazards (primarily landslides). Complete test pitting to determine soil thickness to aid in the foundation feasibility study.

- **Phase 2—**If indicated by the test pitting and preliminary economic analysis, complete a geotechnical drilling program to provide rock characteristic data for comparing the relative feasibilities of the rock anchor, rock socket or P&H foundation designs. Other issues like soil thermal resistivity testing could also be addressed.

The preliminary geotechnical site investigation scope is dependent upon which foundation design chosen for the project. Table 4 displays scope and investigation costs for each foundation choice.

8.2 Final Geotechnical Site Investigation

The final investigation will need to address the data gaps not addressed by the preliminary investigation collecting sufficient geotechnical data to complete foundation design(s). Since the scope of the preliminary investigation is uncertain at this time, as is the final turbine foundation design(s), the potential scope and cost of the final geotechnical investigation may vary.

Rock socket, rock anchor and P&H type foundation locations are limited by the amount of soil overlying bedrock, typically chosen as three feet. A spread footing type foundation has no limitations regarding soil depth, but costs associated excavation and backfill in bedrock will be higher. With that said, a preliminary estimate of soil thicknesses from the USDA NRCS SSURGO database across the project site indicated approximately half of the 66 proposed turbine locations have less than two feet of soil overlying bedrock. This indicates that approximately half of the proposed turbine locations are suitable for a spread footing and approximately half are suitable for a rock socket, rock anchor and P&H foundations. The final geotechnical investigation scope and costs were calculated assuming half of the proposed sites are suitable for spread footing type foundations and the others are adequate for a rock socket or rock anchor type foundation. Final geotechnical investigation scope and costs are shown in Table 4.

Table 4
Estimated Scope and Cost of Future Phases

<table>
<tr><th rowspan="2">Foundation Type</th><th colspan="4">Preliminary Investigation Scope</th><th rowspan="2">Final Investigation Scope</th><th rowspan="2">Final Geotechnical Investigation and Cost Per Turbine</th><th rowspan="2">Estimated Foundation Design Cost</th></tr>
<tr><th>Phase I Scope</th><th>Phase I Cost</th><th>Phase II Scope</th><th>Phase II Cost</th></tr>
<tr><td>Spread Footing Foundation</td><td rowspan="4">• Conduct site recon for all proposed locations including structural geology mapping of potential rock socket or rock anchor type foundation locations.
• Conduct test pitting at all of proposed locations to determine depth to bedrock and collect bulk samples for resistivity testing and road subgrade testing.
• Perform laboratory testing.
• Complete Phase I Preliminary Geotechnical Investigation Report.</td><td rowspan="4">$17970 to $22460</td><td colspan="2">None</td><td>• Geotechnical drilling program at each proposed turbine location consisting of rock coring to approximately 30 feet below ground surface, including the alternate locations, to collect soil and rock samples for laboratory testing,
• Perform laboratory testing
• Complete Final Geotechnical Report</td><td>$3230 to $4030</td><td>$45,000</td></tr>
<tr><td>Rock Socket Foundation</td><td rowspan="3">• Complete a geotechnical drilling program at 4 proposed rock socket (or anchor) turbine locations to approximately 60 feet below ground surface.
• Provide rock characteristic data for comparing the relative feasibilities of the rock anchor and the rock socket foundation designs
• Perform lab testing for both rock socket and rock anchor foundation designs.
• Complete Phase II Preliminary Geotechnical Report.</td><td rowspan="3">$51110 to $63890</td><td>• Geotechnical drilling program at each proposed turbine location consisting of rock coring to approximately 35 feet below ground surface, including the alternate locations, to collect soil and rock samples for laboratory testing,
• Perform laboratory testing
• Complete Final Geotechnical Report</td><td>$4570 to $5720</td><td>$55,000</td></tr>
<tr><td>P&H Foundation</td><td>• Geotechnical drilling program at each proposed turbine location consisting of rock coring to approximately 35 feet below ground surface, including the alternate locations, to collect soil and rock samples for laboratory testing,
• Perform laboratory testing
• Complete Final Geotechnical Report</td><td>$4570 to $5720</td><td>Contact P&H for Foundation Design Costs</td></tr>
<tr><td>Rock Anchor Foundation</td><td>• Geotechnical drilling program at each proposed turbine location consisting of rock coring to approximately 60 feet below ground surface, including the alternate locations, to collect soil and rock samples for laboratory testing,
• Perform laboratory testing
• Complete Final Geotechnical Report</td><td>$6810 to $8510</td><td>$65,000*</td></tr>
</table>

