Geoarchaeological Testing Plan for the Proposed Mojave Solar Project Lockhart, California

Prepared for
Abengoa Solar, Inc.

Prepared by
SWCA Environmental Consultants

July 2009

GEOARCHAEOLOGICAL TESTING PLAN FOR THE MOJAVE SOLAR PROJECT, LOCKHART, CALIFORNIA

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USGS 7.5-Minute Quadrangles
Lockhart, CA and Twelve Gauge Lake, CA

SWCA Project Number 15302
SWCA Cultural Resources Report Database No. 2009-228

July 16, 2009

Keywords: Geoarchaeological testing plan; 1,778+ acres; Townships 10 & 11 North, Range 4 West, San Bernardino County

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INTRODUCTION

The following geoarchaeological testing plan and research design were developed by SWCA Environmental Consultants (SWCA) for the proposed Mojave Solar Project at Lockhart, San Bernardino County, California (Figure 1).

The purposes of the geoarchaeological testing proposed here include bettering our understanding of landform development within the project vicinity and region, identifying buried archaeological deposits, if present, and assessing the potential impacts of the proposed project to those deposits. Because of this focus on buried deposits, the proposed geoarchaeological testing is limited to project components that involve ground disturbance.

This testing plan follows the guidelines described by the California Energy Commission (CEC) for geoarchaeological investigations. This testing plan is guided by the following assumptions.

- A solar facility site on the perimeter of a Pleistocene- to Holocene-age playa lake is proposed with a footprint that will not exceed 1,778 acres.
- There are no associated linears proposed for the Mojave Solar Project facility.

RESEARCH DESIGN

This research design was developed following a literature review that included regional and local geology as well as geomorphology, paleoclimatology, micropaleontology, archaeology, and soils of the Mojave Desert region within San Bernardino County. Sources consulted included archaeological literature that contains geoarchaeological data, geological literature and maps, the San Bernardino County soil survey, paleoclimatology and paleolimnology reports and studies, and Pleistocene and Holocene studies literature. In addition, the results of geotechnical fieldwork conducted and reported by Ninyo and Moore (2009) were evaluated for additional stratigraphic and sedimentary information. The goal of the literature review was to aid in the understanding of the physical, climatic, and anthropogenic formation processes affecting the sediments located within the proposed project's area of potential effects (APE). The goal of the research design is to delineate sedimentary regimes or strata (e.g., paleo beach deposits superimposed onto alluvial fan deposits) that have the potential to contain paleosols (old, buried soils) or buried archaeological deposits. The research design includes questions that guide the focus and approach of the study.

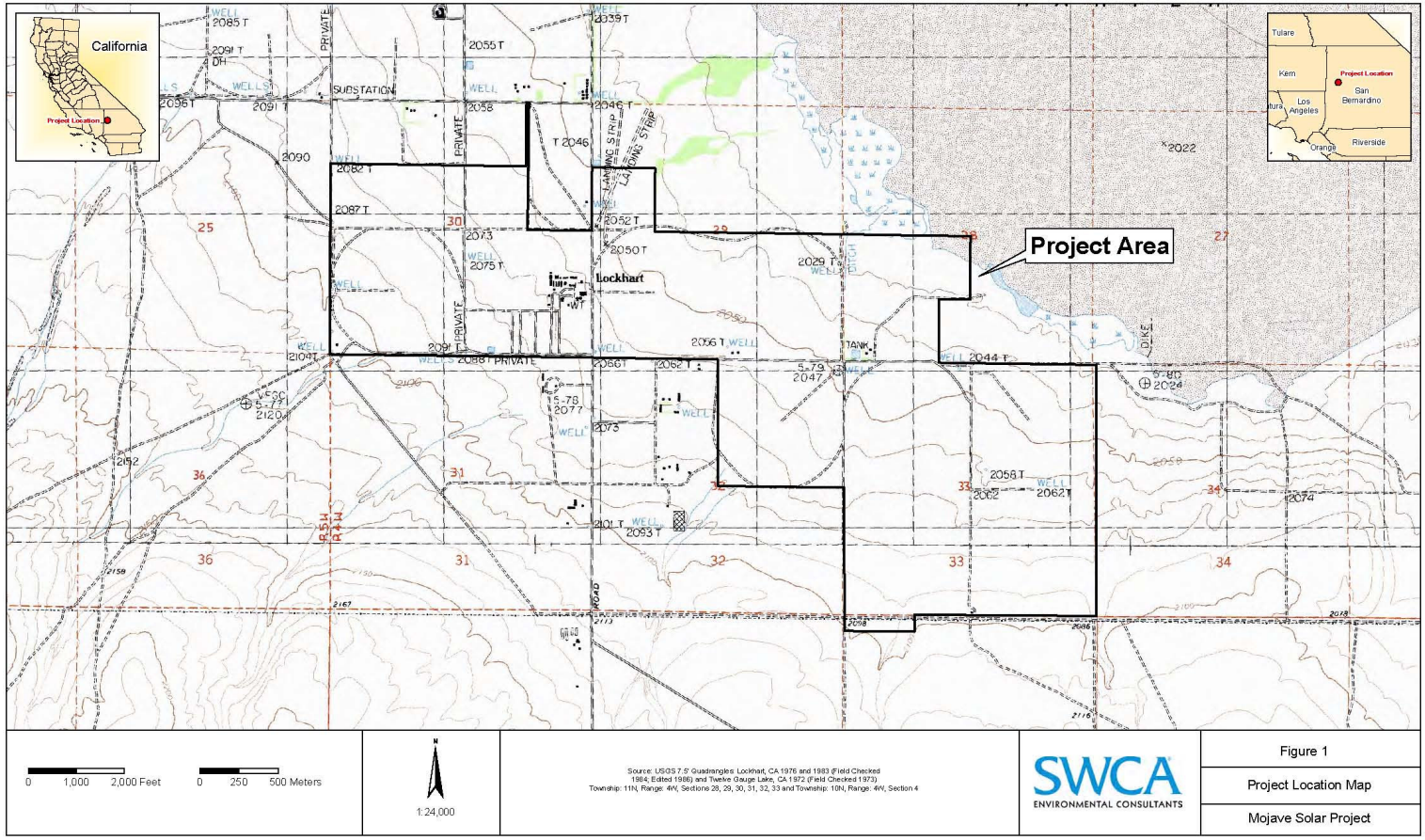

Figure 1. Mojave Solar Project location map.

GEOMORPHOLOGY AND SOILS

The proposed Mojave Solar Project site lies within the eastern portion of the Mojave Desert Geomorphic Province, a large depressional wedge-shaped block bounded by the San Andreas fault to the west and Garlock fault to the north. Within the block are numerous parallel, northwest-trending strike-slip faults (parallel to the San Andreas fault) that form a series of isolated and contorted ridges (horsts) and basins (grabens). Harper Lake lies in a graben between the Lockhart fault to the southwest and Harper fault to the northeast. Both faults have indications of lateral displacement (strike-slip faulting) since the early Miocene, as well as some vertical displacement (oblique faulting) that is coupled with, and controlled by, the San Andreas and Garlock fault movements. The vertical displacement of the block between these parallel faults has formed the Harper Lake basin in which centripetal drainage has formed. During the Pliocene, Pleistocene, and early Holocene epochs, the basin accumulated a thick sequence of sediments in the form of coalescing alluvial fans, or *bajadas* (Enzel et al. 2003; Norris and Webb 1976; Tugel and Woodruff 1986).

During periods of cool climate and low evaporation, the base of the depression formed a lake that transgressed and regressed over time, following climatic oscillations. The Mojave River, now a river of hyporheic (semisubterranean) flow regimes, flowed into the basin until sometime in the late Pleistocene when it was diverted to the south. Previous research has shown that around 25 thousand years ago (kya), water levels within Harper Lake reached an elevation of 2,150 feet (655 meters), which is recorded by highstand beach deposits containing clamshell lags, lacustrine microfossils, and wave-cut cliffs (Enzel et al. 2003). Following diversion (avulsion) of the Mojave River from Harper Lake, sometime after 25 kya, lake levels began dropping, although they fluctuated over time during periods of wet/cool (low evaporation rates/high stands) and warm/dry (high evaporation rates/low stands) climatic regimes. Evidence of lower recessional highstand beach deposits may be preserved in the basin stratigraphy. Enzel et al. (2003) mention that researchers have recorded lower recessional shorelines within the Harper Lake basin, yet do not mention at what elevation the remnants are located. An extreme drying period during the middle Holocene (mid-Holocene Altithermal) likely desiccated the lake until the wetter climate regime of the late Holocene commenced.