*** Rock anchor foundation design will require perfomance testing 2 to 5 percent of the total number of rock anchors costing approximately $20,000 per test**

8.3 Limitations

The opinion of probable costs provided in this report is made on the basis of Barr's experience and qualifications and represents Barr's best judgment as experienced and qualified professionals familiar with the project. The cost opinion is based on project-related information available to Barr at this time and includes a conceptual-level design of the project. The opinion of cost may change as more information becomes available. In addition, since Barr has no control over the cost of labor, materials, equipment, or services furnished by others, over the contractor's methods of determining prices, or over competitive bidding or market conditions, Barr cannot and does not guarantee that proposals, bids, or actual costs will not vary from the opinion of probable cost prepared by Barr. If Iberdrola Renewables wishes greater assurance as to probable cost, Iberdrola Renewables should wait until further information is available.

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Figures

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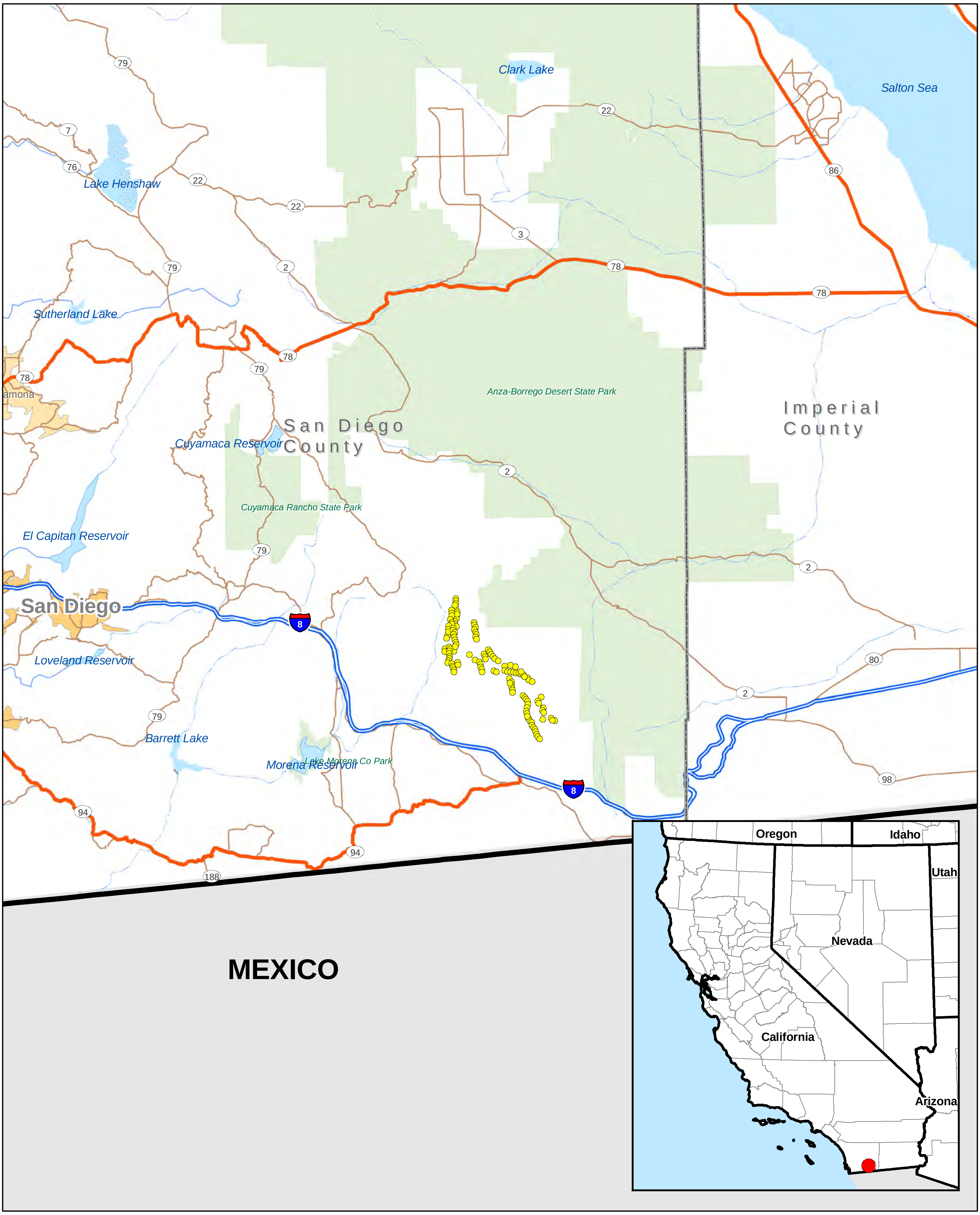

Preliminary Turbine Location
(10/13/2009 Coord.)

Miles
6 0 6

Kilometers
10 0 10

Figure 1

SITE LOCATION
Tule Wind Project
Iberdrola Renewables
San Diego Co., CA

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Imagery Source: 2009 ESRI, i-cubed, GeoEye

Preliminary Turbine Location
(10/13/2009 Coord.)

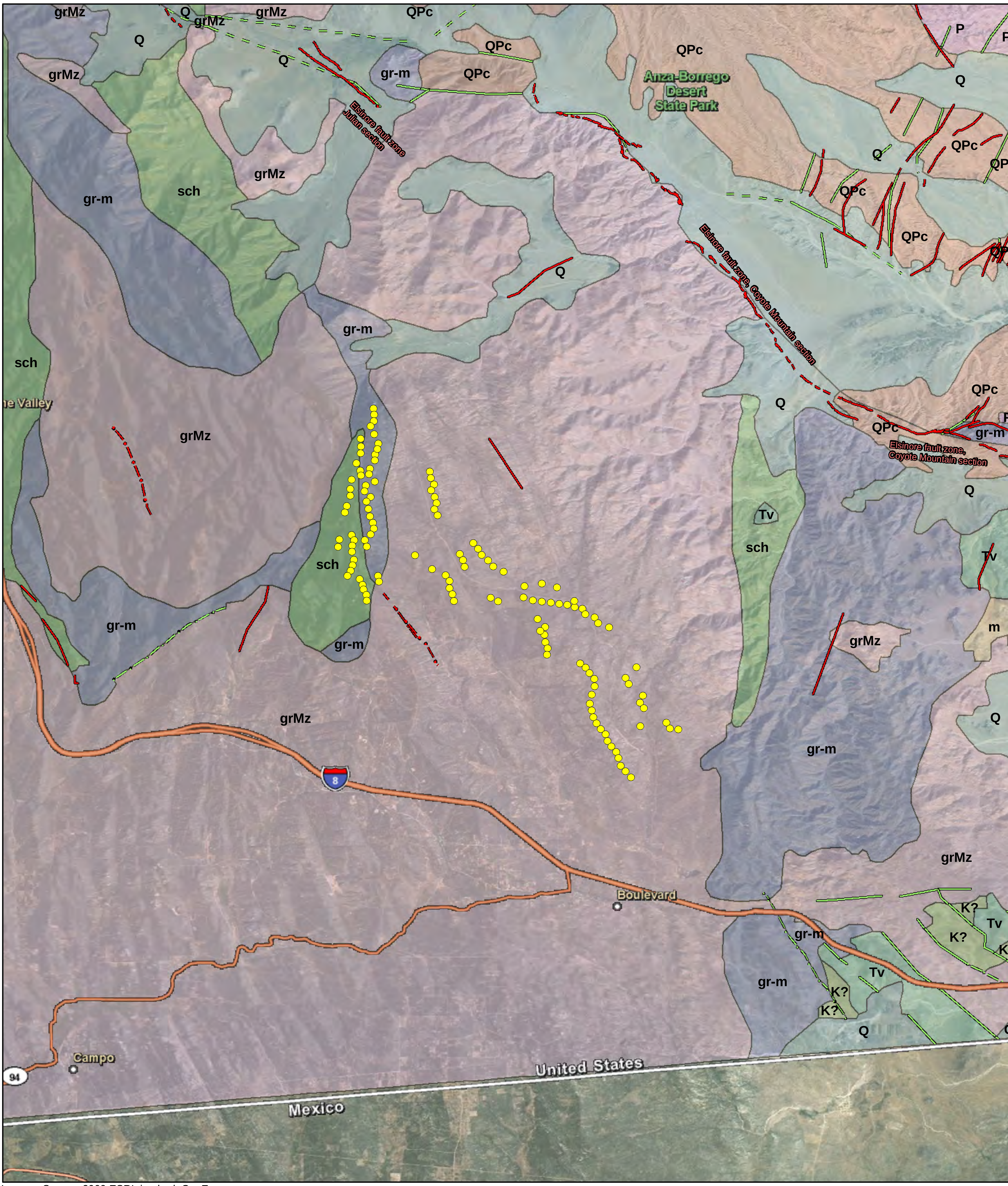
N

Feet
4,000 0 4,000

Meters
1,200 0 1,200

Figure 2

SITE LAYOUT
Tule Wind Project
Iberdrola Renewables
San Diego Co., CA



Imagery Source: 2009 ESRI, i-cubed, GeoEye
Data Sources: U.S. Geological Survey, 2006, http//earthquakes.usgs.gov/regional/qfaults/
California Geological Survey

Preliminary Turbine Location (10/13/2009 Coord.)

Quarternary Fault/Fold (USGS)
- Inferred
- Moderately constrained
- Well constrained

Prelim. Fault Data (USGS)
- Moderately Constrained
- Well Constrained
- Inferred

Bedrock Geology
- (K?) Undivided Cretaceous sandstone, shale, and conglomerate; minor nonmarine rocks in Peninsular Ranges
- (P) Sandstone, siltstone, shale, and conglomerate; in part Pleistocene and Miocene.