According to the *Soil Survey of San Bernardino County, California, Mojave River Area* (Tugel and Woodruff 1986) the soils mapped within the Mojave Solar Project facility project area are dominated by Cajon series soils with minor patches of Kimberlina and Norob-Halloran complex soils (Figure 2). The Cajon series soils mapped within the project area are Cajon sand, 0 to 2 percent slopes (112) and Cajon loamy sand, loamy substratum, 0 to 2 percent slopes (117). The soils are considered very deep and highly permeable, and they were formed in the distal portions of granitic alluvial fans that deposited sand, loamy sand, and gravely sand (Tugel and Woodruff 1986). Due to the granitic source of the sediments, it is expected that the dominant sand grains will consist of quartz, feldspar, and mica.

Small, isolated patches of Kimberlina loamy fine sand (137), on 0 to 2 percent slopes, are mapped within the northwest quadrant of the project APE. These soils, or sediments, are typically formed on the toeslope and footslope of aprons and skirts of alluvial fans. According to the San Bernardino soil survey, the Kimberlina loamy fine sand ranges in elevation from 120 to 1,000 feet (37–305 meters). The soil is mapped within the project APE at elevations 2,030, 2,060, and 2,070 feet (619, 628, and 631 meters respectively). The Kimberlina sand patches, within the project APE, are surrounded by Cajon sands. Interestingly, the Cajon sands are formed on alluvial fan backslopes, whereas the Kimberlina sands are formed on alluvial fan toeslopes. It is possible that the Kimberlina sands represent an older alluvial fan front that was later covered by a transgressing fan, leaving uncovered portions of the paleo fan front as patches, marked by the Kimberlina sands. The Kimberlina sands could also represent a former beach strand line. Geoarchaeological testing may shed light on the chronology and geomorphology of these soils.

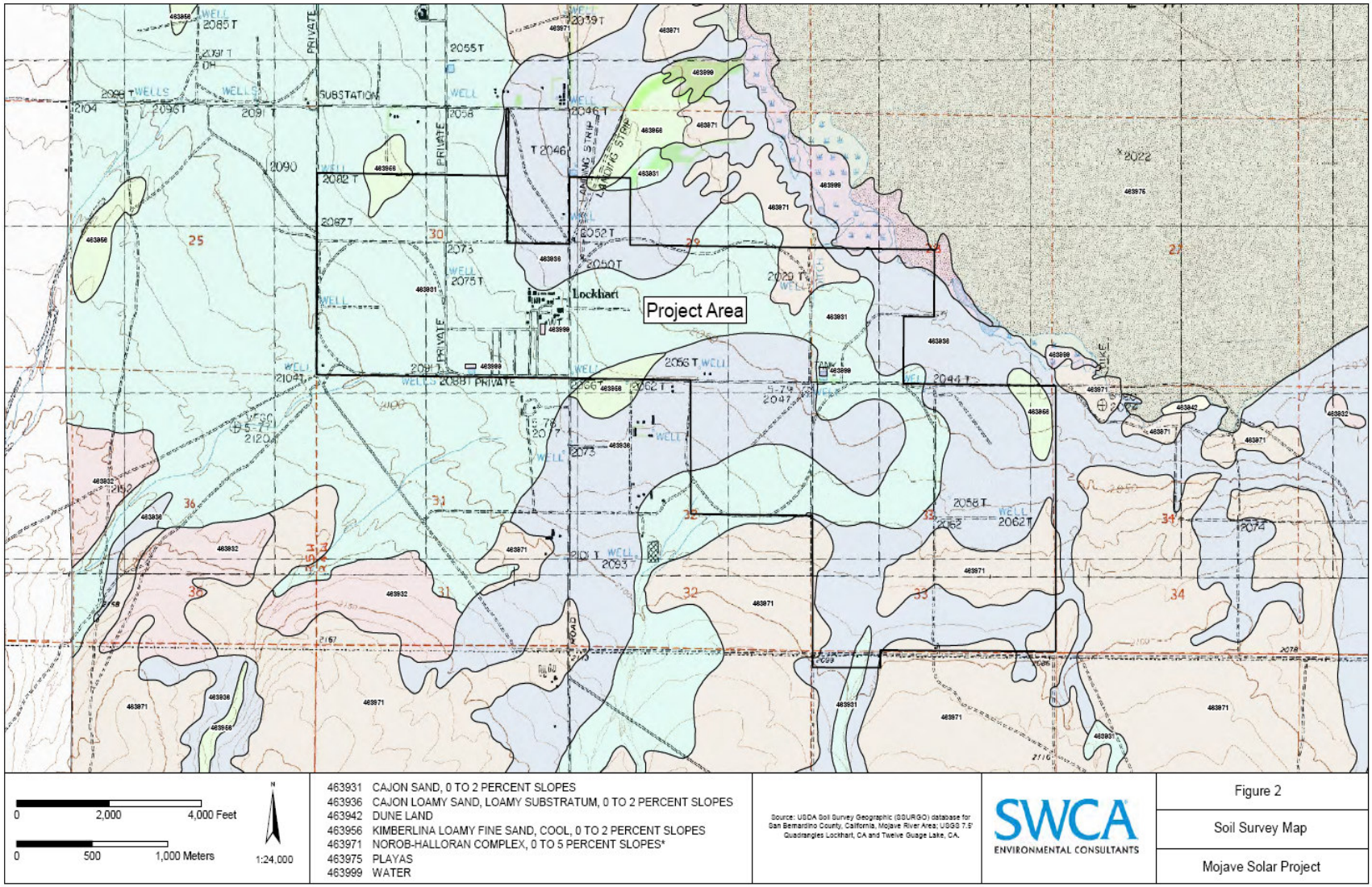

Figure 2. Soils map of proposed solar facility APE. Kimberlina sands are shown in light green, Cajon sands in light blue.

GEOARCHAEOLOGY

Although no geoarchaeological testing studies have been recorded within the vicinity of the project area, the potential exists for locating sealed cultural deposits. The project vicinity has a long history of use by Native Americans, homesteaders, and farmers. It is anticipated that the project area could potentially contain buried archaeological deposits. Sites have been recorded in the region on alluvial fans overlooking Pleistocene lake beds and paleo beach zones; consequently, these deposit types have a high potential for further discoveries.

Other researchers (Davis 1975; Sutton 1996; Wells et al. 1989) have shown that early sites and cultural settlement patterns in the Mojave Desert region focus on ecological zones adjacent to Pleistocene and Holocene lakes, on paleo shorelines. As Sutton (1996) describes, various settlement patterns within the Mojave Desert were focused on Pleistocene and Holocene lakes. For instance, Lake Mojave Period (ca. 10,000–7000 years before present [B.P.]) sites have been recorded on the Terminal Pleistocene and Early Holocene fossil shorelines of Lake Mojave and other Pleistocene-age lakes in the Great Basin. The Pinto Period (ca. 7000–4000 B.P.) followed the Mojave Period and marks a distinct settlement pattern away from lakeshores, which coincides with increased aridity in the area and lake desiccation of the Middle Holocene. However, the Gypsum Period (ca. 4000–1500 B.P.) appears to mark a resettlement strategy back to lakeshore zones. The Gypsum Period coincides with an increased cool and wet climate regime that is recorded for the late Holocene. The late Holocene, after ca. 1500 B.P., seems to indicate a more variable settlement pattern that involved agriculture, trading, and village sites located in more fluvial environments (Sutton 1996).

RESEARCH QUESTIONS

- Is there stratigraphic, sedimentary, and microfossil evidence for recessional beach deposits that may contain cultural deposits?
- What is the potential for buried archaeological deposits and paleosols?
- What is the preservation potential for archaeological deposits within the sediments and soils?
- What is the chronology of the sediments and soils?

TESTING METHODS

Following approval of the testing plan by the CEC, SWCA will conduct the geoarchaeological investigation in the APE for the proposed solar facility. The preliminary geomorphology and soils analysis of the project area presented above indicates that the proposed APE has sediments that have a high potential to contain buried Pleistocene- and Holocene-age archaeological deposits and should be strongly considered for geoarchaeological investigations. Based on the results of a literature search and a review of the geomorphological features of the APE (such as high stand beaches, alluvial fans, and playa deposits), this plan will attempt to identify high-probability areas within those geomorphic regimes that have the potential to contain buried cultural deposits. This plan provides recommendations for testing of those depositional regimes.