- (Q) Alluvium, lake, playa, and terrace deposits; unconsolidated and semi-consolidated. Mostly nonmarine, but includes marine deposits near the coast.
- (QPc) Pliocene and/or Pleistocene sandstone, shale, and gravel deposits; in part Miocene.
- (Tv) Tertiary volcanic flow rocks; minor pyroclastic deposits.
- (gr-m) Granitic and metamorphic rocks, mostly gneiss and other metamorphic rocks injected by granitic rocks. Mesozoic to Precambrian.
- (grMz) Mesozoic granite, quartz monzonite, granodiorite, and quartz diorite
- (m) Undivided pre-Cenozoic metasedimentary and metavolcanic rocks of great variety. Mostly slate, quartzite, hornfels, chert, phyllite, mylonite, schist, gneiss, and minor marble.
- (sch) Schists of various types; mostly Paleozoic or Mesozoic age; some Precambrian; sch, Schists of various types

Figure 3

BEDROCK GEOLOGY
Tule Wind Project
Iberdrola Renewables
San Diego Co., CA

N

Miles
2.5 0 2.5

Kilometers
3 0 3 6

Imagery Source: 2009 ESRI, i-cubed, GeoEye
Data Source: USDA NRCS SSURGO Database

Preliminary Turbine Location (10/13/2009 Coord.)