Testing will be conducted to assess the potential for buried archaeological deposits within the proposed footprint of the solar facility. The proposed plant footprint is 1,778 acres. Following the CEC guidelines, the proposed geoarchaeological testing will target only those areas where project disturbance is expected to go deeper than one meter. The tests will not exceed the expected depths of impacts from the construction of the generation plant. SWCA will also consider engineering recommendations that may exceed the proposed depth of construction (i.e., over-excavation due to soft soils). The precise testing layout and depth will be determined using a grading plan, to be provided by the client, indicating the locations for deep construction excavation, such as spread and spot footings, pipeline trenches, or other deep construction needs.

BACKHOE TEST TRENCHING

The proposed geoarchaeological backhoe trenches will be placed with a longitudinal axis of azimuth 40/220 degrees, an orientation that is perpendicular to the existing Harper Lake shoreline (Figure 3). The trenches will be excavated to a minimum of four meters in length and one meter in width, with a maximum depth determined by the construction grading plan. The focus of the trench excavations—and the goal of this testing plan—is to identify areas of paleo shorelines, paleosols, or depositional environments that indicate a potential to contain such facies, as well as buried archaeological deposits within the plant site. This information will be developed into a three-dimensional framework of the buried depositional horizons. For instance, during the literature and map review phase of the development of this testing plan, a slope analysis was conducted using United States Geological Survey (USGS) 7.5 minute topographical maps. The slope analysis indicated a subtle yet distinct break in slope at elevations of 2,030, 2,050, and 2,070 feet (619, 625, and 631 meters, respectively) within the project area. The breaks in slope may be indicators of paleo shorelines, beach ridges, or changes in lithology, which need to be ground-truthed during geoarchaeological testing.

The geoarchaeological investigation will consist of examination of backhoe trench profiles to identify characteristics of the depositional environment, documentation of those profiles through digital photography and sketches, and limited sediment screening. This investigation will allow SWCA to obtain information on the geomorphological, sedimentological, and stratigraphical development of the landform and to determine whether there is evidence of anthropogenic (human-generated) effects or bioturbation (animal-generated disturbance) of the soils. The screening protocol will enable the detection of artifacts or ecofacts, if present.

Following excavation of the test trenches using a backhoe with a toothless bucket, an SWCA geoarchaeologist will photograph and hand sketch the sedimentary sequence in profile view. Standard field-recording procedures will be used to document the geological and pedological environment of each stratum within and between trenches. Additionally, the following sediment characteristics will be described: sediment texture, color, mottling (redoximorphic features), structure, consistence (including penetration resistance measured in megapascals, stickiness and plasticity, and rupture resistance), pH, effervescence (using one molar dilute hydrochloric acid), root content, evidence of caliche, evidence of lake sediments, shell lags and beach deposits, bedding, sorting, and boundary contacts between strata. Samples of distinct soil or sediment horizons, especially paleosols, or fossil clamshells, may be collected for radiocarbon dating to help construct a chronology for the sediments and soils. Collected radiocarbon samples that would be of use in dating buried archaeological deposits will be sent to the Paleoresearch Laboratory in Colorado for dating.

Because some archaeological deposits are not readily discernible in profile, limited sediment screening will be employed in order to increase the likelihood of detecting subsurface deposits during backhoe trenching. The SWCA geoarchaeologist will acquire sediment samples from each major stratigraphic unit that is exposed in the backhoe trenches. These samples, which will have a minimum volume of 50 l (13.2 gal), will be passed through 6.35-mm (¼-in) hardware cloth in an effort to recover any artifactual or ecofactual material that they contain. A screen column, in which a 50 cm^2 column of soil excavated from the trench wall, may be used for more efficient coverage and control.

Soil horizon nomenclature will follow the Natural Resources Conservation Service (NRCS) field guide (Holliday 1990; NRCS 2008; Schoeneberger et al. 2002). Lithological and sedimentary nomenclature will follow the International Stratigraphic Guide (Hedberg 1976; Johnson and Watson-Stegner 1990; Stein 1990). Finally, all trenches will be mapped in relation to other trenches and features, and their locations will be recorded using a Trimble global positioning system (GPS) receiver with submeter accuracy.

All trench excavations will follow applicable Occupational Safety and Health Administration (OSHA) regulations (29 CFR 1926.652 Subpart P–Excavations). Following these regulations, test trenches will be

either sloped at a 1:1 ratio (45 degrees) or benched with benches that are less than 1.2 m (four ft.) high and stepped at a 1:1 ratio slope away from the trench base.

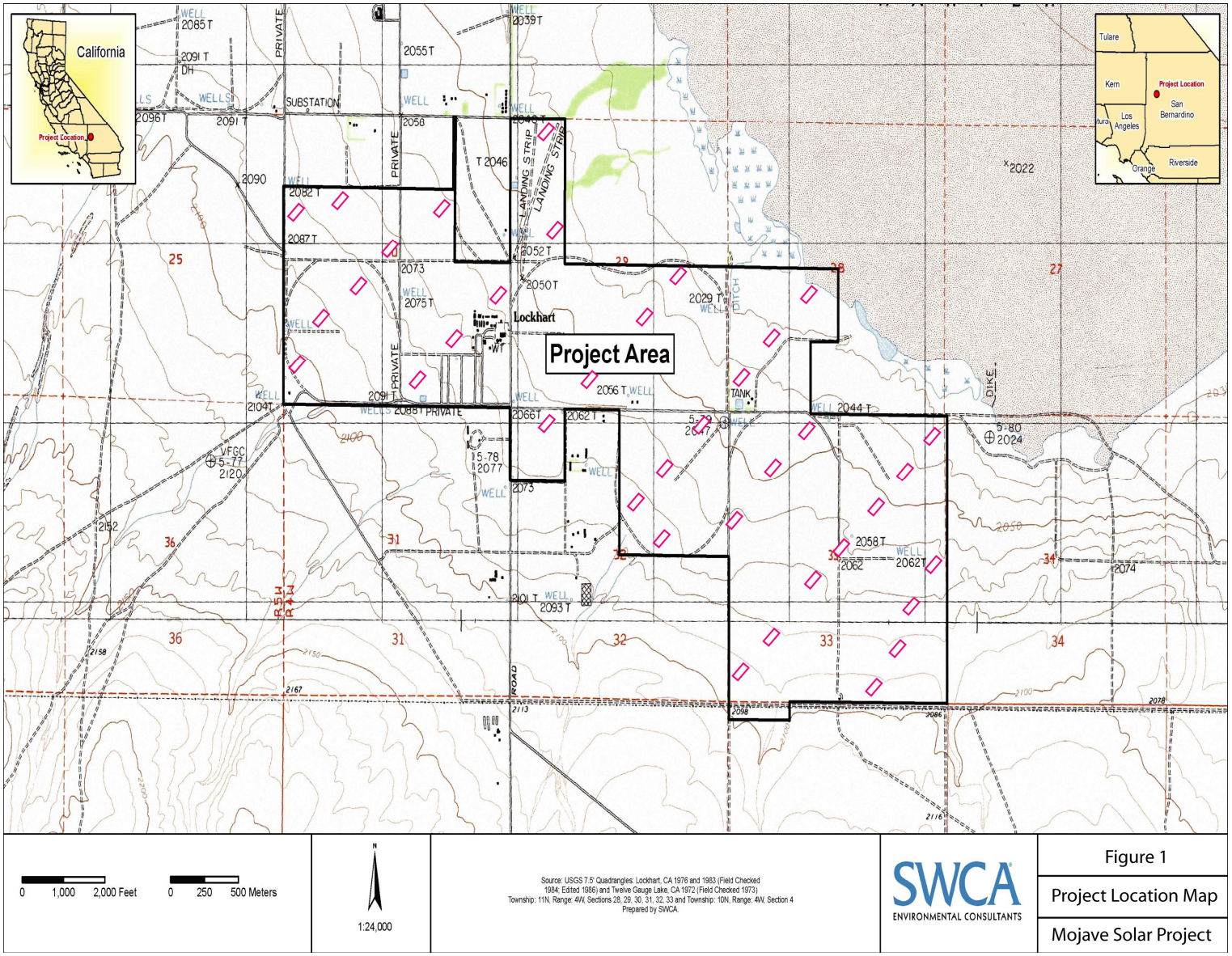

Figure 3. Proposed geoarchaeological test trench locations within the Mojave Solar Project APE.