Soil Map Unit

N

Feet

4,000 0 4,000

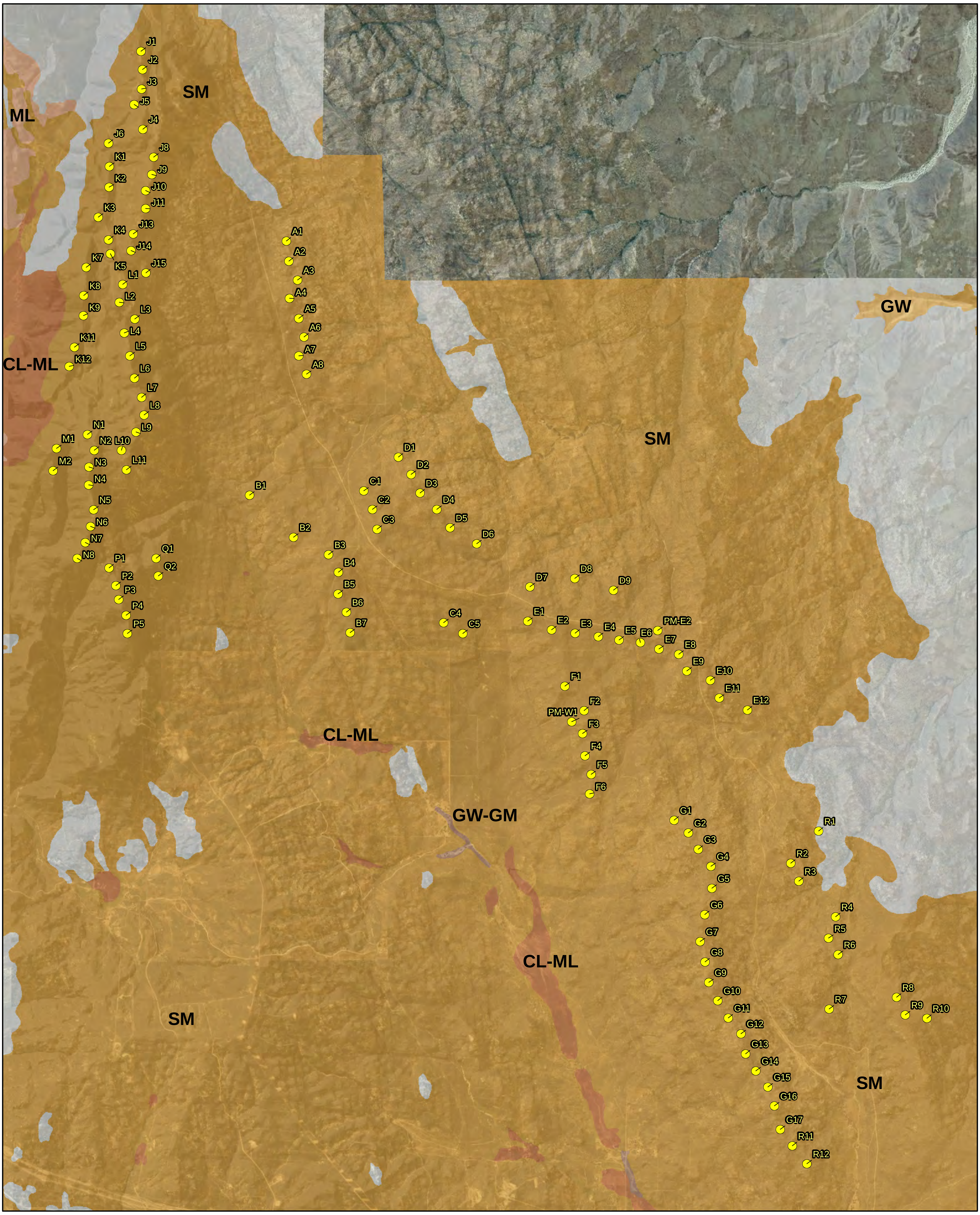
Meters

1,200 0 1,200

Figure 4

SOIL MAP
Tule Wind Project
Iberdrola Renewables
San Diego Co., CA

Barr Footer: Date: 11/24/2009 11:55:33 AM File: I:\Projects\05\37\007\2009\Maps\Reports\Geotech_Report_Nov09\Fig05 Unified Soil Classification.mxd User: mbs2



Imagery Source: 2009 ESRI, i-cubed, GeoEye

Preliminary Turbine Location (10/13/2009 Coord.)