MICROFOSSIL ANALYSIS

Previous research in the Mojave region has determined that numerous Pleistocene and Holocene age archaeological sites have been recorded on paleo beaches adjacent to lakes and playas in the region. The topographies of the large basins consist of nearly imperceptible changes in elevation that can equal only centimeters of vertical change per kilometer of horizontal distance. Therefore, identification of buried sediments that contain paleo beach, beach ridge, or near-shore deposits can be tricky; they can be mistaken for distal alluvial fan/apron deposits unless there are obvious beach deposits, such as clam shells. Additional lines of evidence may be needed to determine the location of paleo beaches.

Research focusing on the preservation of calcium-rich microfossils, such as ostracodes (Cohen et al. 1994), in Quaternary-age lacustrine beach and near-shore deposits has been promising. The adult stage of ostracodes typically fall into a size range equivalent to fine to very coarse sand (0.2-2.0 mm), and can indicate the previous location of beach deposits. Previous research on the highest recorded paleo lakeshore in Harper Basin, at an elevation of 2,155 feet (657 m), indicated beach deposits with lacustrine clays and abundant ostracodes, as well as papershell clams (*Anadonta californiensis*), which were used for radiocarbon dating (Enzel et al. 2003). Thus, through targeted sampling and light microscopy, sediments from trench walls can be analyzed for the presence of ostracodes and evidence of paleo beach deposits.

During geoarchaeological testing of the project APE, SWCA proposes to excavate numerous trenches. Some trenches will be placed in single transects (soldier trenches), beginning near the present playa edge and continuing in a single transect southwest to the edge of the proposed APE (Figure 3). SWCA proposes to use two trench transects for microfossil analysis in addition to the proposed testing regimen described for all trenches. For microfossil analysis, SWCA geoarchaeological staff will obtain small samples (typically about two grams) of sediment from distinct stratigraphic horizons within the transect trench walls. The sample locations will be documented on the trench profile and given a sample number (e.g., MS1 for Microfossil Sample 1). In the lab, the samples will be wet screened over 106-micron mesh screens (United States Standard # 140 screen). The retained portion of the sample will be moved from the screen to a clean Petri dish for analysis and microscopy. The SWCA geoarchaeologist will record the number, as well as the genera and species (if identifiable), of the ostracodes recorded. Previous research in the Harper Basin has shown that the dominant species of ostracode is *Limnocythere bradburyi.*

ARTIFACTS AND SAMPLES

Should artifacts or ecofacts be discovered during backhoe trenching, they will be placed into zip-top bags labeled with the appropriate provenience information. Similarly, if organic materials or other samples warrant collection, each sample will be placed in a zip-top bag and labeled with the proper provenience information, including the trench number, Universal Transverse Mercator (UTM) coordinates, depth, and horizon. All samples containing carbon, if collected for radiometric dating purposes, will be carefully placed in aluminum foil prior to placement in a zip-top bag. The origin of all collected artifacts or samples will be shown on the appropriate trench profile drawing.

DISCOVERY OF HUMAN REMAINS

The specific guidelines for the discovery of human remains are stipulated by the state (State of California Health and Safety Code Section 7050.5). This code section states that no further disturbance shall occur until the County Coroner has made a determination of origin and disposition, pursuant to Public Resources Code Section 5097.98. The County Coroner must be notified of the find immediately. If the human remains are determined to be prehistoric, the Coroner will within 24 hours notify the Native American Heritage Commission, which will determine and notify a most likely descendent (MLD). The MLD shall complete an inspection of the site within 48 hours of notification and may recommend

scientific removal and nondestructive analysis of human remains and items associated with Native American burials.

REPORTING

Upon completion of the geoarchaeological testing, SWCA will summarize the results of the testing program in a technical report. This report will include a presentation of the study's background research, research design, field methods, field conditions, testing results, trench photographs and drawings, radiocarbon dating results, and other relevant data. The report will also include a reconstruction of the historical geomorphology of the plant site as well as a formal assessment of the likelihood of buried archaeological deposits within the project area. The geoarchaeological testing report will be provided to both the CEC and Abengoa Solar.