Unified Soil Classification

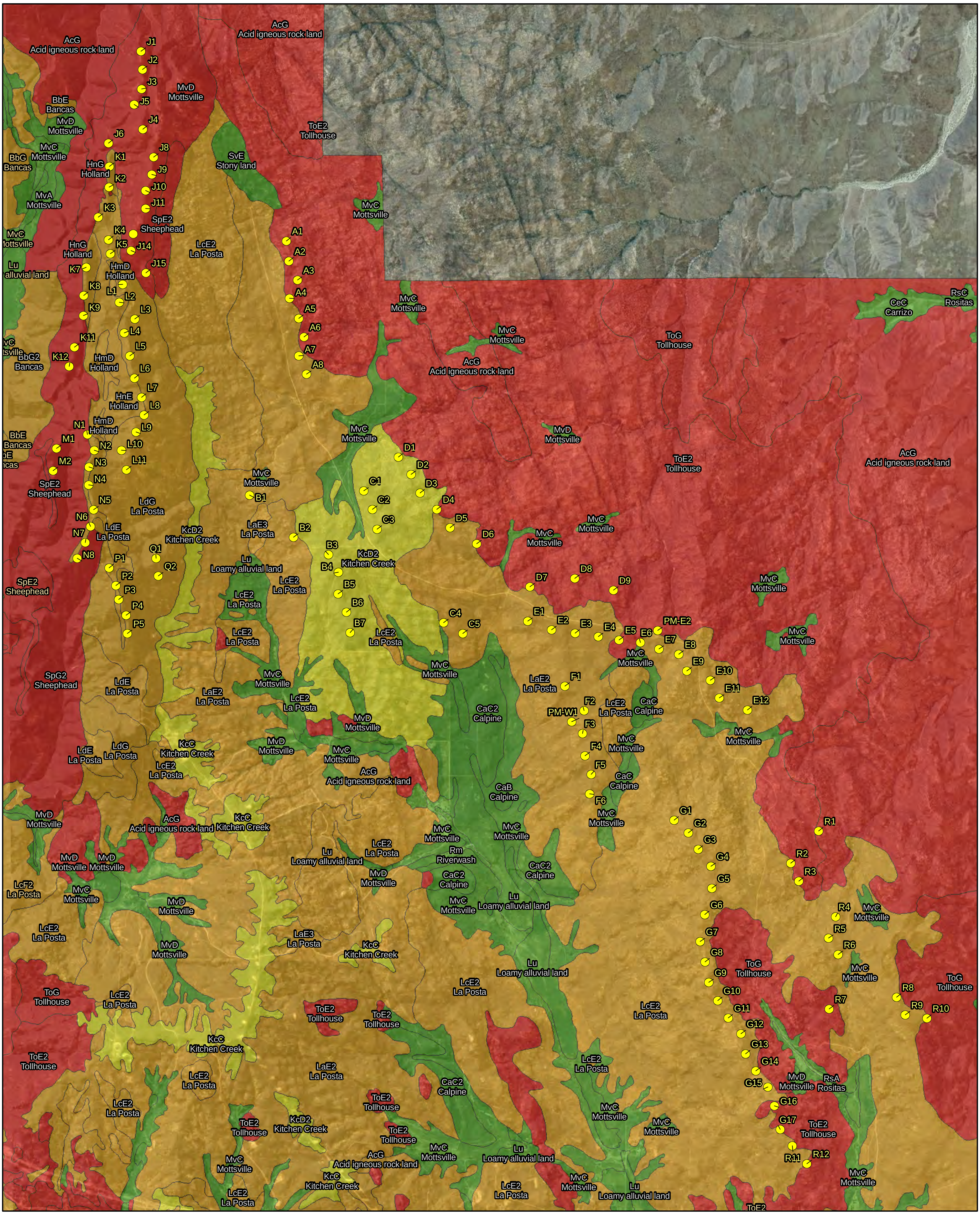
- Undefined
- CL-ML
- GW
- GW-GM
- ML
- SM

Feet: 4,000 0 4,000

Meters: 1,200 0 1,200

Figure 5

UNIFIED SOIL CLASSIFICATION
Tule Wind Project
Iberdrola Renewables
San Diego Co., CA



Imagery Source: 2009 ESRI, i-cubed, GeoEye
Data Source: USGS SSURGO Database

Preliminary Turbine Location (10/13/2009 Coord.)

Unspecified/Greater than 150 cm

0 - 50 cm

50 - 100 cm

100 - 150 cm

Feet

4,000 0 4,000

Meters

1,200 0 1,200

Figure 6

DEPTH TO WEATHERED BEDROCK
Tule Wind Project
Iberdrola Renewables
San Diego Co., CA

Appendix
Site Seismic Information

Conterminous 48 States
2006 International Building Code
Latitude = 32.83
Longitude = -116.37
Spectral Response Accelerations Ss and S1
Ss and S1 = Mapped Spectral Acceleration Values
Site Class B - Fa = 1.0 ,Fv = 1.0
Data are based on a 0.009999999776482582 deg grid spacing

Period (sec)	Sa (g)	
0.2	1.429	(Ss, Site Class B)
1.0	0.519	(S1, Site Class B)

Conterminous 48 States
2006 International Building Code
Latitude = 32.83
Longitude = -116.37
Spectral Response Accelerations SMs and SM1
SMs = Fa x Ss and SM1 = Fv x S1
Site Class B - Fa = 1.0 ,Fv = 1.0

Period (sec)	Sa (g)	
0.2	1.429	(SMs, Site Class B)
1.0	0.519	(SM1, Site Class B)

Conterminous 48 States
2006 International Building Code
Latitude = 32.83
Longitude = -116.37
Design Spectral Response Accelerations SDs and SD1
SDs = 2/3 x SMs and SD1 = 2/3 x SM1
Site Class B - Fa = 1.0 ,Fv = 1.0

Period (sec)	Sa (g)	
0.2	0.953	(SDs, Site Class B)
1.0	0.346	(SD1, Site Class B)

Conterminous 48 States
2006 International Building Code
Latitude = 32.76
Longitude = -116.28
Spectral Response Accelerations Ss and S1
Ss and S1 = Mapped Spectral Acceleration Values
Site Class B - Fa = 1.0 ,Fv = 1.0
Data are based on a 0.009999999776482582 deg grid spacing

Period (sec)	Sa (g)
0.2	1.283 (Ss, Site Class B)
1.0	0.450 (S1, Site Class B)

Conterminous 48 States
2006 International Building Code
Latitude = 32.76
Longitude = -116.28
Spectral Response Accelerations SMs and SM1
SMs = Fa x Ss and SM1 = Fv x S1
Site Class B - Fa = 1.0 ,Fv = 1.0

Period (sec)	Sa (g)
0.2	1.283 (SMs, Site Class B)
1.0	0.450 (SM1, Site Class B)

Conterminous 48 States
2006 International Building Code
Latitude = 32.76
Longitude = -116.28
Design Spectral Response Accelerations SDs and SD1
SDs = 2/3 x SMs and SD1 = 2/3 x SM1
Site Class B - Fa = 1.0 ,Fv = 1.0

Period (sec)	Sa (g)
0.2	0.855 (SDs, Site Class B)
1.0	0.300 (SD1, Site Class B)