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Appendix A:
Geoarchaeologist Resume

SWCA
ENVIRONMENTAL CONSULTANTS

MATTHEW J. STEINKAMP, M.S.
Geoarchaeologist

Education

- M.S., Geology, Oregon State University, 2006
- B.A., Anthropology, University of Cincinnati, Ohio, 1986

Registration / Certification

- NHPA Section 106 Compliance Certification. Instructor: Dr. Thomas King, 2007
- Geologist In Training (G.I.T.) Oregon Board of Geologist Examiners, 2007
- NAUI certified diver, 1991
- HAZWOPER 40-Hour Registration

Expertise

- Cultural resource survey design, testing, data recovery, monitoring, field methods.
- Stratigraphy and Sedimentology
- Geomorphological and geological analysis, core logging.
- Lithic analysis and raw material analysis
- Northwest, Basin and Range, Southwest, Northeast, Southeast, Midwest region prehistoric and historic archaeology.
- Micro-fossil analysis
- Underwater archaeology

Selected Projects

- Geoarchaeologist/Geomorphologist, Geoarchaeological Testing of the Proposed Stockton Generation Plant Facility, Stockton, San Joaquin County, California.
- Geoarchaeologist/Geomorphologist, Cultural Resources Inventory of the Proposed Palomar Gas Transmission Project, Oregon.
- Geoarchaeologist, National Register nomination testing of 35BE34 in Benton County, Oregon.
- Geoarchaeologist, Phase II testing of Site 665NA229 in the Mt. Hood National Forest.
- Geomorphologist, Geomorphology Analysis of Wave Action at the Port of Morrow on the Columbia River.

Matthew Steinkamp is a geologist, geomorphologist, geoarchaeologist, underwater archaeologist, and cultural resources project manager with more than 20 years of prehistoric and historic archaeological and historic preservation experience in all areas of the United States, Hawaiian Islands, Micronesia, and East Africa. He joined SWCA in 2007 and is a geologist, geomorphologist and geoarchaeologist in the Portland Office. He is responsible for assessing the effects of projects on historic and prehistoric resources on land and underwater, and conducting geomorphology and geoarchaeology studies by analyzing the bedrock geology, geomorphic processes, and soils to determine archaeological site formation processes, integrity of deposits, and presence or absence of sealed cultural remains in deep-seated sedimentary environments.

Mr. Steinkamp's work experience has allowed him to acquire extensive knowledge in all phases of prehistoric and historic archaeology. He has worked on numerous cultural resource inventory projects, testing, construction monitoring, mitigation and data-recovery on sites in the Northwest, Southwest, Great Basin, Midwest, Northeast and Southeast United States, as well and the Hawaiian Islands and islands of Micronesia. He has extensive experience in geology and geomorphology, such as piston and gravity coring of Lake Tanganyika, East Africa, core logging of mechanical drilling in the Northwest, as well as analyzing ocean drilling cores from the Pacific Ocean abyssal plain to develop a chronological and intensity sequence of large earthquakes along the Cascadia Subduction Zone and San Andreas Fault for the past 10,000 years.

Mr. Steinkamp also has extensive experience in laboratory methods, lithic analysis, micro-fossil analysis of cherts, flints, and lacustrine sediments utilizing microscopy, raw material analysis, mineral separation, igneous and sedimentary petrography and petrology, field mapping of geological formations, invertebrate fossil analysis and flint-knapping.

Mr. Steinkamp has conducted cultural resource surveys for various state and federal agencies and private-sector clients. His experience has introduced him to numerous types of construction effects on cultural resources including gas and waterline construction, roadways, commercial buildings, parks, dam re-licensing, canals, coal mines, nuclear facilities, and logging operations. Mr. Steinkamp has co-authored numerous cultural resource inventory, testing, and data recovery reports, and his publications include *Lacustrine Micro-Fossil Assemblage from Core NP04-KH3 from the Moba-Kalya Horst Region of Lake Tanganyika, East Africa, as a Biogeochemical Proxy for Late Pleistocene and Early Holocene Climate and Lake Levels* and *Diatoms Are Cool, Yet Do They Indicate Dramatic Climate Shifts in the Holocene, or Are They Just Full of Silica*. Mr. Steinkamp has presented at the University of Dar es Salaam Annual Science Conference in Dar es Salaam, Tanzania.