Probabilistic Seismic Hazards Mapping Ground Motion Page

User Selected Site

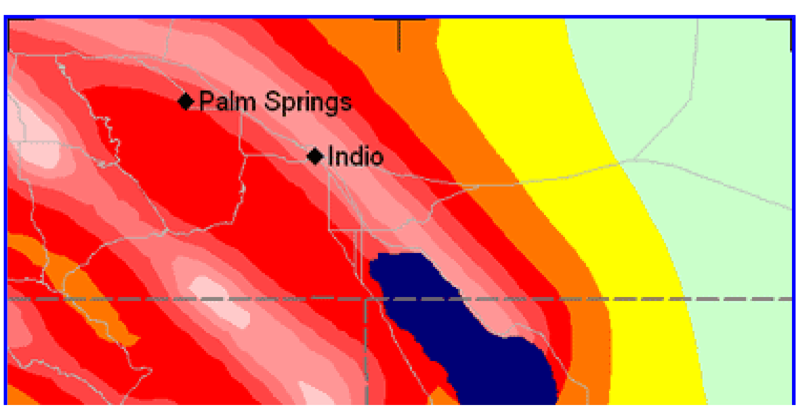
Longitude	-116.32
Latitude	32.8

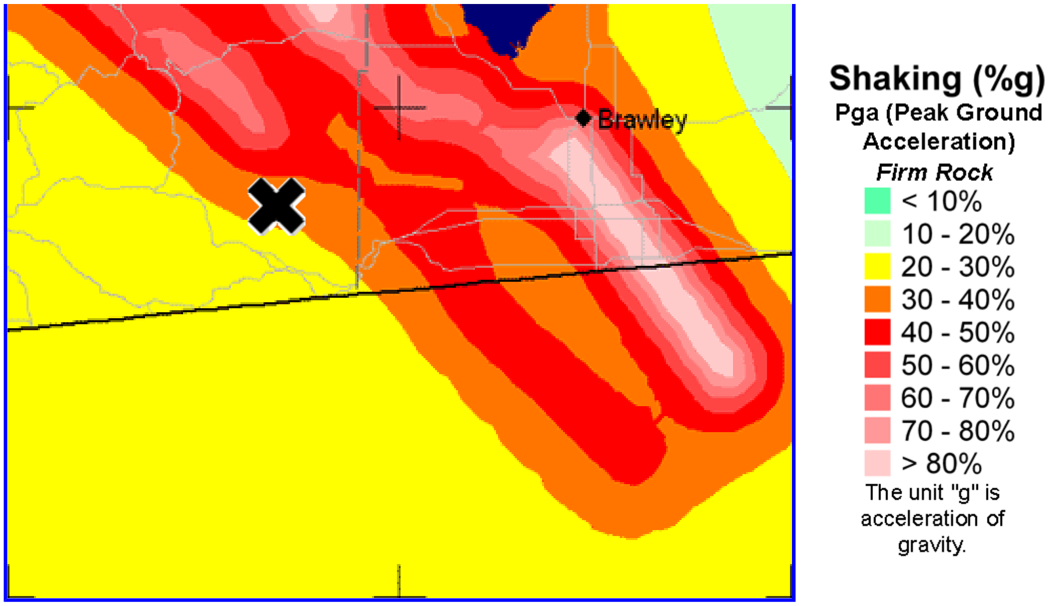
Ground Motions for User Selected Site

Ground motions (10% probability of being exceeded in 50 years) are expressed as a fraction of the acceleration due to gravity (g). Three values of ground motion are shown, peak ground acceleration (Pga), spectral acceleration(Sa) at short (0.2 second) and moderately long (1.0 second) periods. Ground motion values are also modified by the local site soil conditions. Each ground motion value is shown for 3 different site conditions: firm rock (conditions on the boundary between site categories B and C as defined by the building code), soft rock (site category C) and alluvium (site category D).

Ground Motion	Firm Rock	Soft Rock	Alluvium
Pga	0.327	0.342	0.374
Sa 0.2 sec	0.784	0.826	0.901
Sa 1.0 sec	0.282	0.353	0.437

NEHRP Soil Corrections were used to calculate Soft Rock and Alluvium.
Ground Motion values were interpolated from a grid (0.05 degree spacing) of calculated values. Interpolated ground motion may not equal values calculated for a specific site, therefore these values are not intended for design or analysis.





***Click here** to return to the statewide PSHA map or enter new coordinates below:*

Longitude: Latitude: Submit

Please enter coordinates as Decimal Degrees
Example: Longitude -122.0017 Latitude 36.9894

Back to Top of Page